Water Withdrawal and Consumptive Use Estimates for the Delaware River Basin (1990-2017) With Projections Through 2060

New Jersey Water Supply Advisory Council

October 15, 2021

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60 years 1961–2021

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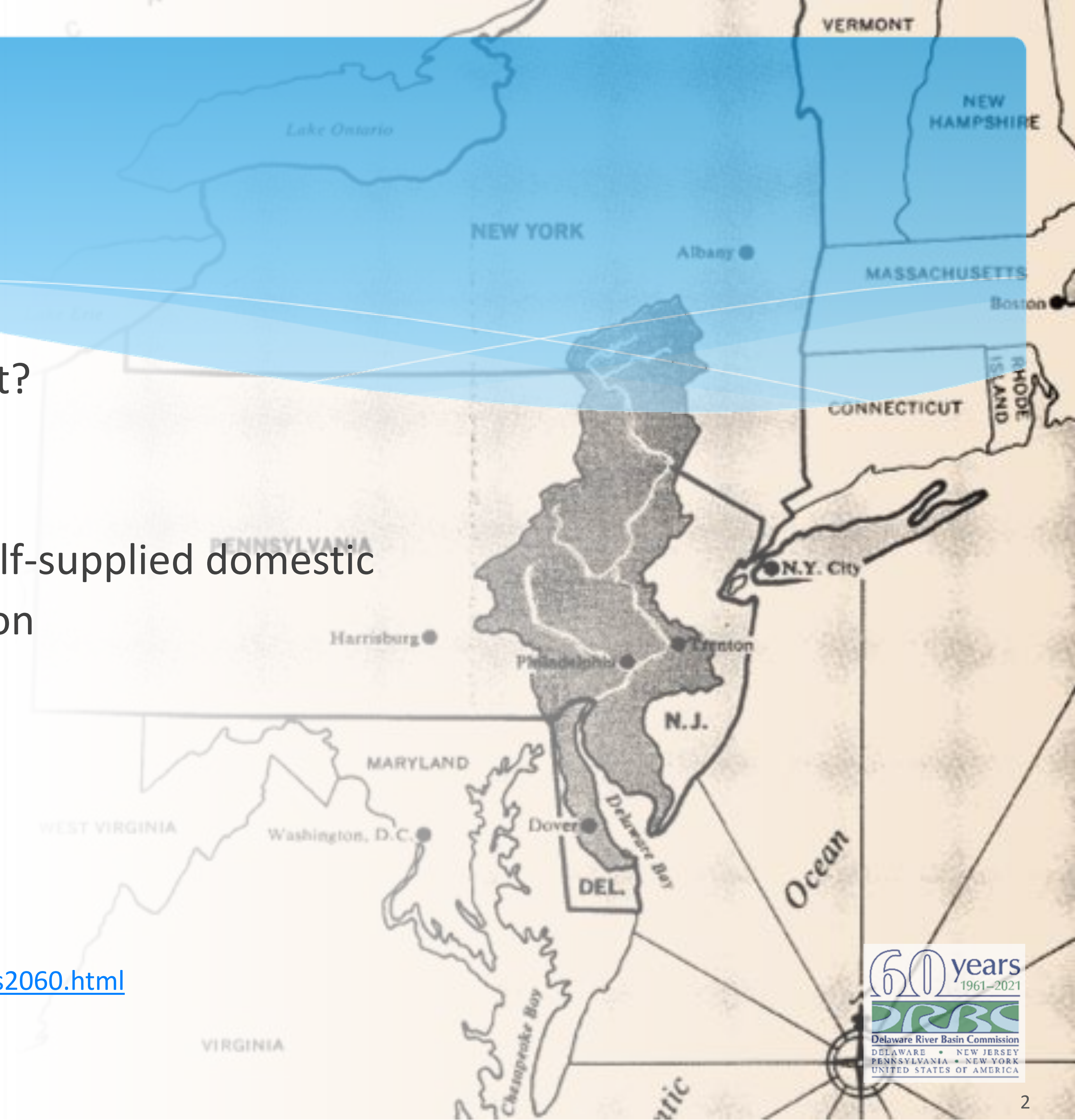
Outline

1. Water Supply Planning – Why and What?
2. Methodology
3. Results
4. Supplemental analysis: population & self-supplied domestic
5. Supplemental analysis: power generation
6. Supplemental analysis: irrigation
7. Next Steps
8. Questions



Report & data:
https://www.nj.gov/drbc/programs/supply/use-demand-projections2060.html

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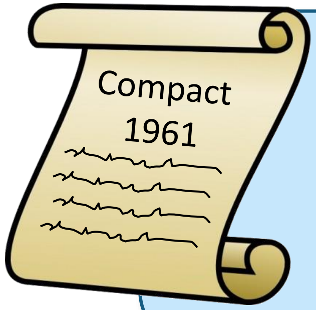
1. Water Supply Planning: Why are we projecting withdrawal data?

Is there enough water to meet future demands?

- What are the current/future demands? ←
- How does it compare against current allocations?
- What about a repeat of the Drought of Record?
- What about climate change?



DELAWARE RIVER BASIN COMPACT (1961)

3.6 General Powers.

- Conduct and sponsor research on water resources
- Collect, compile, correlate, analyze, report and interpret data on water resources and uses in the basin

1. Water Supply Planning: What are the planning objectives?

Provide projections of future average annual water use in the Delaware River Basin, through the year 2060, to be used in future planning assessments.

Represent each water use *sector* at the Basin-wide scale.

Apply GW results to the 147 sub-watersheds (Sloto & Buxton, 2006) and the sub-watersheds of SEPA-GWPA.

Apply SW results at the source level for future availability analyses.

Relate results to regulatory approvals.

2. Methodology: Primary data scale to analyze?

Analysis at the system level (mostly)[1]

Projections at a scale finer than the system level…

- Pertinent metadata is often at the system level (e.g., regulatory)
- Reporting inconsistencies disguised as trends
- System sources show cause-and-effect relationships

[1] Self-supplied domestic and Irrigation used different methodologies

2. Methodology: Breakdown by sector

The primary method is extrapolation of historic reported withdrawal data

Water Withdrawals in the Delaware River Basin

Sector	Report Link	Primary Method
Public Water Supply	Section 3	Extrapolation of historic water withdrawal data
Out-of-Basin Diversion	Section 3	Mean value based on a five-year average.
Self-supplied Domestic	Section 4	Population estimate and per-capita rates.
Power Generation	Section 5	Extrapolation of historic water withdrawal data
Industrial	Section 6	Extrapolation of historic water withdrawal data
Mining	Section 7	Extrapolation of historic water withdrawal data
Irrigation	Section 8	Multivariate regression for temperature and precipitation.
Other	Section 9	Extrapolation of historic water withdrawal data

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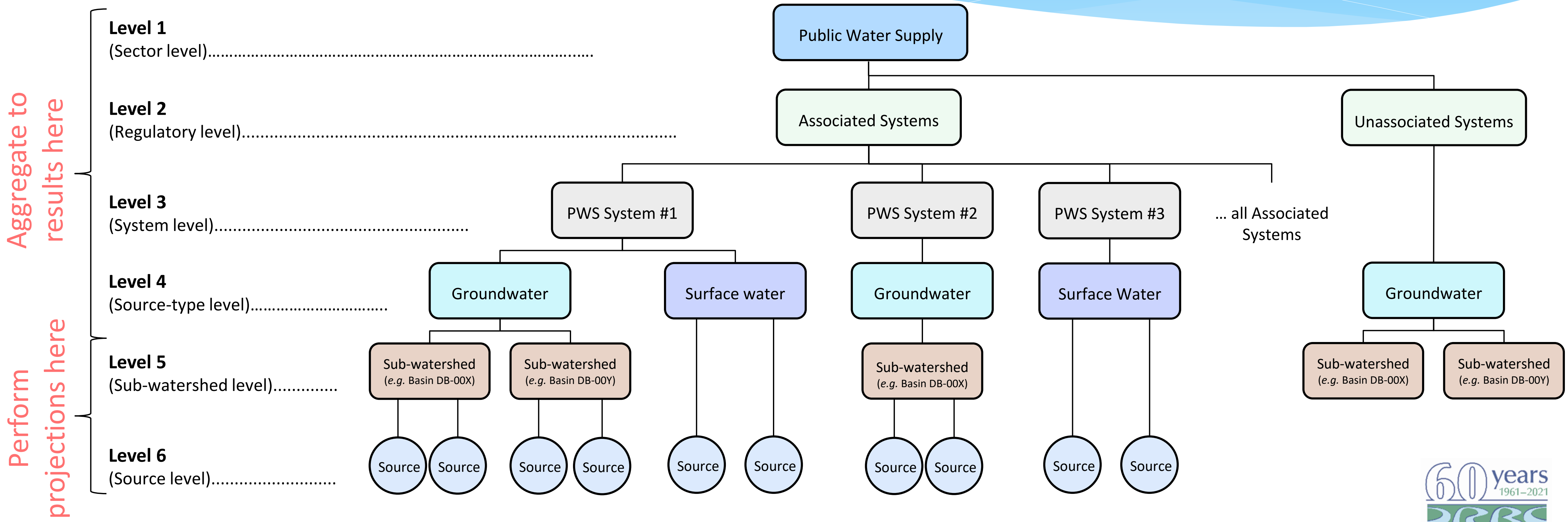
2. Methodology: A plan for projecting data?

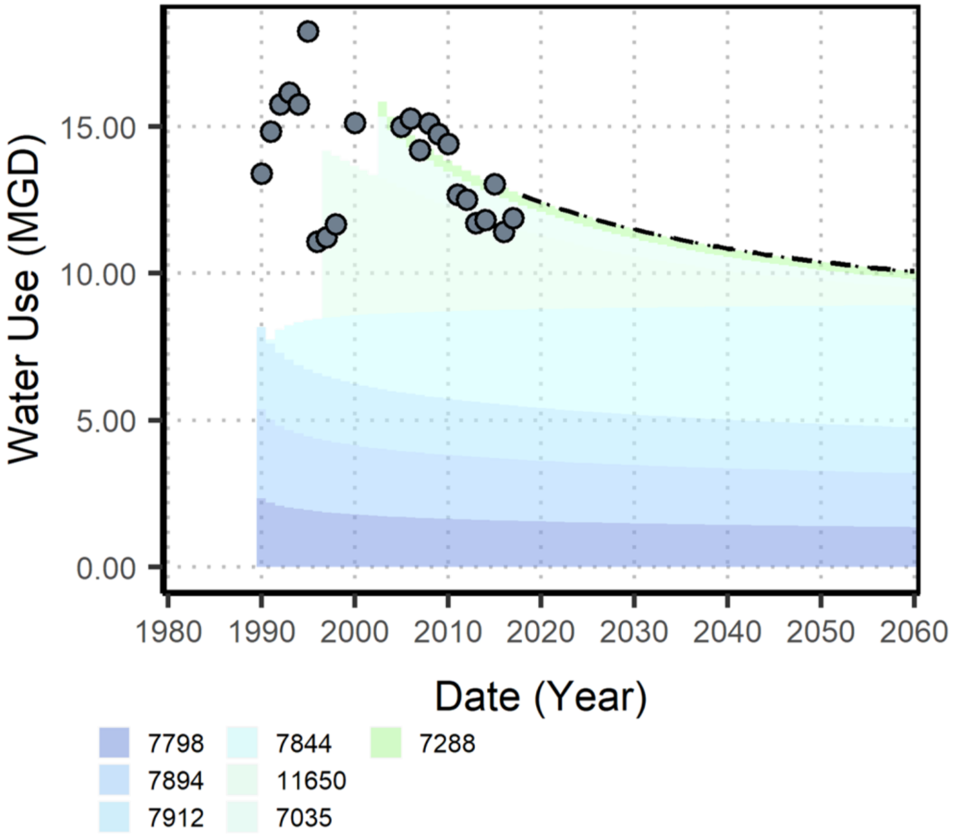
Where do we start?

