HYDROLOGICS

Advancing the management of water resources

Neuse River Basin –
Hydrologic Model
and Data Collection Update
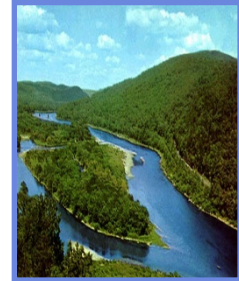
Brian J. McCrodden
Casey Caldwell
Steven Nebiker

November 12, 2008

Portland, OR   *Columbia, MD*   *Raleigh, NC*

Project Timeline

- Two-year effort, ending Feb. 2010
- Components
  - Basin schematic – 2 months (complete)
  - Inflow data – 6 to 18 months (1/2 complete)
    - Calibration
  - Agricultural data – 9 months (2/3 complete)
  - Operating rule – 2 months (1/5 complete)

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Intended Uses of Model

- Evaluation of:
  - Alternative operating protocols
  - Combined effects of water supply plans
  - Interbasin transfer permit applications
- Development of individual water supply plans
  - Model to be accessible on server to stakeholders and their consultants)
- Platform for risk-based drought plans

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Project Finances

Contractor	Budget	Spent thru 10/31/08
Moffatt & Nichol (Data Collection)	$99,000	$49,500
HydroLogics (Model Development)	$195,160	$64,950
TJCOG (Administration)	$25,000	$9,087

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Data Collection

- Reservoirs (HydroLogics)
  - Elevation-storage-area curves and operating rules available for most
  - Historic elevation/release data very limited
- Streamflow (HydroLogics)
  - To be unimpaired if possible using upstream reservoir regulation, water withdrawals, and wastewater discharges
- Precipitation/evaporation (HydroLogics)
  - Use stations nearest the reservoirs of interest

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Data Collection (cont'd.)

- Water supply/wastewater discharge (Moffatt & Nichol)
  - Recent data supplied from utilities/industries or water supply plans/NPDES data submitted to DWR/DEQ
  - Water use data to be extrapolated to earlier years using census population data. Discharge data to be extrapolated using monthly return percentages based on recent data

- Agricultural demand (Moffatt & Nichol)
  - Based on crop and animal use requirements, precipitation, and irrigable area by county.

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Inflow Development

Unimpairment

- Unimpaired inflows necessary for testing impacts of alternative operating policies and demand levels
- Impairments include effects of water withdrawals/discharges and reservoir regulation (including net evaporation)
  - Water withdrawals/discharge data still being collected by Moffatt & Nichol
  - Impairment data limited for many reservoirs, making streamflow unimpairment difficult
- Test accuracy of inflow estimates through model calibration and simulation

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Geographic Scope of Model

NEUSE RIVER BASIN SCHEMATIC
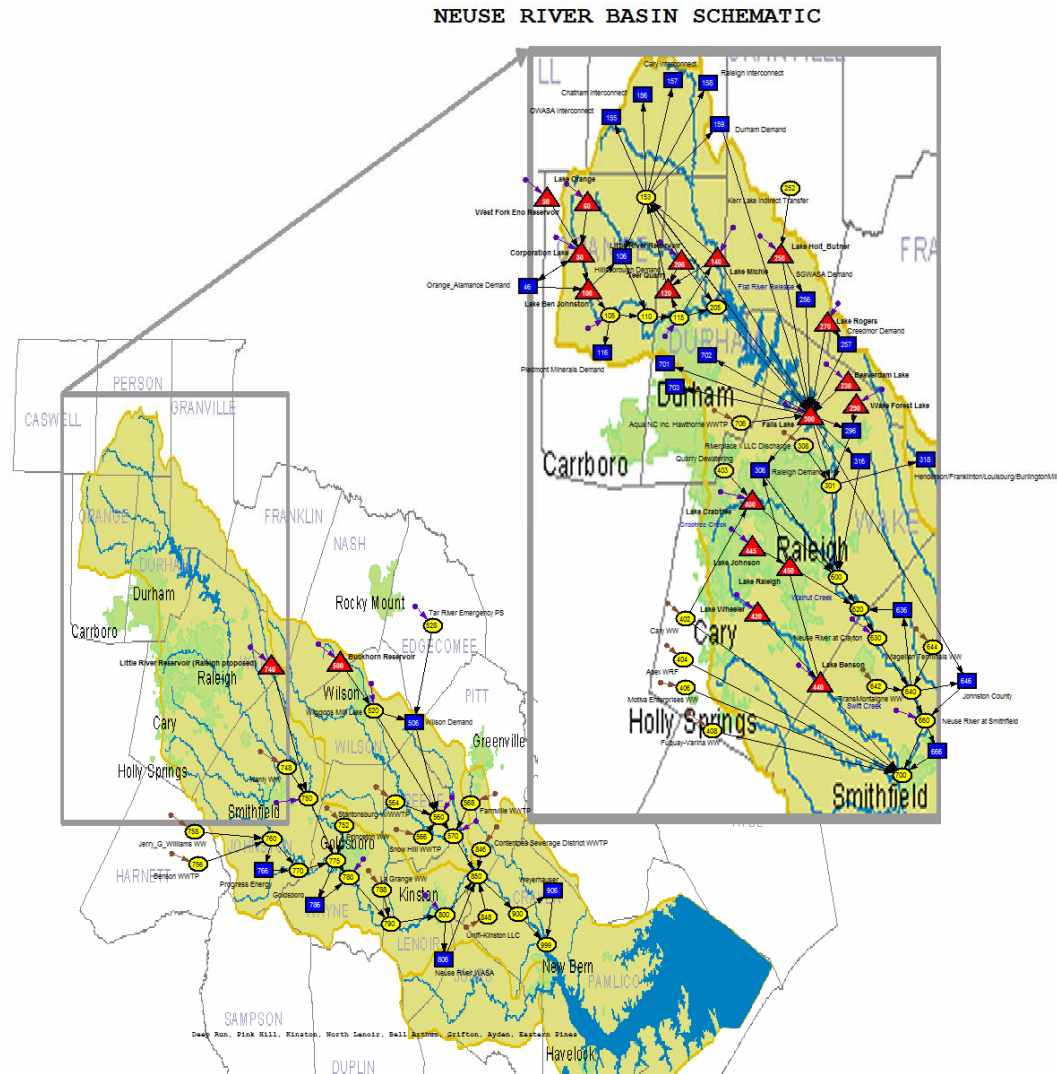
Schematic Updated for Additional Discharges

	Active permitted discharges with Q>0.1MGD/not limited					
Permit	**Owner**	**Facility**	**County**	**Class**	**Flow**	**Receiving Stream**
NC0001376	Riverplace II LLC	Riverplace II LLC	Wake	Minor	5000000	NEUSE RIVER
NC0003417	Progress Energy Carolinas Inc	Lee Steam Electric Plant	Wayne	Major	not limited	NEUSE RIVER
NC0003549	TransMontaigne Operating Company, LP	Selma South terminal	Johnston	Minor	not limited	Mill Creek (at Selma)
NC0003760	Unifi-Kinston LLC	Unifi-Kinston LLC	Lenoir	Major	3600000	NEUSE RIVER
NC0007536	Town of Stantonsburg	Stantonsburg WTP	Wilson	Minor	not limited	Contentnea Creek
NC0020389	Town of Benson	Benson WWTP	Johnston	Major	1900000	Hannah Creek
NC0020842	Town of Snow Hill	Snow Hill WWTP	Greene	Minor	500000	Contentnea Creek
NC0021644	Town of La Grange	La Grange WWTP	Lenoir	Minor	750000	Mosely Creek
NC0022217	Motiva Enterprises LLC	Apex terminal	Wake	Minor	not limited	Middle Creek
NC0026662	Town of Princeton	Princeton WWTP	Johnston	Minor	275000	Little River
NC0029572	Town of Farmville	Farmville WWTP	Pitt	Major	3500000	Little Contentnea Creek
NC0031828	Town of Vanceboro	Vanceboro WWTP	Craven	Minor	300000	Swift Creek
NC0032077	Contentnea Metropolitan Sewerage District	Contentnea Sewerage District WWTP	Pitt	Major	2850000	Contentnea Creek
NC0049662	Aqua North Carolina, Inc.	Hawthorne Subdivision WWTP	Wake	Minor	250000	Upper Barton Creek
NC0051322	Carolina Water Service, Inc. of North Carolina	Ashley Hills WWTP	Wake	Minor	495000	Poplar Creek
NC0052311	Magellan Terminals Holdings L P	Selma Terminal	Johnston	Minor	not limited	Mill Creek (at Selma)
NC0057606	Town of Stantonsburg	Stantonsburg WWTP	Wilson	Minor	375000	Contentnea Creek
NC0061492	Maury Sanitary Land District	Maury Sanitary Land District WWTP	Greene	Minor	225000	Contentnea Creek
NC0064564	Aqua North Carolina, Inc.	Neuse Colony WWTP	Johnston	Minor	750000	NEUSE RIVER
NC0064891	Town of Kenly	Kenly Regional WWTP	Johnston	Minor	630000	Little River (Tarpleys Pond)
NC0066516	Town of Fuquay-Varina	Terrible Creek WWTP	Wake	Major	6000000	Terrible Creek
NC0075281	Craven County Wood Energy, LP	Craven County Wood Energy	Craven	Minor	200000	Bachelor Creek
NC0080519	Lampe & Malphrus Lumber	10th Street Wet-Decking site	Johnston	Minor	not limited	Buffalo Creek
NC0084514	Raleigh Durham Airport Authority	RDU International Airport-WWTP	Wake	Minor	not limited	Brier Creek
NC0085936	Jerry G Williams & Sons, Inc.	Wet Log Deck Storage site	Johnston	Minor	not limited	NEUSE RIVER

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Schematic Updated for Additional Discharges (cont'd.)

Data exists for historical Q>0.1MGD - used for unimpairment only, not in actual model						
NC0003859	Piedmont Minerals Co Inc	Piedmont Minerals Co., Inc.				
NC0020541	City of Kinston	Peachtree WWTP				
NC0021563	Town of Middlesex	Middlesex WWTP, Town Of				
NC0025020	Town of Wendell	Wendell WWTP, Town Of				
NC0026310	City of Durham	Durham (Little Lick Crk WW				
NC0026336	City of Durham	Durham (Eno WWTP)				
NC0030392	Wayne County	Genoa Industrial WWTP				
NC0050041	Town of Morrisville	Morrisville WWTP, Town Of				
NC0050938	Town of Morrisville	Morrisville, Town Of				
NC0063177	U S Air Force	Seymour Johnson Air Force Base				
NC0064149	Jones Dairy Farm Utilities Inc	Jones Dairy Farm WWTP				
NC0064408	Whitewood Properties Inc D	Neuse Crossing WWTP				
NC0072583	Webbers Hatchery	Webbers Hatchery				
NC0076724	Coastal Lumber Co	Kinston lumber yard				

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Usable Storage Comparison
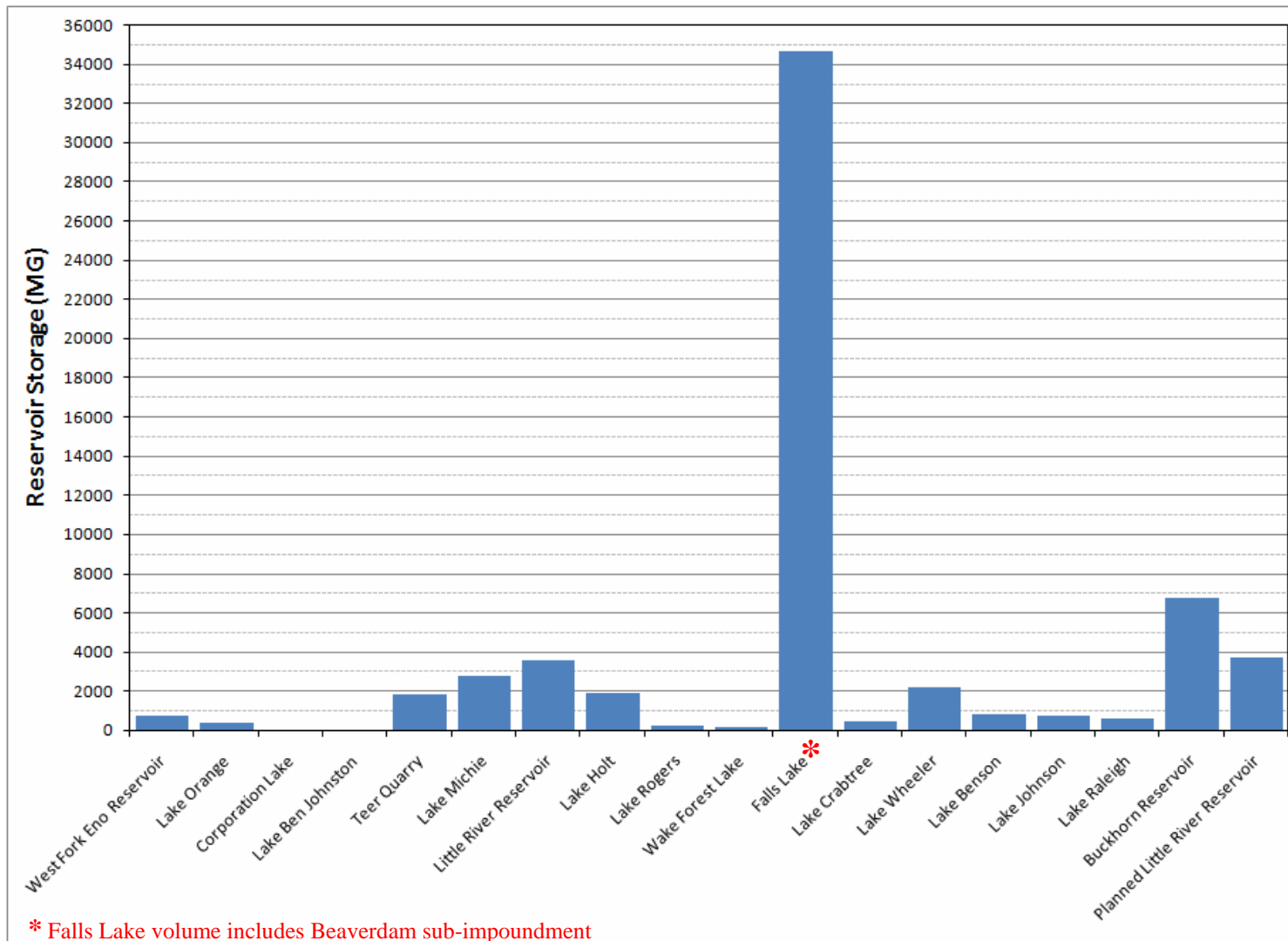
* Falls Lake volume includes Beaverdam sub-impoundment

