Energy Research and Development Division
FINAL PROJECT REPORT

MODELING TOOL TO ASSESS AND MITIGATE THE EFFECTS OF SMALL HYDROPOWER ON STREAM FISHES IN CHANGING CALIFORNIA CLIMATE

Appendix C: Final Workshop Presentation

Prepared for: California Energy Commission
Prepared by: University of California, Davis

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Fish Population & Habitat Model “WEAPhish”, & “Master_WEAPhish” Middle-Ware Link to WEAP

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Environmental Quality • Landscape Processes

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Outline

- Issue, goal and objectives
- Background – Previous modeling work
- Model properties
- Model framework
  - Conceptual model
  - New model – “WEAPhish”
  - Middle-Ware to link WEAPhish to WEAP
- Future applications

Issue and purpose

- Greenhouse gas reduction → more renewable energy → incentive for more small hydropower
- Impacts to native fish → challenges for small hydropower operations
- Mitigation measures and impacts to small hydropower production unclear
- Climate change: change water quantity, temperature and timing → trade-offs

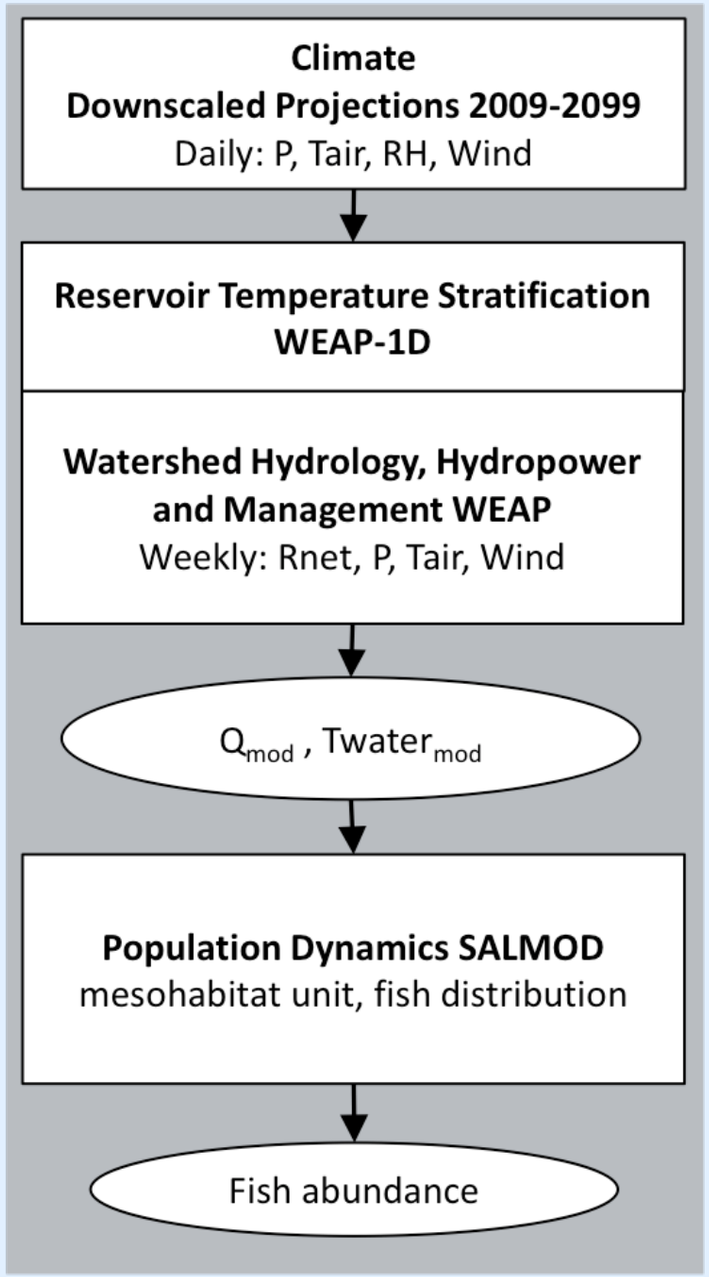
Goal

- Model envisioned as part of an integrated **framework** that:
  - Assesses trade-offs between water use for native fish and cost-efficient operations of **small hydropower** for energy production
  - Evaluates potential effects of climate change using data from climate models with future emissions scenarios

Background: Previous modeling work & workshops to develop new model

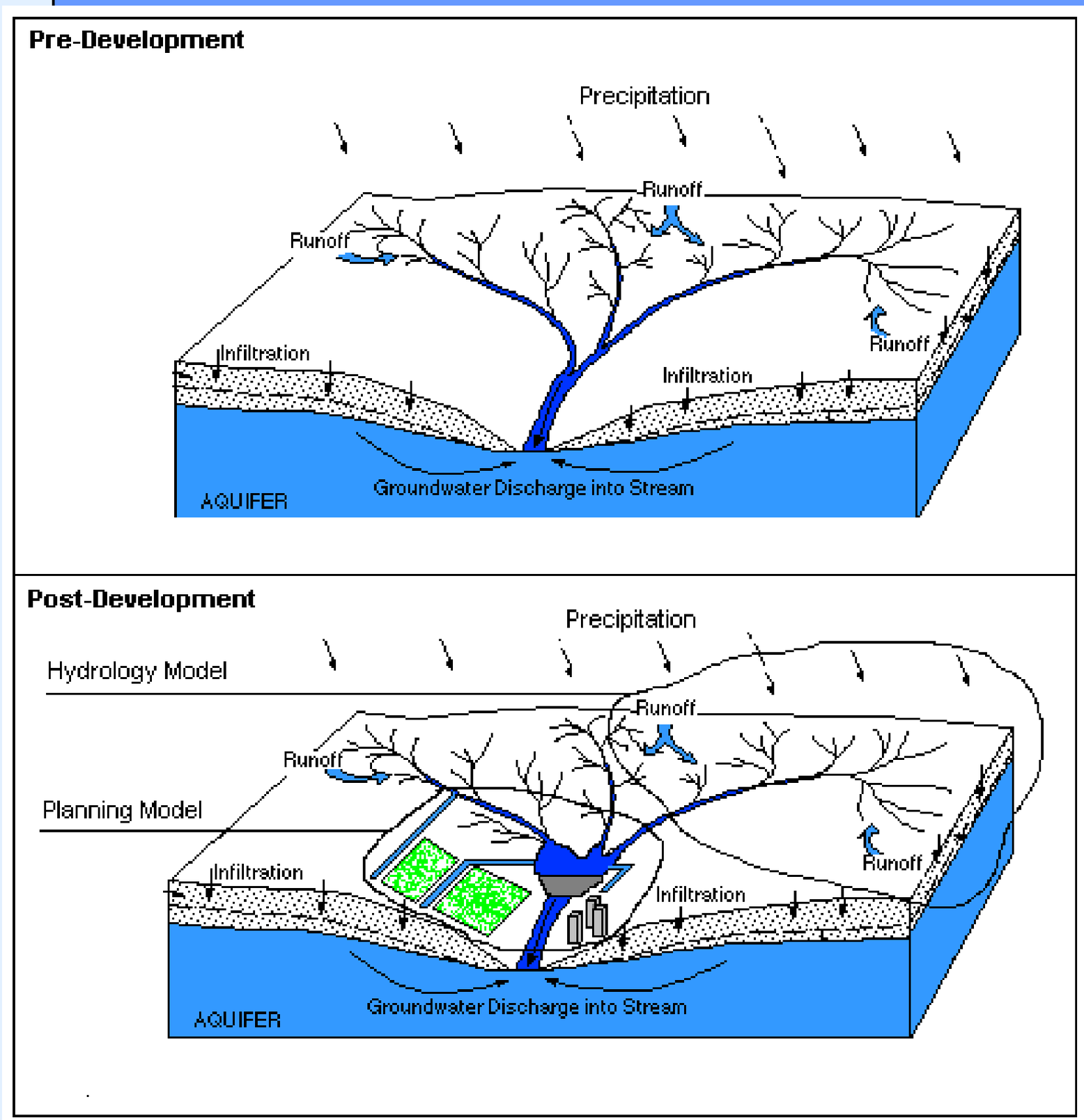
Climate change and spring-run Chinook salmon

- Downscaled climate projections
- WEAP hydrology model
- SALMOD fish model
  - Demographic rates
    - Abundance/survival
    - Reproduction
    - Growth
    - Movement
  - Each cohort tracked over time & space
  - Growth, survival & mortality are functions of water temperature & flow
  - Habitat, life stage specific

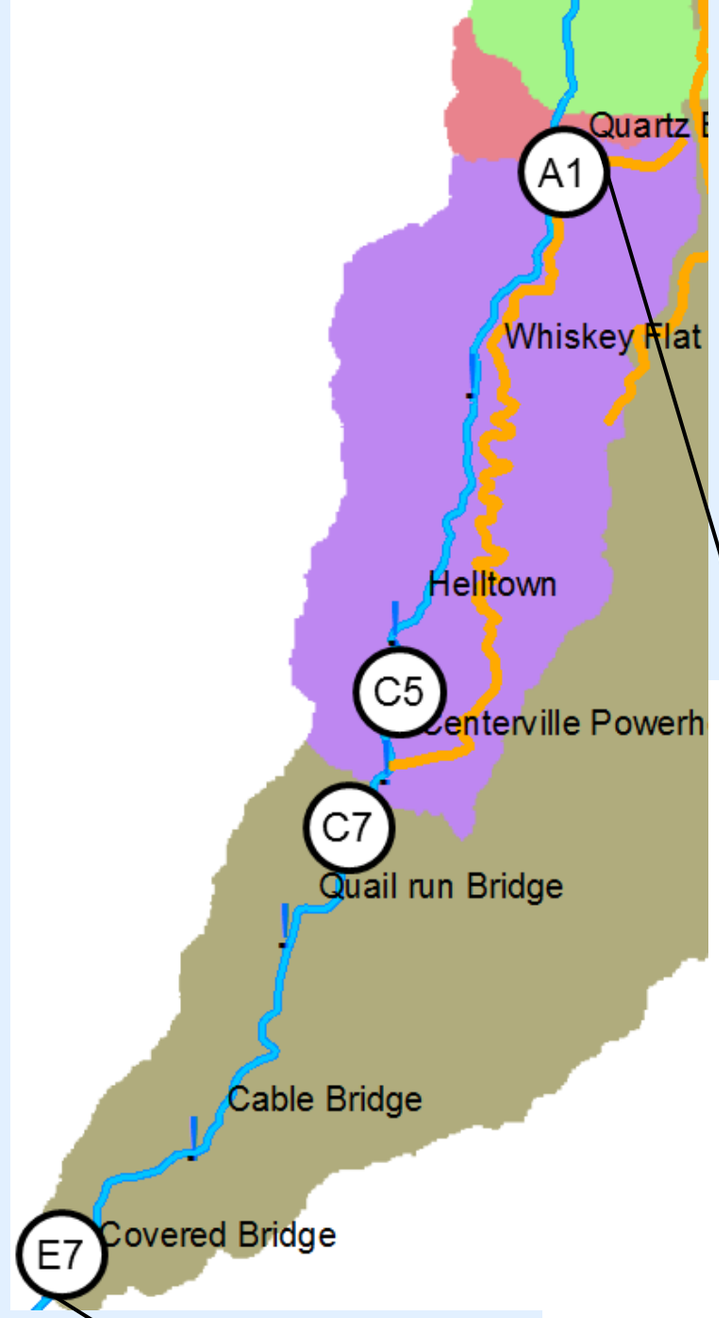


WEAP: Water Evaluation And Planning model

- Developed by Stockholm Environment Institute
- Integrates watershed hydrologic processes with the water resources management system
  - ➢ Climatic information direct input
  - ➢ Based on a holistic vision of integrated water resources management – supply and demand

