



Reliability Analysis Update

Transmission Expansion Advisory
Committee
December 15, 2016



Clean Power Plan (CPP) Reliability Studies

- Provide a representative overview of the types of reliability issues that can be expected.
- Each scenario has a distinct portfolio of generation additions and retirements derived from the economic studies PJM has performed.
- The starting base case that each of the scenarios will be built from is the 2019/20 RPM power flow model.
- All scenarios will be studied for year 2025

- Generator deliverability will be performed on the following scenarios
 - Reference
 - Trade Ready Mass
 - Trade Ready Rate
- Load deliverability will be performed only on the Reference scenario power flow model, but selected individual LDAs will be updated and examined separately to account for the most severe scenario for that LDA if the LDA's forecast CETO exceeds its forecast CETL
 - Reference: BGE & MAAC
 - Reference 5/20: DLCO & EMAAC
 - State MASS NSC: Dayton
 - Low Natural Gas Price: APS & AEP
- PV analysis will be performed on the following scenarios
 - Reference
 - Trade Ready Mass
 - Trade Ready Rate
 - State Mass
 - State Mass NSC
 - State Rate

- The reliability power flow models for each scenario have been developed.
- The generator deliverability studies are nearing completion. The load deliverability studies have been started. Results are expected to be available for the January TEAC.



Immediate Need Reliability Projects

- **PJM Criteria Violation – Load Loss Limit**

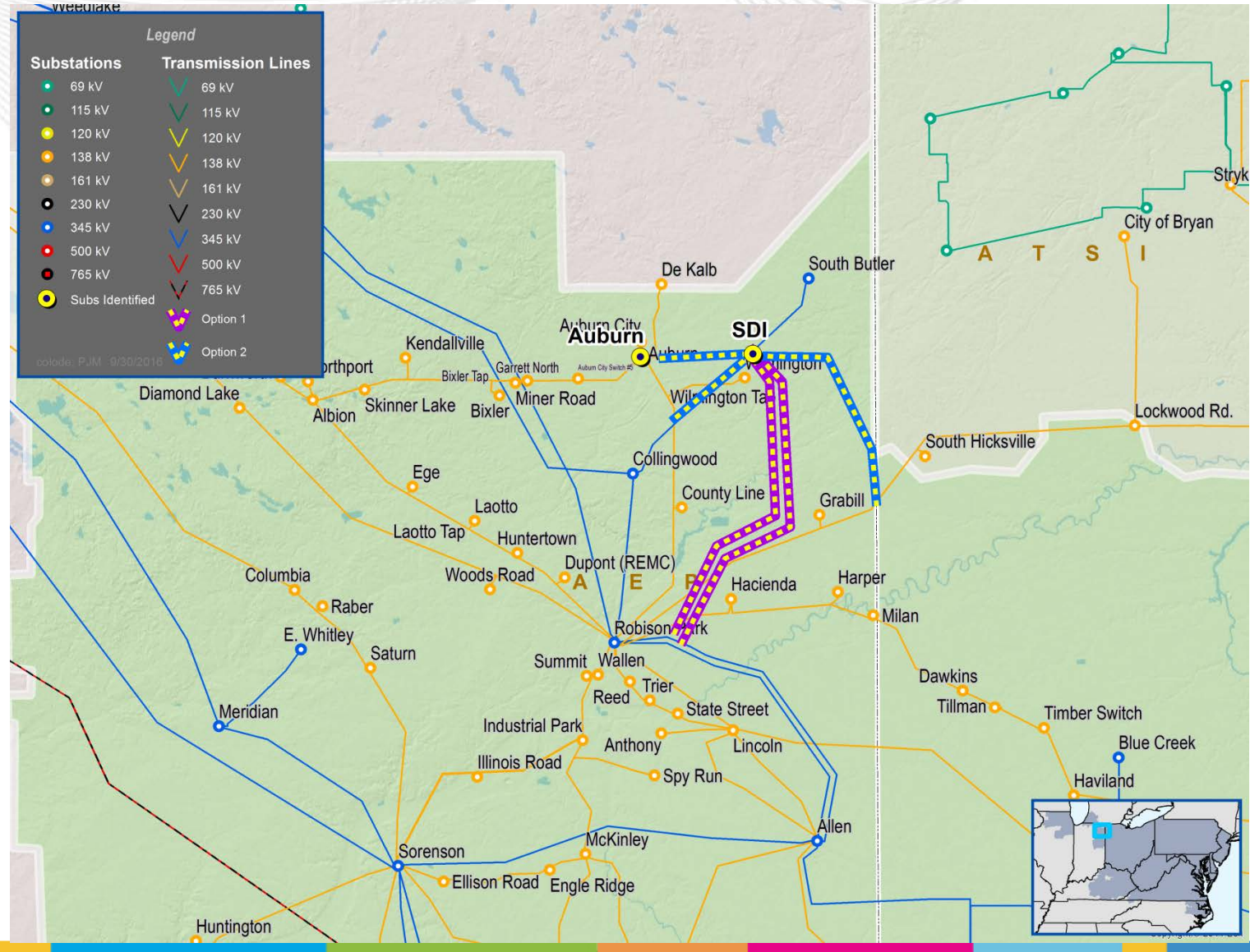
- Load model update -- Consequential Load Loss is greater than 300MW for the loss of the South Butler – Collingwood 345kV line

- **Immediate Need**

- Due to the timing of the need for the reinforcement an RTEP proposal window is infeasible

- **Alternatives Considered**

- Option 1: Construct a new 345 kV switching station near the customer (SDI); Tap the Rob Park –Allen 345 kV line and extend a new double circuit 345kV line (around 17 miles) into this new station (\$76.5M)
- Option 2: Construct a new 138 kV station, Campbell Road, by tapping into the Grabill – South Hicksville 138kV line; Reconstruct sections of the Butler-N.Hicksville and Auburn-Butler 69kV circuits as 138kV double circuit and extend 138kV from Campbell Road station; Construct a new 345/138kV SDI Wilmington Station which will be sourced from Collingwood 345kV and serve the SDI load at 345kV and 138 kV respectively; 138kV circuits will be looped in-out of the new SDI Wilmington station resulting in a direct circuit to Auburn and in direct circuit to Auburn and Rob Park via Dunton Lake, and a circuit to Campbell Road; Reconnector 138kV line section between Dunton Lake – SDI Wilmington; Expand 138kV bus at Auburn (\$107.7M)



- Comparison of two Options**

	Estimated Cost (M)	Right of way Width (feet)	Additional ROW (miles)	Addresses Local Area Needs?	Ease of future area Outage Scheduling?
Option 1 (345kV double circuit)	\$ 76.5	150	~17	No	No
Option 2 (138 kV solution)	\$107.7	100	~7 (~15.5 existing)	Yes*	Yes

- * Local 69kV lines built in the 1950s with wood pole construction with distribution class cross arms and the existing conductor is 4/0 ACSR.
- * During 2013-2016, there were 6 outages on Auburn-Butler 69kV line and 4 outages on Butler-North Hicksville 69kV line.
- * For the Auburn-Butler and Butler-North Hickville 69kV lines, there are 5 towers in A1 condition, 79 towers in A2 conditions, and 22 towers in A3 conditions.
- * The existing 69 kV line passes through an industrial zone and continued area industrial growth is anticipated.
- * Local wholesale distribution cooperative is also served from the 69 kV line of similar vintage and construction. This cooperative just West of this area has experienced multiple forced and momentary outages in the recent past.

NOTE: The 138KV option will use 795ACSR conductor. The cost difference between 556 ACSR and 795 ACSR is about 2-3% of the overall project cost and the rating difference are show in the following table:

Conductor Type	SN/SE (MVA) 69 kV	SN/SE (MVA) 138 kV
4/0 ACSR Penguin (existing)	50/50	N/A
556 ACSR Dove	102/142	205/284
795 ACSR Drake	129/180	257/360

- **Recommended Solution:**

- Construction a new 138 kV station, Campbell Road, tapping into the Grabill – South Hicksville 138kV line (B2779.1)
- Reconstruct sections of the Butler-N.Hicksville and Auburn-Butler 69kV circuits as 138kV double circuit using 795ACSR and extend 138kV from Campbell Road station (B2779.2)
- Construct a new 345/138kV SDI Wilmington Station which will be sourced from Collingwood 345KV and serve the SDI load at 345KV and 138 kV respectively; (B2779.3)
- 138Kv circuits will be looped in-out of the new SDI Willington station resulting in a direct circuit to Auburn and in direct circuit to Auburn and Rob Park via Dunton Lake, and a circuit to Campbell Road; Reconductor 138kV line section between Dunton Lake – SDI Wilmington; (B2779.4)
- Expand 138kV bus at Auburn (B2779.5)

- **Estimated Project Cost: \$107.7M**

- **Required IS Date: Immediate Need**

- **Expected IS Date: 6/1/2019**

Cost Details

138 kV Station on Rob Park-S Hicksville line, Campbell Road	\$4.8
138 kV line single and double ckt sections, 22.5 mi	\$33.0
138 kV Dunton Lake-Wilmington Reconductor, 9.5 mi	\$13.3
345/138 kV South Butler station, (5) 345 kV and (8) 138 kV CBs, (2) 345/138 kV XF, (2) 138 kV Cap Bank and CS, & Land	\$41.5
138kV Expansion at Auburn, (1) 138 kV CB	\$1.0
Total	\$93.6
15% Contingency	\$14.1
Grand Total (Million)	\$107.7

Dominion End of Life Criteria Violation:

- Original SVC at its End of Life
 - Harsh Environment / High Salt Contamination has led to component corrosion
 - Cap/filters have reached end of life
 - Non-redundant design
 - Unique components with no spares

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:

- Due to the immediate need of the project no alternatives were considered

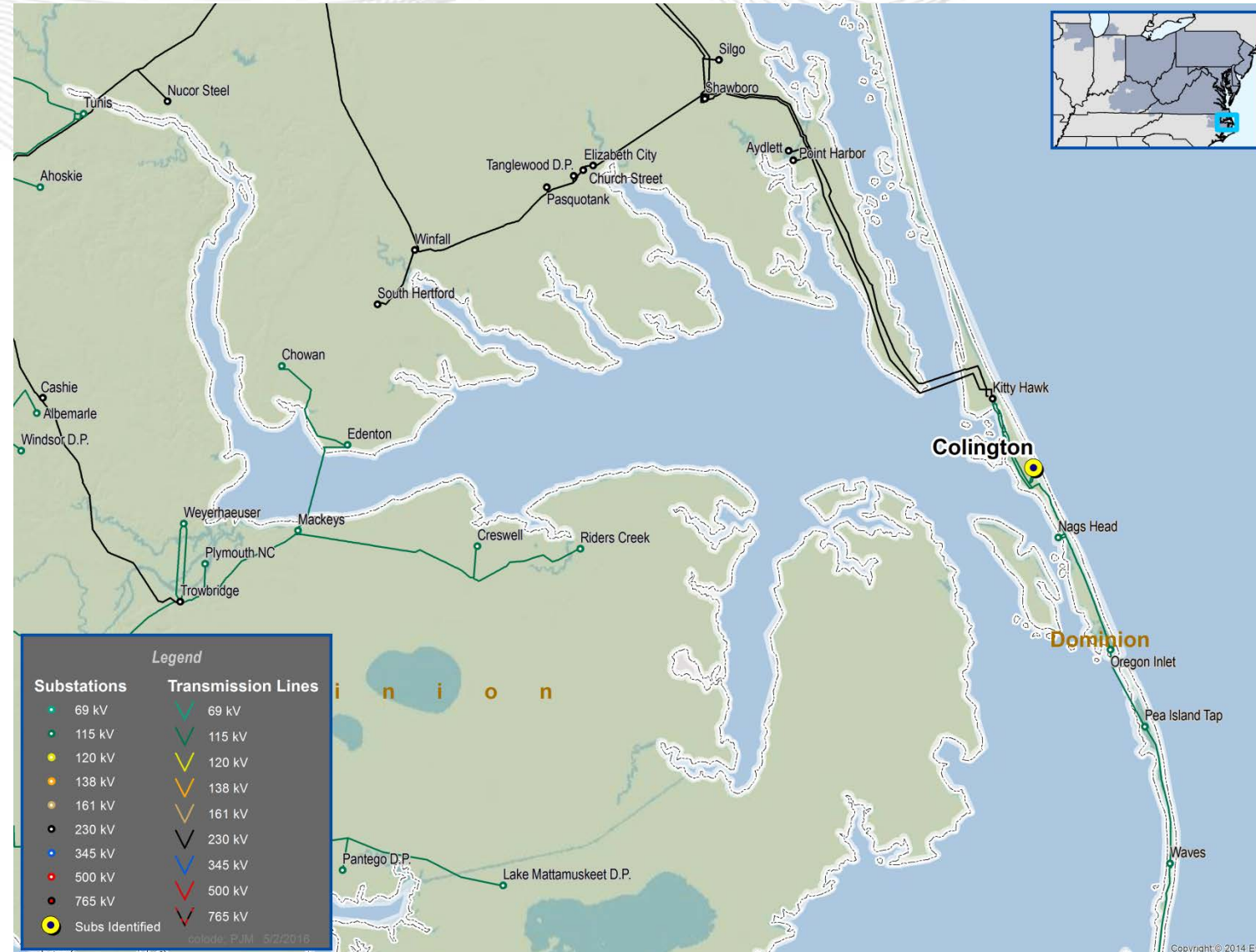
Proposed Solution:

- Install a +/-125 MVAR Statcom at Colington 230kV (B2757)

Estimated Project Cost: \$30 M

Required IS Date: 06/01/2017

Projected IS Date: 06/01/2017



Dominion End of Life Criteria Violation:

- The Dooms - Valley 500 kV Line has reached its End of Life
- Third party evaluation: Confirmed the Dooms - Valley 500 kV has reached its End of Life
- PJM Reliability Assessments without the line result in Criteria violations: Numerous thermal and voltage violations for various contingencies around and at Bath County, Lexington, Clifton, Lowmoor, and Dooms.

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:

- Alternatives that would require new lines to be built were not considered.

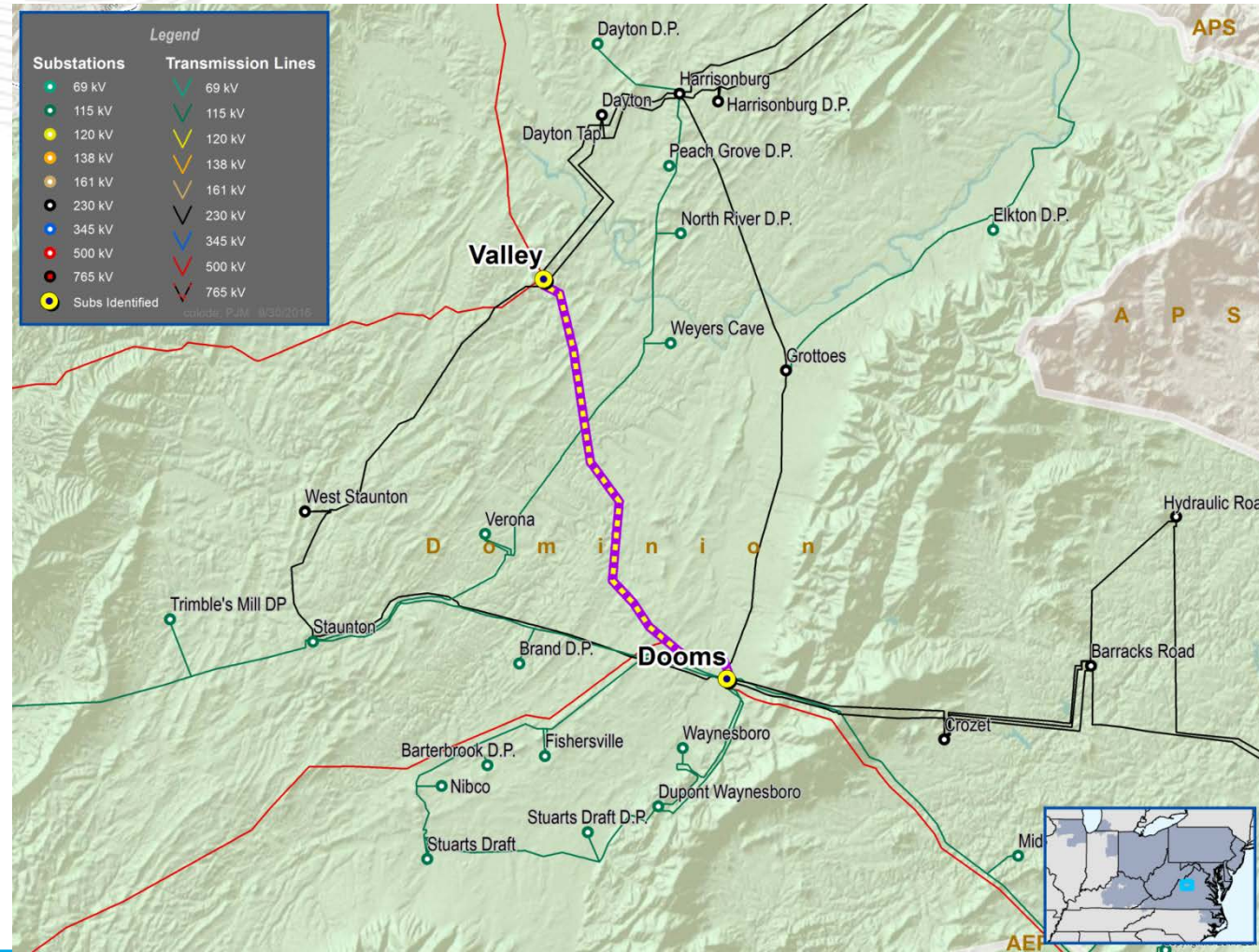
Proposed Solution:

- Rebuild Line #549 Dooms – Valley 500kV (B2758)

Estimated Project Cost: \$58.16 M

Required IS Date: Immediate Need

Projected IS Date: 6/1/2021



Dominion End of Life Criteria Violation:

- The Mt. Storm - Valley 500 kV Line has reached its End of Life
- Third party evaluation: Confirmed the Mt. Storm - Valley 500 kV has reached its End of Life
- PJM Reliability Assessments without the line result in Criteria violations: Numerous thermal and voltage violations for various contingencies around and at Barrack Road, Charlottesville, Bath County, Lexington, Clifton, Endless Caverns, Ox, and Possum.

Immediate Need:

- Due to the immediate need, the timing required for an RTEP proposal window is infeasible. As a result, the local Transmission Owner will be the Designated Entity.

Alternatives Considered:

- Alternatives that would require new lines to be built were not considered.

