BPA's I-5 Corridor Solutions

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April 5, 2018

A New Direction

On May 18, 2017, BPA Administrator Elliot Mainzer announced the decision not to build the proposed Castle Rock – Sundial 500-kV line, also known as the **I-5 Corridor Reinforcement Project**

"My decision today reflects a shift for BPA – from the traditional approach of primarily relying on new construction to meet changing transmission needs, to embracing a more **flexible, scalable, and economically and operationally efficient approach** to managing our transmission system"

Presentation Outline

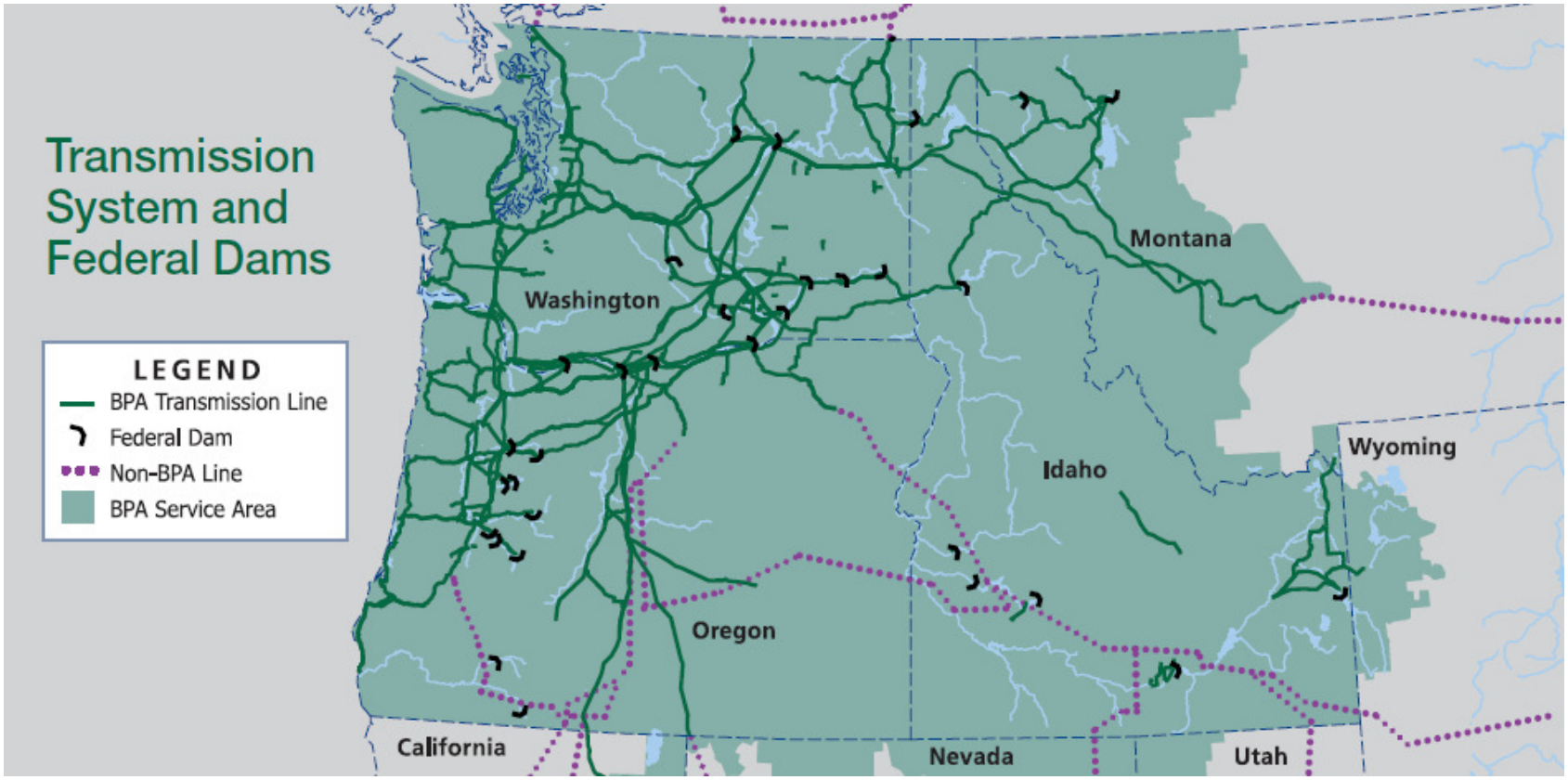
1. BPA Overview
2. I-5 Corridor Reinforcement Project Background and Decision
3. Reinforcement Drivers
    - Reliability Compliance
    - Operational Resiliency
    - Commercial Requests
4. Landscape Changes
5. South of Allston Redispatch Pilot Project

BPA Overview

BPA Profile

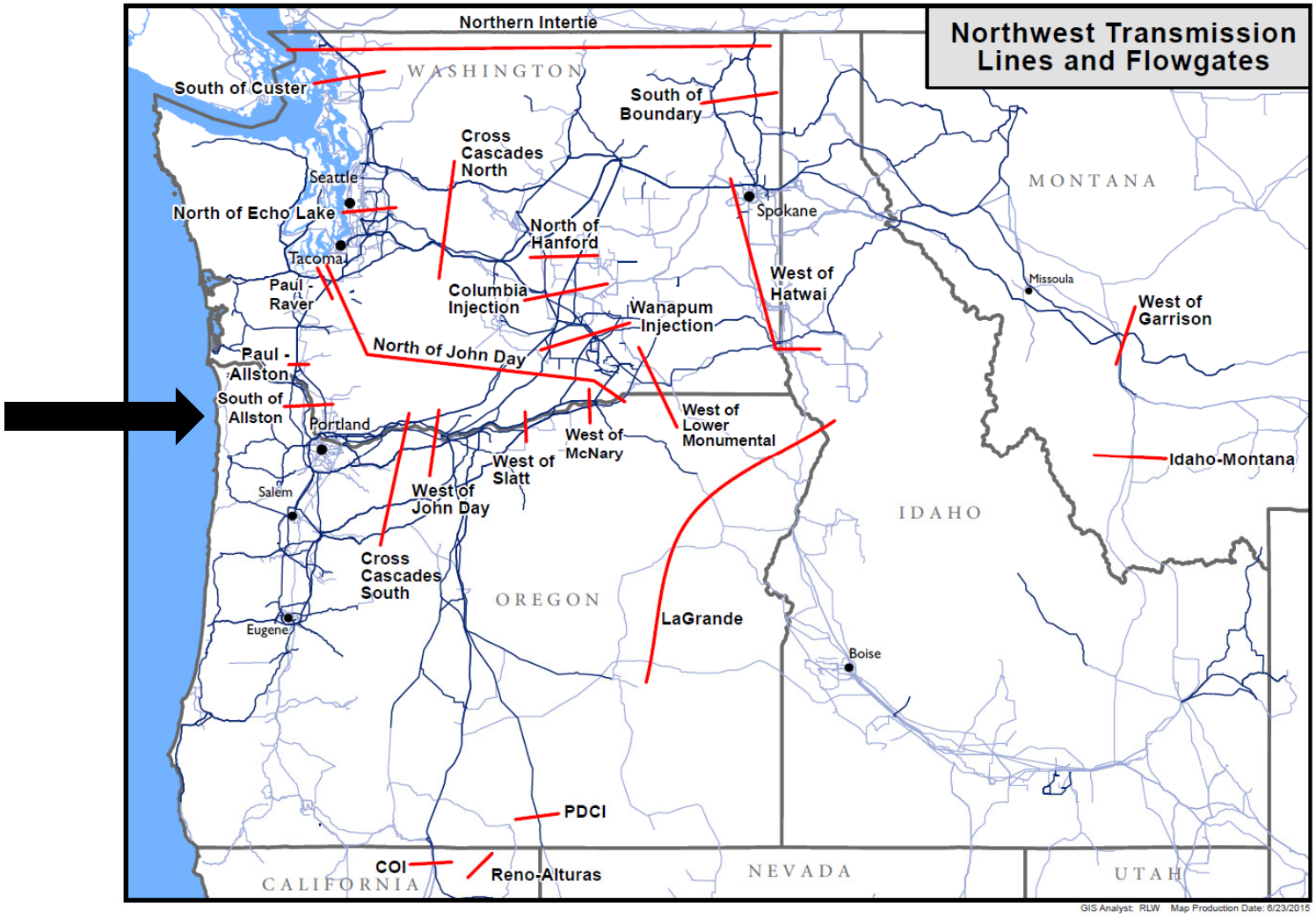
- BPA is a nonprofit federal power marketing administration based in the Pacific Northwest.
  - Although BPA is part of the U.S. Dept. of Energy, it is self-funding and covers its costs by selling its products and services.
  - BPA markets wholesale electrical power from 31 federal hydroelectric projects in the Northwest, one nonfederal nuclear plant and several small nonfederal power plants
- BPA provides about 28 percent of the electric power and operates about ¾ of the high-voltage transmission in its footprint

BPA Service Area



- 300 thousand square mile service area with over 15 thousand circuit miles & 260 substations

