## White Paper Value of Nonrenewable and Renewable Resources in the Upper Delaware River Watershed (draft June 2019) G. J. Kauffman and A. R. Homsey

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The objective of this white paper is to update the value of non-renewable Marcellus shale resources in the Delaware River watershed with protective buffers in place compared to the value of renewable water-based resources such as drinking water, forest, and the river-based recreation economy. Based on well drilling and geologic data (Figure 1), 1,797 mi<sup>2</sup> of potential Marcellus shale lies in the Delaware River watershed. The DRBC, New York State, and Pennsylvania have considered regulations that would set buffers that exclude natural gas drilling from high value landscapes and special protection waters (Table 1 and Figure 2). New York City Catskill reservoir watersheds that convey up to 800 mgd of drinking water from the east and west branches of the Delaware River through the 85-mile Delaware Aqueduct. Natural gas drilling is banned in the Cannonsville (455 mi<sup>2</sup>), Pepacton (371 mi<sup>2</sup>), and Neversink (92 mi<sup>2</sup>) reservoir watersheds and a 4,000 ft reservoir buffer (80 mi<sup>2</sup>). Delaware Water Gap National Recreation Area (109 mi<sup>2</sup>) managed by the National Park Service along 40 miles of the upper Delaware River between Stroudsburg and Port Jervis, Pa. Upper Delaware National Wild & Scenic River (45 mi<sup>2</sup>) from "Ridge to Ridge" from RM 298-331 administered by National Park Service under National Wild & Scenic Rivers Act. Stream and wetland buffers (300 ft wide) along 2,279 stream miles to exclude 259 mi<sup>2</sup> (14%) of the Delaware Basin shale from drilling or 218 mi<sup>2</sup> in New York and 41 mi<sup>2</sup> in Pennsylvania (Table 2). Setbacks from surface water supply intakes (1000 ft), water supply reservoirs (1,000 ft), public water systems (1,000 feet), private wells (500 feet), and steep slopes (>15%).

The Marcellus Shale Formation lies under 1,797 mi<sup>2</sup> or 14% of the upper Delaware River watershed including 1,554 mi<sup>2</sup> in New York and 243 mi<sup>2</sup> in Pennsylvania. The U.S. Geological Survey (Coleman et al. 2011) estimated the 54,000 mi<sup>2</sup> Marcellus Shale Formation in Ohio, West Virginia, Maryland, Pennsylvania and New York holds a mean volume of 84 trillion cubic feet (tcf) of potentially recoverable natural gas. Given the Delaware River watershed covers 1,797 mi<sup>2</sup> or 3.3% of the Marcellus shale, the scaled mean volume of shale gas in the watershed is 2.8 tcf or 0.7 tcf when buffers are considered. During April 2019, the annual natural gas wellhead price was \$2.48 per 1000 cubic feet. Buffers considered by DRBC, NYSDEC, and PADEP would exclude 1,364 mi<sup>2</sup> or 76% of Marcellus shale area in the Delaware River Watershed leaving 433 mi<sup>2</sup> open including 282 mi<sup>2</sup> in New York and 151 mi<sup>2</sup> in Pennsylvania (Table 3). With buffers, the estimated value of potentially recoverable natural gas at the April 2019 price is \$42 million/yr or \$27 million/yr in New York and \$15 million/yr in Pennsylvania (Table 4 and Figure 3). New York has imposed a ban on Marcellus Shale drilling throughout the state. Note that the estimated potential value of Marcellus shale gas within the upper Delaware River watershed is 190 times less than the annual \$8 billion value of renewable resources such as drinking water supply (\$2.8 billion/yr), forests (4.2 billion/yr), and river recreation (\$0.9 billion/yr) as tabulated in Table 5 and Figure 4.



Figure 1. Marcellus shale region of the Delaware River Watershed



Figure 2. Protective buffers in the Marcellus shale area of the Delaware River Watershed

Criteria	NYSDEC	PADEP	DRBC
New York City Catskill Reservoir Watersheds	w/4,000 ft buffer		Yes
Delaware Water Gap National Recreation Area			Yes
Upper Del. National Wild and Scenic River			Yes
State Land	Catskill Preserve	State Parks	
Primary Aquifer	w/500 ft buffer		
Water Body (Stream)	50 ft	300 ft	300 ft
Wetlands	100 ft	100 ft	300 ft
100-yr Floodplain	Yes	Yes	Yes
Public Roads Buffer	75 ft		
Public Water Supply	2,000 ft	1000 ft	1000 ft
Private Wells	500 ft	500 ft	
Financial Bond (per well)	\$250,000	\$2,500	\$125,000