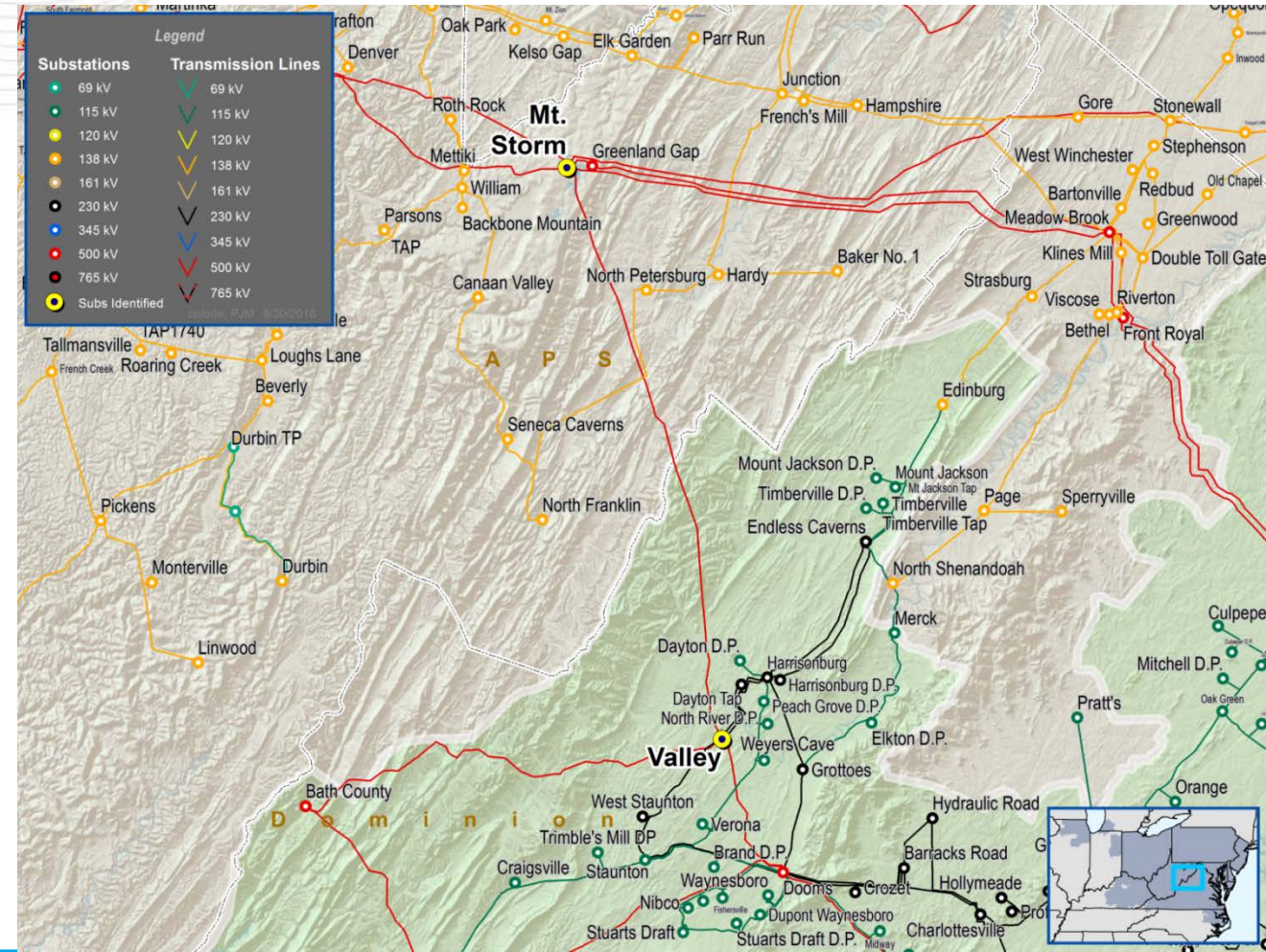
Proposed Solution:

- Rebuild Line #550 Mt. Storm – Valley 500kV (B2759)

Estimated Project Cost: \$225 M

Required IS Date: Immediate Need

Projected IS Date: 6/1/2021



Potential High Voltage issue in PSEG During Light Load

- Background
 - The BLC (*Bergen –Linden Corridor*) project in the Northern PSEG is under construction to be completed by June 2018. The project includes several pieces of underground cable.
 - The northern PSEG area previously experienced high voltage issue.
 - The last three years average load in PSEG was about 4000 MW during light load. The 2015-2016 load average was about 3900 MW during light load hours.

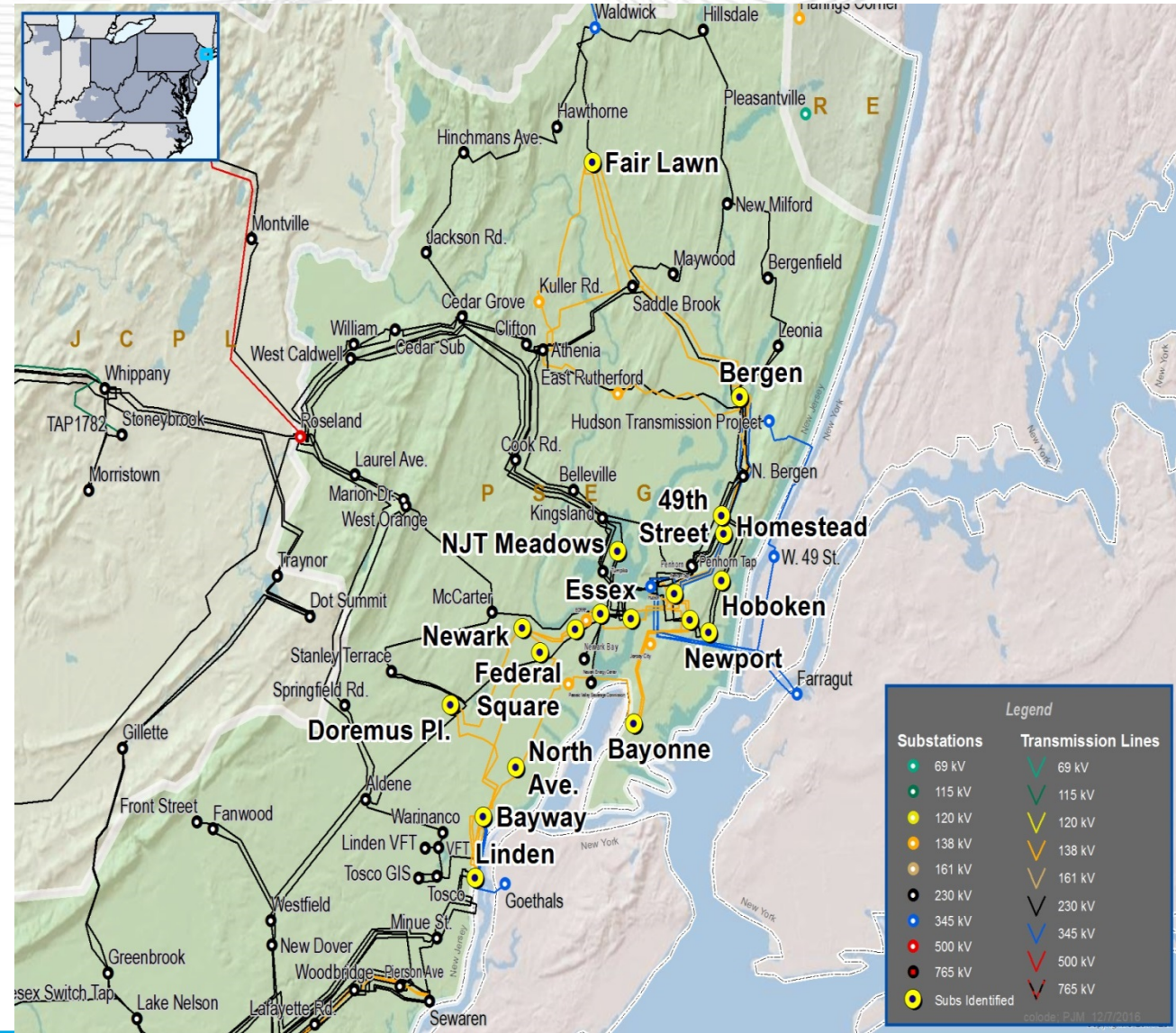
Purpose:

- The purpose of this analysis is to determine if a high voltage violations exist after the Bergen – Linden Corridor is fully energized.

- Assumptions/Analysis
 - PJM performed voltage analysis using the 2021 RTEP Light Load case with 3900 MW load model for PSEG area and identified several high voltage violations in Northern PSEG.
 - System transmission topology is unchanged between 2019 and 2021 in the PSEG North area and therefore the violation is expected to occur during the 2018/2019.

- PSEG stations with High voltage violations

138 kV substation	230 kV substation	345 kV substation
Doremus Place 138 kV	49TH Street R 230 kV	Newark Airport 345 kV
Fair Lawn 138 kV	49th Street Y 230 kV	Bayonne 345 kV
Federal Square 138 kV	Essex 230kV	Bayway 345 kV
Foundry Street 138 kV	Hoboken 230 kV	Bergen 345kV
Newark 138 kV	Homestead 230 kV	Linden 345kV
	Kearny 230 kV	Marion 345 kV
	Madison 230kV	North Avenue 345 kV
	Newport 230 kV	
	NJT Meadows 230 kV	
	Penhoun 230 kV	
	South Water Front 230 kV	



- Conclusion
 - The voltage violations exist after the Bergen-Linden Corridor project is placed in-service in 2018.
 - The addition of reactive devices is an immediate need.
 - 600MVAR of new shunt reactors installed in PSE&G's northern and central zones will address the high system voltages.
 - Because of long shunt reactor procurement time, need to start as soon as possible to meet in-service dates.

- Preliminary Recommendation

Install shunt reactors in the following stations			
Location	Size	Cost	In-Service
Kearny 230kV	2x50 MVAR	\$17.8M	May-19
Hudson 230kV	2x100 MVAR ¹	\$13.5M	Sep-19
Bayway 345kV	2x100 MVAR	\$30.6M	May-19
Linden 345kV	2x100 MVAR	\$28.5M	Jun-19

¹ Existing 2x50 MVAR at Hudson to be replaced with 2X100 MVAR for a net increase of 100 MVAR.

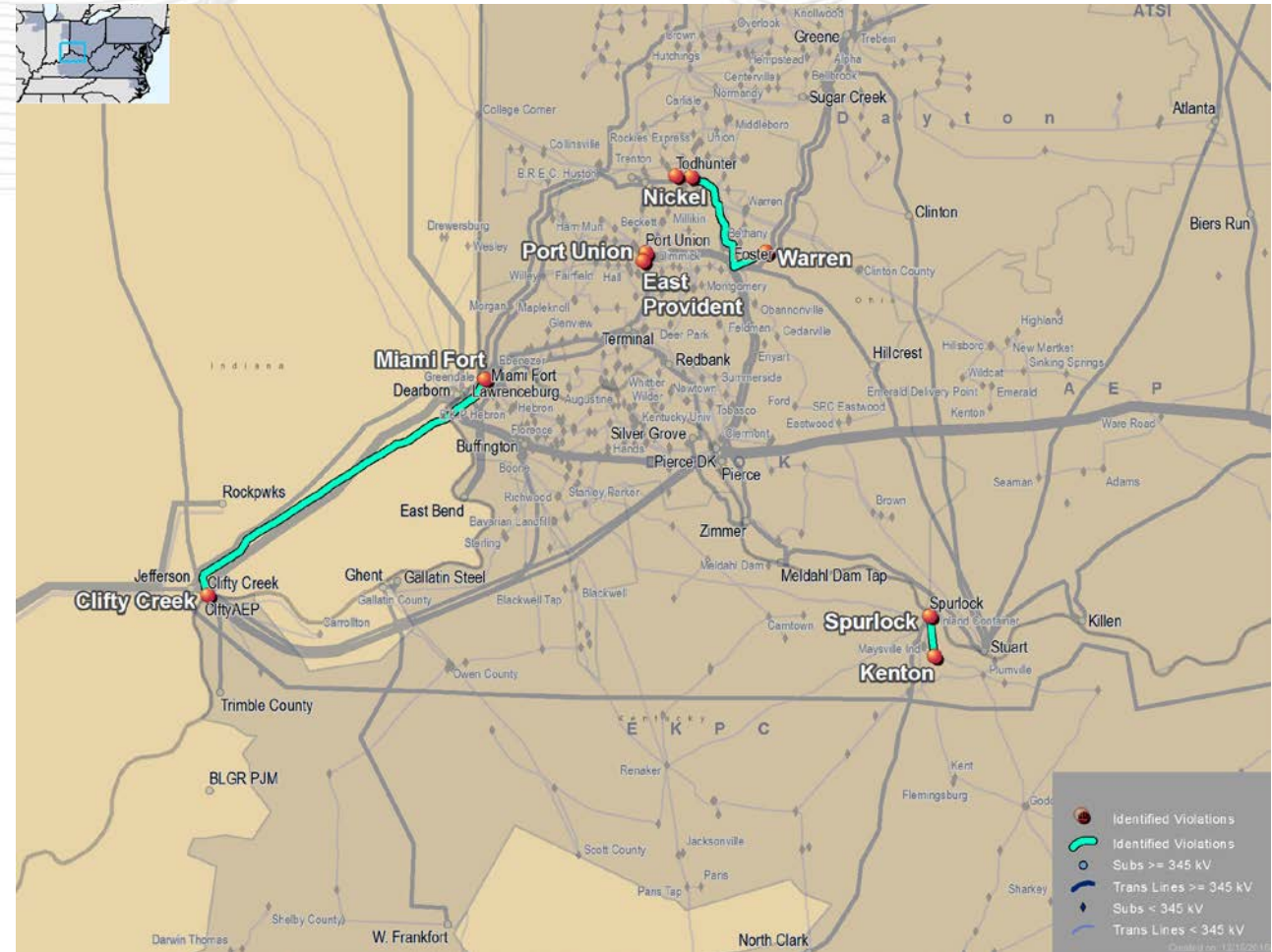


2016 RTEP Proposal Window #2 Updates and Recommendations

- DEOK and EKPC Transmission Zones

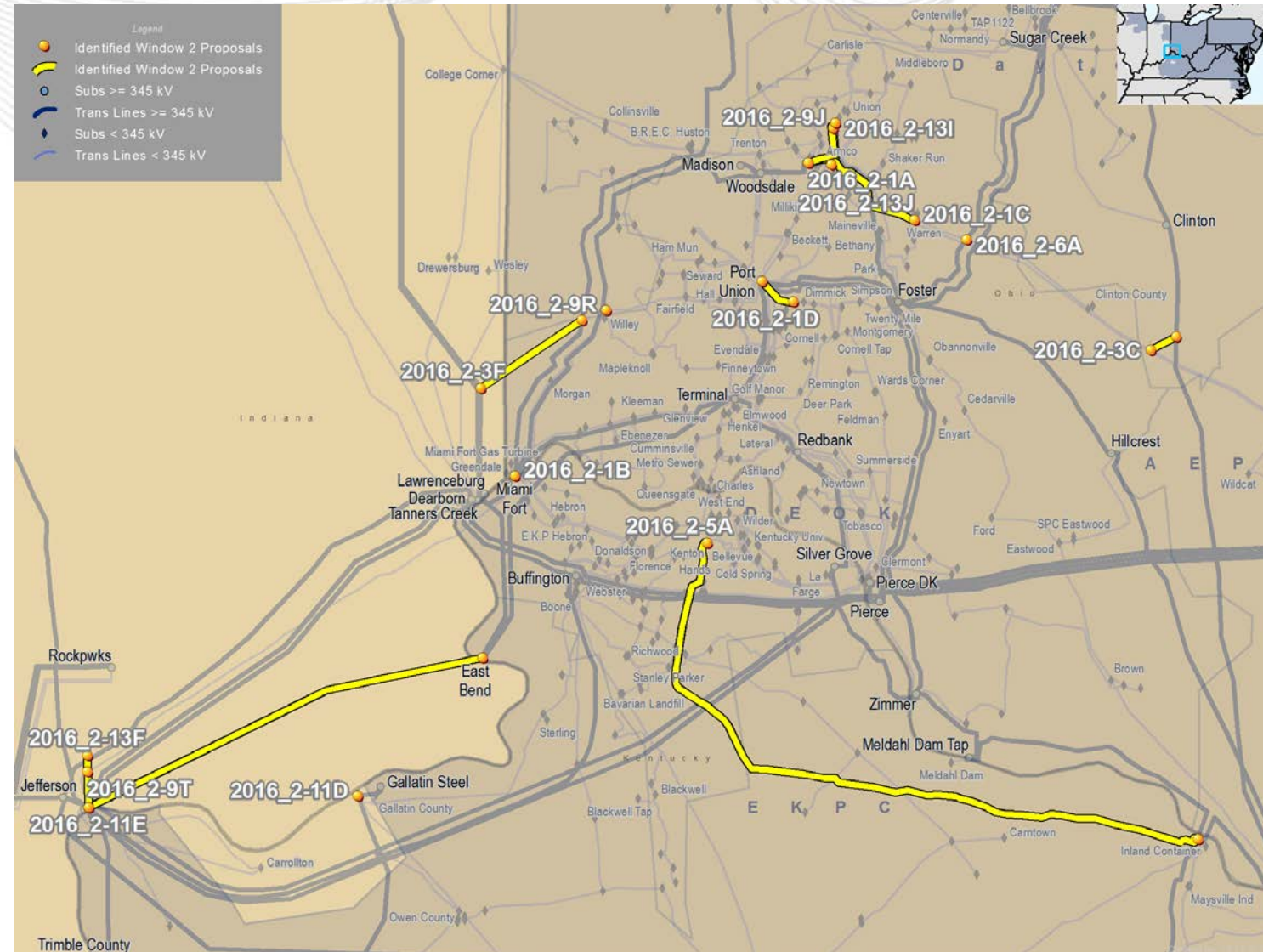
- Reliability Criteria FG#s:

- 897-Thermal Overload on Clifty-Miami Fort 138 kV
- 905-Thermal Overload on SpurKent-Kenton 138 kV
- 906-Thermal Overload on Spurlock-SpurKent 138kV
- 907-Thermal Overload on Nickel-Warren 138kV
- 1137-Thermal Overload on Clifty-Miami Fort 138 kV
- N2-T4-Thermal Overload on Port Union-E Provi 138 kV
- N2-T5-Thermal Overload on Port Union-E Provi 138 kV
- N2-T6-Thermal Overload on Tod Hunter 345/138 kV XFMR
- N2-T7-Thermal Overload on Tod Hunter 345/138 kV XFMR
- N2-T8-Thermal Overload on Tod Hunter 345/138 kV XFMR
- N2-T9-Thermal Overload on Tod Hunter 345/138 kV XFMR
- N2-T10-Thermal Overload on Tod Hunter 345/138 kV XFMR