Pacific Northwest Transmission Paths



Flowgates like South of Allston (SOA) are used for congestion management

I-5 Corridor Reinforcement Project Background and Decision

History

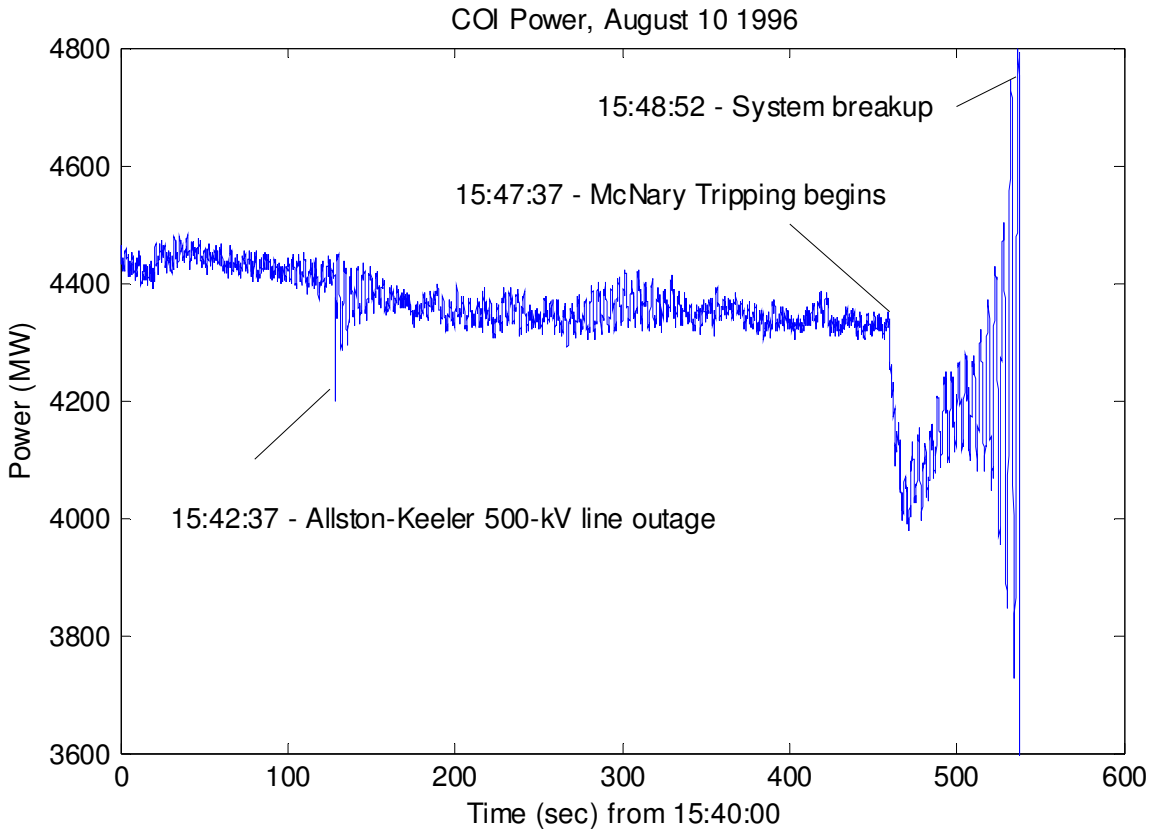
- Late 1960s – early 1970's: Construction of a 500-kV link between Portland and Puget Sound started (Keeler-Allston, Paul-Allston, Paul – Olympia, and Raver-Paul)

- Large thermal generation stations planned between Seattle and Portland
  - 1971: Centralia coal power plant started commercial operation
  - 1976: PGE's 1,130 MW Trojan nuclear power plant and 480 MW Beaver natural gas-fired plant placed in service
  - 1977: Satsop nuclear power plant (WNP-3 and WNP-5) under construction, planned 2,480 MW total capacity of two nuclear units

- **BPA Planning identified the need for a second 500-kV line between Longview and Portland in late 1970s, but…**
  - Load growth rates turned out well below projections
  - 1983: Satsop nuclear plant placed in an extended construction delay and ultimately never completed
  - 1992: Trojan Nuclear Power Plant shut down

History: August 10, 1996 WSCC Outage

Unplanned outage of Keeler – Allston 500-kV line initiated a sequence of cascading events that led to the Western Interconnection system break up and large-scale power outages in California and Arizona



Yes, it was a bad outage:

- 7.5M customers out of power for up to 9 hours
- Estimated financial impact between $1 to $4 billion

Many things went wrong that led to the outage

WSCC and BPA put processes in place to greatly minimize risk of similar outages

History: I-5 Corridor Gas Generation Boom

- About 2,250 MW of gas generation capacity was added along I-5 corridor from 2002 to 2015
- **The need for the I-5 corridor reinforcement was seen during the interconnection studies**

But …

- Not all proposed projects were actually constructed
- Most new gas generation was added to SOA Remedial Action Scheme (RAS)
- Large industrial loads near Portland shut down following the 2001 California Energy Crisis:
  - 235 MW Vanalco aluminum smelter in Vancouver (Alcoa)
  - 254 MW Reynolds aluminum smelter in Troutdale
  - 100 MW Pennwalt plant
  - Several paper mills in Willamette Valley

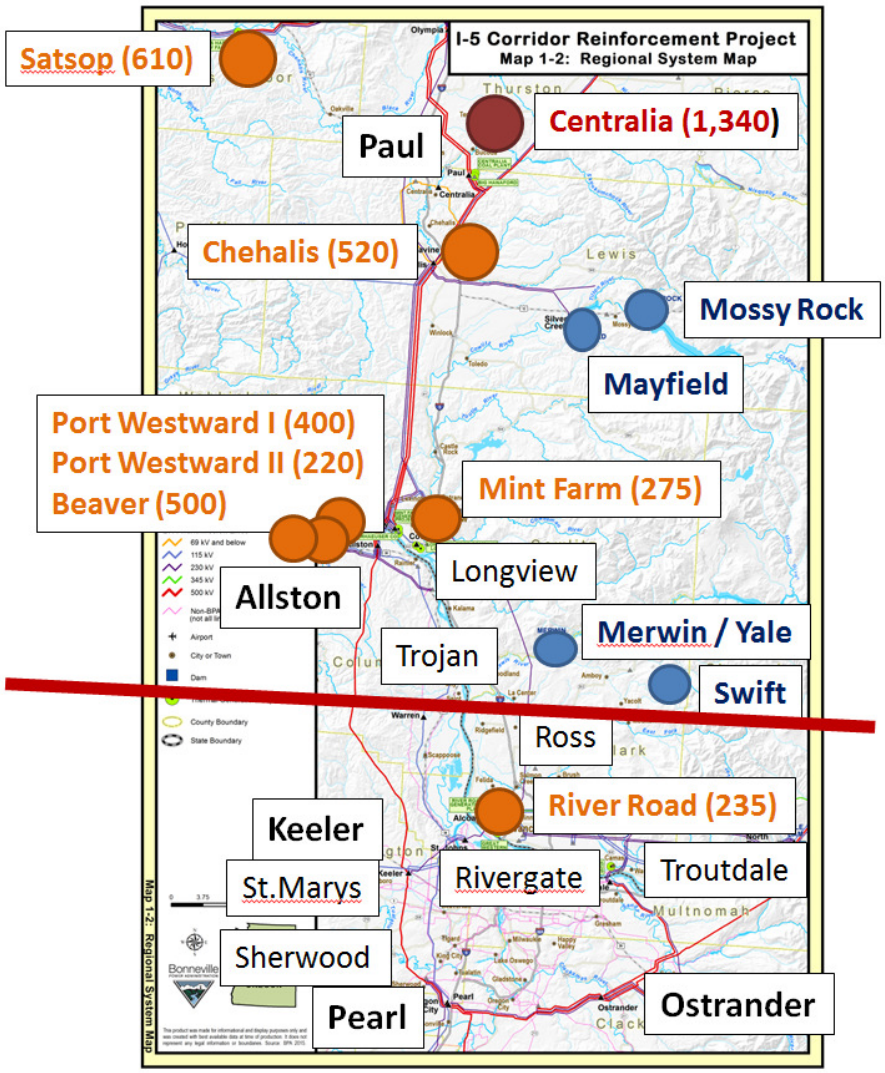
History – Infrastructure Additions

- Major infrastructure additions re-routed power from the I-5 corridor:
  - 2005: Schultz – Wautoma 500-kV line
  - 2015: Knight 500-kV substation, Big Eddy – Knight 500-kV line

- Numerous local infrastructure improvements in the area, including:
  - Second Pearl 500/230-kV transformer
  - Allston 230/115-kV transformer
  - Uprate of Ross – Woodland section of Ross – Lexington 230-kV line
  - Harrison 115-kV current-limiting series reactor
  - Keeler – Horizon 230-kV line, Sunset transformer
  - Keeler 230-kV bus sectionalizing

Numerous system infrastructure improvements and industrial load retirement allowed deferral of the need for the I-5 500 kV line in early 2000s

South of Allston Path



The South of Allston (SOA) path was officially established in 2006 by the agreement between BPA, PGE and PacifiCorp