Time-series hierarchy

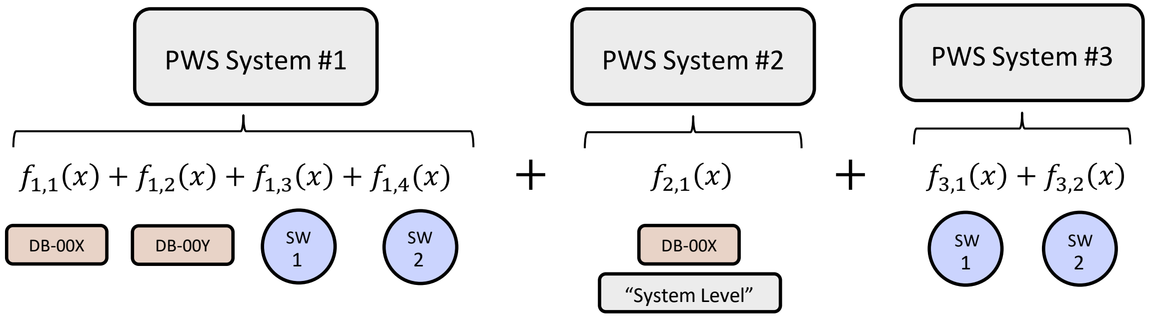


Hyndman, R., & Athanasopoulos, G. (2018). *Forecasting: principles and practice* (2nd ed.). Melbourne, Australia: OTexts. https://otexts.com/fpp2/

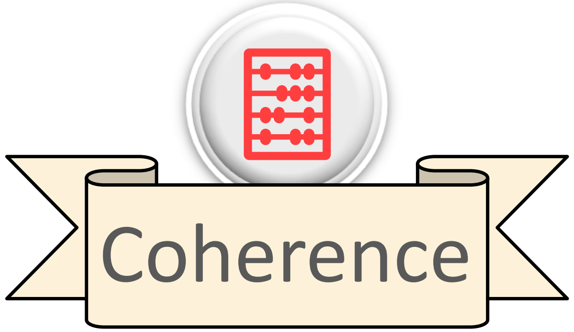
2. Methodology: How do you aggregate projections?



"Bottom-up approach"



$$\boldsymbol{Total} = f_{1,1}(x) + f_{1,2}(x) + f_{1,3}(x) + f_{1,4}(x) + f_{2,1}(x) + f_{3,1}(x) + f_{3,2}(x) + \ldots$$



Do projections aggregate in a manner consistent with the time series?

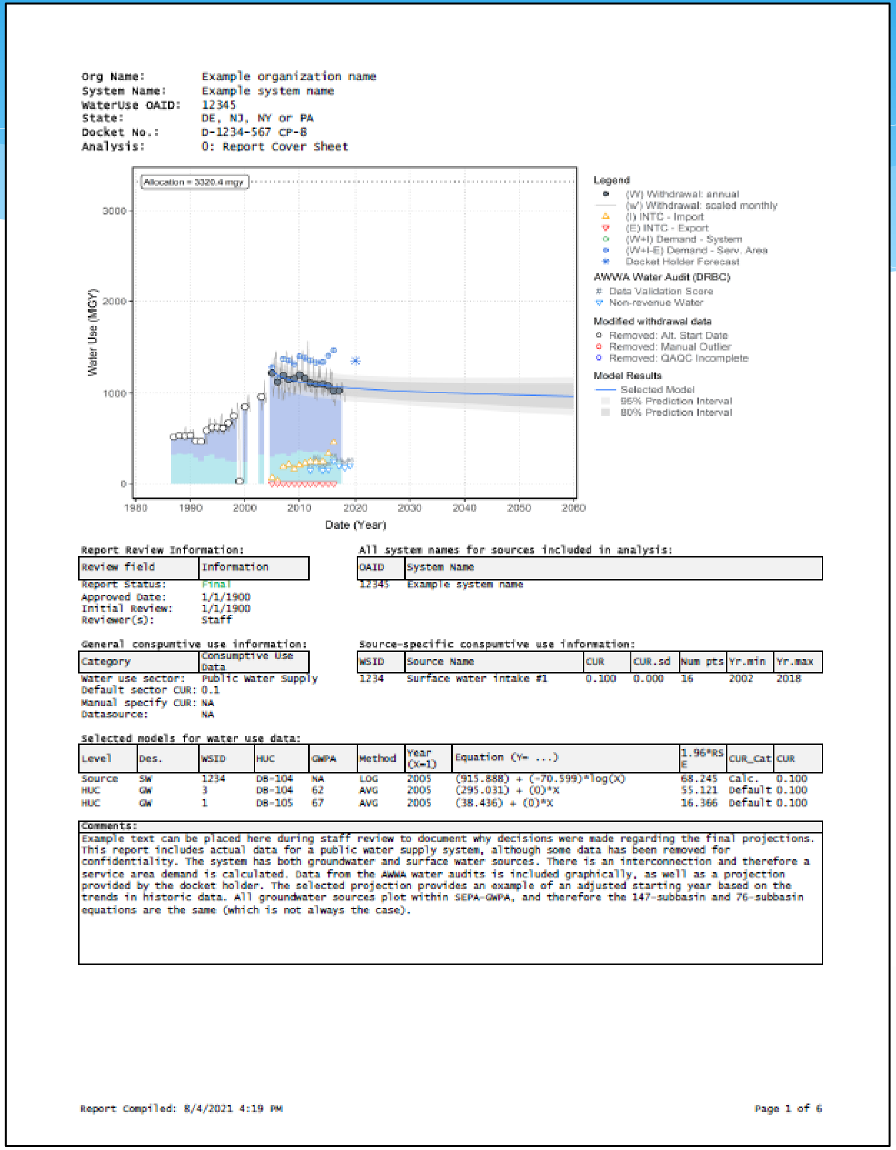
2. Methodology: A plan for projecting data?

The main model is based on extrapolating historic withdrawal data.

- Significant QAQC of historic data
- 600+ system reports
- 1,100+ equations

Method		Associated		Unassociated		Subtotal
		GW	SW	GW	SW	
Mean Value		218	71	147	0	436
OLS	Exponential	72	17	36	0	125
	Linear	83	11	11	0	105
	Logarithmic	250	74	69	0	393
Other		62	48	4	0	114
Subtotal		685	221	267	0	1,173

- OLS = Ordinary Least Squares
- Associated means system operate above review thresholds and has allocation regulatory approval.
- Does not include agriculture and self-supplied domestic analyses



Org Name: Example organization name
System Name: Example system name
WaterUse OAID: 12345
State: DE, NJ, NY or PA
Docket No.: D-1234-567 CP-8
Analysis: 0: Report Cover Sheet

Report Review Information:

Review field	Information
Report Status:	Final
Approved Date:	1/1/1900
Initial Review:	1/1/1900
Reviewer(s):	Staff

All system names for sources included in analysis:

OAID	System Name
12345	Example system name

General conspumtive use information:

Category	Consumptive Use Data
Water use sector:	Public Water Supply
Default sector CUR:	0.1
Manual specify CUR:	NA
Datasource:	NA

Source-specific conspumtive use information:

WSID	Source Name	CUR	CUR.sd	Num pts	Yr.min	Yr.max
1234	Surface water intake #1	0.100	0.000	16	2002	2018

Selected models for water use data:

Level	Des.	WSID	HUC	GWPA	Method	Year (X=1)	Equation (Y= ...)	1.96*RSE	CUR_Cat	CUR
Source	SW	1234	D8-104	NA	LOG	2005	(915.888) + (-70.599)*log(X)	68.245	Calc.	0.100
HUC	GW	3	D8-104	62	AVG	2005	(295.031) + (0)*X	55.121	Default	0.100
HUC	GW	1	D8-105	67	AVG	2005	(38.436) + (0)*X	16.366	Default	0.100

Comments:
Example text can be placed here during staff review to document why decisions were made regarding the final projections. This report includes actual data for a public water supply system, although some data has been removed for confidentiality. The system has both groundwater and surface water sources. There is an interconnection and therefore a service area demand is calculated. Data from the AWWA water audits is included graphically, as well as a projection provided by the docket holder. The selected projection provides an example of an adjusted starting year based on the trends in historic data. All groundwater sources plot within SEPA-GWPA, and therefore the 147-subbasin and 76-subbasin equations are the same (which is not always the case).

Report Compiled: 8/4/2021 4:19 PM Page 1 of 6

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3. Results

Wing Dam on The Delaware River
Lambertville New Jersey on the left and
New Hope Pennsylvania on the right.
Credit: © James Loesch
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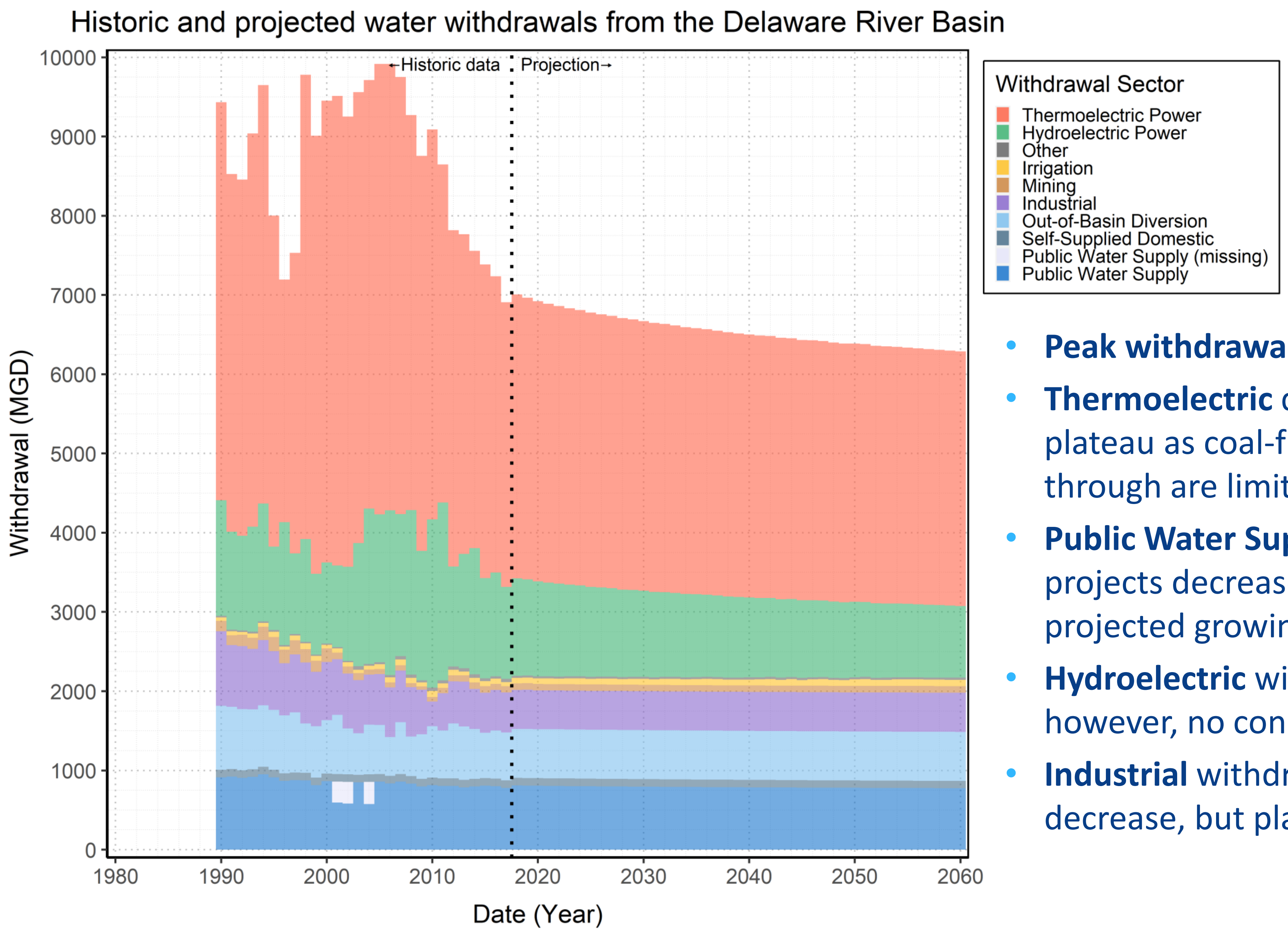

- **Peak withdrawals have occurred**
- **Thermoelectric** decreases since 2007 will plateau as coal-fired facilities using once-through are limiting
- **Public Water Supply** has shown and projects decreases despite historic and projected growing in-Basin population
- **Hydroelectric** withdrawals are significant; however, no consumptive use
- **Industrial** withdrawals historically decrease, but plateau