Proposals:

- 2016_2-1A
- 2016_2-1B
- 2016_2-1C
- 2016_2-1D
- 2016_2-3C
- 2016_2-3F
- 2016_2-5A
- 2016_2-6A
- 2016_2-7S
- 2016_2-9J
- 2016_2-9R
- 2016_2-9T
- 2016_2-10B
- 2016_2-11D
- 2016_2-11E
- 2016_2-13F
- 2016_2-13I
- 2016_2-13J





DEOK/EKPC Transmission Zone

Proposal ID	1A	1C	1D	3C	3F	5A	6A	1B	9J	9R
Proposal										
Alternate Proposal		13I(\$11M), 13J(\$14M)					10B(\$30M)	7S(\$0.82M), 9T(\$6M), 11D(\$44M), 11E(\$86M), 13F(\$12M)		
Proposed Cost (\$M)	18.7	10.5	2.2	19	63	2.5	17.1	1.0	17	18.7
Upgrade/Greenfield	Upgrade	Upgrade	Upgrade	Greenfield	Greenfield	Upgrade	Greenfield	Upgrade	Greenfield	Greenfield
Proposing Entity	DEOK	DEOK	DEOK	Transource	Transource	EKPC	Nextera	AEP	LS Power	LS Power
Flowgates										
897				X	X			X		X
905				X	X	X				
906				X	X	X				
907	O	X		X	X		X		X	
1137				X	X			X		X
N2-T4			X		X					X
N2-T5			X		X					X
N2-T6	X			X	X		X		X	X
N2-T7	X			X	X		X		X	X
N2-T8	X			X	X		X		X	X
N2-T9	X			X	X		X		X	X
N2-T10	X			X	X		X		X	X

O: Proposal solves the FG, but was not indicated in the proposal from the project sponsor

X: Proposal solves the FG as indicated in the proposal

X: Proposal does NOT solve the FG as indicated in the proposal



DEOK/EKPC Transmission Zone Independent Consultant Cost Estimate Result

Proposal ID	1A	1C	3C	6A	9J	9R
Independent Cost Estimate	\$16.6	\$8.8	\$22.2	\$22.3	\$23.2	\$19.1
Upgrade/Greenfield	Upgrade	Upgrade	Greenfield	Greenfield	Greenfield	Greenfield
Proposing Entity	DEOK	DEOK	Transource	Nextera	LS Power	LS Power

- Generally no significant permitting or siting issues identified for any of the proposals
 - Endangered species may require time-of-year work restrictions
- Transource 3C
 - Foster substation expansion has risk of scope increase
 - Current configuration is a 7 position 345kV ring bus
- LS Power 9R
 - Potential for additional studies or surveys to be required due to proximity of historic buildings

Common Mode Outage (FG# 905, 906):

- Spurlock – Kenton 138 kV circuit is overloaded for loss of the tower lines of the Spurlock – Stuart 345KV and the Spurlock- Meldahl 345kV

Alternatives considered:

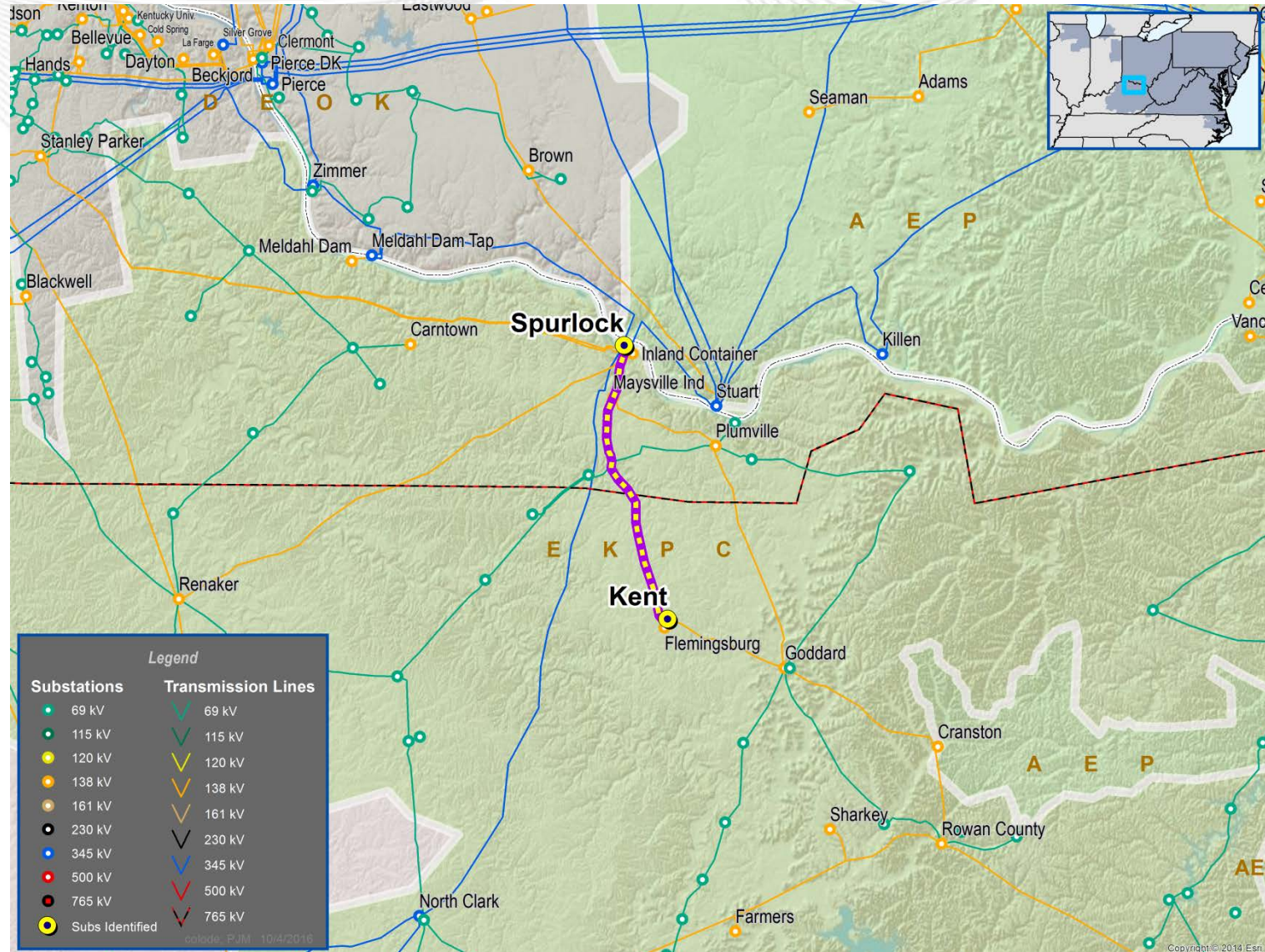
- 2016_2-3C (\$19.0 M)
- 2016_2-3F (\$63.0 M)
- 2016_2-5A (\$2.5 M)

Preliminary Recommendation:

- Upgrade the current 5% impedance 1200A line reactor, which connects the 4SPURLOCK - 4SPUR-KENT-R and 4SPUR-KENT-R - 4KENTON 138kV line sections, to a 6.5% impedance 1600A line reactor.(2016_2-5A)

Estimated Project Cost: \$ 2.5M

Required IS Date: 6/1/2021





DEOK Transmission Zone

Common Mode Outage (FG# 897, 1137):

- The Clifty Creek– Miami Fort 138 kV circuit is overloaded for multiple common model Contingencies

Alternatives considered:

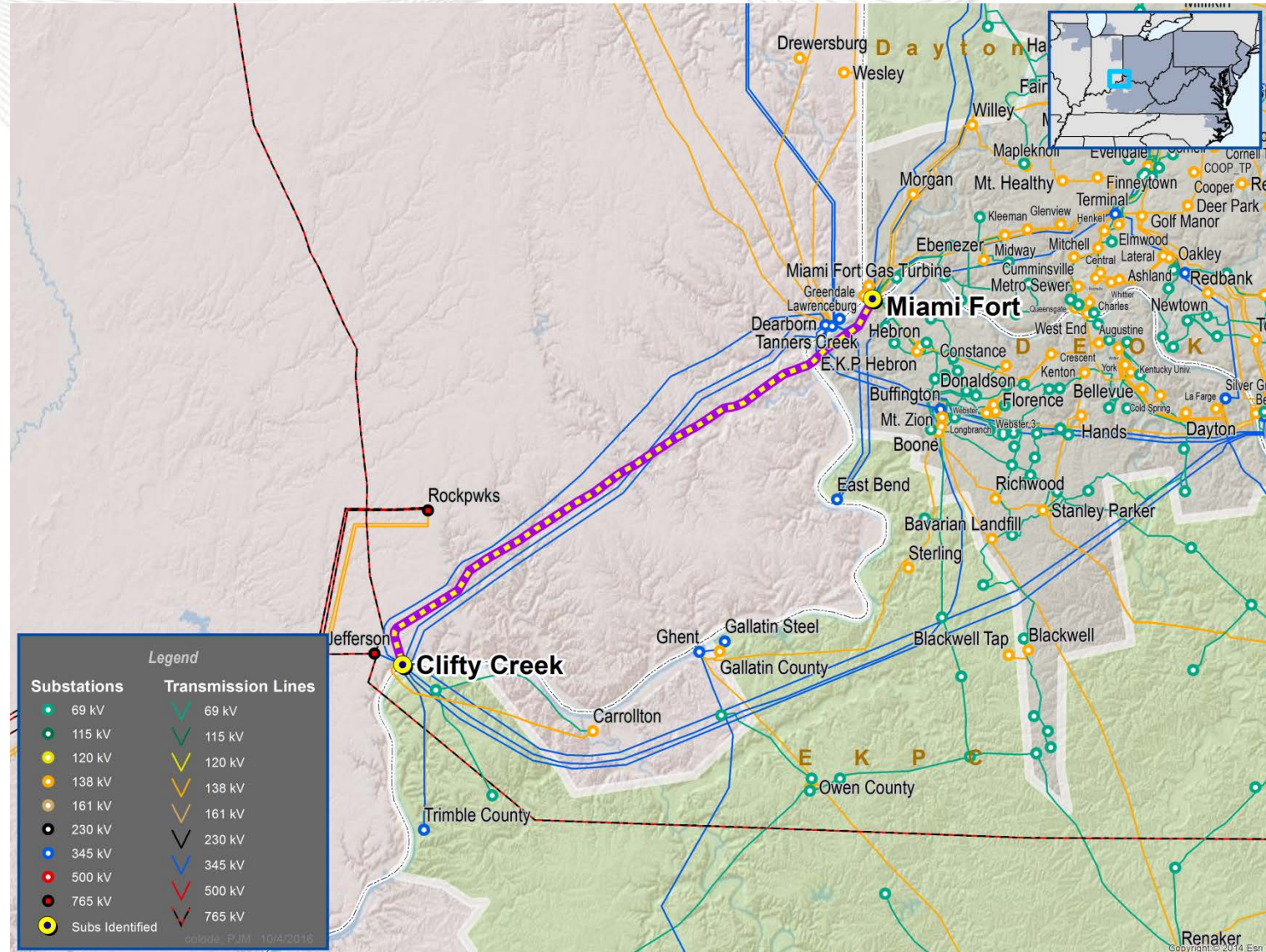
- 2016_2-1B (\$1.0M)
- 2016_2-3C (\$19.0 M)
- 2016_2-3F (\$63.0 M)
- 2016_2-7S (\$0.82M)
- 2016_2-9R (\$18.7M)
- 2016_2-9T (\$6.1M)
- 2016_2-11D (\$44.3M)
- 2016_2-11E (\$85.7M)
- 2016_2-13F (\$12.4M)

Preliminary Recommendation:

- Install 5% reactors at Miami Fort to limit current. (2016_2-1B)

Estimated Project Cost: \$ 1.0M

Required IS Date: 6/1/2021



N-1-1 Thermal Violation (FG# N2-T4, N2-T5):

- The Port Union – EPROV 138 kV circuit is overloaded for loss of the Todhunter – Rockies Express 138kV and the Foster- Garver 345kV

Alternatives considered:

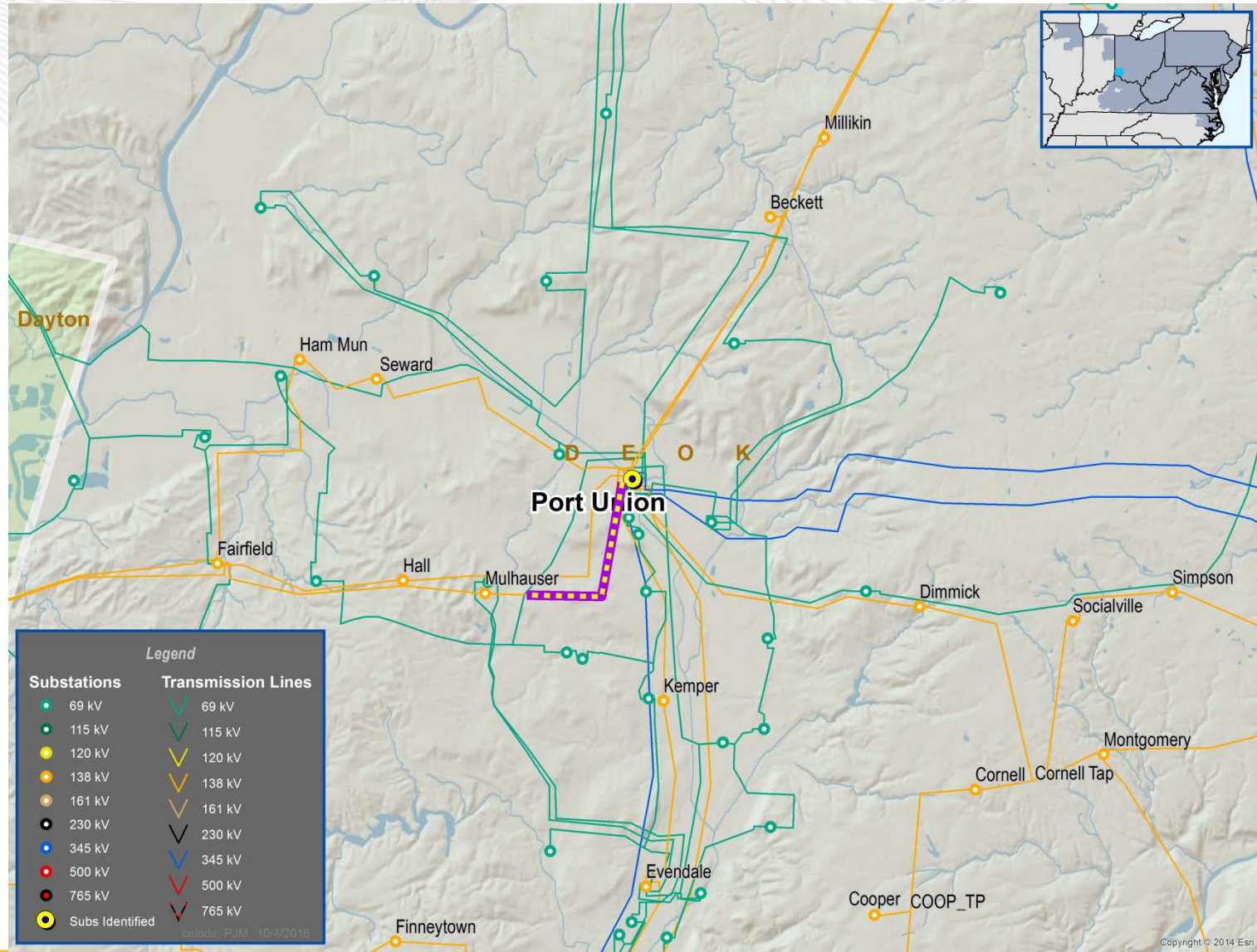
- 2016_2-1D (\$2.19M)
- 2016_2-3F (\$63.0 M)
- 2016_2-9R (\$18.7M)

Preliminary Recommendation:

- Reconductor Feeder from Port Union to East Provident 138kV line for 300MVA. (2016_2-1D)

Estimated Project Cost: \$ 2.19M

Required IS Date: 6/1/2021



Common Mode Outage (FG# 907):

- Nickel – Warren 138 kV circuit is overloaded for loss of the tower lines of the Todhunter – Rockies Express 138kV and the Foster- Garver 345kV

Alternatives considered:

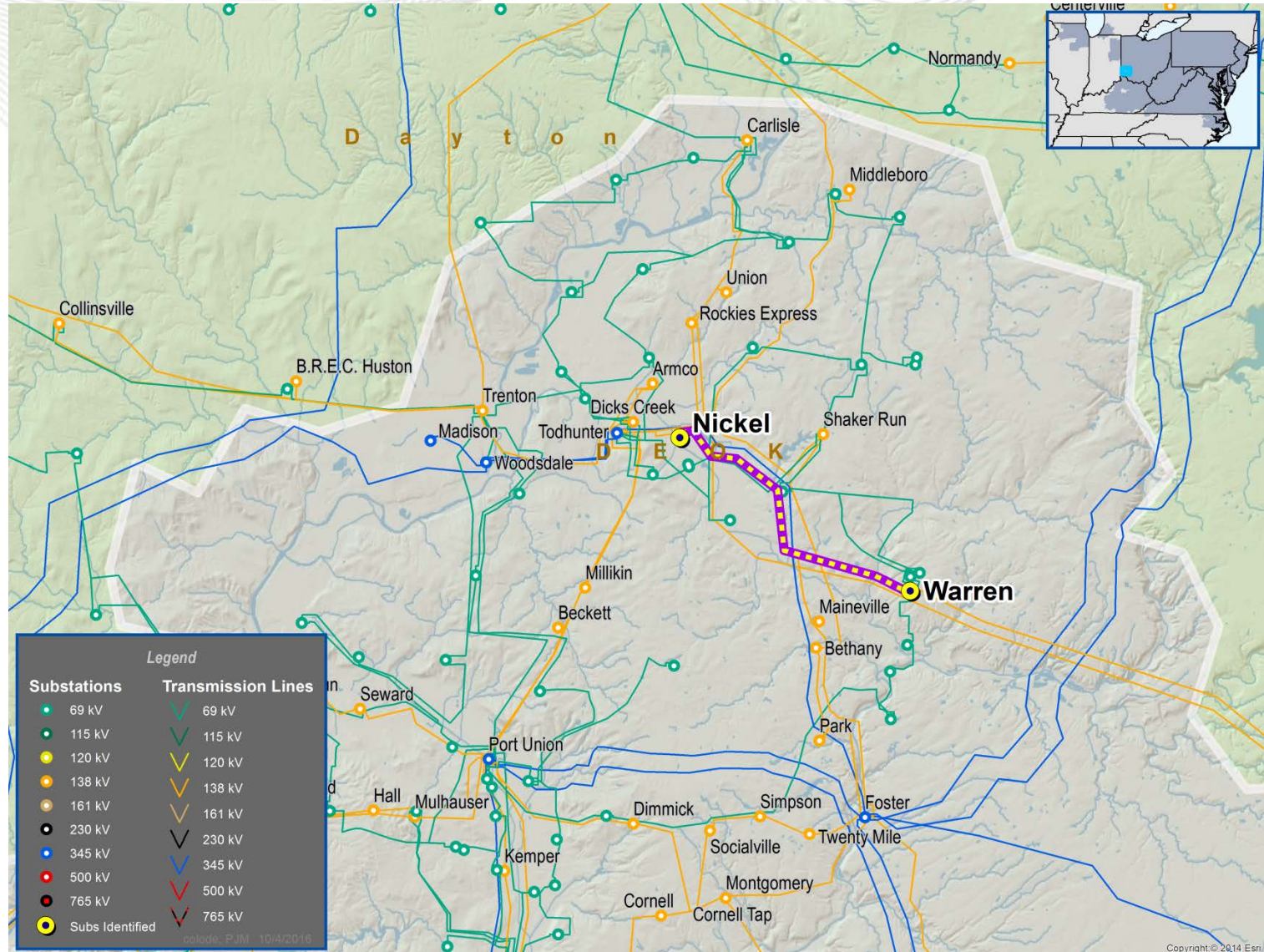
- 2016_2-1C (\$10.48 M)
- 2016_2-13I (\$11.19 M)
- 2016_2- 13J (\$14.27M)
- 2016_2-3C (\$19.0 M)
- 2016_2-3F (\$63.0 M)
- 2016_2- 6A (\$17.1M)
- 2016_2_9J (\$17.0M)
- 2016_2-10B (\$29.5M)
- 2016_2_1A (\$18.7M)

Preliminary Recommendation:

- Expand Garver 345kV sub to include 138kV. Install 1-345kV breaker, 1-345/138kV 400MVA transformer, 6-138kV Breakers and bus work. Connect local 138kV circuits from Todhunter, Rockies Express, and Union. (2016_2-1A)

Estimated Project Cost: \$ 18.7M

Required IS Date: 6/1/2021



N-1-1 Thermal Violation (FG# N2-T6, N2-T7, N2-T8, N2-T9, N2-T10):

- The left one of the three Todhunter 345/138kV transformers is overloaded for loss of the any two of them

Alternatives considered:

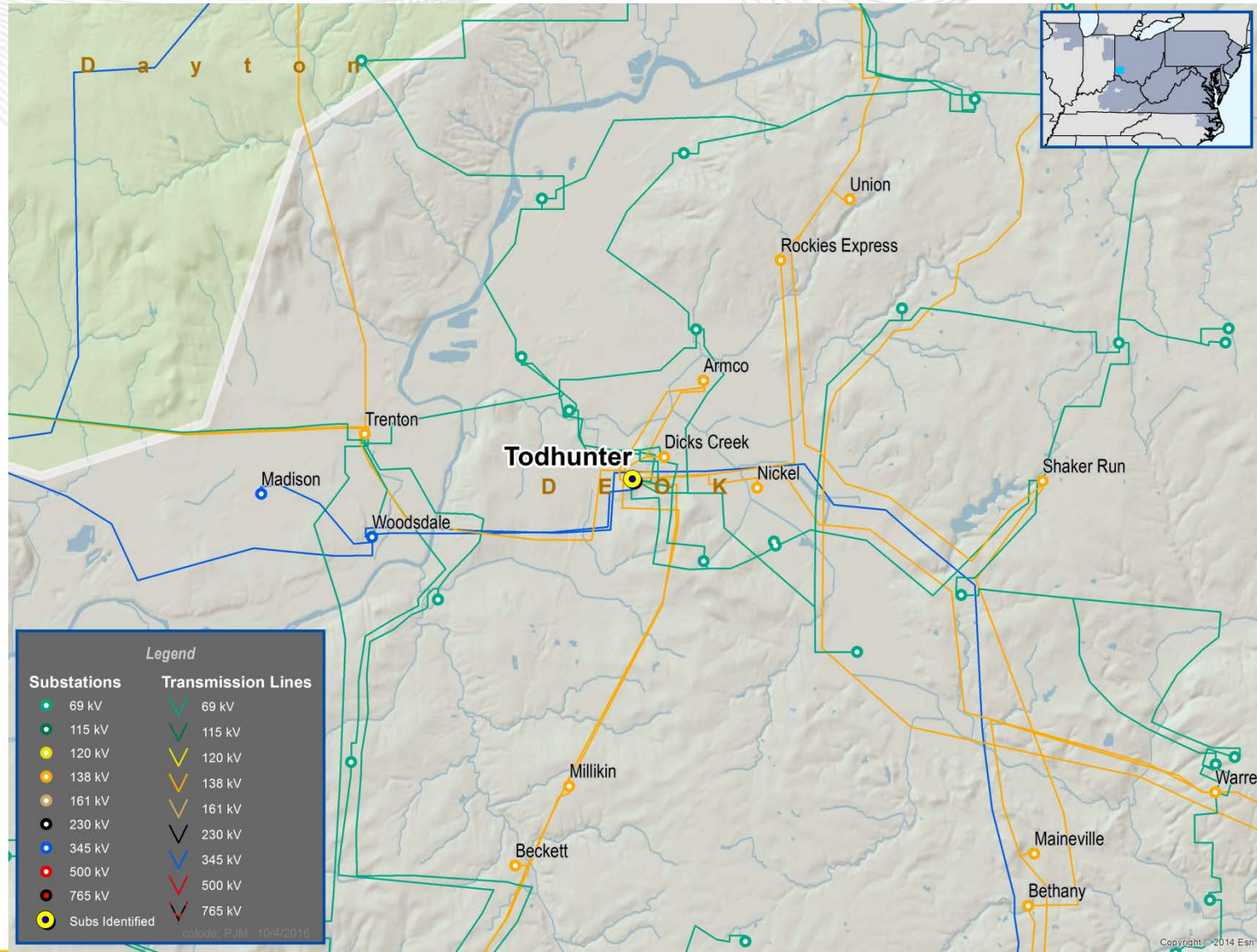
- 2016_2-1A (\$18.7M)
- 2016_2-3C (\$19.0M)
- 2016_2-3F (\$63.0 M)
- 2016_2-6A (\$17.1 M)
- 2016_2-9J (\$17.0 M)
- 2016_2-9R (\$18.7M)
- 2016_2-10B (\$29.5M)

Preliminary Recommendation:

- Expand Garver 345kV sub to include 138kV. Install 1-345kV breaker, 1-345/138kV 400MVA transformer, 6-138kV Breakers and bus work. Connect local 138kV circuits from Todhunter, Rockies Express, and Union. (2016_2-1A)

Estimated Project Cost: \$18.7M

Required IS Date: 6/1/2021



- PJM had to perform retool analysis for the following flowgates from 2016 2nd Window. The facilities are impacted by queue project that recently signed ISA (with IS date of prior to January 31, 2019), and the PSEG/ConED plus RAMAPO PAR settings. PJM completed the retool analysis and the overloaded facilities listed below are no longer overloaded with the exception of the Lackawanna 500/230 kV transformers. Due to the IS date of the queue project, the Lackawanna transformers upgrade will be an immediate need project.

FG #	Fr Bus	Name	To Bus	Name	CKT	KVs	Areas	Rating	FN DC Flow	FN AC Flow	FN DC %	FN AC %	Cont Label	Cont Type	Conductor Rating (MVA)
25	200825	26MESH2REA	200706	26N.MESH2RE	3	115/230	226/226	188	232.01	231.57	123.41	123.18	'PN-P1-2-PN-230-013'	single	Transformer
29	200677	26NO MESH2RE	200825	A	3	115/115	226/226	197	232.11	226.13	117.82	114.79	'PN-P1-2-PN-230-013'	single	Transformer
90	200675	26E.TWANDA	200924	26CANYON	1	230/230	226/226	515	580.01	553.29	112.62	107.43	Base Case	single	Rate A/B = 546/666
91	200675	26E.TWANDA	200924	26CANYON	1	230/230	226/226	615	661.97	634.55	107.64	103.18	'PL:P12:001029'	single	Rate A/B = 546/666
92	200675	26E.TWANDA	200924	26CANYON	1	230/230	226/226	615	643.47	615.27	104.63	100.04	'PL:P12:000189'	single	Rate A/B = 546/666
1042	208009	LACK	200074	LACKAW	4	230/500	229/225	1165	1344.52	1354.97	115.41	116.31	'PL:P42:101630'	breaker	Transformer
1044	208009	LACK	200074	LACKAW	3	230/500	229/225	1165	1344.52	1351.41	115.41	116.	'PL:P42:101631'	breaker	Transformer
1059	200927	26FOURMILE	200820	26ERIE SE	1	115/115	226/226	245	278.63	275.04	113.73	112.26	'PN-P2-3-PN-230-6G'	breaker	Same as basecase
1132	130807	WESTOVER115	200680	26LAUREL L	1	115/115	102/226	149	154.84	154.18	103.92	103.48	'PN-P2-3-PN-115-46G'	breaker	Rate A/B =

Common Mode Outage

- The Lackawanna 500/230 kV transformers # 3 and #4 are overloaded for line fault stuck breaker contingency loss of the Lackawanna – Susquehanna 500 kV circuit and the Lackawanna 500/230 kV transformer #3 or #4.

Immediate Need:

- The Y2-089 queue generation project recently signed ISA and will be in-service by January 2019, in the immediate need timeframe.

Alternatives Considered:

- Install series reactors along the Lackawanna 500/230 kV transformers
- Install Phase Angle Regulator at Lackawanna .
- Replace Lackawanna 500/230 kV transformers.

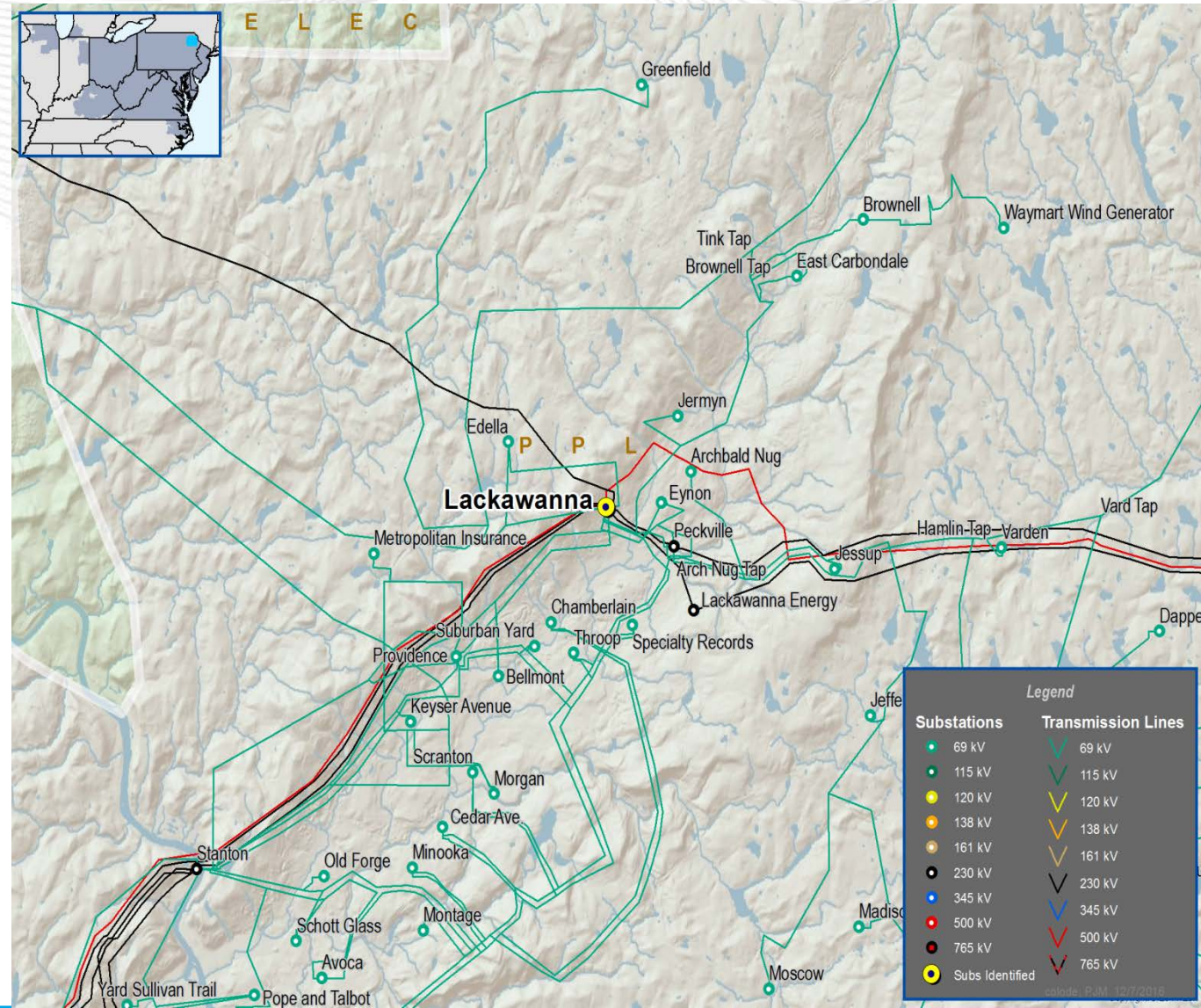
Proposed Solution:

- Reconfigure/Expand the Lackawanna 500 kV substation by adding a third bay with three breakers.

Estimated Project Cost: \$ 11.26 M

Required IS Date: 1/31/2019

Expected IS Date: 1/31/2019





2016 RTEP Proposal Window #3 Update

- Status: 30 Day Portion closed 10/31/2016, Final details due 11/15/2016
- Scope:
 - 2016 RTEP Winter Analysis
 - Baseline N-1 (thermal and Voltage)
 - Generation Deliverability and Common Mode Outage
 - N-1-1 (thermal and Voltage)
 - Load Deliverability (thermal and voltage)
 - 2016 RTEP Light Load Analysis
 - Baseline N-1 (thermal and voltage)
 - Generation Deliverability and Common Mode Outage
 - Short Circuit Analysis

- **Timeline**
 - Window Opened: 9/30/2016
 - Window Closed: 10/31/2016
 - Proposal definitions, simulation data and planning cost estimate due
 - Detailed Cost due: 11/15/2016
 - Additional 15 days to develop and provide detailed cost data
 - See the window documentation for additional information

- 25 total flowgates

Test/kV Level*	<200 kV	230 kV	345 kV	500 kV	765 kV	Total
Short Circuit	2		1			3
Winter Baseline N-1						0
Winter Gen Deliv/CMO	17		3			20
Winter N-1-1						0
Winter Load Deliv						0
Light Load N-1						0
Light Load Gen Deliv						0
Gen Deliv	1					1
Winter Baseline Thermal	1					1
Total	21	0	4	0	0	25

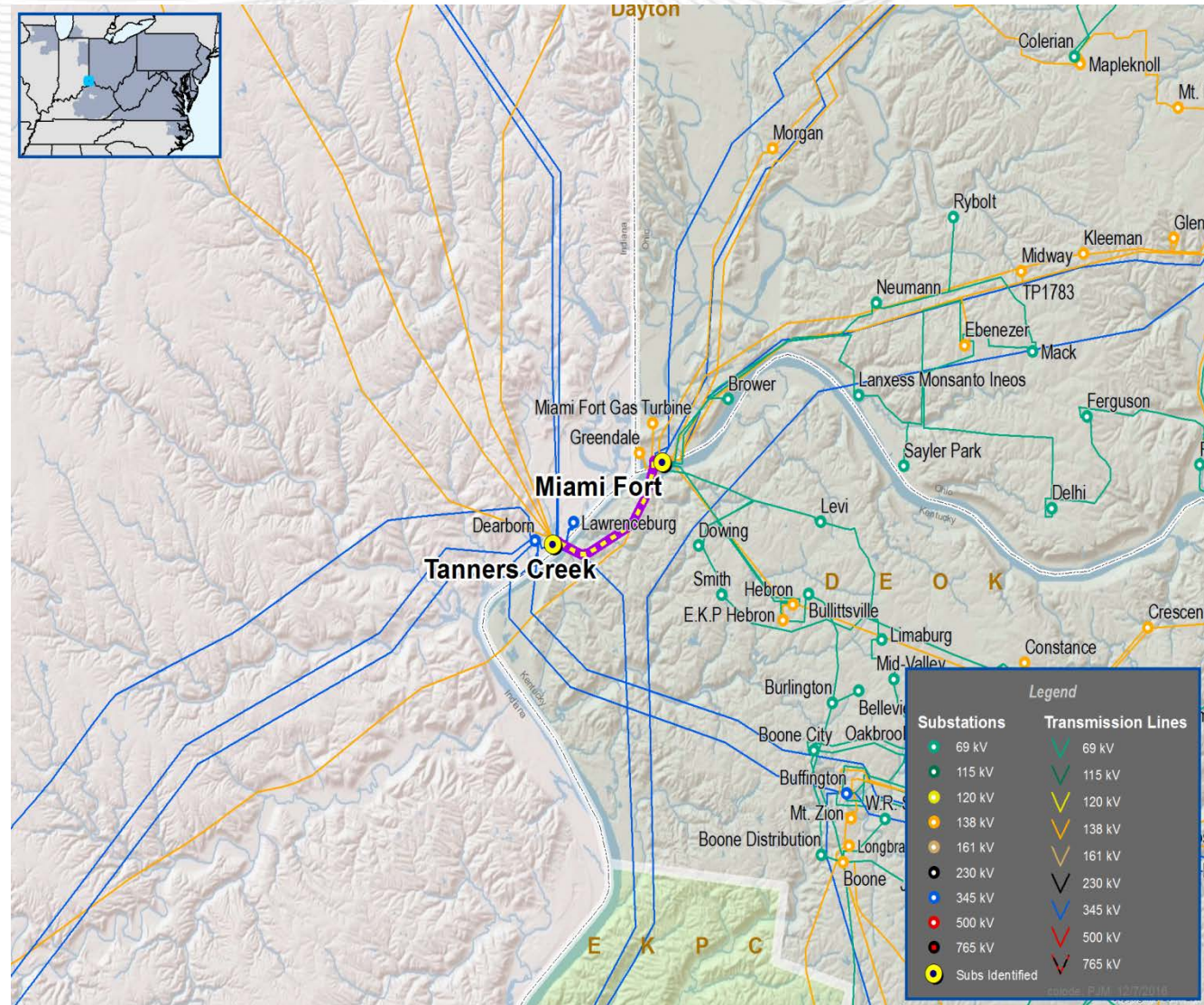
*Transformers are categorized based on low side kV