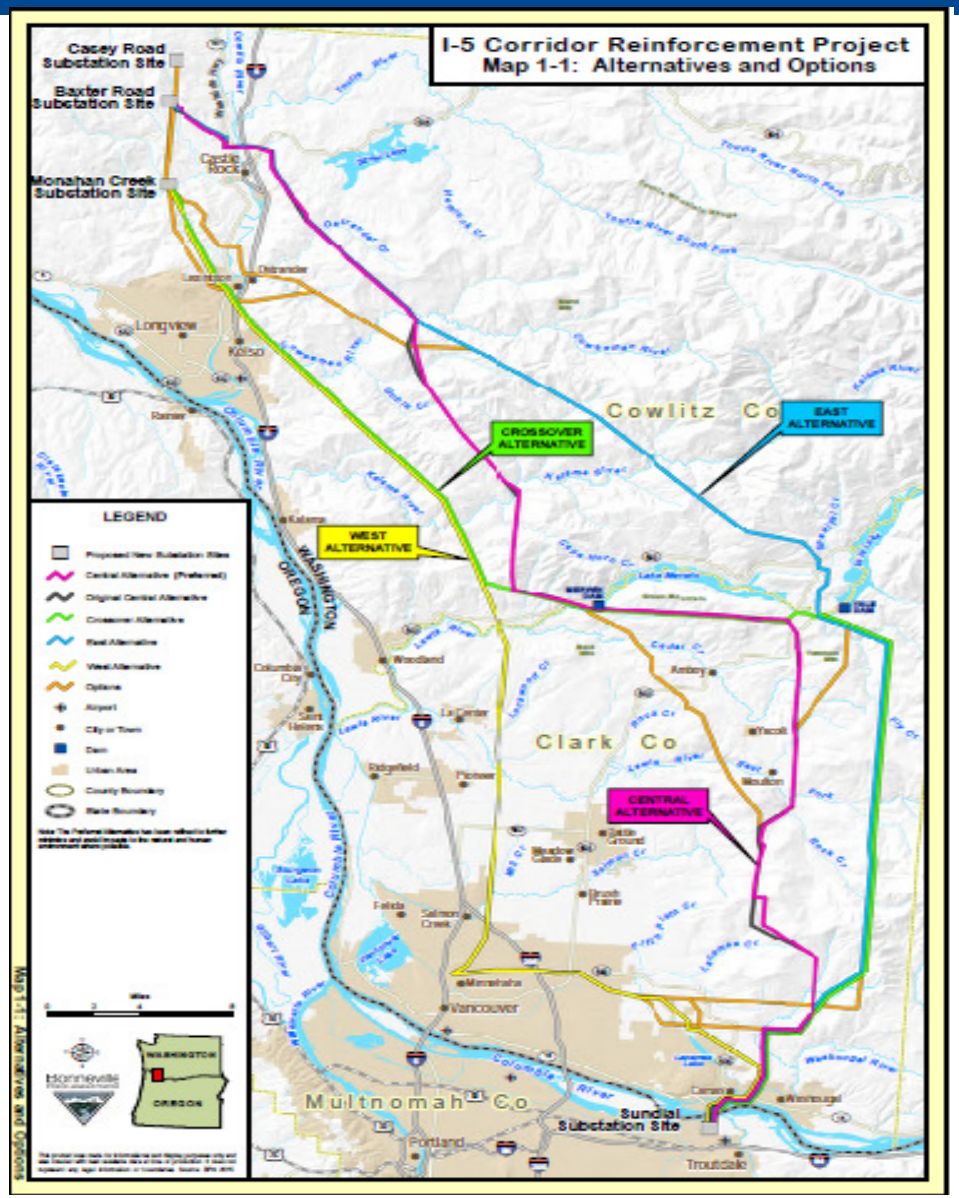
South of Allston Path Elements

- BPA Keeler – Allston 500
- BPA Lexington – Ross 230
- PGE Trojan – Rivergate 230
- PGE Trojan – St.Marys 230
- BPA Allston – Rainier 115
- PAC Merwin – View Tap 115
- PAC Clatsop – Lewis/Clark 115
- PAC Astoria – Astoria Tap 115

I-5 Corridor Reinforcement Project

- Planning studies in 2007 reconfirmed the reliability need for the Castle Rock – Troutdale 500-kV line, now referred to as the I-5 Corridor Reinforcement Project.
  - In 2007, this project went through the WECC Regional Planning Review Process, which was facilitated by ColumbiaGrid.
  - In early 2008, the WECC PCC approved the resulting Regional Planning Project Report for I-5 Corridor Reinforcement Project.
- Planning assessments in subsequent years with updated assumptions continued to show the need for reinforcement in this area for reliability.
- Cluster Studies performed between 2008 and 2016 identified the need for capacity created by this project to accommodate Transmission Service Requests (TSRs)

I-5 Corridor Reinforcement Project



80 mile 500 kV transmission line to back up Paul-Allston, South of Allston, and Keeler – Pearl paths.

New Castle Rock 500 kV substation near Castle Rock, Washington

New Sundial 500 kV substation near Troutdale, Oregon

500 kV Columbia River Crossing between Camas, WA and Troutdale, OR

The line would have completed a 500 kV loop in SW Washington and NW Oregon.

Transmission Planning Review

BPA recognized changes in the environment – coal retirements, solar generation additions, lower load growth

BPA Planning and Operations initiated regional Transmission Planning Review with large NW utilities from February to September 2016

- ✓ Reviewed BPA study assumptions on load growth, contingencies and system performance requirements
- ✓ Explored possible smaller scale solutions to address reliability drivers

Regional Effort

NEPA Process

- In 2009, BPA initiated the environmental (NEPA) process for the I-5 Corridor Reinforcement Project and held a series of public scoping meetings in the fall of 2009.
- In November 2012, BPA released the Draft Environmental Impact Statement (DEIS) for public review and comment.
- In February 2016, BPA released the Final Environmental Impact Statement (FEIS)
- The project costs increased significantly over the original estimates
- Revenue from new transmission service sales enabled by the project not expected to fully pay for the project, putting pressure to increase BPA transmission rates
- In May 2017, the BPA Administrator announced the decision to not build the line and to pursue other solutions

Reinforcement Drivers

Primary drivers include:

- Reliability compliance
- Operational resiliency
- Commercial requests

Reliability Compliance – TPL Standard

2005 Energy Policy Act led to the development of **mandatory** Reliability Standards

NERC TPL Transmission Planning Standards drive decisions on capital investments

Reliability Standards are evolving

The latest version is NERC TPL-001-4 Transmission System Planning Performance Requirements

http://www.nerc.com/files/tpl-001-4.pdf

Effective date 1/1/2015

Reliability Compliance – TPL Standard

Transmission Planning covers Near-Term (1 to 5 year) and Long Term (up to 10 year) Transmission Planning Horizons

Planners create **study cases** that represent forecasted load levels, expected generation patterns and transfers, expected transmission reinforcements/outages, planned generation additions and retirements

Study cases are subjected to the list of contingencies and checked whether they meet required performance (stability, acceptable voltages, overloads, interruption of firm transmission service, loss of load)

Reliability Compliance – TPL Standard

In simple terms:

- For high likelihood contingencies, e.g. N-1, G-1
  - Generally, firm transmission service can not be interrupted, or non-consequential loss of load is not allowed
- For low likelihood contingencies, e.g. N-2, N-1-1 (P6)
  - Generally, firm transmission service can be interrupted, or non-consequential loss of load is allowed. Certain jurisdictions, e.g. California, require higher performance level for large urban areas and do not permit loss of load
  - BPA evaluates risk and consequence and prioritizes reinforcements that provide the most benefit
  - For BPA, loss of load may be complicated because it is not BPA load that could be lost in majority of situations
- For all contingencies:
  - System must be stable, voltages must be within acceptable limits, applicable Facility Ratings shall not be exceeded

Reliability Compliance: "Need Date"

- Summer 2016 was identified as initial "need date" by 2008 planning studies
  - "Need date" was re-studied every year
  - "Need date" is studied only for **existing obligations**
- "Need date" changed over the years as new information became available:
  - Slower load growth due to the recession pushed the "need date" to 2021 at one point
  - Smaller, targeted reinforcements provided some relief
  - TPL-001-4 lowered TTC (Total Transfer Capability) because of N-1-1 (P6) requirement
  - Scheduled Centralia coal retirement, uncertainty with its replacement, and other changes pushed "the need date" out even further (to the mid-to-late 2020s in a December 2016 analysis)

Addressing Reliability Compliance Need

- PGE has several approved **reliability** projects in the area, including Harborton 230-kV substation, Harborton – Horizon 230-kV line, second 230/115 Sunset transformer
- BPA identified several transmission line upgrades
- BPA is working with regional utilities to continue refining smaller builds and non-wires solutions
- BPA Transmission Planning has launched a study to increase SOA capacity and reduce SOA flows, including series capacitors on east of the Cascades, line upgrades, flow control devices, and energy storage solutions

