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Technical Memorandum

Review Water Quality Certification Materials, Proposed PennEast Pipeline

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1.0 INTRODUCTION

PennEast Pipeline Company, LLC (PennEast) proposes to construct a pipeline to transport natural gas from the Marcellus Shale production region in northern Pennsylvania to portions of southern New Jersey and southeastern Pennsylvania. This technical memorandum reviews groundwater and related groundwater quality and quantity impacts caused by the development of that pipeline and shows that the pipeline will not meet the requirements of the relevant Pennsylvania code.

PennEast submitted applications to the Delaware River Basin Commission (DRBC), State of Pennsylvania (PA), and the Federal Energy Regulation Commission (FERC) for approval. FERC has prepared a draft environmental impact statement (DEIS) for the project which includes information not in in this application or in other documents. Currently, the PennEast Pipeline is being considered for Pennsylvania water quality certification under as required under Section 401 of the Clean Water Act (33 USC § 1341) as implemented in Pennsylvania under 25 Pa. Code § 105.13 and .14. The application for certification includes PennEast (2016a and b), the primary documents reviewed in this technical memorandum. Because those documents do not contain much information regarding the potential impacts to water quality, additional PennEast documents were reviewed. The primary chapter for additional review is Resource Report 2 (RR2)[1]. RR2 discusses the aquifers the pipeline would cross, specifies the recharge areas and rates, and discusses contamination; RR2 is much more complete than PennEast (2016a). To supplement the review of RR2, I also reviewed the general project description, Resource Report 1[2], geology report, Resource Report 6[3], soils report, Resource Report 7[4], the vegetation report, Resource Report 3[5], and the wetland delineations reports and maps, Appendix D, USFWS Wetland Delineation Maps. The DEIS is also consulted regarding issues not covered elsewhere.

2.0 SUMMARY OF GROUNDWATER IMPACTS

Penn East has failed to provide the impacts analysis which require "[a] detailed analysis of the potential impacts, to the extent applicable, of the proposed project on **water quality, stream flow**, fish and wildlife, **aquatic habitat**, Federal and State forests, parks, recreation, **instream and downstream water use**, prime farmlands, areas or structures of historic significance, streams which are identified candidates for or are included within the Federal or State wild and scenic river systems and other relevant significant environmental factors" (25 Pa. Code § 105.15(e)(1)(x), emphasis added). The emphasized factors in the quote (Id.) are hydrogeology related such that changes in groundwater relations, including recharge, preferential flow, pipeline induced drawdown, and contaminant transport, could impact wetlands and streams crossed by or closely approached by the proposed pipeline The

[1] PennEast Pipeline, Resource Report 2, Water Use and Quality, September 2015. Hereinafter referred to as RR2.
[2] PennEast Pipeline, Resource Report 1, General Project Description, September 2015. Hereinafter referred to as RR1.
[3] Penn East Pipeline, Resource Report 6, Geological Resources, September 2015. Hereinafter referred to as RR6.
[4] Penn East Pipeline, Resource Report 7, Soils, September 2015. Hereinafter referred to as RR7.
[5] PennEast Pipeline, Resource Report 3, Fisheries, Vegetation, and Wildlife, September 2015. Hereinafter referred to as RR3.

following summary discusses how pipeline construction and operation would affect groundwater and how the application fails to consider the impacts on groundwater and the factors noted above.

Pipeline construction could affect groundwater by changing recharge rates and locations, causing drawdown both temporarily, during construction, and permanently causing pathways for contaminants to enter the subsurface, creating preferential flow pathways for shallow groundwater flow, and changing drainage patterns which would affect where recharge occurs. The pipeline would primarily contain natural gas, meaning methane although small amounts of ethane and longer chain gases could be included. A methane leak would be directly into shallow groundwater if the pipeline is below the water table (which would be the case in areas with a shallow water table such as wetlands and stream crossings).

- Pipeline construction changes recharge by changing properties of the soils within the right of way (compaction, scraping), properties of the aquifer where it is excavated and backfilled, and by changing surface drainage patterns which could affect the recharge of runoff.
- Pipeline construction lowers the water table temporarily by dewatering the trench. It lowers the water table permanently by changing the aquifer properties within the trench; for example, increased conductivity in the backfill could create a pathway with lower resistance and change the water table level within the trench.
- Pipeline construction creates preferential pathways by changing the properties of the aquifer due to differing properties of the backfill.
    - If the backfill has higher conductivity than the surrounding aquifer, groundwater will flow preferentially within the backfilled trench.
    - If the backfill has lower conductivity, which is possible with substantial compaction of the backfill in a till or alluvial aquifer, it could block flow across the pipeline. The extreme case would be for the pipeline to cause water to surface upgradient from the trench.
- Pipeline construction through bedrock aquifers would change the properties as described in the previous bullet.
    - If the bedrock is highly fractured, such as in parts of the Catskill formation, backfill with silty till could easily have lower conductivity than the surrounding fractured bedrock.
    - Backfill with alluvium through intact bedrock would cause a high conductivity pathway.
- A leak in a pipeline would enter the groundwater in the trench, and its disposition would depend on properties of the backfill and probably even the rate.
    - A large leak would probably bubble to the surface and volatilize.
    - A small leak would probably dissolve into the groundwater, which can hold methane up to 28 mg/l at atmospheric pressure, and transport along with the groundwater flow as described in previous bullets.
    - Interestingly, because of the gas dissolving into the groundwater and because a small leak could be less detectable, a small leak could cause longer term groundwater problems.

- Pipeline construction can also change surface drainage patterns which could change the location where runoff becomes recharge.

The review in this memorandum regarding groundwater will follow and expand on the outline in the previous bullets.

3.0 GROUNDWATER BACKGROUND

Construction and operations of the proposed pipeline affects groundwater in numerous ways that can then affect surface water and wetlands. The diameter of the pipeline would be 36 inches with two of the laterals having either 24- or 12-inch diameter. The pipeline would have a minimum cover of 48 inches, except in a few places (RR1, p 1-66). That suggests the bottom of the pipeline would be at least seven feet below ground surface (bgs). It would also go under other pipelines that it crosses, so ostensibly it could be deeper than seven feet (Id.). Backfill is material removed from the trench (RR1, p 1-68) with the bedding being “rock-free dirt” (Id.) of an unspecified thickness.

The project could decrease groundwater recharge, which will decrease the groundwater discharge as well. Groundwater discharge controls stream baseflow and maintains the water level in wetlands during dry periods. Trench construction and backfill changes the conductivity of the formations which either causes preferential flow or blocks flow. Higher conductivity leads to preferential flow which can cause an aquifer to drain more quickly and ease the pathway for contaminants to reach wetland and streams. Lower conductivity backfill would restrict groundwater flow that intersects the trench and possibly divert from its natural discharge point or even cause it to surface. All of these factors can decrease surface baseflow, cause wetlands to dry more quickly, and cause more contaminants to reach streams and aquifers. The application documents outline the aquifers, soils, vegetation, and natural recharge (RR2, RR3, and RR6) but does not consider the impacts that pipeline construction and operation would have on them and the ultimate effect on streams and wetlands, in violation of the relevant requirements (25 Pa. Code § 105.15(e)(1)(x)).

3.1 Recharge

The applicant’s recharge map (RR2, Figure 2.2.4-1 for Pennsylvania) shows broad areas of distributed recharge. Distributed recharge means the recharge estimate is based on recharg being spread over a broad area. The rate is simply a flow, assumed to emanate from recharge over the entire area, divided by area expressed in length/time, usually inches/ year. It does not account for heterogeneities in the geology, such as caused by faults or anticlines (the folding away from the crest of an anticline causes tension cracks in the bedrock which allows more meteoric water to enter the aquifer at the crest than elsewhere) or topography.

Recharge (RR2, Figure 2.2.4-1) was estimated using Wolock (2003), a nationwide digital data set of recharge estimates on a nationwide grid of 1 km grid cells. The abstract for Wolock (2003) is as follows: “This 1-kilometer resolution raster (grid) dataset is an index of mean annual natural ground-water recharge. The dataset was created by multiplying a grid of base-flow index (BFI) values by a grid of mean annual runoff values derived from a 1951-80 mean annual runoff contour map. Mean annual runoff is long-term average streamflow expressed on a per-unit-area basis". Reese and Risser (2010) noted that Wolock emphasized the recharge values "are strictly for the long term, and qualifies the use of the results and method" (Reese and Risser 2010, p 9) and that "site-specific recharge values are not expected to be accurate because of the generalization of data over time and space" (Id.). The values in RR2 Figure 2.2.4-1 should not be considered to represent the specific recharge at a point, such as the pipeline route.

Reese and Risser (2010) present an alternative recharge estimate for the state of Pennsylvania based on estimates for HUC10 watershed scales, which in Pennsylvania range from about 50 to 400 square miles. Comparison of Reese and Riser (2010) Plate 3 and RR2 Figure 2.2.4-1 does not suggest substantial differences in the methods. Reese and Risser (2010) Plate 5 indicates the estimation errors in the area of the pipeline (in PA) range from 2.0 to 3.83 inches. The regression equation used to develop the statewide estimates (Risser et al. 2008) had the following significant independent variables.

- Mean annual precipitation – more precipitation leads to more recharge, all else being equal. Factors that concentrated precipitation in an area should also increase the recharge.
- Average daily maximum temperature – this would be a surrogate variable for evapotranspiration and recharge likely decreases as this variable increases.
- Percent carbonate rock – carbonate rock is very conductive and this variable is a surrogate for the control that geology exerts on recharge. A larger percentage of carbonate rock means more recharge.
- Percent sand in soil – this probably relates the infiltration capacity of the soil, so that more sand means more recharge.
- Average stream channel slope – this would be a surrogate for more relief which would probably relate to relief and steepness, with more runoff and less recharge occurring where the slope is steeper.

Although these factors were developed at a watershed scale, they could represent factors at a point. Methods used to estimate recharge at a point (for example, Flint and Flint 2008) try to complete a water balance and require estimates of at least the first four factors in the bullet list. Pipelines can have the largest, most widespread impacts to soils and vegetation (Pierre et al. 2015), which would primarily be represented as percent sand in the Risser et al regression equation. Effects on soils would primarily be compaction and lost vegetation.

Sections 3.11 through 3.14 outline factors that affect recharge or are soils related that could have significantly negative effects on hydrogeology including groundwater and surface water quality. The application (PennEast 2016a, RR2) does not address the impacts at all. These sections present a preliminary analysis that should be expanded greatly prior to considering a water quality certification.

3.11 Soils Review

Soils control recharge by affecting infiltration through the ground surface and by storing precipitation for use by vegetation or for percolation to groundwater. RR7 is the PennEast soils report which provides maps showing soil types along the proposed pipeline (Figure 7.1-1) and tables listing characteristics of the soils along the pipeline (RR7, Tables 7.1-1, -2). It has a summary table showing the percent of the proposed pipeline with critical characteristics including poorly or very poorly drained, excessively drained, poor revegetation potential, high compaction, severe erosion potential, prime farmland crossed, and slope. These tables and figures describe the base soil characteristics, except they fail to include hydrologic soil group (see next paragraph) and fail to consider characteristics together which could lead to more critical conditions. For example, constructing a pipeline through soils that are poorly drained with high compaction, especially on steep slopes, would create zones that would have significantly reduced recharge in the long term and probably increased runoff that could cause erosion down gradient.