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Upper Basin
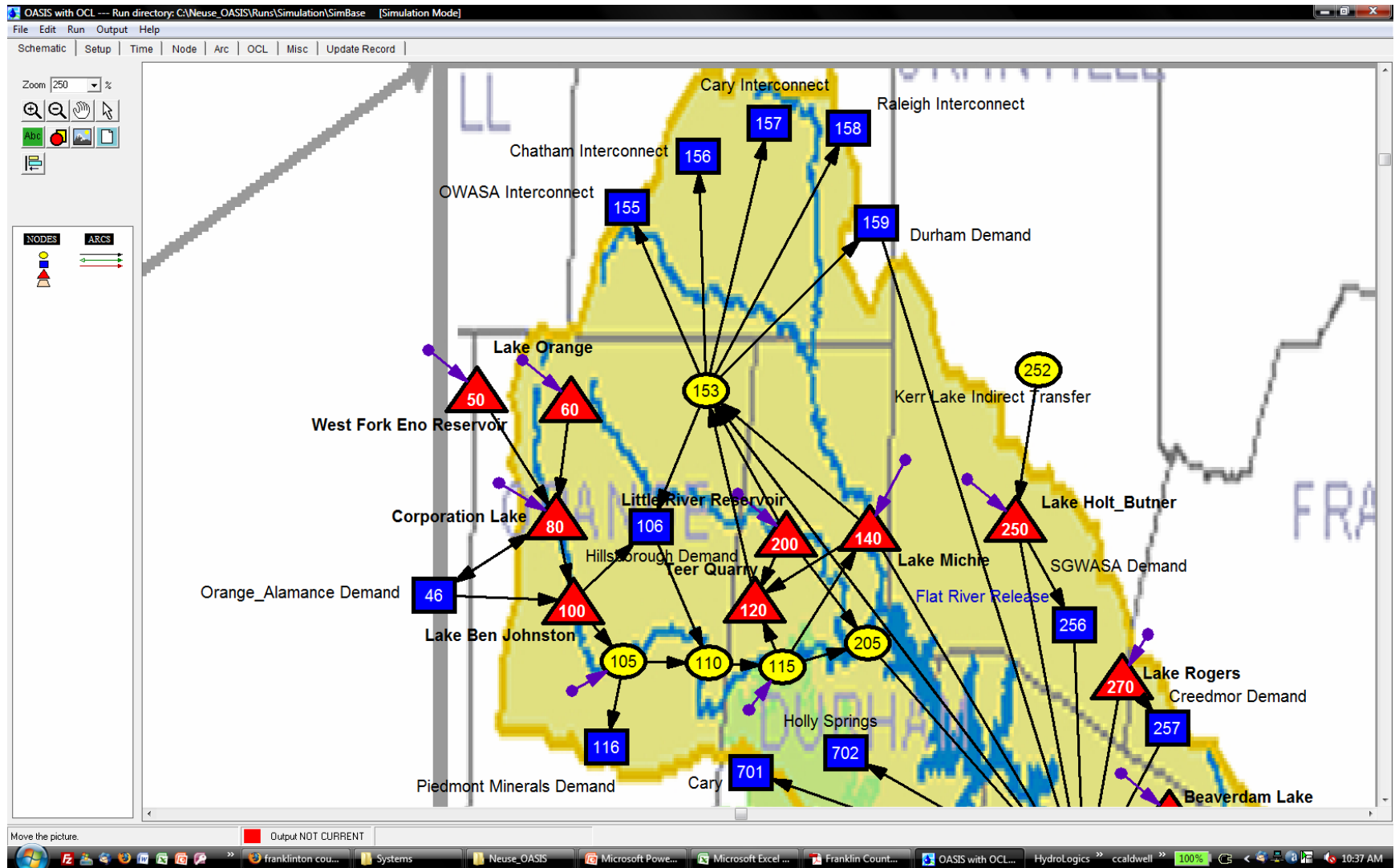
Middle Basin
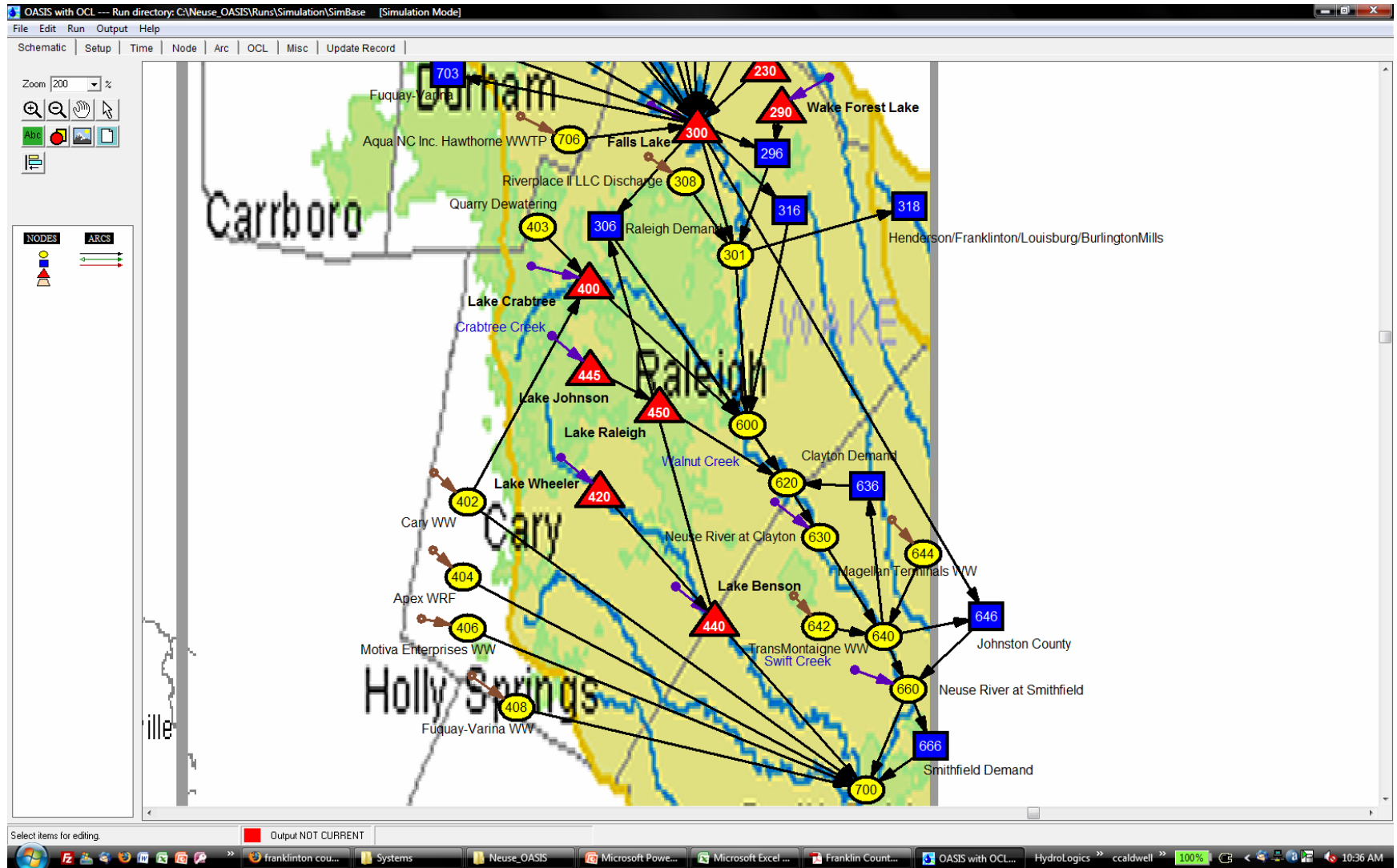
Lower Basin
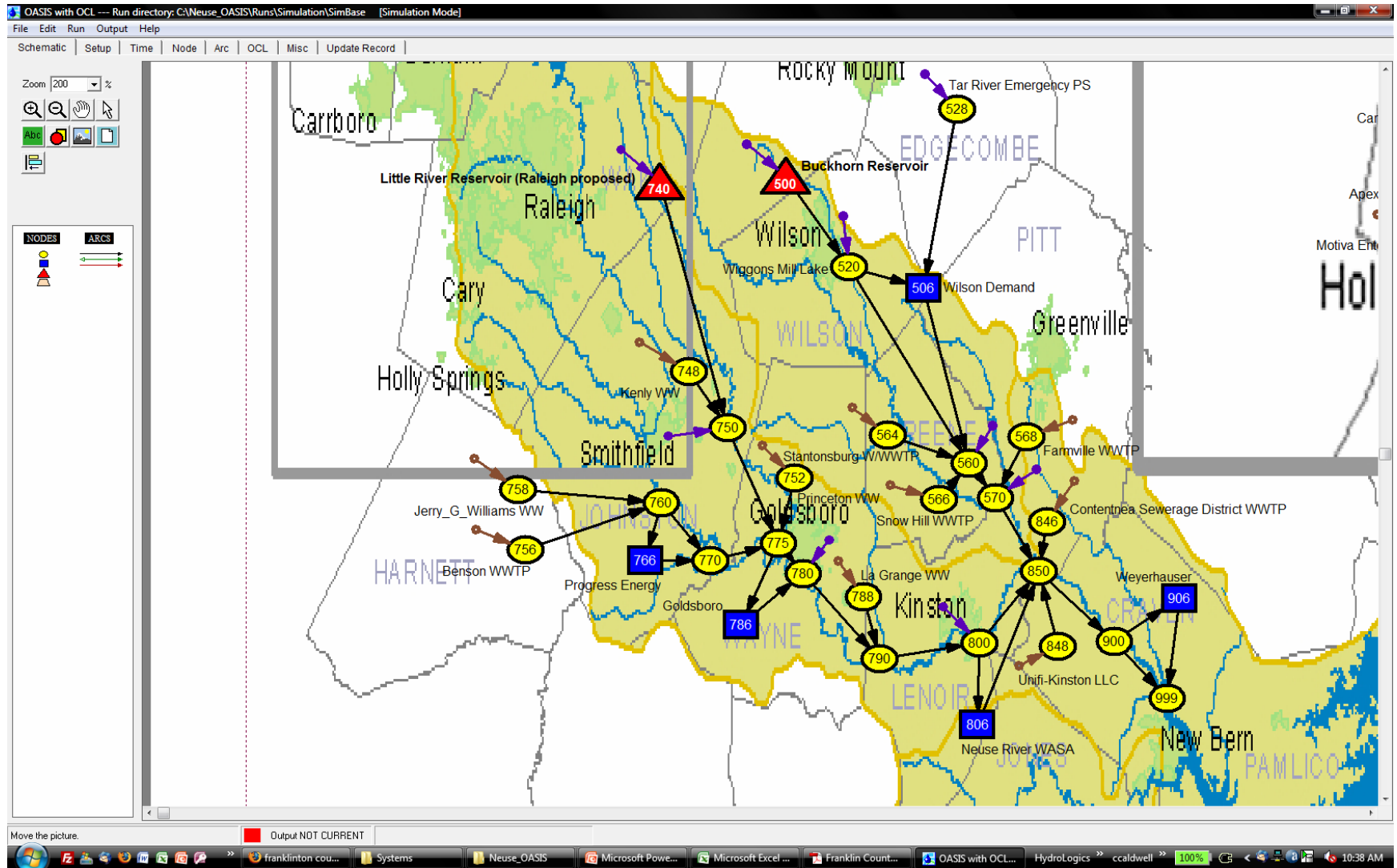
Neuse Gage Timeline

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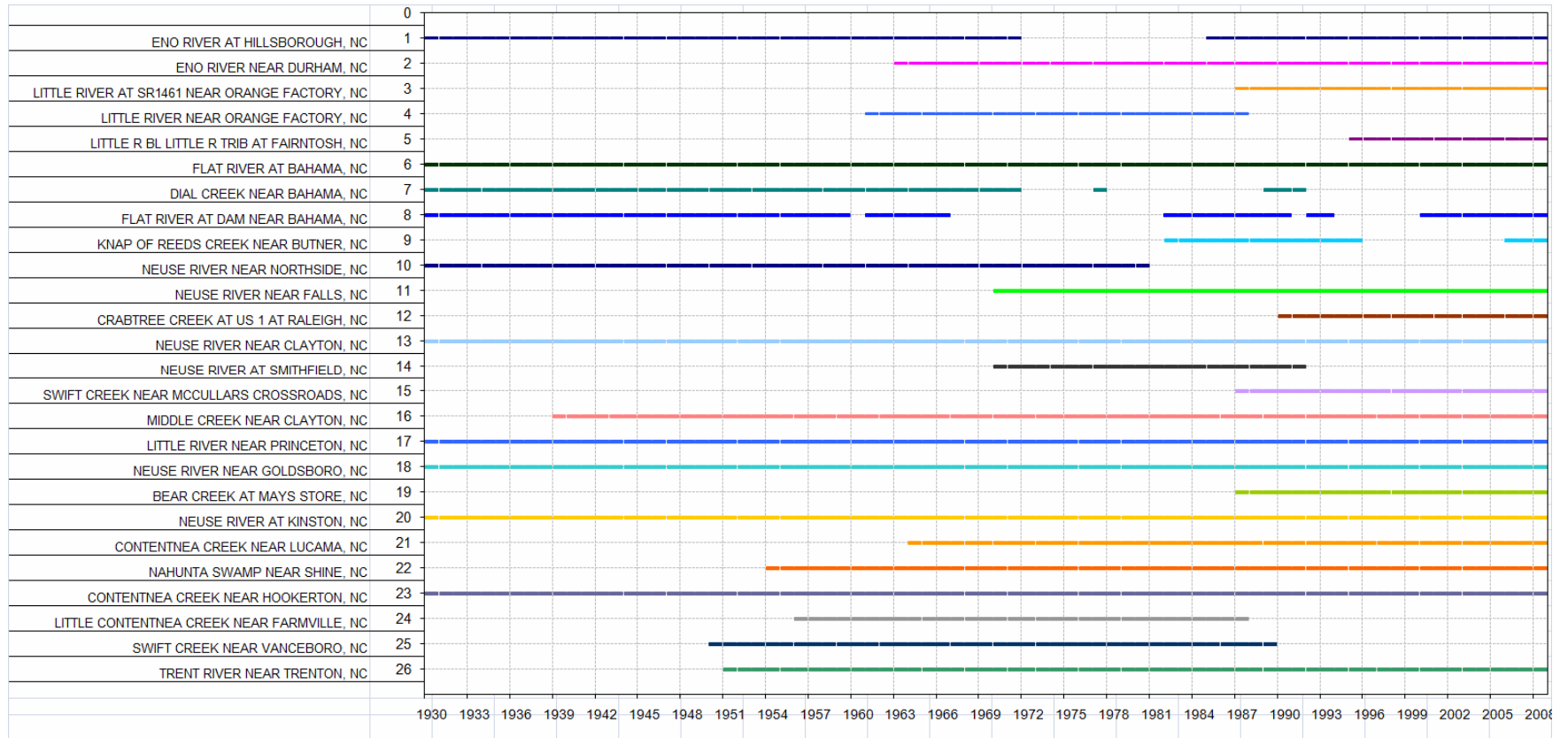
Long-term Gage Availability

Gage is impaired significantly

Gage is unimpaired – use to estimate inflows for nearby reservoirs

(2007 Average flow, and 7-day minimum flow)

Flat River at Bahama (115 cfs, 0.05 cfs)

Eno River at Hillsborough (44 cfs, 1.6 cfs)

Neuse River nr Clayton (994 cfs, 223 cfs)

Middle Creek nr Clayton (90 cfs, 6.6 cfs)

Little River nr Princeton (176 cfs, 0.01 cfs)

Contentnea Creek at Hookerton (735 cfs, 35 cfs)

Neuse River nr Goldsboro (2,196 cfs, 226 cfs)

Neuse River at Kinston (2,710 cfs, 303 cfs)

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Developing Inflow Records

- Reservoirs
  - Use unimpaired stream gages immediately upstream
    - Only available for Lake Michie and Little River (Durham)
  - Otherwise, back-calculate from reservoir outflows and change in storage
    - Data only available for Falls Lake and Buckhorn Reservoir
  - Otherwise, use representative (and unimpaired) gages in the basin adjusted for drainage area (and possibly runoff differences using regression equations)
    - Flat River for estimating inflows to upper basin
    - Middle Creek for estimating inflows to middle basin
    - Little River for estimating inflows to lower basin

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Developing Inflow Records (cont'd.)