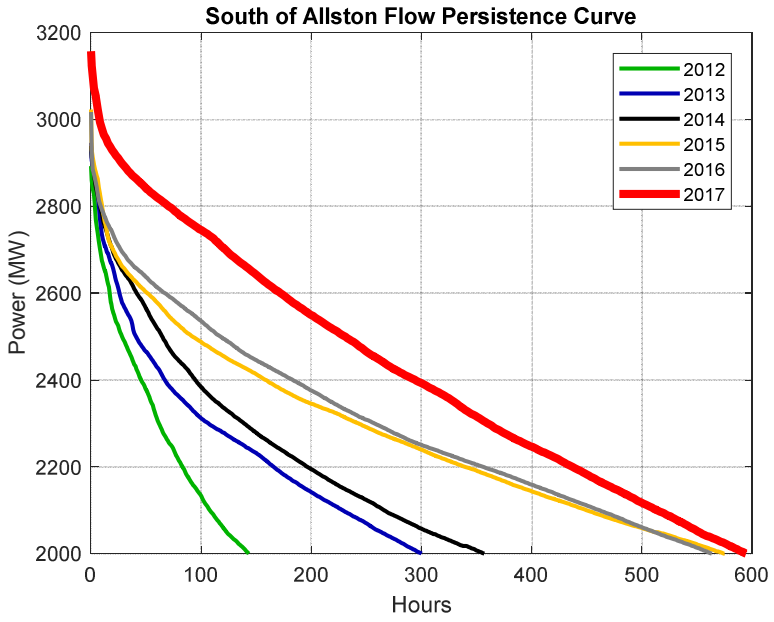
The ultimate portfolio of projects will represent a “flexible, scalable” alternative to the new 500 kV line

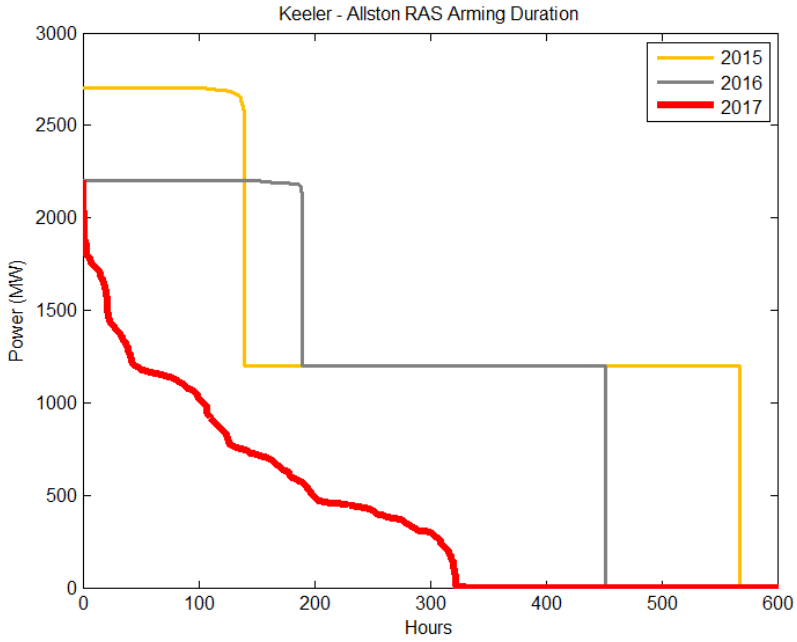
Operational Risks: N-1 RAS

- RAS allows loading transmission lines higher pre-contingency, by taking more aggressive mitigation actions post-contingency
- RAS makes economic sense, but high speed generation dropping temporarily reduces the frequency across the Interconnection
- BPA has used RAS successfully to mitigate multiple contingencies for decades
  - BPA implemented N-1 RAS for a single 500 kV line outage after 1996, and over time increased the maximum generation drop to 2,700 MW
  - RAS generation dropping is very rare (forced outage must occur when scheme is armed)
- While widely accepted for multiple contingencies, use of RAS generation dropping for N-1 contingencies has been debated in the industry
- Following FERC and NERC directives from September 8, 2011 Arizona and Southern California outage, BPA Planning initiated a comprehensive review of its RAS schemes
  - Based on the outcome of review, BPA reduced N-1 RAS to 2,200 MW with minimum/no impact on SOA transfer capability

RAS Automation Success

- BPA RAS Automation and Optimization project developed algorithms to arm a more precise amount of generation based on actual system conditions
- South of Allston flows were the highest during 2017 summer (left). Yet optimized algorithms greatly reduced both the amount and hours of RAS arming for SOA (right)