Neither RR7 nor RR2 discusses NRCS (1986) hydrologic soil groups, commonly known as A, B, C, or D groups, considered the most important soils classification for hydrology (Pierre et al. 2015). Soils are assigned a curve number which describes their runoff potential and their sensitivity to disturbance which increases the curve number (and therefore runoff and decreases recharge). The runoff classification can even be used to assess recharge because higher runoff soils (ie, group D) allow less recharge. Although some of the characteristics provided in RR7 include similar information, descriptions are not as useful for considering the impacts over a large project as would be curve number classifications.

Pipeline construction disturbs soils in two ways. It removes vegetation which shelters the soil from raindrop erosion and compacts and furrows the soil. Some vegetation will regrow but shrub and tree canopy would require decades to reestablish, if allowed to do so due to maintenance requirements.

Table 1 shows the mileage for soils that have high compaction potential and poor drainage along the pipeline developed from RR7 Table 7.1-2. Approximately 9.25 miles or 7.8% of the total length in both states including laterals have high compaction potential and poor drainage. The slopes were moderate, with the steepest being 6%, enough to generate significant runoff from disturbed slopes. Silt and clay make soil easier to compact so pipeline reaches with high silt/clay could be most compacted and recharge most reduced.

Table 1: Soils subject to a high potential of compaction, by mile post. From RR7 Table 7.1-2.

Begin	End MP	Length	Drainage	Slope	Soil series
0	0	0.05	Poorly	6	Chippewa silt loam
3.1	3.1	0.05	Very poorly	2	Wayland silt load
5.5	5.5	0.05	Poorly	6	Rexford loam
6.2	6.3	0.1	Poorly	2	Holly Silt Loam
6.5	6.5	0.05	Poorly	2	Holly Silt Loam
13.1	13.3	0.2	Poorly	6	Rexford loam

16.8	16.9	0.1	Very poorly	4	Chippewa very stony silt loam
17.7	17.7	0.05	Very poorly	4	Chippewa very stony silt loam
17.7	17.8	0.1	Very poorly	1	muck
24.5	24.5	0.05	Very poorly	3	Lickdale and Tughill very stony loams
26.5	26.6	0.1	Very poorly	4	Norwich very stony loam
27	27.3	0.3	Very poorly	1	muck and peat
29.5	29.6	0.1	Very poorly	1	muck and peat
30.1	30.9	0.8	Poorly	4	Shelmadine very stony silt loam
30.9	31.1	0.2	Very poorly	3	Lickdale and Tughill very stony loams
31.1	31.2	0.1	Poorly	2	Shelmadine silt loam
32.4	32.6	0.2	Very poorly	3	Lickdale and Tughill very stony loams
33.1	33.1	0.05	Poorly	2	Holly Silt Loam
34.5	34.8	0.3	Very poorly	1	Papakating silty clay loam
35.1	35.4	0.3	Poorly	4	Shelmadine very stony silt loam
35.4	35.4	0.05	Poorly	4	Shelmadine very stony silt loam
36	36	0.05	Poorly	4	Shelmadine very stony silt loam
36	36.1	0.1	Very poorly	3	Lickdale and Tughill very stony loams
36.1	36.2	0.1	Poorly	4	Shelmadine very stony silt loam
36.1	36.1	0.05	Poorly	2	Holly Silt Loam
36.5	36.6	0.1	Poorly	4	Shelmadine very stony silt loam
36.6	36.8	0.2	Very poorly	3	Lickdale and Tughill very stony loams
36.8	36.9	0.1	Poorly	4	Alvira and Shalmadine very stony silt
36.9	37.2	0.3	Poorly	2	Alvira and Shalmadine very stony silt
41.1	41.2	0.1	Poorly	2	Alvira and Shalmadine very stony silt
41.2	41.5	0.3	Poorly	4	Alvira and Shalmadine very stony silt
41.6	41.6	0.05	Poorly	2	Holly Silt Loam
45	45.1	0.1	Poorly	2	Holly Silt Loam
49	49.4	0.4	Very poorly	1	Papakating silty clay loam
53.5	53.5	0.05	Poorly	4	Andover-Buchanan gravelly loams
53.5	53.5	0.05	Poorly	4	Andover-Buchanan gravelly loams
53.7	53.7	0.05	Poorly	2	Andover-Buchanan gravelly loams
54.2	54.3	0.1	Poorly	2	Andover-Buchanan gravelly loams
54.3	54.4	0.1	Poorly	2	Andover-Buchanan gravelly loams
54.3	54.3	0.05	Poorly	4	Andover-Buchanan gravelly loams
55.9	56	0.1	Poorly	2	Brinkerton-Comly silt loams
56.7	56.7	0.05	Poorly	6	Brinkerton-Comly silt loams
58.5	58.5	0.05	Poorly	2	Brinkerton-Comly silt loams
59.2	59.2	0.05	Poorly	6	Brinkerton-Comly silt loams
60.3	60.3	0.05	Poorly	2	Holly Silt Loam
61.4	61.5	0.1	Poorly	2	Brinkerton-Comly silt loams
63.5	63.6	0.1	Poorly	2	Holly Silt Loam
70.9	71	0.1	Poorly	1	Fluvaquents
72.5	72.8	0.3	Poorly	4	Cokesbury-Califon channery silt loams
72.9	73	0.1	Poorly	5	Cokesbury silt loam
73.1	73.4	0.3	Poorly	4	Cokesbury-Califon channery silt loams
73.4	73.6	0.2	Poorly	5	Cokesbury silt loam
1.3	1.4	0.1	Poorly	5	Cokesbury silt loam
92.5	92.7	0.2	Poorly	1	Croton silt load
92.7	92.8	0.1	Poorly	1	Bowmansville silt loam
92.8	93	0.2	Poorly	1	Croton silt load

93	93.5	0.5	Poorly	1	Croton silt load
93.3	93.3	0.05	Poorly	4	Croton silt load
94	94.1	0.1	Poorly	4	Croton silt load
94.3	94.3	0.05	Poorly	3	Croton silt load
94.5	94.6	0.1	Poorly	3	Croton silt load
94.5	94.6	0.1	Poorly	1	Croton silt load
95	95.1	0.1	Poorly	4	Croton silt load
97.4	97.5	0.1	Poorly	4	Reaville wet variant silt loam
104.8	104.8	0.05	Poorly	1	Bowmansville silt loam
105.9	106	0.1	Poorly	1	Bowmansville silt loam
108.3	108.3	0.05	Poorly	1	Doylestown and Reaville variant silt
112.7	112.9	0.2	Poorly	1	Doylestown and Reaville variant silt

Individual reaches shown in Table 1 are mostly less than 0.3 miles in length, with a 0.8 mile reach at MP 30.1 being an exception. Details of these areas would help determine the significance of the impact. Knowing depth to bedrock is essential because it defines the thickness through which groundwater flow would occur, but the presentation of such information in RR6 is very poor, with depth to bedrock provided only as related to soil types without mile posts (RR6, Table 6.3-4). Starting at MP 29.5 is a series of high compactable soils through MP31.2 (Table 1 and Figure 1). This reach is generally up and down the slopes of a ridge in Hickory Mountain State Park so runoff would be straight downhill. Pipeline construction would cause a strip of decreased recharge and increased overland flow. Recharge along the pipeline from about MP 29.6 to 30.0 would directly support the wetland centered at MP 29.6 (Figure 2). Recharge varies from 20 to 22.2 in/y in this area (Figure 2.2.4-1, RR2), so pipeline construction would reduce recharge (and inflow to the wetland) by as much as 4.4 af/y (0.006 cfs or 2.8 gpm). Based on the size of the wetland, the area affected by the pipeline appears to be a couple percent of its tributary area, but the effect of losing it would depend on the connectivity of parts of the wetland.

Figure 1: Snapshot of a portion of RR7 Figure 7.1-1 showing soils along the proposed pipeline, MP 29.5 to MP 31.8.

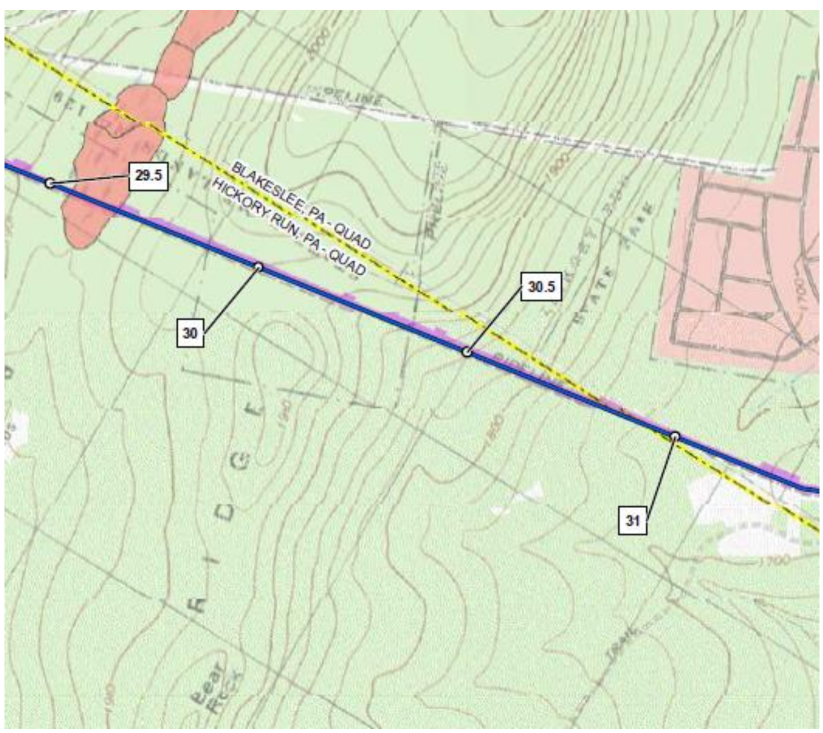

Figure 2: Snapshot of wetlands map (Appendix D, p 9 of 32).

At least 0.2 miles of compactible soil between MP 94.5 and MP 95.1 would reduce flow to the wetlands MP 95.1 (Figure 3). The soil is Croton silt loam (Figure 4). Other wetlands cross or bound the pipeline near MP 94.5 (Figure 3). The pipeline could intercept recharge either percolating at these points or flowing to the wetlands through shallow groundwater.

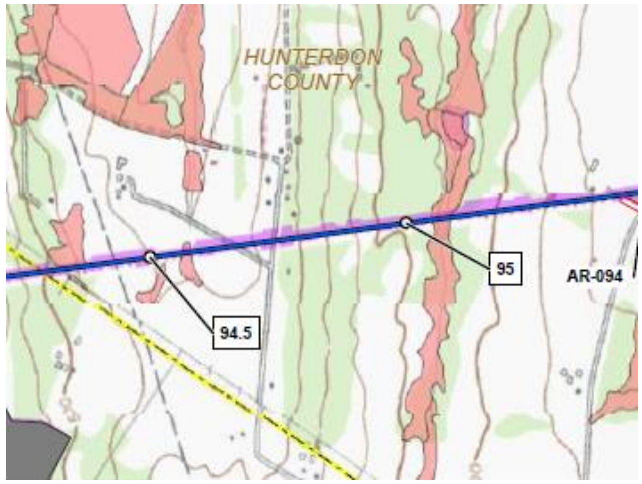

Figure 3: Snapshot of wetlands map (Appendix D, p 26 of 32).

