CalSim3 Misc Updates

Modeling Support Office

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Part I: CalSim3 Weights/Penalty Range Reduction and Integer Removal

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Goal:

Reduce weight (priority) range to increase stability of CS3 runs

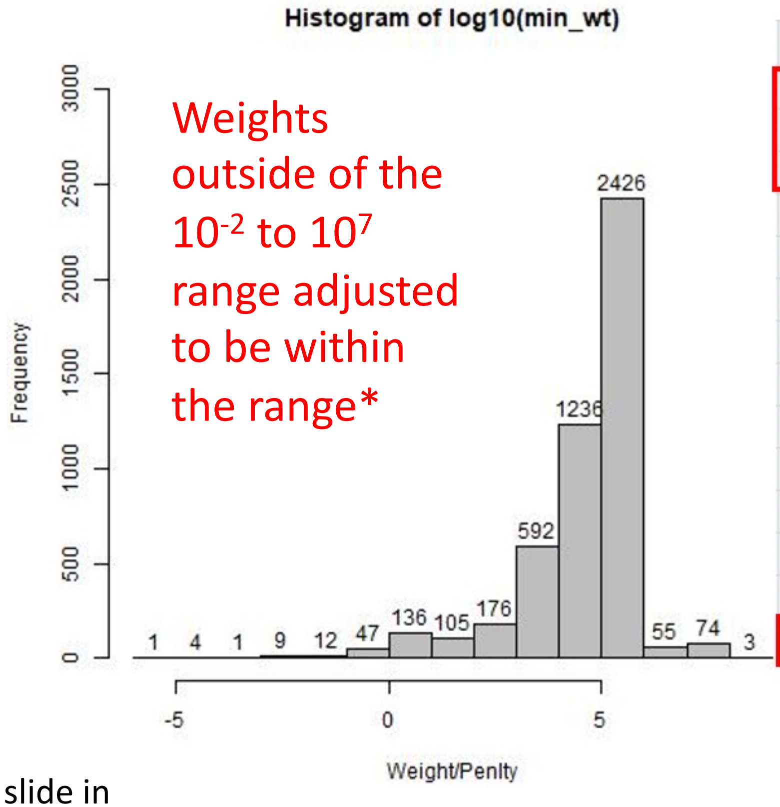
Method:

Develop an alternative CS3 study such that the ratio of the maximum weight/penalty to the minimum weight/penalty resolution is within the recommended range of 10^9.

Results: Changes in Weight/Penalty Frequency Distribution

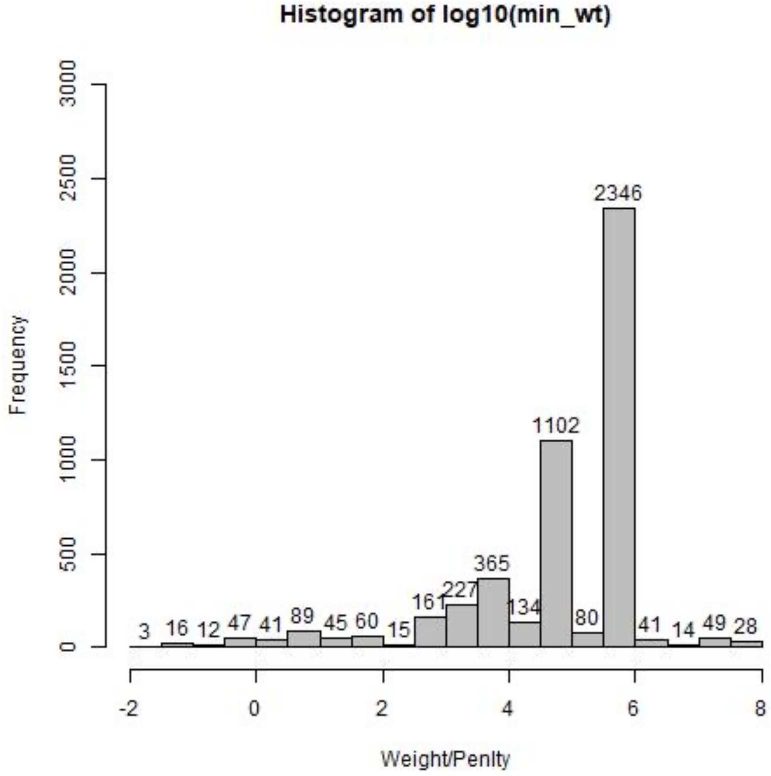
Base: 06.53_DCR21_BL_wsidi
Alternative: 06.54_DCR21_BL_wsidi

Base (Before Adjustment)



Weights outside of the 10^{-2} to 10^{7} range adjusted to be within the range*

minwt	Freq
(1e-05,0.0001]	4
(0.0001,0.001]	1
(0.001,0.01]	9
(0.01,0.1]	12
(0.1,1]	47
(1,10]	136
(10,100]	105
(100,1e+03]	176
(1e+03,1e+04]	592
(1e+04,1e+05]	1236
(1e+05,1e+06]	2426
(1e+06,1e+07]	55
(1e+07,1e+08]	74
(1e+08,1e+09]	3



minwt	Freq
(1e-05,0.0001]	0
(0.0001,0.001]	0
(0.001,0.01]	1
(0.01,0.1]	18
(0.1,1]	59
(1,10]	130
(10,100]	105
(100,1e+03]	176
(1e+03,1e+04]	592
(1e+04,1e+05]	1236
(1e+05,1e+06]	2426
(1e+06,1e+07]	55
(1e+07,1e+08]	77
(1e+08,1e+09]	0

*refer to Methods slide in Supplemental for details.

Original range: 10^-6 to 10^8
Ratio – 10^14

Updated Range: 10^-2 to 10^7
Ratio – 10^9

Results: System Summary

Before Re-weighting: 06.53_DCR21_BL_wsidi
After Re-weighting: 06.54_DCR21_BL_wsidi

	1922-2015			
	06.54_DCR21_BL_wsidi	06.53_DCR21_BL_wsidi	Diff	% Diff
River Flows				
Trinity R blw Lewiston	769	772	-3	0
Trinity Export	483	480	3	1
Clear Cr blw Whiskeytown	149	148	0	0
Sacramento R @ Keswick	6145	6142	3	0
Sacramento R @ Wilkins Slough	6253	6252	0	0
Feather R blw Thermalito	2993	2993	0	0
Feather R: at Sac R confluence	5271	5272	-1	0
Yuba R @ Marysville	1499	1499	0	0
Sacramento R @ Verona	12956	12957	-1	0
American R blw Nimbus	2427	2427	0	0
American R: at Sac R confluence	2345	2346	0	0
Delta Inflow	**21535**	**21534**	**1**	0
Sacramento R @ Hood	15522	15524	-1	0
Yolo Bypass	2326	2323	3	0
Mokelumne R	845	845	0	0
Calaveras R	111	111	0	0
San Joaquin R d/s Vernalis	2732	2732	0	0