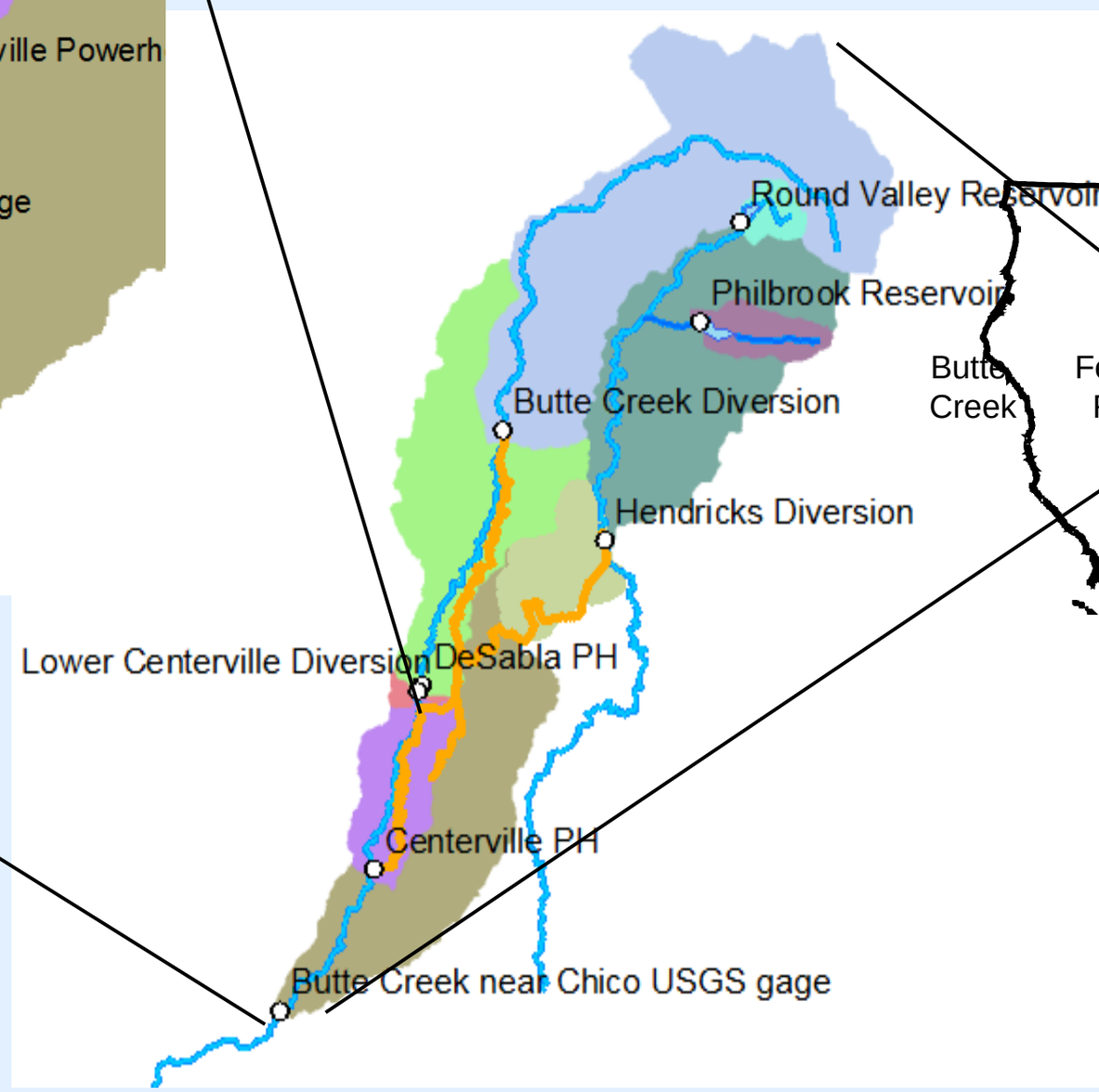


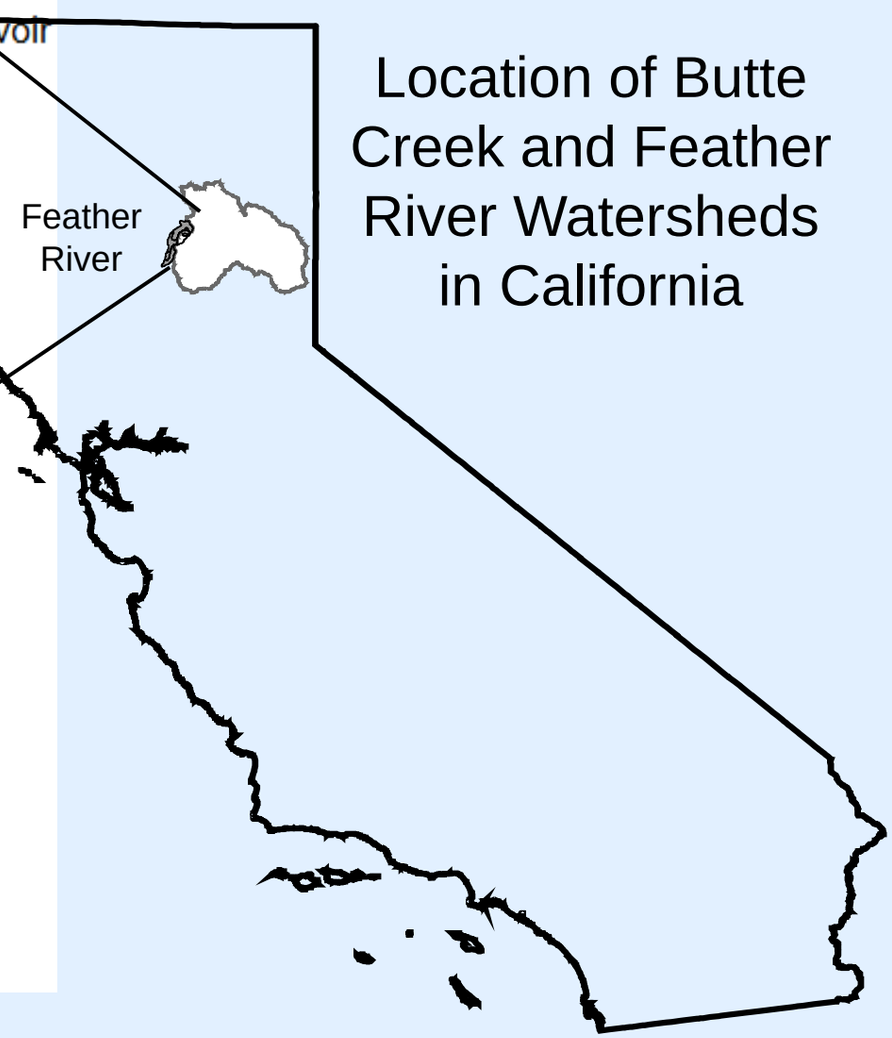
Butte Creek Watershed



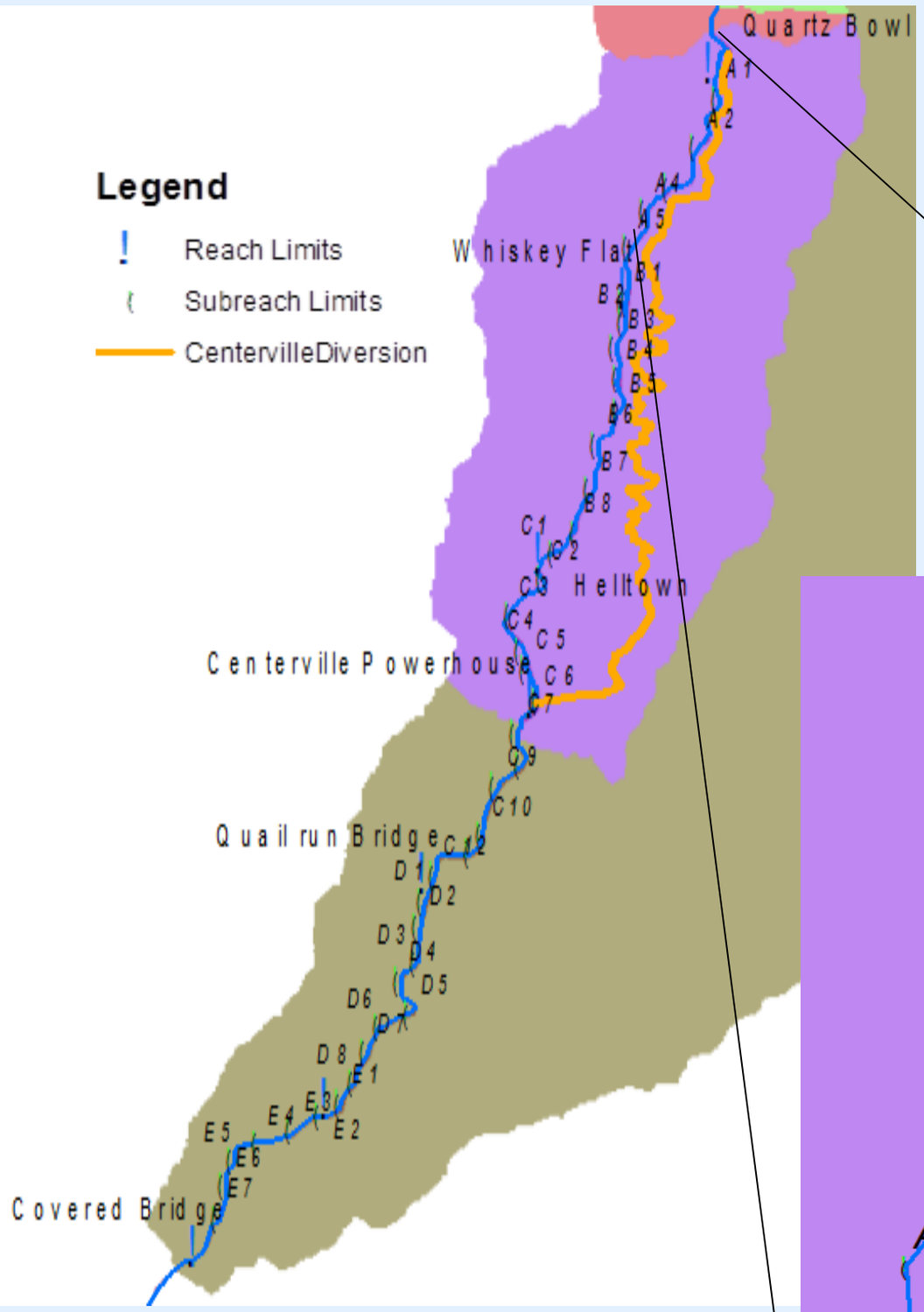
Reaches and Subreaches for Temperature Module

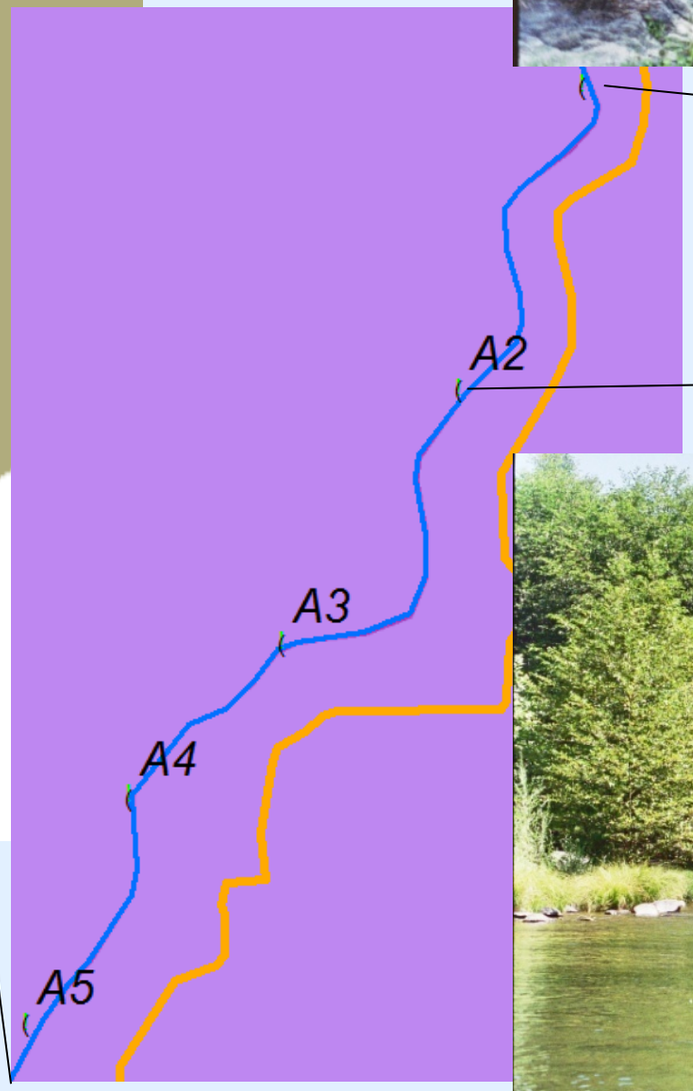
Subwatersheds for Rainfall Runoff Module





Location of Butte Creek and Feather River Watersheds in California





Pool
Riffle
Run

Temperature
Model Domain

Butte Creek: SALMOD results

- Long-term survival of salmon is questionable
- Water management adaptations may extend survival
- Climate Scenarios
  - A2: Salmon gone for all models
  - B1: Salmon may last to end of century
- Management Adaptations:
  - No diversion: Salmon survival time extended 0 – 17 years
  - Some adaptations led to no improvement in salmon and loss of hydropower production
- **Analytical framework may be useful elsewhere**

Ways to improve

1. SALMOD’s source code is unavailable, and is no longer supported by the USGS
2. SALMOD does not incorporate habitat-induced migration and movement within the stream habitat, disease-related stresses, or metapopulation dynamics
3. Limited to weekly time-steps
4. Inconvenient to work with WEAP
5. Requires detailed input on all life stages and habitats → simpler
6. Does not connect generations
7. No ocean life phase

Modeling objectives

- Develop fish habitat & population model to forecast the influence of small hydropower on native fishes in CA streams
  - Flexible – apply to multiple watersheds
  - Salmon, resident rainbow trout, hardhead
- Dynamically link the fish model to an existing hydrological model (WEAP)
- Assess trade-offs associated with different water management adaptations

Population model properties

1. Realism – accurately reflects population behavior
2. Precision – testable compare to data
3. Generality – applies to all cases

- Only get two of three
- For management, want Realism & Precision
- Build a General model that is Realistic & Precise

Stakeholder Comments

Butte Creek

- Trade-offs between hydropower costs and fish
- Daily time step for hydrology & fish
- Habitat and life-cycle complexity similar to SALMOD
- Model survival & growth during ocean & downstream of Butte Creek
- Hydrology reflects predicted changes in seasonality of snowpack & rain

South Fork American

- Additional habitat class = Cascade (steep, no gravel)
- Warm and cool water species along the temperature river gradient
- Tributaries act as sources of fish

North Fork American

- Habitat upstream of the dam is of interest
- If hydropower facility installed, potential for impingement and entrainment
- Interest in adding a Reservoir habitat class (with thermal refuge in summer) to allow modeling of potential habitat use by rainbow trout

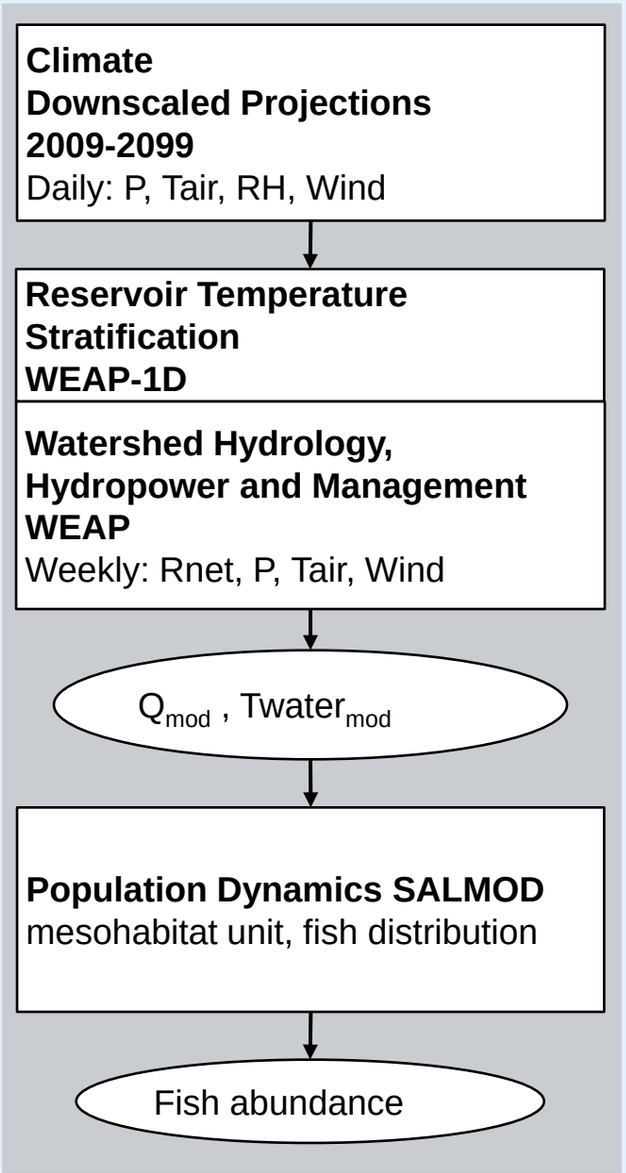
Conceptual model

- Stream hydrology
  - Natural and managed
- Climatic conditions
- Key ecological relationships to stream temperature and flow
  - Survival, growth, movement, reproduction
- Key ecological relationships to physical habitat
  - Capacity, ontogenetic habitat preferences