- 25 flowgates recommended for proposals
- 29 Proposals Received from 7 entities addressing 6 Target Zones
 - 17 Greenfield
 - 12 Transmission Owner Upgrade

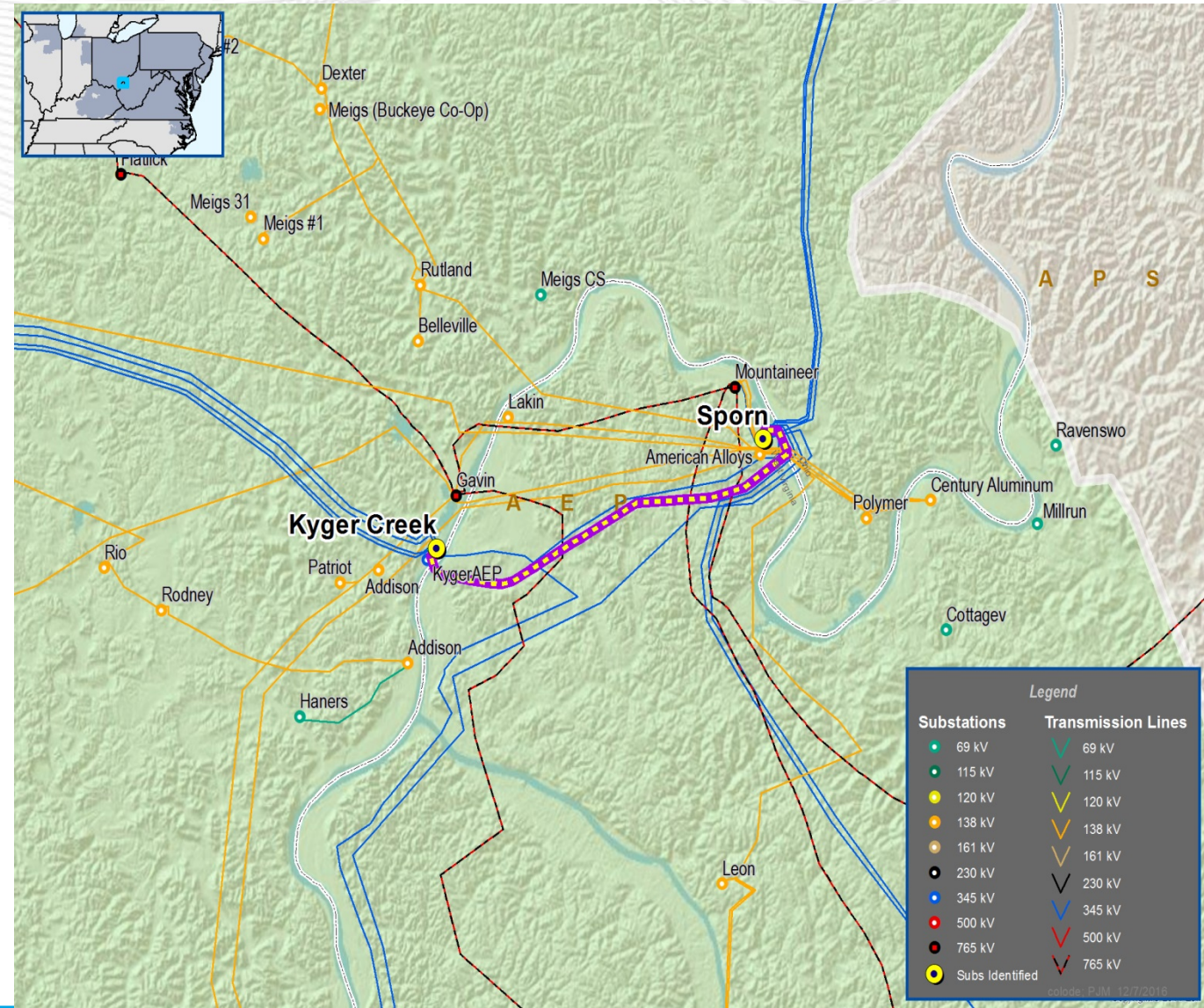


2016 RTEP Proposal Window #3 Recommendations

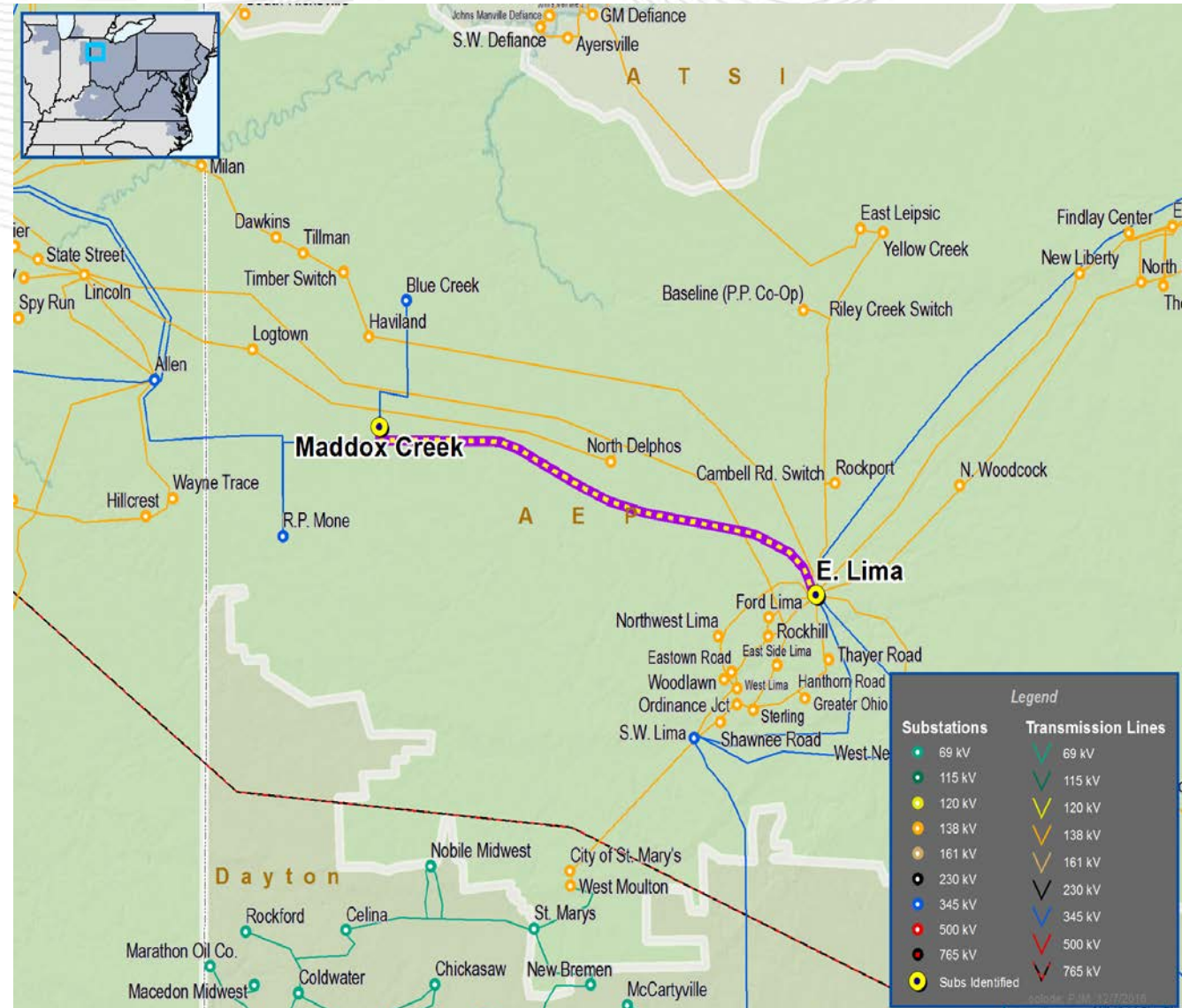
- Generation Deliverability (FG# 41):
- Tanner Creek to Miami Fort 345 kV circuit is overloaded for the loss of the Terminal – East Bend 345 kV circuit.
- **Alternatives considered:**
 - 2016_3-1A (\$7.8 M)
 - 2016_3-2A (\$14.5 M)
 - 2016_3-2E (\$59.8 M)
 - 2016_3-5G (\$14.5 M)
- **Preliminary Recommendation:**
 - Upgrade the Tanner Creek to Miami Fort 345 kV circuit. (2016_3-1A)
- **Estimated Project Cost: \$ 7.8 M**
- **Required IS Date: 12/1/2021**



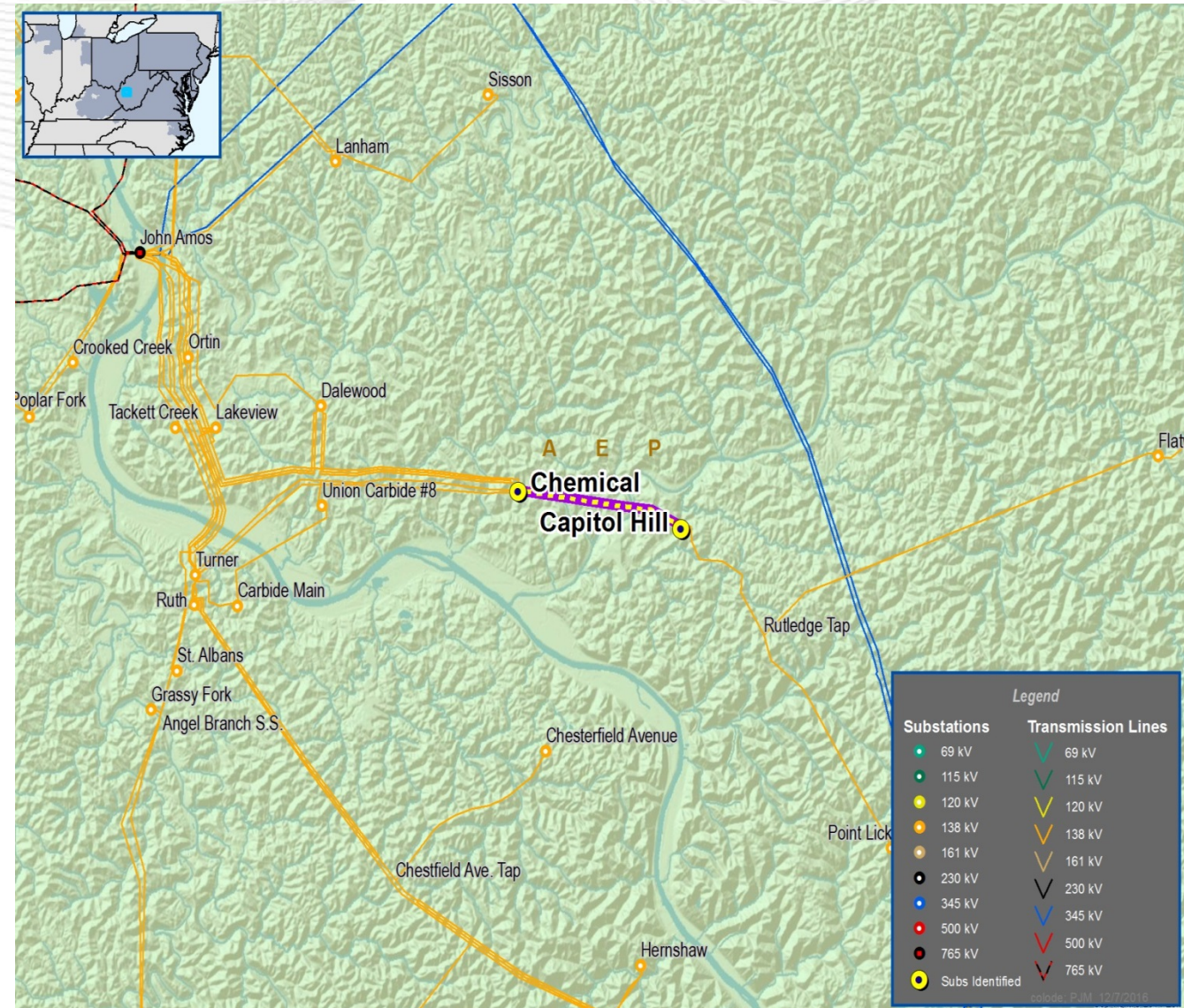
- Generation Deliverability (FG# 84) :
- Kyger Creek to Sporn 345 kV circuit #2 is overloaded for single contingency loss of the Kyger Creek – Sporn 345 kV circuit #1.
- **Alternatives considered:**
 - 2016_3-4B (\$ 15.5 M)
 - 2016_3-4C (\$ 0.3 M)
 - 2016_3-5E (\$ 19.8 M)
- **Preliminary Recommendation:**
 - Six wire the Kyger Creek to Sporn 345 kV circuits #1 and #2 and convert them to one circuit . (2016_3-4C)
- **Estimated Project Cost:** \$ 0.3 M
- **Required IS Date:** 12/1/2021



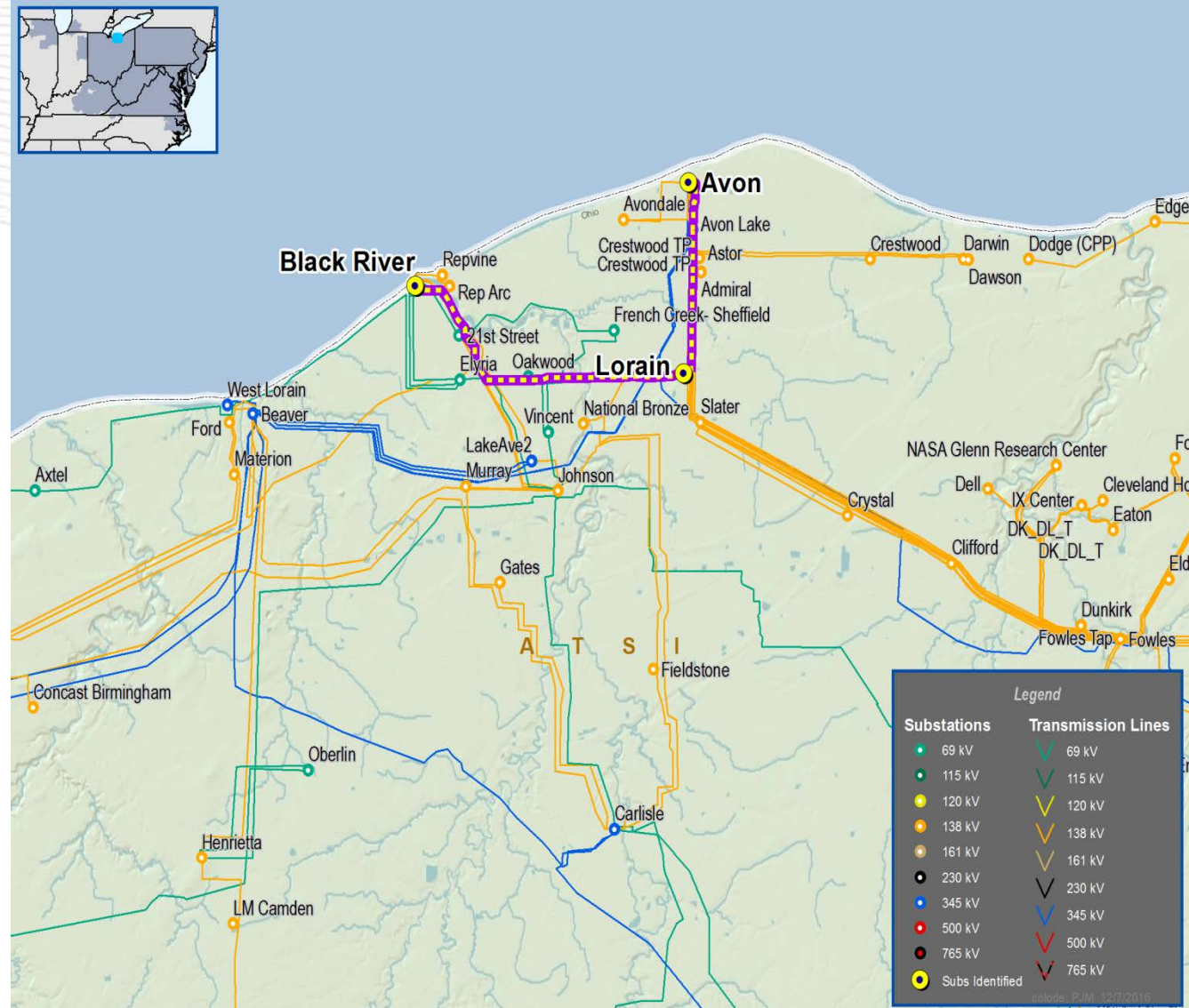
- Baseline and Common Mode Outage (FG# 123) :
- Maddox Creek to East Lima 345 kV circuit is overloaded for single contingency loss of the Marysville – Sorenson 765 kV circuit.
- **Alternatives considered:**
 - 2016_3-3A (\$ 5.95 M)
 - 2016_3-4D (\$ 18.2 M)
 - 2016_3-4F (\$ 67.7 M)
 - 2016_3-4G (\$ 69.3 M)
 - 2016_3-7A (\$ 55.9 M)
- **Preliminary Recommendation:**
 - Reconductor the Maddox Creek to East Lima 345 kV circuit with 2-954 ACSS Cardinal conductor. (2016_3-4D)
- **Estimated Project Cost:** \$ 18.2 M
- **Required IS Date:** 12/1/2021