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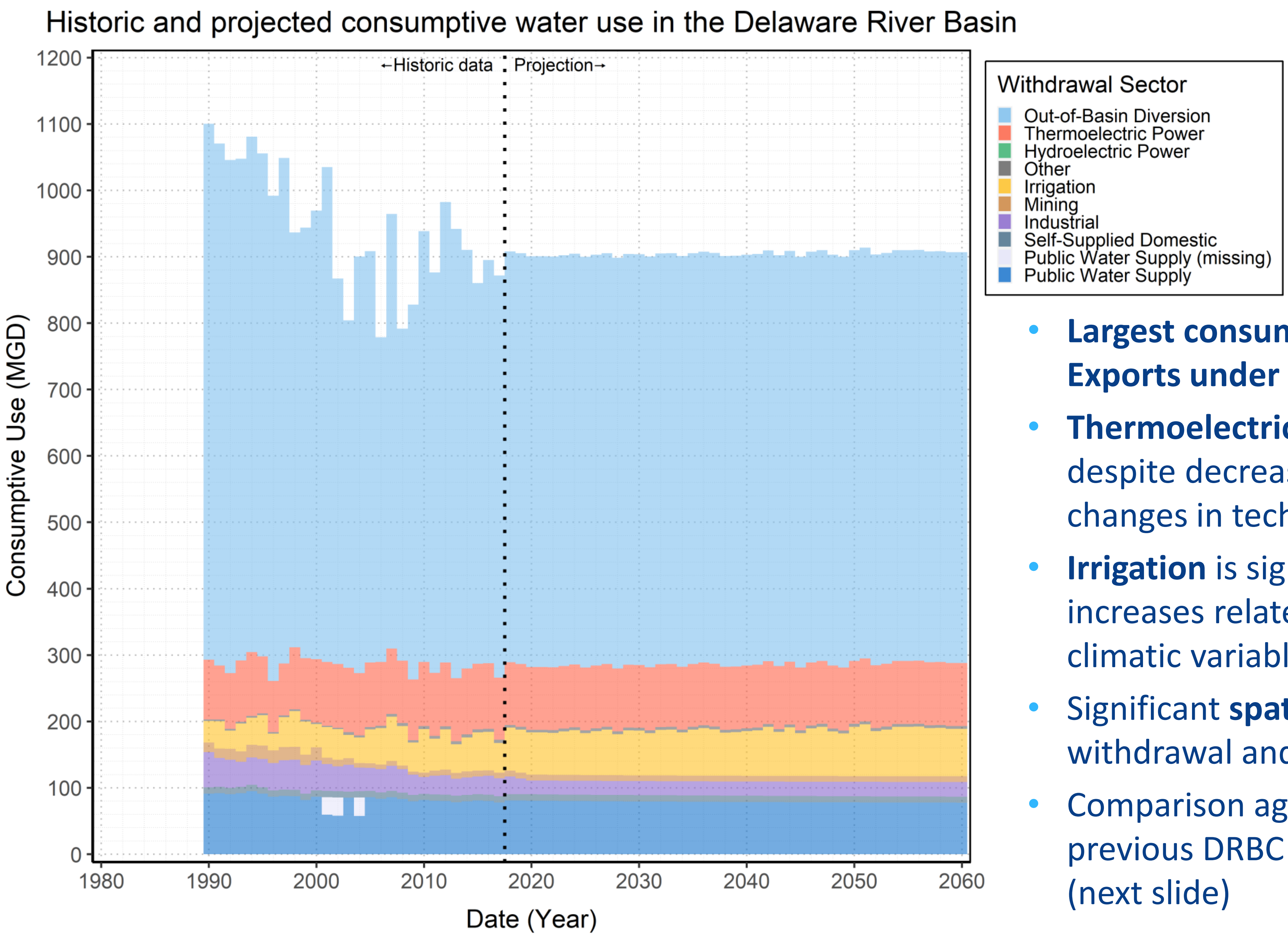

- **Consumptive use projected to remain relatively constant**
- **Largest consumptive use is Out-of-Basin Exports under a U.S. Supreme Court Decree**
- **Thermoelectric** consumptive use constant despite decreased withdrawals due to changes in technology
- **Irrigation** is significant and shows slight increases related to projected changes in climatic variables
- Significant **spatial variation** in terms of both withdrawal and consumptive use
- Comparison against previous DRBC estimates (next slide)

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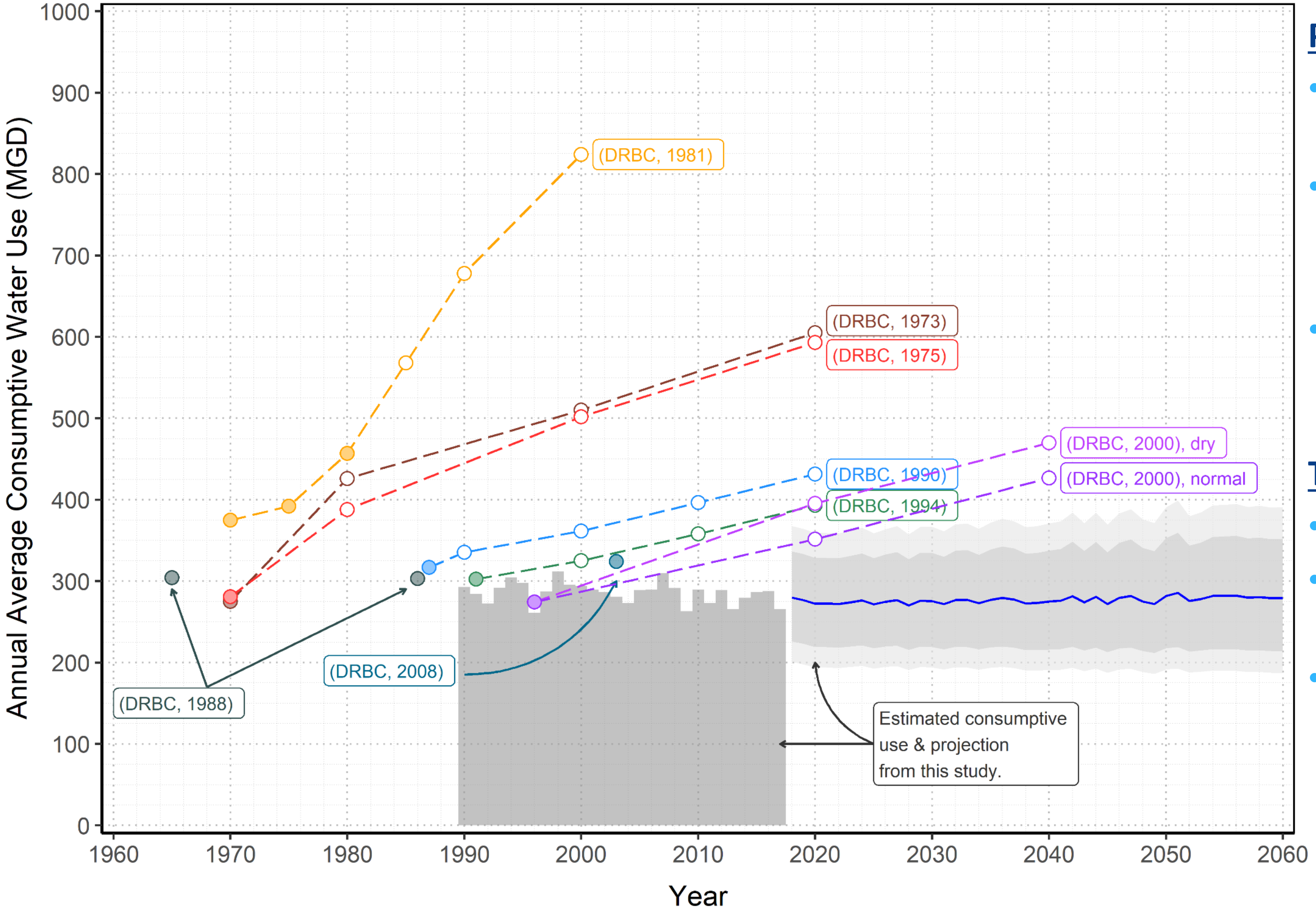
Previous DRBC projections of Basin-wide consumptive water use (comparison)



Prior projections often:

- Work from one estimated year of withdrawal data
- Are performed indirectly (e.g., applying population projections)
- May have considered/ accounted for planned facilities (e.g., power)

This study:

- Almost 30 years of data
- Aligns with previous *estimates*
- Most conservative projection

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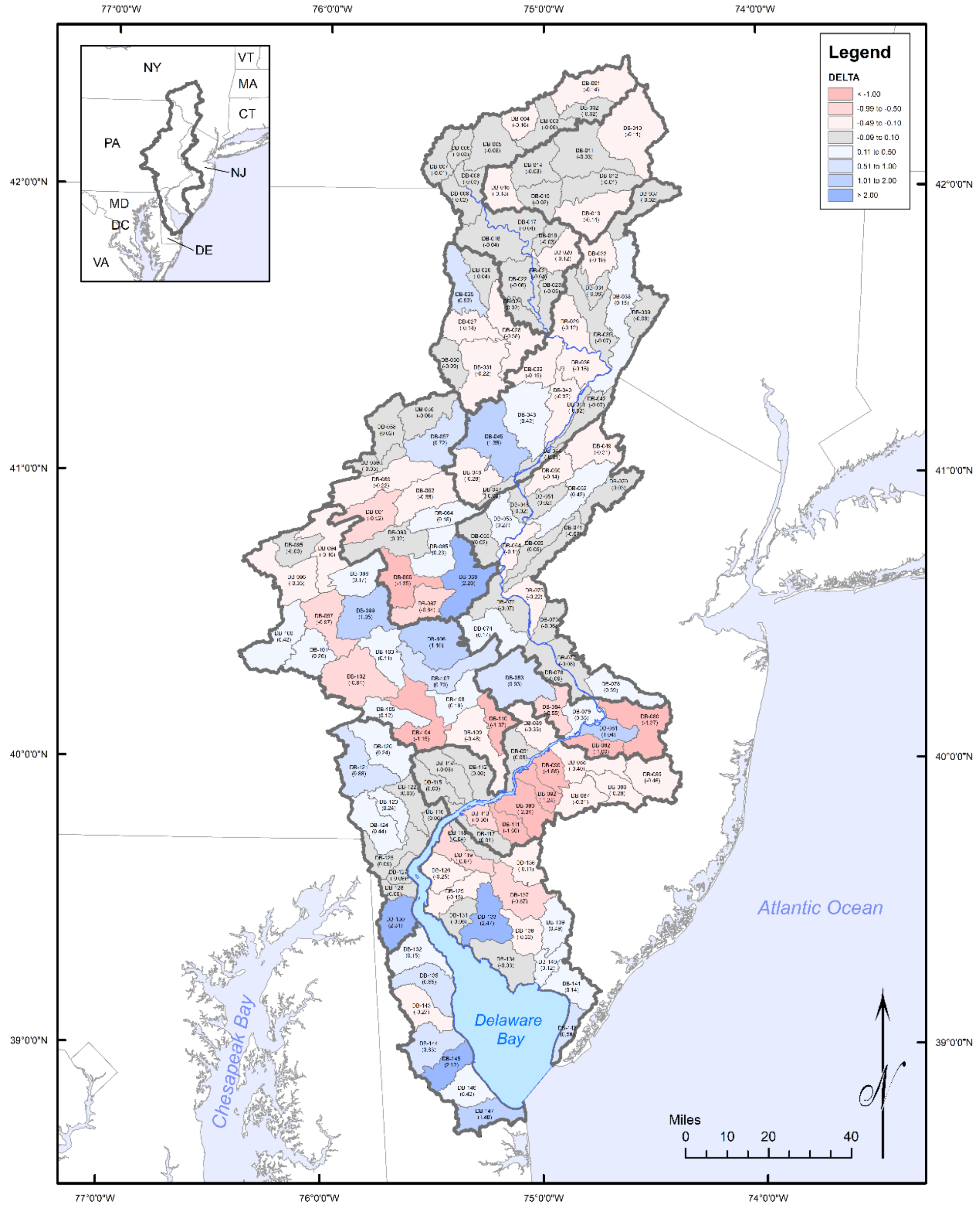
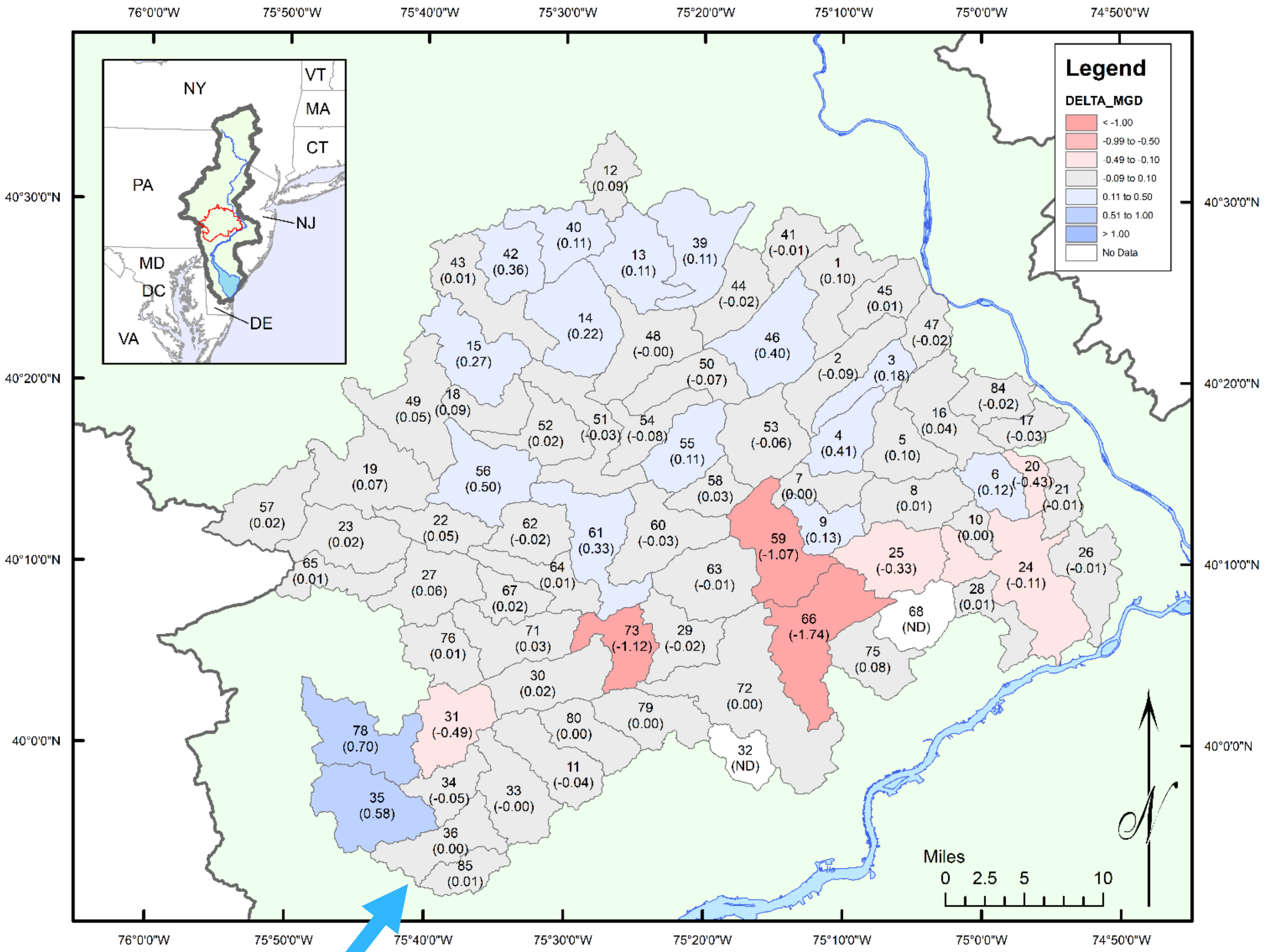