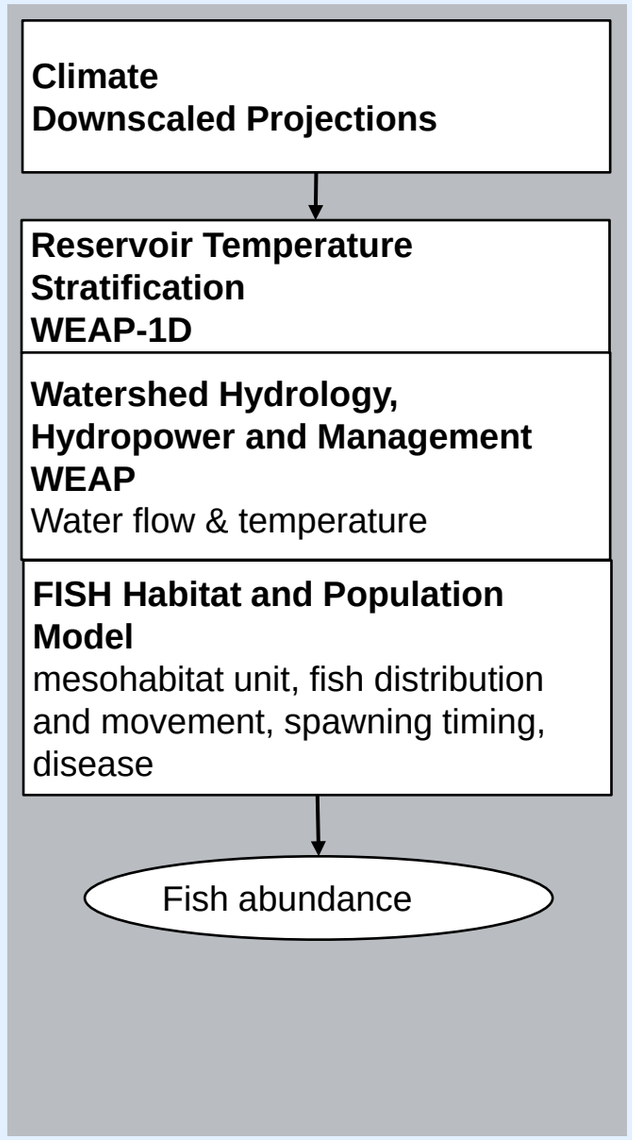
Model framework: New fish model and link to WEAP watershed model

Comparing frameworks

Previous



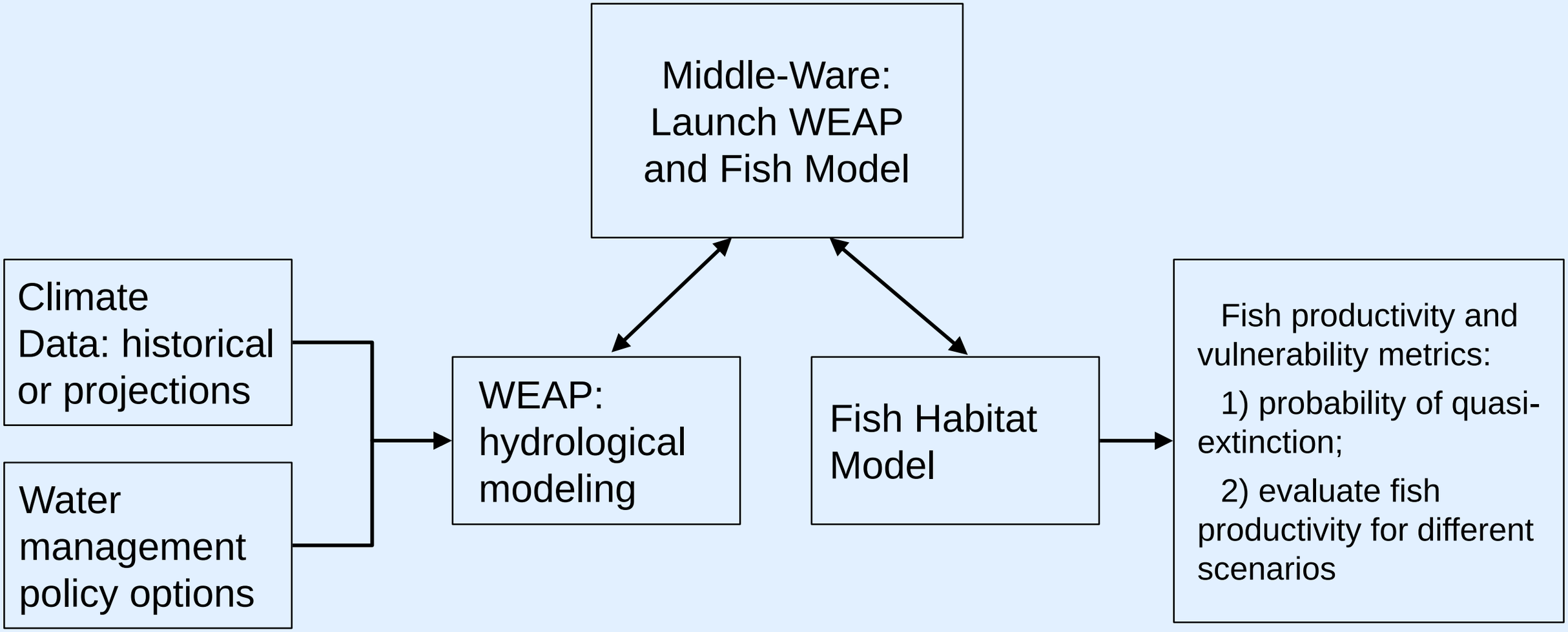
Current development



Metrics

- Fish: Population productivity, time to extinction
- Hydropower: Changes to hydropower generation resulting from fish-centric operations

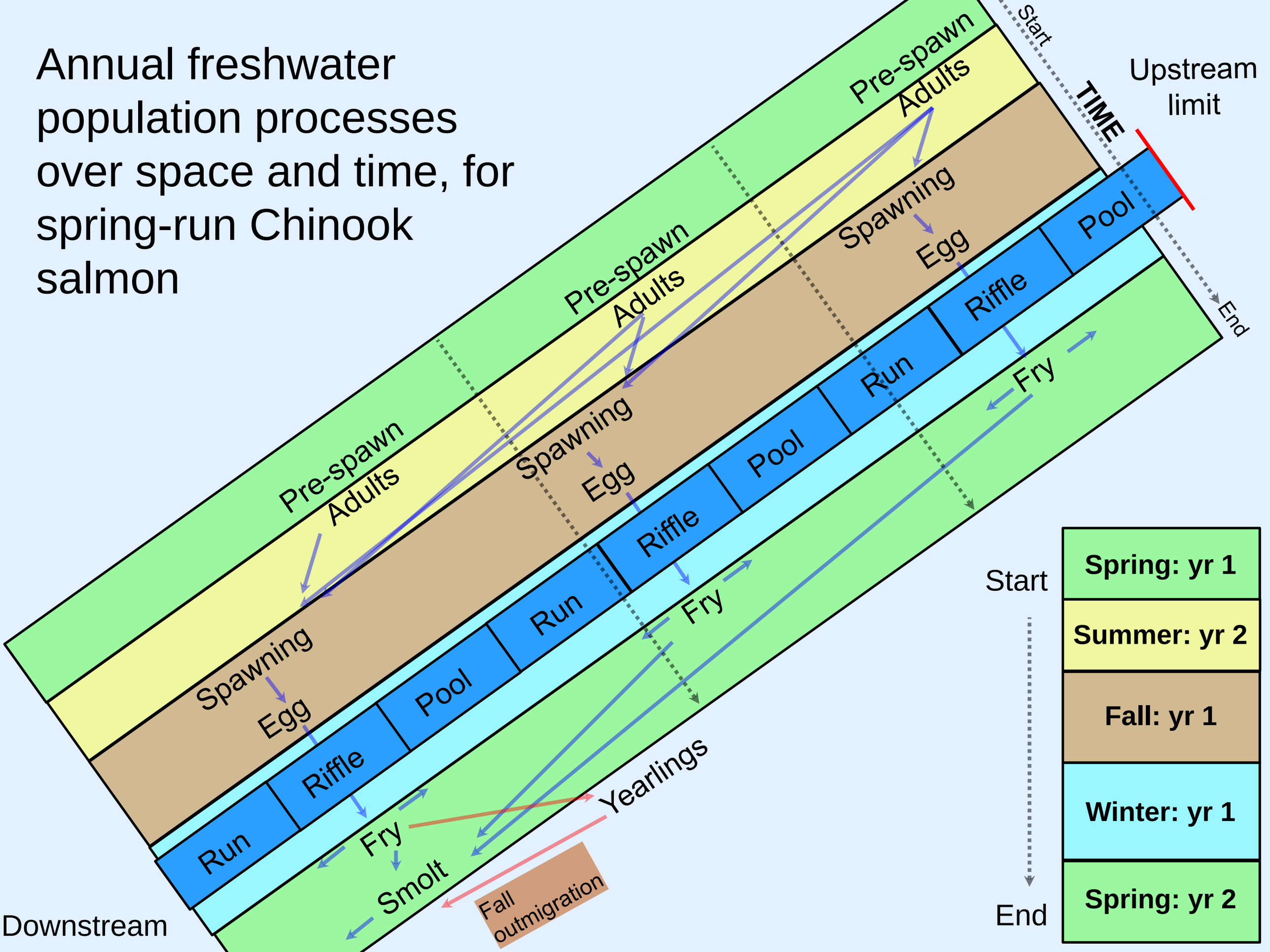
Model integration overview



WEAPhish Flow

- Configure model
  - Load input data: specifies the parameters, ecological & biophysical relationships, and data that drive the simulations
- Run the model
  - I'll show you (quickly) how to run the model from the "command line"
  - Don't worry, Sooyeon and Sam will show you how to configure and run the model from Excel
- View output data from simulation.

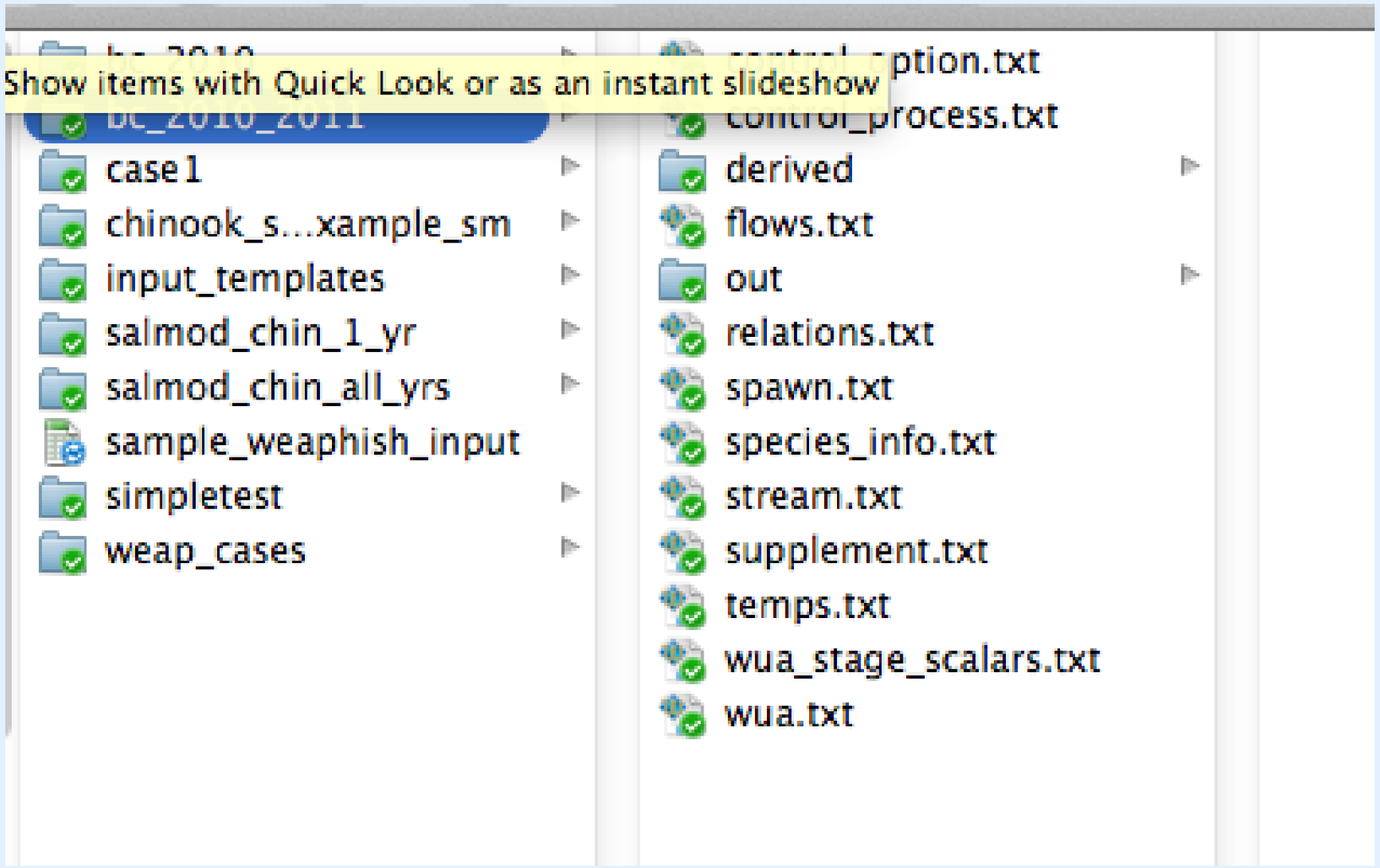
Annual freshwater population processes over space and time, for spring-run Chinook salmon



Input data

- Defines the simulation period (e.g., model year, length of simulation run)
- Species stages and size classes, number to “seed”
- Order that ecological process operate each time step (currently a week)
- Stream characteristics (number of habitat units, type, length)
- Weighted usable are for different habitat types for each stage in model
- Biological/ecological relationships for the species/system
- Temperature and flow data for stream segments over all time steps
- Timing and intensity of spawning

