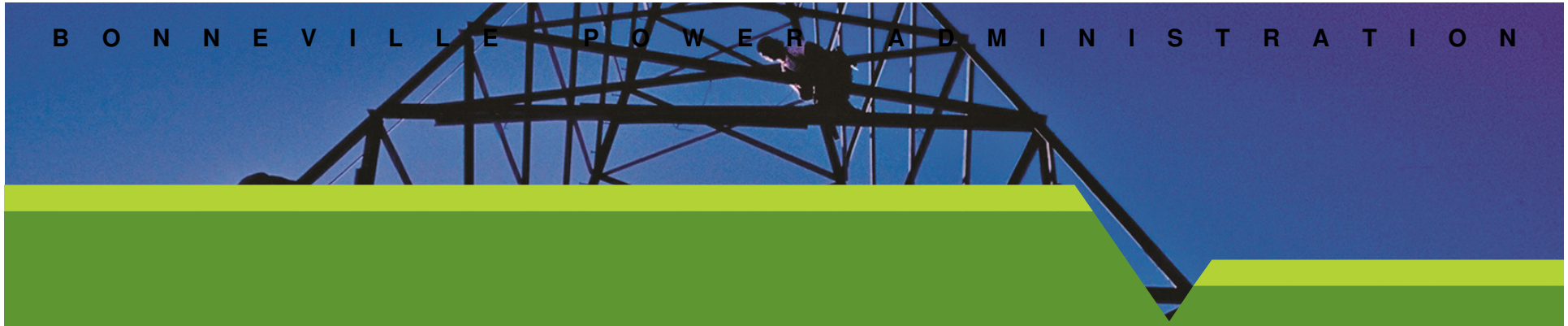


Short-Term Network Flow Forecasting

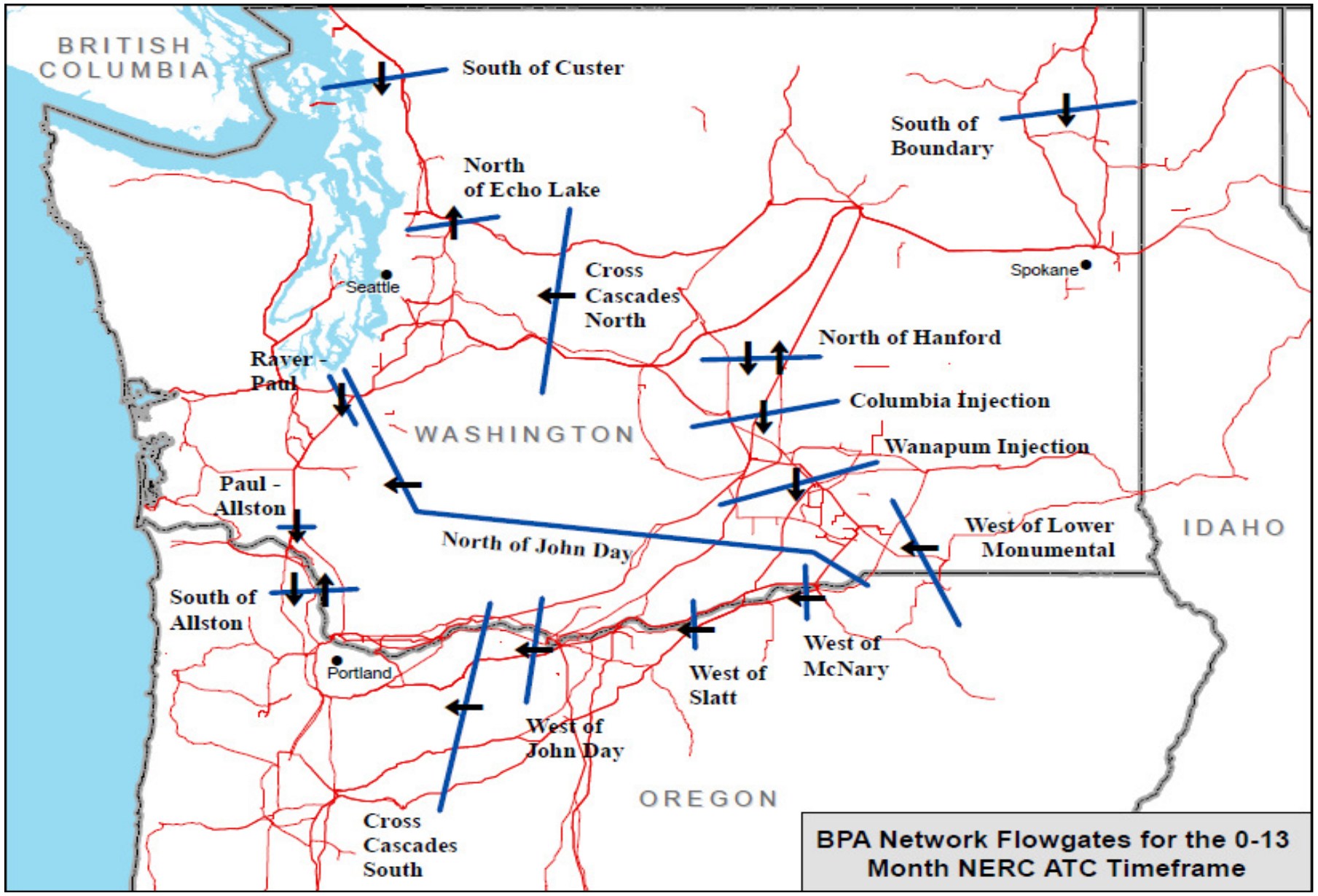
August 7, 2014

Today's Topics

- Motivation
- Flow-Forecasting Model
- Modeled Flow (MF)
- Model Inputs
- Challenges with Modeling Flow
- How Good Are Impacts Alone Operationally?
- Forecast Enhancement Methodology
- Historical Operational Results
- Performance Summary
- True Positive Rates and Event-Detection Rates
- Takeaways for Event Rates
- Sample: Before-Hour NOEL Curtailments (April 2013)
- How Will This Be Used?
- Questions

Motivation

- In 2007, BPA did some preliminary work outlining a potential approach to forecasting internal flowgate flows up to four hours ahead;
- For the implementation of PSANI flowgates (particularly NOEL) in early 2013, dispatch requested new tools for managing congestion events;
- The Accounting for Network Flows (ANF) project was revived to provide a 1–3 hour flow forecast that dispatch could base their ahead-of-hour curtailments on for internal flowgates like NOEL; and
- 15-Minute scheduling has the potential to cause flows to change within the hour — proactive flowgate management will mitigate the risk of SOL excursions in the upcoming 20–35 minutes.


BRITISH COLUMBIA
South of Custer
South of Boundary
North of Echo Lake
Seattle
Cross Cascades North
Spokane
North of Hanford
Raver - Paul
Columbia Injection
WASHINGTON
Wanapum Injection
Paul - Allston
West of Lower Monumental
IDAHO
North of John Day
South of Allston
Portland
West of McNary
West of Slatt
West of John Day
OREGON
Cross Cascades South
BPA Network Flowgates for the 0-13 Month NERC ATC Timeframe

Flow-Forecasting Model

- Time horizon: Next 1 to 3 hours ahead;
- Time resolution: 5-minute averages in anticipation of 15-minute scheduling and EIM/SCED later;
- Two main components:
  - **"Modeled Flow (a.k.a. Fundamental Impacts)"** based on PTDFs (Power Transfer Distribution Factors); and
  - **"Forecast Enhancement Methodology"** based on control theory / time series techniques.
- Initial emphasis on North of Echo Lake (NOEL) flowgate, but method is applicable to all internal flowgates.

Modeled Flow (MF)

- For a given scheduling interval, modeled flow is calculated using PTDFs with the following formula:

$$MF = \sum_{i=1}^{x} Tag_i \left(PTDF_{POR_i} - PTDF_{POD_i} \right) + \sum_{i=1}^{y} Load_i \left(PTDF_{FCRPS} - PTDF_{Load_i} \right)$$

