Channel Routing & Lakes/Reservoirs in WRF-Hydro

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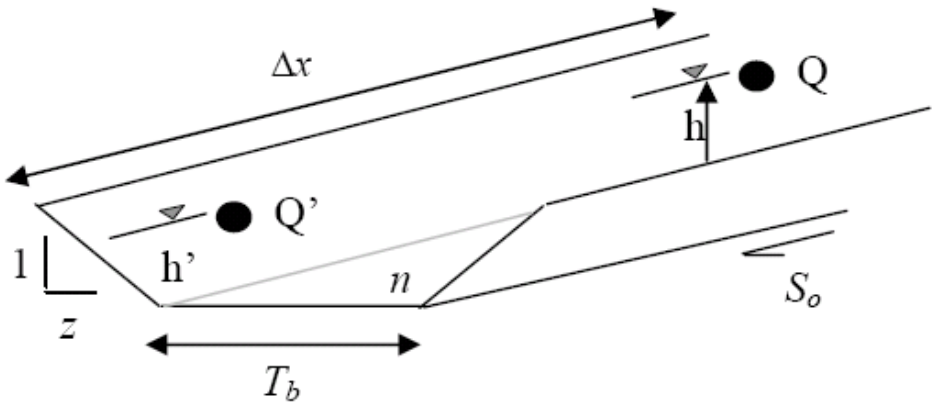
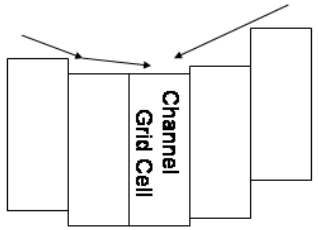
Channel Routing

Channel Routing Methods

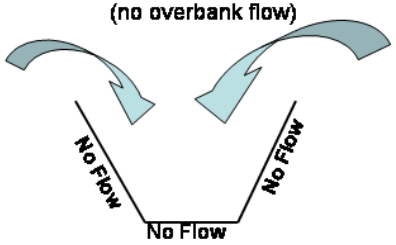
- Set in hydro.namelist with the channel_option = 1, 2 or 3
- Channel_option 1 or 2 is “reach-based” routing using Muskingum Methods
- Channel_option = 3 is “gridded” using a 1-d diffusive wave





- Surface water on channel grid cells get deposited in channel as 'lateral inflow'

- One-way ov. flow into channel
- No sub-surface losses
- 'Infinite' channel depth (no overbank flow)



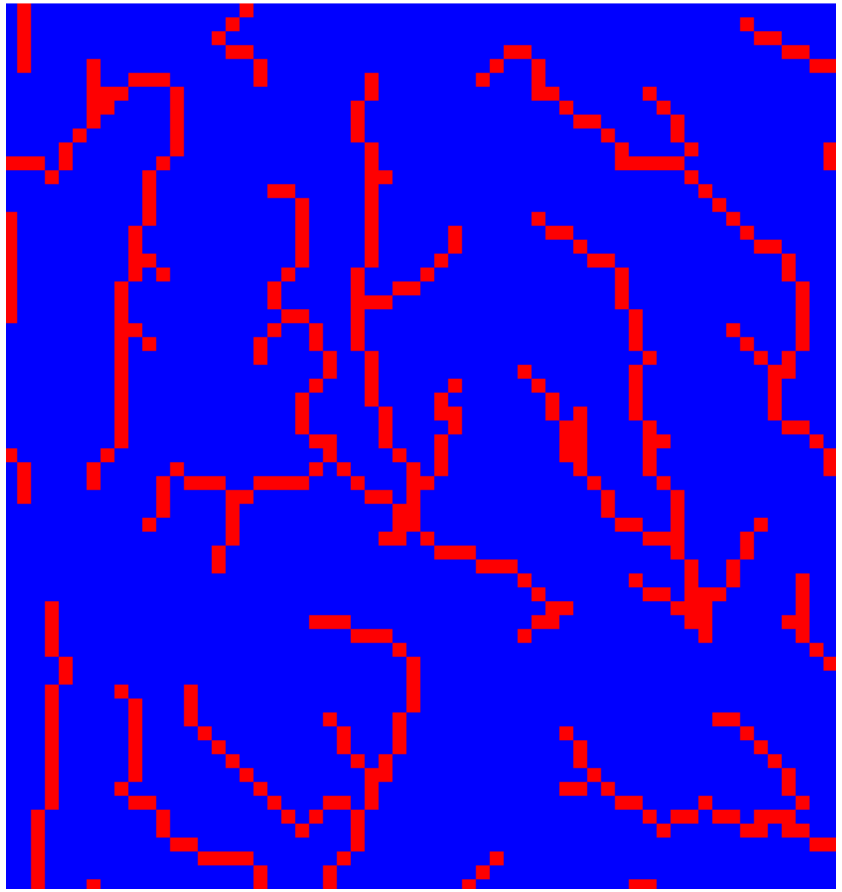
Gridded or Diffusive Wave Routing

- Explicit, 1-D, variable time-stepping
- Diffusive wave in the model: simplified version of Continuity and Momentum St. Venant equations.

$$\frac{\partial V}{\partial t} + V\frac{\partial V}{\partial x} + g\frac{\partial y}{\partial x} - g(S_o - S_f) = 0$$

Diffusive wave: includes pressure in addition to friction and gravity forces

- A numeric solution per channel grid pixel is obtained by discretizing the continuity eqn.