Input data



Take a look at excel

Simulation flow

- Create the “habitat” from input files
  - For each stream segment and each model time step “map” the physical conditions
    - Temperature
    - Flow
    - Weighted usable area and capacity [life stage specific]
- Seed the stream with adult fish at the beginning of simulation (by available habitat for stages seeded)
- Simulate fish population dynamics given demographic relationships temperature, flow, and habitat data
- View results

WEAPhish code layout

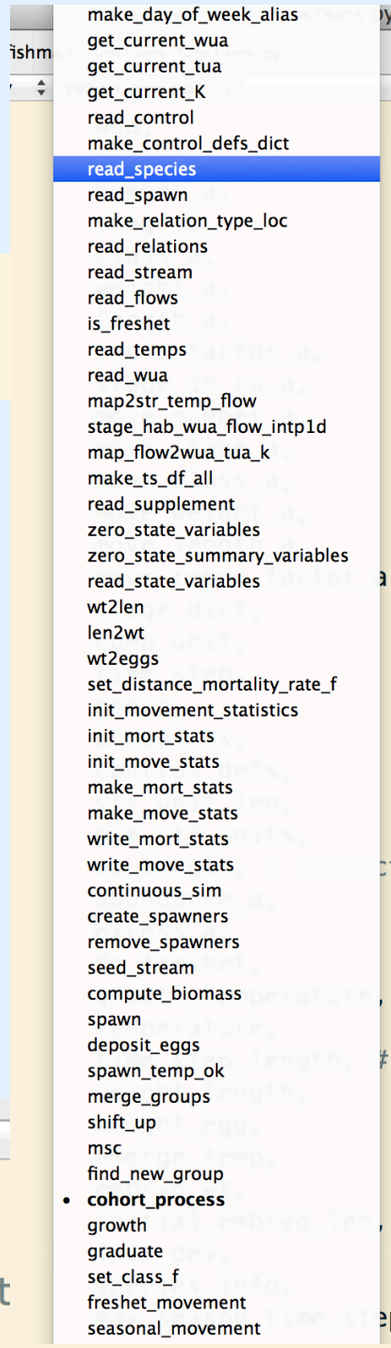
Python: with Numpy & Pandas; Continuum Analytics *Anaconda* distribution

fish_main.py: called from command line or from Master_WEAPhish spreadsheet, calls loads (via a Python import statement) then runs ***continuous_sim()***

```
from loads.loads import *
from functions.functions import *
```

loads.py: reads all input data files, sets model parameters, initializes data storage arrays (memory and disk), and maps input data to stream habitat

functions.py: contains all the demographic functions (growth, spawn, mortality, movement, etc.), data loading functions, and support functions for running simulations



fish_main.py
functions.py
loads.py
untitled text 19
untitled text 47

fish_main.py (no symbol selected)

```
simulation_start_time = datetime.now()

sim_type = 'continuous' # only choice, until 'weekly' implement

for time_step in range(total_time_steps):
    print "TIME STEP {}".format(time_step)
    out_sim = continuous_sim(sim_type=sim_type,
                             time_step=time_step,
                             total_time_steps=total_time_steps,
                             ts_ref=ts_ref,
                             process_controls=process_controls,
                             comp_unit_process_list=comp_unit_process_list,
```

Fire up a model run!

- From the bash shell:
- Set working directory

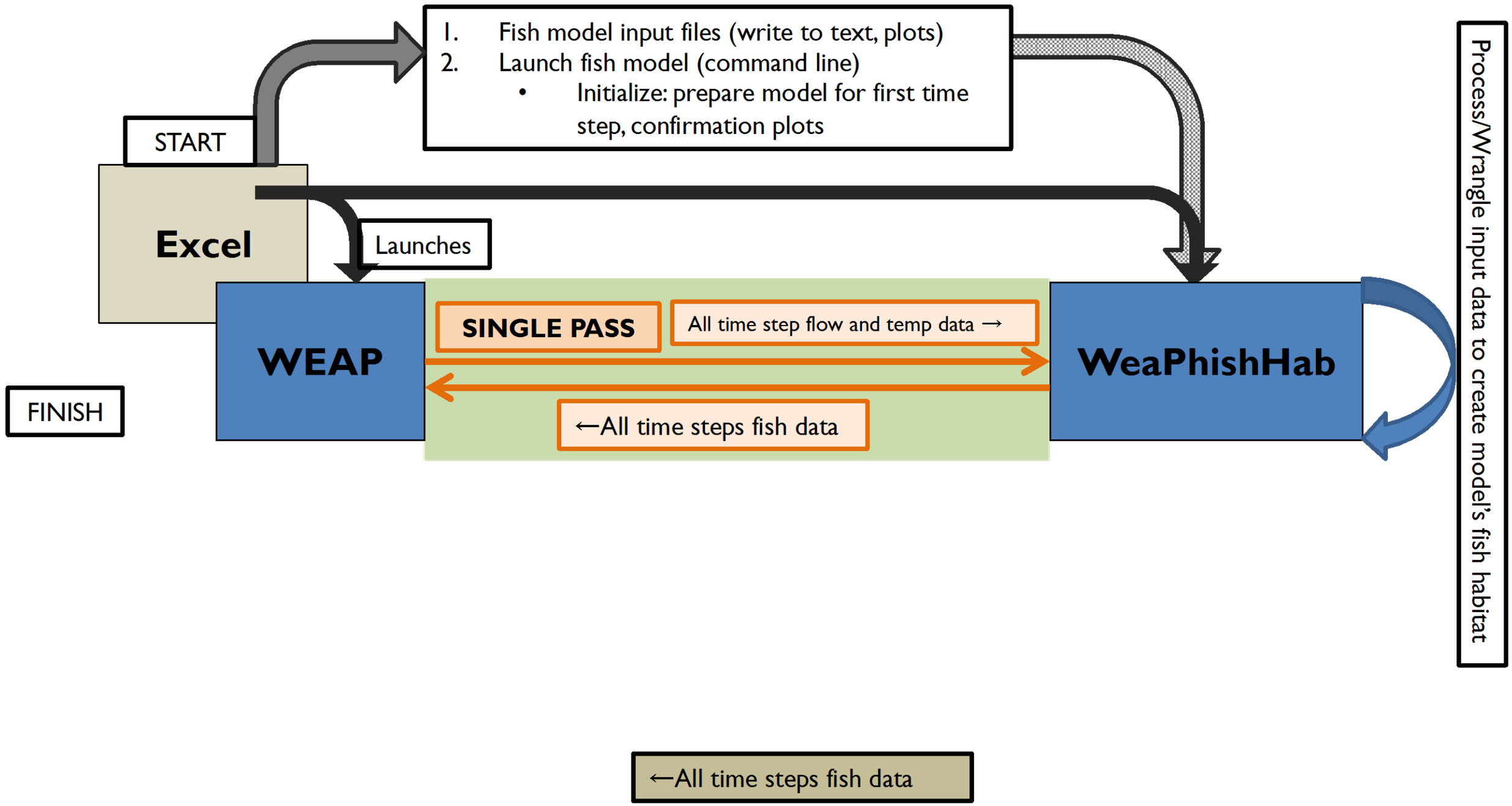
> cd /path/to/input/data

- Run fish_main.py script

> python path/to/fish_main.py

```
bc_2010_2011 — bash — 143×24
Patricks-MacBook-Pro-2:bc_2010_2019 patrickkilduff$ cd ~/Dropbox/fish_model_runs/bc_2010_2011/
Patricks-MacBook-Pro-2:bc_2010_2011 patrickkilduff$ time ipython ~/weaphish/fishmain/fish_main.py
START FISH MAIN
FLOW DATA LOADED
FRESHET DATA IN MEMORY
TEMP DATA LOADED
WUA AND CAPACITY DATA LOADED IN MEMORY
LOADED DATA IN FUNCTIONS, PROCEED FISH_MAIN
SHOULD HAVE DERIVED FOLDER LOADED WITH LOTS OF DATA
TIME STEP 0
TIME STEP 1
TIME STEP 2
TIME STEP 3
TIME STEP 4
TIME STEP 5
TIME STEP 6
TIME STEP 7
TIME STEP 8
TIME STEP 9
TIME STEP 10
TIME STEP 11
TIME STEP 12
TIME STEP 13
TIME STEP 14
```

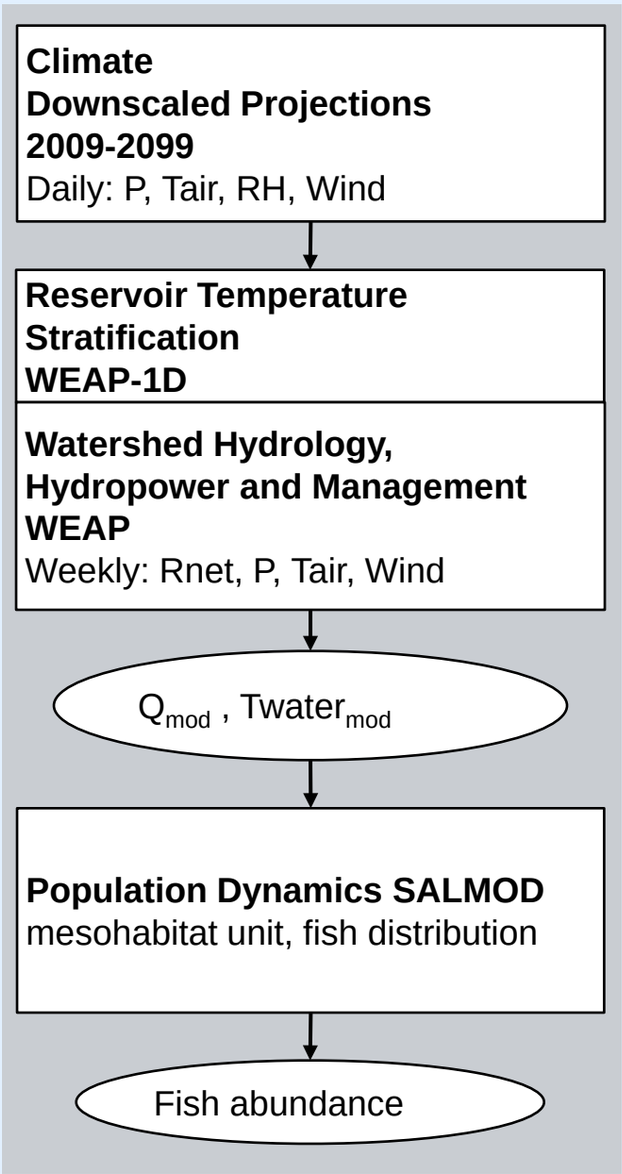
```
TIME STEP 100
TIME STEP 101
TIME STEP 102
TIME STEP 103
Continuous simulation has run
model run completed. it took 2:11:05.443707
2015-03-22 17:08:50.201423

real    131m8.237s
user    82m56.236s
sys     0m27.560s
Patricks-MacBook-Pro-2:bc_2010_2011 patrickkilduff$
```



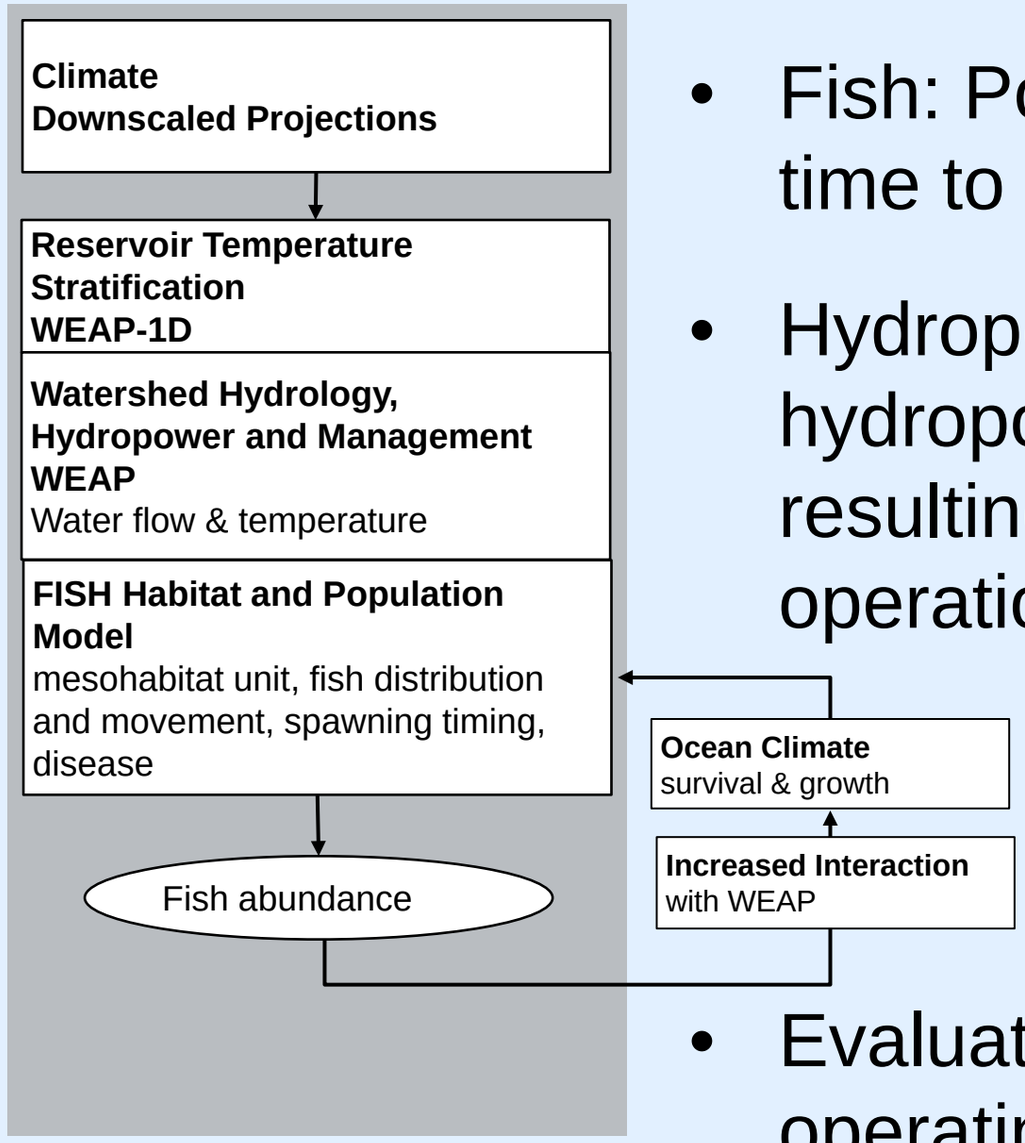
R scripts and functions for visualizing data.