Table 1. Marcellus shale buffers considered by DRBC, New York, & Pennsylvania

Table 2. Stream and wetland buffers considered by I	DRBC,	NYSDEC.	and PADEP
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	Stream	Watershed Area	Stream Buffer	% Watershed
Watershed	Length (mi)	(mi <sup>2</sup> )	(mi <sup>2</sup> )	Protected
EW1 West Branch (Cannonsville)	763	615	87	14%
EW2 East Branch (Pepacton)	1,017	840	116	14%
EW3 Mainstem (above Narrowsburg)	140	98	16	16%
New York	1,920	1,554	218	14%
EW1 West Branch (Cannonsville)	68	51	8	15%
EW3 Mainstem (above Narrowsburg)	146	91	17	18%
LW1 Lackawaxen	145	102	17	16%
Pennsylvania	360	243	41	17%
Total	2,279	1,797	259	14%

Buffers in Marcellus Shale of the DRB	NY (mi <sup>2</sup> )	PA (mi <sup>2</sup> )	DRB (mi <sup>2</sup> )
New York City Reservoirs			
Cannonsville Watershed	455		455
Pepacton Watershed	371		371
Neversink Watershed	0		0
4000 foot buffer	55		55
Delaware Water Gap National Recreational Area			0
Upper Delaware National Wild and Scenic River (RM 298-330)	21	24	45
Water and Wetlands 300 foot Buffer	218	41	259
Catskill Forest Preserve	56		56
Protected State Lands	96	27	123
Total Buffers	1,272	92	1,364
Marcellus Shale Area in DRW		243	1,797
Available Marcellus Shale Area w/buffers	282	151	433
% Available Marcellus Shale Area w/buffers	18%	62%	24%

Table 3. Marcellus shale buffers considered in the Delaware River Watershed

Table 4. Wellhead value (2019) of Marcellus shale gas in the Delaware River Watershed with buffers

State/Basin	Marcellus Shale Area (mi <sup>2</sup> )	Buffer Area (mi <sup>2</sup> )	Available Shale (mi <sup>2</sup> )	Natural Gas Vol. <sup>1</sup> (tcf)	Available Gas Vol. <sup>2</sup> (tcf)	Total Value <sup>3</sup> (\$ mil)	Annual Value <sup>4</sup> (\$ mil/yr)
Pennsylvania	243	92	151	0.4	0.2	616	15
New York	1,554	1,272	282	2.4	0.4	1,080	27
Delaware Basin	1,797	1,364	433	2.8	0.7	1,697	42

1. USGS 2011. 2. w/ DRBC, NYSDEC, PADEP buffers. 3. April 2019 wellhead price \$2.48/1000 cf. 4. 40-year recovery period.

Table 5. Value of natural resources in the Marcellus shale region of the Delaware River Watershed

Economic Value	2010 (\$ mil/yr)	Sources
Marcellus Shale Gas (0.7 tcf @ \$2.48/1000 cf)	42	Coleman et al. 2011 (USGS)
Drinking Water (1,605 mgd @ \$4.78/1000 gal)	2,800	DRBC 2010, NJWSA 2011, Corrozi & Seymour 2008
Forests (2,057,492 ac @ \$2,036/ac)	4,189	NJDEP 2007
River Recreation	942	
Instream Use (7.9 million ac-ft @ \$10/ac-ft)	79	Frederick et al. 1996
Boating, Fishing, Swimming (WTP = \$139/person)	80	Parsons, Helm, and Bondelid 2003
Paddling-based Recreation (147,664 participants)	86	Outdoor Industry Association 2006
Delaware Water Gap Recreation (267,000 visits)	41	Cordell et al. 1990 (USFS/National Park Service)
Canoe/Kayak/Rafting (204,000 trips, \$50/trip)	10	Canoe and Kayak Liveries 2012
Fishing (11-18 trips/angler, \$53/trip)	107	U. S. Fish and Wildlife Service 2008
Hunting (16 trips/hunter, \$50/trip)	114	U. S. Fish and Wildlife Service 2008
Wildlife/Bird-watching (8-13 trips/yr, \$27/trip)	142	U. S. Fish and Wildlife Service 2008
Shad Fishing (63,000 angler trips, \$102/trip)	6	Pennsylvania Fish and Boat Commission. 2011
Wild Trout Fishing	29	Maharaj, McGurrin, Carpenter 1998 (Trout Unlimited)
Del. Water Gap Natl. Rec. Area (5.6 million visits)	160	Stynes 2011
Skiing (9 resorts, 1.9 million ski visits, \$45/day)	88	Pennsylvania Ski Areas Association 2009



Figure 4. Annual economic value of nonrenewable/renewable resources in Delaware River Watershed

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