	1922-2015			
	06.54_DCR21_BL_wsidi	06.53_DCR21_BL_wsidi	Diff	% Diff
NDOI	**15177**	**15178**	-1	0
Surplus Outflow	10056	10058	-2	0
Surplus Outflow - ANN	299	309	-10	-3
Surplus Outflow - CVP	5260	5260	0	0
Surplus Outflow - SWP	4448	4441	8	0
Surplus Outflow - VSA				
Surplus Outflow - SJRR	34	33	1	3
Surplus Outflow - WHLCV	13	13	0	2
Surplus Outflow - WHLJP	0	0	0	-100
Surplus Outflow - WTS	3	3	0	0
Min Outflow	5121	5120	1	0
Delta Exports	**4985**	**4984**	**1**	0
Banks	2485	2484	1	0
Banks SWP	2393	2391	2	0
Banks CVP	68	69	-1	-2
Banks WTS	24	24	0	0
Jones	2500	2500	1	0
Jones CVP	2500	2500	1	0
Jones WTS	0	0	0	
SWP Delivery: TA+CO	**2326**	**2324**	**2**	0
Table A	2102	2100	2	0
Article 21	88	88	0	0
Article 56	224	224	0	0

Minor differences in long term annual averages.

Sensitivity Analysis (1) – Impacts of Integers Switching

Higher C_CAA003_CVC in Oct 1921 in Base is due to the switching of the integer, INT_HANDS from 1 to 0 in [TRANSFER_STAGE1] cycle (cycle 32). When this happens, model sees capacity for delta surplus in [TRANSFER_STAGE1] cycle, which goes into C_CAA003_CVC in the CVC cycle.

Base

Year	Month	Cycles
1921	10	32 – 35
1976	11	22 – 35
1977	10	26
1977	11	22 - 35
1982	10	22 – 35
1982	11	22 – 35
1983	11	22 - 35
1991	11	23 – 35
1992	11	27, 28, 30 - 35
1998	11	22 – 35
2009	11	22 – 35

Alt

Year	Month	Cycles
1976	11	22 – 35
1977	10	26
1977	11	23 – 35
1982	10	22 – 35
1982	11	22 – 35
1983	11	22 – 35
1991	11	22 – 35
1992	11	22 – 35
1998	11	22 – 35
2009	11	23 - 35

Tables show time steps and cycles which INT_HANDS are assigned 0 values. In the remaining times and cycles, INT_HANDS are assigned value of 1.

Switching of integer value is NOT a reasonable model behavior since key regulatory processes that could have affected INT_HANDS values have been modeled in the earlier cycle, [DELTA].

Such behavior as shown in the Base study can be attributed to the solver: at that time step and cycle, model solution when INT_HANDS = 1 was a little over the tolerance limit so solver made the decision to switch to 0, (Kevin Kao, DWR pers. Comm.).

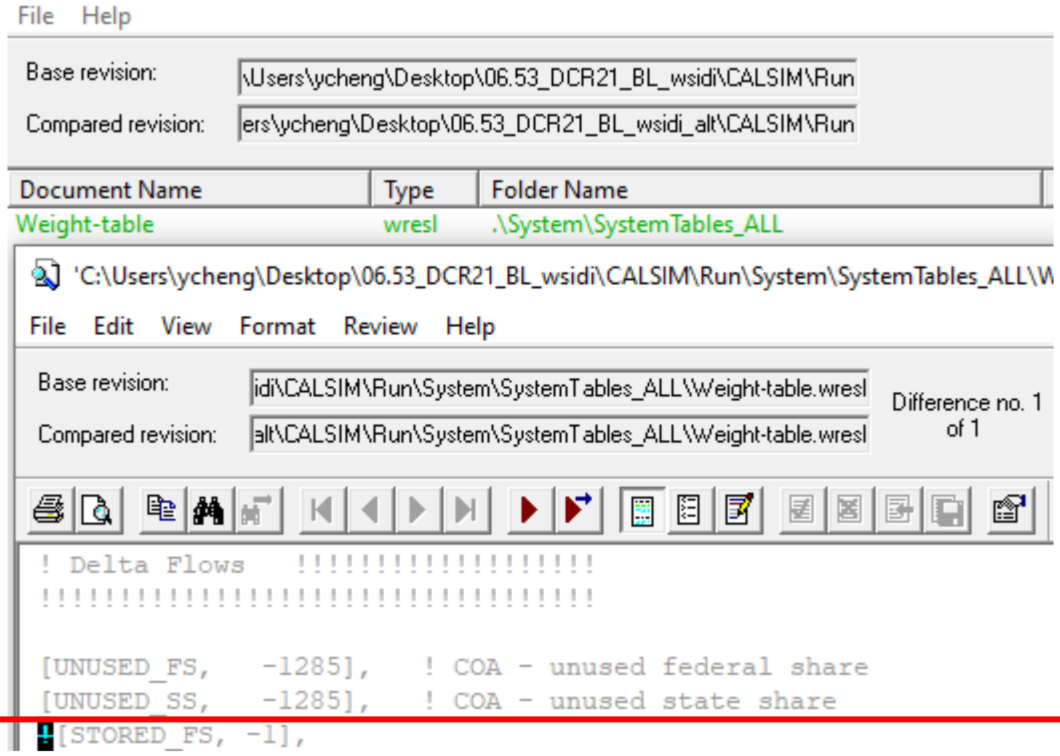
Sensitivity Analysis (2) – Impact of Weight Perturbation

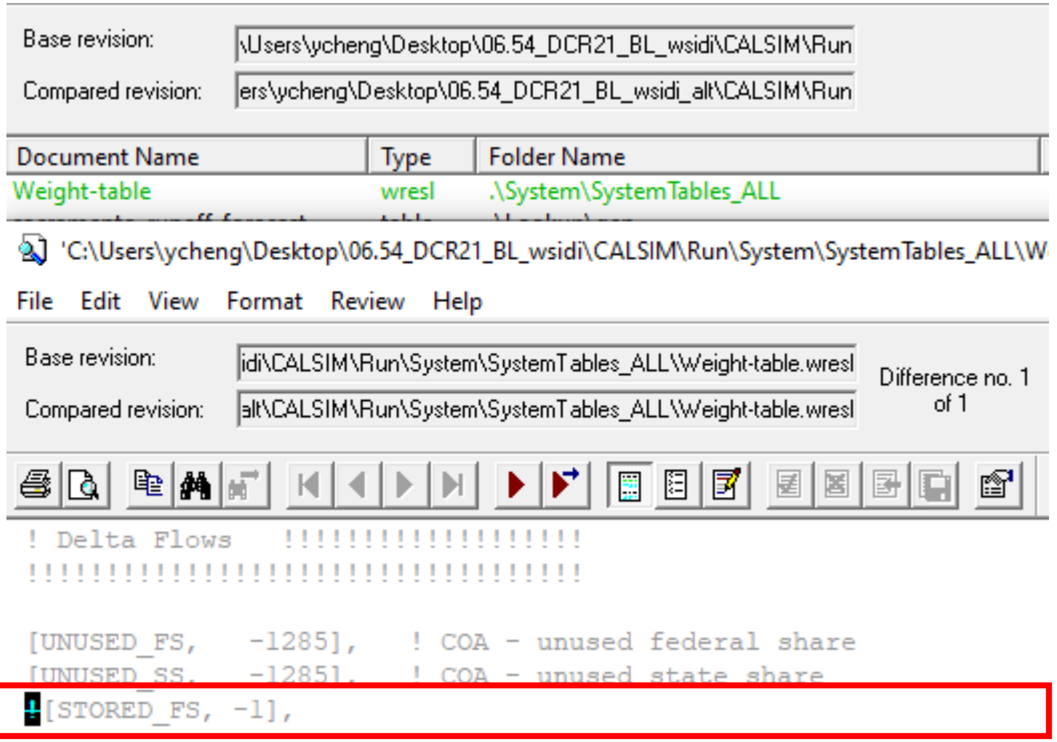
Introduce small weight change (perturbation).