Figure 4: Snapshot of soils maps from MP 93.8 to 95.8 (RR7, Figure 7.1-1). CoxBb is compactible Croton silt loam.

Compactible soils from MP 27 to 27.3 coincided directly with wetlands between the same mile posts. This could be one of the more challenging areas for pipeline construction and likely one of the areas that will be highly impacted. Compaction will prevent recharge through a significant section of the wetland and prevent flow which could create segmented aquifers within the wetland. This would render either section more susceptible to drought and more susceptible to a contaminant spill because the dilution potential would be reduced.

Compactible soils from MP 34.5 through 34.8 control drainage to both sides of a wetland at MP 35.6 (Figures 5 and 6). If compaction eliminates up to 3.3 af/y of recharge that supports a wetlands not much larger than 3.3 acres (Figure 6), the water balance of the wetlands would be considerably changed and the wetland would become impacted by drought. Groundwater quality impacts affected by water balance would be worsened by the pipeline.

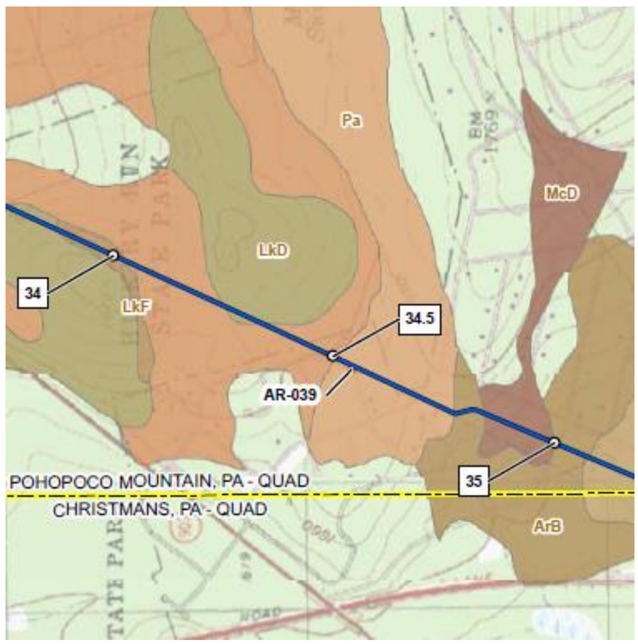

Figure 5: Snapshot of soils map from MP 33.8 to 35.2 (RR7, Figure 7.1-1).

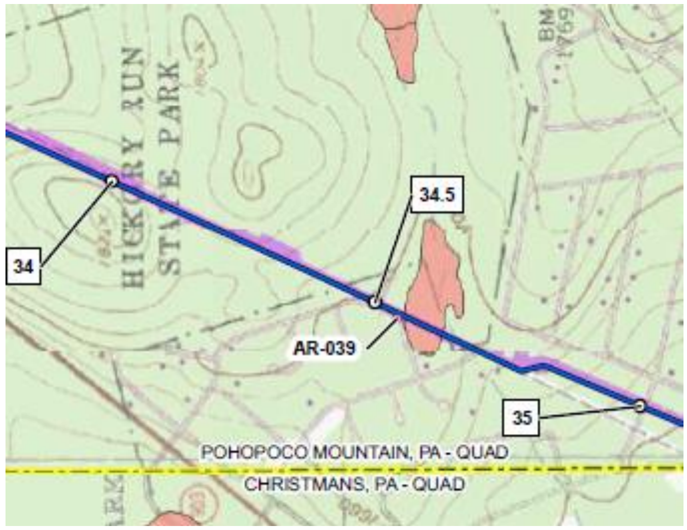

Figure 6: Snapshot of wetlands map (Appendix D, p 10 of 32).

Compactible soils from MP 49 to 49.4 coincide with wetlands between the same mile posts along the Aquashicola Creek. (Figure 7). This section will be in the floodplain of Aquashicola Creek in Papakating silty loam (Table 1), which is considered poorly draining. Compaction in this soil at this area may not affect recharge as much as it will prevent recharge from the south from reaching the creek. The trench would create a barrier that segments the floodplain. Considering the width of the floodplain area with a compacted trench bisecting it, the pipeline could cause geomorphic impacts during flood events. The stream could be captured by the trench or shifted from side to side. Groundwater forced to the surface by the trench could form small channels near the pipeline.

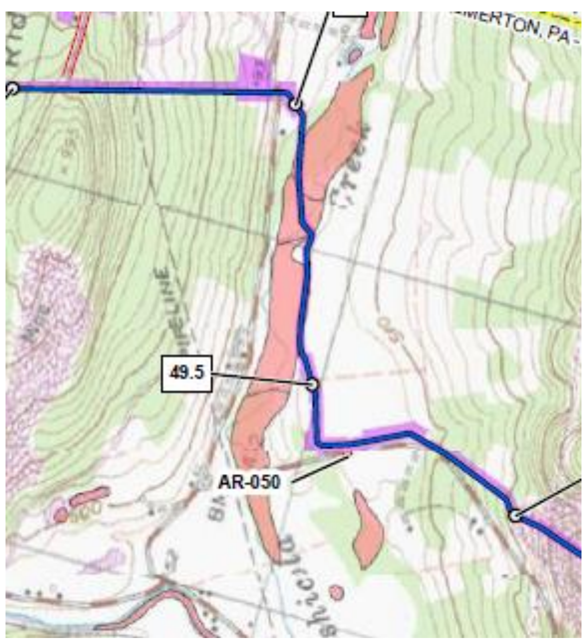

Figure 7: Snapshot of wetlands map (Appendix D, p 14 of 32).

3.12 Bedrock Aquifers Underlying the Pipeline

RR2 delineates aquifers crossed by the proposed pipeline as bedrock (PADCNR 2000), principal (Trapp and Horn 1997), and surficial aquifers (Id.). Bedrock aquifers are simply the geologic formation that underlies the pipeline. RR2 (p 2-2) claims there are up to 40 bedrock aquifer types based on the difference in bedrock formations to be crossed by the proposed pipeline. Therefore, there are up to 40 different sets of transmissivity and groundwater storage properties which means up to 40 different responses to stresses on the aquifer. The map (RR2, Figure 2.2-1) does not show the locations very well but the table (RR2, Table 2.2-1) specifies mile posts along the pipeline for each formation. Structural aspects of the bedrock formations, such as faulting and folding (synclines, anticlines) exert control over the bedrock aquifer properties, but the application does not specify where these factors control the properties (RR2, p 2-2). Maps showing broad generalizations of aquifer specific capacity (RR2, Figure 2.2-1) or aquifer yield (RR2, Figure 2.2-2) are not a substitute for transmissivity or aquifer storage properties.

Bedrock beneath the shallow aquifers controls whether recharge circulates deeply or flows a short distance and discharges to a surface channel; at a small scale such as on ridge tops or slopes the channels are probably small. Fractures control where recharge enters the bedrock as well as how contaminants circulate through the aquifers. Fractures allow a higher proportion of the recharge to enter the bedrock whereas areas with no fractures will force most of the recharge to flow elsewhere and possibly recharge at points away from where the precipitation falls. Two factors, the formation type and topographic position, control bedrock fractures, and therefore conductivity, specific yield, and the ability for recharge to enter the bedrock and how deeply it circulates.

The basis for specifying bedrock aquifers in RR2 is very general; Trapp and Horn (1997) provide broad aquifer descriptions based on a regional analysis. RR2 Figure 2.2-1 shows broad aquifer zones with large ranges of specific capacity. Specific capacity is an easy to estimate property that reflect the conductivity of the bedrock at a point (see http://www.wrd.org/engineering/specific-capacity-well-1.php). Other reports that are not even referenced in RR2 provide much more detail about the bedrock aquifer properties. Taylor (1984) describes the properties of bedrock aquifers that underlie the pipeline from MP 0.0 to about 62.8. Low et al (2002) describes the properties of underlying bedrock formations from MP 62.8 to about 77.6, through Northhampton and Bucks County. Herman (2001) describes in detail the properties of bedrock aquifers through the Newark Basin of New Jersey. Poth (1972) discusses the Martinsburg Formation. Rather than relying on broad generalizations, PennEast should discuss details of the bedrock underlying the pipeline by milepost, as it does for soils and wetlands.

The topography partially controls the location of fractures. Taylor further describes the variability:

> Wells in higher topographic positions (hilltops and hillsides) have smaller yields than those in lower topographic positions (valley, gullies, and draws). Valleys and draws often form where the rocks are most susceptible to physical or chemical weathering. Hilltops are generally underlain by more resistant rocks. Lithologic variations and weaknesses in rocks caused by bedding partings, joints, cleavage, and faults promote rapid weathering and can produce low

> areas in the topography. These types of geologic features often occur in high-permeability zones which yield significant amounts of water to wells. (Taylor 1984, p 29).

Specific capacity shows how the yield varies through the depth of the wells and suggests the location of shallow fractures that would allow recharge to enter the bedrock and deep fractures that control how deep the recharge circulates (Taylor 1984). Most bedrock formations have the maximum fractures between 100 and 150 feet bgs with the Catskill Formation having the most fractures from 150 to 250 feet bgs (Taylor 1984, Table 2). Hamilton group bedrock has relatively more fractures near the ground surface, between 0 and 50 feet bgs than other formations (Id.). The topographic position therefore better describes the tendency for surface fractures and describes locations where bedrock is most receptive to recharge.

The surface geology map in RR6 Figure 6.6-2 shows just the thin mantle of till or alluvium and the bedrock geology map in RR6 Figure 6.6-1 is one page showing the entire pipeline. Although RR2 acknowledges that fractures may have a larger specific capacity, nothing in RR2 provides details of how specific capacity varies along the pipeline layout. The broadscale mapping in RR2 Figure 2.2-1 does not provide sufficient detail on mile posts to verify the table.

RR2 Table 2.2-1 is also not very useful because it shows just the mile posts for start and end of bedrock aquifers. Without an indication of the geomorphology of the reach, it is not possible to know whether the reach would be an area with or without fractures, meaning it does not disclose much about the recharge along the reach. Table 2.2-1 should include a column indicate whether it is a ridge top, valley bottom, or slope greater than a given percent. Its proximity to anticlines and synclines should also be noted as these structures affect the location of the fractures. The geomorphic feature could differ among provinces.

Lower specific capacity on ridges means that recharge will remain in the shallow till or alluvial aquifers mantling the bedrock. As noted, the depth to bedrock in many areas is only a few feet so recharge flows as shallow groundwater. The shallow groundwater flow from ridgetops reaches drainages, usually high elevation first order drainages, where the bedrock has higher yields and some of the shallow groundwater enters it. Recharge maps such as Figure 2.2.4-1 (RR2) are highly misleading because they present recharge as a rate, inches per year, distributed over an area. Reality is that the rate is highly variable with the underlying geology, soil type and thickness, and topography controlling the actual recharge location.