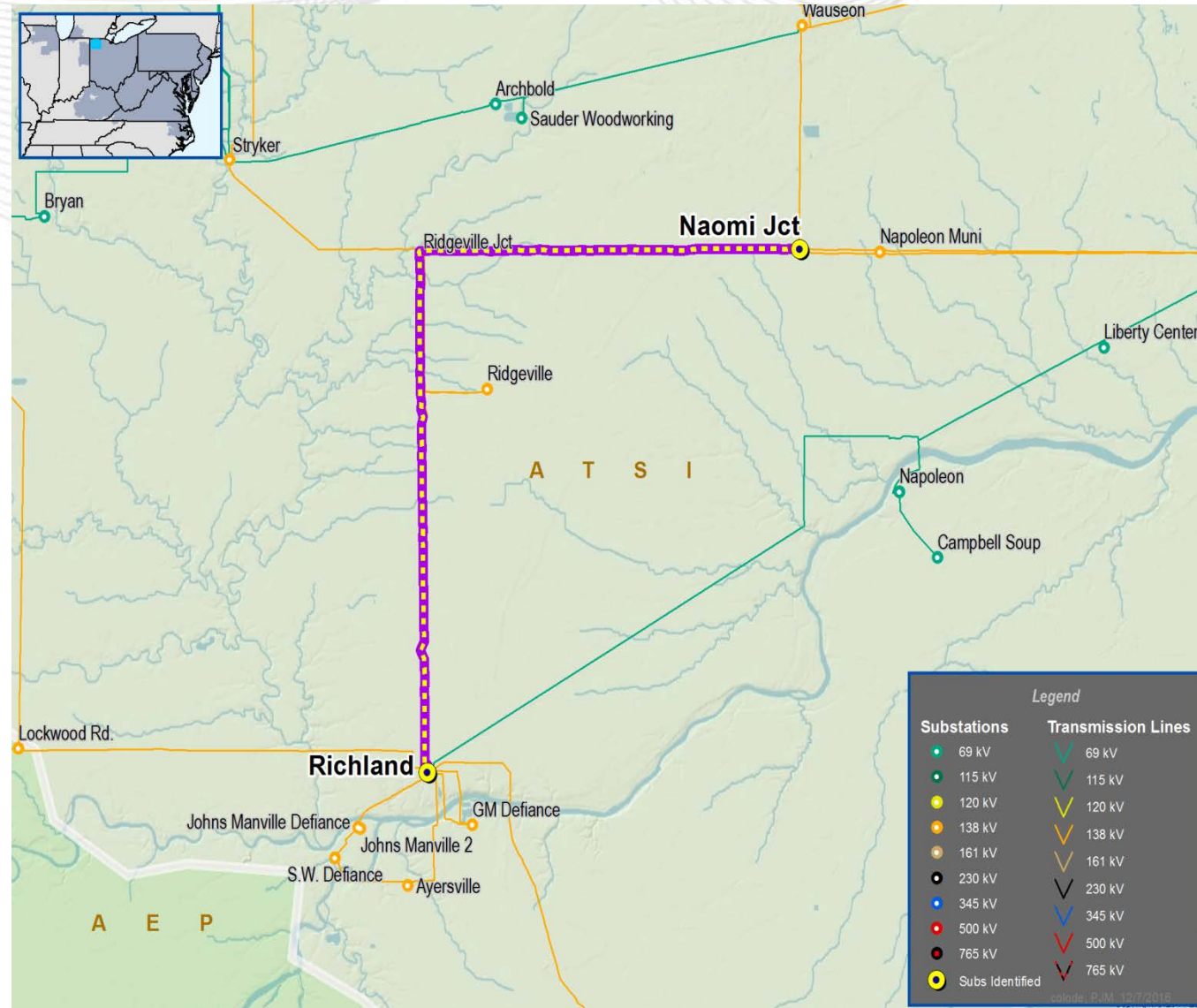
- Baseline and Common Mode Outage (FG# 394, 395, 396, 397, 398 and N1-35) :
- Chemical to Capitol Hill 138 kV circuit is overloaded for several tower outages.
- **Alternatives considered:**
 - 2016_3-4A (\$ 7.3 M)
 - 2016_3-5C (\$ 30 M)
- **Preliminary Recommendation:**
 - Reconductor and string open position and sixwire 6.2 miles of the Chemical to Capitol Hill 138 kV circuit. (2016_3-4A)
- **Estimated Project Cost:** \$ 7.3 M
- **Required IS Date:** 12/1/2021



- Generation Deliverability and Common Mode Outage (FG# 392, 393, 400, 407, 489, 490, 493 and 504) :
- Black River – Lorain - Avon 138 kV circuit is overloaded for tower outage loss of Avon – Lake Ave 345 kV circuits and line fault stuck breaker contingency loss of the Avon – Lake Ave 345 kV circuits.
- **Alternatives considered:**
 - 2016_3-2C
 - 2016_3-5B
 - 2016_3-5D
 - 2016_3-6B
 - 2016_3-6C
 - 2016_3-6D
- **Status:**
 - Evaluation in progress
 - PJM will continue to evaluate these proposals along with those submitted in 2016 RTEP Proposal Window 3 Addendum



- Common Mode Outage (FG# 1, 2, and 3) :
- Richland to Naomi Junction 138 kV circuit is overloaded for multiple bus and line fault stuck breaker contingencies.
- **Alternatives considered:**
 - 2016_3-2B (\$ 8.3 M)
 - 2016_3-2D (\$ 17.2 M)
 - 2016_3-5A (\$ 8.5 M)
 - 2016_3-5H (\$ 6.1 M)
 - 2016_3-6E (\$ 9.1 M)
- **Status:**
 - Evaluation in progress



Short Circuit

Scope and Cost Change for B2631 Upgrade

Problem: Short Circuit

- The Linden 230kV GSU breakers are overstressed

Old Proposed Solution:

- Replace the four Linden 230 kV GSU breakers with 80kA breakers (b2631)

New Proposed Solution:

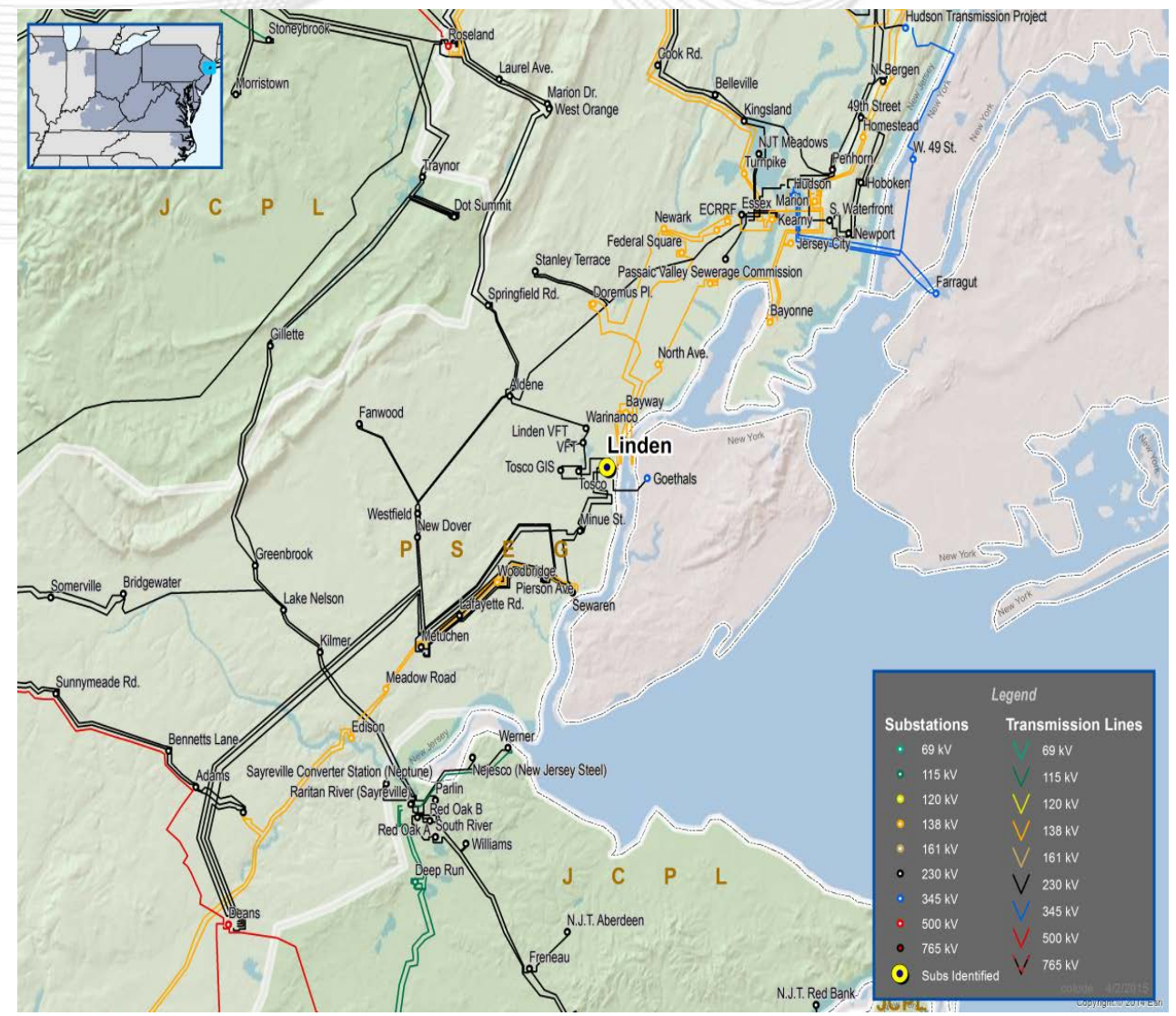
- Install 0.123% series reactor on the Z-2252 230 kV circuit connecting the Linden generators to Linden station.

Old Estimated Project Cost: \$4.5 M

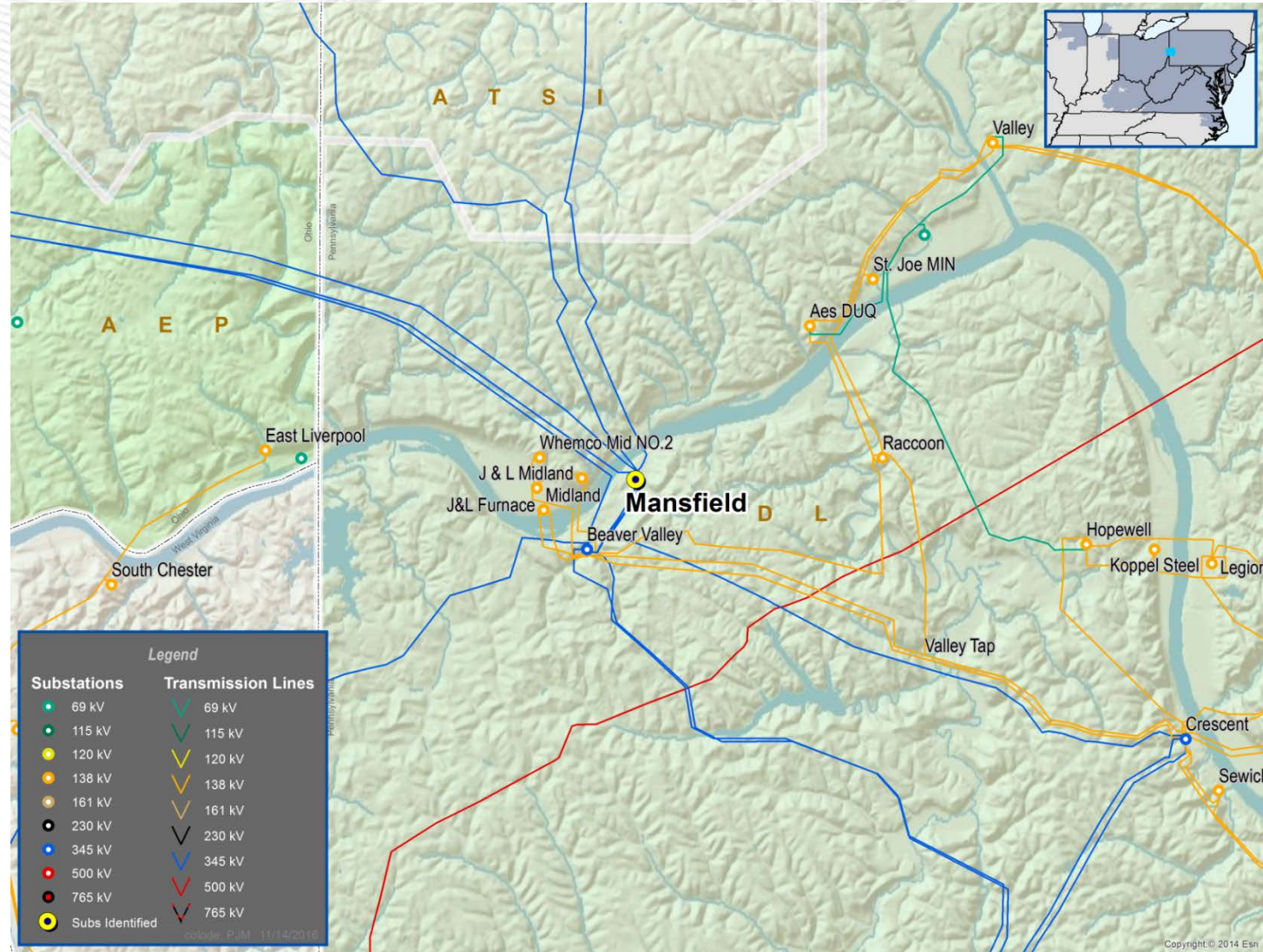
New Estimated Project Cost: \$8.25 M

This is a PSE&G generation funded project.

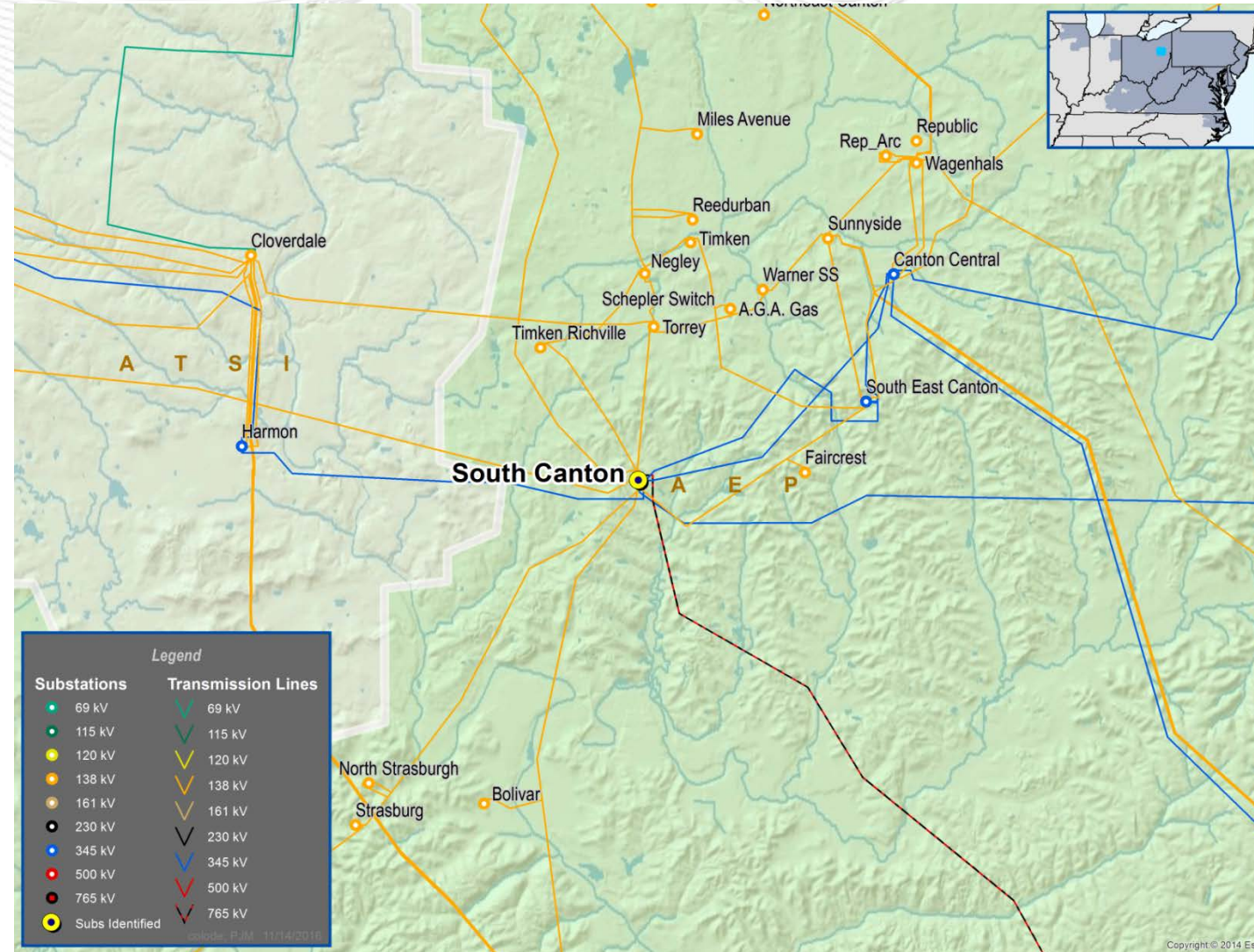
Required IS Date: 6/1/2018



- Short Circuit (FG# SC-1):
- The Bruce Mansfield 345 kV breaker 'B57' is overstressed.
- **Recommendation:**
 - Replace Bruce Mansfield 345 kV breaker 'B57' with an 80 kA breaker, and associated gang-operated disconnect switches D56 and D58 (2016_3-6F) (B2780)
- **Estimated Project Cost: \$1.3 M**
- **Required IS Date: 6/1/2021**
- **Projected IS Date: 11/30/2017**



- Short Circuit (FG# SC-4, SC-5):
- The South Canton 138 kV breakers 'L' and 'L2' are overstressed.
- **Recommendation:**
 - Replace South Canton 138 kV breakers 'L' and 'L2' with 80 kA breakers (2016_3-4E) (B2733)
- **Estimated Project Cost: \$780 K**
- **Required IS Date: 6/1/2021**