Reaching Routing Using Muskingum Routing

- Storage routing method based on the continuity equation where,

$I - O = \frac{dS}{dt}$, I = inflow, O is outflow, S is storage and t is time

- General Muskingum equation:

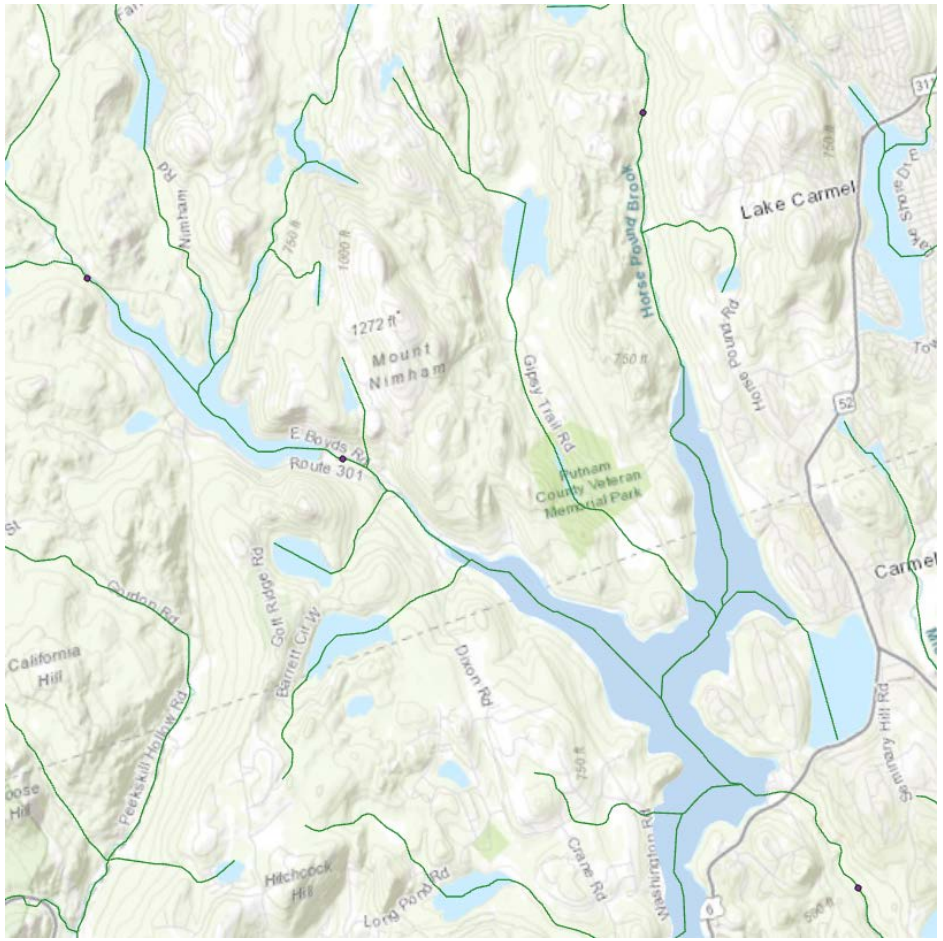
$$S = K[xI + (1-x)O]$$

where K is a storage constant (also referred to as lag, travel time, etc.) and X is a weighting factor expressing relative importance of I & O to S.

- Simplified, implemented per reach in the channel network:

$$O_2 = c_0 I_2 + c_1 I_1 + c_2 O_1$$

where c_o, c_1 and c_2 are functions of K, X and t, whose sum is 1.