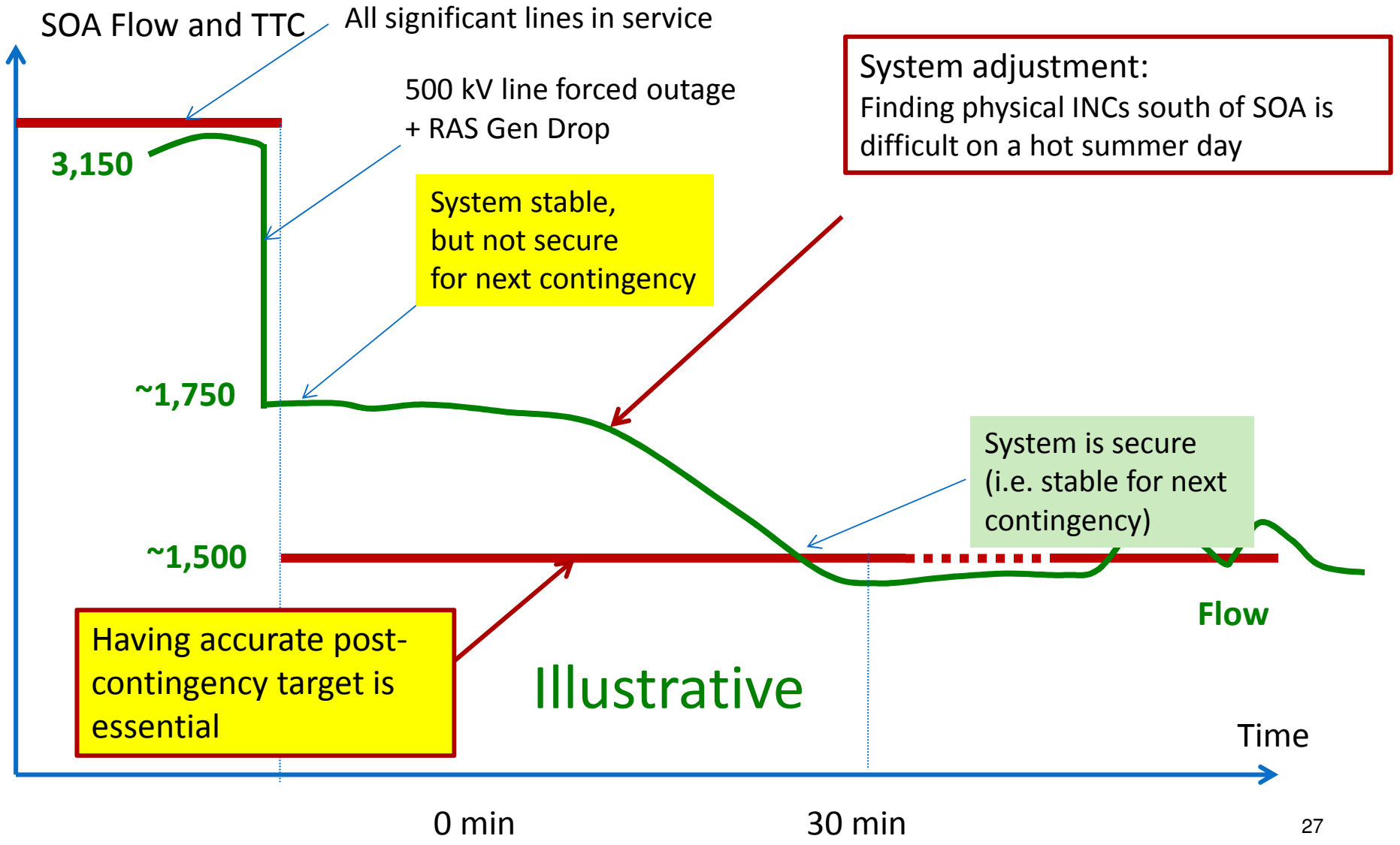




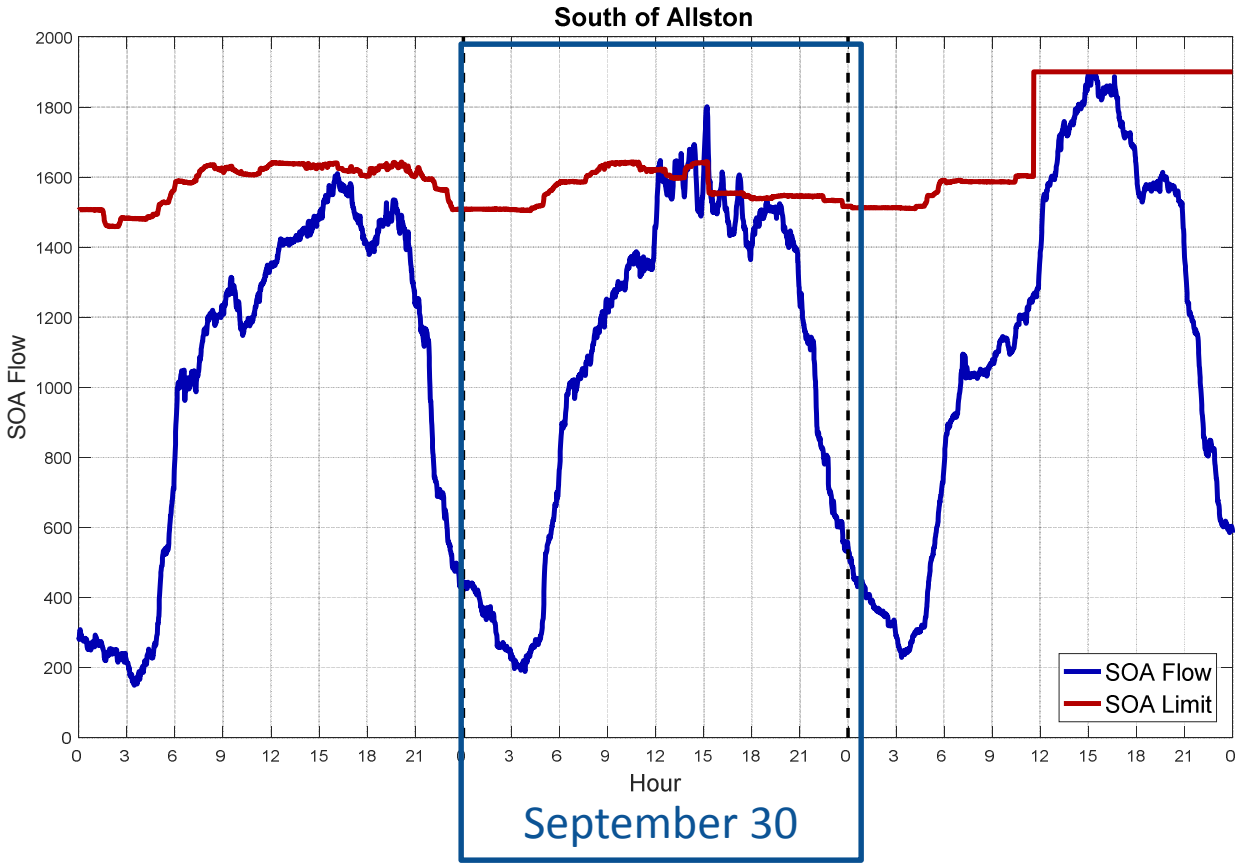
Operational Risks: Outage Resiliency

- **Under all lines in service (ALIS):**
  - SOA TTC is about 3,200 MW under summer generation patterns
- **During certain outages:**
  - SOA TTC is about 1,400 to 1,800 MW (much less than the ALIS TTC)
  - Managing system right after an outage could be challenging
  - Managing congestion under outage conditions could be challenging

Operational Risks: Outage Resiliency



September 30, 2008 Curtailment



- Multiple curtailments (almost hourly) occurred between 12 pm and 8 pm on September 30, 2008
- 500 kV line was out of service for maintenance, resulting in lower operating limit

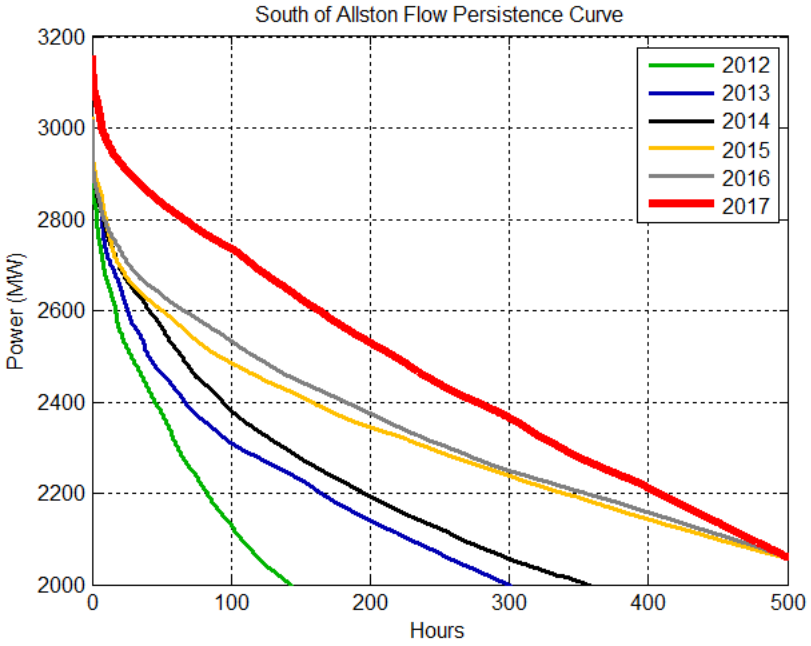
Dynamic TTC & Real-time Reliability Assessment Tools

- SOA TTC varies depending on outages and local generation patterns
- BPA deployed Dynamic TTC on South of Allston in summer 2016
  - The Dynamic TTC is determined in real-time based on the actual system conditions
  - Dynamic TTC greatly reduced the risk of curtailments
- April 1, 2017: Real-time reliability assessment tools further reduced the risk of curtailments, and allows operating closer to the true limit of the system

2017 Summer Season

High SOA flows were driven by combination of Portland area loads and exports to California during sunset hours

- SOA peak flows have been increasing
- Peak SOA flow of 3,157 MW on 8/31
- SOA flows were above 2,800 MW on 25 days
- Portland area load set all-time summer peak records in early August
- High through-flows from BC and NW to CA, particularly during sunset hours, usually under more moderate NW loads
- I-5 thermal generation was high during peak load and peak exports
- No major outages or firm curtailments



Commercial Drivers

- 2008, 2009, 2010, 2013, and 2016 Cluster Studies have all identified the need for South of Allston Reinforcement to accommodate Transmission Service Requests (TSRs)
- The I-5 reinforcement project was identified as the plan of service to accommodate the TSRs
- Following "no-build" decision, BPA is studying other alternatives, including non-wires options, to serve the TSRs
  - Some of these options were not technically feasible or commercially viable at the quantities needed when the earlier studies were performed
  - These options can be more aligned to the quantity and service term of the requests

Landscape Changes

Landscape Changes

"I skate to where the puck is going to be, not to where it has been"
Wayne Gretzky

It is the job of planners to recognize the landscape changes and make investments for the system ahead and not the system behind

Let's take a look how various known things impact South of Allston

Landscape Changes (Font size = impact)

- PGE and BPA System Improvements
- Coal generation retirement
- Peak RC SOL Methodology
- BC Hydro (2 units at Mica, Site C)
- California and NW Solar
- Large industrial load additions in Portland Metro
- Projected load growth in Portland is on lower end
- Climate Change and Extreme Weather Events
- Energy Storage costs are coming down, could become an economic alternative to new transmission
- Energy Imbalance Market

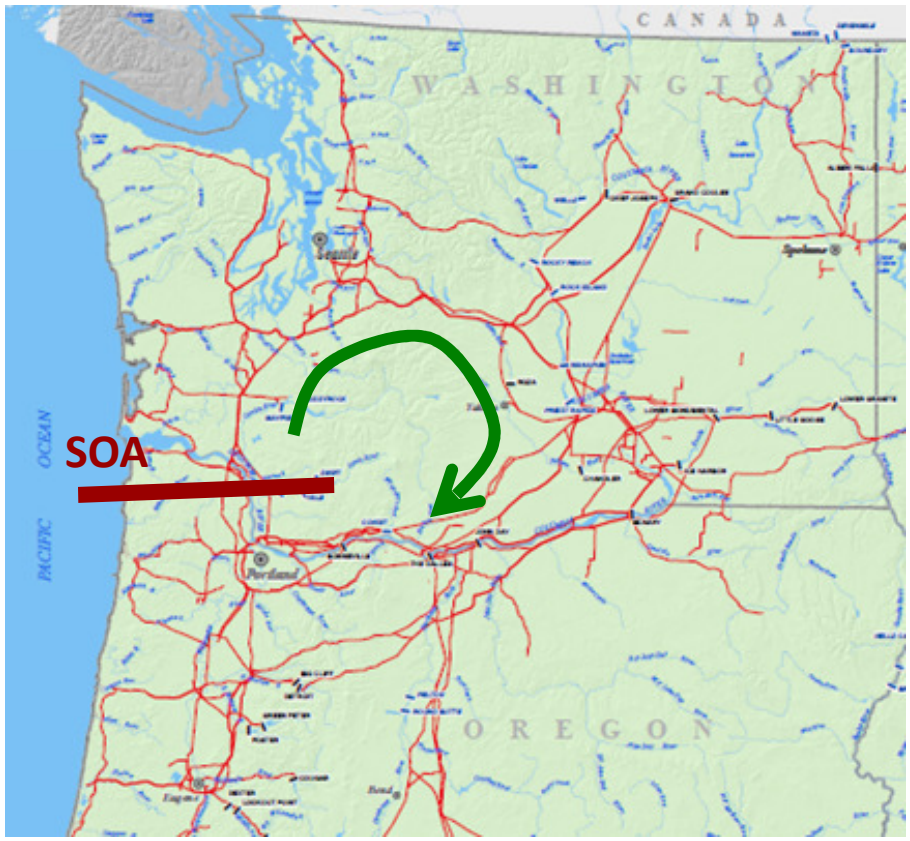
Green = reduce SOA stress, Red = increased SOA stress

System Improvements

PGE has identified line and substation improvements in the Portland area that improve reliability and resiliency of load service

BPA also identified several reinforcements required to maintain and potentially increase transmission capacity on the South of Allston path

BPA is studying power flow control technologies to re-direct power from the I-5 corridor to the east side (illustrated on right)



Local reinforcements improve reliability and power flow control solution can optimize utilization of the existing infrastructure