- Other nodes (e.g., stream gaging sites)
  - Adjust inflows for impairments between upstream and downstream inflow locations (e.g, between Falls Lake and Clayton)
  - If impairments are not known, use representative (and unimpaired) gages in the basin adjusted for drainage area/runoff differences
- Fill in missing inflow records by correlating with unimpaired inflows at other nodes
- Inflows will be forced to match monthly unimpaired gage flows, meaning measurement error is embedded in impairments and not gage flows

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Spreadsheet Showing Gage Unimpairment

	Reservoirs		Discharges						Withdrawals	Total Adjustment this Subbasin	Total Adjustment Upstream Subbasin	Neuse River near Clayton gage	Unregulated gage
02087500 Neuse River near Clayton													
All flows in cfs													
Date	Change in Storage at Falls	Net Evap at Falls	Riverplace II WWTP	Cary NRF (Crabtree) WWTP	Raleigh Smith Creek WWTP	Whitewood Neuse Crossing WWTP	Raleigh Neuse River WWTP	Clayton WWTP	Raleigh Water Supply WD				Neuse nr Clayton
1/1/1930										= ΔS + Net Evap - Disch. + WDs		920	= Gage flow + total impairments upstream
1/2/1930												980	
1/3/1930												750	
1/4/1930												750	
1/5/1930												860	
1/6/1930												860	
1/7/1930												805	
1/8/1930												860	
1/9/1930												805	
1/10/1930												750	
1/11/1930												695	
1/12/1930												645	
1/13/1930												645	
1/14/1930												695	
1/15/1930												860	
1/16/1930												750	
1/17/1930												980	
1/18/1930												1350	
1/19/1930												1960	
1/20/1930												2980	
1/21/1930												3620	
1/22/1930												2660	
1/23/1930												1750	
1/24/1930												2260	
1/25/1930												2500	
1/26/1930												1960	
1/27/1930												1540	
1/28/1930												1350	
1/29/1930												1220	
1/30/1930												1220	

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Upper Basin

- Eno River
    - Key gages: Hillsborough and Durham gages
    - Cannot unimpair since Lake Orange releases are not recorded
    - Use drainage area adjustment of Flat River gage
- Flat River – unimpaired gage data for full record
- Little River – fill in missing record based on Flat River

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Middle Basin

- Falls/Beaverdam Lake
  - Use back-calculated inflows since project inception
  - Otherwise, use unimpaired Neuse River near Northside gage adjusted for drainage area
    - Flows impacted by Durham reservoirs upstream, but operating data are mostly unavailable
    - Consult with Corps
- Lakes Crabtree, Wheeler, Benson, Raleigh, and Johnson
  - Use drainage area adjustment of Middle Creek
  - Gages downstream cannot be unimpaired since lake operations are not recorded
- Neuse River gages (Clayton)
  - Pre-Falls: Impact of upper basin impairments are small
  - Post-Falls: Major impairments available

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Lower Basin

- Buckhorn Reservoir
  - Develop regression of unimpaired Little River and unimpaired Contentnea Creek near Lucama gage flows
  - Use regression to estimate Buckhorn Reservoir inflows
- Neuse River gages (Goldsboro, Kinston)
  - Pre-Falls: Impact of upper basin impairments are small
  - Post-Falls: Major impairments available

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Calibration/Simulation

- Calibration used to test accuracy of inflow estimates
- Simulation used to also confirm operating rules

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Calibration/Simulation by Sub-Basin

- Upper basin:
    - Upper Eno: West Fork Eno Reservoir, Lake Orange, Hillsborough gage
    - Lake Michie, Little River Reservoir
- Middle basin:
    - Lake Wheeler <u>inflows</u>
    - Falls Lake
- Lower basin: Buckhorn Reservoir

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West Fork Eno Reservoir

Storage at node 050 -- West Fork Eno Reservoir

Initial reservoir impoundment during this period; operating notes also indicate some leaks being repaired at the time

Computed   Historic

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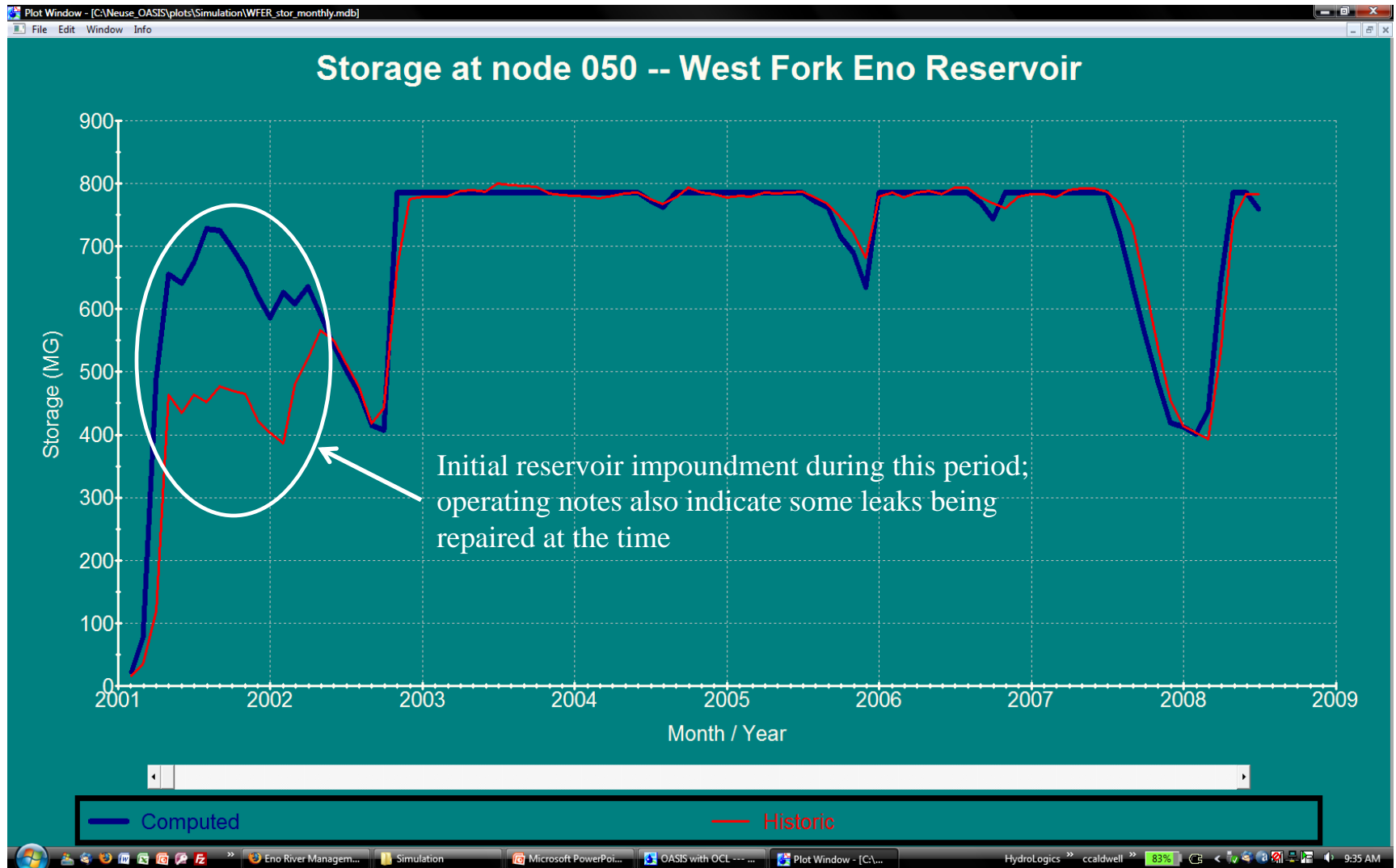
Lake Orange