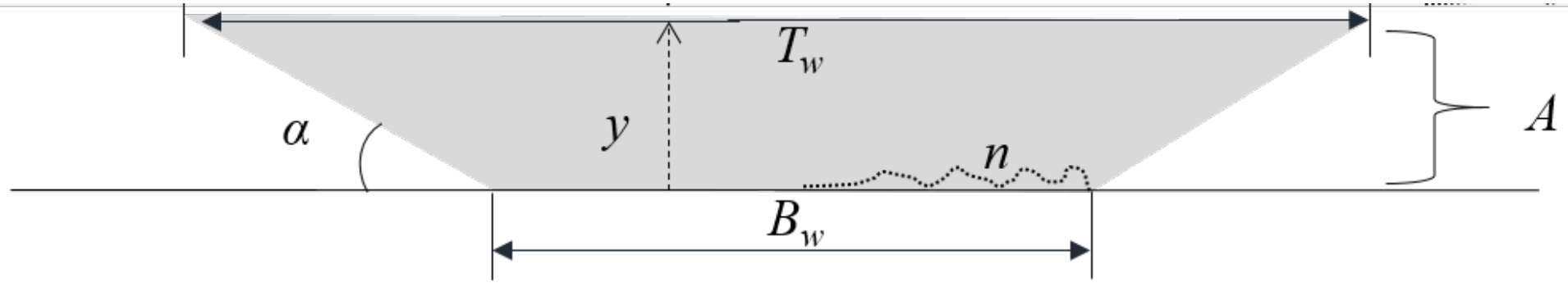


Muskingum – Cunge Routing

- Similar to Muskingum, but with hydraulically derived parameters, *K*, the "storage constant" and *X,* "weighting factor"
- $K = \frac{\Delta x}{c}$, where *Δx* = reach length and *c* is the celerity (wave speed)
- $X = \frac{1}{2}\left(1 - \frac{Q}{BcS_0\Delta x}\right)$, where *B* = bottom width, S_0 is the slope
- NWM channel routing uses this option for CONUS.
- Benefits: faster computation and stable; Cons – flat, long reaches may not be appropriate.

Channel Parameters

- Defaults for both: order based parameters.



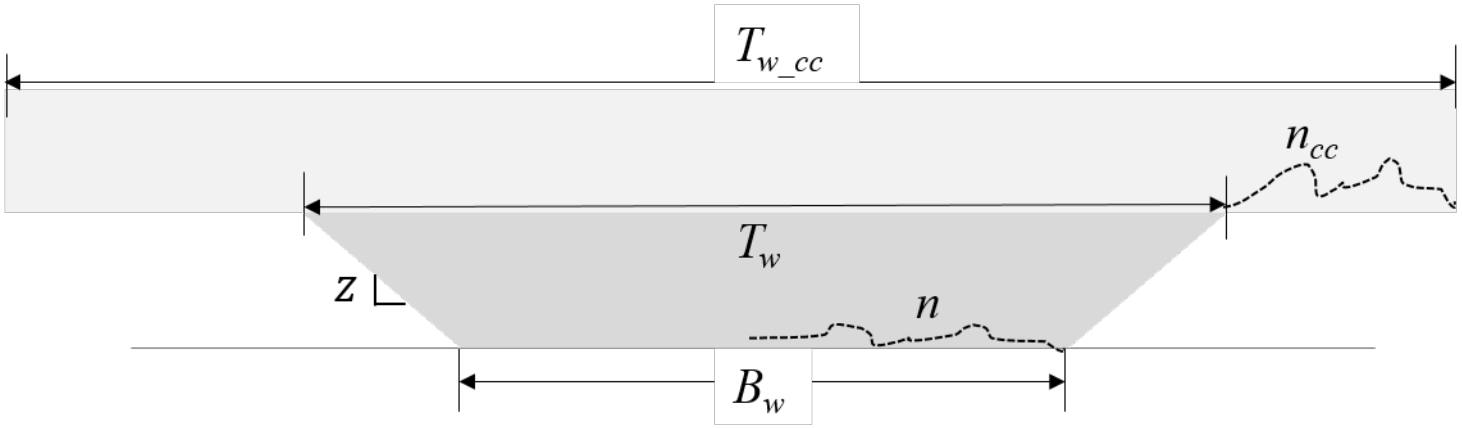
For gridded, channel_option = 3, we use the CHANPARM.TBL file to specify bottom width (Bw), side slope (z), roughness (n), HLINK.

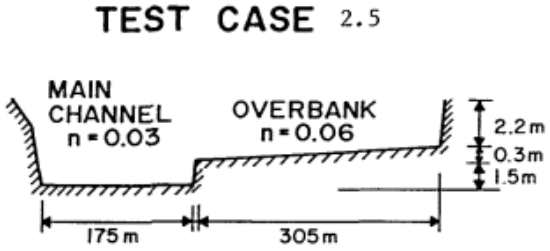
```
Channel Parameters
StreamOrder
10,1,   'Bw      HLINK    ChSSlp    MannN'
1,      1.5,     0.02,     3.0,       0.55
2,      3.0,     0.02,     1.0,       0.35
3,      5.0,     0.02,     0.5,       0.15
4,      10.,     0.03,    0.18,       0.10
5,      20.,     0.03,    0.05,       0.07
6,      40.,     0.03,    0.05,       0.05
7,      60.,     0.03,    0.05,       0.04
8,      70.,     0.10,    0.05,       0.03
9,      80.,     0.30,    0.05,       0.02
10,     100.,     0.30,    0.05,       0.01
```