Comparing frameworks

Previous



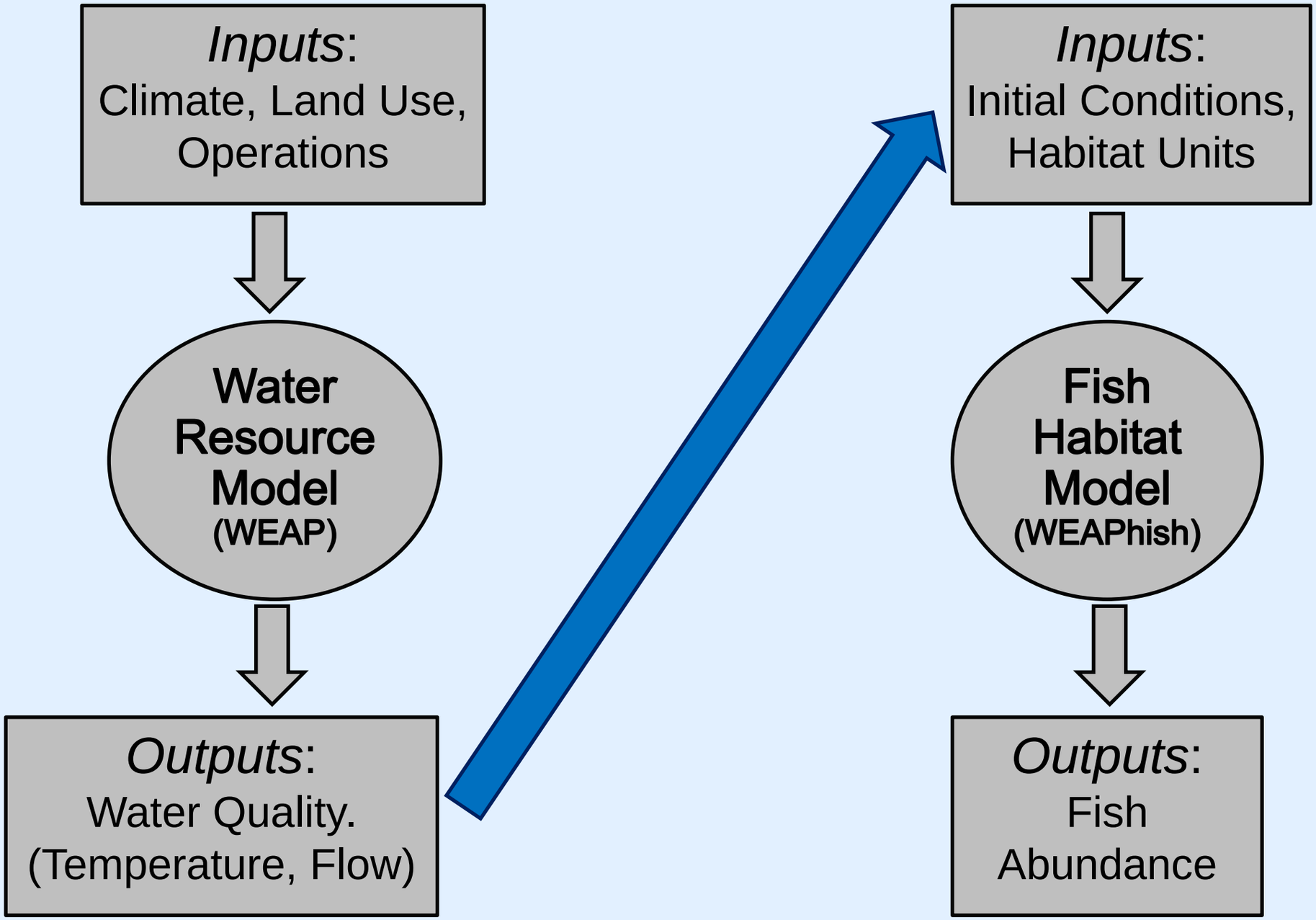
Current development



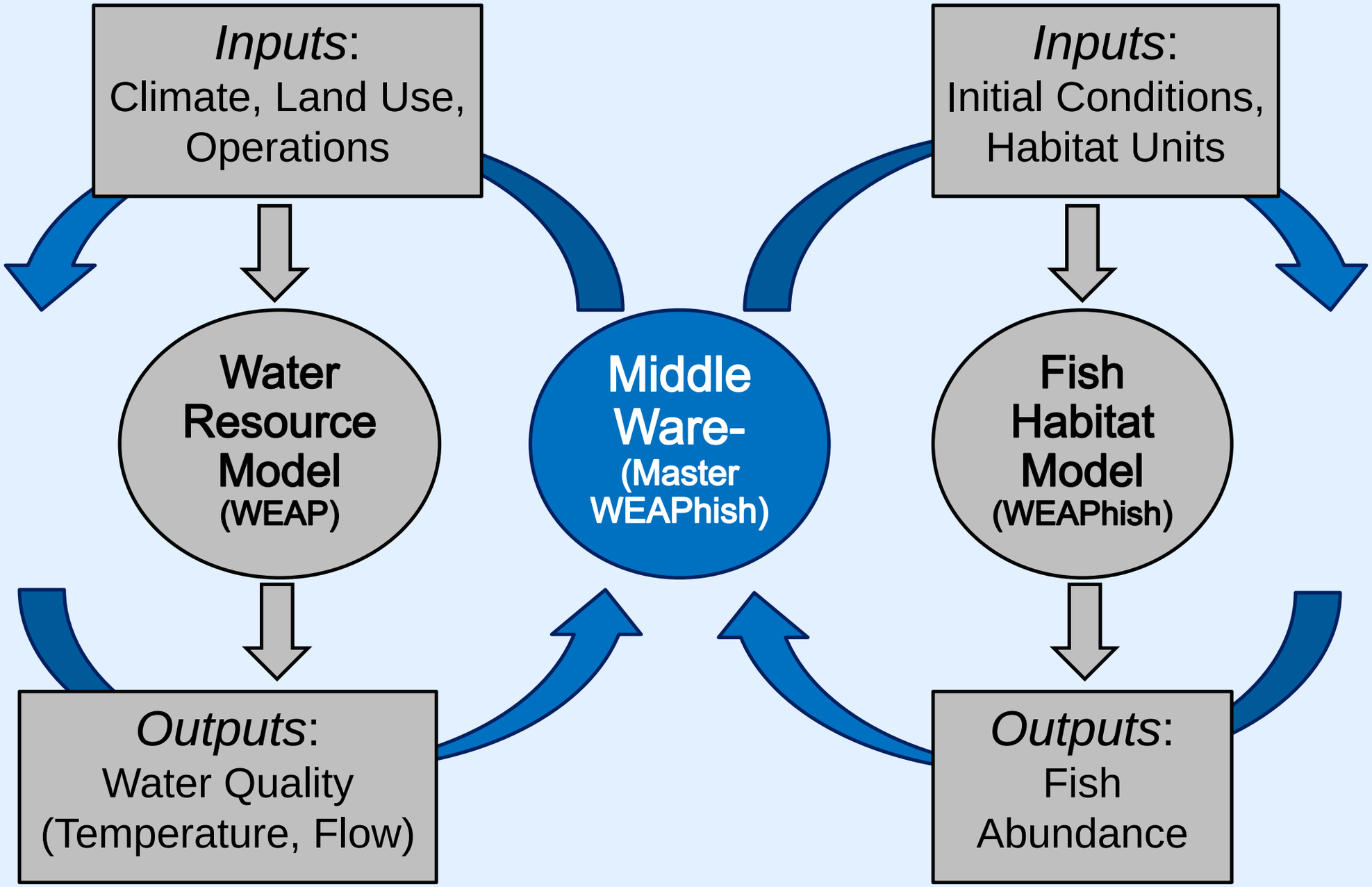
Metrics

- Fish: Population productivity, time to extinction
- Hydropower: Changes to hydropower generation resulting from fish-centric operations
- Evaluate dynamic fish-based operating rules

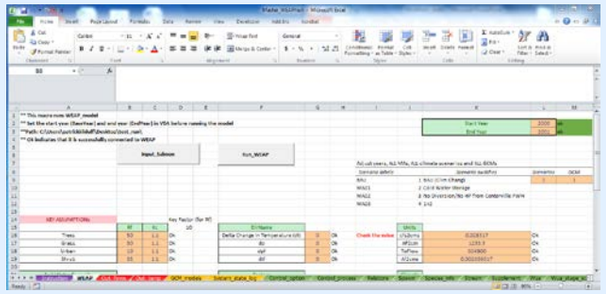
Model integration overview



Model integration overview



Model integration overview



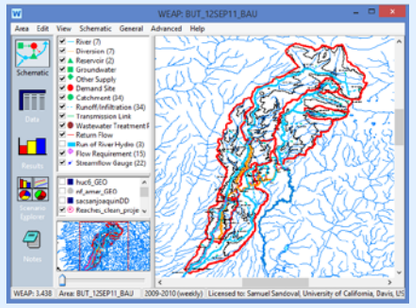
Inputs:
Climate, Land Use, Operations

Inputs:
Initial Conditions, Habitat Units

WEAP

WEAPhish

Water Resource Model (WEAP)



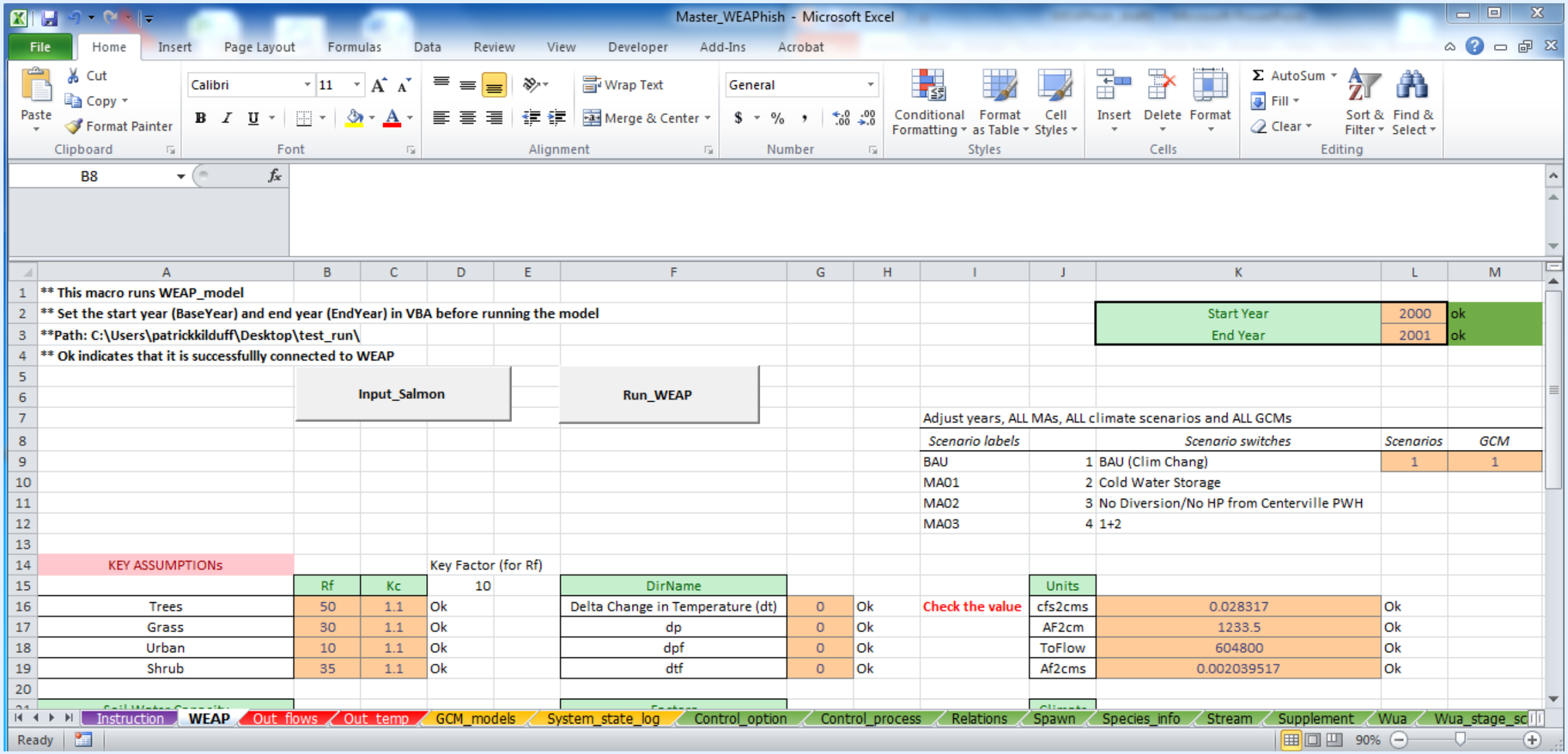
Middle-Ware (Master WEAPhish)

Fish Habitat Model (WEAPhish)

Outputs:
Water Quality (Temperature, Flow)

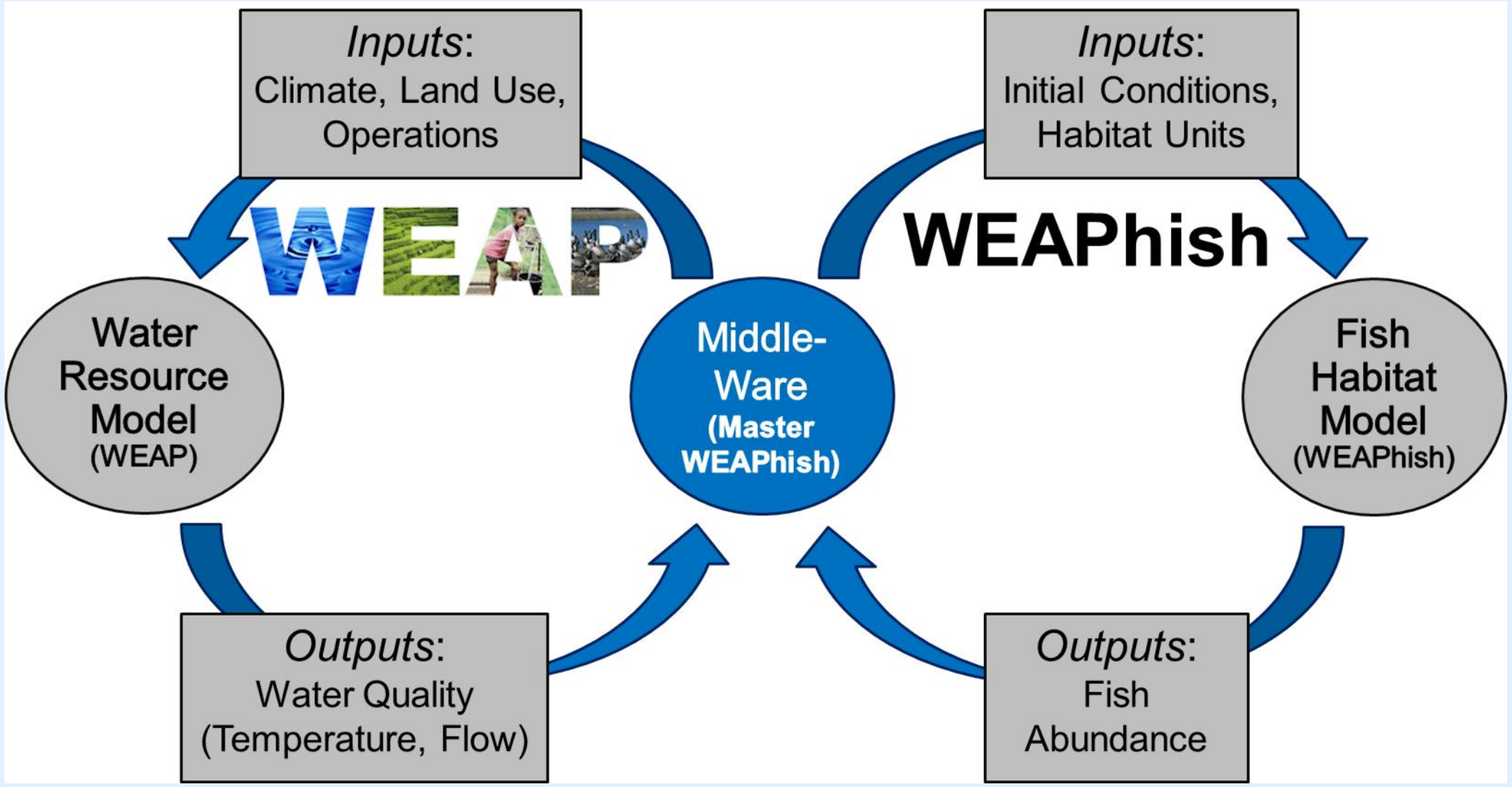
Outputs:
Fish Abundance

What is "*Master_WEAPhish*"?