Model Inputs

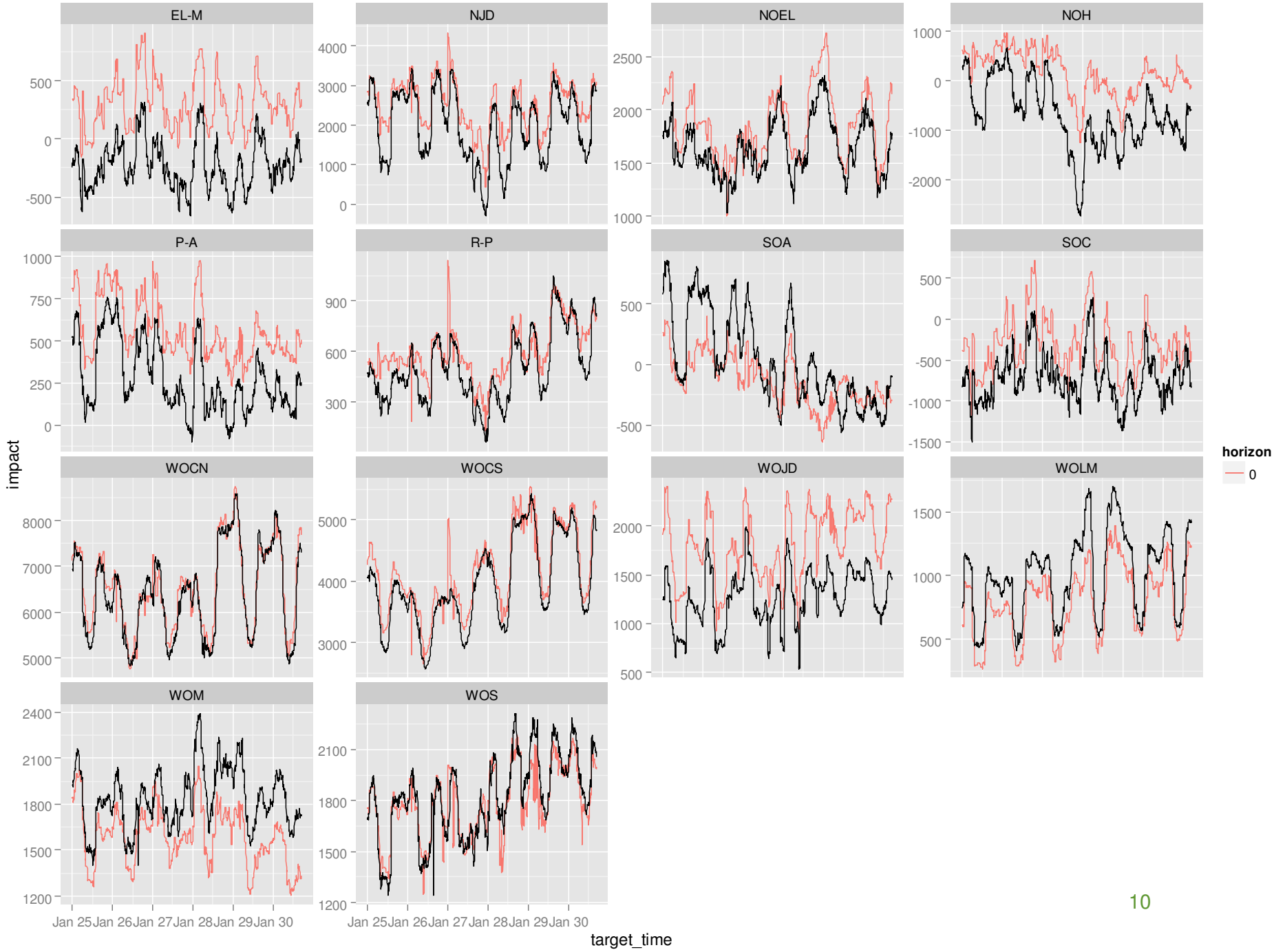
- BPA e-tags;
- BPA load forecasts;
- BPA hydro generation forecasts;
- PTDFs:
  - State Estimator;
  - WECC case with scheduled outages; and
  - Weighted PTDFs.
- Current actual values:
  - Flowgate actual loading and SOL; and
  - BPA hydro generation.
- Mappings/deemings:
  - NERC Names to Bus Numbers; and
  - Bus Numbers to State Estimator nodes.

Challenges with Modeling Flow

- PTDFs are an approximation assuming a DC power flow;
- Usage of first BPA POR / last BPA POD instead of tag Source/Sink;
- Vague tag POR/POD names leading to inaccurate deeming assumptions;
- Impacts from tags outside BPA;
- Unscheduled load from adjacent BAs;
- Forecast inaccuracies for BPA customer load and/or FCRPS generation;
- Dynamic transfers;
- Imbalance between schedules and actual generation/load amounts; and
- Schedule changes through time.

Short-Term Network Flow Forecasting Engine

How good are impacts alone operationally?


EL-M
NJD
NOEL
NOH
P-A
R-P
SOA
SOC
WOCN
WOCS
WOJD
WOLM
WOM
WOS
impact
target_time
Jan 25
Jan 26
Jan 27
Jan 28
Jan 29
Jan 30
horizon
0