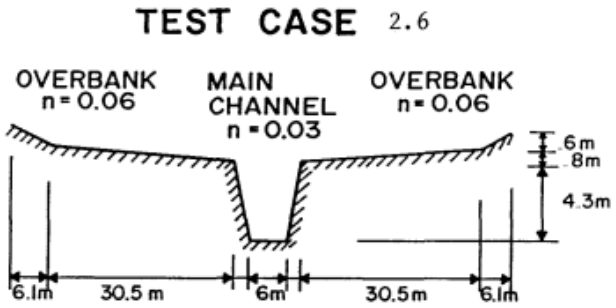
For reach-based, channel_option = 1 or 2, the Routelink.nc file specifies the parameters for every reach.

Active in NWM only now: Addition of the Compound Channel

Rectangular compound channel on top of the trapezoidal base channel







Tw_cc = TopWidth of the compound

n_cc = Roughness of the compound

Channel Routing: Key Settings & Parameters

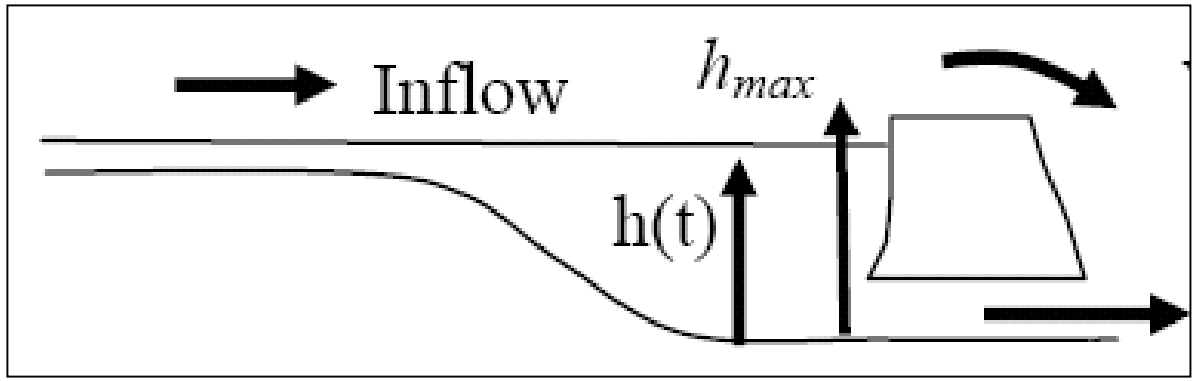
Parameter/Setting	Description	Scale/File	Estimate
Runtime Settings			
CHANRTSWCRT	Channel switch (on or off)	hydro.namelist	Landscape/event
channel_option	Routing method (Muskingum, Musk-Cunge, diffusive wave)	hydro.namelist	Landscape/event, compute resources (can be computationally intensive)
DTRT_CH	Channel routing timestep	hydro.namelist	Based on channel reach or grid size, landscape/event
Parameters			
CHANNELGRID	Channel/land mapping	Routing grid (Fulldom)	Landscape
BtmWidth, ChSlp	Channel geometry: bottom width and side slope	Reach (Route_Link) or CHANPARM lookup table	Linear model based on stream order or statistically derived
n	Channel roughness (Manning's n)	Reach (Route_Link) or lookup table	Linear model based on stream order
So	Longitudinal downstream channel slope (reach only)	Reach (Route_Link)	Calculated from topography
MusK, MusX	Muskingum routing parameters (reach only)	Reach (Route_Link)	Estimated based on channel properties