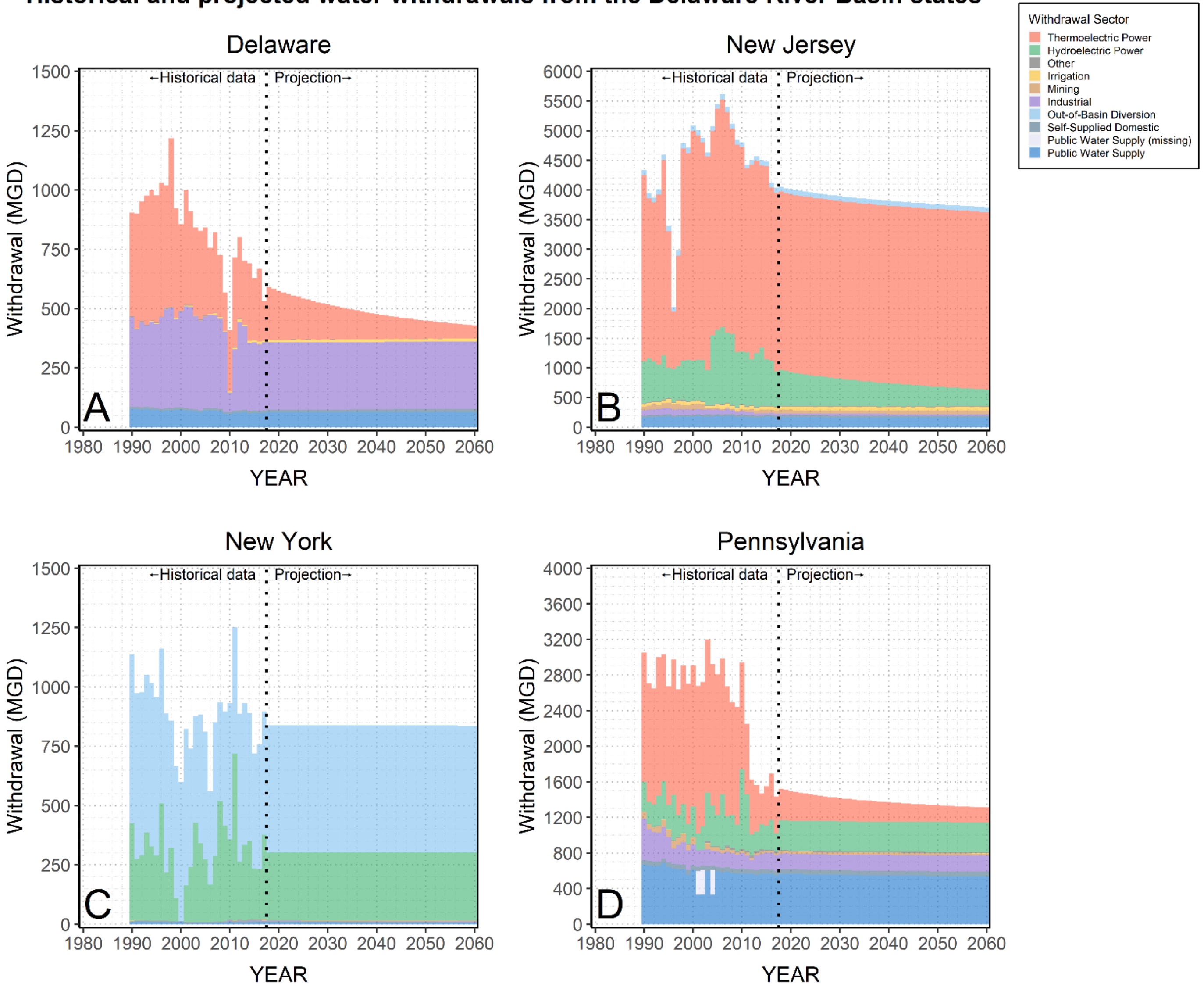
SEPA-GWPA:

- Decreasing (Δ < -0.10 MGD) 7 subbasins (-5.273 MGD)
- Neutral (-0.10 < Δ < 0.10 MGD) 51 subbasins (+0.325 MGD)
- Increasing (Δ > 0.10 MGD) 16 subbasins (+4.629 MGD)

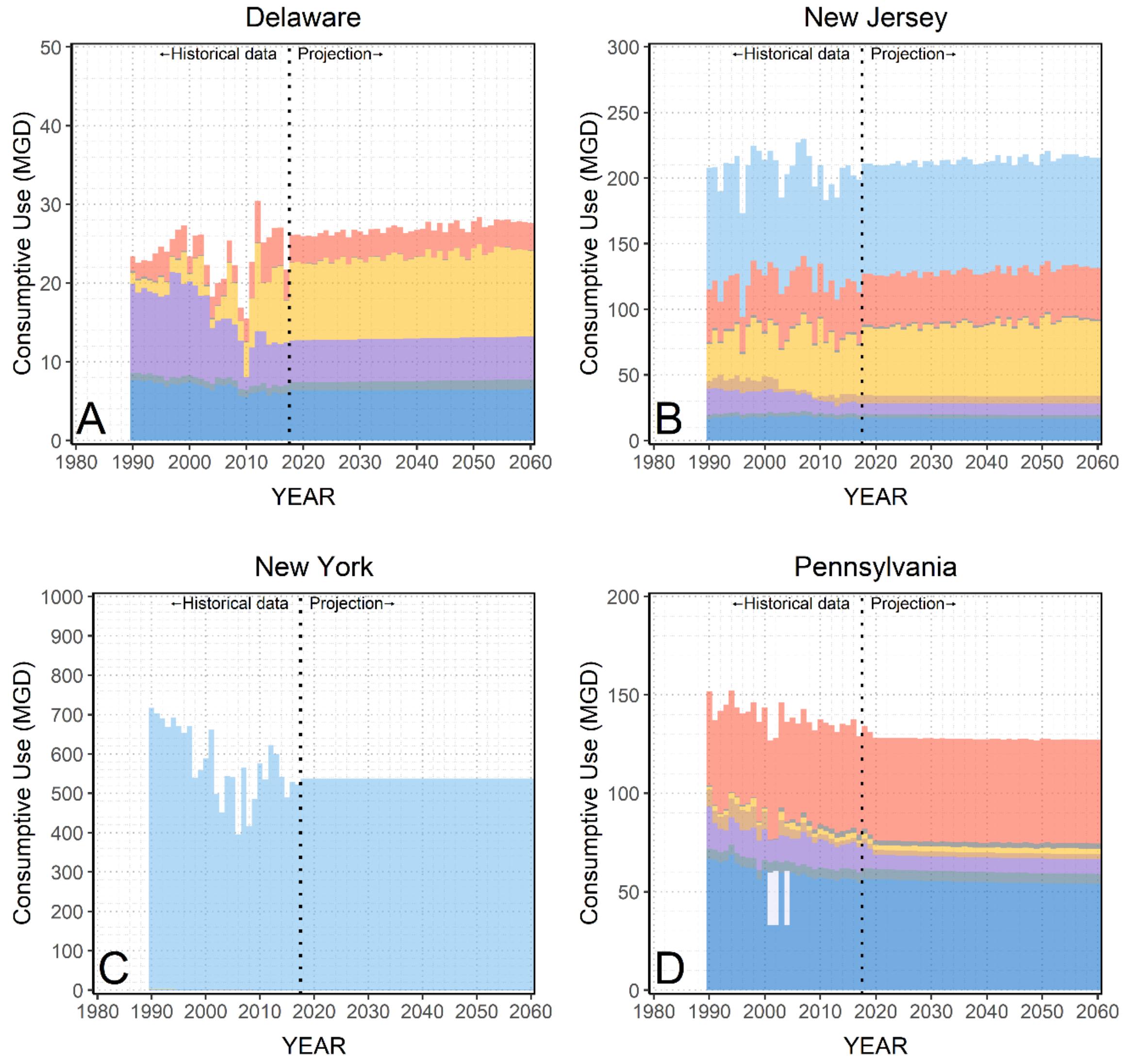
147 Subbasins:

- Decreasing (Δ < -0.10 MGD) 51 subbasins (-26.500 MGD)
- Neutral (-0.10 < Δ < 0.10 MGD) 56 subbasins (-1.451 MGD)
- Increasing (Δ > 0.10 MGD) 40 subbasins (+26.930 MGD)

Historical and projected water withdrawals from the Delaware River Basin states

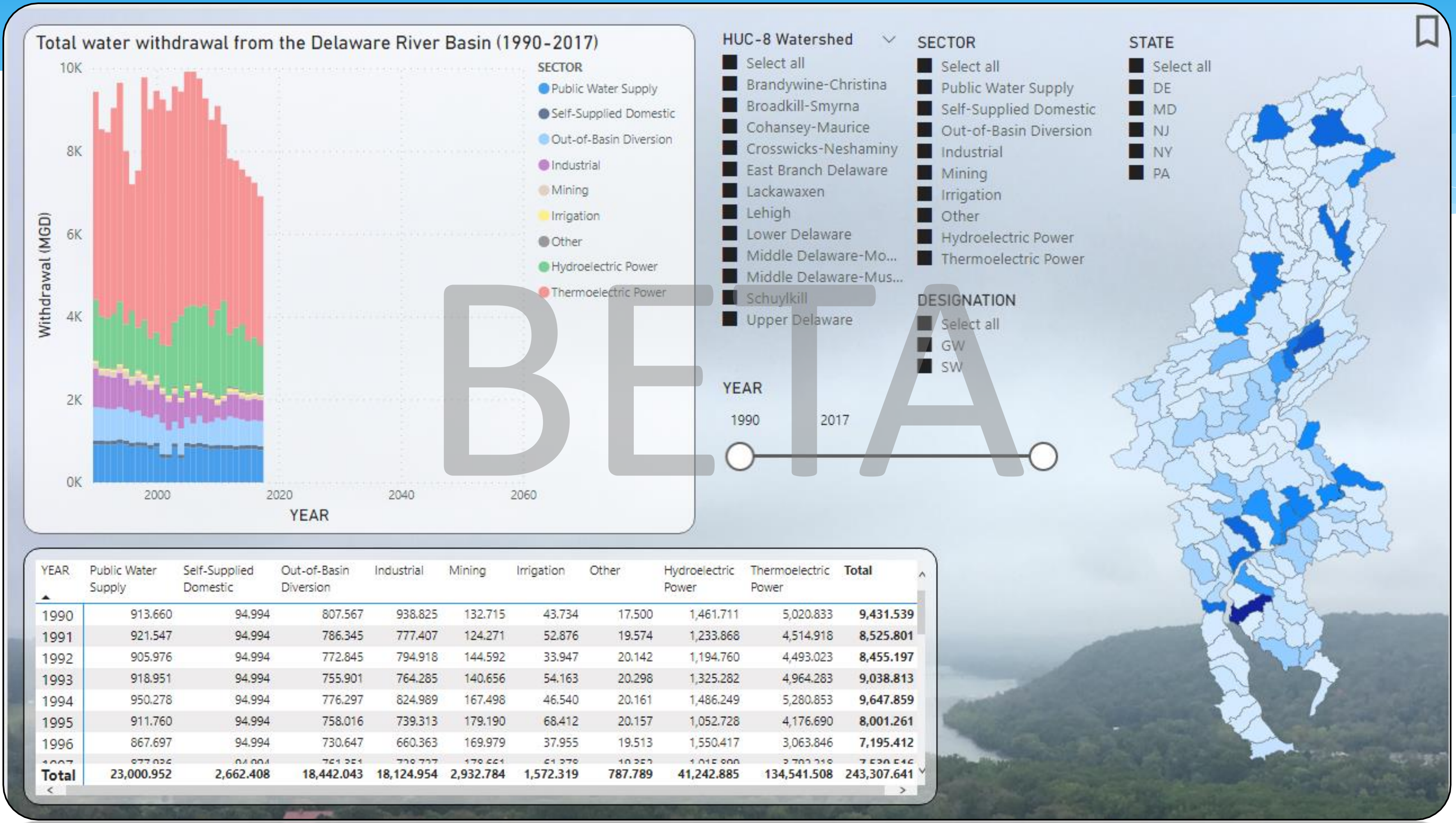


Historical and projected consumptive water use in the Delaware River Basin states