Expectation: Recoloring of water, but no significant change in key system behavior/outputs.

```
goal setUNUSED_FS { C_CAA003_EXP2 + D408_P_WHL_SB_E2 + Stored_FS < UNUSED_FS }
```

Before Re-weighting	After Re-weighting
Base: 06.53_DCR21_BL_wsidi Alt: 06.53_DCR21_BL_wsidi_alt	Base: 06.54_DCR21_BL_wsidi Alt: 06.54_DCR21_BL_wsidi_alt





Sensitivity Analysis (2) – Impact of Weight Perturbation

Before Re-weighting

Base: 06.53_DCR21_BL_wsidi
Alt: 06.53_DCR21_BL_wsidi_alt

	1922-2015			
	06.53_DCR21_BL_wsidi_alt	06.53_DCR21_BL_wsidi	Diff	% Diff
River Flows				
Trinity R blw Lewiston	770	772	-2	0
Trinity Export	482	480	2	0
Clear Cr blw Whiskeytown	148	148	0	0
Sacramento R @ Keswick	6144	6142	2	0
Sacramento R @ Wilkins Slough	6255	6252	3	0
Feather R blw Thermalito	2993	2993	0	0
Feather R: at Sac R confluence	5272	5272	0	0
Yuba R @ Marysville	1499	1499	0	0
Sacramento R @ Verona	12958	12957	1	0
American R blw Nimbus	2427	2427	0	0
American R: at Sac R confluence	2345	2346	0	0
Delta Inflow	**21536**	**21534**	**2**	0
Sacramento R @ Hood	15524	15524	1	0
Yolo Bypass	2325	2323	2	0
Mokelumne R	845	845	0	0
Calaveras R	111	111	0	0
San Joaquin R d/s Vernalis	2732	2732	-1	0

After Re-weighting

Base: 06.54_DCR21_BL_wsidi
Alt: 06.54_DCR21_BL_wsidi_alt

	1922-2015			
	06.54_DCR21_BL_wsidi_alt	06.54_DCR21_BL_wsidi	Diff	% Diff
River Flows				
Trinity R blw Lewiston	769	769	0	0
Trinity Export	483	483	0	0
Clear Cr blw Whiskeytown	149	149	0	0
Sacramento R @ Keswick	6145	6145	0	0
Sacramento R @ Wilkins Slough	6252	6253	0	0
Feather R blw Thermalito	2993	2993	0	0
Feather R: at Sac R confluence	5271	5271	0	0
Yuba R @ Marysville	1499	1499	0	0
Sacramento R @ Verona	12956	12956	0	0
American R blw Nimbus	2427	2427	0	0
American R: at Sac R confluence	2345	2345	0	0
Delta Inflow	**21535**	**21535**	**0**	0
Sacramento R @ Hood	15522	15522	0	0
Yolo Bypass	2326	2326	0	0
Mokelumne R	845	845	0	0
Calaveras R	111	111	0	0
San Joaquin R d/s Vernalis	2732	2732	0	0

Re-weighted study seem to be less sensitivity to weight adjustments (perturbations).

Protocols for Future Studies

Based on this investigation, here are some recommendations for assigning weights/penalties in future studies:

- weights/penalties do not exceed the upper limit of 10^7,
- weights/penalties do not go lower than the lower limit of 10^{-2}, or
- differences in weights/penalties between relative decision variables (resolution) to not go lower than the lower limit of 10^{-2}.

On-Going Work: Fixing Integers

Goal: Fix integers after certain cycles to improve solver stability and model runtime.

Expectation:
It is expected that if all the integers are fixed and assigned to state variables in the later cycles, the LP problem sent to the CBC solver will become simple (no longer mixed integer), reducing runtime and increasing model stability.

Characterization:
- 29 integers in CS3
- 22 integers identified to be fixed at least by TRANSFER cycle (if not earlier)
- First cut - 7 integers related to weir operations were fixed (and set to state variables) after SETUP cycle

On-Going Work: Fixing Integers

	1922-2015				1977-1977				1987-1992			
	06.54_DC R21_BL_ wsidi_int3 R	06.54_DC R21_BL_ wsidi	Diff	% Diff	06.54_DC R21_BL_ wsidi_int3 R	06.54_DC R21_BL_ wsidi	Diff	% Diff	06.54_DC R21_BL_ wsidi_int3 R	06.54_DC R21_BL_ wsidi	Diff	% Diff
River Flows												
Trinity R blw Lewiston	769	769	0	0	420	420	0	0	523	523	0	0
Trinity Export	483	483	0	0	478	478	0	0	395	395	0	0
Clear Cr blw Whiskeytown	149	149	0	0	113	113	0	0	128	128	0	0
Sacramento R @ Keswick	6145	6145	0	0	5233	5233	0	0	4529	4530	-1	0
Sacramento R @ Wilkins Slough	6253	6253	0	0	3914	3914	0	0	4497	4499	-1	0
Feather R blw Thermalito	2993	2993	0	0	1158	1158	0	0	1396	1397	0	0
Feather R: at Sac R confluence	5271	5271	0	0	1431	1431	0	0	2357	2357	0	0
Yuba R @ Marysville	1499	1499	0	0	235	235	0	0	664	664	0	0
Sacramento R @ Verona	12956	12956	0	0	5977	5977	0	0	7893	7895	-2	0
American R blw Nimbus	2427	2427	0	0	403	403	0	0	1202	1202	0	0
American R: at Sac R confluence	2345	2345	0	0	318	318	0	0	1110	1110	0	0
Delta Inflow	**21535**	**21535**	**0**	**0**	**7323**	**7323**	**0**	**0**	**10898**	**10900**	**-2**	**0**
Sacramento R @ Hood	15522	15522	0	0	6097	6096	0	0	9168	9170	-2	0
Yolo Bypass	2326	2326	0	0	109	109	0	0	246	246	0	0
Mokelumne R	845	845	0	0	110	110	0	0	259	259	0	0
Calaveras R	111	111	0	0	1	1	0	0	10	10	0	0
San Joaquin R d/s Vernalis	2732	2732	0	0	1006	1006	0	0	1214	1214	0	0
NDOI	**15177**	**15177**	**0**	**0**	**3817**	**3817**	**0**	**0**	**6406**	**6408**	**-2**	**0**
Surplus Outflow	10056	10056	0	0	560	560	0	0	2211	2215	-4	0
Surplus Outflow - ANN	299	299	0	0	477	477	0	0	473	475	-2	0
Surplus Outflow - CVP	5260	5260	1	0	4	4	0	0	728	728	-1	0
Surplus Outflow - SWP	4447	4448	-1	0	79	79	0	0	998	999	-1	0
Surplus Outflow - VSA												
Surplus Outflow - SJRR	34	34	0	0	0	0	0		5	5	0	0
Surplus Outflow - WHLCV	13	13	0	0	0	0	0		4	4	0	0
Surplus Outflow - WHLJP	0	0	0		0	0	0		0	0	0	
Surplus Outflow - WTS	3	3	0	0	0	0	0	0	3	3	0	0
Min Outflow	5121	5121	0	0	3256	3256	0	0	4195	4193	2	0

Minor differences observed between Base and Alt.