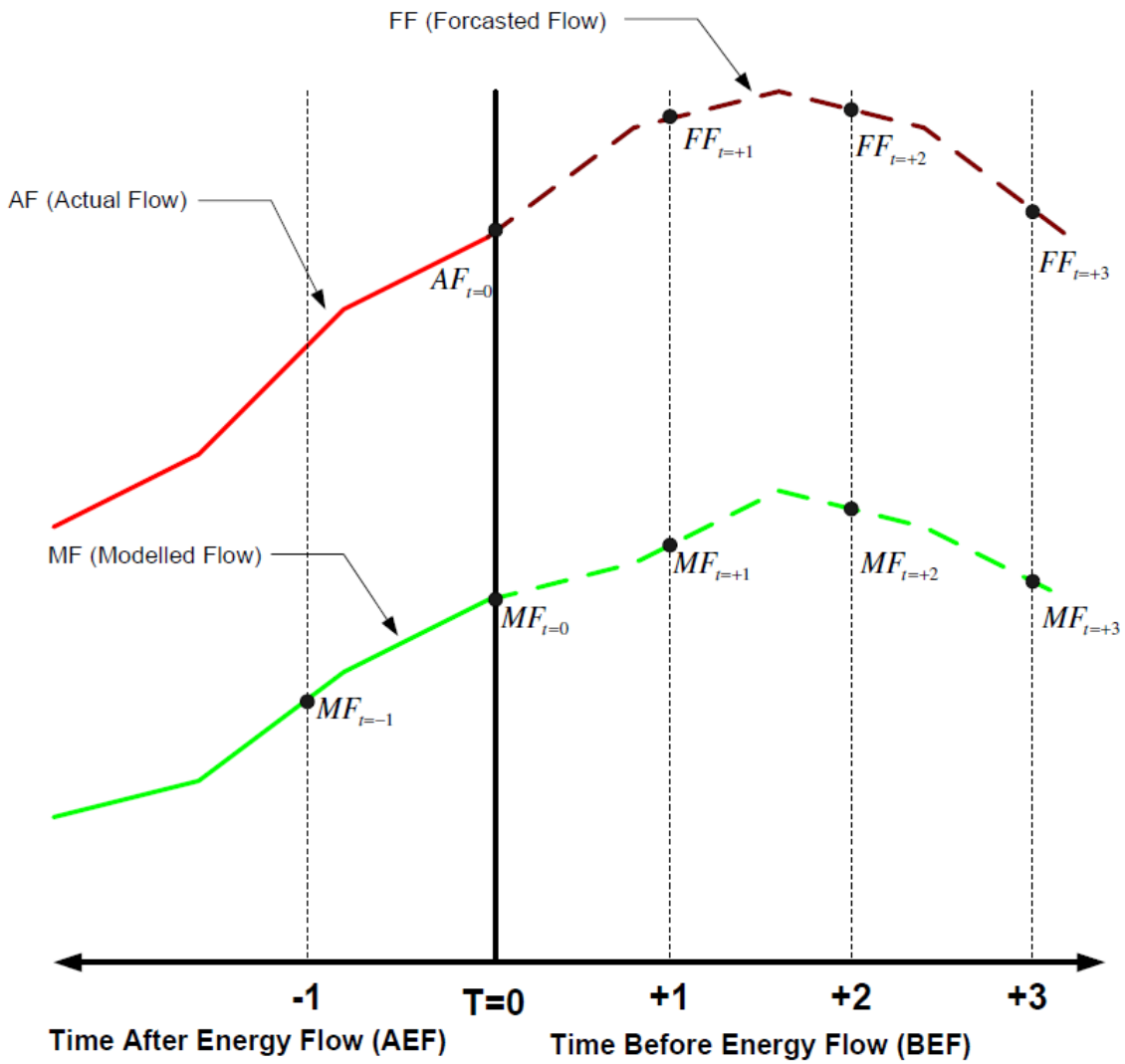
Forecast Enhancement Methodology

- A “simple feed-forward” approach can correct for much of the error:

$$FF_t = MF_t + \left(AF_{t-1} - MF_{t-1}\right)$$

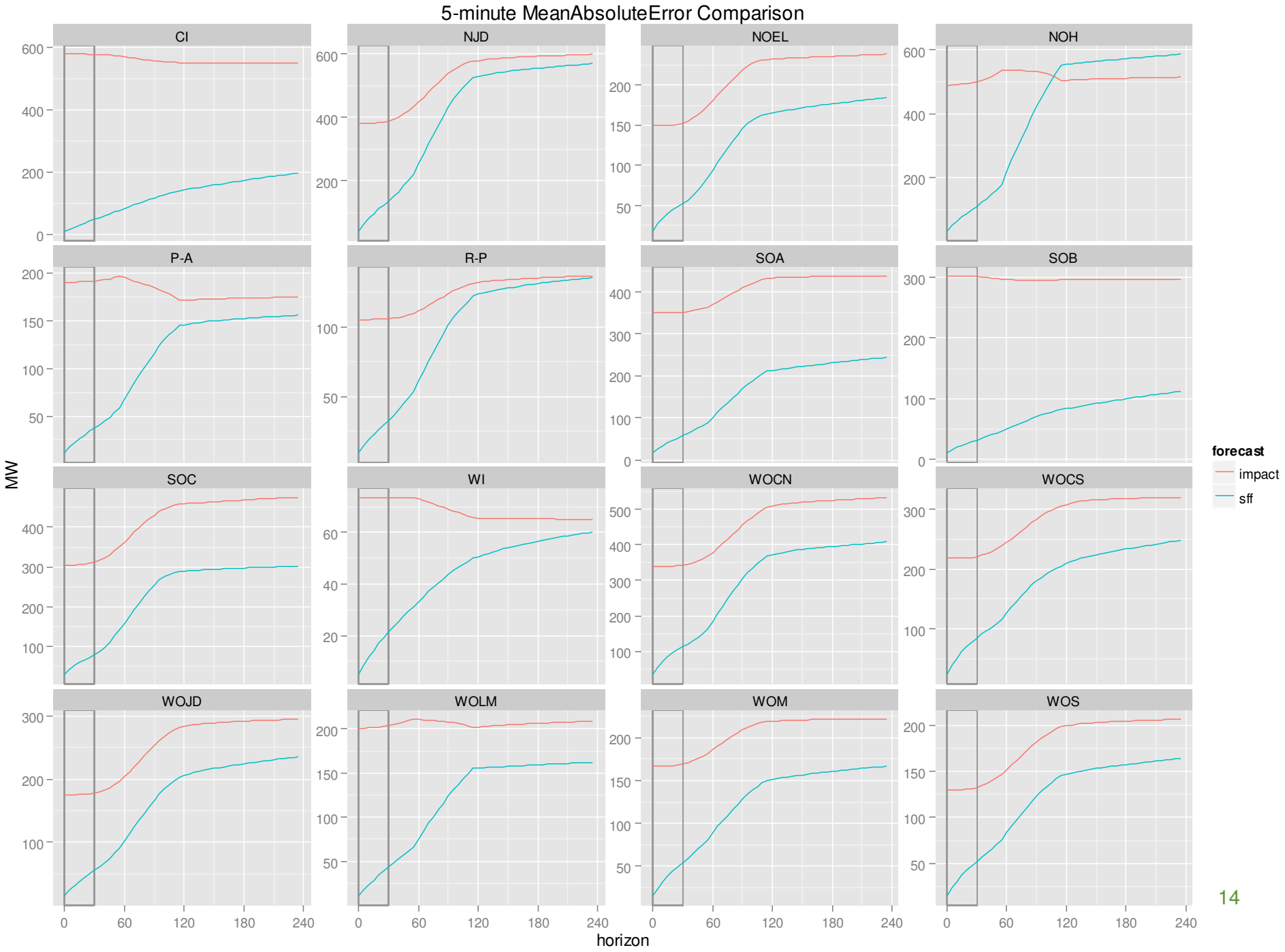
- Intuitively, we take the current deviation between actual flow and modeled flow and feed it forward to future time periods; and