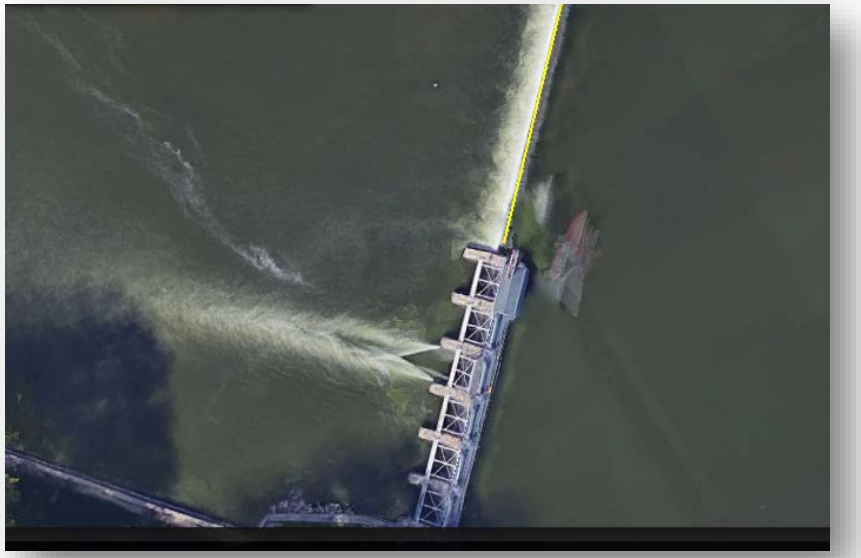
Lakes & Reservoirs

Lakes & Reservoirs in WRF-Hydro

- Level-pool storage
- Multiple discharge modes

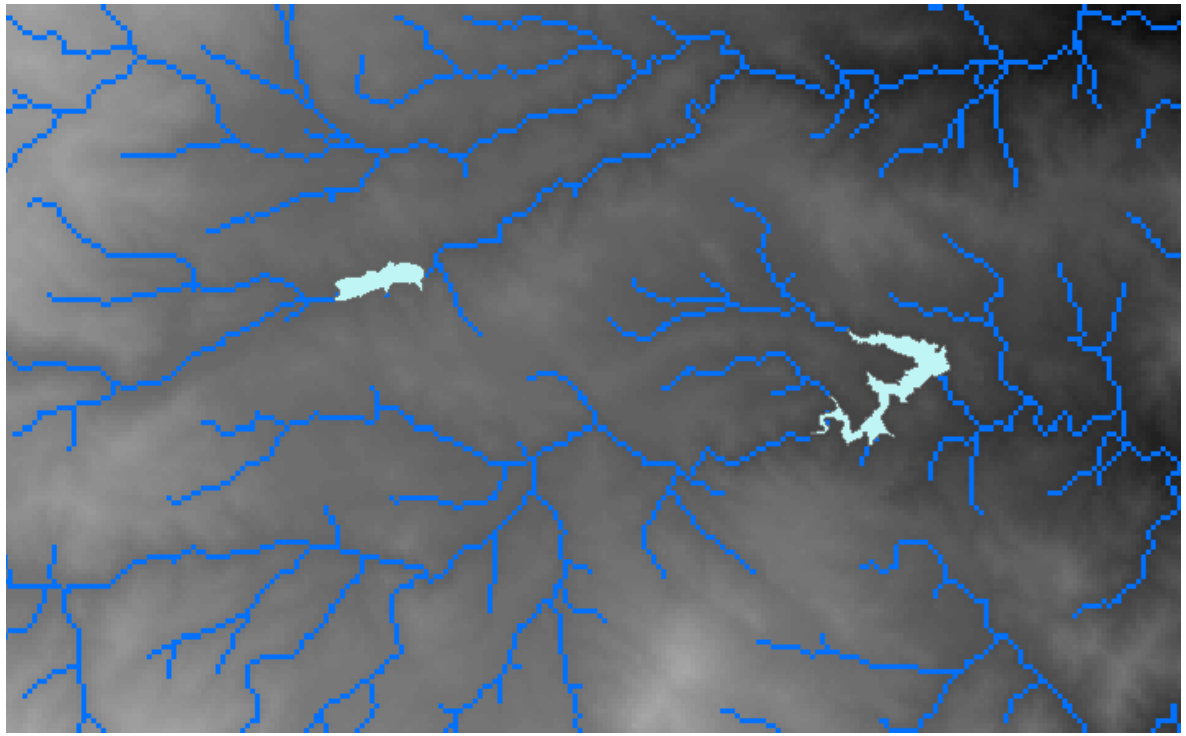
3 ‘passive’ discharge mechanisms:
- Orifice flow
- Spillway flow
- Direct Pass-through
- $\Delta S = I - O$