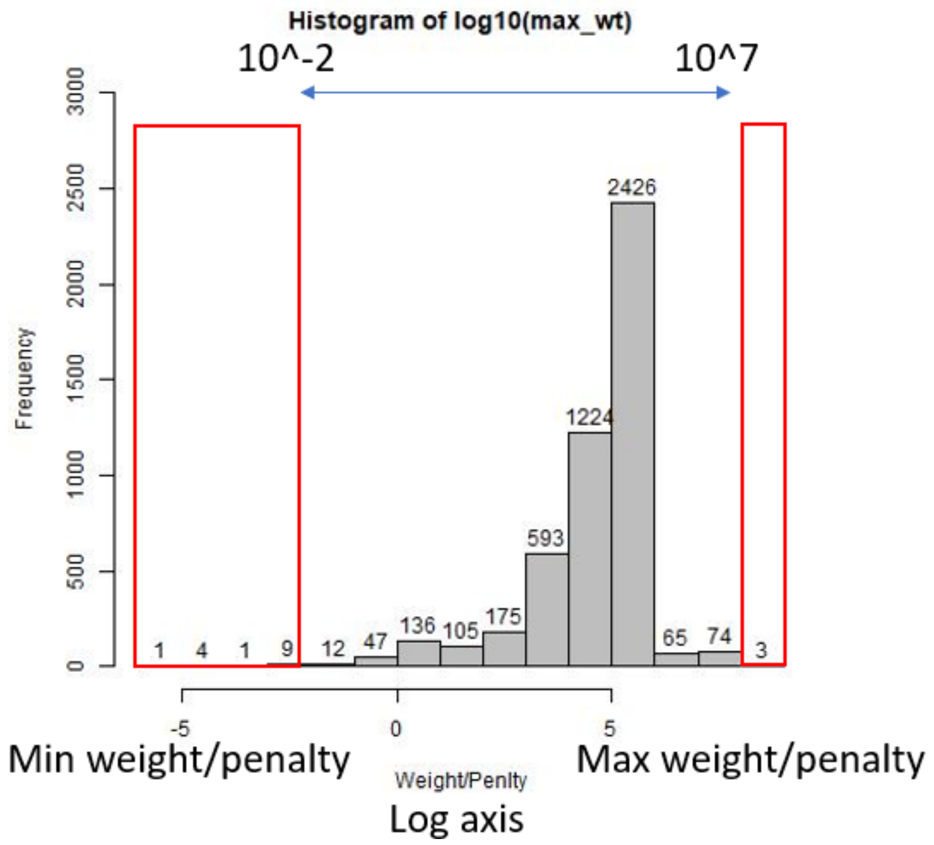
Reduction in Sac flow related to reduction in NDOI_ADD_ANN in Feb 1991.

Some minor differences expected since we are changing the solution matrix.

No speedup observed yet. May need to fix “critical mass” number of integers before we see any speedups.

Summary

- Updates were made to the weights/penalties of a CS3 DCR study to reduce the ratio of the maximum weight/penalty to the minimum weight/penalty resolution to 10^9 from 10^{14}.
- 28 weights/penalties were investigated and adjusted (commented out when necessary).
- Minor differences in long term annual averages between the *Base* and *Alt (reweighted)* studies.



- Model stability when utilizing the CBC solver seems to have increased based on additional sensitivity analyses:
  - Unwarranted integer switching observed in *Base* study but not in the *Alt* study.
  - In response to introduction of a small weight change (perturbation), the *Alt* study seems to be less sensitive to the perturbation than the *Base* study.

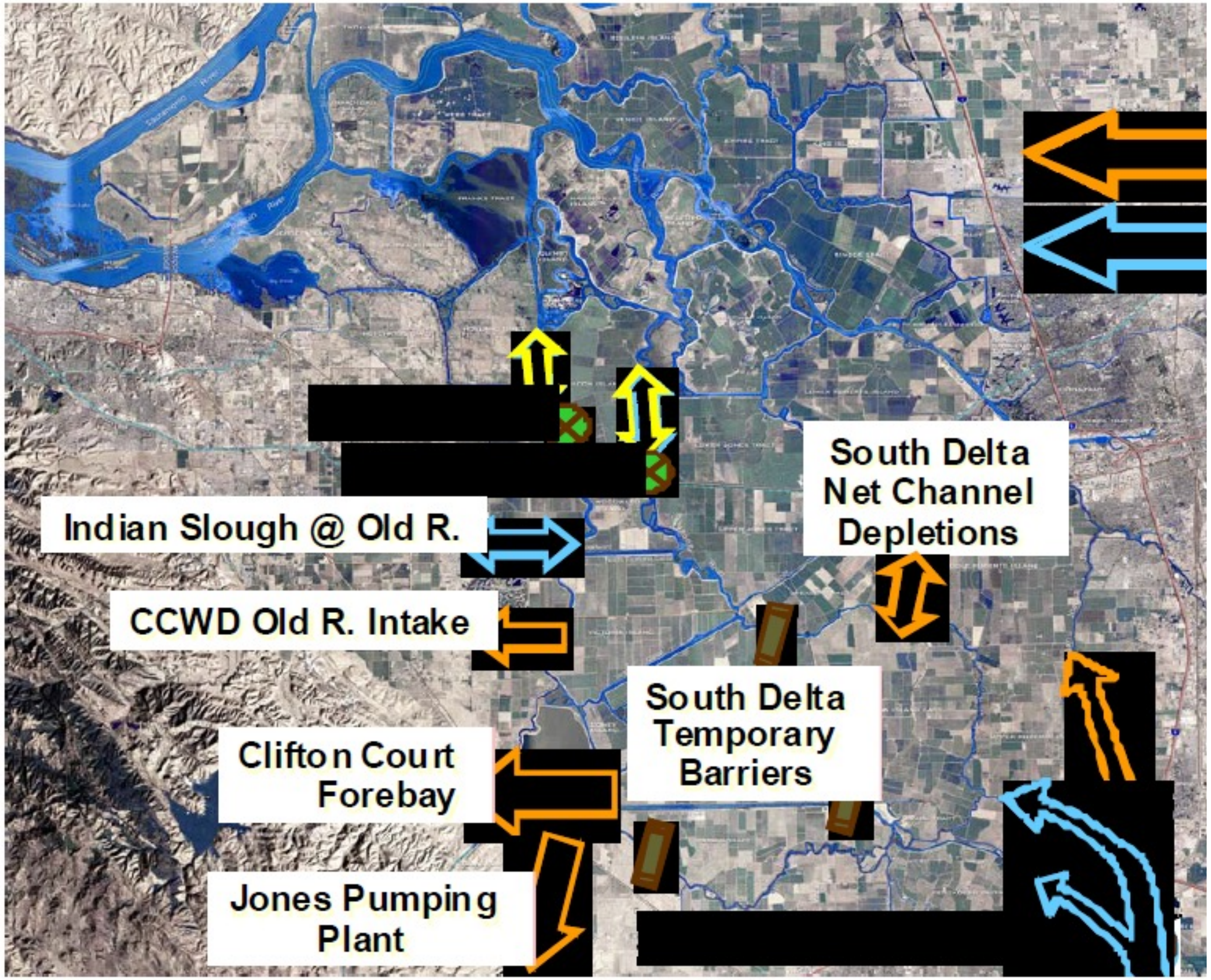
- In addition, findings from the current re-weighting study laid the groundwork for the next phase in improving model stability and reducing runtime - Fixing integer values after certain cycles