- Since the deviations naturally persist in the short-term, this enhancement is quite effective.

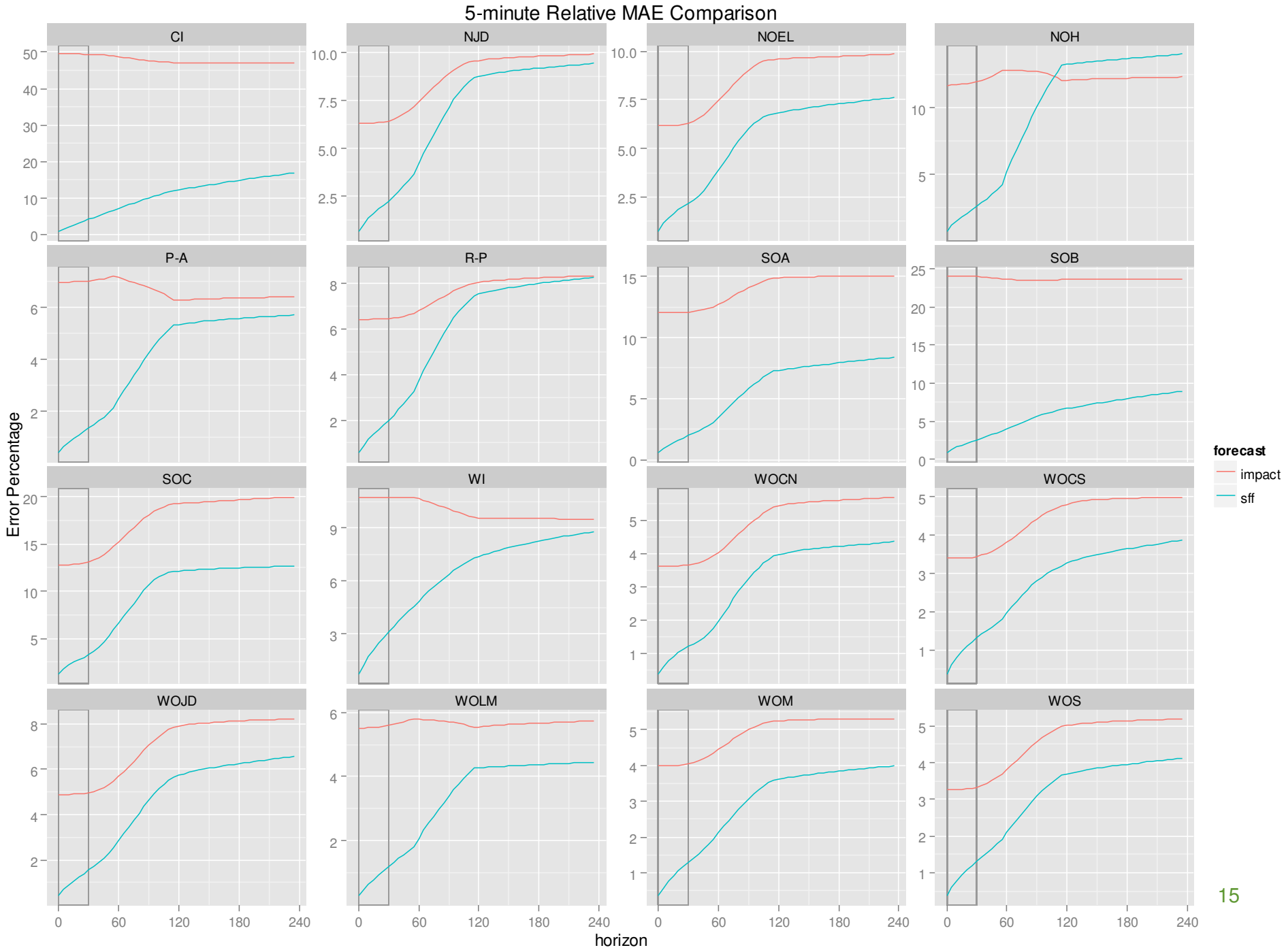
Forecast Enhancement Methodology, *continued*