Peak RC System Operating Limit (SOL) Methodology

Peak RC implemented a new SOL Methodology on April 1, 2017

Key changes

- Path SOLs are no longer used for thermally limited paths
  - SOA is a thermally limited path
- To ensure system reliability, BPA monitors SOA area using real-time reliability assessment tools for thermal and steady-state voltage issues
  - Operations I-5 team played a key role in improving the quality and credibility of real-time reliability assessment tools
- Reduced set of “always credible” multiple contingencies
  - A double line outage of 230 kV circuits is no longer classified as a credible multiple operational contingency

Peak RC Methodology reduces the risk of SOA curtailments

Coal Retirements

Centralia Unit 1 retirement is scheduled for December 2020, and Unit 2 for December 2025

Centralia to California transaction has 50 to 60% impact on SOA

Generation replacement is not committed at this time

Boardman Unit scheduled for December 2020 retirement

Uncertainty of Centralia replacement favors flexible and scalable solution

Western Energy Imbalance Market

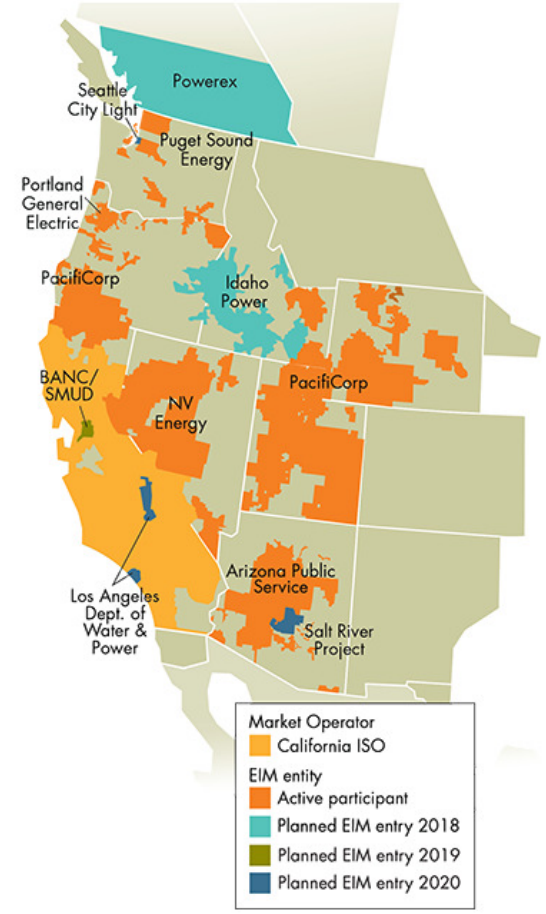
The Western EIM is a real-time wholesale energy trading market that enables participants anywhere in the West to buy and sell energy when needed

- Resources controlled by several EIM members can impact flows on SOA

BPA-CAISO Coordinated Transmission Agreement

- BPA can request that flows don't increase due to EIM activity during SOA congestion events in the direction we are mitigating and can request a pro-rata reduction in flows associated with the EIM Area

Western EIM active and pending participants



(https://www.westerneim.com/Pages/About/default.aspx)

BC Hydro Capacity Expansion

- Due to recent generation unit additions and transmission upgrades on its system, BC Hydro is likely to be able to deliver surplus resources to the BC-US border during the conditions when SOA flows are high
- BC Hydro is also developing the 1,100 MW Site C hydro project on the Peace River, scheduled to be operational in 2024
- PowerEx plans to join Western EIM in April 2018

We expect higher imports from BC to continue during summer peak and sunset hours

Solar Generation

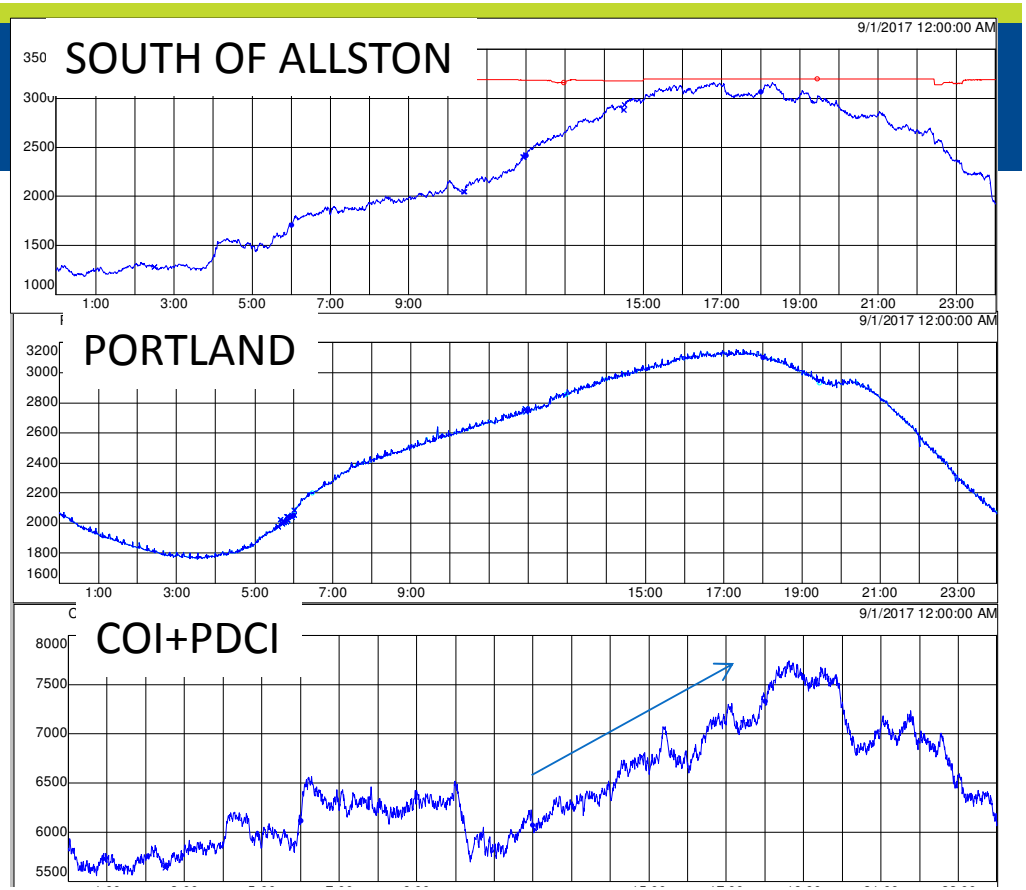
South of Allston Flows are driven by SW Washington / NW Oregon loads and exports to California

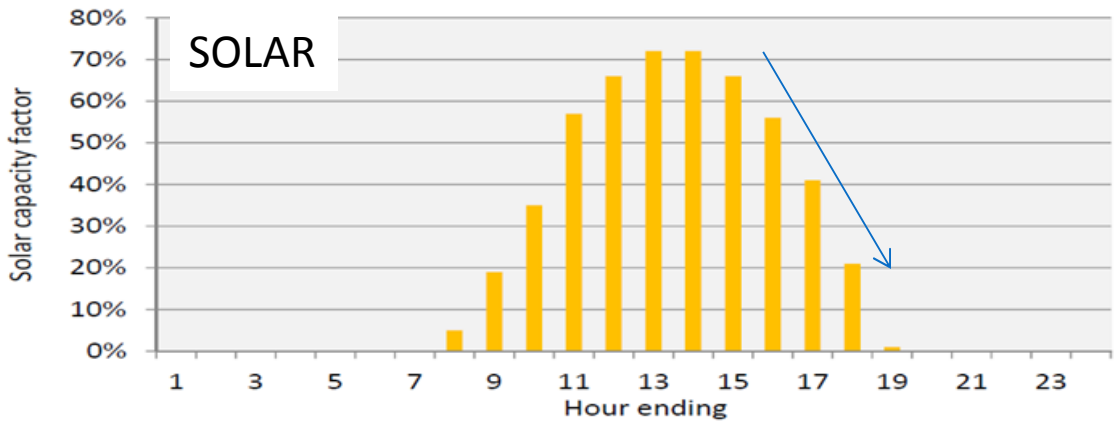
California solar offsets COI and PDCI exports during the day, but increases the exports during sunset hours

The cumulative effect expands the duration of high SOA flows, as we saw in 2017

We expect the trend to continue, as there is significant amount of flexible generating capacity north of SOA

- More I-5 entities join Western EIM
- BC Hydro expands its generation capacity
- Grand Coulee and Chief Joseph generation returns to its full capacity following a decade-long refurbishment





Energy Storage

- Technology is maturing, modular, and can be installed quickly
- SCE installed 20 MW x 4-hour battery and SDG&E installed 30 MW x 4-hour battery in less than 6 months in response to Aliso Canyon gas emergency

- California and Oregon have energy storage requirements
- Not needed currently to meet reliability compliance on SOA, but BPA is exploring if it makes commercial sense

BPA is monitoring technology trends

South of Allston Redispatch Pilot Project

Redispatch Pilot Objectives

1. Secure a non-wires portfolio to reduce flows on SOA flowgate during summer peak periods

2. Measure and validate post-event data to determine amount of flow reduction

3. Leverage learning to inform future non-wires program design choices

BPA expects to meet all pilot objectives by end of 2018

For Discussion Purposes Only

Redispatch Pilot Implementation

- BPA acquired incremental and decremental capacity and energy to reduce flows on SOA flowgate during summer peak periods
  - RFO released in April 2016
  - Performance period: July - September, 2017 - 2018
  - Annual transmission budget to fund pilot program is $5M/year.
- Non-wires portfolio chosen is balanced with roughly 200 MW of incremental capacity and 200 MW of decremental capacity
- Redispatch can be called weekdays only and deployed in four hour blocks, late afternoon through evening, for up to 40 hours per year
  - Third-party suppliers are notified of need to dispatch on a pre-schedule day-ahead basis
  - An event notice is posted on OASIS for each event
- More information on BPA's FY17-18 SOA Non-Wires Pilot available at: https://www.bpa.gov/transmission/CustomerInvolvement/Non-Wire-SOA/Pages/default.aspx