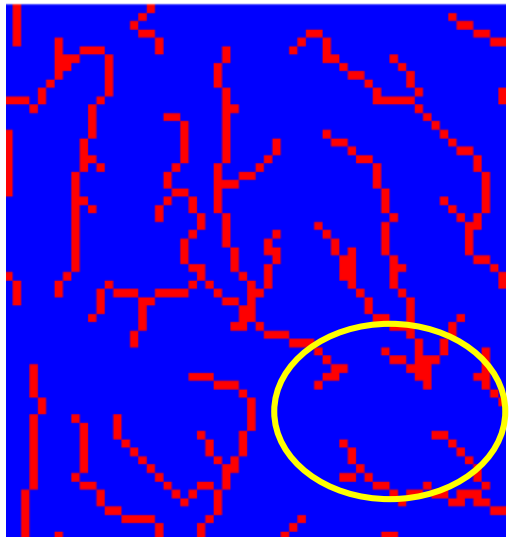




Lakes in Gridded Routing

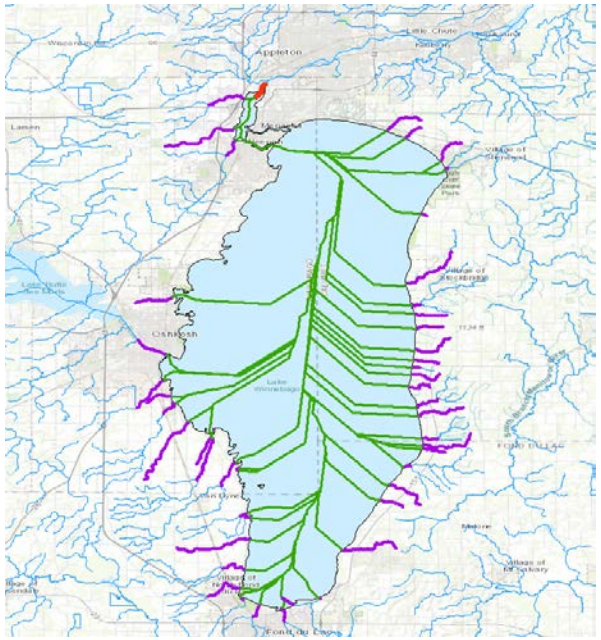
- Lakes are defined on the fine grid (in the Fulldom file ‘LAKEGRID’ var.)
- Channel pixels under lakes are erased
- Model identifies pixels as ‘inflow’ or ‘outflow’; only 1 outflow pixel allowed
- Level-pool performed on outflow pixel

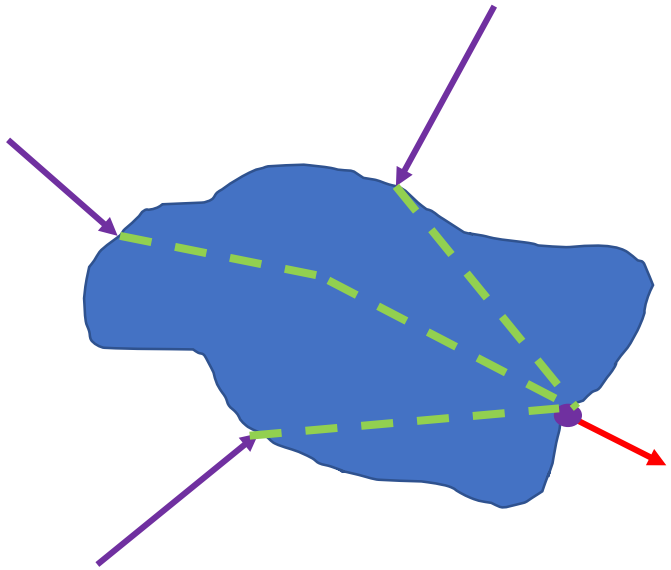




Lakes in Reach-Based Channel Routing (e.g. NWM)