- No calibration possible since release data are not collected

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Simulation of Upper Eno

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West Fork Eno Reservoir

Lake Orange

Lake Orange upstream impoundments

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Lake Orange Simulation
with 60% inflow reduction
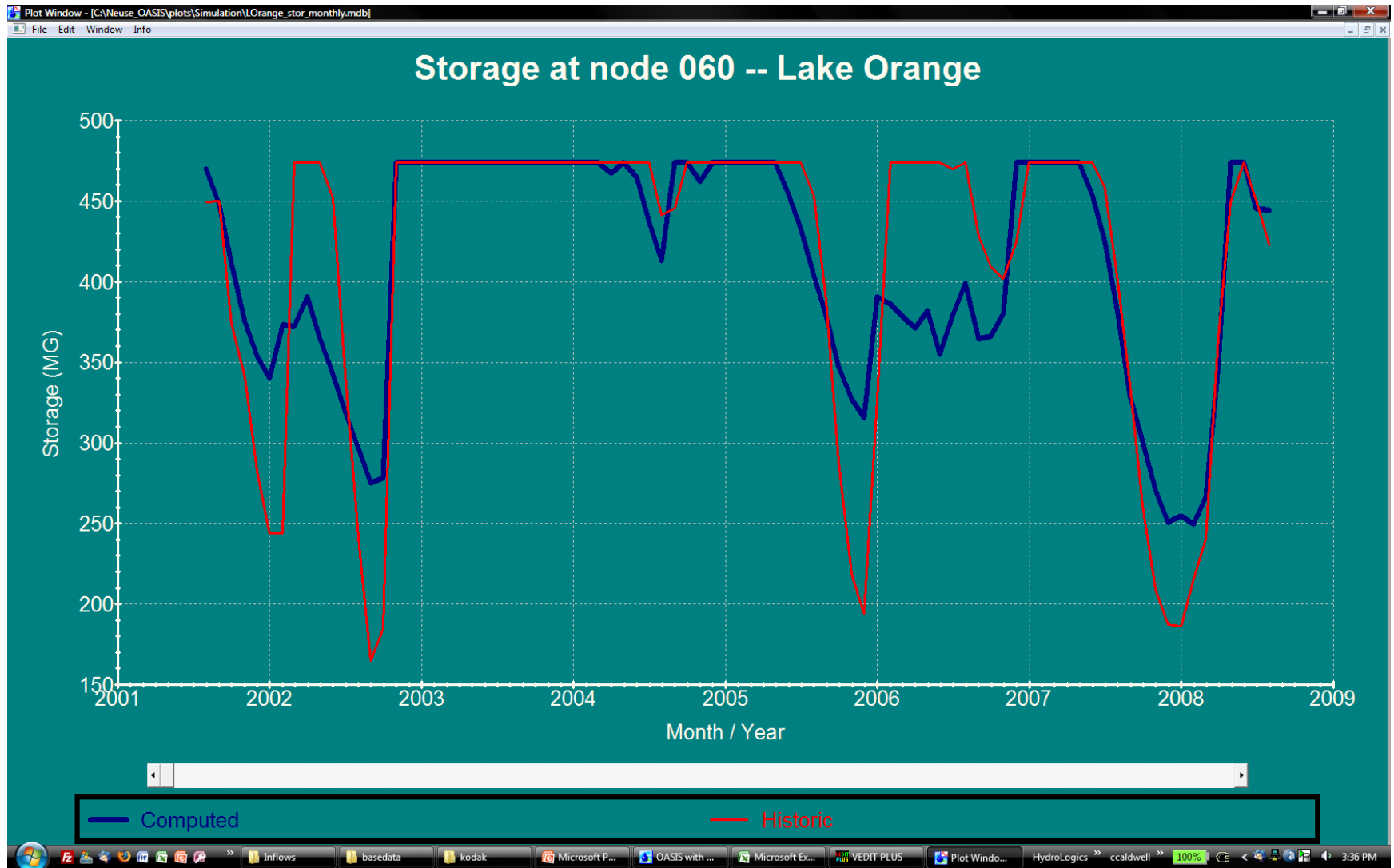
Lake Orange
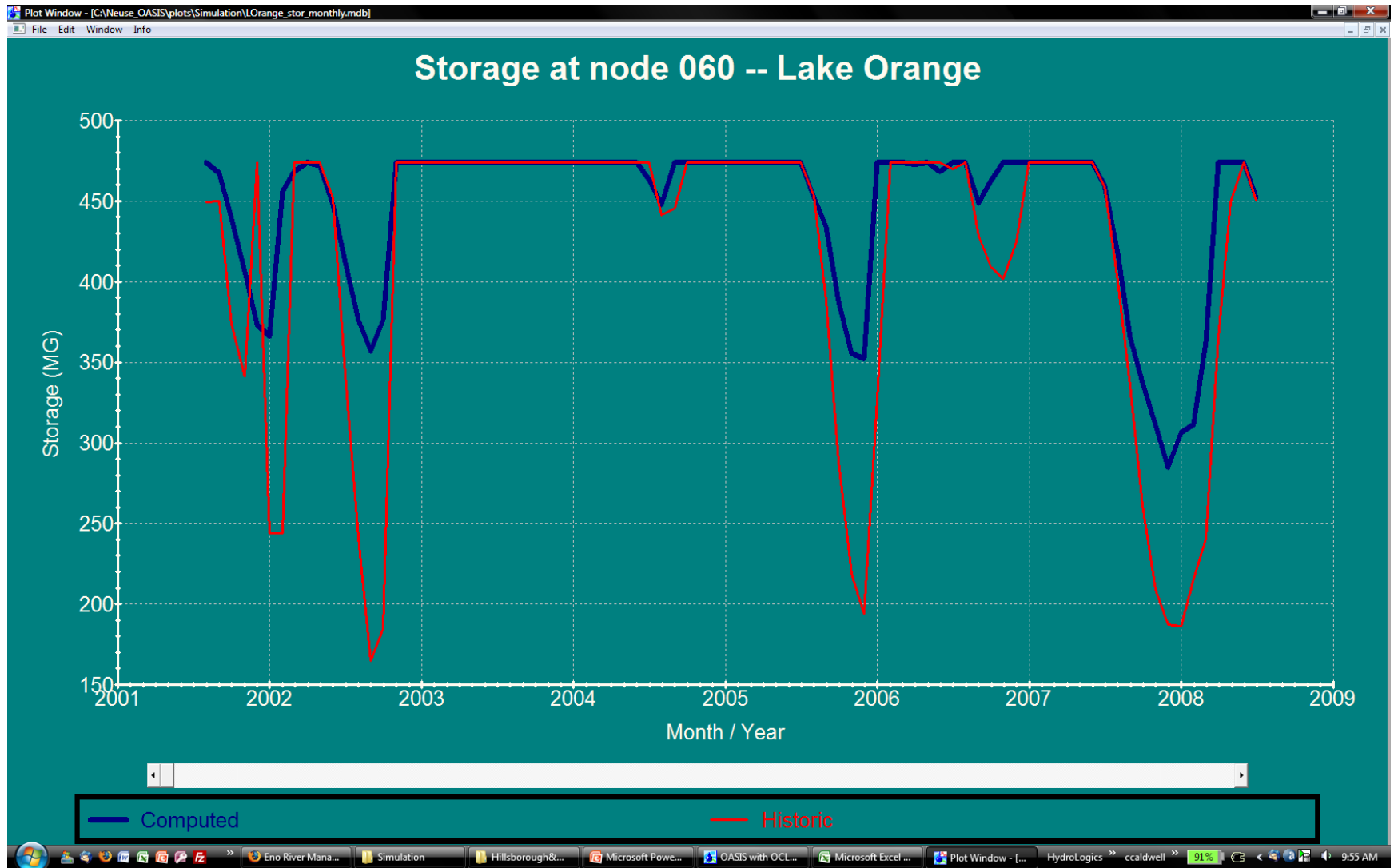
Hillsborough Gage
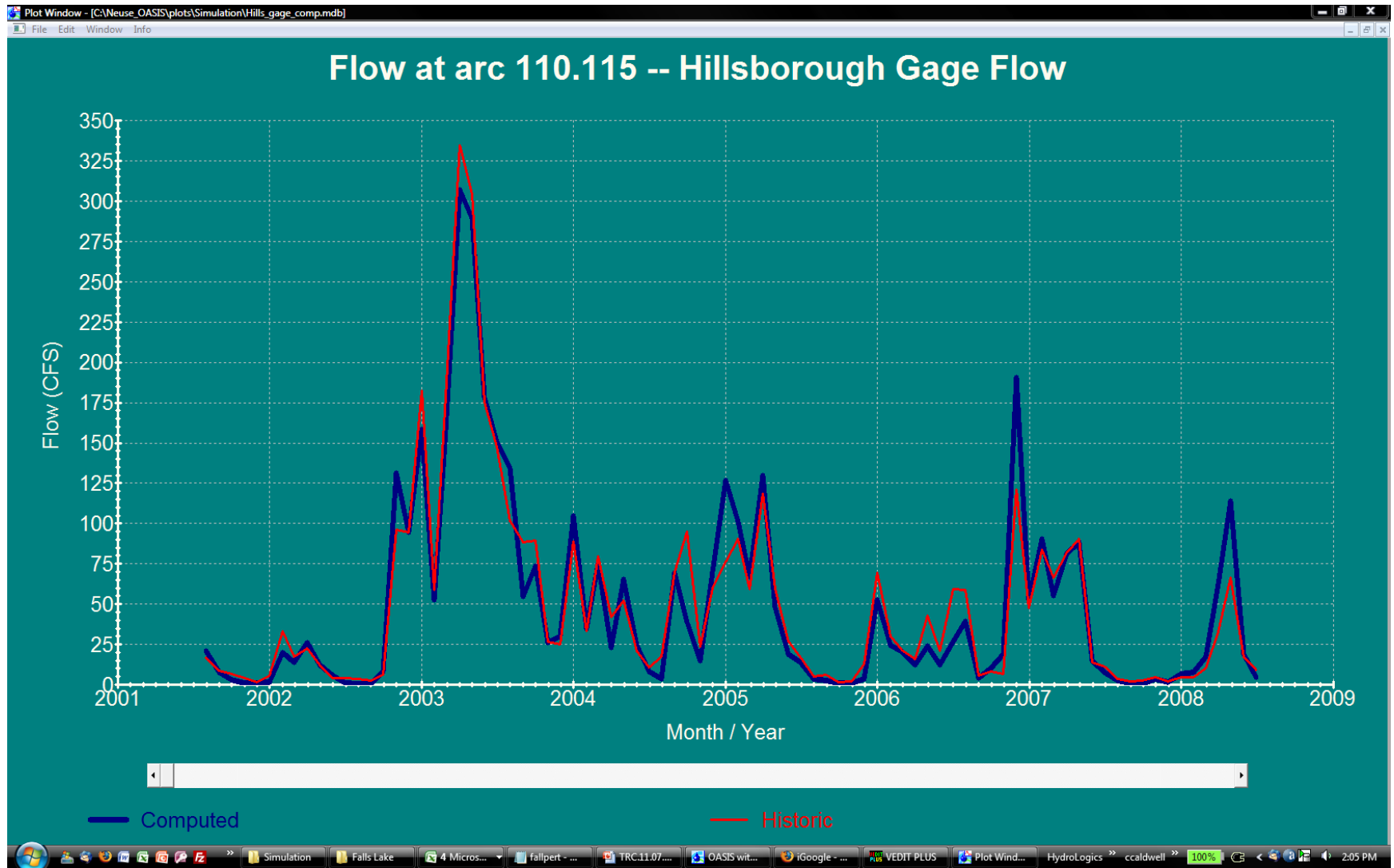
Hillsborough Gage - Simulation

Flow at arc 110.115 -- Hillsborough Gage Flow
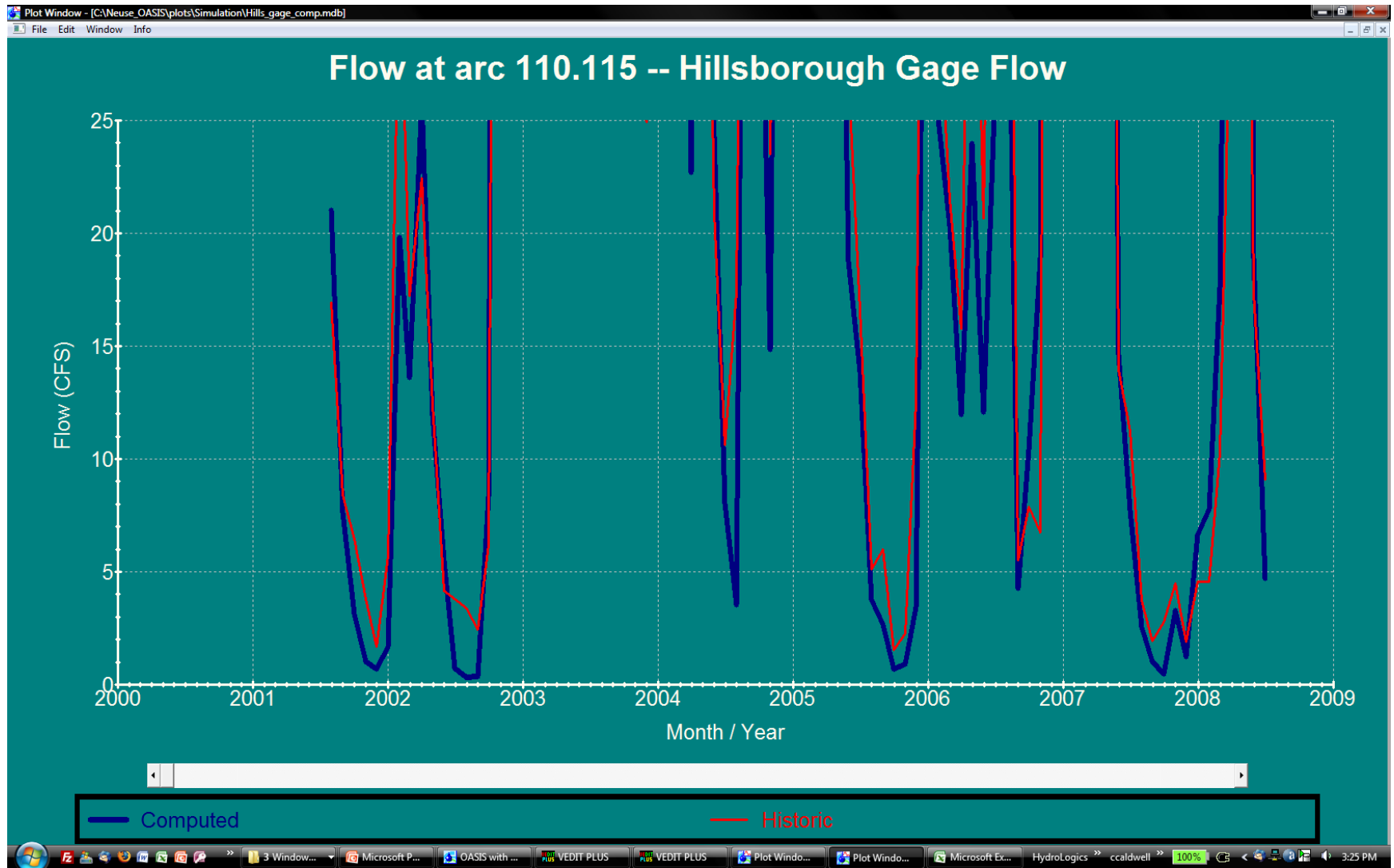
Durham Calibration