For example, between MP 29.5 and 31.2, a reach discussed above regarding soils, the bedrock is Catskill Formation with aquifer specific capacity of 0 to 43 gpm/ft according to RR2 Figure 2.2-1. The range of 0 to 43 gpm/ft is very high. Taylor (1984) documented well yields (he did not calculate specific capacity) for the Catskill Formation up to 300 gpm. The wide range in yields is due to the variability found in fractured bedrock aquifers. Compaction could reduce recharge up to 4.4 af/y through this reach, therefore bedrock properties control whether the lost recharge is shallow or deep.

- RR2 does not provide the detail necessary to adequately assess how the lost recharge will affect hydrogeology of the area.

As noted there is a large variation in properties for bedrock aquifers. For example, specific capacity at wells in the Brunswick Formation varies from 0.13 to 140 with a median equal to 2.0 (Low et al 2002), which indicates that most wells have very low specific capacity but occasional wells are in high yield fracture zones. The 90th percentile value is 11 gpm/ft, so the 140 gpm/ft value is clearly a highly fractured outlier. Highly conductive zones allow far more water to enter the aquifer than simply falls at the location of the fractures. Surface water could collect and percolate deeply into the bedrock where the channels lie over the fractures, which tend to occur more in valley bottoms. Shallow groundwater flow or interflow over a bedrock would enter fracture zones preferentially as well. Compaction of surface soils and shallow aquifers could either prevent the recharge at a point from entering the fracture zone or prevent the shallow flow from reaching the fractures.

- RR2 should provide a table of bedrock aquifers that includes relevant properties, including specific capacity statistics or well yields, and conductivity where available. If properties for a given bedrock aquifer have not been published, it is reasonable for PennEast to complete the analyses for existing wells.

Table 2 shows relevant properties for bedrock types over which the pipeline. Considered with the soils Table 2 and the topographic position of the reach, it is possible to match locations where recharge will be most affected (Table 1) with the areas in which bedrock accepts most recharge (Table 2) to determine where pipeline construction and compaction could affect deep recharge the most. Compacting areas overlying shallow, conductive bedrock will most affect deep groundwater recharge.

- The PennEast application completely failed to consider how pipeline construction will affect water availability for recharge into bedrock by not considering how compaction will prevent water from accessing fracture zones.

Table 2: Hydrogeologic properties of bedrock formations near the PennEast pipeline. SC is specific capacity. All data from Taylorl (1984) and Low et al. (2002), unless otherwise specified.

Formation	**Min**	**Max**	**Domestic**	**Nondomestic**	**Comments**
Catskill	0	300	12	35	1146 wells analyzed
Pocono	3	350	12	18	
Mauch Chunk	0	710	25	50	
Llewellyn	2	50	10		limited data, just seven domestic wells
Pottsville	5	300	25	48	
Spechty Kopf	-				a thin formation between the Catskill and
Trimmers Rock	1	60	6	15	
Mahantango	-				Hamilton Group
Marcellus	1	900	10	65	Hamilton Group
Buttermilk Falls	-				

Ridgeley	2	650	10		122	part of Onondaga and Old Port Formatin
Decker	-					
Bloomsburg	2	500	6		66	
Shawangunk	-					
Jacksonburg	1	1200	17		75	dolomite (Drake 1965), properties from
Allentown	5	1500	30		150	dolomite (Drake 1965), properties from
Leithsville	2	1000	25		250	dolomite (Drake 1965), properties from
	Min	**Max**	**Median SC**	**Yield**	**Median**	**Comments**
Hardyston	0.04	18	0.57	31	0.24	
Felsic to mafic	-					
Hornblende	-					
Trenton gravel	0.01	80	6.6	105	430	very shallow
Igneous and	-					
Brunswick conglomerate	-					Conglomerate for other formations, but not Brunswick
Brunswick	0.07	140	1.5	60	1.3	
Lockatong	0.05	40	0.4	10	0.78	
Stockton	0.07	75	1.3	60	1.2	
Diabase	0.01	5	0.12	7.5		very few, very shallow fractures
Martinsburg	0.06	10	0.61	1	1.3	Northhampton County only, K from model
Jacksonburg	0.01	34	1.2		3.1	properties from Lehigh County, K from model
Allentown	0.03	125	4.3		47	properties from Lehigh County, K from model
Leithsville	0.18	375	2.4		125	properties from Lehigh County, K from model

3.13 Analysis of Impacts

The application did not consider how pipeline construction and operations could affect recharge and shallow groundwater flow in aquifers near the proposed pipeline. Areas where the pipeline compacts soils over critical recharge areas, especially on ridge tops and valley bottoms, would increase runoff and decrease recharge. As discussed previously in this section, recharge supports baseflow therefore decreasing recharge will affect baseflow in streams. Most importantly groundwater discharge would be decreased during low flow periods.

Table 3 shows mile posts between which pipeline construction would compact soils in valley bottoms, not including Susquehanna and Delaware River. There are 8.1 miles of pipeline in valley bottoms with 1.9 miles overlain by compactible soils. Recharge varies significantly as discussed above, but if all of the recharge is lost over the area affected by the pipeline, for 10 or 22 in/y, the total lost recharge is 40.9 and 90 af/y, respectively, 0.056 or 0.124 cfs. Considered as flow rate per mile, the loss is 0.007 or 0.15 cfs/mile, which can be significant for small streams during baseflow or small wetlands.

Table 3: Proposed pipeline reaches by milepost which lie in drainage bottoms. Compactible soils is a marker showing the soil overlying the bedrock is compactible as defined in Table 1.

Beginning MP	Ending MP	Miles	Bedrock	Compactible soils
0.5	0.8	0.3	Catskill	
4.2	4.4	0.2	Catskill	
11.5	12	0.5	Pottsville, Mauch Chunk	
16.6	16.7	0.1	Catskill	
18.2	18.4	0.2	Catskill	
19.5	19.7	0.2	Catskill	
22.6	23.2	0.6	Spechty Kopf	
33	33.2	0.2	Catskill	X
38.7	38.9	0.2	Catskill	
39.4	40.5	1.1	Catskill	
43.4	43.6	0.2	Marcellus	
45	45.1	0.1	Catskill	X
45.2	45.3	0.1	Catskill	
45.5	45.6	0.1	Catskill	
48.1	48.3	0.2	Mahantango	
49	49.7	0.7	Decker through Pocono Island	X
55.8	55.9	0.1	Graywack and shale of	
56.6	56.8	0.2	Graywack and shale of	
60.2	60.4	0.2	Martinsburg	
61.4	61.5	0.1	Jacksonburg	X
70.3	70.4	0.1	Allentown	
70.8	71.1	0.3	Leithsville	X
81.2	81.3	0.1	Brunswicke conglomerate	
81.7	81.8	0.1	Brunswicke conglomerate	
82.2	82.3	0.1	Brunswick	
82.7	82.8	0.1	Brunswick	
82.9	83.1	0.2	Brunswick	
83.8	83.9	0.1	Brunswick	
84.8	84.9	0.1	Brunswick	
86.7	86.8	0.1	Brunswick	
87.6	87.8	0.2	Brunswick	
88.3	88.4	0.1	Brunswick	
89.5	89.6	0.1	Brunswick	
89.7	89.8	0.1	Brunswick	
99.9	100	0.1	Diabase	
100.2	100.3	0.1	Diabase	
104.4	104.9	0.5	Brunswick	x

Pipeline construction in valley bottoms affects groundwater flow in other ways. If the conductivity of the backfill is higher than that of the surrounding aquifer material, the trench could intercept flow to the stream and cause it to flow elsewhere, possibly never to reach the stream. If the conductivity is lower than that of the surrounding aquifer material, it could deflect the groundwater flow away from the stream, although it could also cause the groundwater flow to discharge to the surface away from the stream. These effects are discussed below in the Preferential Flow section, Section 3.2, and quantified using numerical simulations below.

Table 4 shows mile posts between which pipeline construction would compact soils on ridge tops. Recharge on ridges has a longer path to follow to reach streams, although some is very shallow and may support isolated streams and springs. On ridge tops with receptive bedrock, a significant amount of recharge will circulate deeply into the bedrock. There are 17.1 miles of pipeline on ridge tops so, considering recharge at just 10 in/y, total lost recharge is as much as 86 af/y. Considered as flow rate per mile, the loss is 0.007 or 0.15 cfs/mile, which can be significant for small streams during baseflow.

Table 4: Proposed pipeline reaches by milepost which lie in drainage bottoms.

Beginning	Ending	Miles	Bedrock
0.8	1.1	0.3	Catskill
1.7	2	0.3	Catskill
2.3	2.5	0.2	Catskill
3.6	4.1	0.5	Catskill
12.7	12.9	0.2	Mauch Chunk
14.3	14.5	0.2	Spechty Kopf
15.3	15.6	0.3	Catskill
17.2	17.7	0.5	Spechty Kopf
20.4	21.2	0.8	Pocono
23.4	24	0.6	Catskill
29.5	30.5	1	Catskill
33.8	34.4	0.6	Spechty Kopf/Catskill
39	39.5	0.5	Catskill
45.2	47.7	2.5	Catskill
48.4	48.8	0.4	Buttermilk Falls Limestone
51	51.3	0.3	Shawangunk
59.6	61.3	1.7	Martinsburg
73.6	74.2	0.6	Hornblende gneiss
78.2	79	0.8	Jacksonburg limestone
80.6	81.2	0.6	Brunswick conglomerate
81.3	81.6	0.3	Brunswick
81.8	82.2	0.4	Brunswick
82.4	82.7	0.3	Brunswick
84.1	84.9	0.8	Brunswick
85.7	86.7	1	Brunswick

87.9	88.3	0.4	Brunswick
88.5	89.5	1	Brunswick

3.14 Summary and Recommendations

Pipeline construction would affect recharge distribution in the areas crossed by the pipeline. It does this by compaction and vegetation removal. This increases runoff as well which may allow recharge to occur elsewhere downhill. Trench compaction may also prevent groundwater from flowing across floodplains and reaching streams or wetlands near their normal discharge point.

- PennEast should compete site-specific impact analyses that considers the potential for pipeline construction effects, including compaction and vegetation removal, to change recharge patterns.
- PennEast should complete site-specific impact analyses showing how the changed location and rates of recharge would change baseflow in streams and it wetlands.
- PennEast should propose methods to monitor these effects. Piezometers should be installed in wetlands downgradient from the pipeline to monitor changes in water levels and compare those changes to predicted changes. Piezometers should also be installed in strategic locations of the trend backfill and just outside the trench to determine whether the trench is causing drawdown or whether preferential flow is occurring (see Sections 3.2 and 3.3).
- PennEast should proposed methods to mitigate these effects. If the analysis shows changes in recharge or flow patterns, the backfill could have drains installed to allow cross-trench flow. If necessary the surface of the pipeline could be scarified to increase infiltration through the soils.

3.2 Preferential Flow

Groundwater follows the path of least resistance, which usually means the path with the highest conductivity. All but the most homogeneous formations have pathways that are much more conductive than the overall formation. The proportion of the overall flow through an aquifer that occurs through these natural pathways can be quite large.