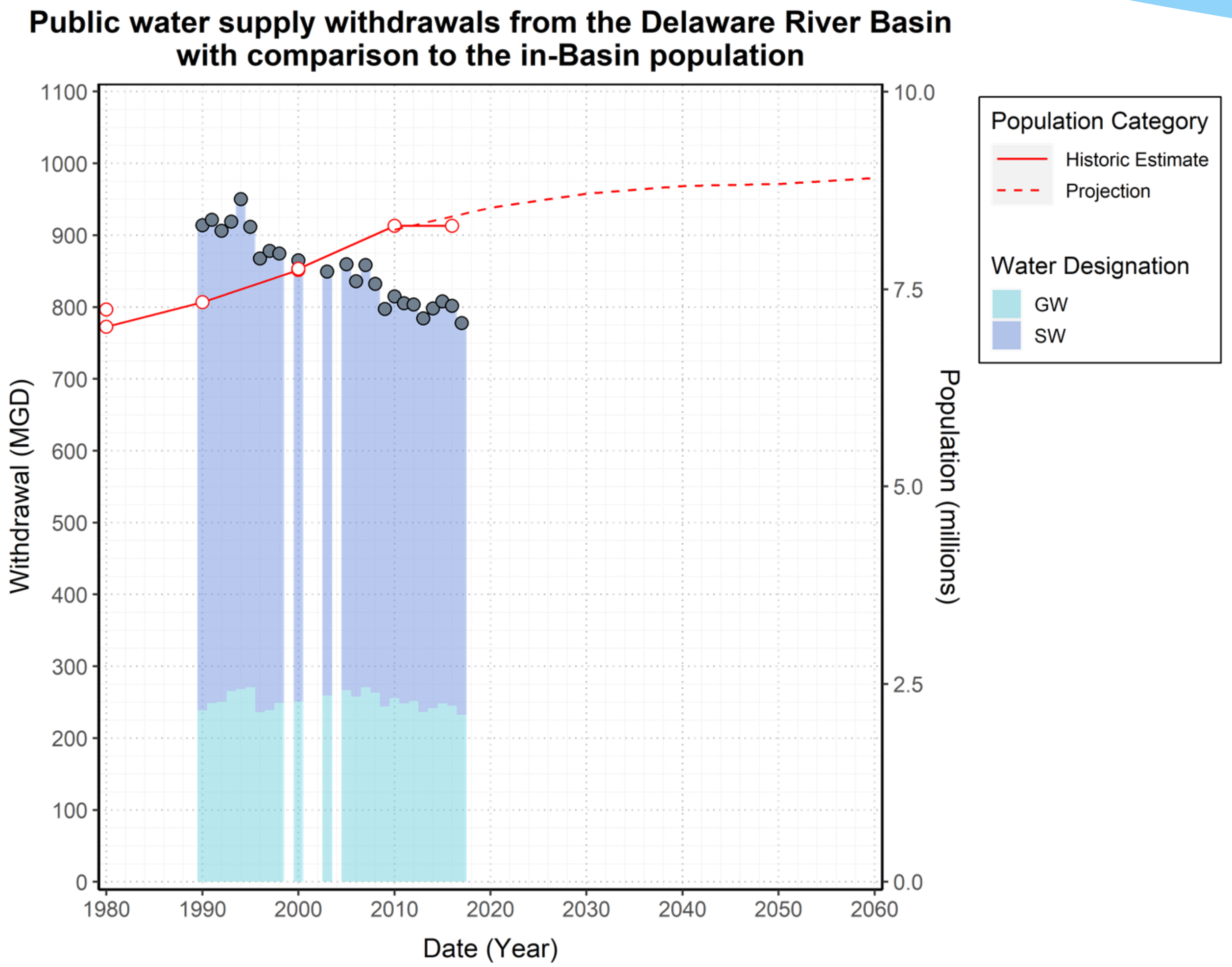


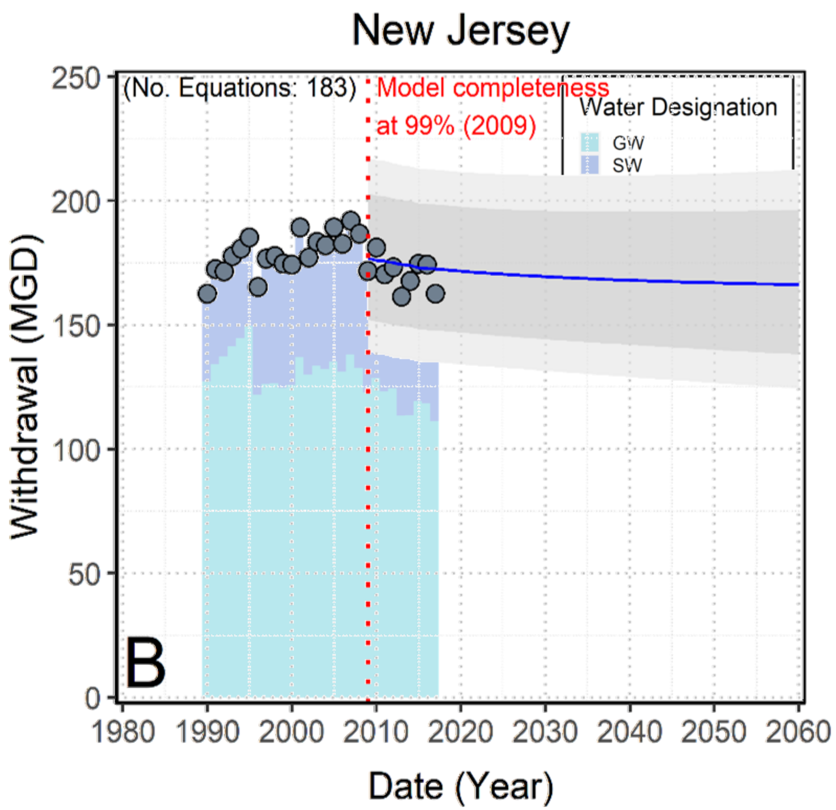
3. DEMO: Data exploration

Power BI

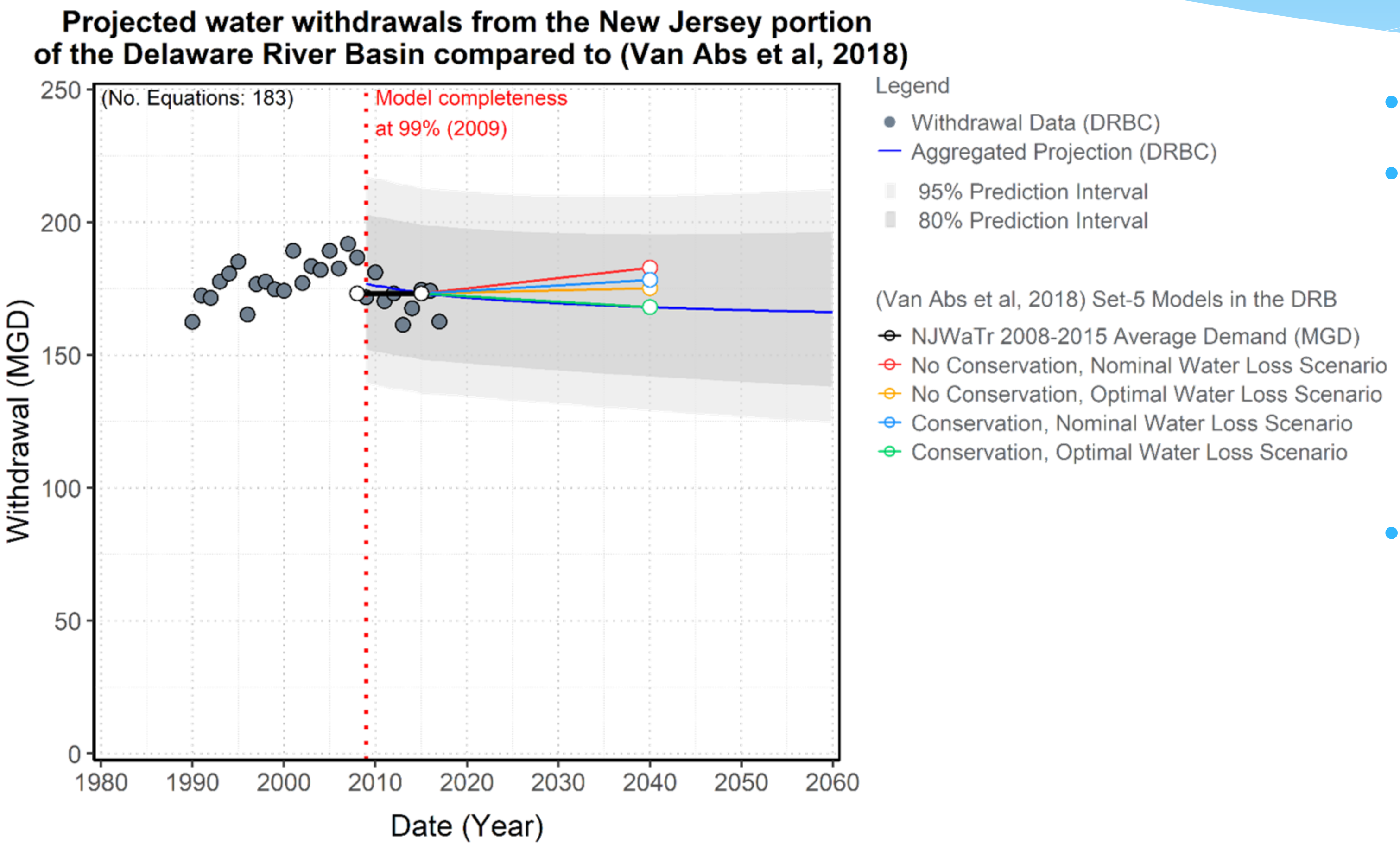


3. New Jersey DRB Public Water Supply



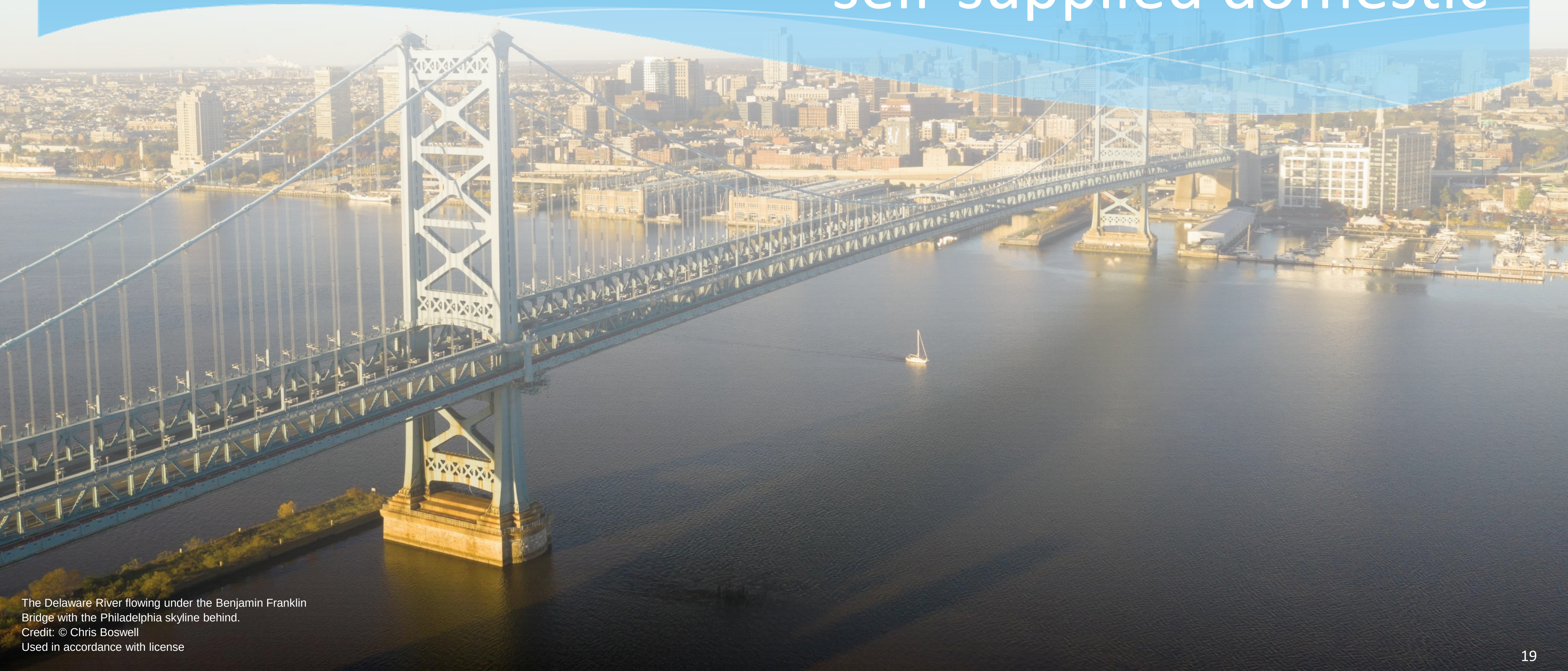


3. New Jersey DRB Public Water Supply

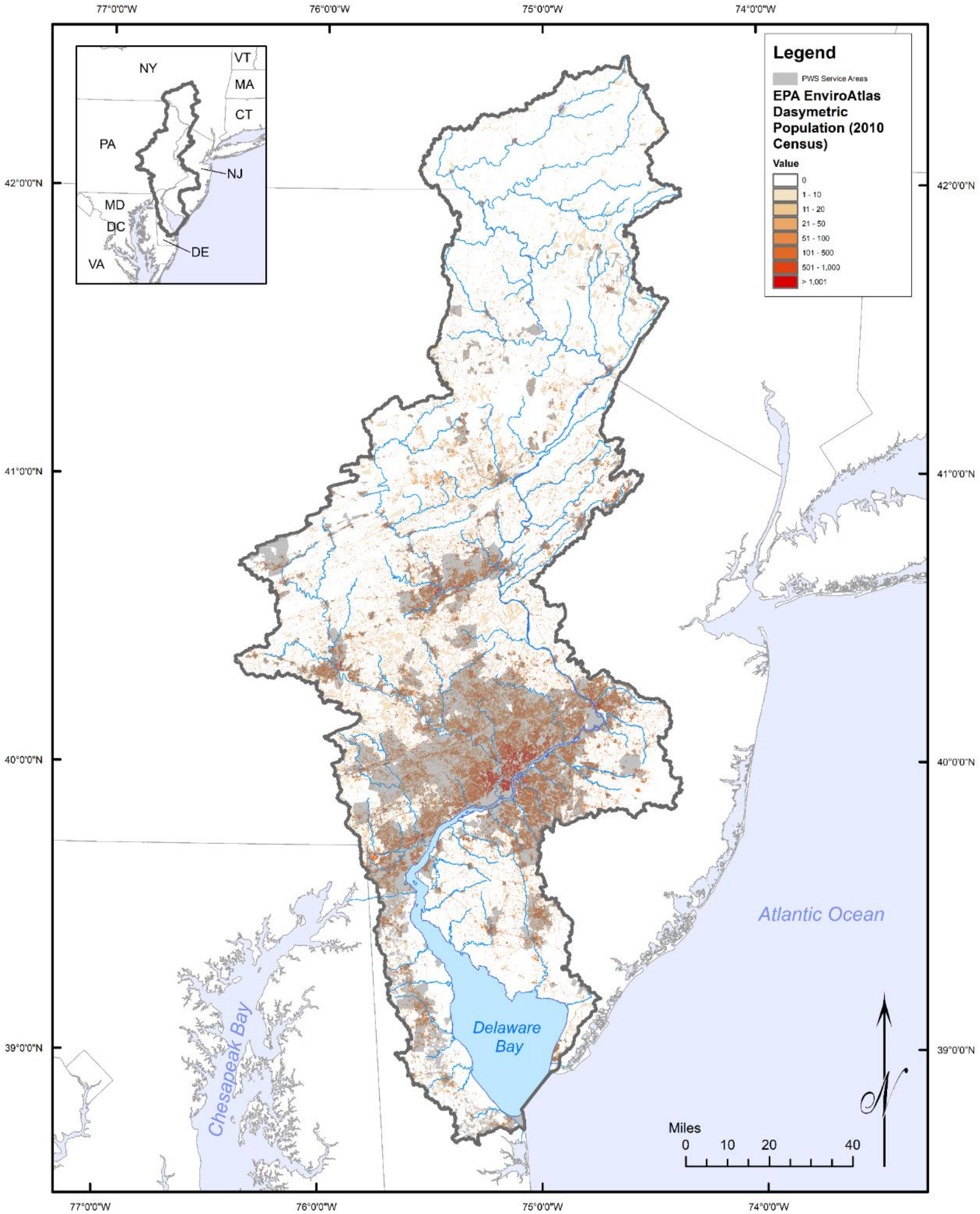


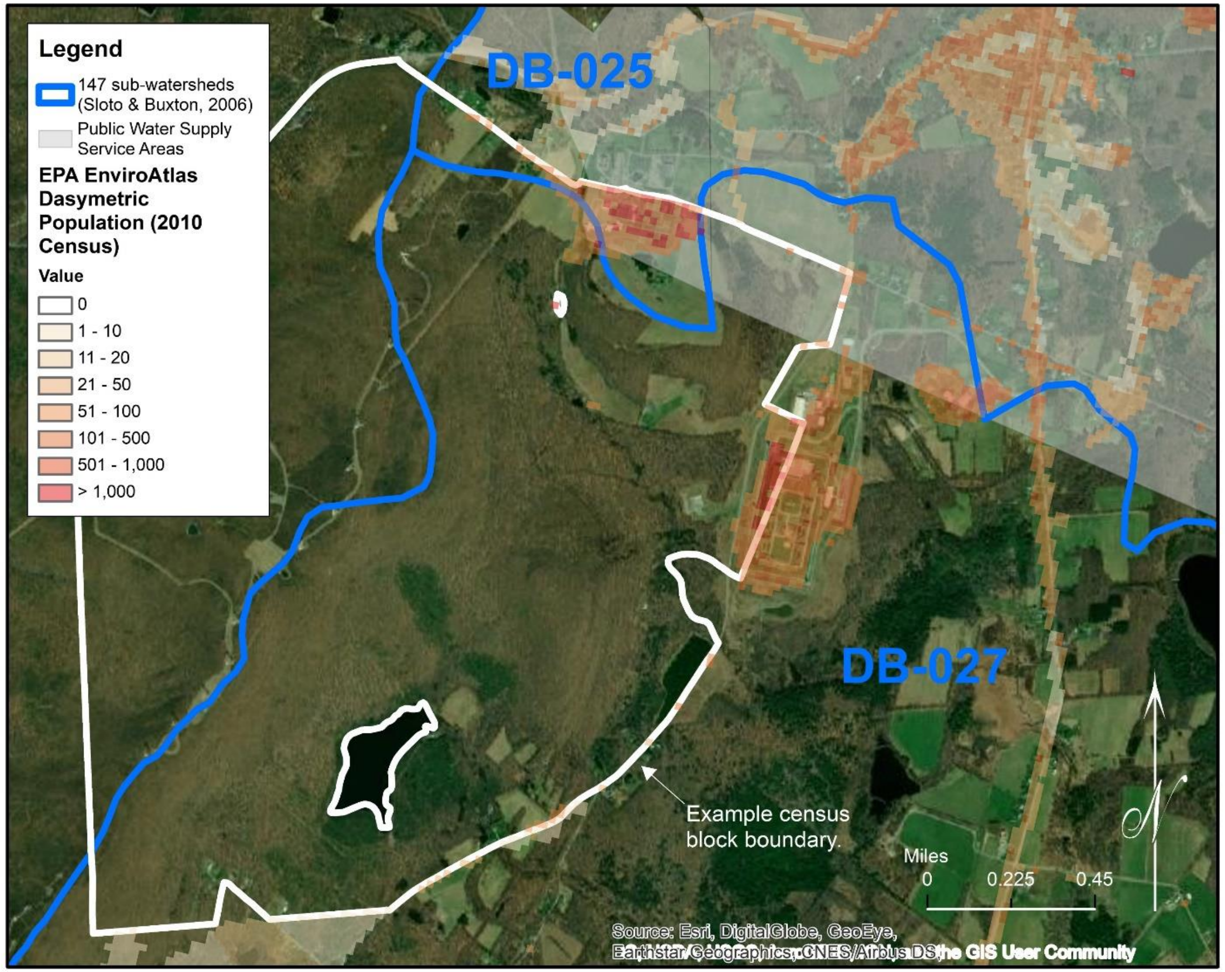
- **Compared against (Van Abs et al, 2018)**
- **Two preliminary conclusions:**
  - Water moves within the Basin a lot, but not necessarily in/out of the Basin
  - Van Abs et al, 2018 demands vs. DRBC: 9 systems had difference ≥0.5 MGD; 6 service areas on the Basin boundary
- Van Abs study on demand is comparable to DRBC study on withdrawal as long as it is at the Basin scale (low import/export) **AND** Correct the Van Abs y-year average by the offset of systems on Basin divide