Pilot is designed to reduce flows prior to a contingency on the system

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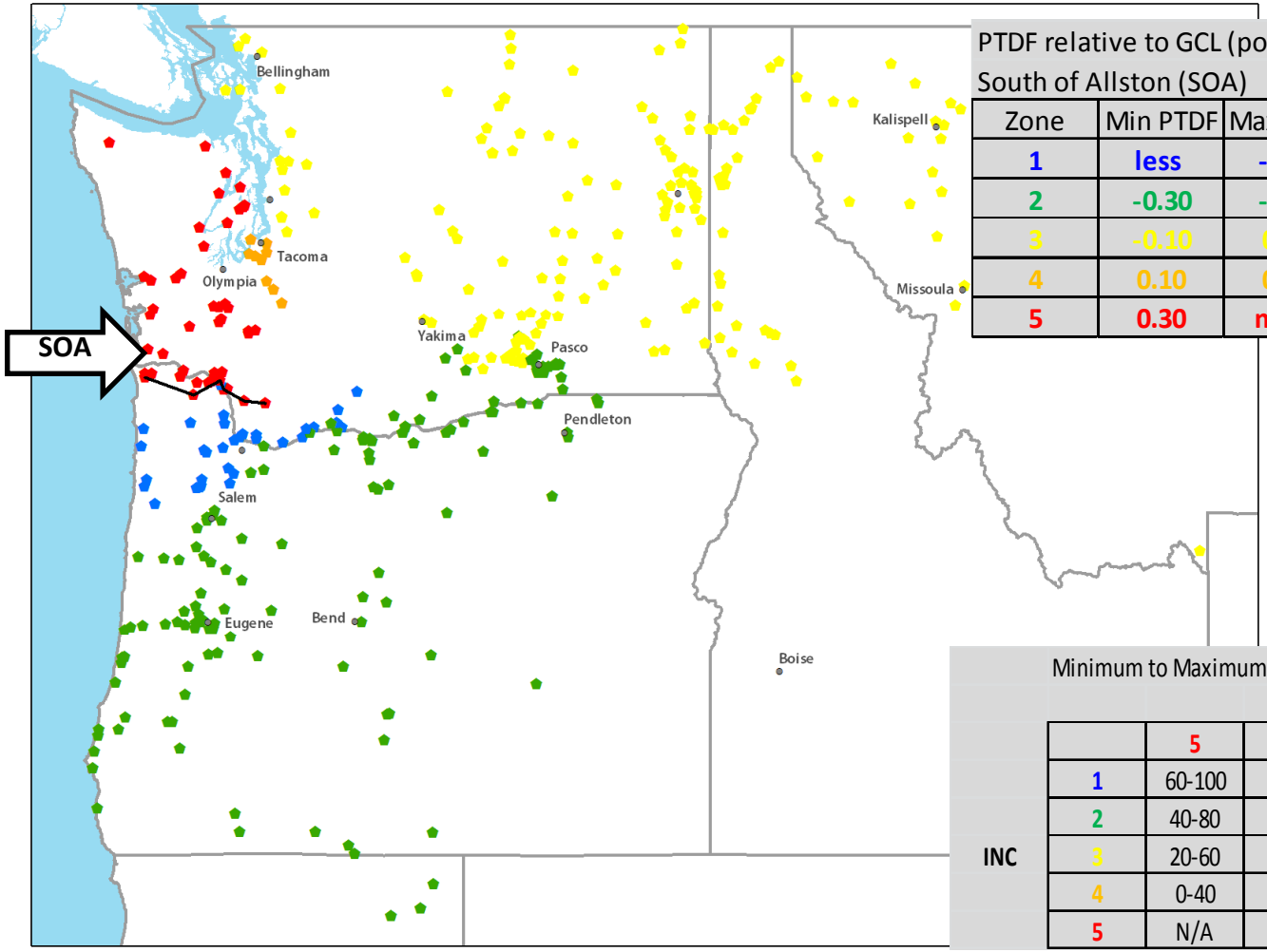
SOA Congestion Map



PTDF relative to GCL (posted PTDFs)
South of Allston (SOA)

Zone	Min PTDF	Max PTDF	INC/DEC
1	less	-0.30	Best INC
2	-0.30	-0.10	Good INC
3	-0.10	0.10	Potential INC or DEC
4	0.10	0.30	Good DEC
5	0.30	more	Best DEC

Minimum to Maximum % Relief on SOA by INC and DEC Zone

INC \ DEC	5	4	3	2	1
1	60-100	40-80	20-60	0-40	N/A
2	40-80	20-60	0-40	N/A	
3	20-60	0-40	N/A		
4	0-40	N/A			
5	N/A				

This map was created by BPA for prospective bidders to respond to BPA's RFO seeking non-wires

For Discussion Purposes Only

Forecasting Tool

- BPA developed in-house a trigger tool that generates a daily peak flow forecast across SOA.
  - The purpose of the tool is to maximize the value of the limited number of redispatch hours.
- The tool indicates when to deploy the SOA Pilot based on the next day's forecasted flow relative to forecasted TTC.
  - The tool was developed using a statistical ridge regression model that leverages data back to 2012, and has been enhanced for 2018
  - The forecast is calculated at 04:00 on preschedule day for an eight hour window (14:00-22:00) .
- After considering system conditions and outages, BPA uses the tool to decide to deploy the SOA Pilot or not.

Forecasting tool was used to inform pilot deployments to maximize performance of the SOA Pilot

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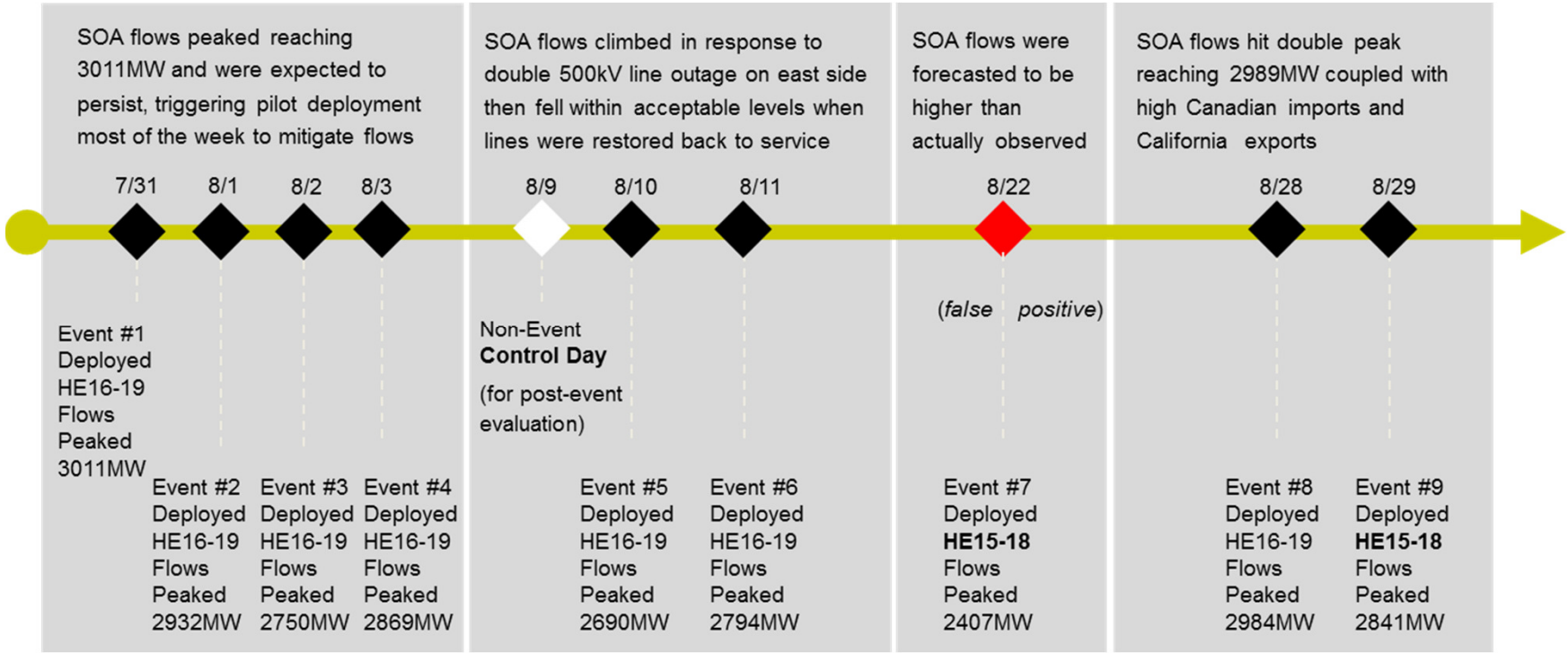
Pilot Event Days

- BPA purchased the right to deploy 10 events totaling 40 hours per summer (each event deployed in four-hour blocks).
- A total of nine events were deployed in 2017.