Pipeline construction would create preferential flow pathways in two ways. One would be by creating a trench with higher conductivity than the surrounding formation. Groundwater would tend to flow into and then through the high-conductivity trench. This could occur in shallow groundwater either in low conductivity glacial till deposits or bedrock deposits. This could be most critical where the pipeline follows a steep gradient along a mountainside.

The second way is by blocking the natural flow paths with a lower conductivity backfill that diverts groundwater along the interface between the trench and the natural formation. This could occur by compacting a trench developed in high conductivity alluvium or highly fractured bedrock so that the backfill has a lower conductivity and diverts the flow along the contact. This would be most critical in areas where the pipeline follows a steep gradient along a mountainside.

PennEast has not even acknowledged this potential issue, much less analyzed it. Preferential flow is most probable along slopes where groundwater flows from ridges to valley bottoms, although the effects could also occur in valley bottoms and ridgetops. It could be analyzed with analytic or numerical calculations for groundwater flow along a pipeline reach from recharge to discharge.

- PennEast should divide the pipeline into reaches from ridge top to wetland or stream to consider the effect of changing conductivity on groundwater flow. Impact analysis would include analytic or numerical[6] calculations with and without the pipeline, and include recharge estimates along the reach and different baseline (natural in-situ) parameters for the bedrock and shallow aquifers. The with-project scenario would include the trench parameterized with values representative of lower and higher conductivity backfill. PennEast should estimate the changes in discharge to downgradient wetlands or streams. Because the model is interpretative, the results are indicative of potential changes. PennEast should identify the areas where the impacts are most likely and propose monitoring and mitigation (see section 3.14) for the potential impacts.

3.3 Drawdown

A pipeline causes drawdown by providing preferential flow paths, as described in the previous section, which will change flow gradients and groundwater levels. This would affect areas depending on shallow groundwater tables, which would include wetlands where small difference in water level that persists for a substantial time period could change the character of the wetland. It would also include areas that have vegetation that depends on shallow groundwater. Lowering the water table, even a small amount, for a substantial period could have long term effects on the vegetation types, whether formally delineated as a wetland or not.

Wetlands crossed by the project depend on groundwater. Wetlands in four Pennsylvania Counties, Luzerne, Carbon, Northhampton, and Bucks had as their most common primary indicators of hydrology high water table (A2), saturation (A3), and oxidized rhizospheres on living roots (C3), with second indicators including drainage patterns (B10)[7].

RR3 discusses the importance of shallow groundwater for several vegetation types or features. The following list is just several observations from RR3 in which the importance of shallow groundwater was emphasized. Shallow groundwater is likely important for other vegetation types in other areas.

- Perhaps the most important is the leatherleaf – cranberry bog found along the pipeline route in Luzerne County (RR3, Table 3.3-4).

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[6] Numerical calculations would include the use of numerical groundwater models to make interpretative simulations. Interpretative means that the model would be parameterized according to commonly accepted field estimates of the properties. Using logical parameter changes to reflect the backfill, the model would be run with the trench. The with- and without trench results would be compared to assess potential impacts. An interpretative model is not predictive but only indicative of likely changes because it has not calibrated.

[7] PennEast Pipeline Project, Wetland Delineation Report – Pennsylvania, February 3, 2016, p 1-6 through 1-9.

- There are also vernal pools which may be seasonally supported by a high groundwater table (RR3, p 3-27). Pipeline construction could affect vernal pools by preventing the groundwater table from supporting the pool as it did prior to construction. A pipeline could also divert the drainage patterns that seasonally fill the pools.
- Scrub-shrub wetlands depend on the "presence of high groundwater for extended periods" (RR3, p 3-39).
- RR3 notes the importance of springs for creating habitat to support the endangered (in Pennsylvania and New Jersey) bog turtle. "Bog turtles inhabit distinct types of wetland habitats that include spring-fed hydrology and mucky soils. Clear groundwater with rivulets and shallow pockets of surface water typify the hydrology of bog turtle wetlands, and subterranean tunnels with flowing water are used by bog turtles both in winter for hibernation and during the hot summer months. Deep, organic, mucky soils in which bog turtles can burrow are an important component of their habitat" (RR3, p 3-65). Pipelines near enough to springs to lower the water table could decrease the flow of necessary clear groundwater. It would not just be those within 150 feet of the pipeline, but could include springs supported by groundwater flow that has been diverted by preferential flow paths in the trench or blocked by the trench.
- A species of special concern in New Jersey, the American oystercatcher, could be affected by restrictions on the groundwater flow in its habitat (RR3, Appendix 3B-2).

Pipeline construction could affect hydrology in ways that could affect vegetation or aquatic life, in addition to the simple construction impacts. The application does not analyze how the pipeline would affect any specific area with important vegetation types or aquatic species. There are broad statements about temporary impacts during construction, but there no analysis of the change in groundwater flow patterns as described herein.

- PennEast should use the numerical and analytic analyses recommended in Section 3.2 to estimate the drawdown in the groundwater along pipeline reaches.
- PennEast should list areas with special vegetation that are near shallow aquifers that could be impacted by drawdown from the pipeline determine in the previous bullet.

3.4 Contaminant Sources

The proposed pipeline would cross several contaminated areas, but PennEast (2016b) barely mentions them or how they would be avoided or how contamination released due to construction would be mitigated.

3.41 PCP Contamination

There are non-point sources of pollution on some of the rivers that could be stirred up by construction, but PennEast has failed to even inventory the potential contamination (PennEast 2016a, p 2-26). There are fish advisories on both the Lehigh and Susquehanna Rivers near the proposed crossings (Id.). "No testing has been conducted to determine if PCBs are in the sediment at the specific crossing locations or where the fish were exposed to the PCBs. Given that no sediment testing has been conducted at these locations, it would be difficult to quantify the PCB load in the sediment or to provide a location of where the PCBs are in the sediment" (Id.). Because there is not even an inventory of sediment quality, it is impossible to conclude the project will not cause a massive release of PCBs from river crossings, especially the dry crossing of the Susquehanna River.

PennEast claims they will eventually sample sediments. "PennEast will develop a plan for collecting an appropriate number of sediment samples within the Susquehanna River to determine whether PCBs are present in the Project area. … In the event that PCBs are found … PennEast will consult with the appropriate agencies to determine whether the concentration present is at a level that would warrant PennEast to take additional precautions to prevent the release of PCBs into the water column" (Id.). Thus, PennEast is requesting water quality certification without even providing evidence regarding whether it will encounter conditions that would cause PCBs to be released from stream sediments.

- PennEast should sample the sediments to determine whether PCBs would be a potential issue.
- PennEast should inventory potential sources near the pipeline route to determine whether PCBs or other contaminants need to be secured prior to contruction.

3.42 Arsenic Leaching from Bedrock along the Pipeline Route

Arsenic occurs naturally in the bedrock of the Newark Basin portion of the proposed preferred pipeline route and alternatives (DEIS, p 4-11). PennEast (2016a) does not even mention this arsenic, even though the Newark Basin lies partly in Pennsylvania (DEIS, p 4-11). The DEIS notes that the primary source is the mineral pyrite.

The DEIS states that "shallow groundwater … generally have (sic) low arsenic concentrations and that high arsenic concentrations … are the result of more mature groundwater interacting with geochemically susceptible and arsenic-enriched water bearing zones, which are often deeper wells" (DEIS, p 4-12). The DEIS recognizes that the potential to mobilize arsenic is uncertain but then claims they have "no indication that common construction activities that involve shallow excavation, such as home construction, has resulted in increased arsenic concentrations in water supply wells" (Id.). The DEIS relies on the Serfes (2016) analysis which involved leach testing samples of Lockatong and Passaic Formation to conclude that the potential for arsenic leaching from soils disturbed by trench construction is less than significant. The Lockatong lies near the ground surface and is representative of rock that will be disturbed by trench construction. Serfes' evidence and descriptions do not support his conclusions so the DEIS inappropriately minimizes the potential contamination and the 401 certification application (PennEast 2016a) is deficient due to ignoring this source.

- The samples for the Lockatong Formation were "obtained by compositing approximately 100 pounds each of competent unweathered boulders randomly selected adjacent to roadside outcrops" (Serfes 2016, p 3). Boulders may not be representative either structurally or geochemically of the standard fractured bedrock of the formation. Samples should have been drawn from the outcrop but deep enough that weathering would have been minimal.

- The EPA 1627 method calls for leaching with CO2-saturated, deionized reagent water whereas Serfes (2016) states the saturation occurred with deionized water without mentioning CO2. Without CO2 saturation, Serfes' samples could leach oxidation products more quickly than the method would otherwise call for. This would change the results.
- Serfes claims that hydrous ferric oxides (HFO) that form on pyrite surfaces (observed during the test) would sequester arsenic from reaching groundwater. This could result from the HFO crusting process (Serfes 2016, p 5) occurring faster than arsenic release due to pyrite oxidation in the test. This could be due to the sample particle size distribution (PSD) not being representative of the particles in the field. It may not represent field conditions.
- Pyrite oxidation and arsenic mobilization in the field could occur through preferential flow zones that have a much smaller proportion of ferrous products with which to form HFOs that will sequester arsenic.
- Results of leach tests for sample ML-2, ML-DUP-2, and ML-6 exceed 10 ug/l for the first four weeks, and some for the first seven weeks, and this could represent some of the first contaminant flushes from the project. There is no appropriate reason given for why this is not representative of the leaching that will occur initially after pipeline construction.
- Serfes (2016) Figure 13 shows graphs of arsenic, sulfate and iron with time. Serfes suggests the sulfate figure shows that pyrite oxidation decreased after week 9. "Note sulfide (sic) concentration increase in (b) indicates aggressive pyrite oxidation between weeks 5 and 9" (Serfes 2016, Figure 13). The figures indicate post week 9 for ML-DUP-2 is a pyrite mostly oxidized phase. Data in Serfes (2016) Table 2 does not support his conclusion of most pyrite being oxidized by week 9. Although the sulfate concentrations are highly variable there is no consistent change that occurs at week 8. The highest sulfate concentration for ML-2 occurs in week 11. The variation shown in Serfes Table 2 demonstrates that conditions along the pipeline will be highly variable; if the roadside samples are representative, Table 2 shows simply that some areas can oxidize a great deal more than others.

The results of the arsenic leaching tests relied on by the DEIS show that arsenic leaching could be more variable than expected. It depends on how the particle size distribution compares with that occurring on the site and whether oxidation would occur faster in some than other areas. It also depends on how fast ferric ions can be mobilized to form hydrous ferric oxides s. Finally, it depends on whether preferential flow zones that could release arsenic and not contact HFOs could occur along the pipeline. The highly variable arsenic concentrations in shallow wells further exemplifies how variable arsenic occurrence could be near the pipeline.

- The arsenic analysis is insufficient to indicate that arsenic leaching from pipeline construction in the Newark Basin would not be a problem for shallow groundwater. The 401 certification needs to legitimately and scientifically analyze this issue and threat in order to properly inform avoidance and mitigation options.

3.43 Palmerton Zinc Pile Superfund Site

Another issue not even mentioned by PennEast (2016a) is the Palmerton Zinc Pile Superfund Site, which is mentioned in the DEIS although it also fails to consider whether pipeline construction will release contaminants from it[8]. Photo 1 shows the zinc slag pile near Palmerton. The DEIS fails to consider whether groundwater plumes or air born transport could have moved contaminants from to the pipeline route.