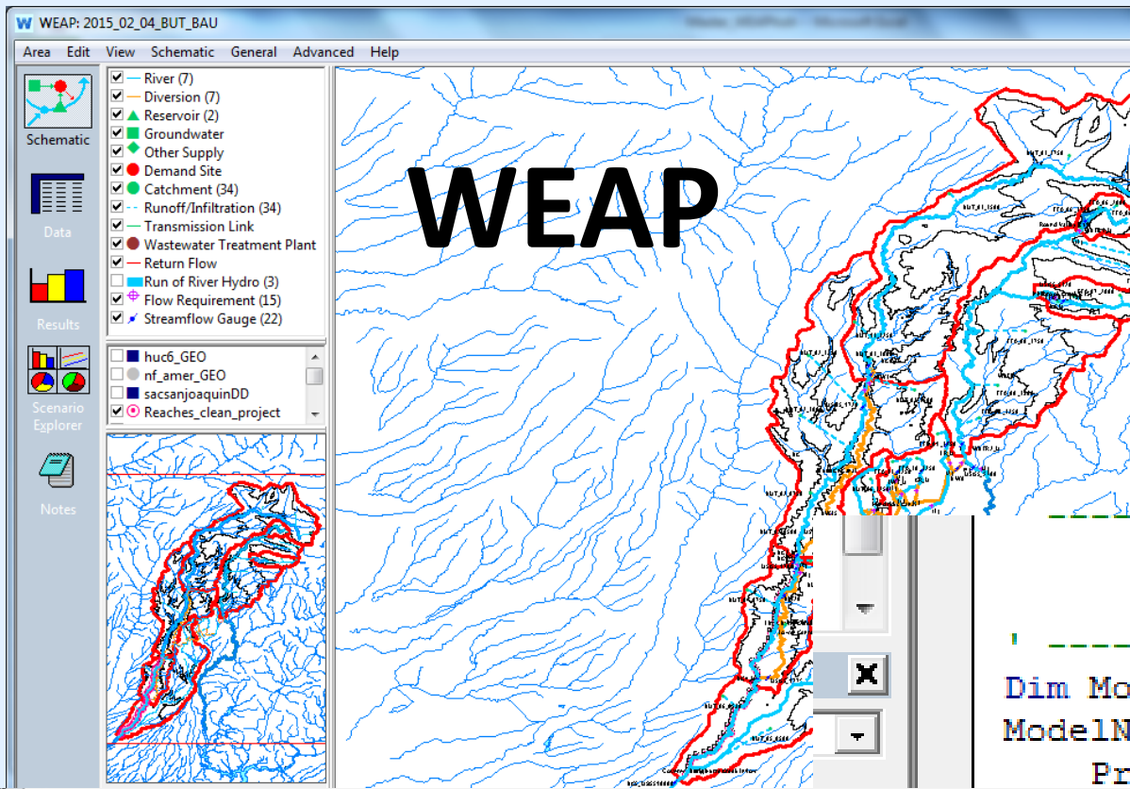
Linking a water resources model (**WEAP**) and a fish population model (**WEAPhish**) scripted in Python, we developed the middle-ware called **Master_WEAPhish** scripted in Visual Basic for Applications (VBA®) in Excel

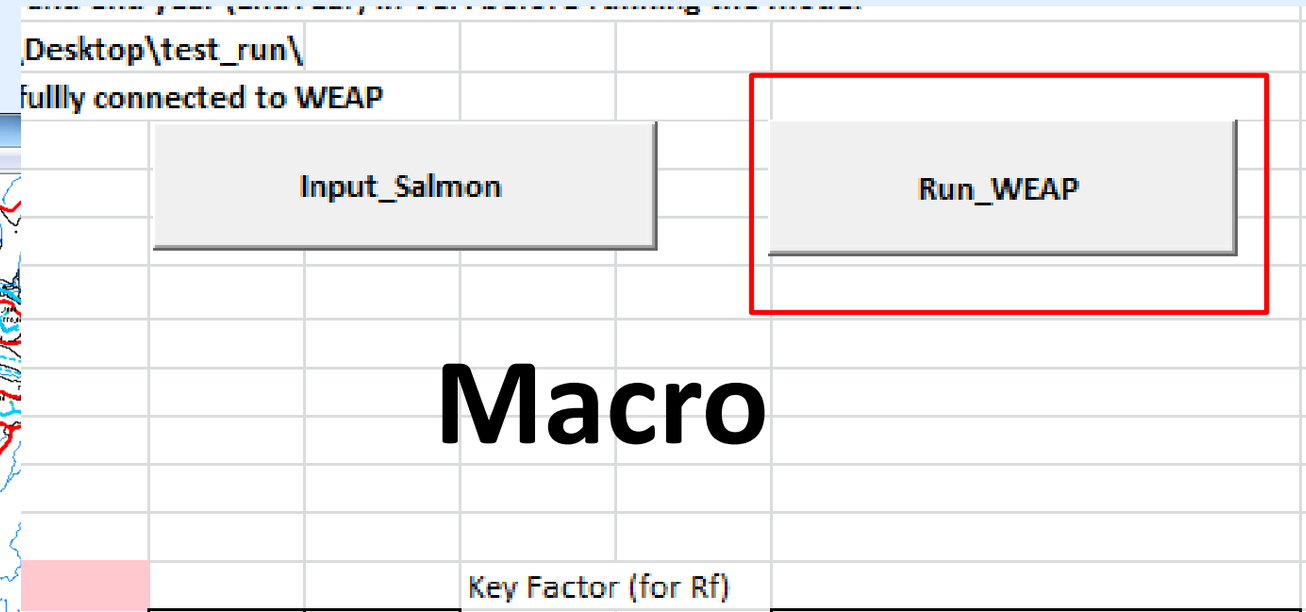
What is "*Master_WEAPhish*"?

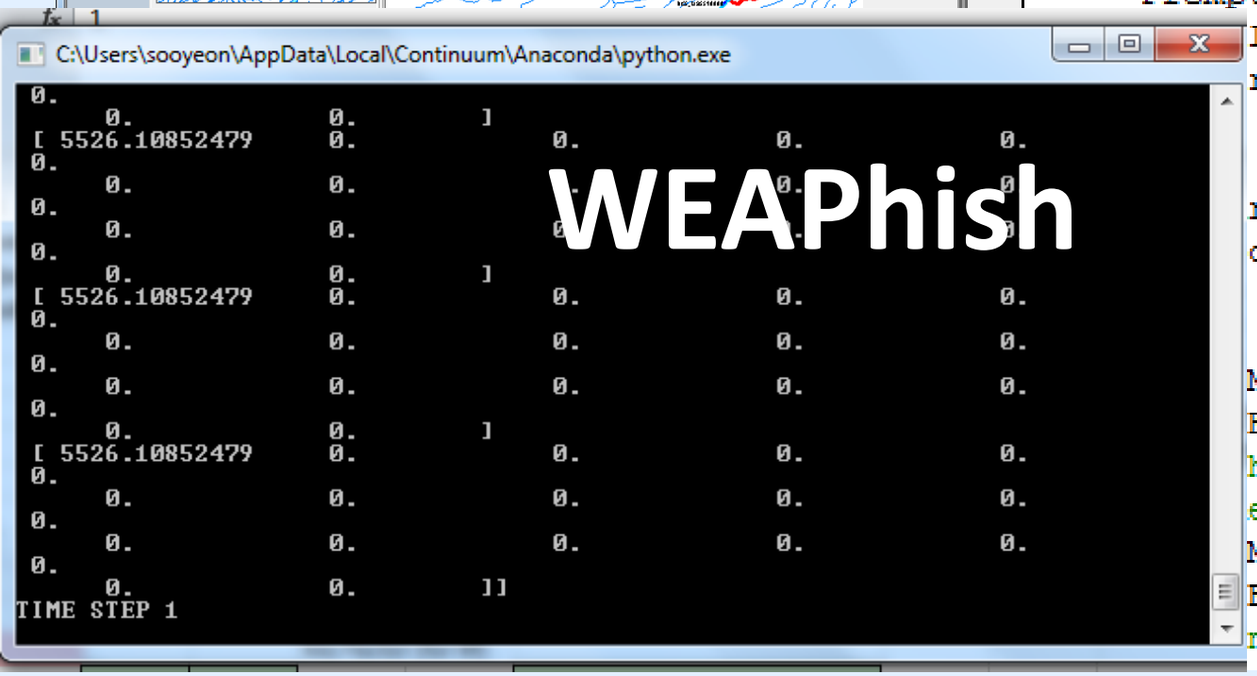


- Repetitive process
- Convenient to store inputs and outputs
- Adjust more than one parameter at each run

What is the "*Master_WEAPhish*"?



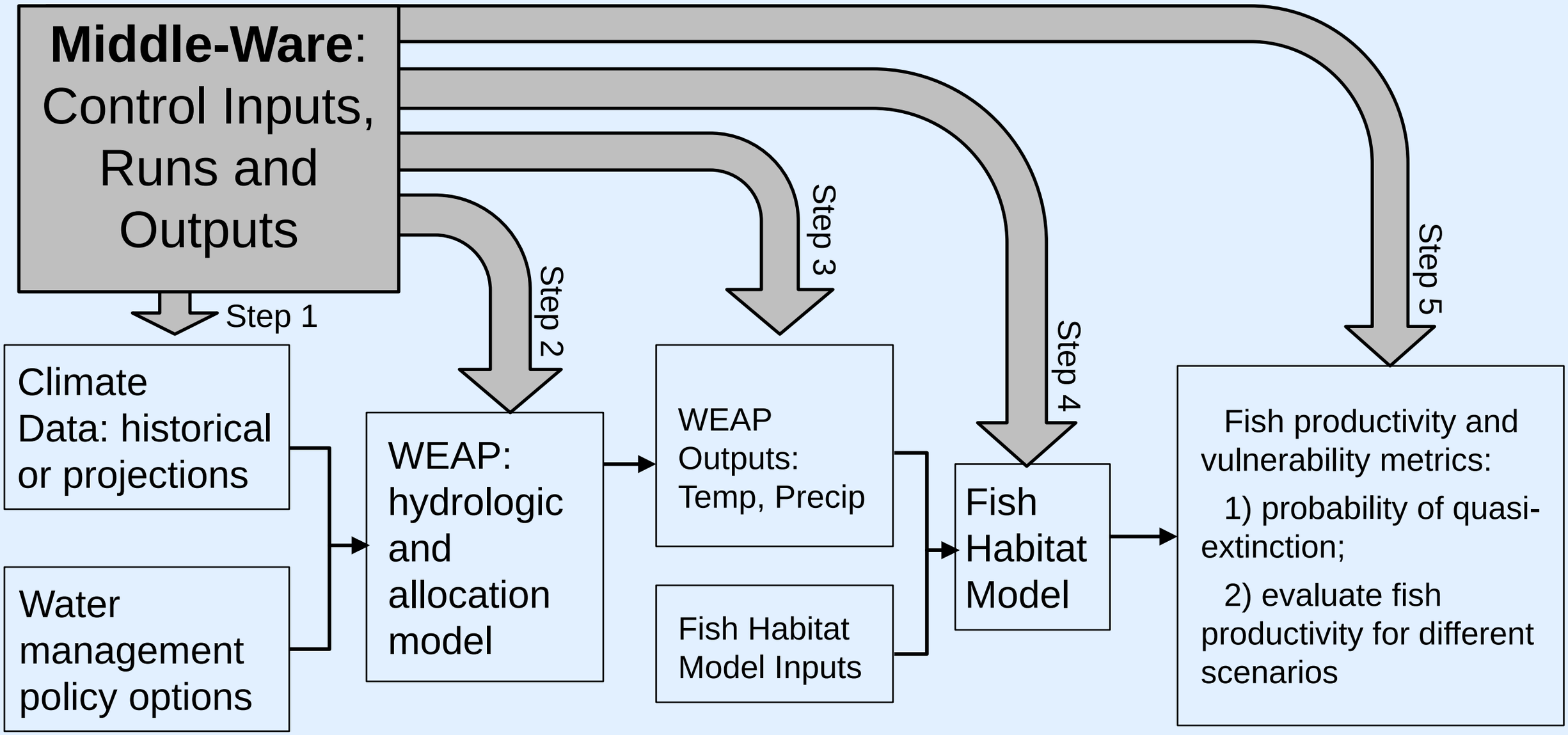





```
------- End of Exporting inputs needed for SALMOD ----------

' ------- Activating WEAP ---------
Dim ModelName As String
ModelName = InputBox( _
    Prompt:="Please enter the exact name of the model to run", _
lt:="2015_02_04_BUT_BAU")
reateObject("WEAP.WEAPApplication")
 = 1
 = W.Directory + "C:\WEAP_Results\WEAPErrors.txt"
rea = ModelName
cenario = "Current Accounts"
 you don't wanna see WEAP Running
 = True
Master_WEAPhish.xlsm").Activate
EAP").Select
h = ActiveWorkbook.Path
e = ActiveWorkbook.Name
Master_WEAPhish.xlsm").Activate
EAP").Select
ng Period of Analysis in WEAP
```

VBA

Master_WEAPhish Overview



What are Inputs to Master_WEAPhish?