As operating conditions drove flows up, the SOA Pilot acted to reduce peak flows and provide congestion relief

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SOA Pilot Results

- Analysis shows that summer 2017 flows on the SOA were reduced when the SOA Pilot was deployed
- The amount of flow reduction, attributable to the SOA Pilot, varies depending on whether or not the total portfolio was dispatched

	Total Portfolio Dispatch			Partial Portfolio Dispatch		
	Max	Avg	Min	Max	Avg	Min
Best Case Calculates impacts based on system topology, taking into account outages	-119	-118	-117	-87	-86	-85
Schedule Informed Calculates impacts based on schedules before and during events, including resupply schedules	-112	-105	-101	-86	-69	-49
Worst Case Calculates impacts based on the weighted average of all resources increasing generation around events	-68	-65	-61	-52	-48	-46

While flows did not reduce as much as expected, the net effect is lower flows attributable to the pilot

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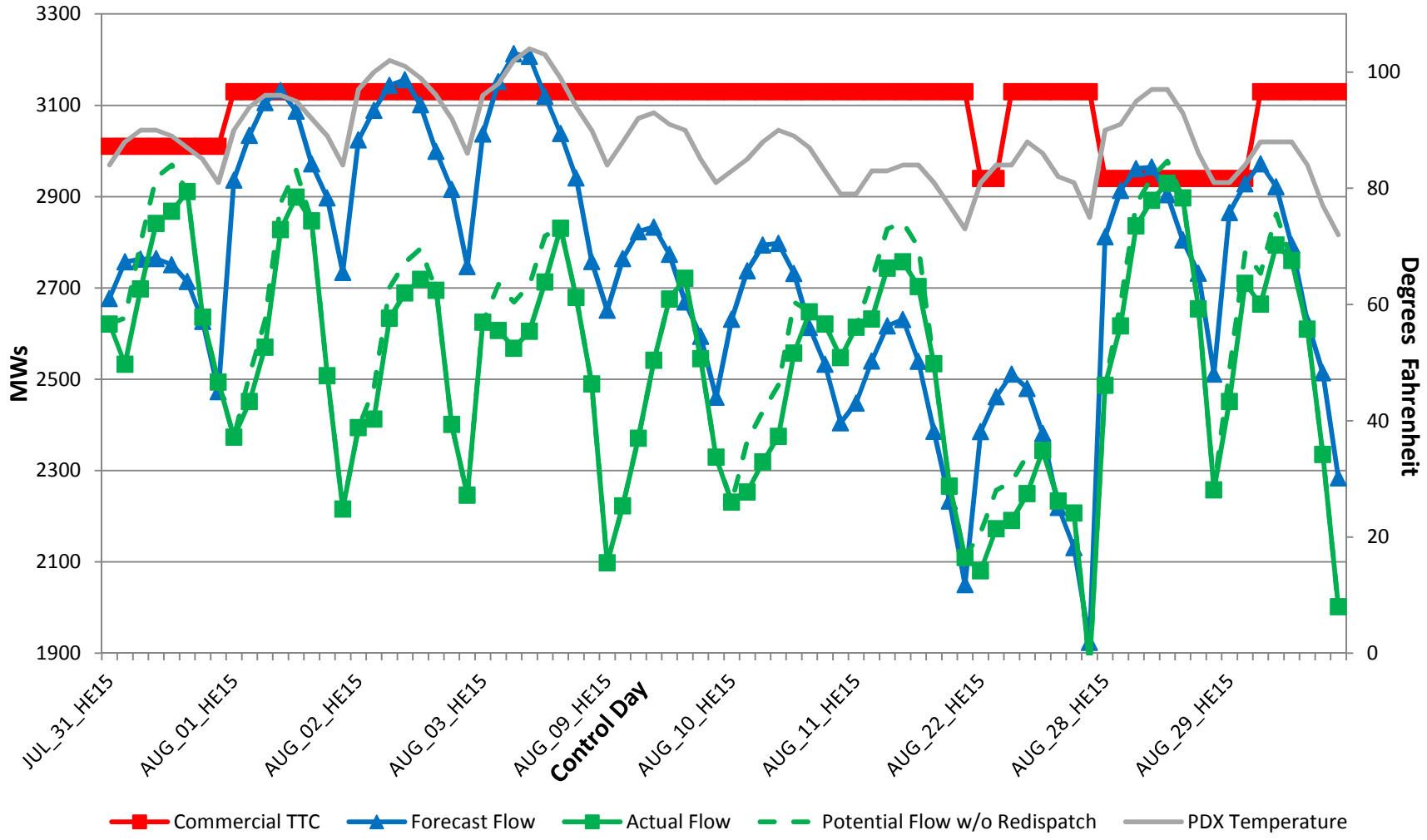
SOA Pilot Reduced Flows Chart



SOA summer peak flows were lower with pilot than without it!

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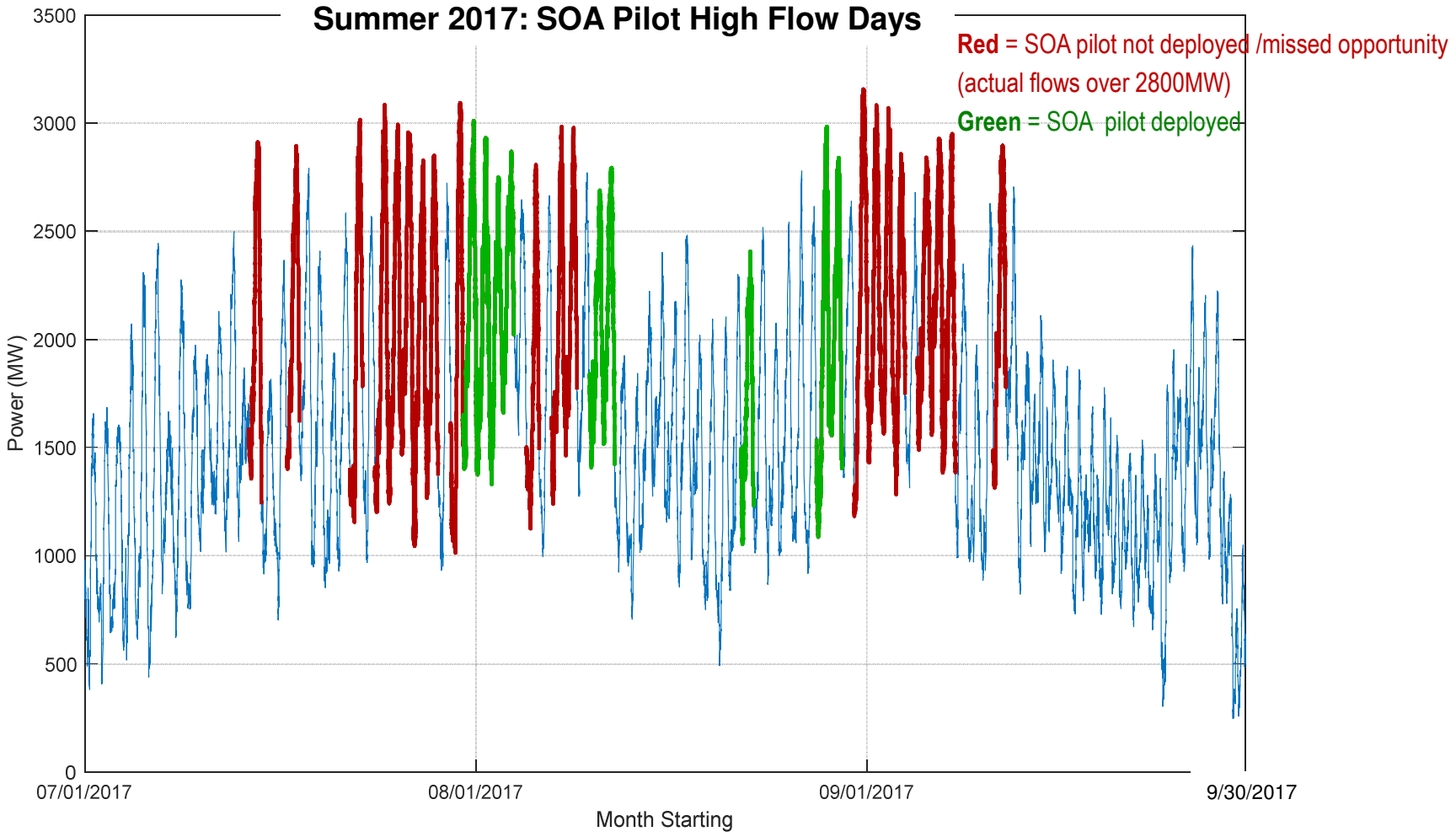
Insights



SOA high flow days missed provide insight into the future scope of BPA's non-wires program

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Conclusion

- BPA has successfully implemented a series of improvements to reduce operational risks, including RAS automation and optimization, dynamic TTC, and real-time reliability assessment tools

- Landscape changes reinforce the BPA path to adopt a flexible and a scalable solution to address (a) reliability compliance, (b) operational resiliency and flexibility, and (c) commercial needs

- Preliminary results of the South of Allston Redispatch Pilot are positive and provide insight into future program design

Questions?