The proposed preferred pipeline route would lie within the one-mile buffer zone of the Palmerton Zinc Pile superfund site, as mapped (EPA 2011); the pipeline reach between the Aquashicola Creek floodplain and the Blue Mountain Ski Area parking lot would be within the buffer around the superfund site. The value of the buffer zone is questionable for two reasons. First, EPA states that the contaminated groundwater status is not under control (https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0300624, accessed 8/12/16). Second, the Superfund site is within a mile west of the project site, which is upwind. The slag is clearly unvegetated and unstabilized (Photo 1), and wind would easily move smaller-size sediments from the pile. There is no information on the final Remedial Investigation/Feasibility Study for the site, which would possibly outline the extent of existing contamination. Therefore, there is no final mapping of the potential contamination near the site. The DRAFT Restoration Plan and Environmental Assessment (Trustees of the Palmerton Zinc Pile Superfund Site 2010) notes that hazardous substances contaminated several miles of Aquashicola Creek and 40 acres of wetlands within the Aquashicola watershed through processes including aerial deposition and shallow groundwater contamination (Id., p 11). Because the Superfund site is downwind of the proposed pipeline, there is likely contamination along the proposed pipeline route. Given that the Palmerton Water Company has four production wells at the foot of Blue Mountain that supply water to the towns of Palmerton and Aquashicola, an analysis of groundwater impacts and potential threats to this important drinking water supply for thousands needs to be earnestly and scientifically considered by the DEIS; as written, it is not.

- Prior to any water quality certification, the certification analysis must consider the potential for pipeline construction causing contaminants from the Superfund site to be released to

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[8] As described by EPA (https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0300624, accessed 8/12/16): "The Palmerton Zinc Pile Site is the area of a former primary zinc smelting operation. The site encompasses the Borough of Palmerton and surrounding areas, Blue Mountain, a large smelting residue pile called the Cinder Bank and much of the valley. For nearly 70 years, the New Jersey Zinc Company deposited 33 million tons of slag at the site, creating a cinder bank that extends for 2 1/2 miles and measures over 100 feet high and 500 to 1,000 feet wide. The smelting operations emitted huge quantities of heavy metals throughout the valley. As a result, approximately 2,000 acres on Blue Mountain, which is adjacent to the former smelters, have been defoliated, leaving a barren mountain side. Soil on the defoliated area of the mountain has contaminated the rain water flowing across it. The runoff and erosion have carried contaminants into Aquashicola (spelled correctly here) Creek and the Lehigh River. Approximately 850 people live within one mile of the site; the population of the town of Palmerton is approximately 5,000. The Palmerton Water Company has four production wells at the foot of Blue Mountain that supply water to the towns of Palmerton and Aquashicola; these wells have not been effected by contaminants from the site to date. This site was proposed to the National Priority List (NPL) on December 30, 1982 and formally added to the list on September 8, 1983."

groundwater or to the Aquashicola Creek. The analysis should include a plume map of groundwater contamination and a map showing soils contamination from the Palmerton Zinc Pile Superfund site. The analysis should also assess the implications of the various proposed pipeline routes for water, groundwater and drinking water contamination.

Photo 1: Zinc tailings at the Palmerton Zinc Pile Site.

3.44 Mine-Impacted Soils

Beginning at about MP 5.1 and continuing to MP 11.2, the soils table (RR7, Table 7.1-1) lists pipeline reaches as having soils classified as “mine dump” or strip mine, burned”. The geology section notes strip mines in this area (RR6, p 6-22). Partially shown on Figure 8, these soils cover substantial areas on the east side of the Susquehanna River crossing. Excavating or otherwise disturbing mine spoil can release contaminants, including acid mine drainage if sulfides are present. The primary mineral of concern, apparently, is arsenic (Id.). The mine spoil is highly conductive (RR7, p 7-15), so the potential for contaminants released by construction disturbance is relatively high. It has the potential for high erosion when disturbed (RR7, p 7-16). The report states that “PennEast **is developing** a Karst Mitigation Plan” (RR6, p 6-46, emphasis added) which means the impacts of the pipeline due to encountering karst is not known. It is not appropriate to publish an environmental study for review without having the more important aspects of the geology to be affected by the project not understood.

- The PennEast application does not assess the potential for pipeline construction to generate acid generation or leach arsenic in areas where it crosses mine spoil. The application was submitted before they completed relevant studies. The application should be revised to address the potential impact of acid drainage and arsenic leaching and specify appropriate monitoring and mitigation.

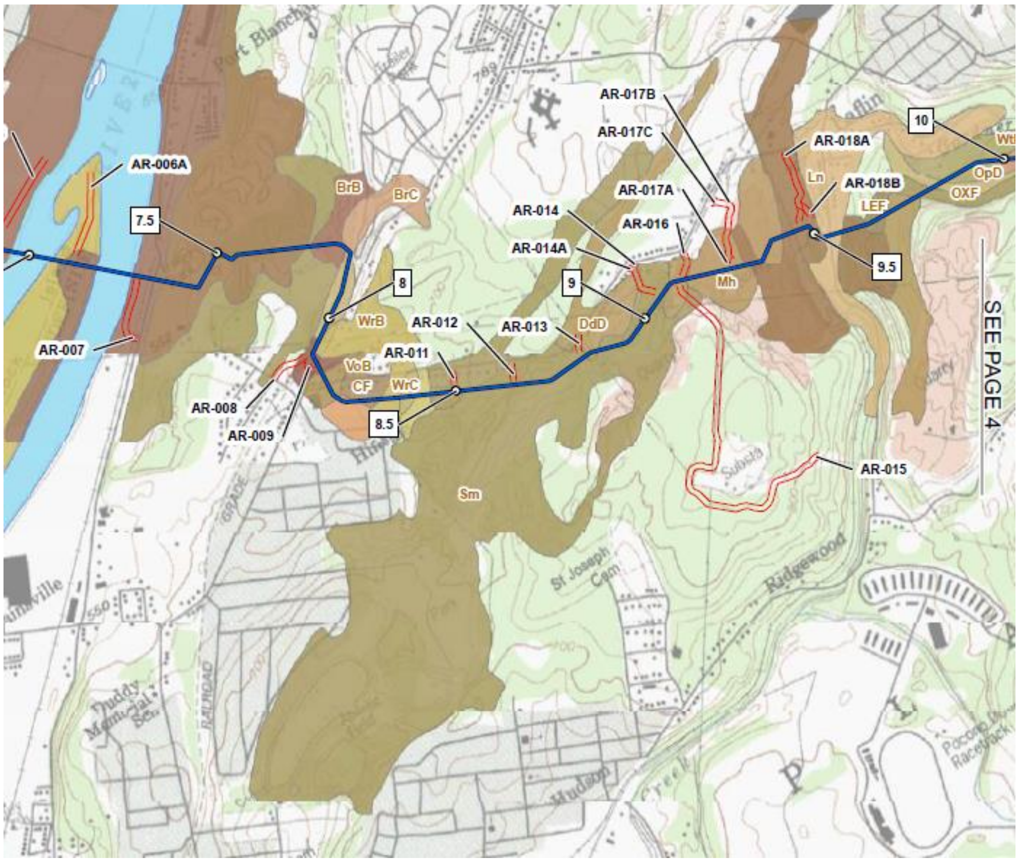

Figure 8: Snapshot of soils map (RR7, Figure 2.1-1) showing MP 7.0 to 10.0. Soil SM is strip mine.

3.5 Contaminant Transport

The preferential flow analyzed in section 3.2 can also enhance the movement of contaminants into wetlands or streams. Consideration of contaminants in the application mostly relies on mitigation of spills and the location of the pipeline away from hazardous waste sites. RR2 Table 2.2-7 lists 13 sites that potentially have hazardous waste, but fails to note the type of waste. RR2 does not analyze the potential for the pipeline construction causing contaminants to be leached and transported to a nearby receptor. RR2 only states that hazardous waste encountered during construction will be handled in accordance with applicable federal law. However, it does not present a methodology for locating hazardous wastes, such as in sampling in advance of construction.

As noted above, there is also a reach with potentially acid producing soils, but RR2 does not analyze the potential transport of acid or acid-related contaminants due to pipeline construction. There is also no proposal for sampling acid soils before construction.

Methane leaks from the pipeline are a potential contaminant source due to the pipeline. RR2 and PennEast (2016a) suggest that leak detection would help to prevent such problem. The implication is that leak detection will prevent any problem, but there is no indication about the accuracy of such claims. "Any pipeline leaks, if they occur, would be expected to be released in gas phase and only for limited time periods until they are observed and repaired" (PennEast 2016a, p 3-65). There is no discussion as to what rate of leak could be detected. PennEast cites a reference, Molofsky et al (2013) regarding the fact that a "small percentage of natural aquifers may contain some methane" (Id.). This reference is not appropriate here because it pertains to northeast Pennsylvania, near Bradford County; it does not pertain to the aquifers near this proposed pipeline. Also, the article pertains to questions of the source of methane in shallow aquifers – natural or related to hydraulic fracturing and wellbores. This article presented one conclusion that has been disputed by others (Olmstead et al 2013, Jackson et al 2012, Osborn et al 2011). PennEast (2016a) should not selectively cite an article regarding an issue that is not settled in the literature.

Mapping wells (RR2, p 2-9) or springs and streams (RR2, p 2-11) within 150 feet of the pipeline is not sufficient to protect water sources because contaminants can easily flow far beyond that distance from the pipeline. This is particularly true where the trench intersects fracture zone or higher conductivity zones.

- The application should consider the transport of contaminants, either methane or spills, along the preferential flow pathways and assess where they would discharge. This could be into a stream or spring, or into a broader aquifer where it could affect wells. This could be done using the numerical or analytic calculation methods established in section 3.2. Because they are mapped, the analysis should include the areas with mapped hazardous waste sites.
- PennEast should disclose details about the pipeline leak detection. What rate of leak can be detected?
- PennEast should analyze the extent that methane could spread from the pipeline through the groundwater due to a leak. This is probably a preferential flow issue in that the methane would disperse along the higher conductivity in the trench until it reaches a receptive fracture intersecting the pipeline or wetland or stream.

4.0 Alternative Routes

Pennsylvania regulations require the applicant to complete a "detailed analysis of alternatives to the proposed action, **including alternative locations, routings or designs** to avoid or minimize adverse environmental impacts" (25 Pa. Code § 105.13(e)(1)(viii), emphasis added). The water quality certification application considers the development of changes to the pipeline route that resulted in the final choice (PennEast 2016b), but the application does not make a detailed comparison between the changes based on the quality of features that would be affected. It also does not in any justify any decision to avoid or minimize adverse impacts.

The DEIS presented alternatives that could have been preferable to the proposed preferred alternative. This section first considers alternatives presented in the DEIS showing that the DEIS fails to adequately consider the benefits of the alternative. These alternatives could be better than alternatives considered in PennEast (2016b). Second, this section considers specific route changes that could avoid or minimize impacts that were not considered in the DEIS or by PennEast (2016b).