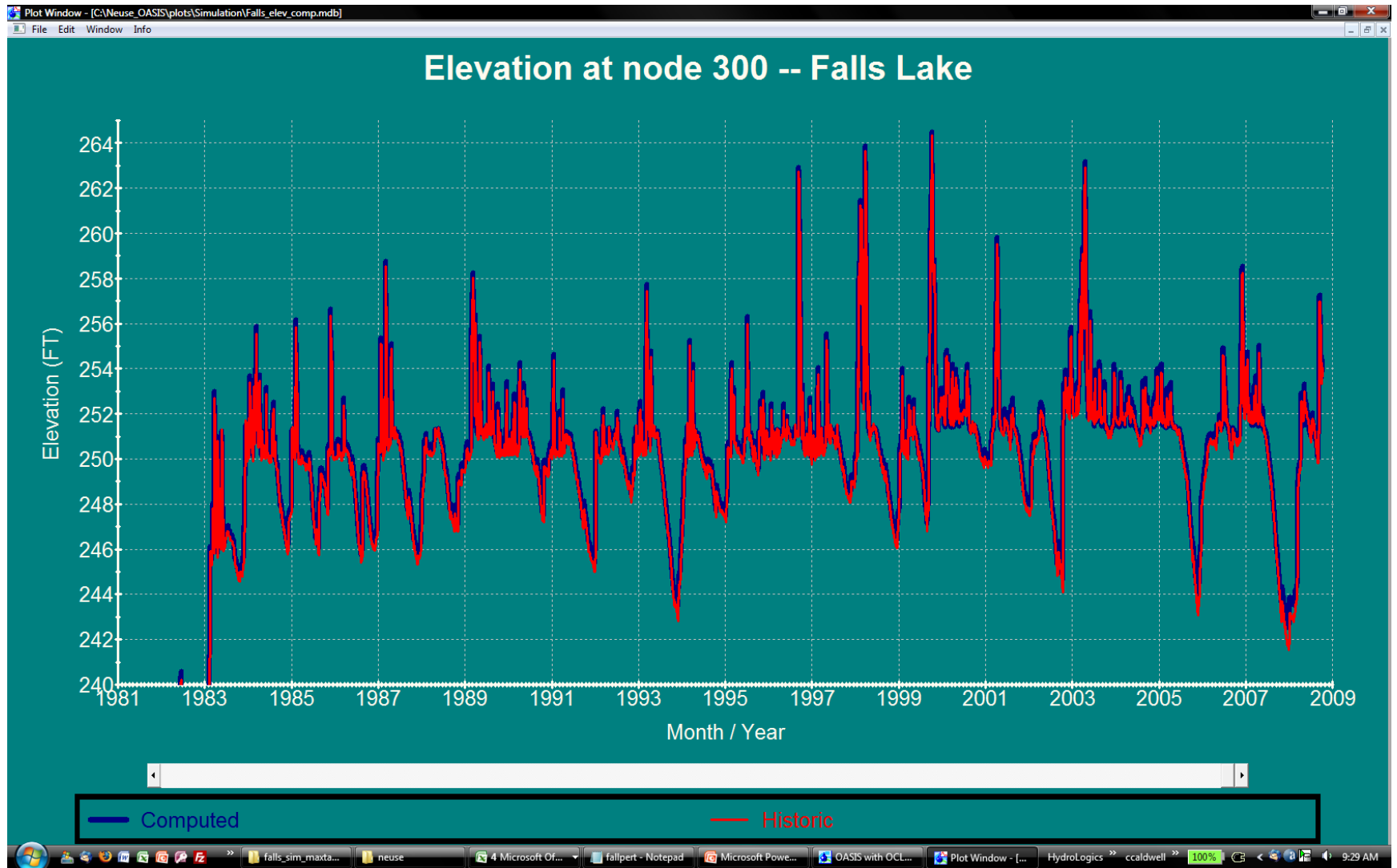# Lake Michie
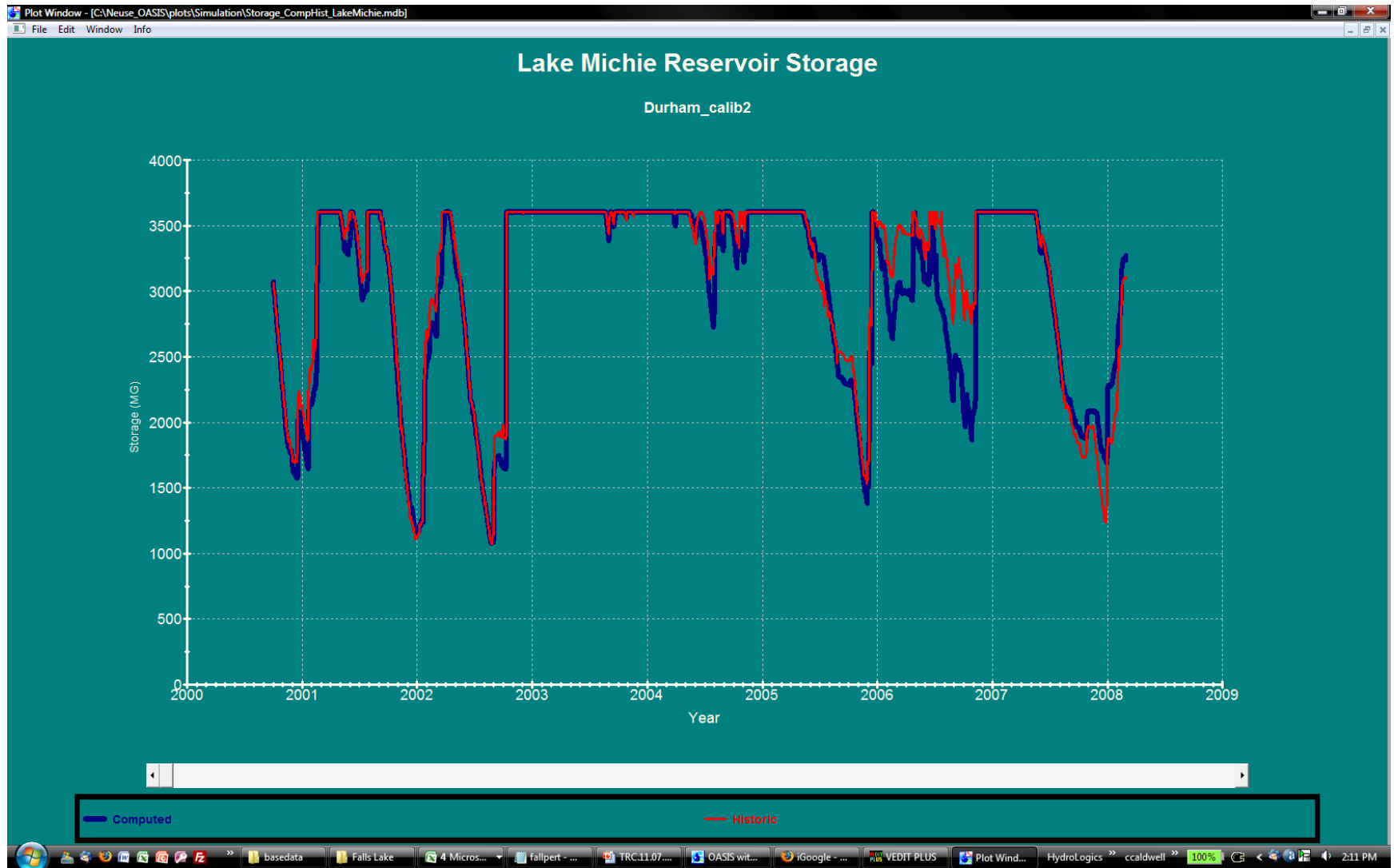
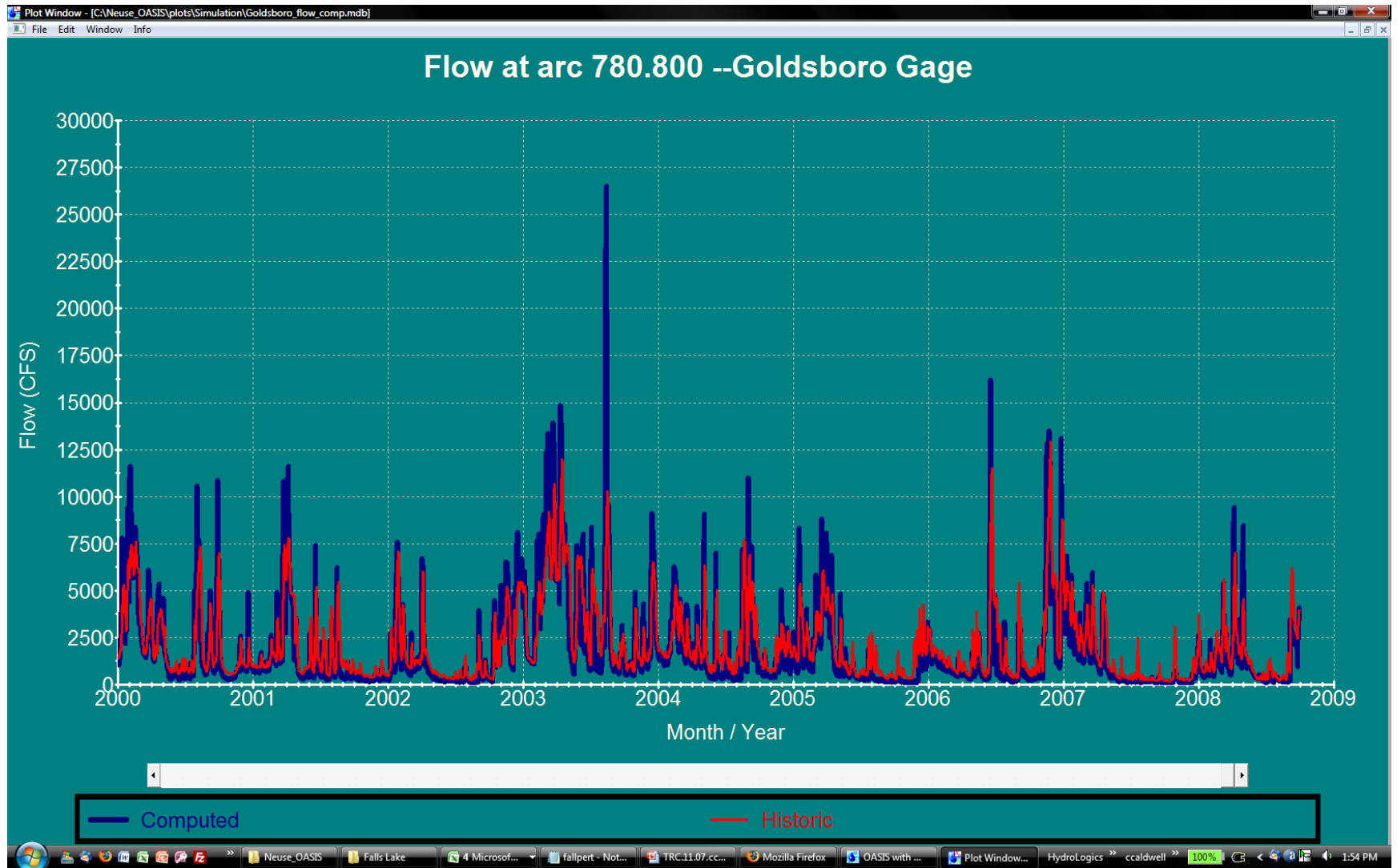# Little River
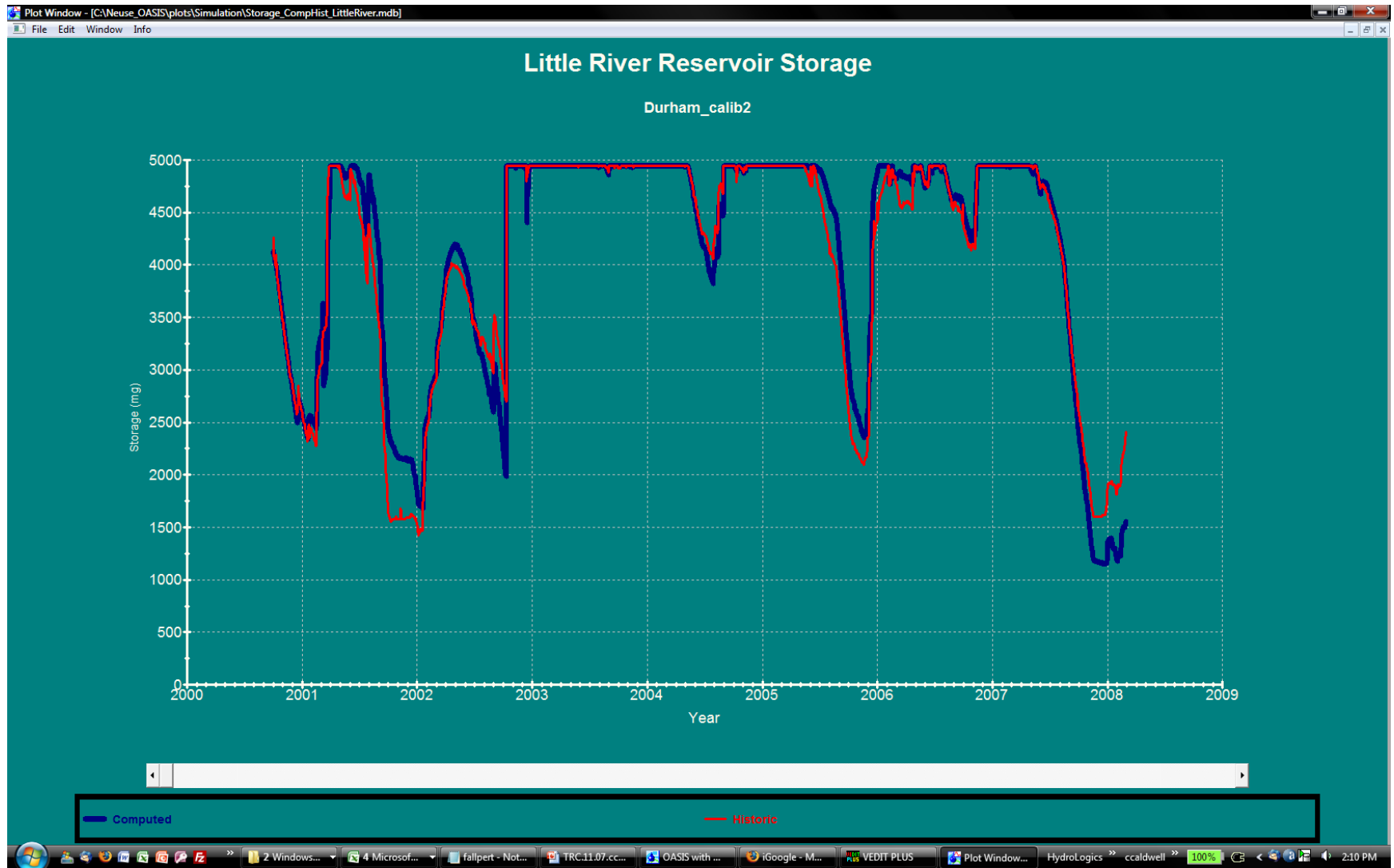
Lake Michie and Little River
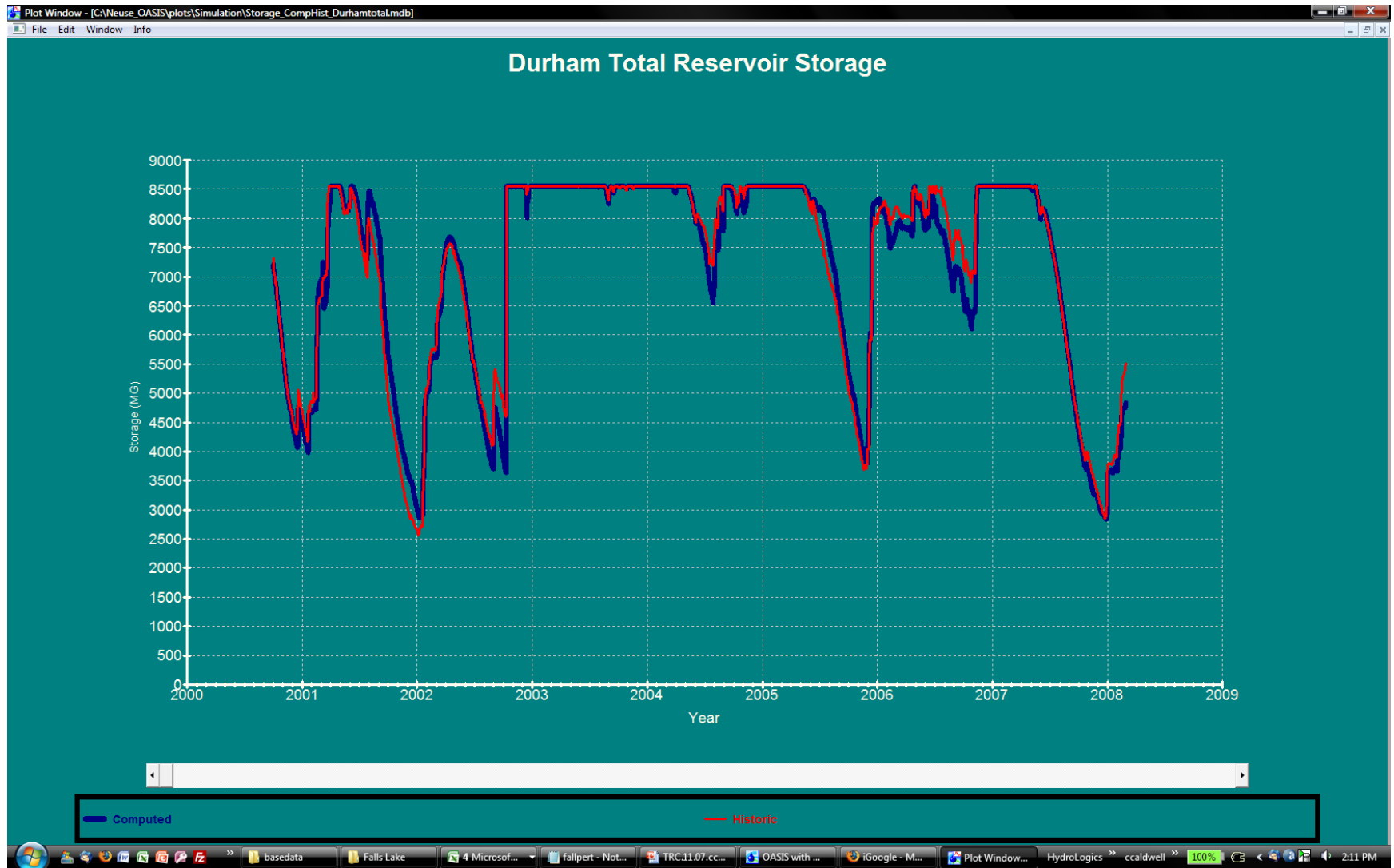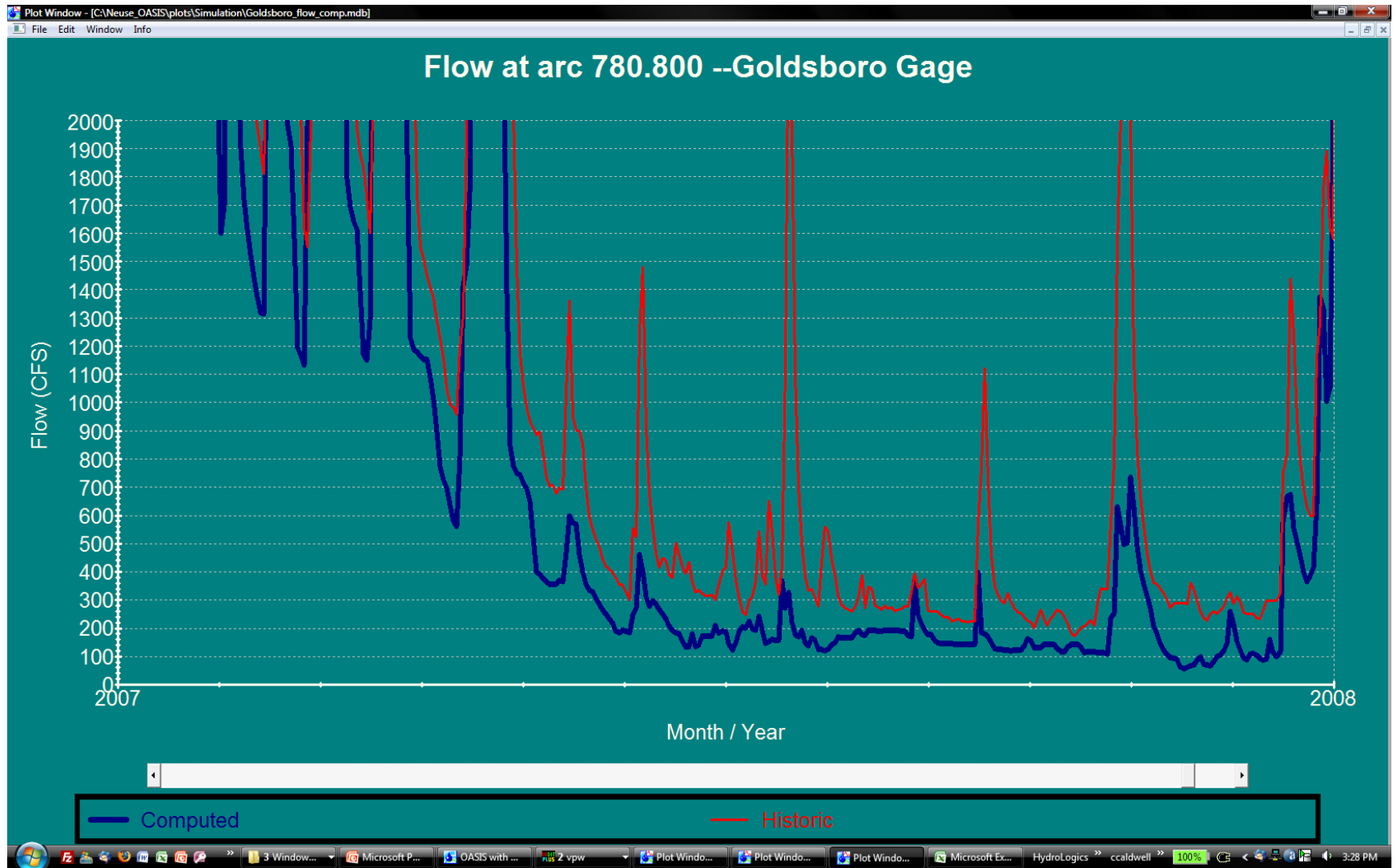
Simulation
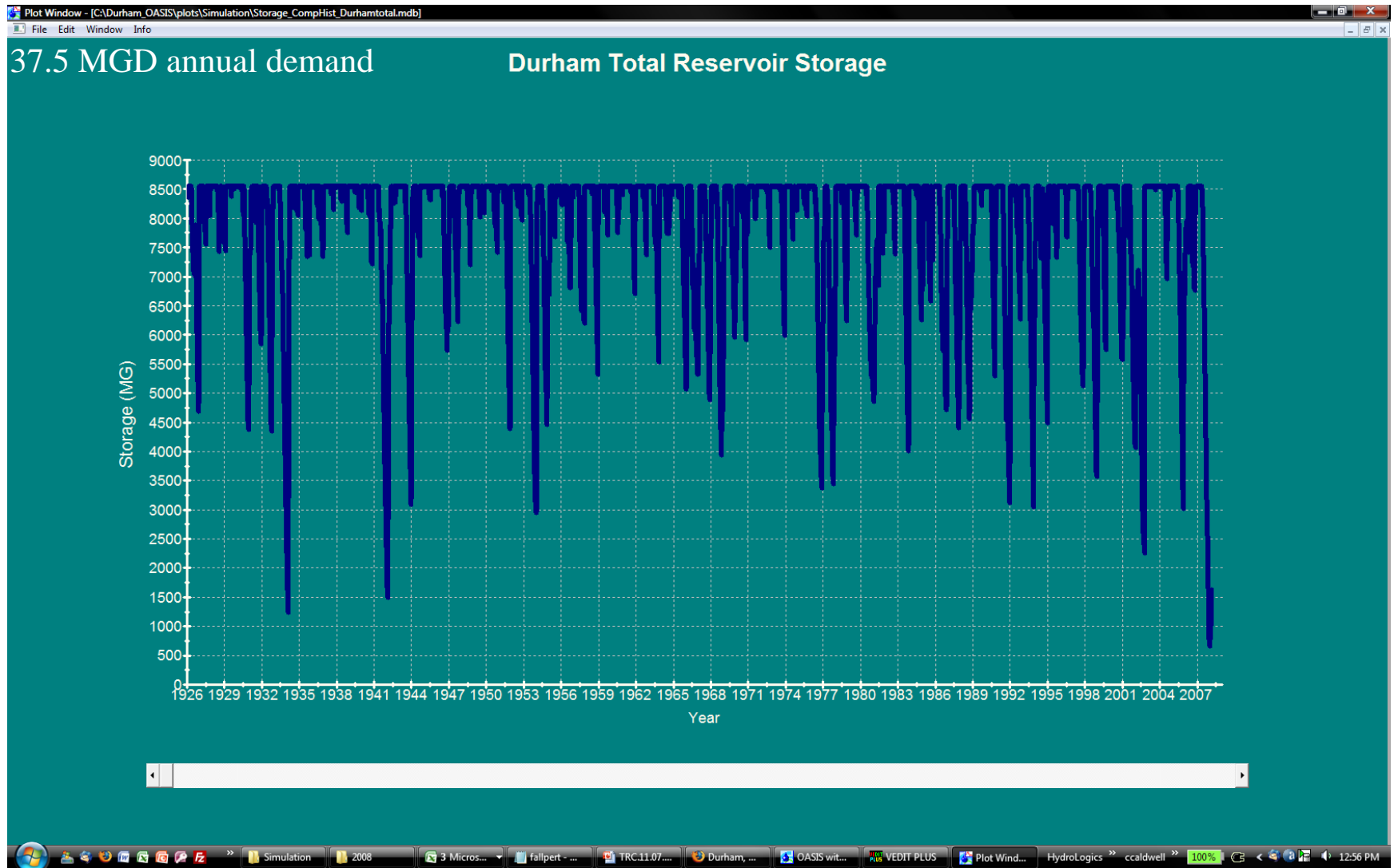
Falls Lake Calibration/Simulation
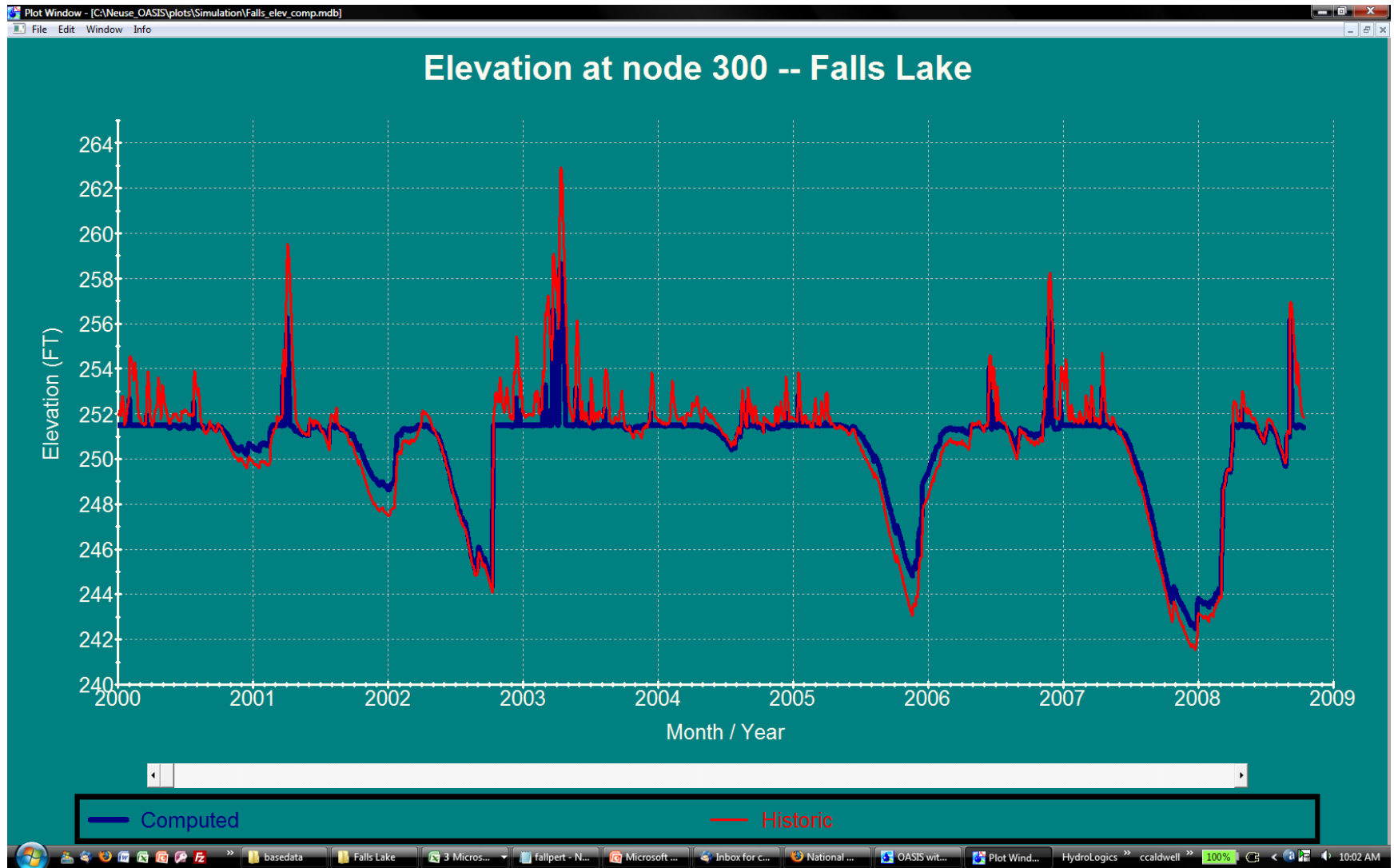
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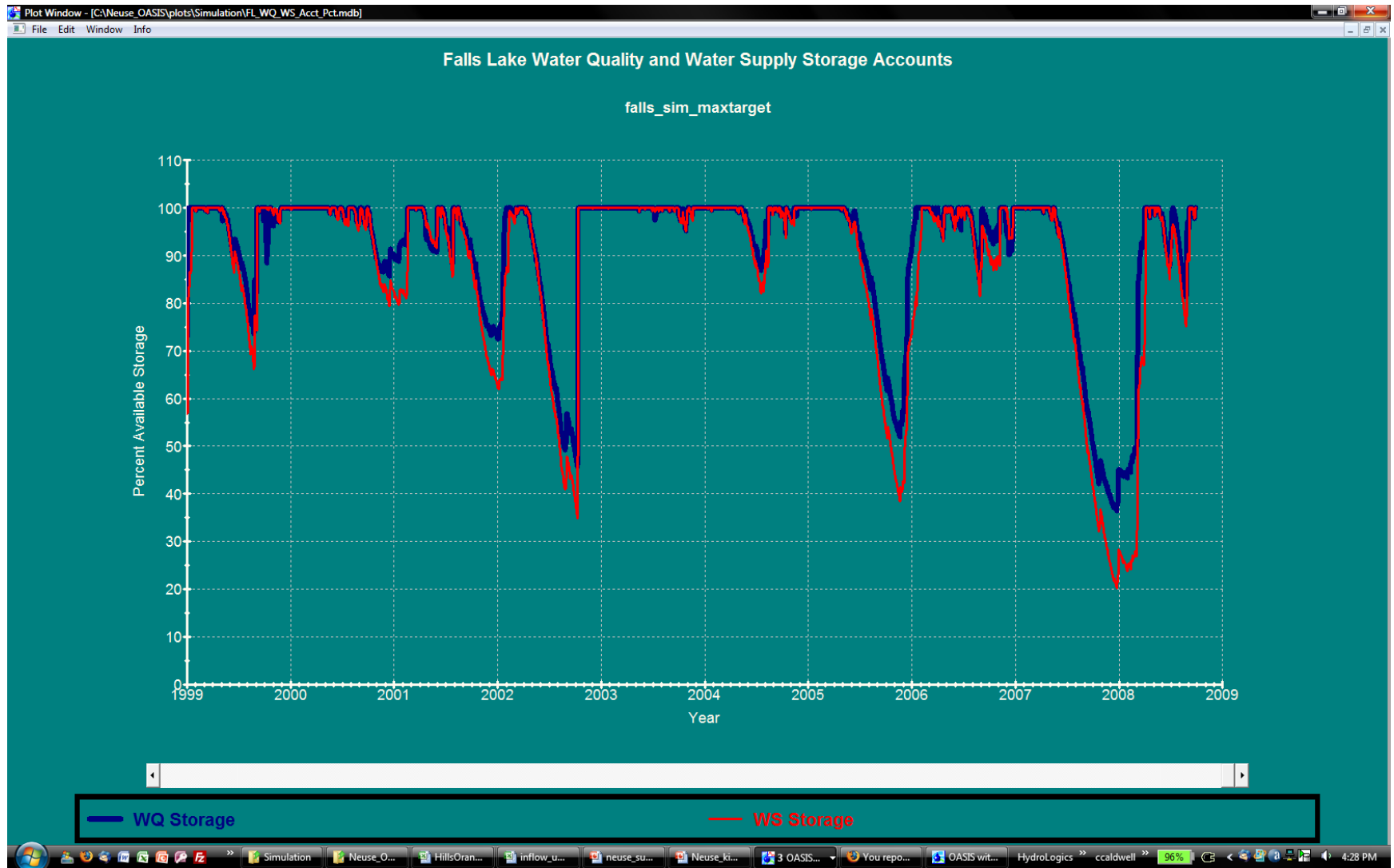
Calibration