- Lakes are objects

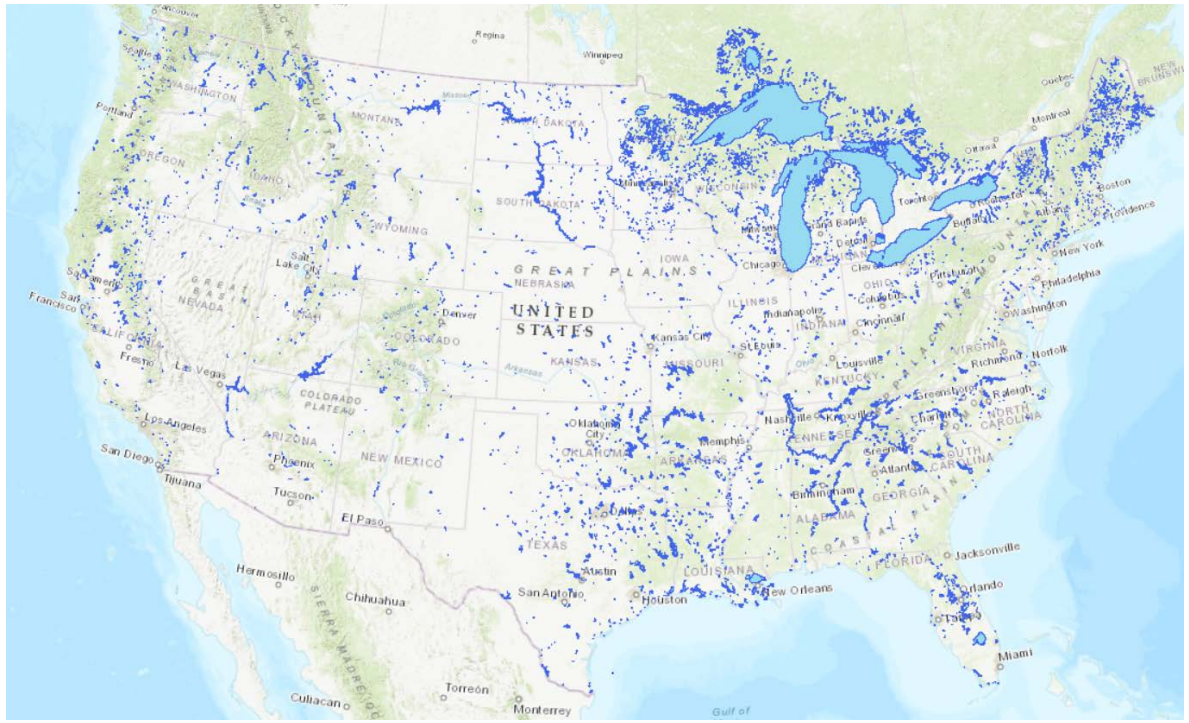




- **Why**: We can easily integrate with the flow network; vectorization speed.
- **Implications**: Lakes outflow at a single point; the lake ‘module’ is run independently.

National Water Model Reservoir Attributes

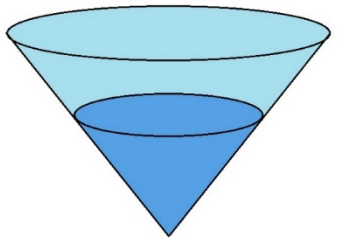
- V2.1: 5,783 NHDPlus waterbodies
- Depths derived from topography
- Default reservoir configuration: Level-pool scheme with parameterized discharge mechanisms:
  - orifice
  - spillway
- Great Lakes basin included in the domain (including Canadian side)
- Reservoir active management in specific locations

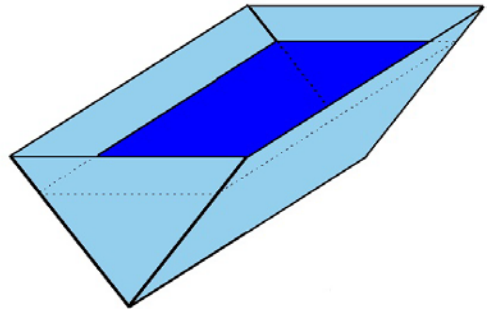


1. Persistence of streamflow at 58 USGS sites and 152 USACE sites
2. Forecasts from River Forecast Centers at 324 reservoirs

Future Work in Reservoir Development

- **Targeted for NWM V3.0 Operations:**
  - Alternative reservoir shape options in addition to the current box shape (vertical walls):
    - Cone
    - Triangular Prism
    - head-Area-Volume relationships
  - Updated discharge characteristics of the reservoirs (e.g., weir and orifice parameters)