4.1 Comparison of DEIS Alternatives

DEIS Section 3.3 considers alternative projects that would meet the purpose and need of the project, but would fail to avoid and/or minimize environmental impacts. The DEIS compared alternative routings based on the length and amount of wetland and forest impacts and on the number of various features either crossed or closely approached, without analyzing the value of those features; for example, there is no comparison of water crossings beyond the number crossed. Also, there is an apparent preference for utilizing existing rights of way (ROWs), a seemingly reasonable preference only until one realizes that construction would be adjacent to existing ROWs rather than within them (DEIS, p 3-8). An existing 50- to 100-foot wide treeless swath through a forest could be doubled as the result of the preference to follow existing ROWs within a forest area. Such a width doubling could have foreseeable (but unanticipated by the DEIS) effects especially in valuable forest regions such as in Hickory Run State Park (Photo 7, p 38). In a wetland, such as in Photo 7, the area exposed to solar insolation could significantly increase which would both warm the water and increase evapotranspiration. Similarly, PennEast (2016b) does not consider such factors in its comparison of alternatives.

4.11 Luzerne and Carbon Counties Route DEIS Alternative (Luzerne-Carbon Alternative)

This alternative route (DEIS, p 3-8) would replace the proposed pipeline route between MP 8.4 and 37.5. This is a critical area because of the amount of forest land. The Luzerne-Carbon alternative would be about 1.7 miles, or 6% shorter than the proposed route. While very little of the Luzerne-Carbon alternative would be adjacent to an existing pipeline route but much of proposed preferred route along an existing pipeline is within forest land so pipeline construction would increase the width of the existing pipeline corridor through the forest (see discussion above, this page). The Luzerne-Carbon alternative would avoid creating larger corridors. However, overall there would also be a 15 acre increase in the clearing of forested land for the alternative, or a 4% increase, as well as 28 stream crossings for the Luzerne-Carbon alternative as opposed to 21 stream crossings for the proposed preferred route. However, it is necessary to consider the specifics of the crossings to adequately consider whether one would impact water quality more.

The most obvious advantage of the Luzerne-Carbon alternative is that just 1.5 acres of wetland would be affected by construction while for the proposed preferred route, 12 acres would be affected. The DEIS does not compare wetland type or value, but the much smaller area for the alternative suggests it could be much less impactful. Also, the Luzerne-Carbon reach also includes the extremely saturated wetland area just south of I-80 on the proposed route, which the DEIS describes as a difficult area for construction (DEIS, p 4-69 and discussion below in Section 3.33). It is also likely an area where construction could have significant impacts to water quality. The water quality certification analysis should consider the advantages of not constructing the pipeline through this wetland.

The DEIS notes the increase in stream crossings and small increase in forest area clearing in its rejection of the alternative (DEIS, p 3-11). The increases are not discussed regarding the quality of the streams or forest affected, nor does it consider the value of the wetlands not impacted, so the DEIS does not provide adequate evidence in support of the choice of the proposed route.

Another factor not considered by FERC in any comparison among alternatives is the temporary work spaces. In forests areas and wetlands, the additional space needed for construction activities could increase the impacts beyond that considered in the alternatives. This would be most apparent with respect to forests, where trees may be removed to provide construction space. The DEIS must disclose if forests could be cut to provide additional work space.

4.12 Small Routing Changes

DEIS Table 3.3.2-1 lists various small changes in the proposed preferred route that were supposedly evaluated and Appendix F provides maps. Some were incorporated into the proposed preferred route and others dismissed, with brief reasons indicated for incorporation or rejection. The longest proposals, variations numbered 7 and 9, appear to have been proposed for watershed protection reasons by the Bethlehem Authority watershed district but were rejected. These proposals are both longer than ten miles but the DEIS does not provide reasons for their rejection. Route deviation 7 (DEIS App F, p F-5) would run the pipeline east and upstream of Beltzville Reservoir and avoid a crossing of that reservoir which would seem to be desirable.

The reason listed for rejection of No. 9 is engineering constraints associated with crossing Beltzville Lake. An HDD crossing should be possible at most any point under that lake, albeit longer than at the upstream end. Environmental benefits could outweigh cost issues and should be better discussed in the water quality certification analysis.

PennEast (2016b) should evaluate DEIS variations 7 and 9 (DEIS, Section 3.3.2) because, given their watershed protection benefits, they could have much less impact than the current proposed route.

4.23 Alternative Routings

As part of my review of the 401 certification application, I visited many proposed pipeline sites. This section outlines a number of deficiencies identified during those site visits.

Aquashicola Creek Crossing (MP 49 to 49.7): The proposed preferred route crosses an extensive wetland and parallels Aquashicola Creek for more than half a mile (Figure 9). The proposed preferred route appears to almost maximize the area of wetlands and floodplain affected by the pipeline. The pipeline crossing the floodplain could significantly divert groundwater flow and affect wetland water balances and baseflow in the creek. Direct impacts due to construction on the creek are also obvious. The values of the wetlands on the floodplain are obvious from a site visit, with Aquashicola Creek meandering through dense shrub/herbaceous vegetation (Photo 2).

- Penn East should consider extending the straight reach from MP48.5 to 49.0 another approximate 0.2 miles across the stream, floodplain, and wetlands prior to diverting southward. An obvious location for the new layout to intersect the pipeline would be at about MP 49.75 where the proposed pipeline changes direction to go southeast. This proposal would require negotiating a route through some Blue Mountain Ski Area facilities but this would be less environmentally damaging than the proposed layout. There would also be less potential for construction to disturb polluted groundwater or aerially deposited sediments due to the Palmerton Zinc Pile Superfund Site (EPA 2011). There would be much less impact on wetlands and less direct stream crossing.

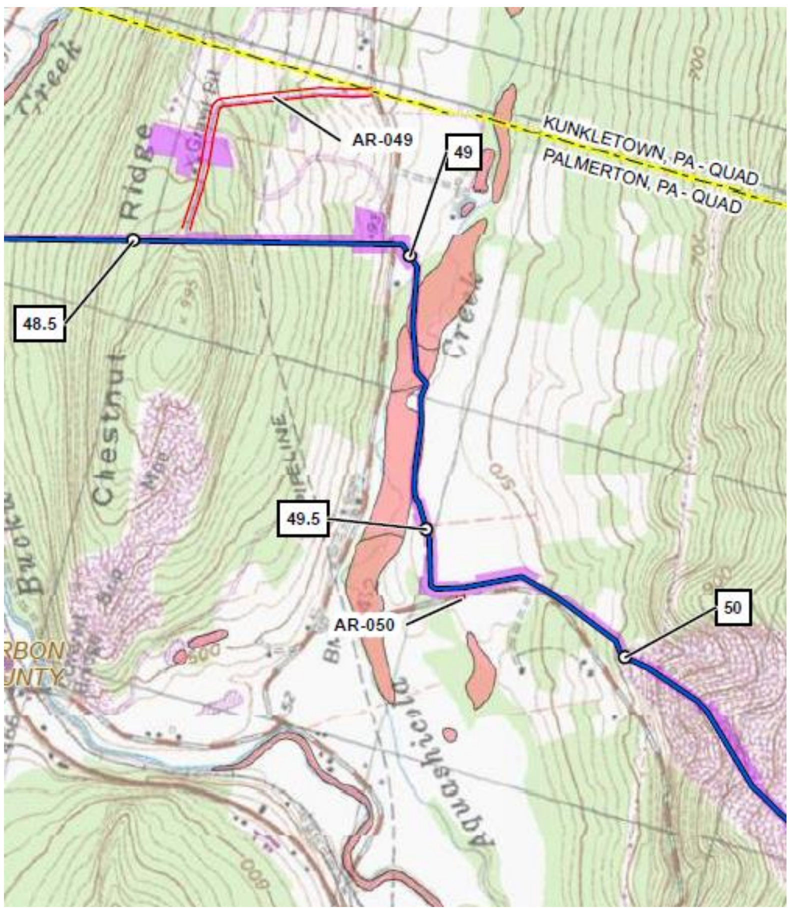

Figure 9: National Wetlands Inventory map of the proposed PennEast Pipeline along the Aquashicola Creek.

Photo 2: Floodplain and stream along Aquashicola Creek near Little Gap, PA.

Monocacy Creek, MP 60.0 to 60.5: The pipeline in this vicinity would border on a steep slope southwest of Klein Hill (Figure 10) and cross a broad floodplain with a small stream providing groundwater discharge to Monocacy Creek (Photo 3). The route avoids the White Tail golf course but in so doing it impacts the floodplain (Photo 3) thereby affecting groundwater discharge to Monocacy Creek. Its route along the steep slopes may also cause erosion or intercept groundwater flowing from Klein Hill to the Monocacy Creek tributary (Figure 10). The crossing of East Branch Monocacy Creek near MP 61.5 (Figure 10) also involves the pipeline cutting vertically down a steeper slope.

- Penn East should consider an alternative route through this area to improve the crossing of both creeks just mentioned. Directing the proposed route east across Klein Hill would miss wetlands. All potential routings in this vicinity are in need of greater consideration.

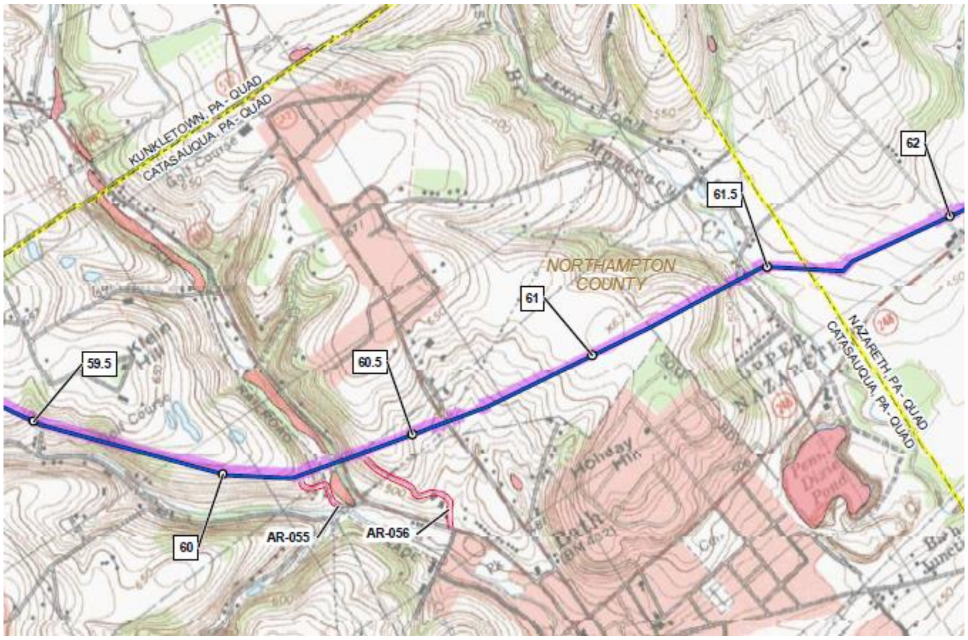

Figure 10: Snapshot of proposed pipeline near Monocacy and East Branch Monocracy Creek, near Bath, PA. MP 59.5 to 62.

Photo 3: Floodplain and small groundwater fed stream just above confluence with Monocacy Creek near MP 60.25.