Historical Operational Results

- Data from 2013-02-13 to 2014-05-01;
- Updates performed every five minutes;
- Comparison of both model components:
  - Raw fundamental impacts; and
  - Simple feed forward (SFF).
- Performance evaluated via Mean Absolute Error (MAE) and "Relative MAE."


5-minute MeanAbsoluteError Comparison
CI
NJD
NOEL
NOH
P-A
R-P
SOA
SOB
SOC
WI
WOCN
WOCS
WOJD
WOLM
WOM
WOS
MW
horizon
forecast
impact
sff


5-minute Relative MAE Comparison
CI
NJD
NOEL
NOH
P-A
R-P
SOA
SOB
SOC
WI
WOCN
WOCS
WOJD
WOLM
WOM
WOS
Error Percentage
horizon
forecast
impact
sff

Performance Summary

	MAE			Relative MAE			
Flowgate	60-min	30-min	20-min	60-min	30-min	20-min	Average SOL
CI	83	48	36	7.1%	4.1%	3.1%	1167
NJD	256	137	111	4.3%	2.3%	1.8%	6020
NOEL	95	52	45	3.9%	2.2%	1.8%	2423
NOH	217	109	87	5.2%	2.6%	2.1%	4180
P-A	68	37	30	2.5%	1.4%	1.1%	2727
R-P	61	33	26	3.7%	2.0%	1.6%	1640
SOA	101	57	46	3.5%	2.0%	1.6%	2910
SOB	51	32	26	4.0%	2.5%	2.1%	1255
SOC	157	78	66	6.6%	3.3%	2.8%	2383
WI	33	21	17	4.8%	3.1%	2.5%	685
WOCN	184	114	97	2.0%	1.2%	1.0%	9379
WOCS	126	85	71	2.0%	1.3%	1.1%	6416
WOJD	103	56	45	2.9%	1.6%	1.2%	3581
WOLM	76	43	34	2.1%	1.2%	0.9%	3642
WOM	89	54	44	2.1%	1.3%	1.1%	4180
WOS	84	52	43	2.1%	1.3%	1.1%	3975

True Positive Rates and Event-Detection Rates (out of 10,593 hours)

Flowgate	TruePositivesWithin5%	NumberOfSignals	CurtailDetectionRate	ActualCurtailments
CI	NA	NA	NA	NA
NJD	86%	29	90%	10
NOH	38%	8	100%	1
P-A	NA	NA	NA	NA
R-P	NA	NA	NA	NA
SOA	83%	6	67%	3
SOB	NA	NA	NA	NA
SOC	NA	NA	NA	NA
WI	NA	NA	NA	NA
WOCN	NA	NA	NA*	1*
WOCS	NA	NA	NA	NA
WOJD	100%	4	NA	NA
WOLM	NA	NA	NA	NA
WOM	100%	1	0%	1
WOS	NA	NA	NA	NA