4. Supplemental analysis: population & self-supplied domestic

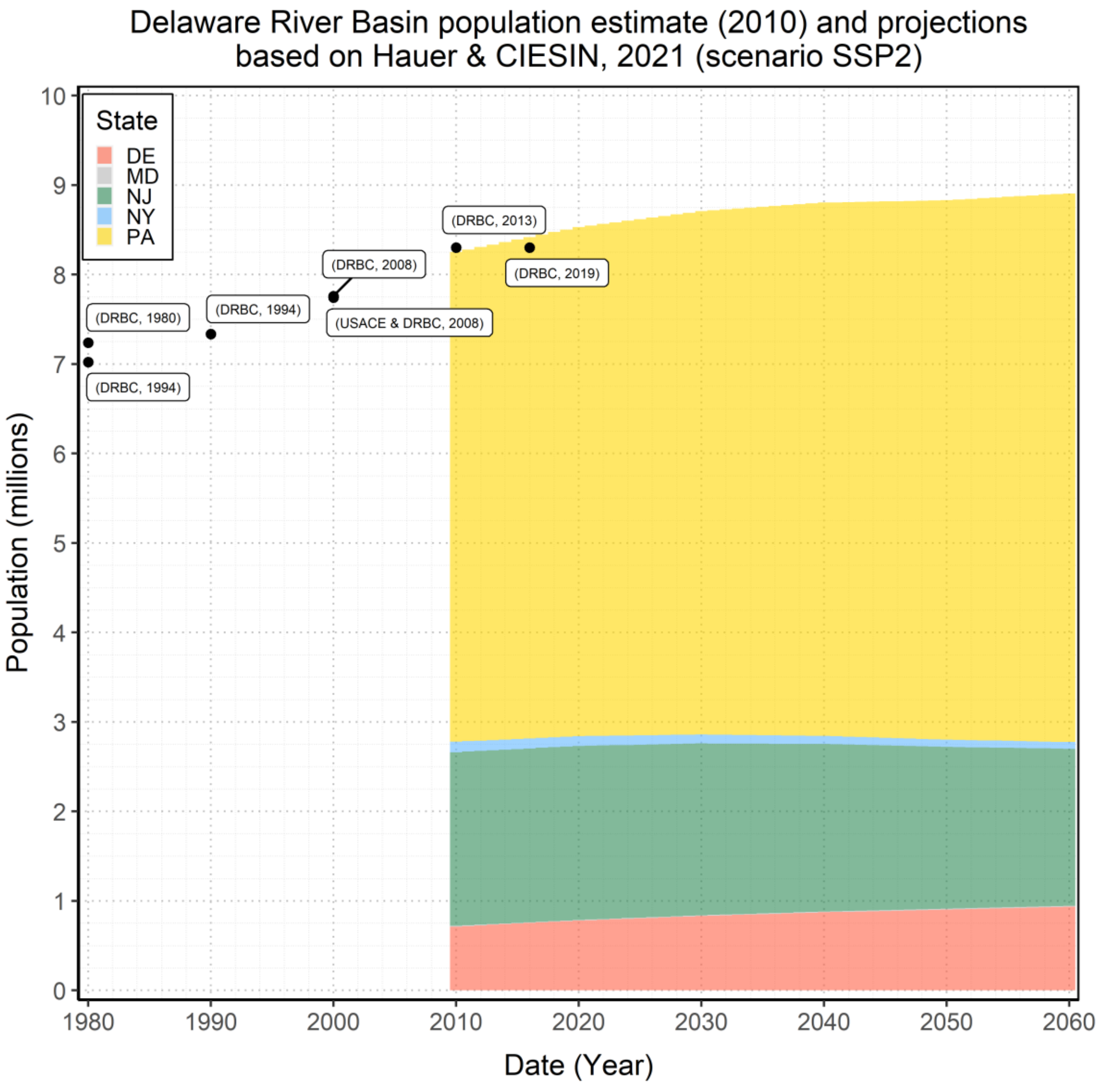


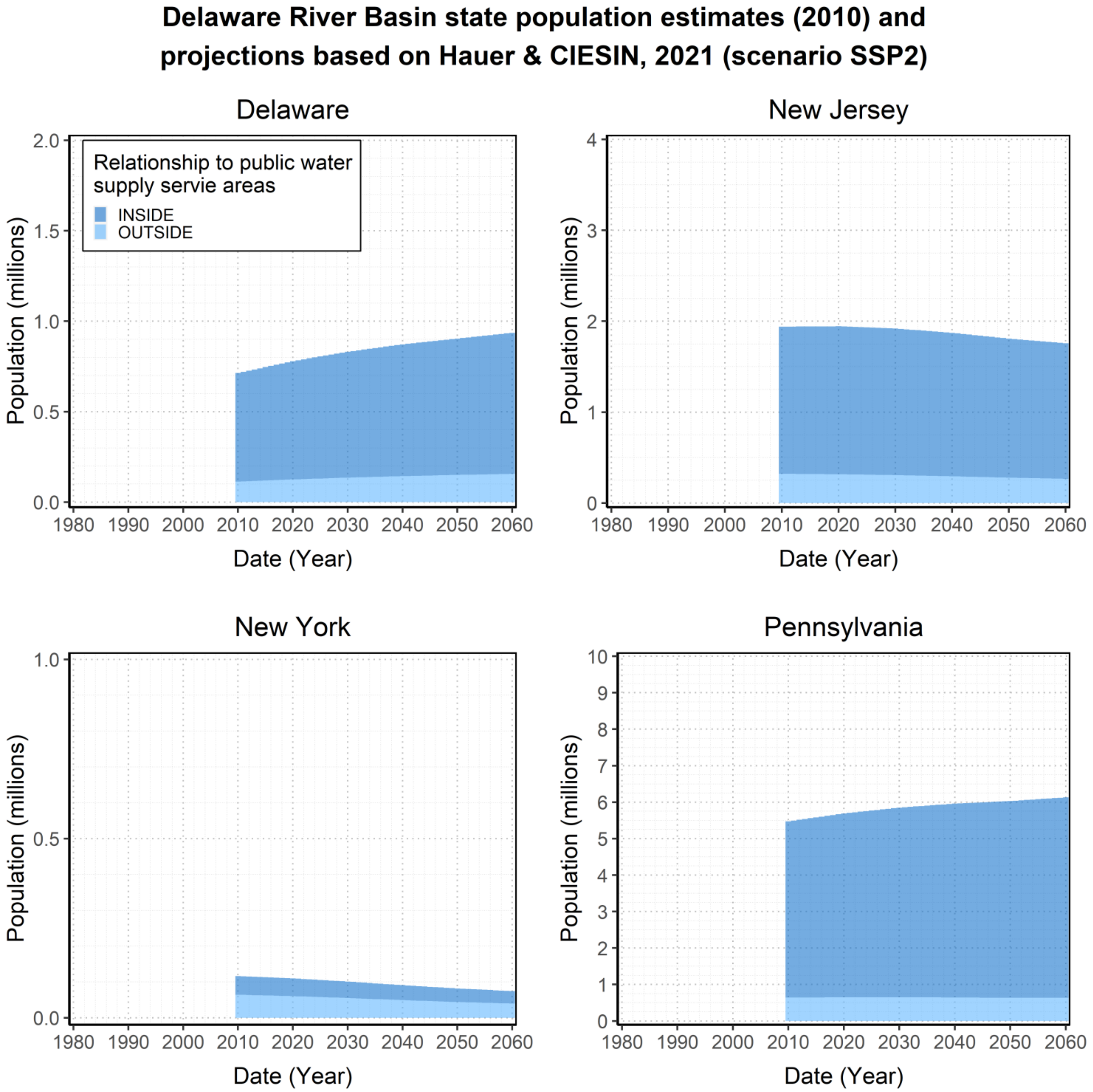
The Delaware River flowing under the Benjamin Franklin Bridge with the Philadelphia skyline behind.
Credit: © Chris Boswell
Used in accordance with license





- EPA EnviroAtlas dasymetrically mapped 2010 population to 30x30m pixels
- Public water supplier service areas
- Raster analyses show 2010 population: ~8.252 MM people
  - 1.146MM (~14%) reside outside services areas





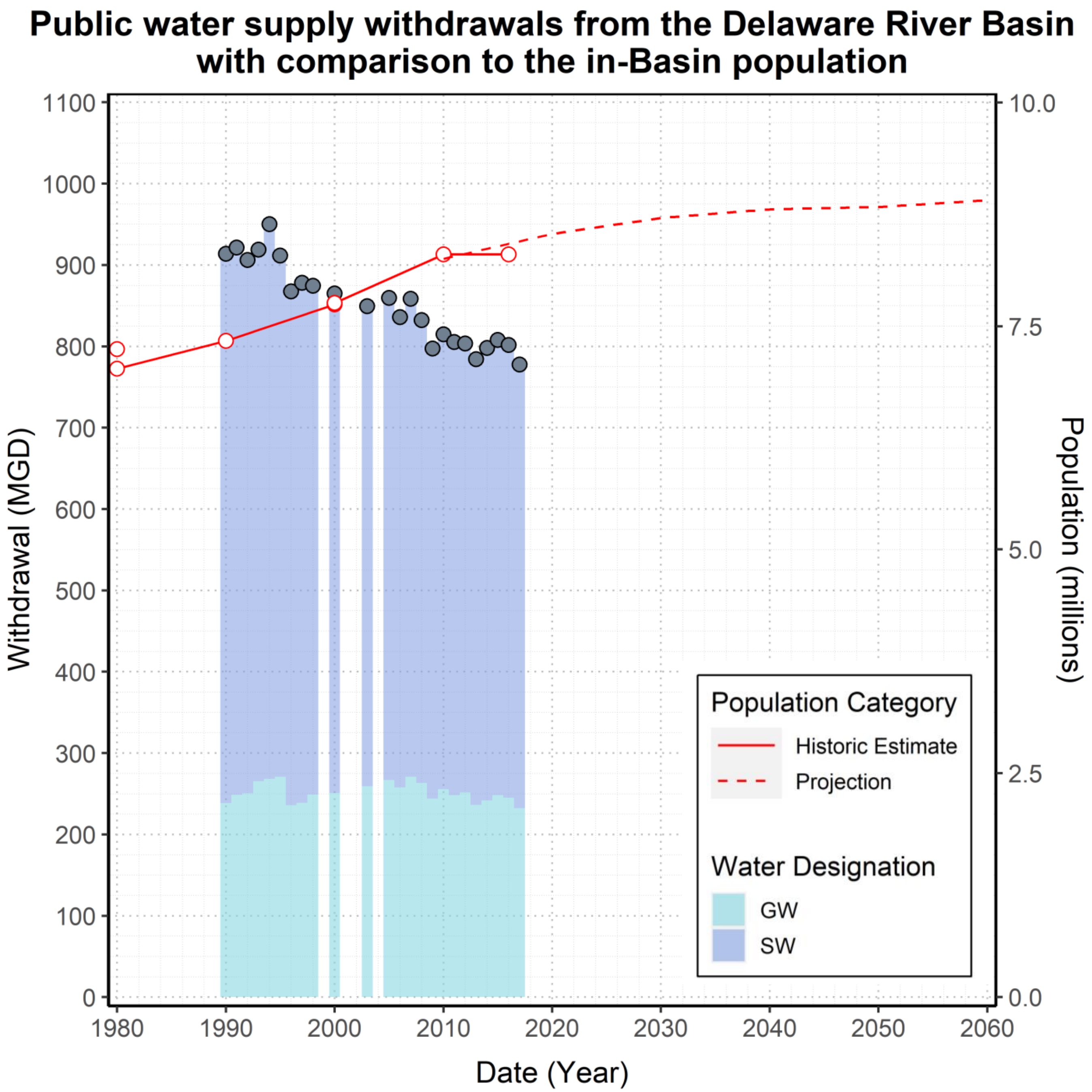
Projected populations were calculated by applying the county-level annual percent changes determined from
M. Hauer & CIESIN, 2021 ; SSP2

Self-Supplied Groundwater Withdrawal Projections

Year	Delaware River Basin Population (estimate)	Inside public water supply service areas		Outisde public water supply service areas		Self-supplied domestic withdrawal (MGD)	Self-supplied domestic consumptive use (MGD)
		Population	%	Population	%		
2010	8,251,815	7,105,813	86.1%	1,146,002	13.9%	95.224	9.522
2020	8,530,210	7,371,663	86.4%	1,158,547	13.6%	96.159	9.616
2030	8,708,203	7,551,844	86.7%	1,156,359	13.3%	95.865	9.586
2040	8,804,505	7,664,729	87.1%	1,139,776	12.9%	94.387	9.439
2050	8,830,378	7,715,283	87.4%	1,115,095	12.6%	92.242	9.224
2060	8,907,241	7,803,099	87.6%	1,104,142	12.4%	91.238	9.124

- SSD withdrawals calculated based on per-capita rates (1 number per state).
  (MD population excluded from calculations)
- Population growth weighted inside PWS Service Areas; declining SSD population & withdrawal

- Population had increased, projected to continue increasing.
- Withdrawals by public water suppliers have decreased, projected to continue decreasing.