Supplemental Projects



ComEd Transmission Area

Supplemental Project

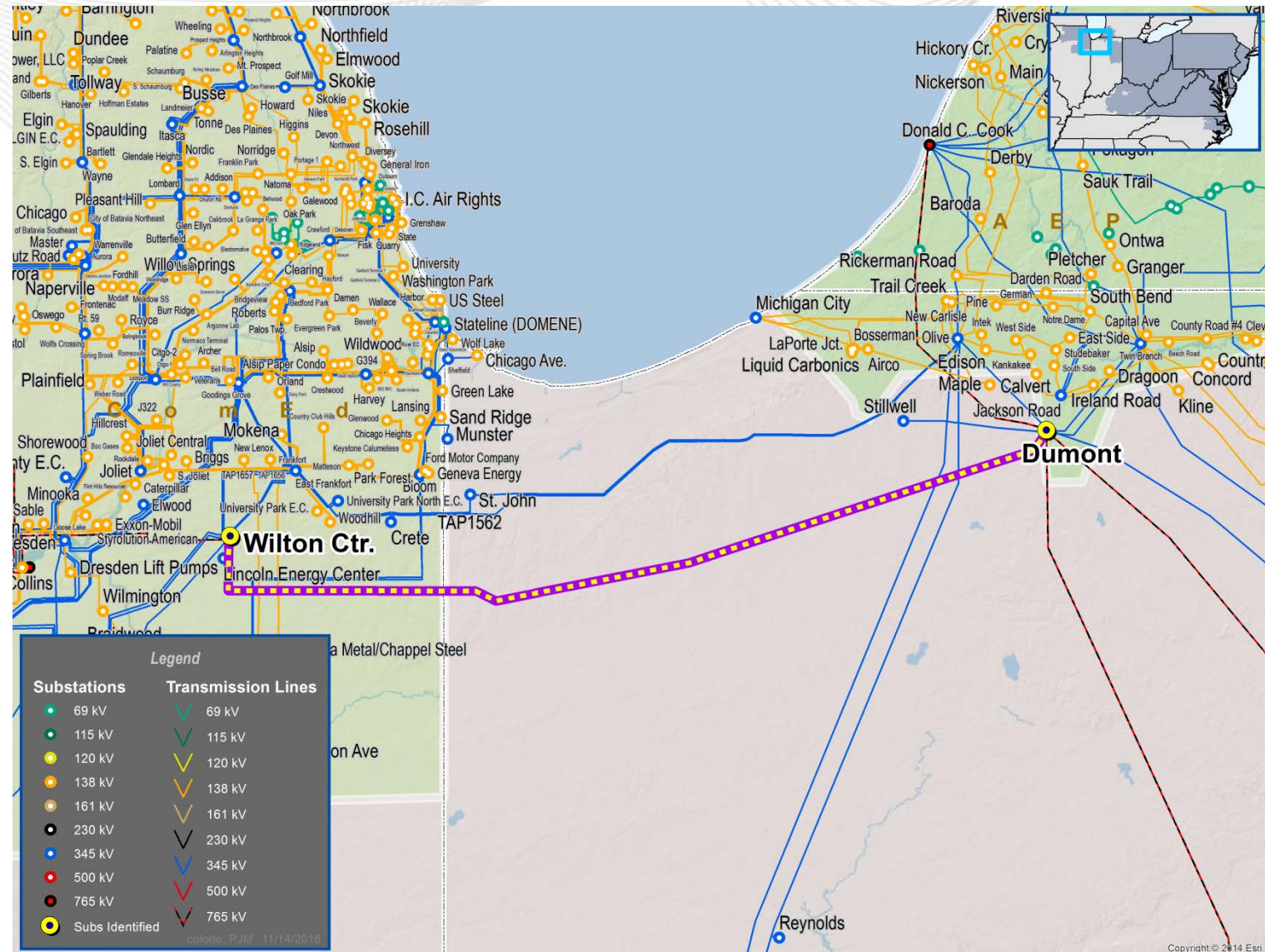
Problem Statement:

- 765 kV line 11215 from Wilton Center to Dumont has a 150 MVAR shunt inductor at Wilton Center and a 300 MVAR shunt inductor at Dumont in AEP. The AEP inductor will have a circuit breaker installed under b2231 (Install 765 kV reactor breaker at Dumont 765 kV substation on the Dumont - Wilton Center line).
- The Wilton Center inductor is bolted to the line with no switching device.
- This line has a large impact on the PJM market.
- The inductor is removed in summer months for voltage support and returned to service in the fall. Each time it is switched requires a day long outage to bolt or unbolt the connections.
- Installing a CB on the inductor will have several benefits:
 - No more line outages required for seasonal switching.
 - The inductor can be switched in and out as conditions change instead of being switched seasonally
 - The inductor will automatically close in the event of a high voltage condition.
 - Line will stay in service for inductor faults

Potential Solution:

Install 765 kV CB at Wilton Center 765kV substation on line 11215 (Wilton Center – Dumont 765kV line) shunt inductor (S1204)

- Estimated Project Cost: \$5.8M
- Projected IS Date: 12/31/2017
- Project Status: Engineering Phase





Supplemental Project

Problem Statement:

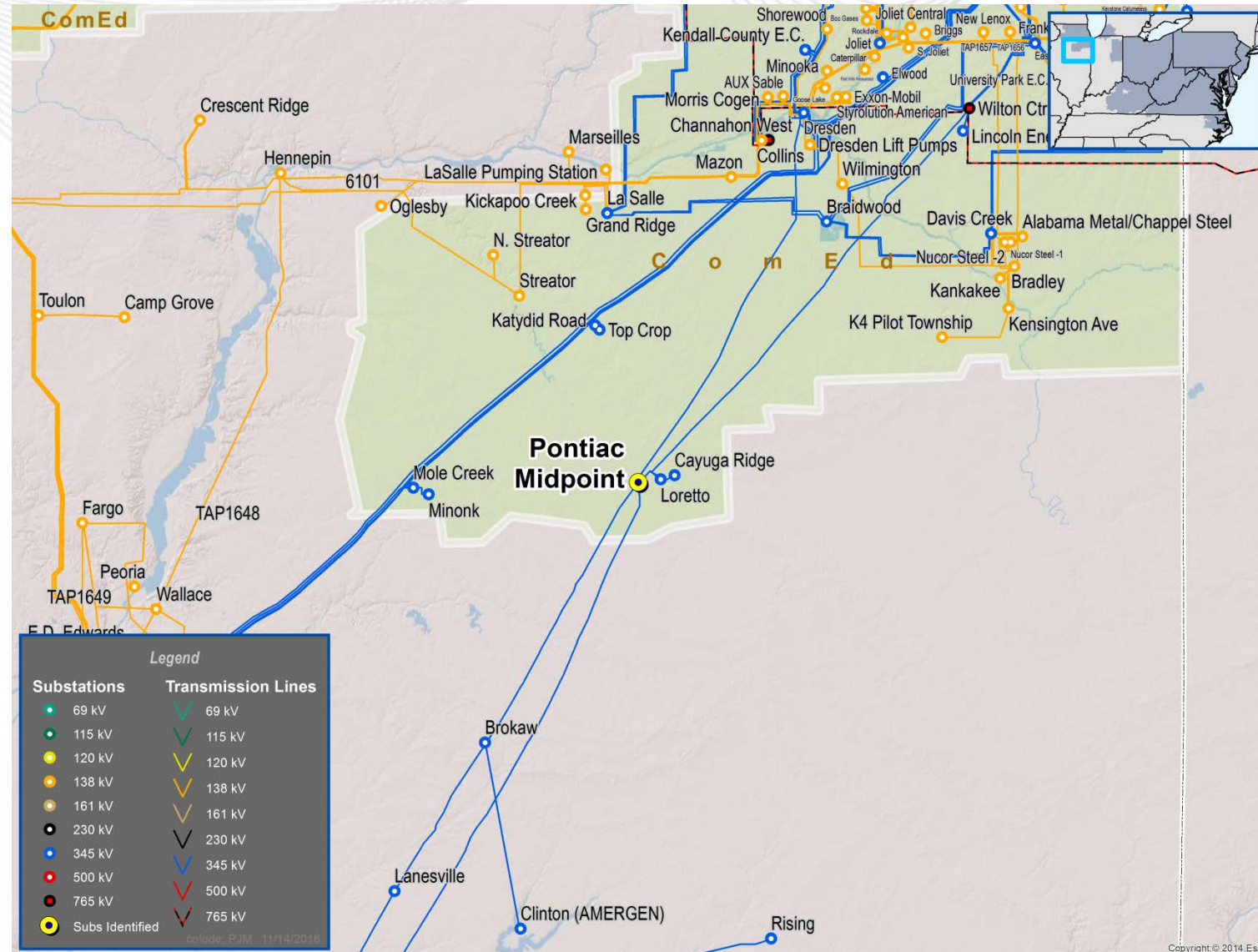
- Presently Pontiac transformer 82 shares a 345 kV ring bus position with 345 kV line 8014 (Pontiac – Dresden).
 - There is no high-side circuit breaker on transformer 82, so any transformer fault trips line 8014.
 - The line must be switched out of service to switch the transformer off.
 - A line fault on 8014 trips transformer 82.

Potential Solution:

At Pontiac 345kV station, install 345 kV bus tie 6-7 to separate the transformer and line onto their own bus sections and Install a high side circuit breaker on transformer 82 to bring it up to current standards. (S1205)

- Estimated Project Cost: \$4.1M
- Projected IS Date: 12/31/2017
- Project Status: Engineering Phase

ComEd Transmission Area

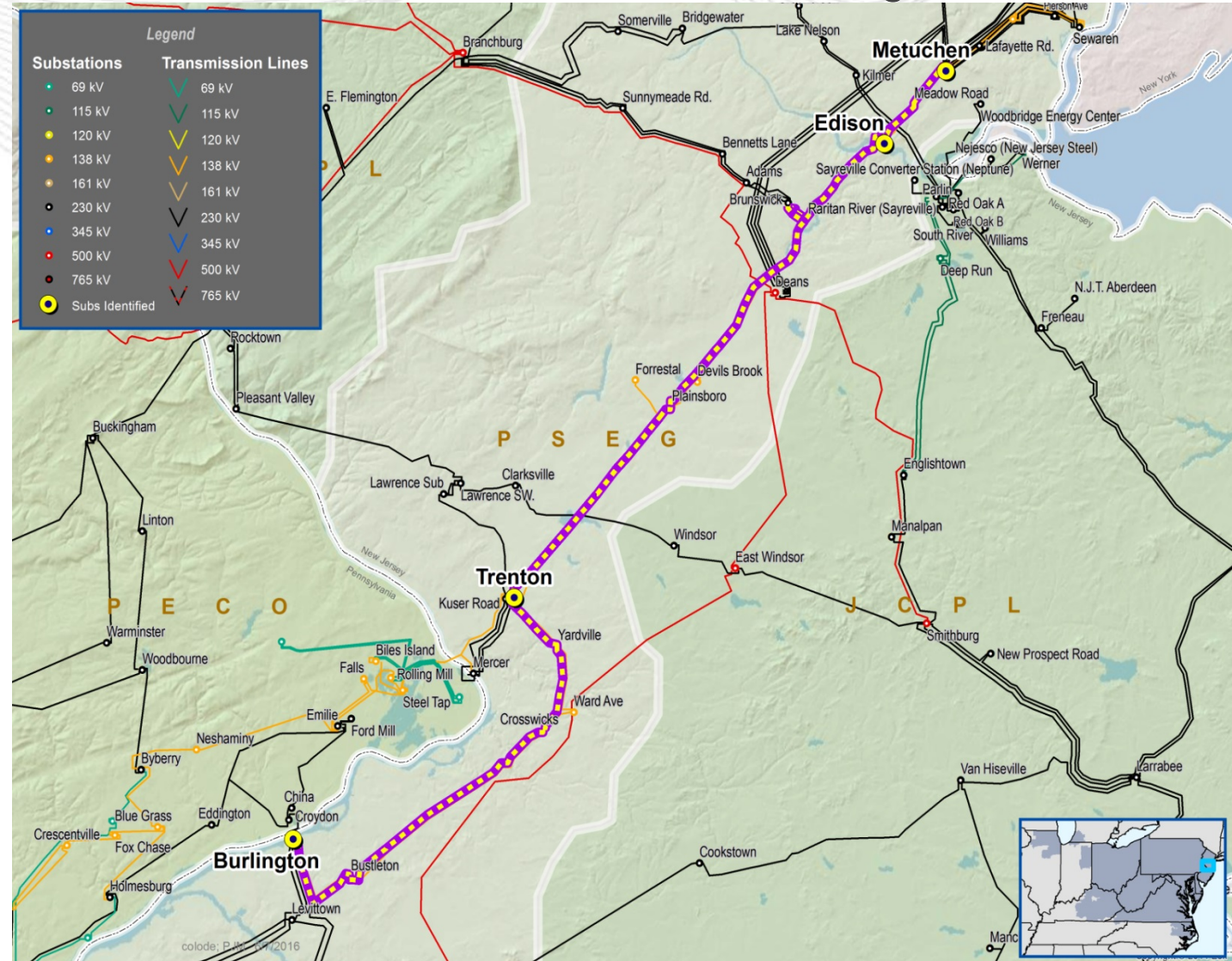


PSE&G End Of Life Assessment Metuchen – Edison – Trenton – Burlington Corridor



PSE&G Transmission Zone Metuchen – Burlington Corridor

- PSE&G's FERC 715 Transmission Owner criterion addresses equipment condition assessments
 - PSE&G assessed the condition of the Metuchen to Trenton (MT-T) and Trenton to Burlington (T-BU) 138 kV circuits.



- Refer to PSE&G criteria:

VII. EQUIPMENT ASSESSMENT AND STORM HARDENING

<http://www.pjm.com/~media/planning/planning-criteria/PSE&G-planning-criteria.ashx>

- Metuchen to Trenton is approximately 30 miles of 138 kV circuit and the average structure age is 86 years.
- Trenton to Burlington is approximately 22 miles of 138 kV circuit and the average structure age is 75 years.

- Assessment Result:
 - Consultant - Foundation assessment
 - 23% and 30% of structures for MT-T and T-BU respectively will require extensive foundation rehabilitation or total foundation replacement.
 - Consultant – Tower line assessment
 - 25% of the tower structures exceed the tower load carrying design capability
 - 35% of the towers are at 99-100% of the tower's load bearing capability, and 81% of the towers at 95-100% of the tower's capability.



Figure 1: Examples of 25-30% foundation structure loss

- Deteriorating tower leg, gusset plates and angles due to corrosion
- “Condition E” in the consultant report indicates greater than 50% thickness loss of steel member
- Load carrying capability compromised



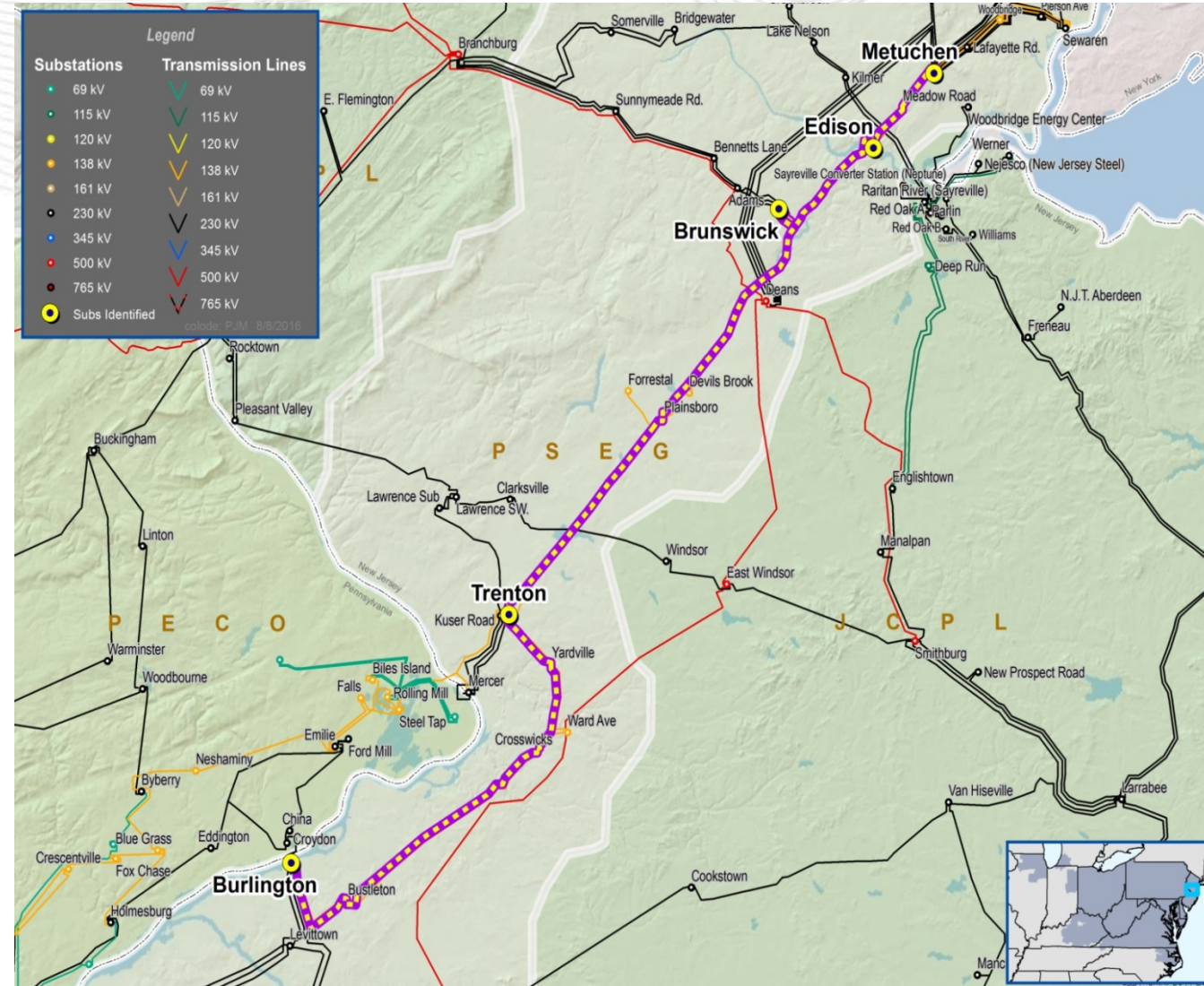
Problem:

PSE&G FERC 715 Transmission Owner Criteria

- Equipment condition assessment for the entire corridor
- Equipment has reached its end of life

NERC Reliability Criteria

- N-1-1 voltage violations in the Metuchen vicinity in the 2016 RTEP Window #2



- Remove the 138 kV corridor without replacing
- Install new parallel circuit on new right of way and remove the existing corridor
- Replace / rebuild the 138 kV corridor in kind with new foundations, 138 kV structures and hardware.
- Convert the 138 kV corridor to 230 kV

Remove Existing Corridor Without Replacing

- Load (approximately 544 MVA) would need alternative supply at nine stations
- No transmission supply available near Devils Brook, Plainsboro, Yardville, Crosswicks, and Bustleton.
- Would require extensive new 69kV line construction
- Loss of existing transmission corridor
- High population density
 - Would require extensive underground construction.
- This option does not eliminate b2590, “Install two 75 MVAR 230 kV capacitors at Sewaren station” (\$8.4M). Also, does not eliminate b2589, “Install a 100 MVAR 230 kV shunt reactor at Mercer station” (\$7.2M).