Start Year and End Year

K	L
Start Year	2000
End Year	2001

Key Assumptions

Factors		
Swd_cap	2	Ok
Sws_cap	0.46353	Ok
Rf	10	Ok
Ks_SwCond	0.11506	Ok
Ks_SwCond_FEA_RV	0.4	Ok
Ks_SwCond_FEA_P	0.5	Ok
Ks_SwCond_FEA	0.48	Ok
Dw_DeepCap_FEA_RV	0.013	Ok
Dw_DeepCap_FEA_P	0.24	Ok
Dw_DeepCap_FEA	1.75	Ok
Swd_cap_FEA	0.51	Ok
Sws_cap_FEA	0.38	Ok
f_FlowDir_FEA	0.885	Ok
Kd_DeepCond_FEA	0.75	Ok
Swd_cap_FEA_RV	1	Ok
Swd_cap_FEA_P	1	Ok

What are Inputs to Master_WEAPhish?

Four Scenarios

General Circulation Models (GCMs)

Adjust years, ALL MAs, ALL climate scenarios and ALL GCMs				
Scenario labels		*Scenario switches*	*Scenarios*	*GCM*
BAU	1	BAU (Clim Chang)	1	6
MA01	2	Cold Water Storage		
MA02	3	No Diversion/No HP from Centerville PWH		
MA03	4	1+2		

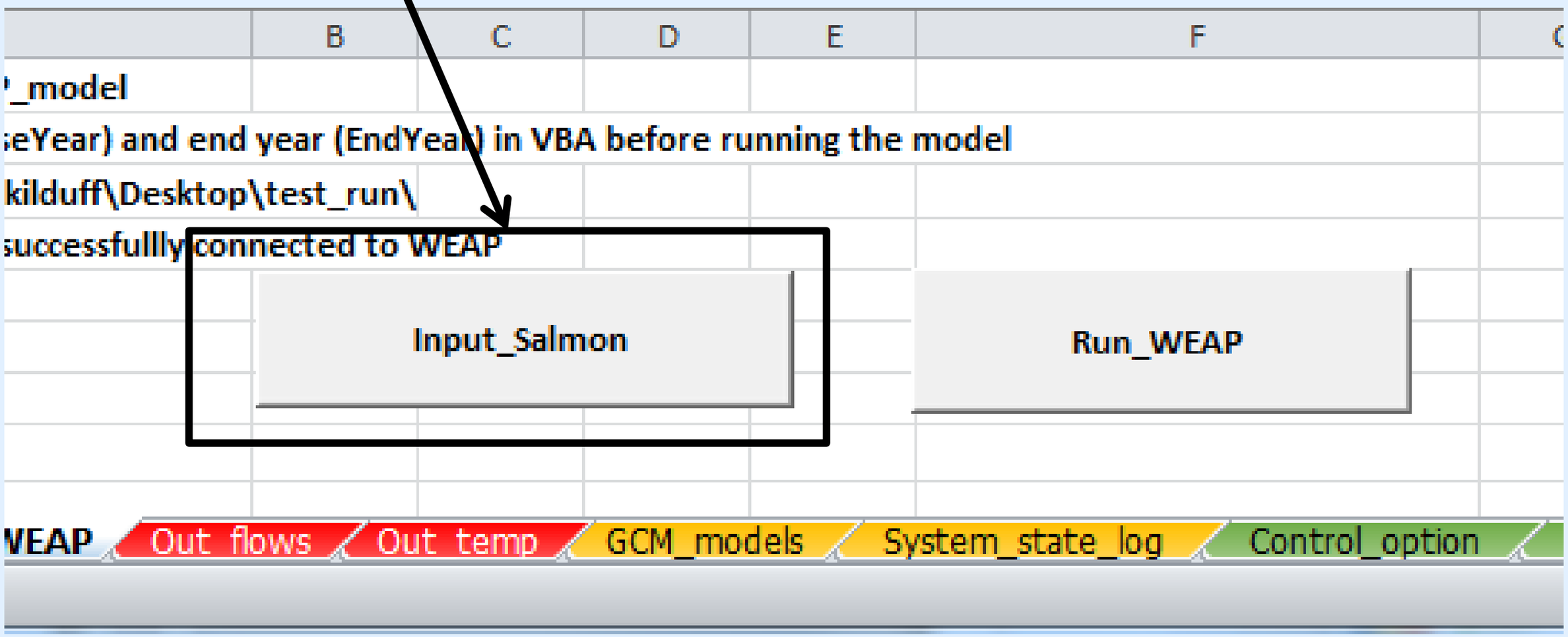
We have **4 scenarios** and **12 GCMs.**

User can easily adjust these in the following two cells

How to Run Master_WEAPhish?

(1) Update All Input Data macro

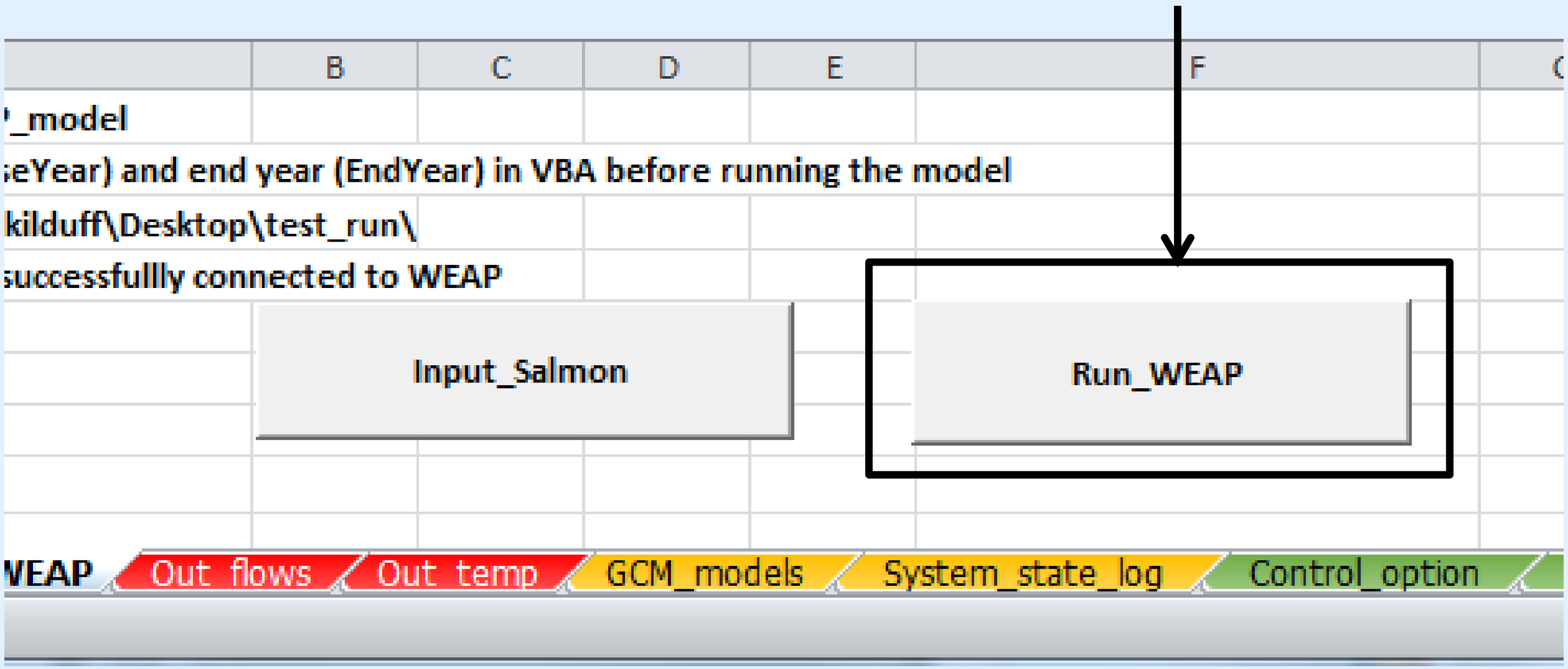
(2) Run WEAP macro



How to Run Master_WEAPhish?

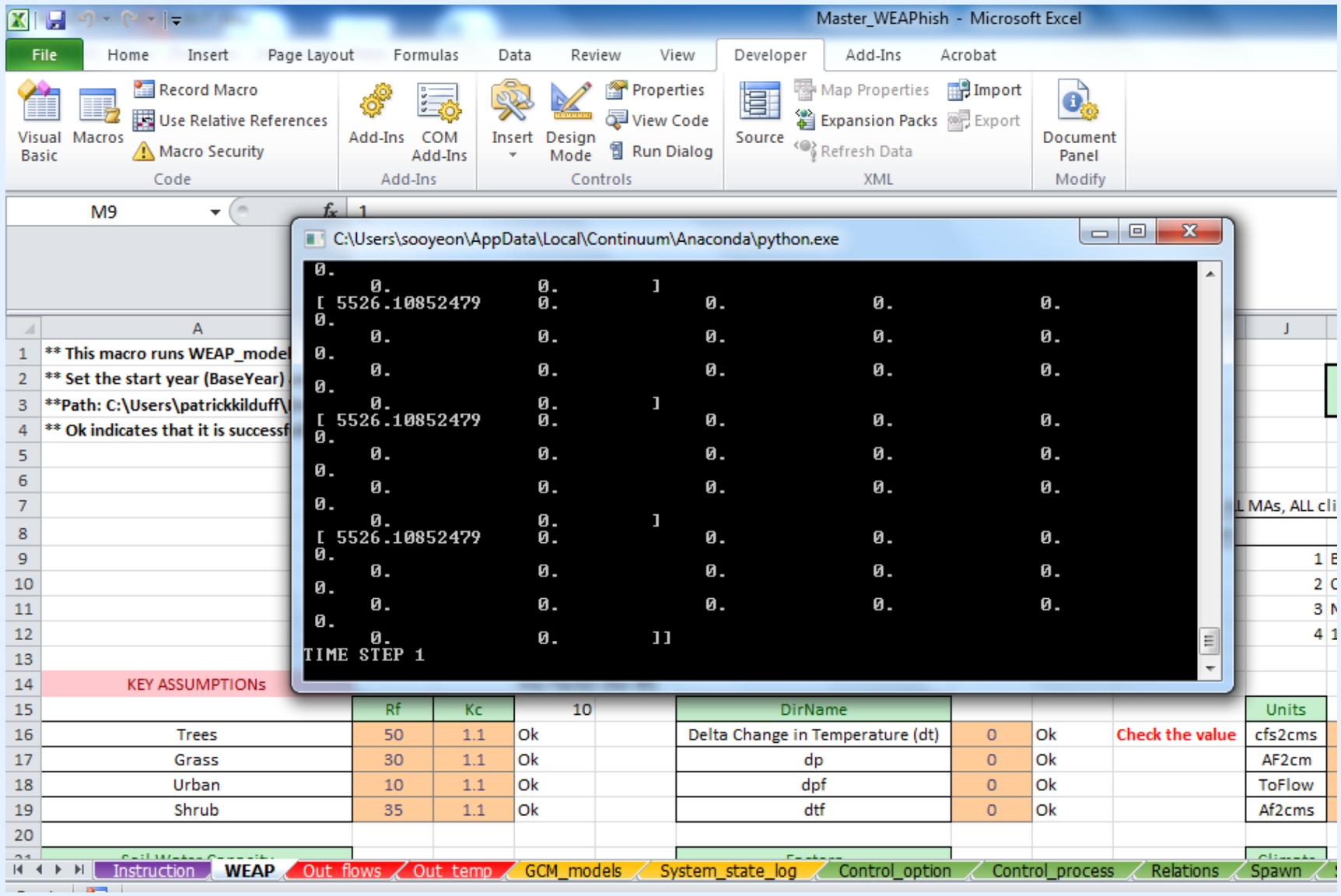
(1) Update All Input Data macro

(2) Run WEAP macro



What are Outputs from Master_WEAPhish?

Linked with WEAPhish



What are Outputs from Master_WEAPhish?

Output files: Flow and Temperature Data

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	5/25/1999	40	40	40	40	40	40	40	40	40	40	40	40
2	6/1/1999	40	40	40	40	40	40	40	40	40	40	40	40
3	6/8/1999	40	40	40	40	40	40	40	40	40	40	40	40
4	6/15/1999	40	40	40	40	40	40	40	40	40	40	40	40
5	6/22/1999	40	40	40	40	40	40	40	40	40	40	40	40
6	6/29/1999	40	40	40	40	40	40	40	40	40	40	40	40
7	7/6/1999	40	40	40	40	40	40	40	40	40	40	40	40
8	7/13/1999	40.023	40.023	40.023	40.023	40.023	40.023	40.023	40.023	40.023	40.023	40.023	40.023
9	7/20/1999	40	40	40	40	40	40	40	40	40	40	40	40
10	7/27/1999	40.001	40.001	40.001	40.001	40.001	40.001	40.001	40.001	40.001	40.001	40.001	40.001
11	8/3/1999	36.219	36.219	36.219	36.219	36.219	36.219	36.219	36.219	36.219	36.219	36.219	36.219
12	8/10/1999	32.424	32.424	32.424	32.424	32.424	32.424	32.424	32.424	32.424	32.424	32.424	32.424
13	8/17/1999	29.006	29.006	29.006	29.006	29.006	29.006	29.006	29.006	29.006	29.006	29.006	29.006
14	8/24/1999	26.05	26.05	26.05	26.05	26.05	26.05	26.05	26.05	26.05	26.05	26.05	26.05
15	8/31/1999	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3	23.3
16	9/7/1999	20.899	20.899	20.899	20.899	20.899	20.899	20.899	20.899	20.899	20.899	20.899	20.899
17	9/14/1999	18.651	18.651	18.651	18.651	18.651	18.651	18.651	18.651	18.651	18.651	18.651	18.651
18	9/21/1999	16.648	16.648	16.648	16.648	16.648	16.648	16.648	16.648	16.648	16.648	16.648	16.648
19	9/28/1999	14.759	14.759	14.759	14.759	14.759	14.759	14.759	14.759	14.759	14.759	14.759	14.759
20	10/5/1999	401.77	401.77	401.77	401.77	401.77	401.77	401.77	401.77	401.77	401.77	401.77	401.77
21	10/12/1999	409.39	409.39	409.39	409.39	409.39	409.39	409.39	409.39	409.39	409.39	409.39	409.39
22	10/19/1999	56.264	56.264	56.264	56.264	56.264	56.264	56.264	56.264	56.264	56.264	56.264	56.264

WEAP | Out_flows | Out_temp | GCM_models | System_state_log | Control_option | Control

What are Outputs from Master_WEAPhish?