Calibration – Goldsboro gage
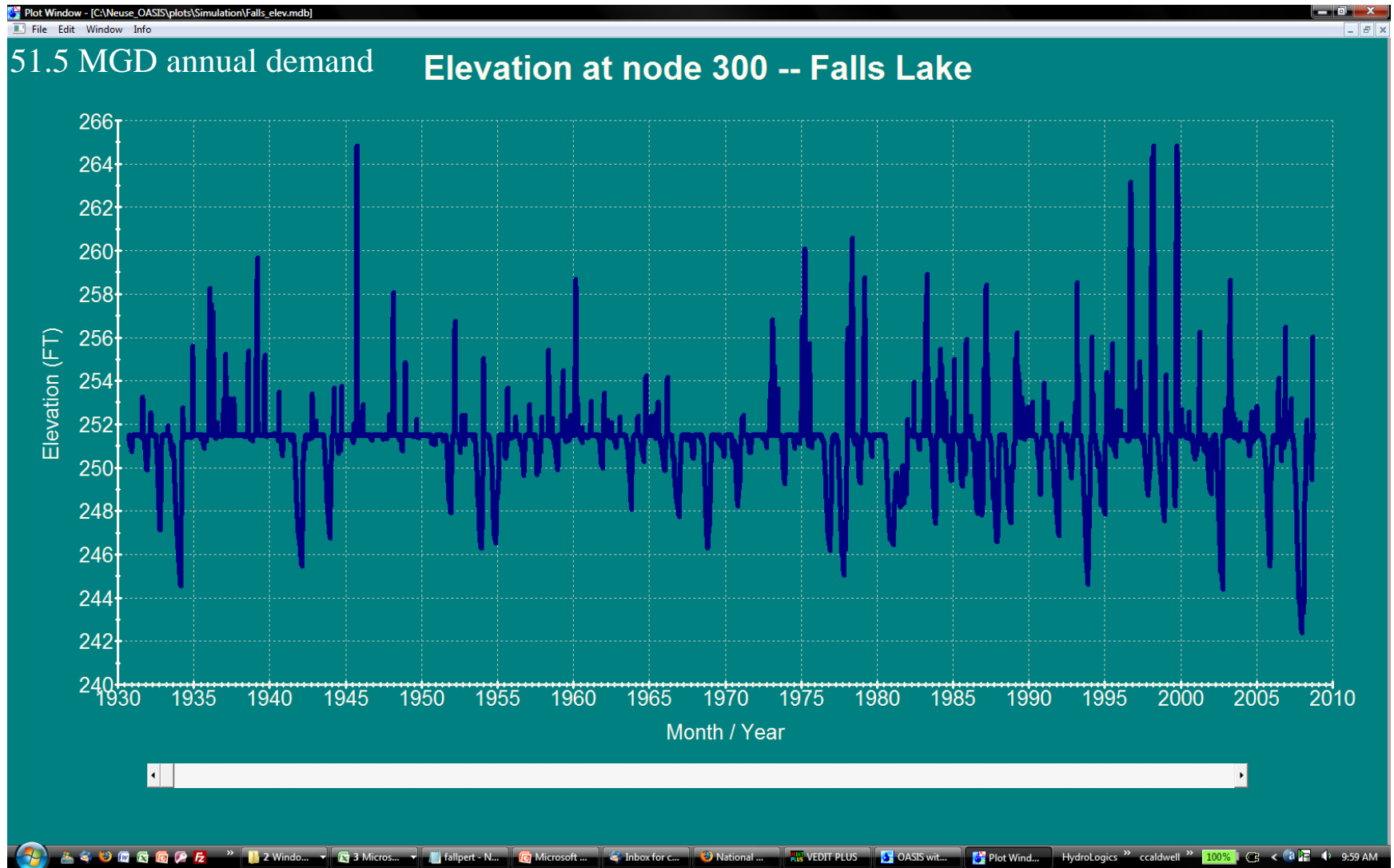
Calibration – Goldsboro gage