Part II: Machine Learning Methods in Calculation of Old-Middle River Flow

Yiwei Cheng, Shima Shamkhali Chenar, Nicole Osorio, Nazrul Islam

Old Middle River Flow

- Represent the amount and direction of water flows in the South Delta between the Projects' export facilities and the lower San Joaquin River.
- Impacted by: (1) flow into the Delta from tributaries, (2) flows exported from the Delta by the Projects, (3) spring-neap tidal cycles, (4) diversions by local users of water.
- Used to in water management decisions to comply with a variety of court decisions and biological opinions under the Endangered Species Act (a 14-day average of the measured (tidal) flows). Biological Opinions replies on OMR flow restrictions on the Projects' exports for fish protections (Dec – Jun).



Hutton 2008

OMR flow = San Joaquin River flow @ Vernalis + Indian Slough flow @ Old River – San Joaquin River flow downstream of HOR – Clifton Court Forebay diversions – Jones Pumping Plant diversions – CCWD Old River Intake diversions – South Delta net channel depletion

Hutton 2008: Model Characteristics

- Empirical
- Calibrated with data generated by DWR's Delta Simulation Model (DSM2) and validated with field observations
- Data Range: 1998 - 2006
- Higher accuracy in comparison to earlier models
- Model coefficients vary depending on HORB, GLC Barrier and Vernalis flow.

Table ES-3
MWD OMR Flow Model Coefficients

$$Q_{OMR}\ (cfs) = A * Q_{Vernalis} + B * Q_{South\ Delta\ Diversions} + C$$

Where: $Q_{South\ Delta\ Diversions} = Q_{CCF} + Q_{Jones} + Q_{CCWD} + Q_{South\ Delta\ NCD}$

HORB	GLC Barrier	Vernalis (cfs)	A	B	C
Out	Out	< 16,000	0.471	-0.911	83
Out	Out	16,000-28,000	0.681	-0.940	-3008
Out	Out	> 28,000	0.633	-0.940	-1644
Out	In	All	0.419	-0.924	-26
In (Spring)	Out/In	All	0.079	-0.940	69
In (Fall)	Out/In	All	0.238	-0.930	-51

Question: Can we utilize machine learning models in the calculation of OMR flows.
Advantages: (1) longer time period covering wider range of climate and operational conditions.
(2) no need to distinguish between different cases with different conditions.

Data: Stations from CDEC (2008 – 2017)

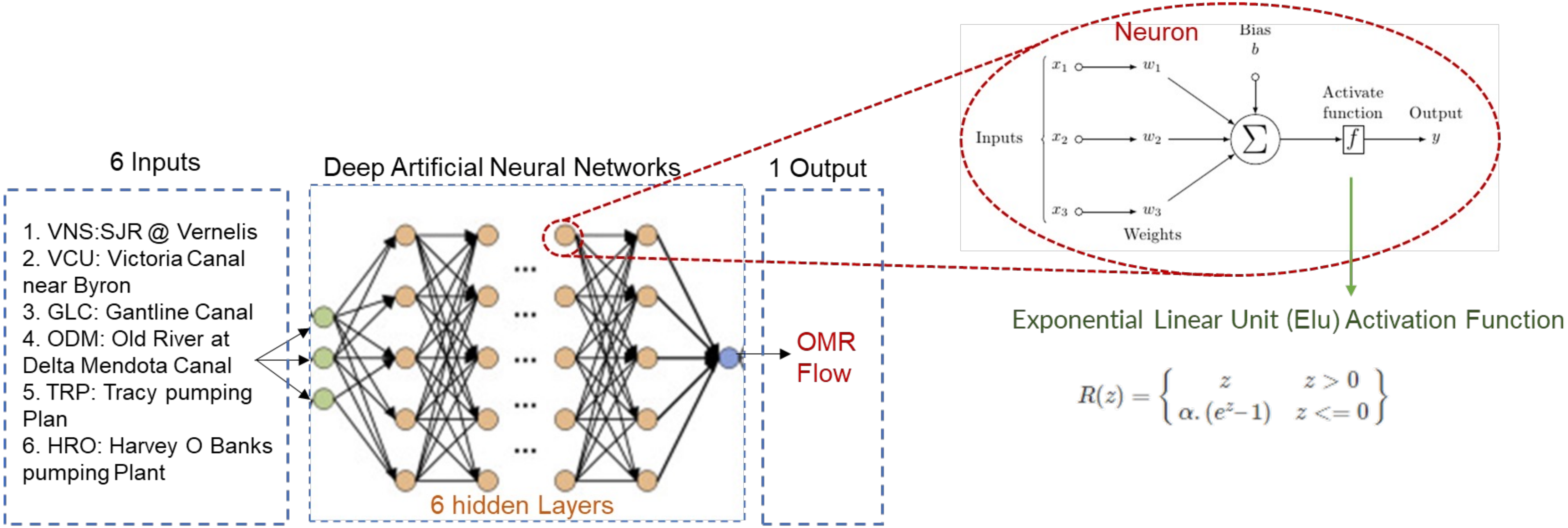
OBI – Old River @ Bacon Island
MDM – Middle River @ Middle River

VNS – SJR @ Vernalis
VCU - VICTORIA CANAL NEAR BYRON
GLC - GRANTLINE CANAL
ODM - OLD RIVER AT DELTA MENDOTA CANAL
TRP - TRACY PUMPING PLANT
HRO - HARVEY O BANKS PUMPING PLANT

- Referred to by the regulatory agencies as OMR (Old and Middle River flow)
- Data used to in water management decisions to comply with a variety of court decisions and biological opinions under the Endangered Species Act (a 14-day average of the measured (tidal) flows).