Different output files for different scenario and GCMs

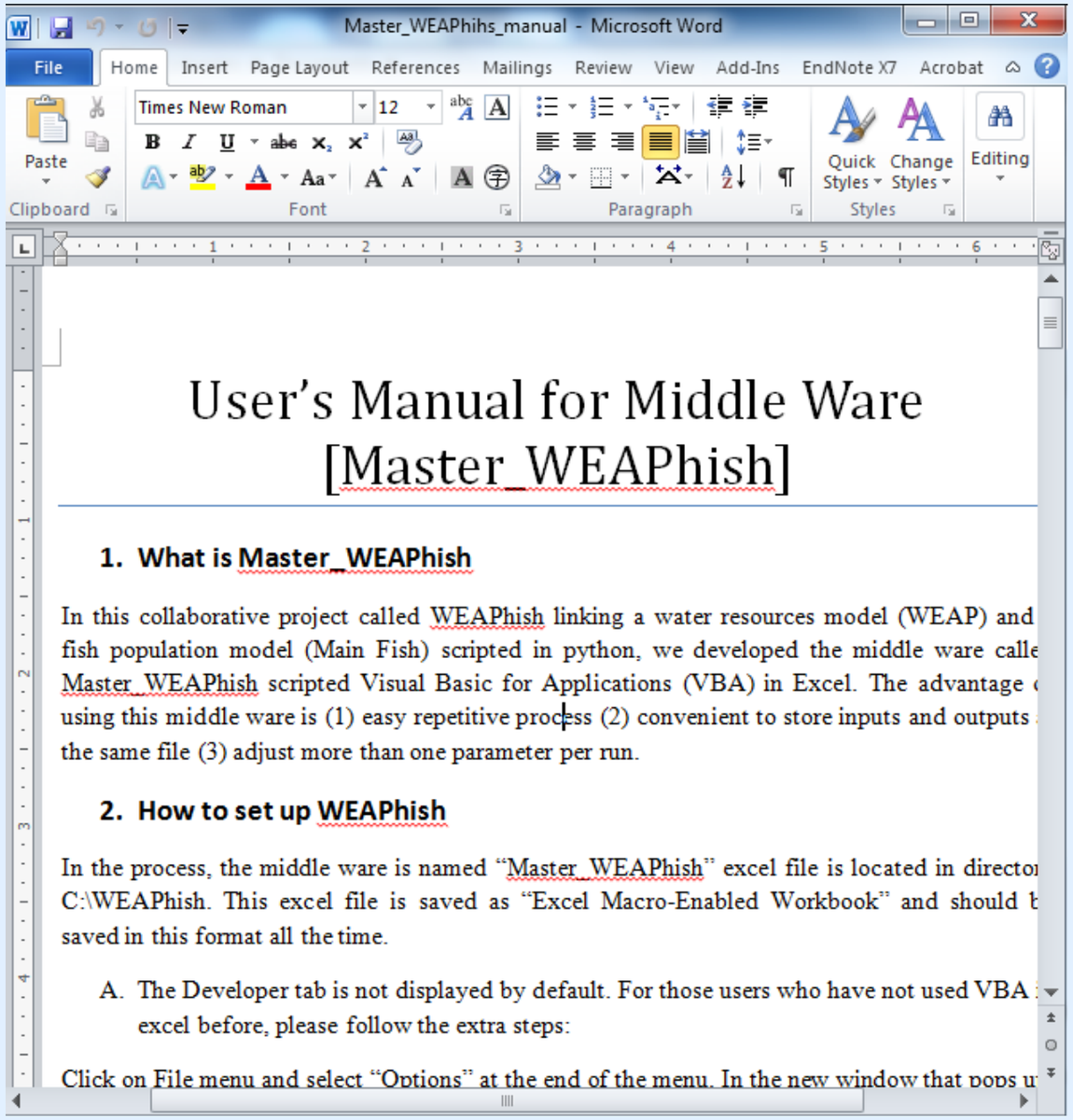
Name	Date modified
BAU_T_sresA2_cnrmcm3	3/17/2015 12:50 PM
BAU_Q_sresA2_cnrmcm3	3/17/2015 12:50 PM
BAU_System_state_log_sresA2_cnrmcm3	3/17/2015 12:50 PM
BAU_T_sresA2_ncarpcm1	3/17/2015 12:49 PM
BAU_Q_sresA2_ncarpcm1	3/17/2015 12:49 PM
BAU_System_state_log_sresA2_ncarpcm1	3/17/2015 12:49 PM
BAU_Q_sresA2_ncarccsm3	3/17/2015 12:48 PM
BAU_System_state_log_sresA2_ncarccsm3	3/17/2015 12:48 PM
BAU_T_sresA2_ncarccsm3	3/17/2015 12:48 PM
BAU_Q_sresA2_mpiecham5	3/17/2015 12:47 PM
BAU_System_state_log_sresA2_mpiecham5	3/17/2015 12:47 PM
BAU_T_sresA2_mpiecham5	3/17/2015 12:47 PM
BAU_Q_sresA2_miroc32med	3/17/2015 12:46 PM
BAU_System_state_log_sresA2_miroc32med	3/17/2015 12:46 PM
BAU_T_sresA2_miroc32med	3/17/2015 12:46 PM
BAU_T_sresA2_gfdlcm21	3/17/2015 12:45 PM
BAU_Q_sresA2_gfdlcm21	3/17/2015 12:45 PM
BAU_System_state_log_sresA2_gfdlcm21	3/17/2015 12:45 PM
BAU_System_state_log__date	3/16/2015 4:54 PM
Empty_file	3/2/2015 5:04 PM

For example

- BAU_T_sresA2_cnrmcm3
- BAU_Q_sresA2_cnrmcm3
- BAU_System_state_log_sresA2_cnrmcm3

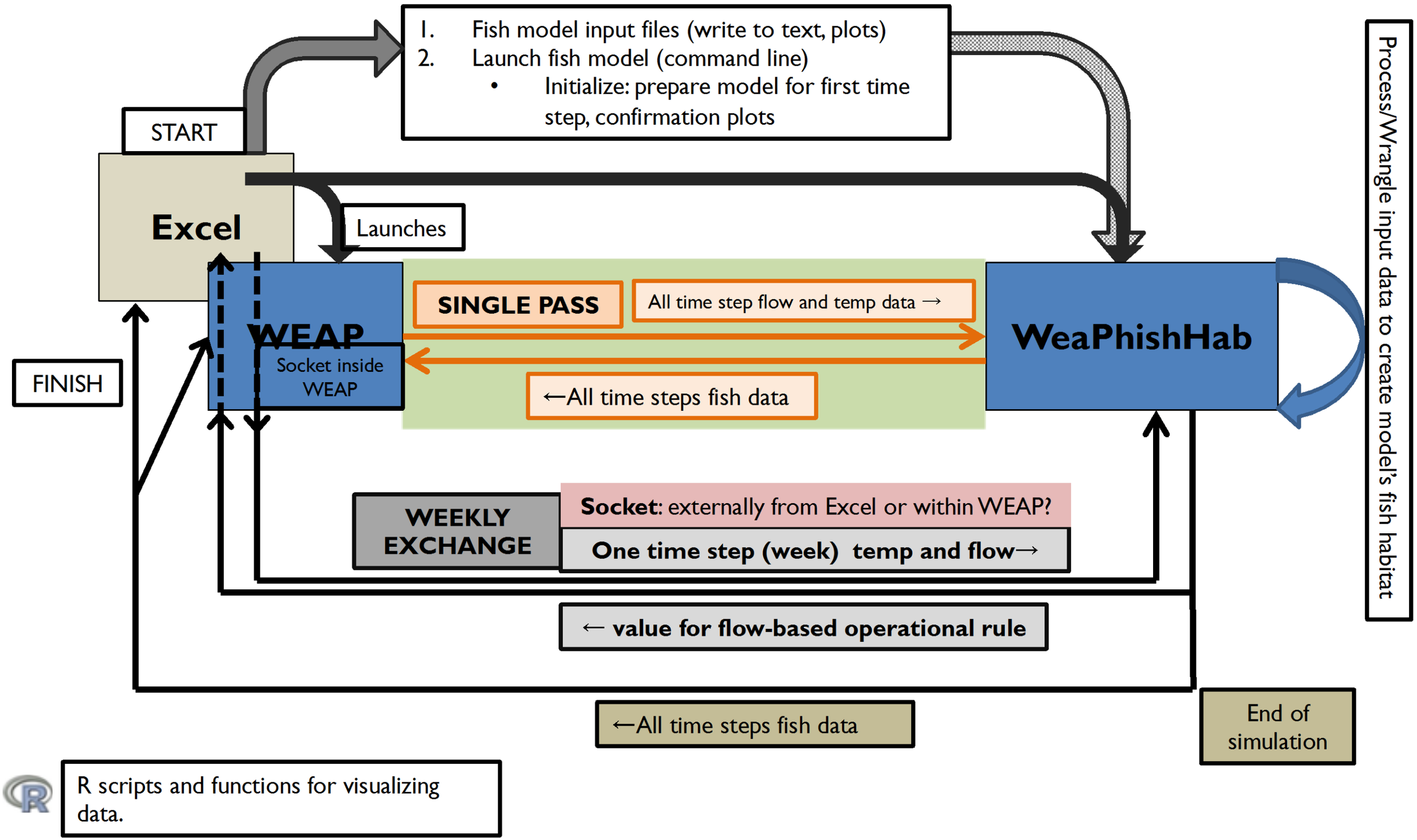
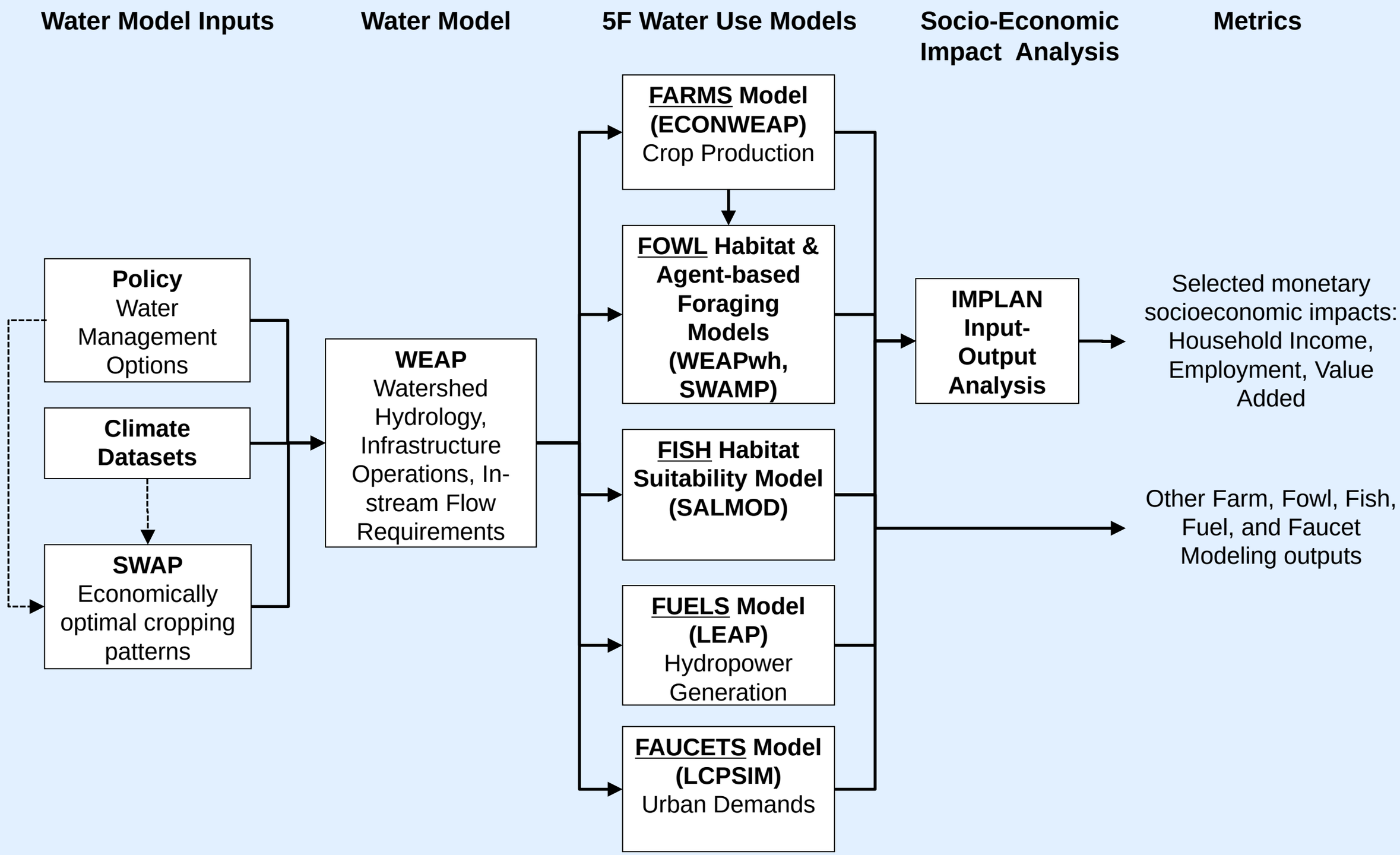
How to use Master_WEAPhish?

User's Manual for Middle-Ware



How to set up WEAPhish

- Enable Macro / Developer in Excel
- Anaconda
- Python 2.7
- Set up sub-folders in specific directory
- Contact: scyi@ucdavis.edu, samsandoval@ucdavis.edu


1. Fish model input files (write to text, plots)
2. Launch fish model (command line)
• Initialize: prepare model for first time step, confirmation plots
START
Excel
Launches
WEAP
Socket inside WEAP
SINGLE PASS
All time step flow and temp data →
←All time steps fish data
WeaPhishHab
Process/Wrangle input data to create model's fish habitat
FINISH
WEEKLY EXCHANGE
Socket: externally from Excel or within WEAP?
One time step (week) temp and flow→
← value for flow-based operational rule
←All time steps fish data
End of simulation
R scripts and functions for visualizing data.

Future applications: 5 F Framework