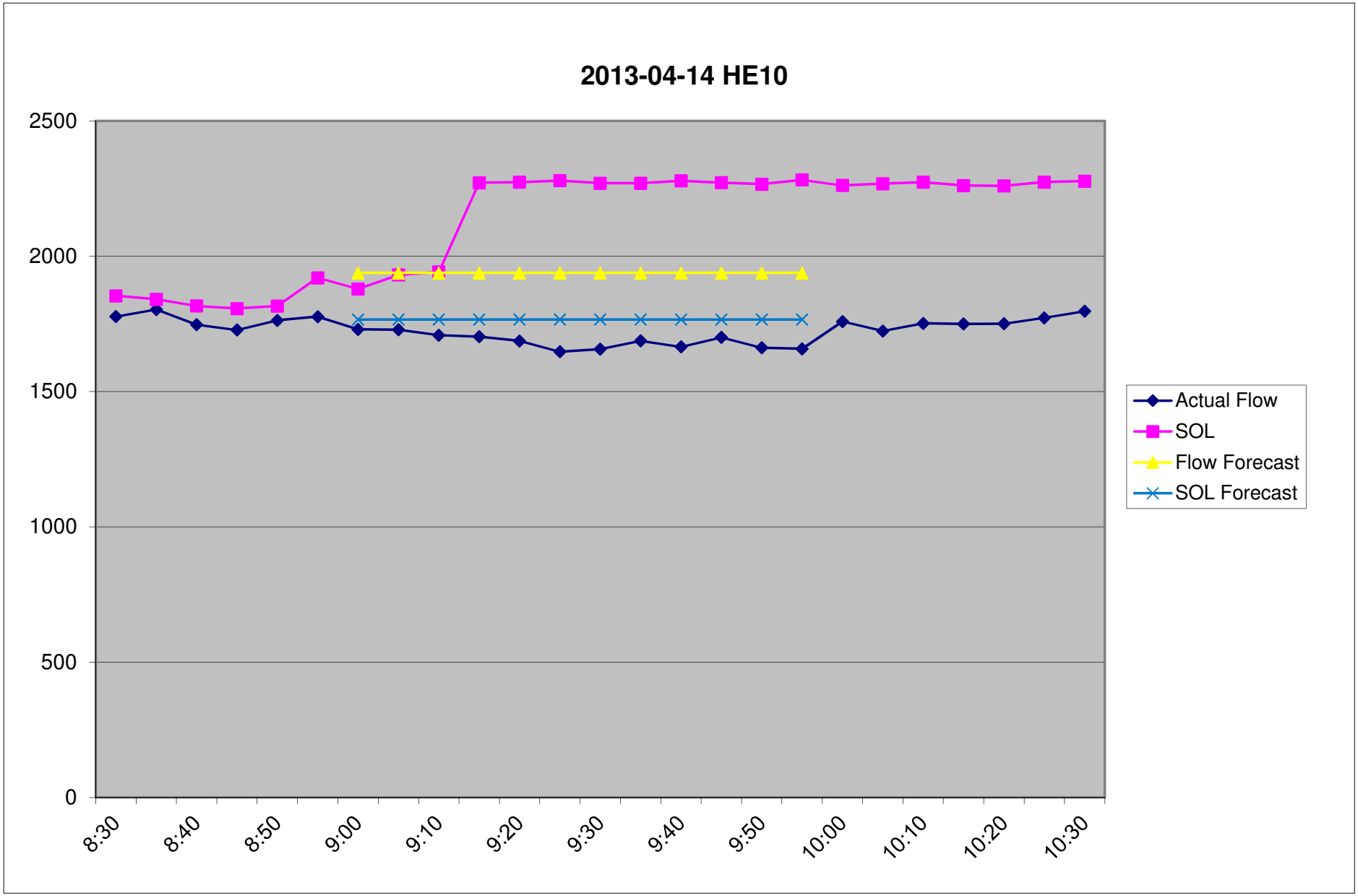
*See next slide

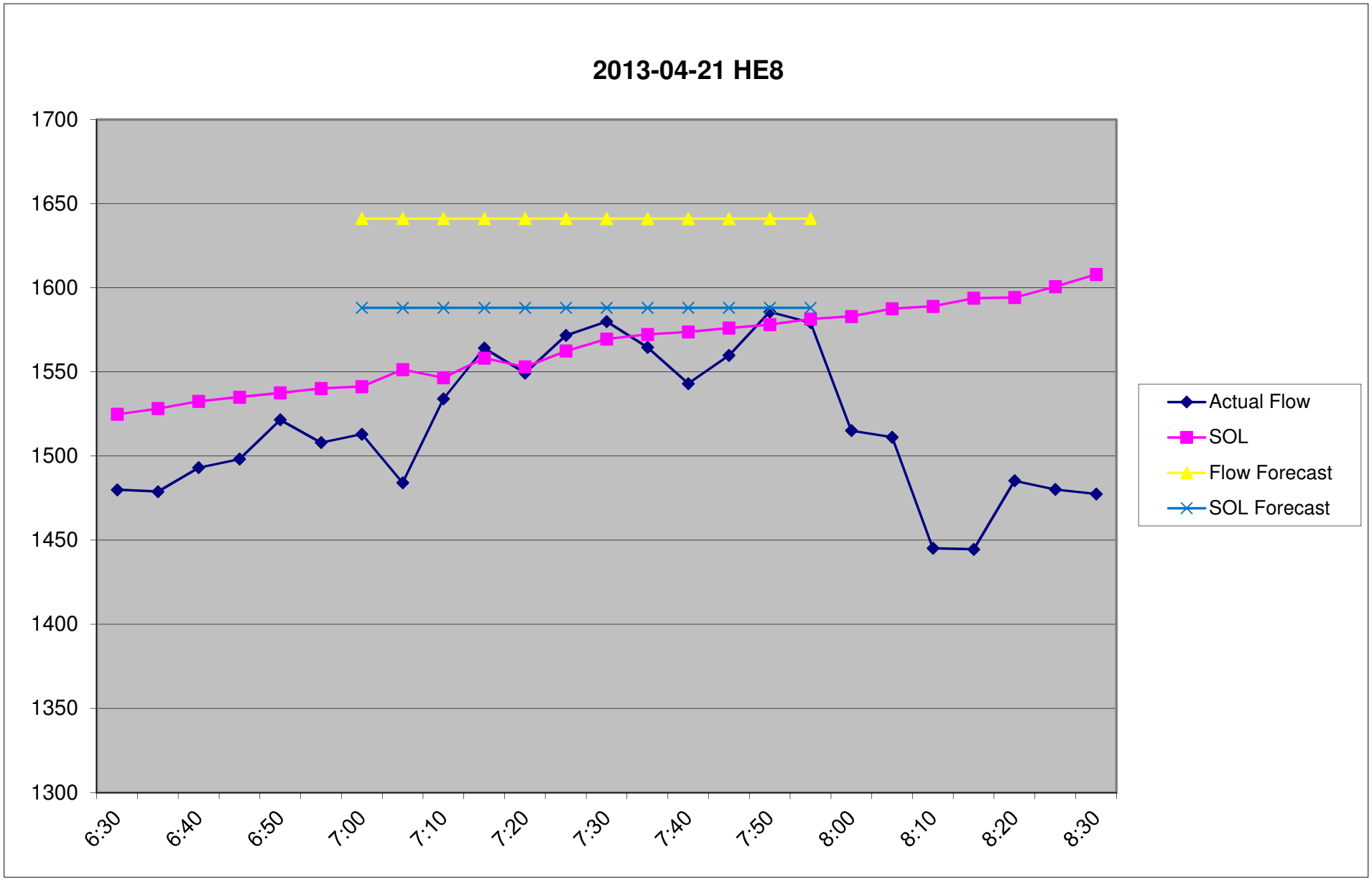
Takeaways for Event Rates

- Very little data since few flowgates have any events:
  - 9 out of 15 flowgates had 0 curtailment events and 0 forecast signals ("perfect performance"); and
  - * WOCN curtailment was triggered because of west side load problem, not flow exceedance.
- Limited curtailment data shows forecast signals could have been useful in predicting needed curtailments:
  - NJD had 9 out of 10 actual curtailments correctly predicted; and
  - SOA had 2 out of 3 actual curtailments correctly predicted.
- Forecast signals tend to correspond with actual flows exceeding or coming close to the SOL.

Sample: Before-Hour NOEL Curtailments (April 2013)

Date	HE	Target	Relief Needed	MW to Curtail	NERC Priority 1	NERC Priority 2	NERC Priority 6	NERC Priority 7 (Firm)
04/14/2013 08:46:00.000PDT	10	NOEL	172	453	308	68	0	77