Deep Neural Networks (DNN) Approach for Predicting OMR Flow

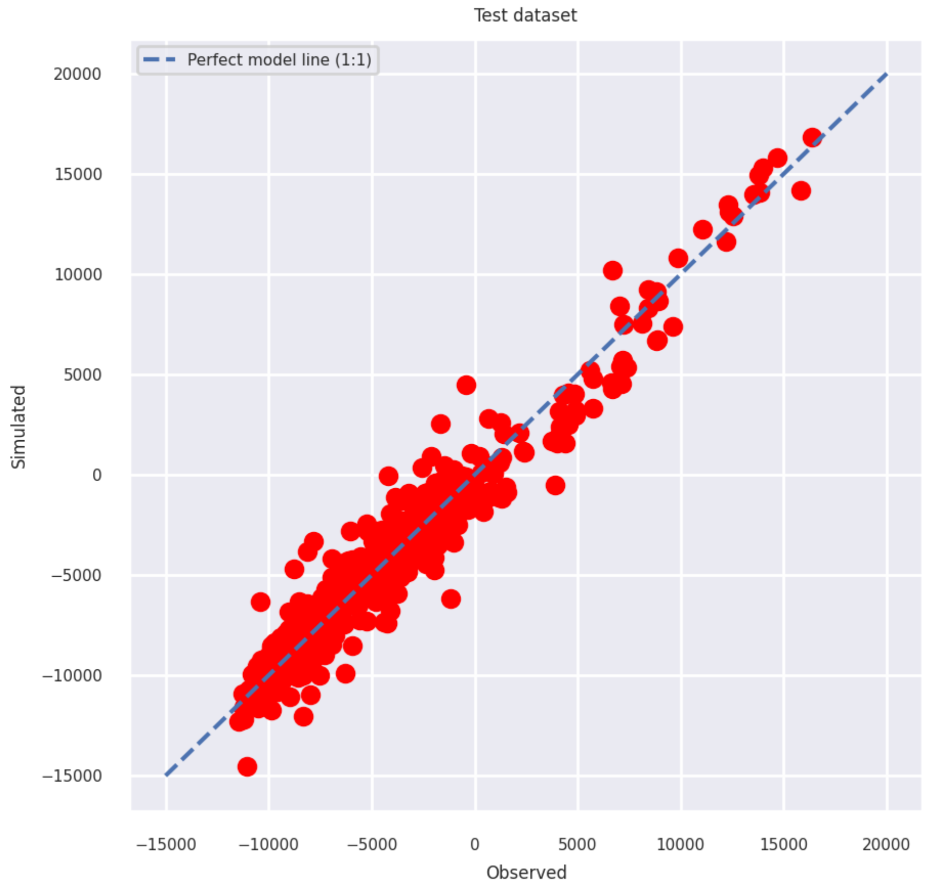
- DNN model with 6 inputs and 6 hidden layers was trained and tested.
- Collected data from 2008 to 2015 were used for training (80% of dataset) and data from 2016 to 2017 were used for testing (20% of dataset).