Simulation

Simulation

Simulation

Simulation

Using area-adjusted Little River flows as gains downstream of Falls Lake

Elevation at node 300 -- Falls Lake

Legend: Computed, Historic

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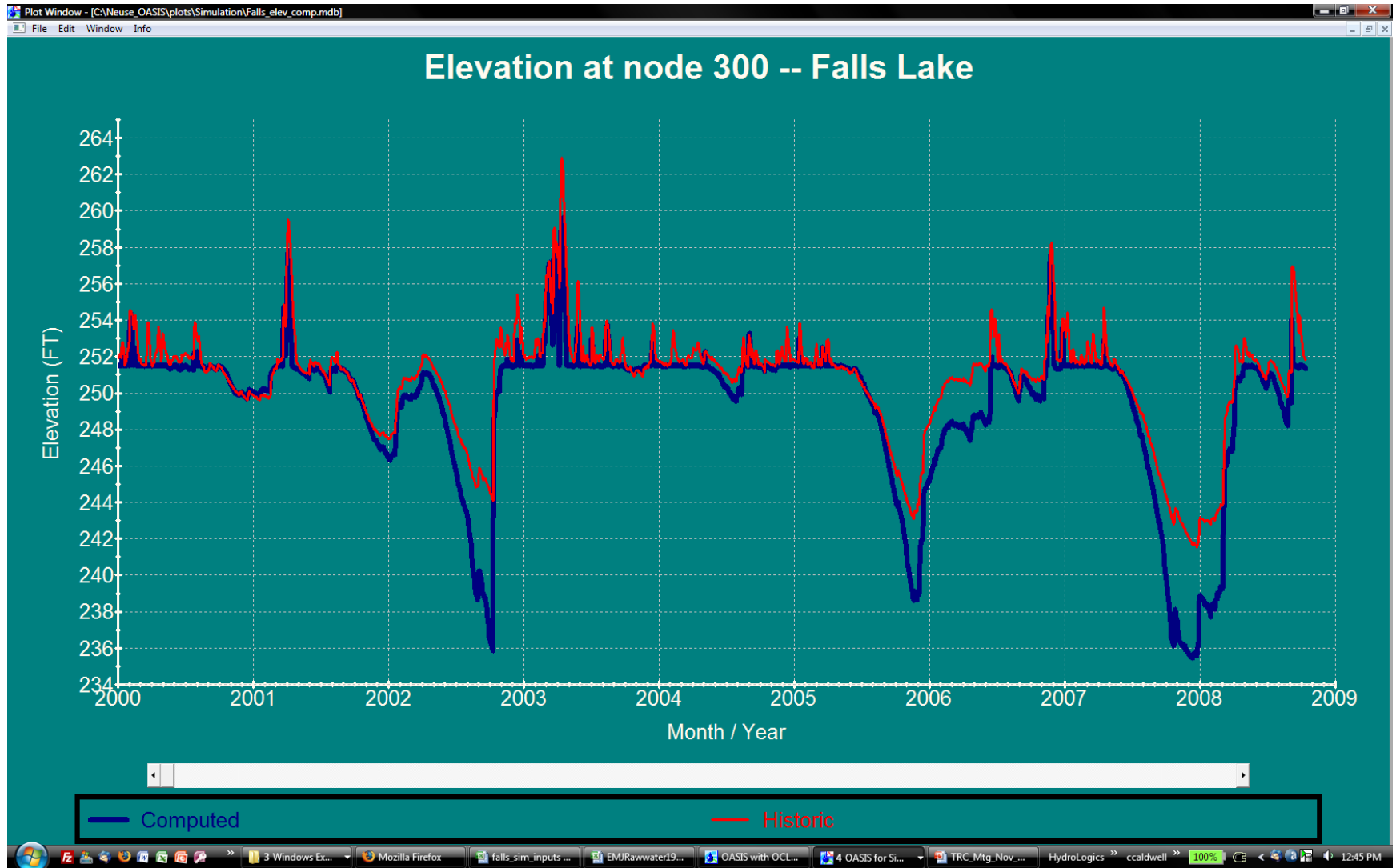
Simulation
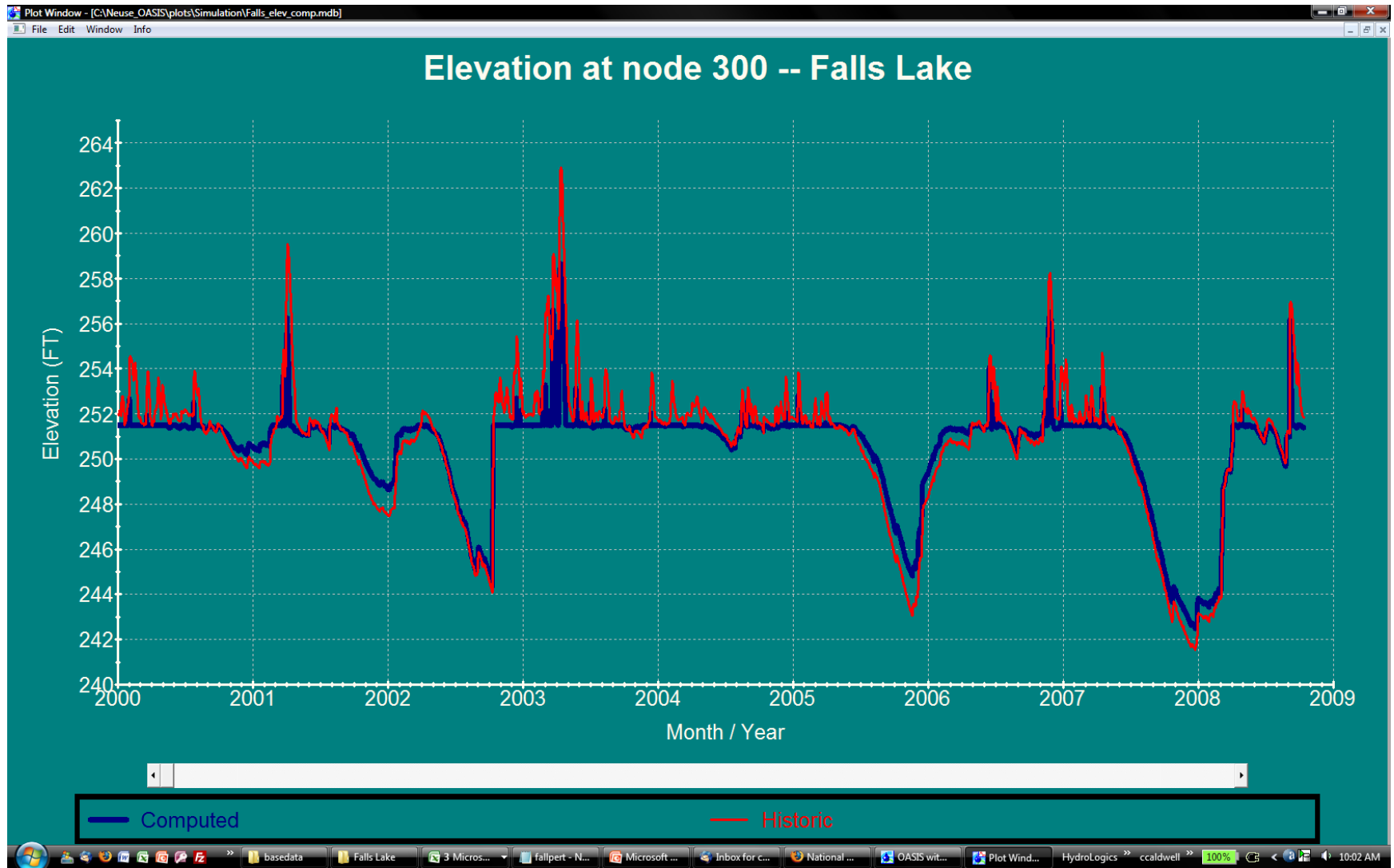
Calibration – Other Reservoirs

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Lake Wheeler Inflows
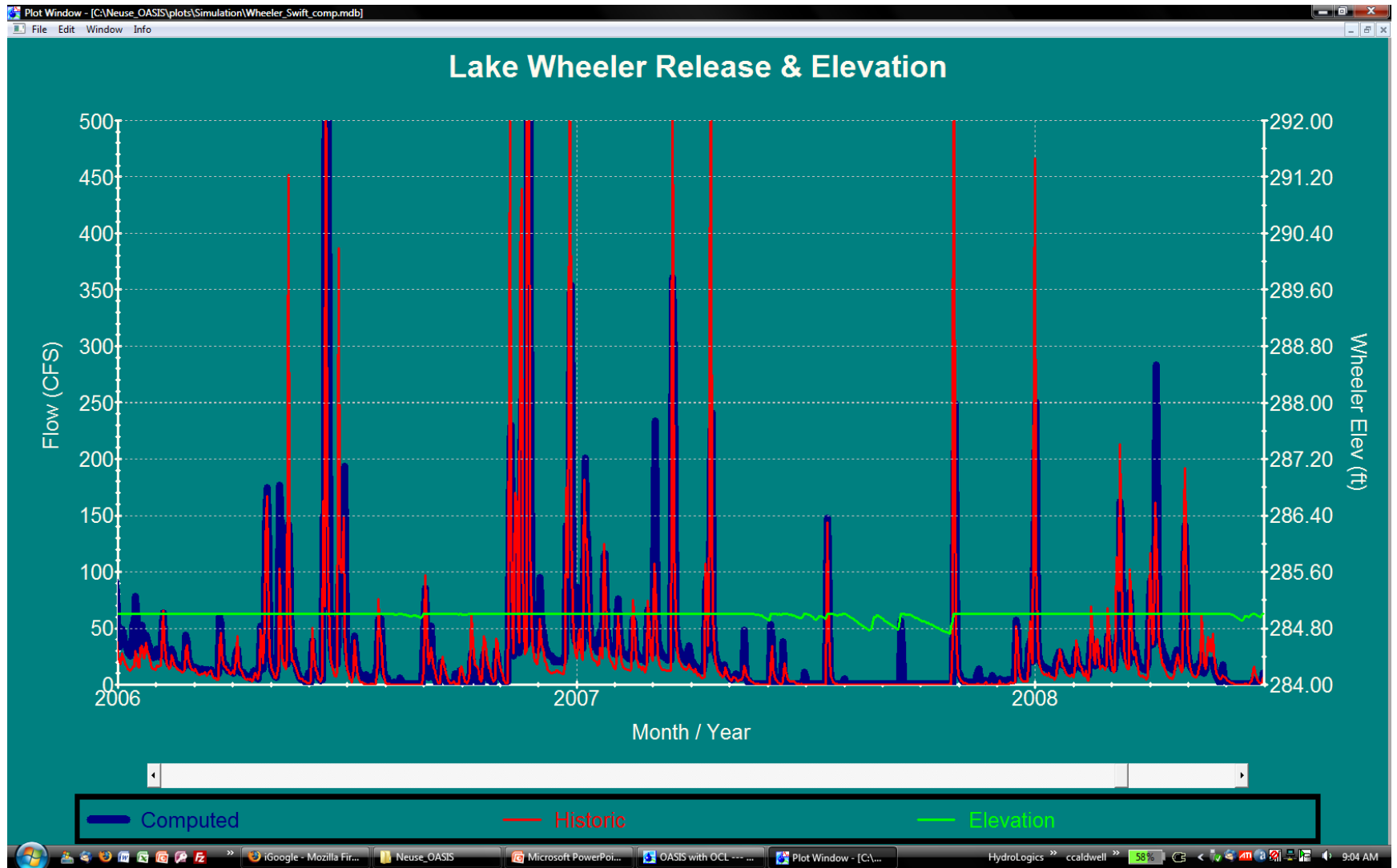
Lake Wheeler Inflows