Install New Circuit and Remove/Abandon Existing

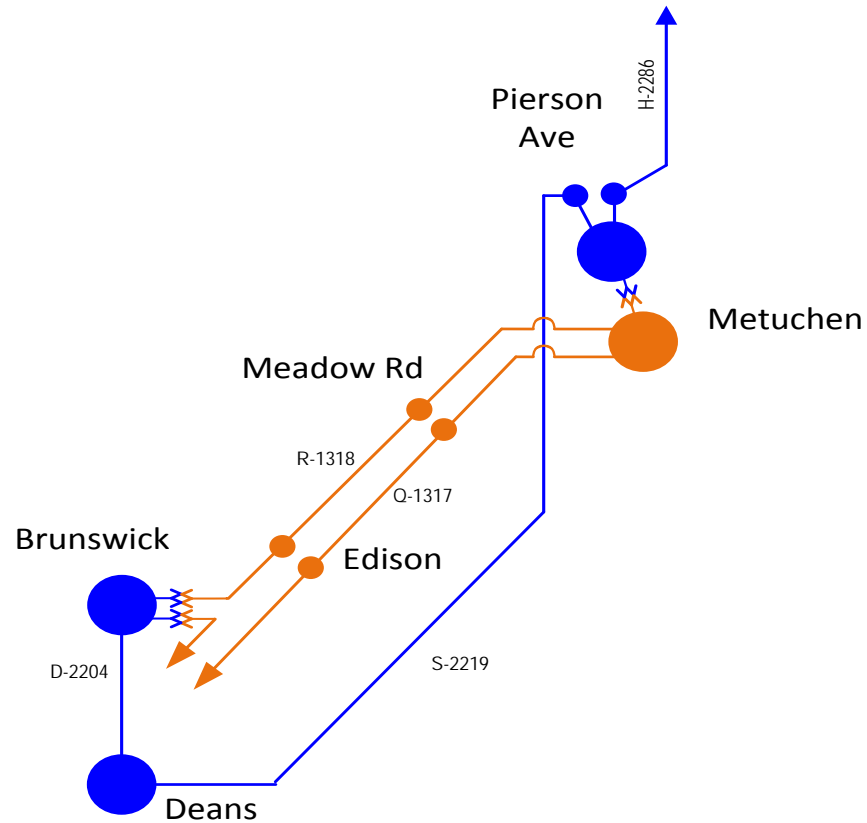
- High population density in the corridor
 - ability to obtain new transmission ROW feasibility is challenging or not feasible
 - would require extensive underground construction
- Need to supply nine existing stations, requiring new circuits to loop in an out of the existing stations
- Would require extensive new 69kV line construction.
- Limited 69 kV circuit capacity and line length due to voltage drop
- This option does not eliminate b2590, “Install two 75 MVAR 230 kV capacitors at Sewaren station” (\$8.4M). Also, does not eliminate b2589, “Install a 100 MVAR 230 kV shunt reactor at Mercer station” (\$7.2M).

- Rebuild / Replace existing facilities
- Costs
 - Metuchen to Brunswick - \$126M
 - Brunswick to Trenton - \$265M
 - Trenton to Burlington - \$293M

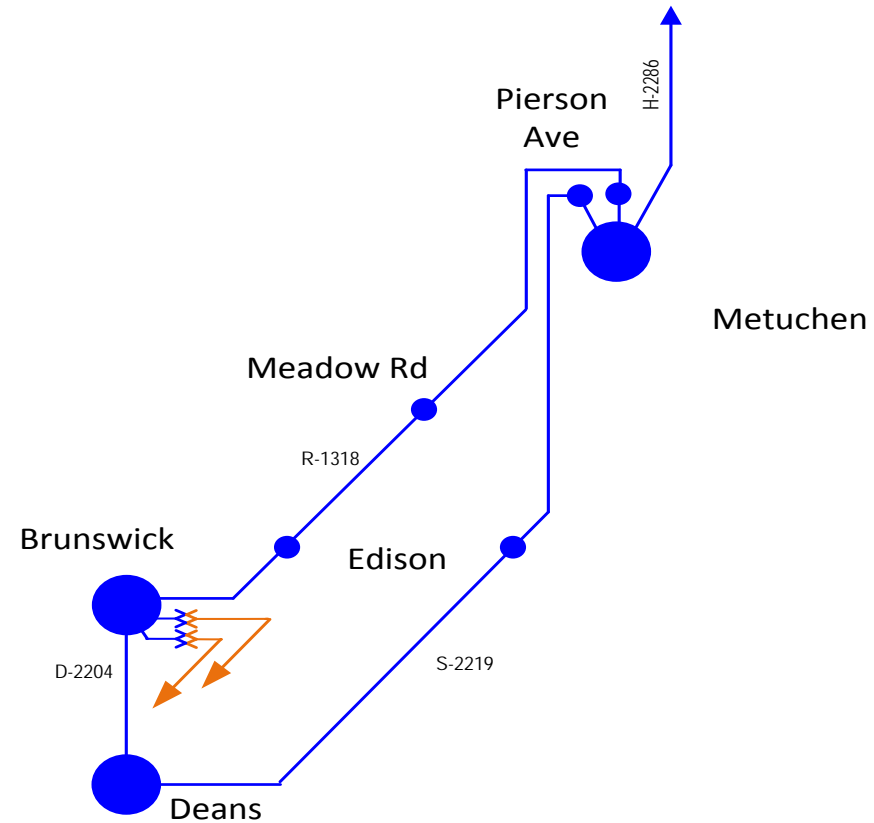
- Potential Solution for Metuchen - Burlington:
 - Convert the R-1318 and Q1317 (Edison – Metuchen) 138 kV circuits to one 230 kV circuit
 - Metuchen 138 kV will be eliminated
 - The Brunswick 230/138 kV autotransformer will be eliminated
 - The new converted 230 kV circuit will be terminated at the existing Metuchen and Brunswick 230 kV stations.
- Project Benefits:
 - Resolves voltage violation in the Metuchen vicinity identified in the 2016 RTEP 2nd Window
 - Eliminates the need for baseline upgrade (B2590 – Install two 75 MVAR 230 kV capacitors at Sewaren station) identified in the 2014 RTEP window.
 - Strengthens the system by replacing 138 kV circuits with 230 kV circuits, improving capacity and voltage.
 - Creates a strong tie between Southern and Central PSE&G
 - Increases transfers capability to Central PSE&G
 - Addresses future reliability and economic needs
- Estimated Project Cost: \$ 125 M

Metuchen – Brunswick Existing and Future Diagram

Before



After



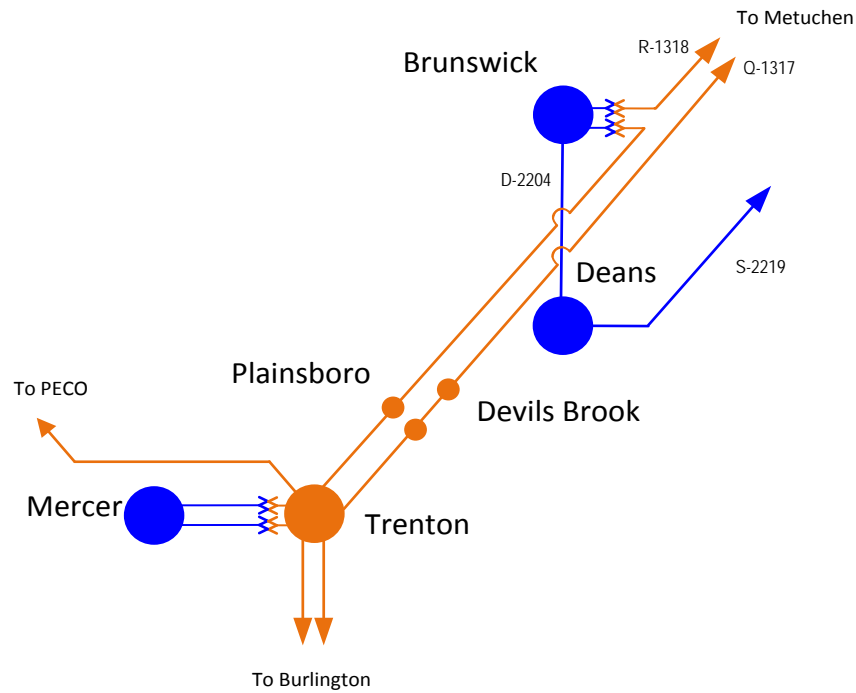


- **Potential Solution for Brunswick - Trenton:**
 - Convert the N-1340 and T-1372/D-1330 (Brunswick – Trenton) 138 kV circuits to 230 kV circuits
 - The converted circuits will be terminated at the existing Brunswick 230 kV
 - The new converted 230 kV circuit will be terminated at the Trenton 138 kV station with two 138 kV transformers
- **Project Benefit:**
 - Strengthens the system by replacing 138 kV circuits with 230 kV circuits, improving capacity and voltage.
 - Provides better transfers across the network
 - Addresses future reliability and economic needs

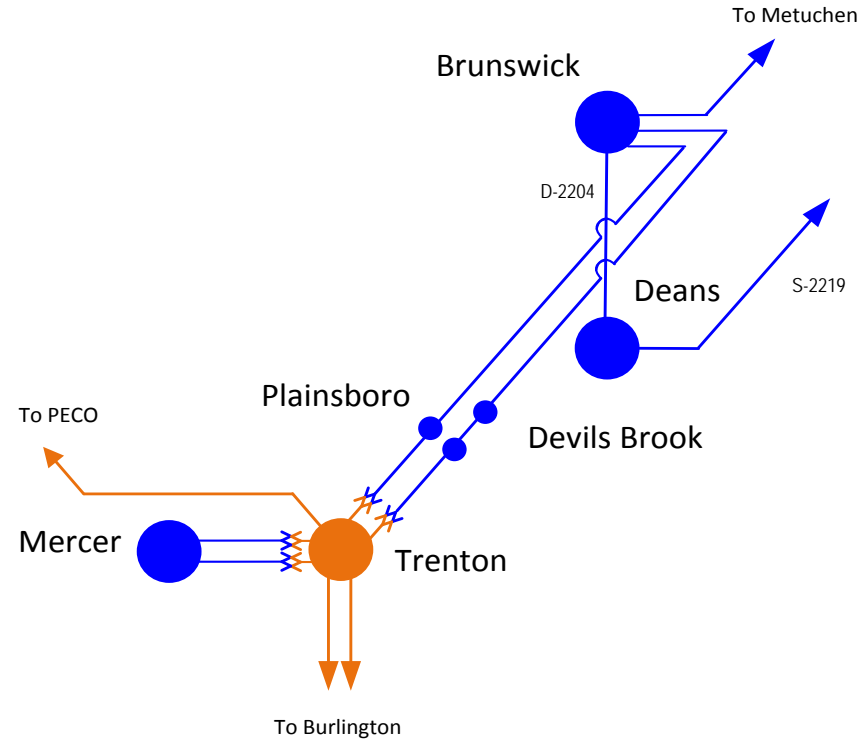
Estimated Project Cost: \$ 302 M

Brunswick – Trenton Existing and Future Diagram

Before



After





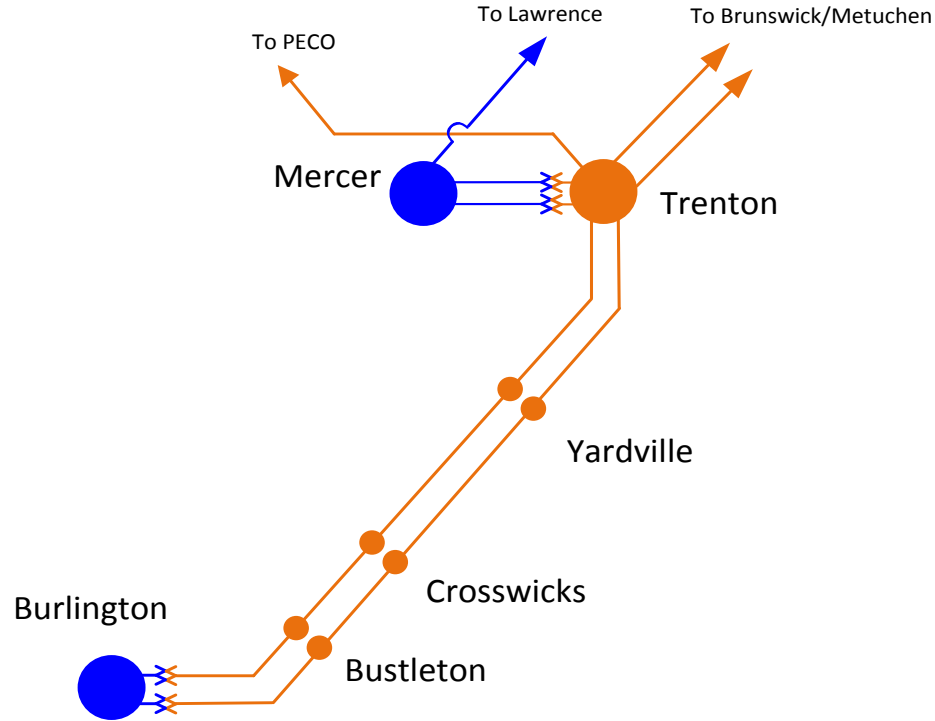
Convert the R-1318 and Q1317 (Edison – Metuchen) 138 kV circuits to one 230 kV circuit

- Potential Solution for Trenton - Burlington:
 - Convert the F-1358/Z1326 and K1363/Y-1325 (Trenton - Burlington) 138 kV circuits to 230 kV circuits
 - Trenton 138 kV substation will be replaced with six bay breaker and half 230 kV substation
 - Install 230/138 kV transformer at Trenton to serve the Trenton – US Steele 138 kV circuit.
- Project Benefit:
 - Eliminates the need for baseline upgrade (B2589 – Install a 100 MVAR 230 kV shunt reactor at Mercer station) identified in the 2014 RTEP window.
 - Strengthens the system by replacing 138 kV circuits with 230 kV circuits, improving capacity and voltage.
 - Provides better transfers across the network

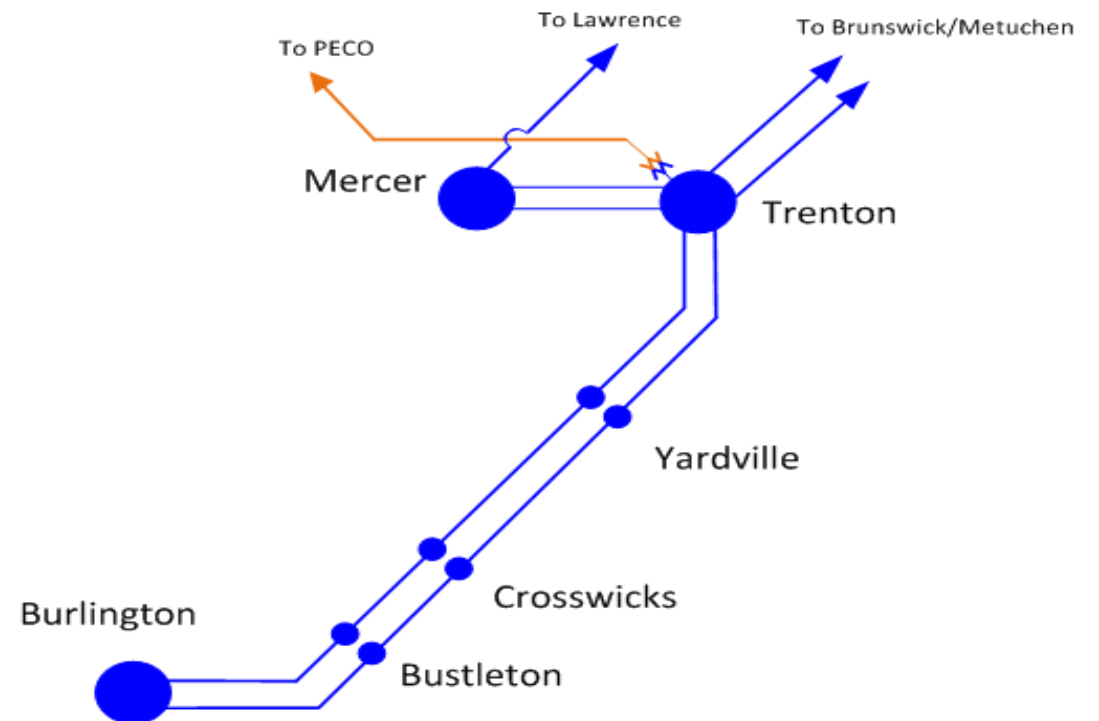
Estimated Project Cost: \$ 312

Trenton – Burlington Existing and Future Diagram

Before



After



- Cost: 138kV vs 230kV cost estimates
 - Metuchen – Brunswick
 - \$126M for 138 kV and \$125M* for 230 kV
 - Brunswick – Trenton
 - \$265M for 138 kV and \$302M for 230 kV
 - Trenton – Burlington
 - \$293M for 138 kV and \$312M for 230 kV
- Replacing with 138kV does not address voltage issues in the Metuchen area
- The 230 kV conversion option will eliminate the need for the following projects (total cost - \$67.1 M)
 - Metuchen and Edison 138kV Stations approaching end of life and require replacement in the near term - \$28 M
 - Sewaren Caps and Mercer Reactors required with the 138kV option - \$15.6 M
 - Class-H transformers that require replacement in the near term - \$10.5
 - Autotransformers (3) savings from other projects - \$7 M
 - Refurbishment of Trenton control house building - \$1 M
 - Refurbishment of Metuchen auto transformer and installation of Brunswick autotransformer - \$5 M

*Higher cost of the 138kV attributed to replacement of the existing Brunswick 230-138kV transformer, the 230kV option eliminates the transformer.



RTEP Next Steps

- 1/5/2017
 - SRRTEP-West, SRRTEP-Mid-Atlantic, SRRTEP-South meetings scheduled
 - 2017 Subregional Assumptions & Local Transmission Owner Assumptions Review
 - Reliability and Supplemental Project Review

- 1/12/2017
 - TEAC
 - Continue 2017 RTEP Assumptions Review
 - Reliability and Supplemental Project Review

- 2/14 – 2/15/2017
 - PJM Board Meeting

Questions?

Email: RTEP@pjm.com

- Revision History
 - V1 – 12/13/2016 – Original Version Posted to PJM.com
 - V2 – 12/14/2016 – Updated slide 41 to show evaluation in progress, update slide 21 to correct typo for project 3C and FG 907
 - V3 – 12/14/2016 – Added slide 21 to include FG detail; Updated slide 31, expected IS date; Added section with slides for Metuchen-Trenton-Burlington Corridor
 - V4 – 12/15/2016 – Updated map on Slide 21