Mill Creek, MP 12.0: Mill Creek near MP 12.0 likely should have a different layout (Figure 11). The proposed pipeline would parallel the stream next to a hillslope for about 0.3 mile (Figure 11). However, most of the alluvium forming the base of the valley lies north of the proposed pipeline. The pipeline trench could likely divert much of the groundwater discharge from the alluvium away from the stream during low flow conditions. A preferred alternative would have the pipeline cut directly across the floodplain at about MP 12.1 and merge with the current layout at MP 11.5.

Figure 11: Snapshot of the wetlands map for MP11.5 to 12.5.

Trout Brook, MP 0.5-0.8, and AR-002a: The proposed pipeline would cross Trout Brook at a critical location in its watershed. The surrounding watershed is rolling hills which would provide substantial shallow groundwater flow to the stream. The floodplain and terraces near the stream are broad even though the drainage is well-defined. This area would store groundwater for release to the stream during dry periods, such as observed on 9/24/16 (Photo 4), a date which follows a long mostly dry spell. Cutting this area with a pipeline would very likely intercept groundwater flow and prevent it from reaching the stream. There is no acceptable alternative routing in this area so a long HDD under the stream and surrounding terraces would be necessary to avoid unacceptable impacts to groundwater.

Photo 4: Trout Brook near MP 1.5 taken on 9/24/16. This area shows the importance of groundwater discharge in supporting baseflow in the stream.

- Pipeline construction would unacceptably damage groundwater flows in the area of the pipeline, as revealed by site visits and demonstrated in photos and with the maps. Water quality certification should be denied unless less damaging routes or construction techniques are used for these areas, and probably others that were not visited.

4.2 Alternative Designs and Construction Practices

4.21 Trench Plugs

Trench plugs are a factor in the design that are poorly analyzed. As described in the DEIS:

> Permanent trench plugs are intended to slow subsurface water flow and erosion along the trench and around the pipe in sloping terrain. Permanent trench plugs will be constructed with sand bags or an equivalent as identified in the permit requirements. On severe slopes greater than 30 percent, "Sakrete" may be used at the discretion of the Chief Inspector. Topsoil shall not be used to construct trench plugs. Permanent trench plugs, which are used in conjunction with

waterbars (slope breakers), shall be installed at the locations shown on the construction drawings or as determined by the EI. Trench plugs shall be installed at the base of slopes adjacent to waterbodies and wetlands, and where needed to avoid draining of a resource. (DEIS, Appendix D, section 9.5.8.1)

Trench plugs are used to interrupt flow along a trench, which could be considered preferential flow as discussed elsewhere in this memo. However, Penn East does not analyze how trench plugs would operate or whether they would do as claimed. A plug presumably with lower conductivity than the rest of the trench backfill would interrupt flow through the trench and potentially cause water to discharge to the ground surface. FERC does not provide for accommodating this surface flow or consider how it changes groundwater flow.

- The alternative design that must be considered would include a drain through the plug to lower the hydrostatic pressure in the trench caused by the plug and a plan for discharge of trench flow that may discharge to the surface.

4.22 Stream Crossing Methods

There would be 165 stream crossings in Pennsylvania, respectively (DEIS, p 2-9). All dry stream crossing construction methods would involve development of a trench across the stream with subsequent backfill. Dry stream crossing techniques involve temporarily diverting the stream from the streambed so that trenching occurs without flowing water, using either a flume or a dam and pump method (RR2, p 2-28; RR1, p 1-84, -85). The method used to trench and install the proposed pipeline would not influence the effect that trench and streambed crossing could have on groundwater/surface water relations near the crossing.

Trench backfill would have different conductivity than the surrounding alluvium, usually lower if the trench backfill is compacted and the surrounding is alluvium. The trench therefore would hydraulically impede groundwater flowing parallel to the stream and force it to surface into the stream. Depending on conditions downstream of the trench, the surface water would either percolate back into the alluvium or continue flowing as surface water, leaving less water stored in the alluvium than would otherwise be stored there. This could result in lower baseflow downstream of the trench because the trench effectively dams the groundwater flow so that groundwater discharges to the stream at times when the aquifer should be filling with percolating surface water. Each crossing is a different circumstance, but the DEIS has not analyzed the groundwater hydrology near any of the crossings.

- There should be an analysis of the hydrogeology at each crossing to assure that the design impacts groundwater flow and water quality the least and preserves surface baseflow.

Horizontal borings would affect the groundwater flow and groundwater/surface water interactions much less than trenches with backfill. This is simply because the bores have less effect on the overburden above the pipeline and do not interrupt the groundwater flow.

- There should be a site-by-site basis for each waterbody crossing to estimate whether a horizontal boring would be less impactful to groundwater and cause less decrease to baseflow and degradation of water quality than would a trench.

Some of the crossings discussed in section 3.32 are obviously better suited for horizontal borings rather than dry trenches. These include Aquashicola Creek and Monacacy Creek, and Hokendauqua Creek. Streams with potentially contaminated sediments, such as East Monacacy Creek, are also better suited for boring rather than trenching.

- All crossings listed in DEIS Table G-5 (for Pennsylvania) and G-6 (for New Jersey) should be considered with respect to whether a boring would be preferable. The most obvious candidates are those proposed to have a dry crossing but are also FERC class intermediate (for 10 to 100 feet wide) or major. Large crossing widths with small watersheds are more likely to have streams dependent on groundwater, because large width indicates higher flow and a larger floodplain and small watershed suggests less surface water runoff in the stream.

The crossing of Mud Run at MP 33.1 (Photos 5 and 6) presents several challenges. It is a FERC intermediate crossing with a very large watershed and proposed dry crossing. However, it has a bedrock channel, as shown in Photo 5. There is also a groundwater dependent tributary running on floodplain (Photo 6). A trench would intercept much of the groundwater flow in the alluvium which would support baseflow in this channel. This crossing should be done with an HDD which would have the added advantage of not trenching along a steep side canyon on the north side of the stream that likely is highly erodable.

Photo 5: Bedrock stream bottom in Mud Creek near MP 33.1

Photo 6: Spring flow on floodplain near MP 33.1.

4.23 Wetland Crossing Methods

Open trenching is the primary means of crossing wetlands, regardless of wetland type or value (RR2, p 2-55). PennEast has done no analysis of the impacts of trenching across wetlands nor does the DEIS present any analysis. That analysis specifically should be of groundwater flows through the wetland. Most of the wetlands are at least partly groundwater dependent with the wetland being supported by lateral groundwater flow into the wetland area. The trench would intercept some of that groundwater flow causing it to surface and impact surface water flow and quality, as described in section 3.32.

A good example occurs at about MP 29.6 where the pipeline crosses an existing wetland that depends on groundwater for support (Figure 6, Photo 7). There is no obvious surface water inflow, other than storm runoff (Figure 6). The wetland straddles a minor topographic divide, so the area supporting the south end of the wetland is limited. A trench that causes groundwater to surface could significantly change the water balance in the south end of the wetland thereby causing it to be lost due to indirect impacts - indirect being not direct construction but a loss of water.

- At wetlands like this, PennEast should analyze that value of wetlands not lost to trenching if a deeper boring is used to prevent indirect losses of wetlands. They should analyze in this way all significant wetlands crossed by the proposed pipeline.

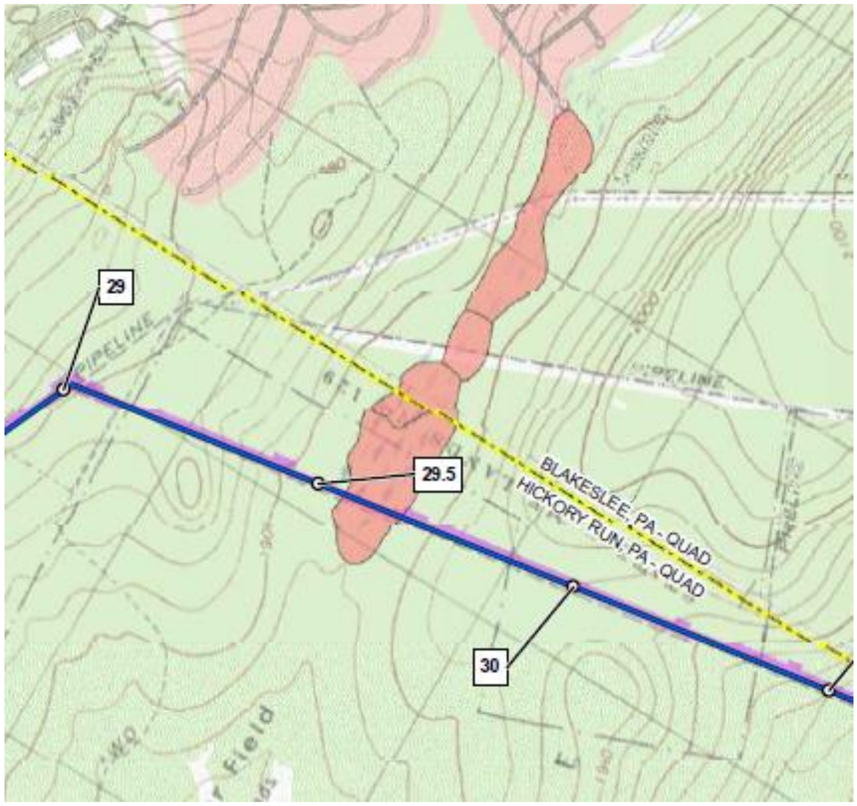

Figure 12: Map of wetland and topography near MP 29.6.

Photo 7: Groundwater dependent wetland, MP 29.6. Shows vehicle damage.

The existing pipeline corridor provided access to many areas for inspection, but it was also obvious that the pipeline corridor allowed 4WD access to water features along the pipeline. At MP 29.5 in Hickory Run State Park, vehicles using the pipeline for access had damaged a wetland the proposed preferred route for PennEast would cross (Photo 8). This access allows repeated and continual damage to water resources near the pipeline.

- Penn East should limit vehicular access to any pipeline ROW. The DEIS should assess the potential for ancillary damages to water resources (and other features) caused by the pipeline, such as due to enhanced access. The DEIS should also discuss how to prevent and mitigate these damages, including closing areas to vehicular access and providing enhanced enforcement strategies (gates alone do not work ATVs go around them).

Photo 8: Vehicular damage to wetlands near MP 29.5 in Hickory Run State Park.

5.0 CONCLUSION

The application for 401 water quality certification does not indicate or prove that the proposed pipeline would not damage surface and groundwater quality in the areas near the proposed route. Pipeline construction will affect groundwater recharge and flow, thereby affecting surface water flow and wetlands water balances. It can affect water quality by providing transport pathways for contaminants to reach wetlands or surface water. Specifically, the proposed project could affect “water quality” by transporting contaminants into streams or nearby groundwater, “stream flow” by diverting groundwater or preventing recharge, “aquatic habitat” by decreasing flow during baseflow conditions which would eliminate aquatic habitat, and “instream and downstream water use” by decreasing flow or contaminating it.

PennEast does not analyze any of these impacts as required by 25 Pa. Code § 105.15(e)(1)(x). The application is incomplete because it does not include sufficient data or analysis of available regarding groundwater. The application also fails to consider routes or construction amendments at various locations, some of which were visited and reviewed herein, which would likely have less impact than the proposed route. Pennsylvania should not even consider the certification until the analyses and data requested herein have been provided.

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