04/15/2013 10:45:00.000PDT	12	NOEL	78	199	199	0	0	0
04/21/2013 06:45:00.000PDT	8	NOEL	53	136	136	0	0	0
04/25/2013 05:45:00.000PDT	7	NOEL	51	157	73	23	0	61
04/25/2013 06:45:00.000PDT	8	NOEL	20	86	40	26	0	20
04/25/2013 20:45:00.000PDT	22	NOEL	26	77	77	0	0	0


2013-04-14 HE10
2500
2000
1500
1000
500
0
8:30
8:40
8:50
9:00
9:10
9:20
9:30
9:40
9:50
10:00
10:10
10:20
10:30
Actual Flow
SOL
Flow Forecast
SOL Forecast


2013-04-21 HE8
1700
1650
1600
1550
1500
1450
1400
1350
1300
6:30
6:40
6:50
7:00
7:10
7:20
7:30
7:40
7:50
8:00
8:10
8:20
8:30
Actual Flow
SOL
Flow Forecast
SOL Forecast

How Will This Be Used?

- Flow forecasts will be used in the Single Curtailment Tool as part of BPA's 15-minute scheduling rollout; and
- Ahead-of-interval curtailments will be performed up to 20 minutes before the start of a 15-minute schedule (i.e., only after the close of the scheduling window).

Short-Term Network Flow Forecasting

Questions?