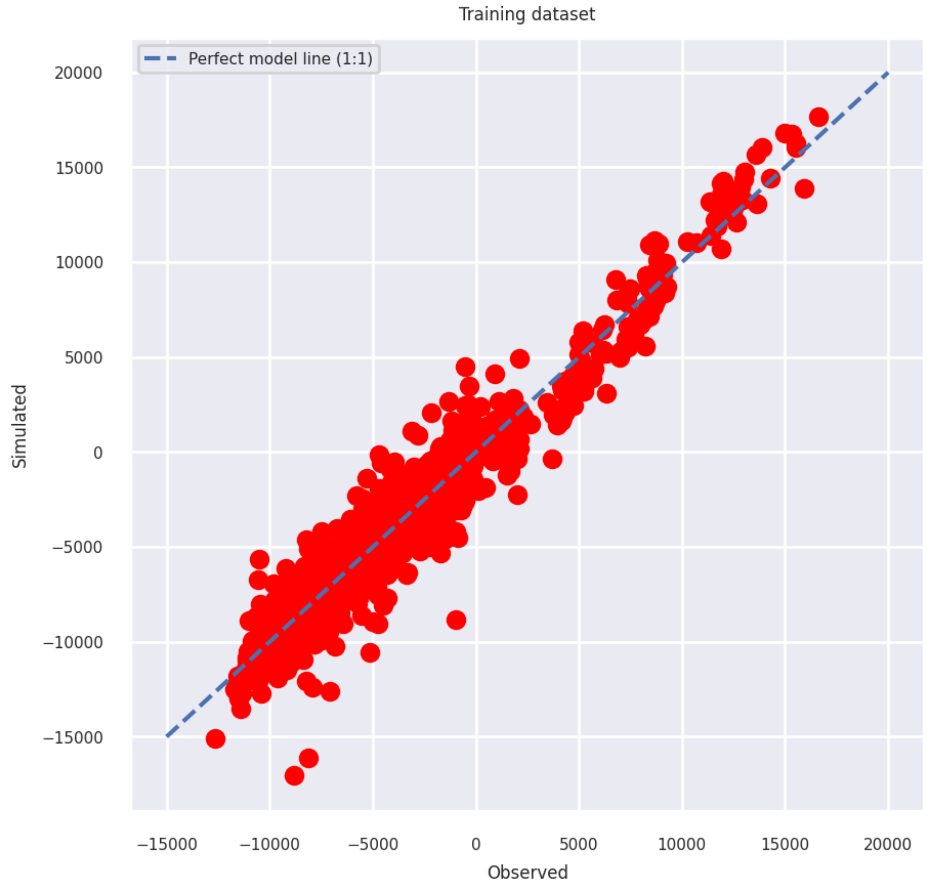


$$R(z) = \begin{cases} z & z > 0 \\ \alpha.(e^z - 1) & z <= 0 \end{cases}$$

DNN Model Performance Results

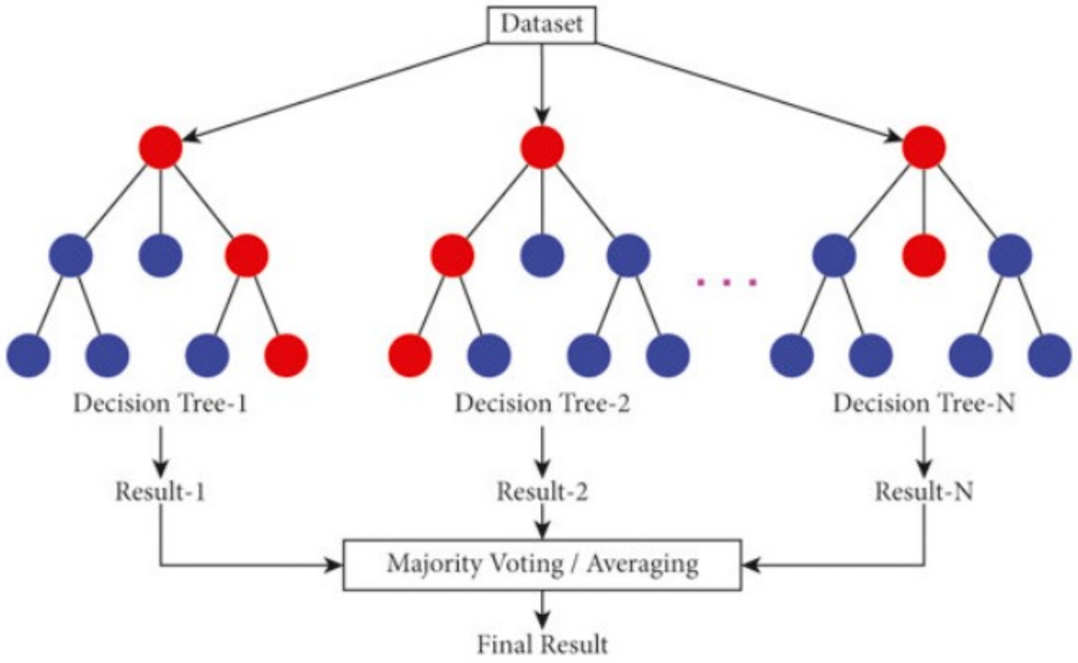
DNN Model Performance Metrics	R^2 (R-Squared)	MAE (Mean Absolute Error)
Training set	0.94	783
Test Set	0.93	843





Random Forests Approach for Predicting OMR Flow

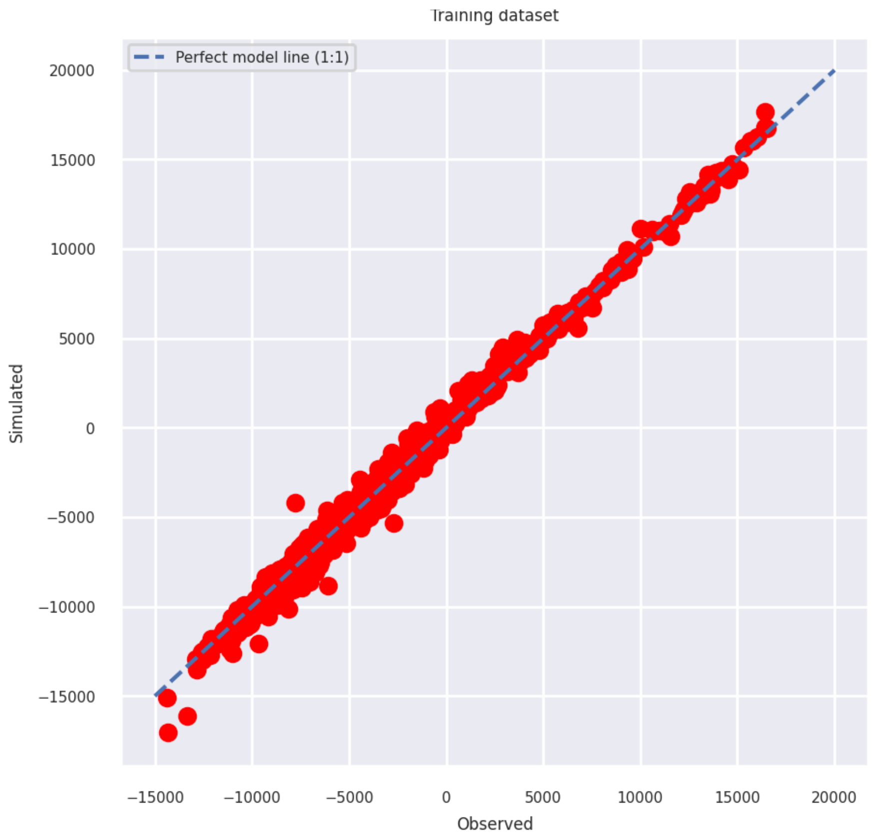
- RF model with 100 trees was trained and tested.
- Collected data from 2008 to 2015 were used for training (80% of dataset) and data from 2016 to 2017 were used for testing (20% of dataset).

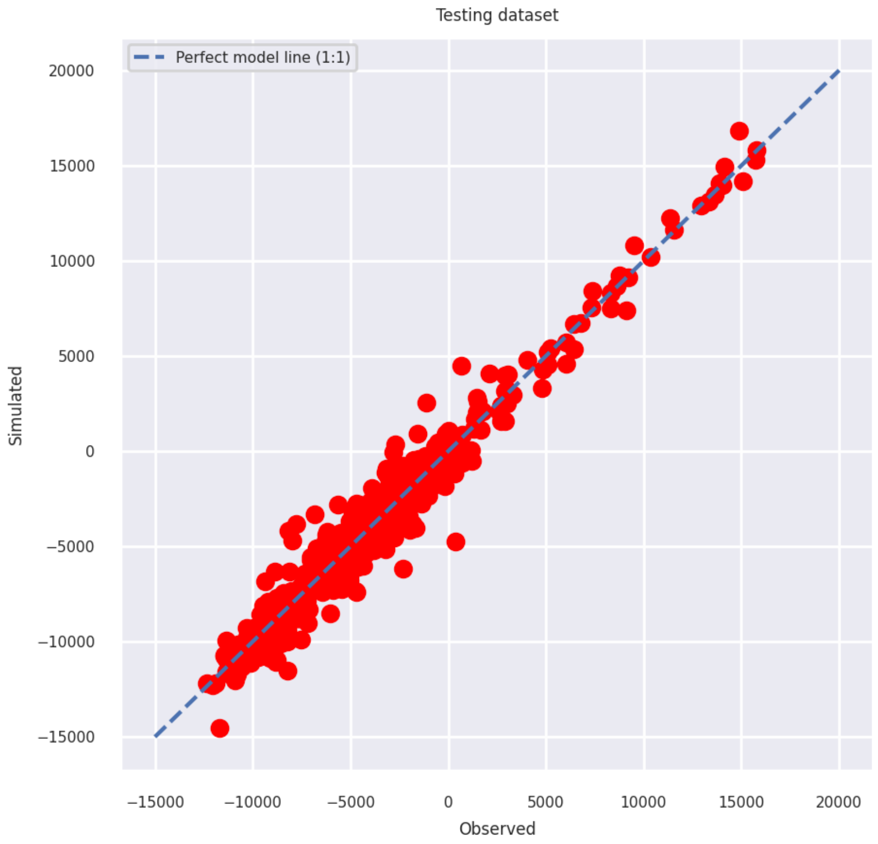


[adapted from Khan, M. Y., et.al (2021). Automated Prediction of Good Dictionary EXamples (GDEX): A Comprehensive Experiment with Distant Supervision, Machine Learning, and Word Embedding-Based Deep Learning Techniques]