Buckhorn Reservoir

Buckhorn Reservoir Storage

buckhorn_calib_regression

Off by ~ 11cfs during 2005 drawdown, or about 50% of the average inflow
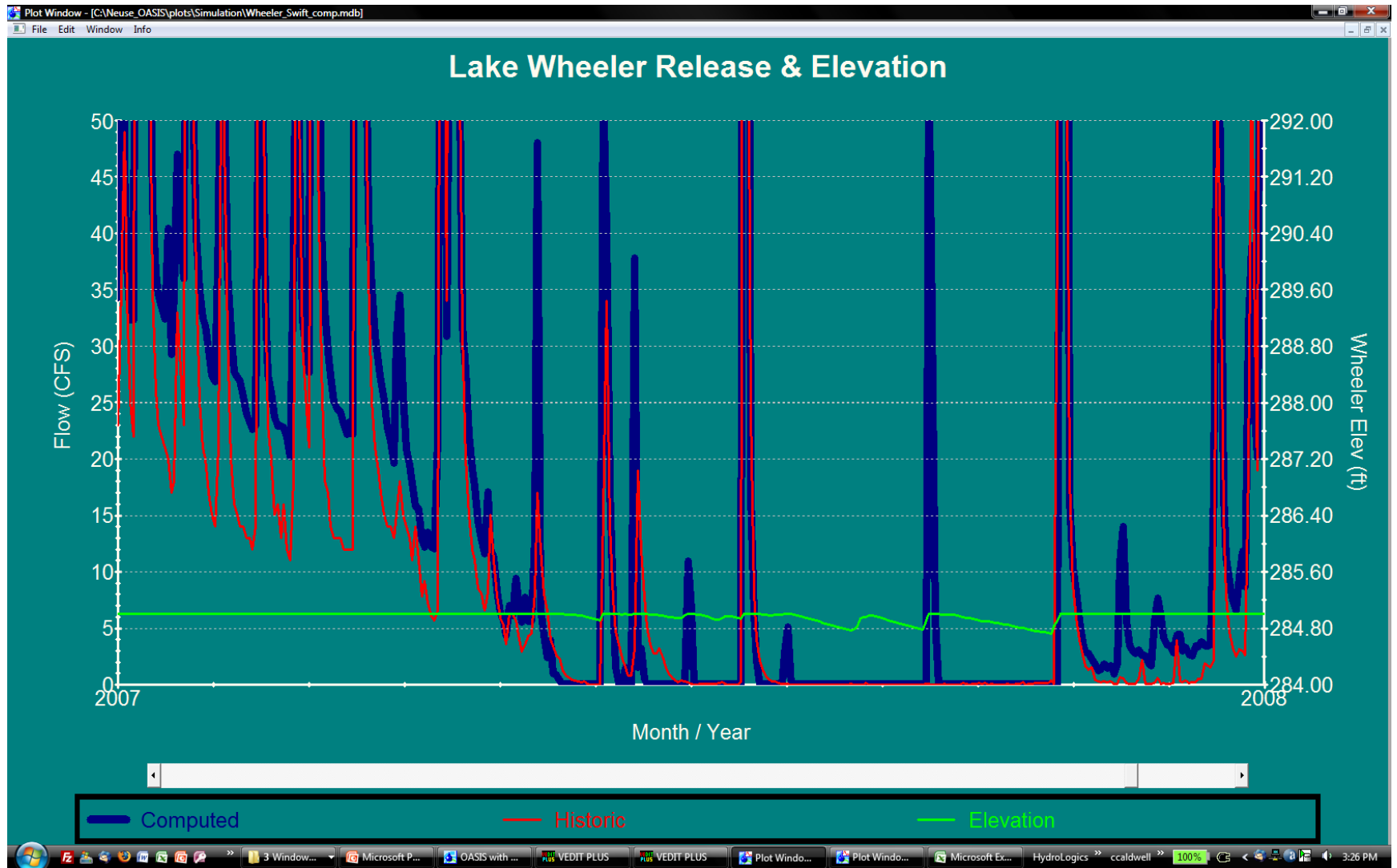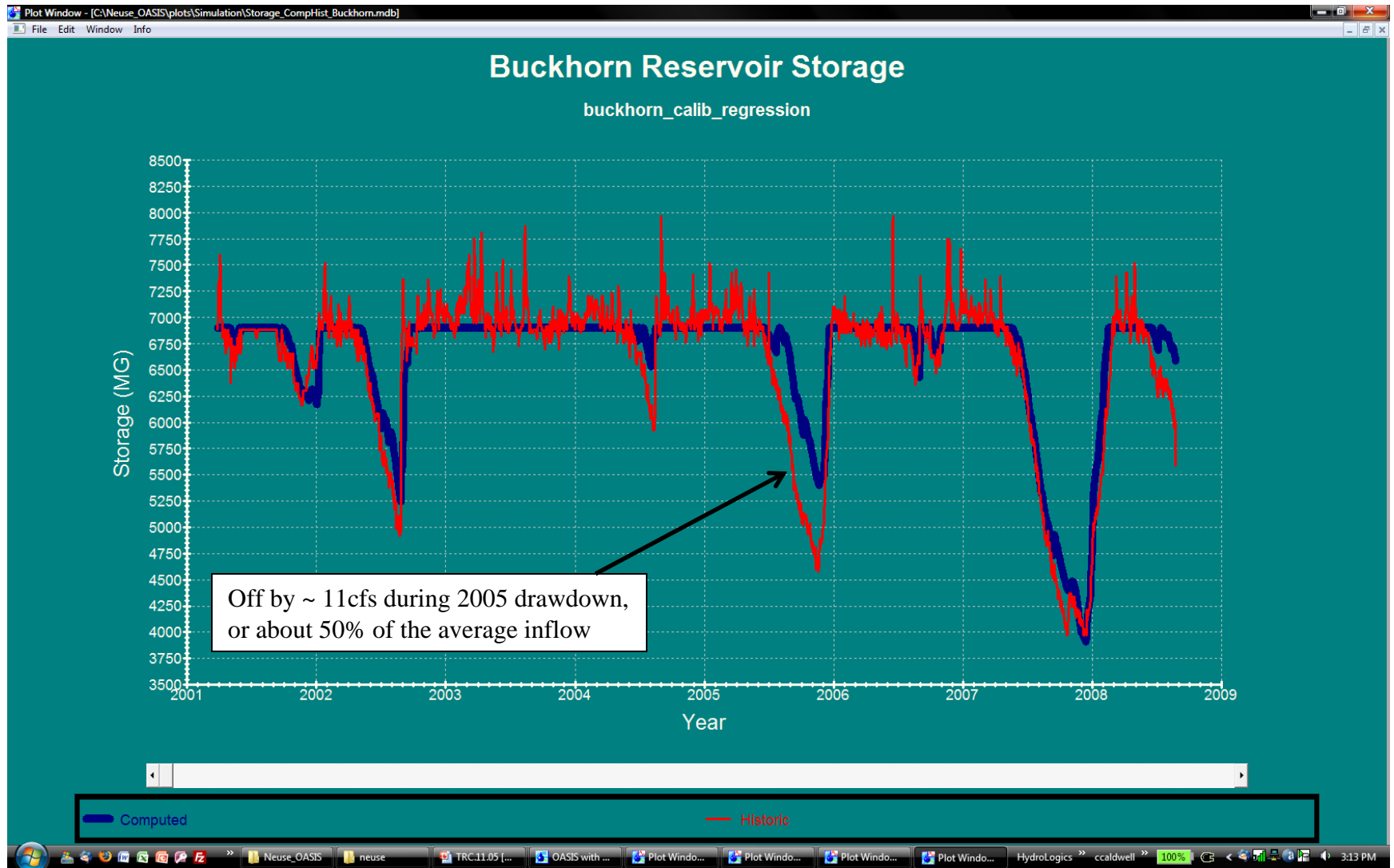
Remaining Calibration Issues

- Lake Rogers, Lake Holt, Wake Forest Lake

- Lake Crabtree
  - Managed by USDA
  - Have elevation-storage relationship for dam above normal pool; can estimate volume of pool based on area and average depth

- Falls Lake
  - WQ/WS accounting
  - Beaverdam operations

- Other inflow points

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Backup Slides

West Fork Eno Reservoir (WFER)

- Use area-adjusted Flat River flows
  - WFER: 9.45 sq. mi.
  - Flat River gage: 149 sq. mi.

- Calibration: Match historic releases since 2001 provided by Hillsborough
  - Not at regular time intervals, so had to use monthly average. Assume daily release = monthly average, which will not impact calibration of drawdown events

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Lake Orange

- Use area-adjusted Flat River flows
  - Lake Orange: 9.09 sq. mi.
  - Flat River gage: 149 sq. mi.

- No calibration possible since outflow data are not available

- There is some reduction of effective watershed area due to upstream impoundments
  - During low flows
  - Also agricultural withdrawals

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Lake Orange Min. Release Policy

Maximum Allowable Surface Water Withdrawals Based on Lake Orange Water Level

	Percent of Storage Remaining at Lake Orange	Drawdown in feet from top of 1-ft. flashboard	Allowable Surface Water Withdrawal (gallons per day)			Instream Flow Requirement at Hillsborough Gage (gallons per day)		
			Town of Hillsborough[†]	Orange-Alamance	Piedmont Minerals	From Lake Orange	From West Fork Eno Reservoir	Total Flow at Hillsborough Gage
	> 100	spilling	*[†]	*	**	1,100,000	650,000	1,750,000
Stage 1	100 - 80	0.0	1,510,000[†]	820,000	430,000	1,100,000	650,000	1,750,000
Stage 2	80 - 60	2.0	1,360,000[†]	740,000	380,000	650,000	650,000	1,300,000
Stage 3	60 - 50	4.3	1,280,000[†]	700,000	360,000	450,000	650,000	1,100,000
Stage 4	50 - 40	5.8	1,280,000[†]	700,000	320,000	450,000	650,000	1,100,000
Stage 5	40 - 30	7.4	1,130,000[†]	620,000	190,000	0	650,000	650,000
Stage 6	<= 30	9.3	680,000[†]	370,000	0	0	650,000	650,000

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WFER Min. Release Policy

- Greater of A or B:

A.

Flow Releases (CFS):

Month	Tier 1 (100%-60%, 633-628ft) Habitat Maint.	Flow Augm.	Total Release	Tier 2 (60%-40%, 628-624ft) Habitat Maint.	Flow Augm.	Total Release	Tier 3 (40%-0%, 624-592ft) Habitat Maint.	Flow Augm.	Total Release
January	3.5		3.5	1.9		1.9	0.1	0.9	1.0
February	3.5		3.5	1.9		1.9	0.1	0.9	1.0
March	3.5		3.5	1.9		1.9	0.1	0.9	1.0
April	4.0		4.0	2.2		2.2	0.2	0.8	1.0
May	3.0		3.0	1.6		1.6	0.2	0.8	1.0
June	1.8		1.8	1.0		1.0	0.2	0.8	1.0
July	1.4		1.4	1.0		1.0	0.2	0.8	1.0
August	1.0		1.0	0.6	0.4	1.0	0.2	0.8	1.0
September	1.0		1.0	0.6	0.4	1.0	0.2	0.8	1.0
October	1.0		1.0	0.6	0.4	1.0	0.2	0.8	1.0
November	1.6		1.6	1.0		1.0	0.2	0.8	1.0
December	2.6		2.6	1.3		1.3	0.1	0.9	1.0

B.

Discharge at USGS gage 02085000 in Hillsborough	Estimated Channel Losses	Required Release at West Fork Eno Reservoir dam
more than 12 cfs	none	1.0 cfs + water supply demand
between 4 and 12 cfs	10%	**1.1** x (1.0 cfs + water supply demand)
less than 4 cfs	20%	**1.2** x (1.0 cfs + water supply demand)

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Durham's system calibration

- Use Flat River and Little River gage flows adjusted to drainage area of reservoir's

- Emulate reservoir releases by matching downstream gage flows

- Estimate demand from reservoir withdrawals and pipe meter readings provided by Durham
  - Much of this record had to be estimated

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Swift Creek (Lake Wheeler)

- Use area-adjusted Middle Creek flows
  - Unimpair Middle Creek w/ Cary & Apex discharges
    - Have 1997 – 2008 data
  - Lake Wheeler: 35 sq. mi.
  - Middle Creek gage: 149 sq. mi.
  - Middle Creek flows were used in 2005 Arcadis study

- Lakes have not been in operation 1997-2008
  - Set Lake Wheeler outflow to zero when level drops below spillway (285 ft)

- Can use the same method for Lake Crabtree, Lake Raleigh and Lake Johnson

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Falls Lake

- Inflows
  - Pre-dam: Neuse at Northside gage
  - Post-dam: COE net inflows
- Calibration run by matching releases
- Simulation run
  - Min. release at dam
    - 100 cfs Apr. – Oct., 65 cfs Nov. – Mar.
  - Target at Clayton gage
    - 254 cfs Apr. – Oct., 184 cfs Nov. – Mar.
  - Maximum flow targets at Clayton, Goldsboro, and Kinston to simulate flood control storage
    - Compute unimpaired gains at gages using Little River at Princeton, can be improved upon by unimpairing actual gage flows
- Raleigh WS withdrawals from COE data
- Still need to incorporate Beaverdam

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Buckhorn Reservoir

- Use adjusted Little River at Princeton flows
  - Buckhorn Reservoir: 155 sq. mi.
  - Little River gage: 232 sq. mi.
  - Use drainage area adjustment and regression based on analysis during unimpaired period (1964 – 1974)
- Match historic releases as recorded at Contentnea Creek at Lucama gage
  - USGS rates records as fair
  - Withdrawals are captured (they are taken out downstream)
- Results appear that inflow estimates may be low for some drawdown periods

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Wilson

- Other reservoirs for Wilson (Wiggins Mill, Toisnot, Wilson) are small, stage-storage-area data not available
  - 95% of capacity is in Buckhorn

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