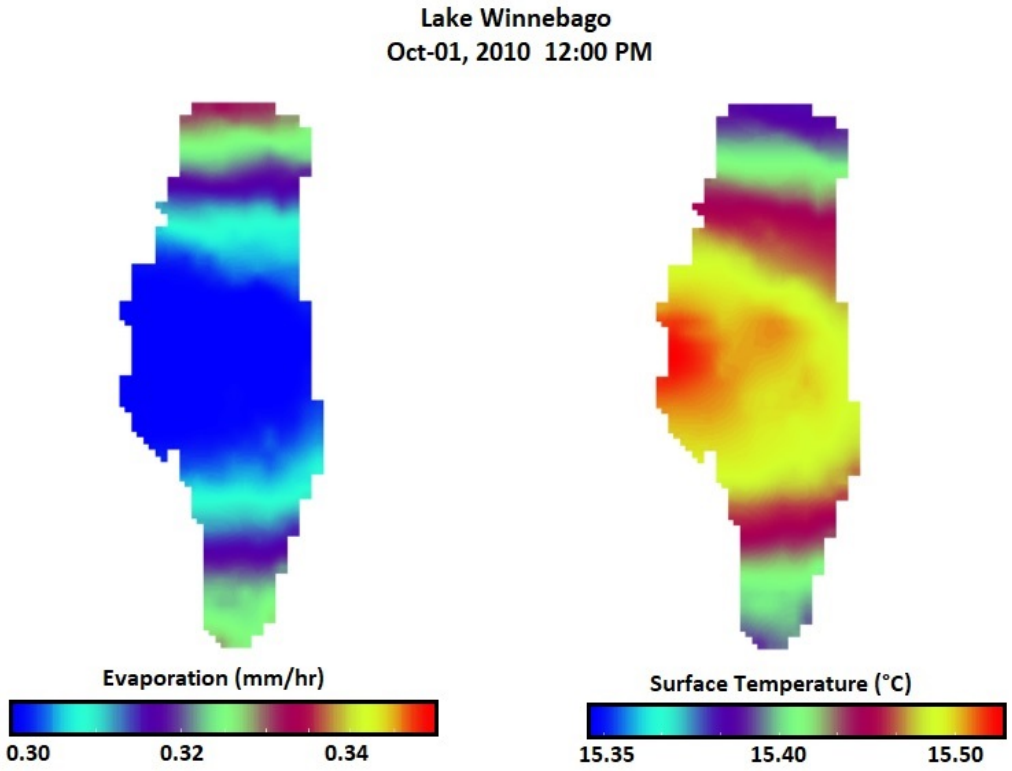


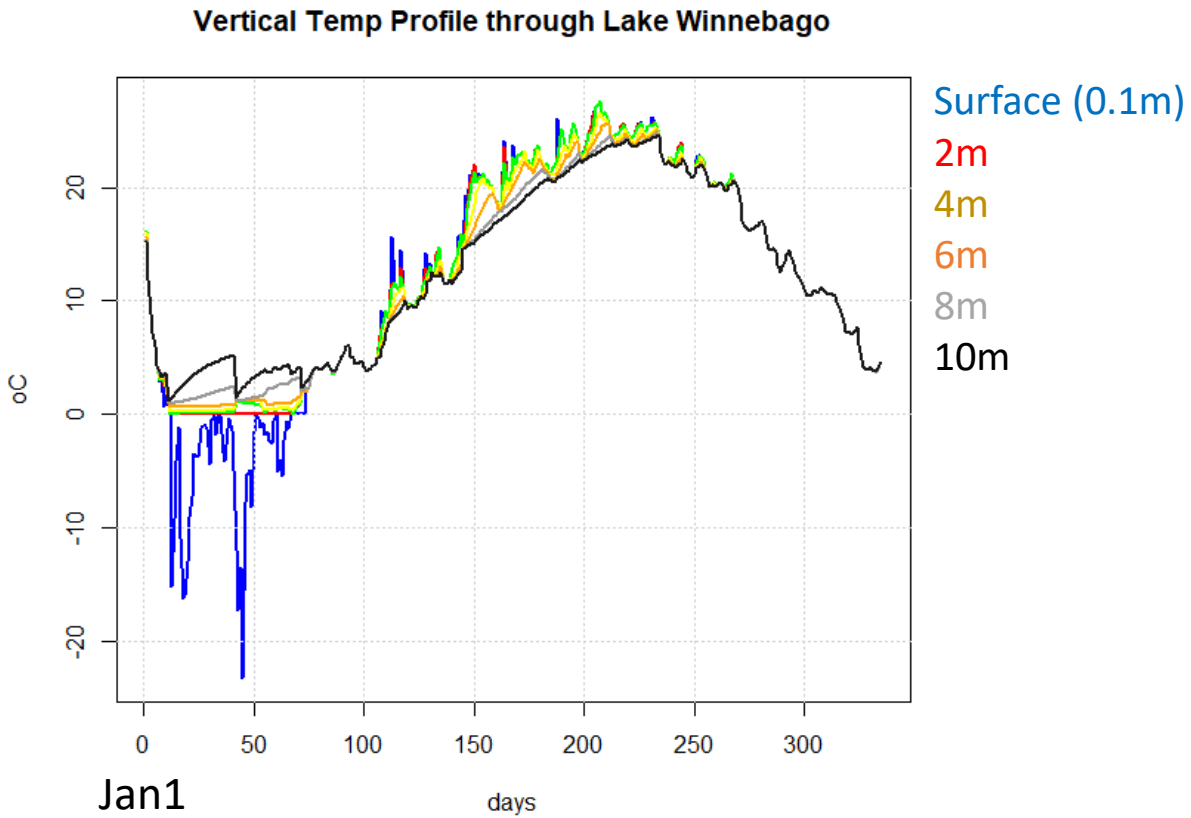
- **Lake Physics Module (see next slide)**

Lake Temperature Model

Implementation of 1-dimensional lake model

- Account for ice formation, rainfall, and evaporation fluxes over lakes and provide estimates for temperature fields in lakes
- Adapt the WRF-lake (originally CLM-LISSS) lake scheme





Reservoir Level-Pool Routing: Key Settings & Parameters

Parameter/Setting	Description	Scale/File	Estimate
Runtime Settings			
route_lake_f	Path to lake parameter file (if provided, lake model will be active)	hydro.namelist	Landscape/event
Parameters			
LAKEGRID or NHDWaterbodyComID	Location of lake object (gridded) ID of waterbody (NWM)	Routing grid (Fulldom) Route_Link	Landscape/event
LkArea, LkMxE	Lake geometry	LAKEPARM.nc file	Area: derived from NHDPlus or provided; LkMxE derived from elevation grid
WeirC, WeirL, WeirE	Lake weir properties (constitutes “uncontrolled flow”)	LAKEPARM.nc file	WeirE from elevation grid; coeff and length defaults
OrificeC, OrificeA, OrificeE	Lake orifice properties (constitutes “controlled flow”)	LAKEPARM.nc file	OrificeE from elevation grid; coeff and area are defaults