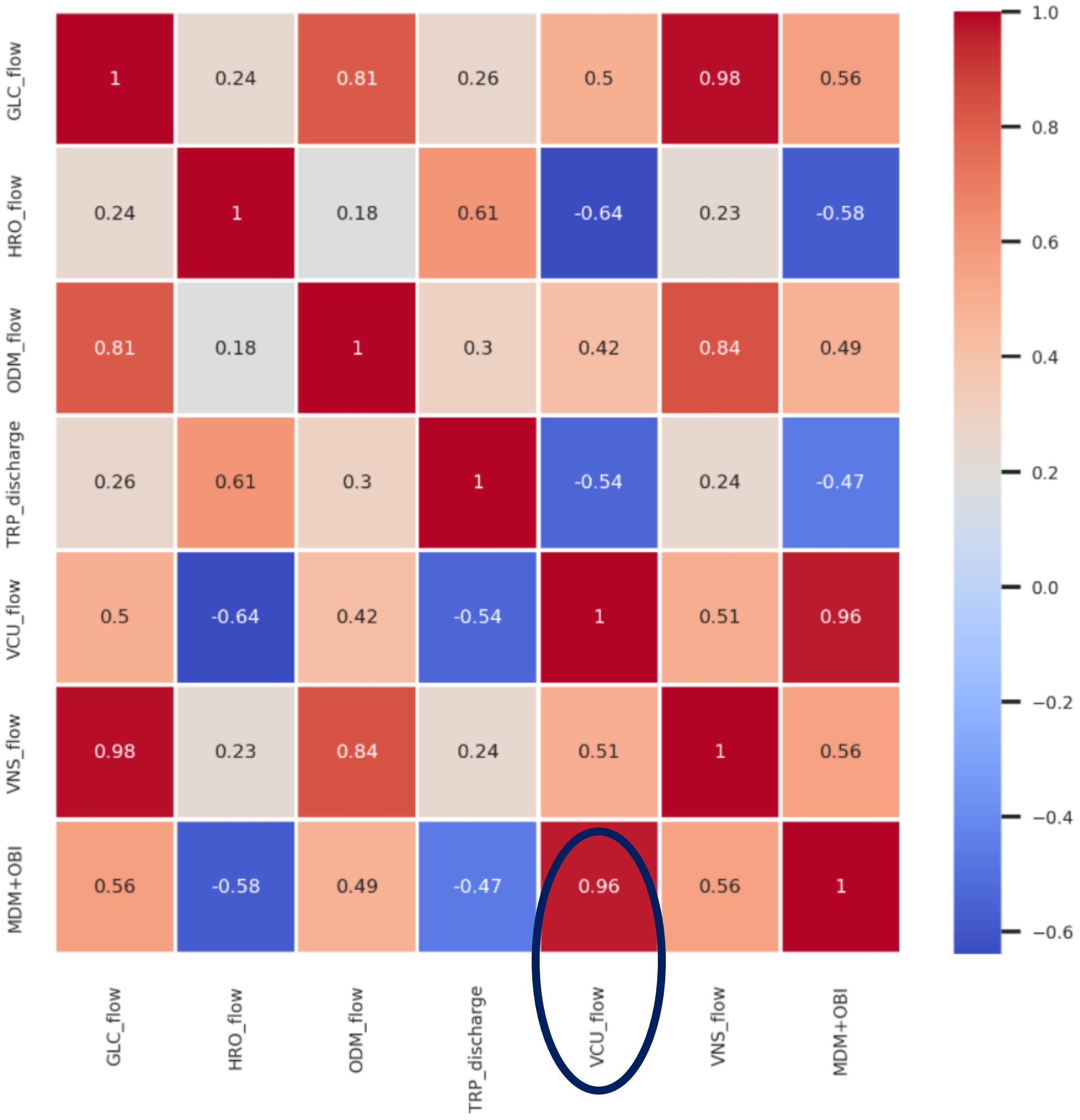
RF Model Performance Results

DNN Model Performance Metrics	R^2 (R-Squared)	MAE (Mean Absolute Error)
Training set	0.99	253
Test Set	0.96	685

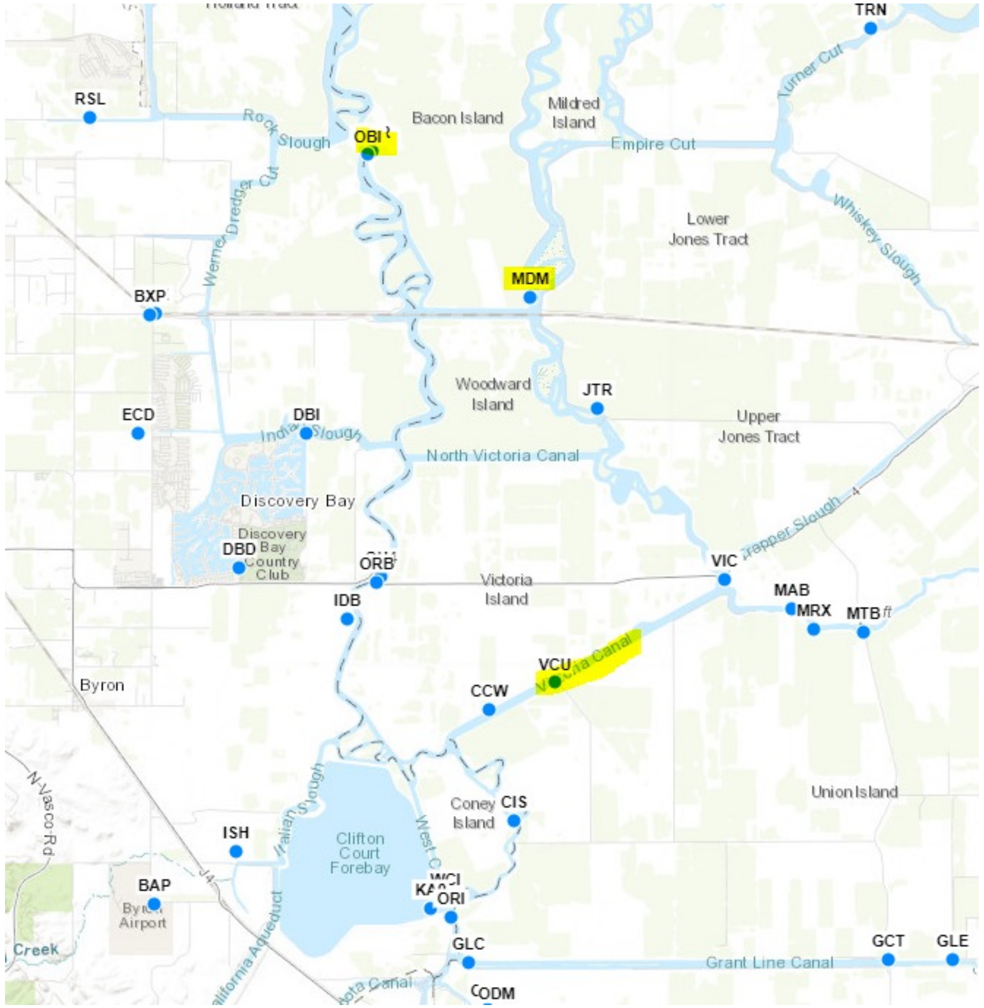




Parameter Sensitivity



Victoria Canal Near Byron is highly corrected with OMR flow



On-Going Work:

- Validation
- Incorporation within CS3