5. Supplemental analysis: power generation

Hope Creek and Salem Generating Stations
in Salem County, New Jersey.
Credit: © John Beatty
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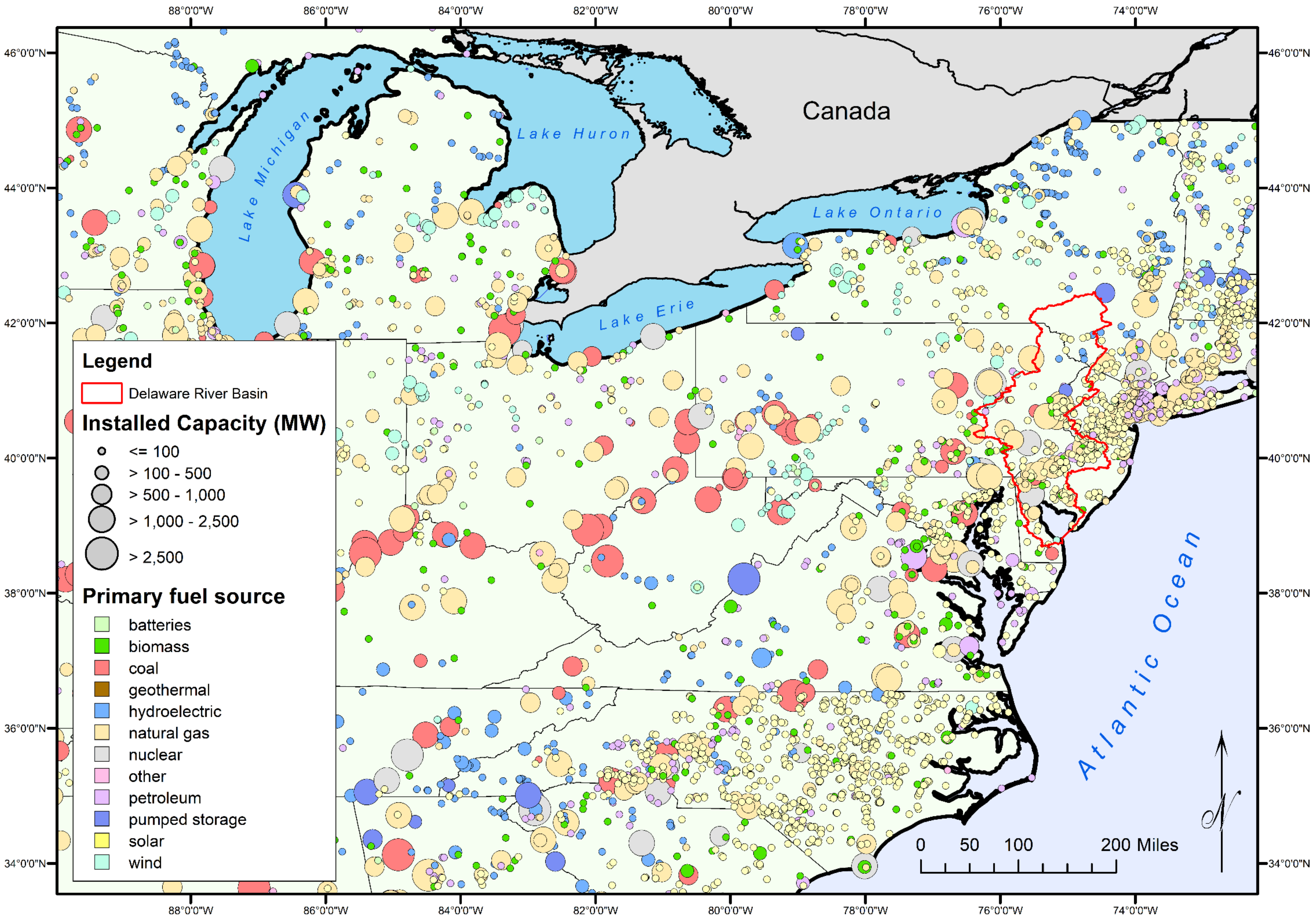
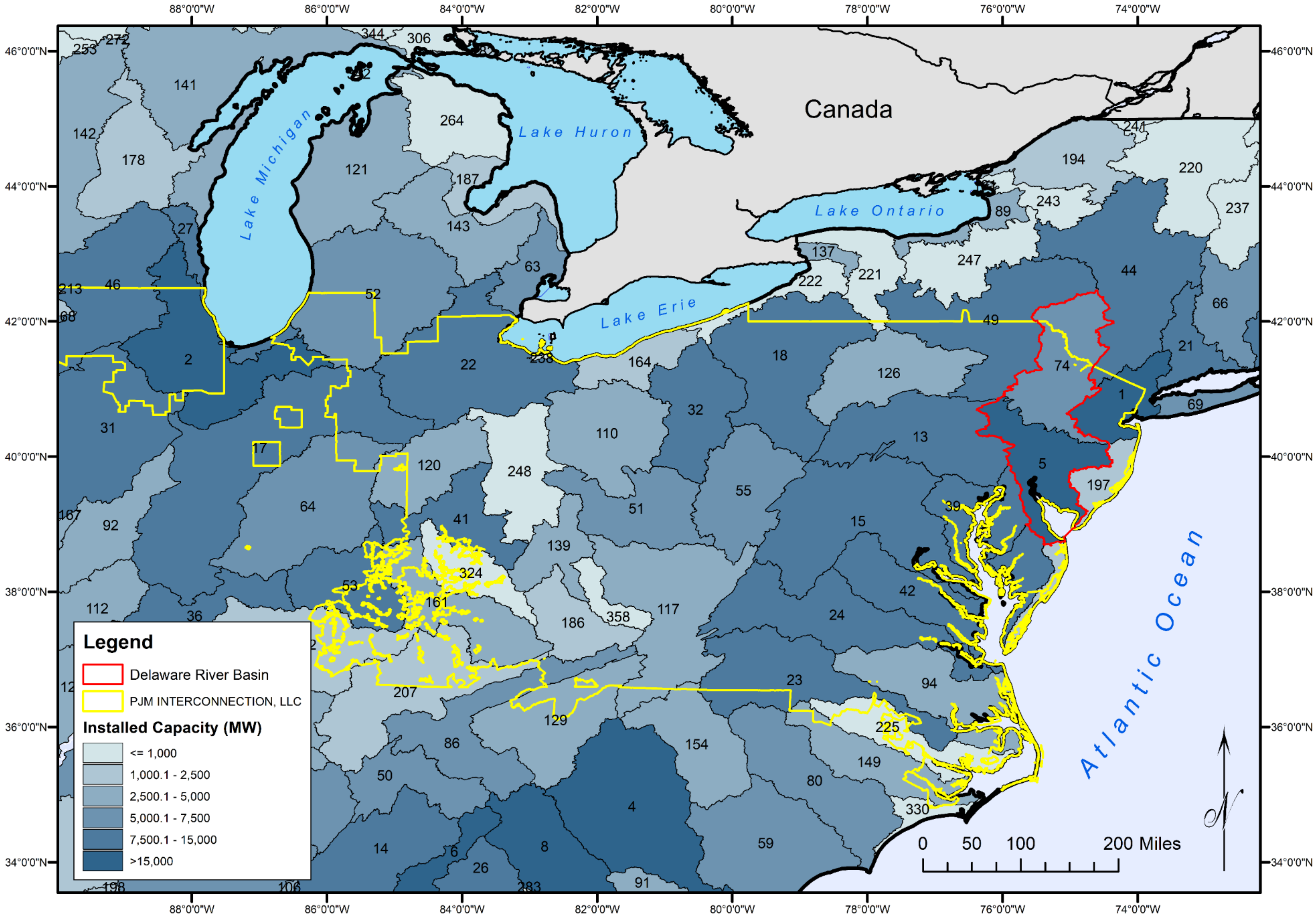
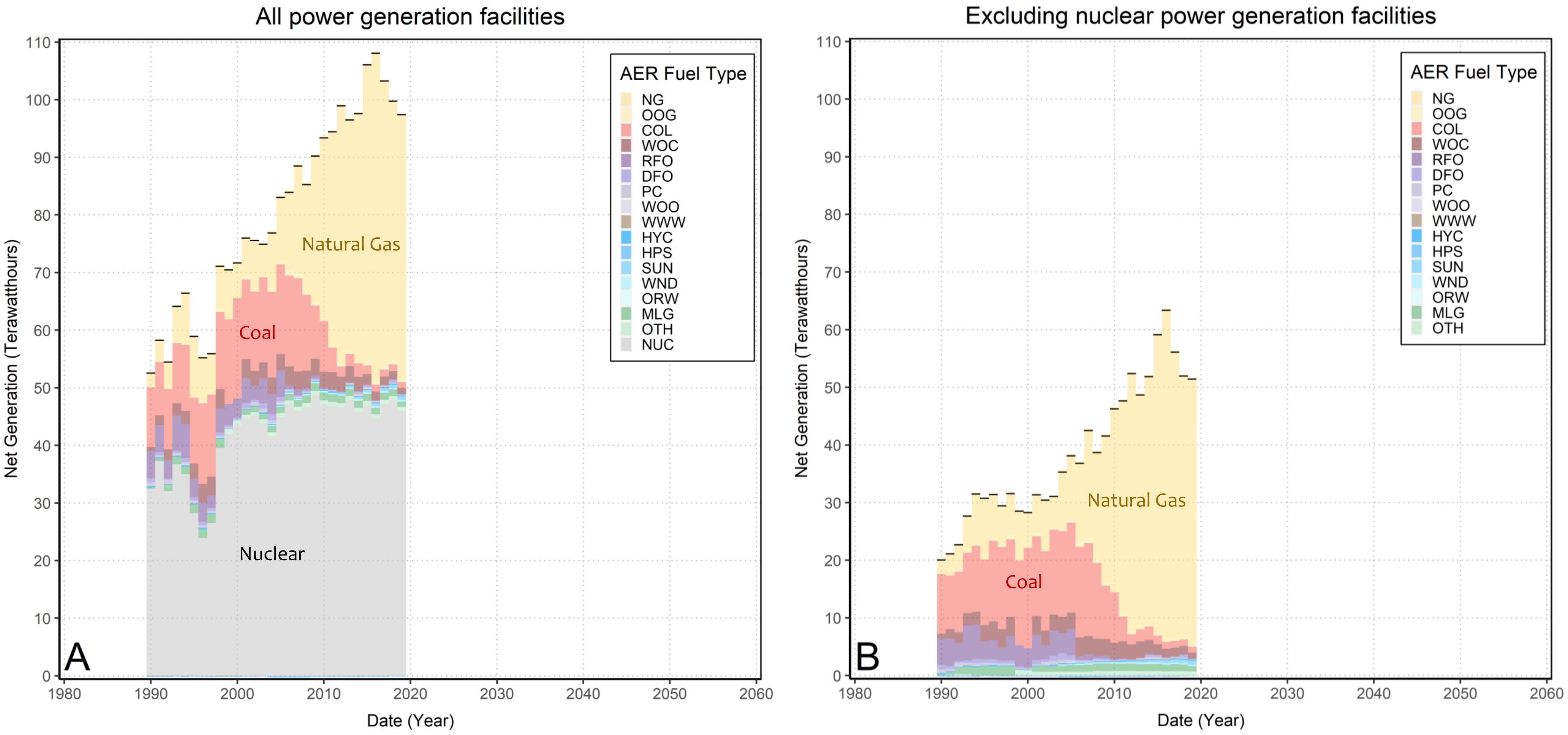
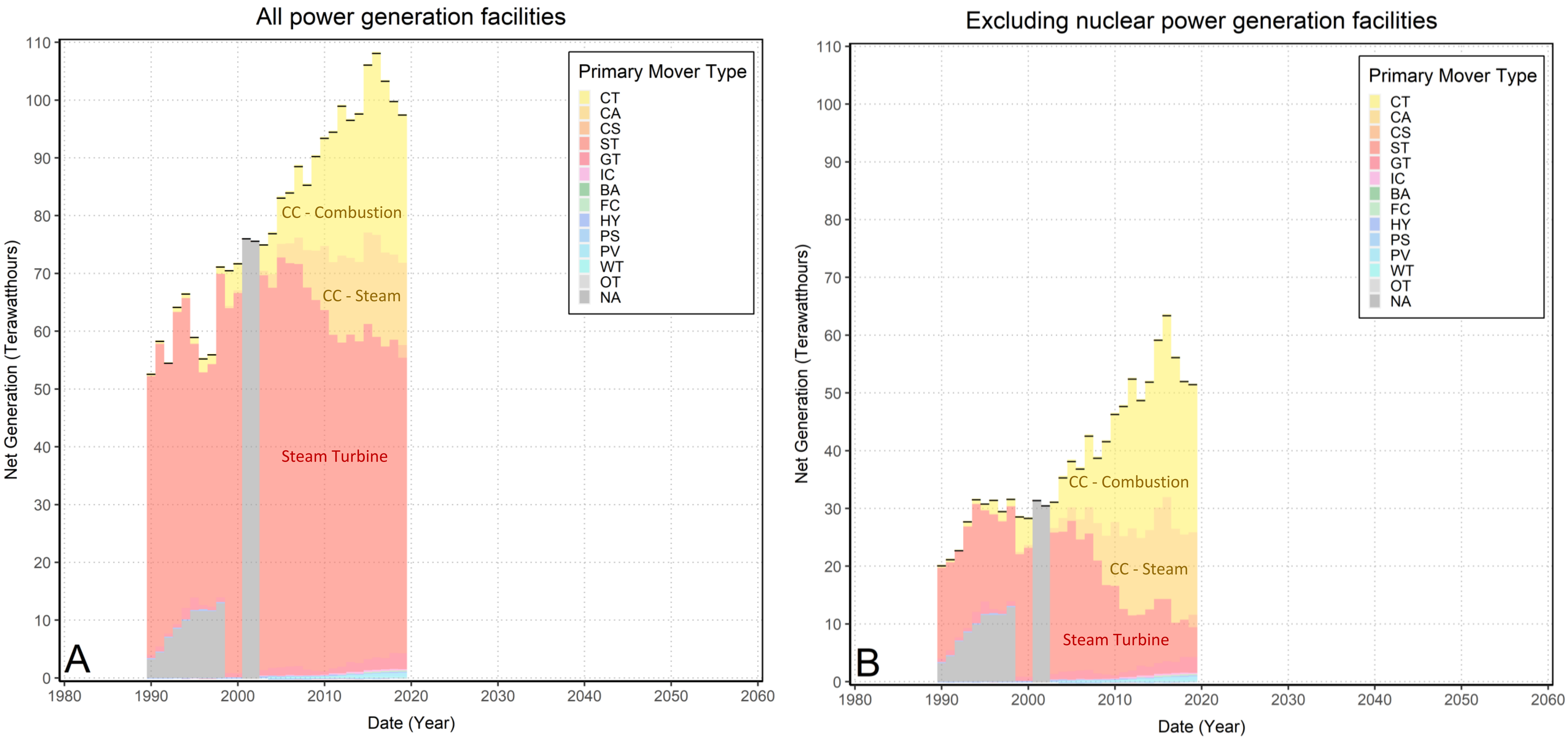

Legend
Delaware River Basin
Installed Capacity (MW)
<= 100
> 100 - 500
> 500 - 1,000
> 1,000 - 2,500
> 2,500
Primary fuel source
batteries
biomass
coal
geothermal
hydroelectric
natural gas
nuclear
other
petroleum
pumped storage
solar
wind
Canada
Lake Michigan
Lake Huron
Lake Ontario
Lake Erie
Atlantic Ocean
0 50 100 200 Miles
88°0'0"W
86°0'0"W
84°0'0"W
82°0'0"W
80°0'0"W
78°0'0"W
76°0'0"W
74°0'0"W
46°0'0"N
44°0'0"N
42°0'0"N
40°0'0"N
38°0'0"N
36°0'0"N
34°0'0"N

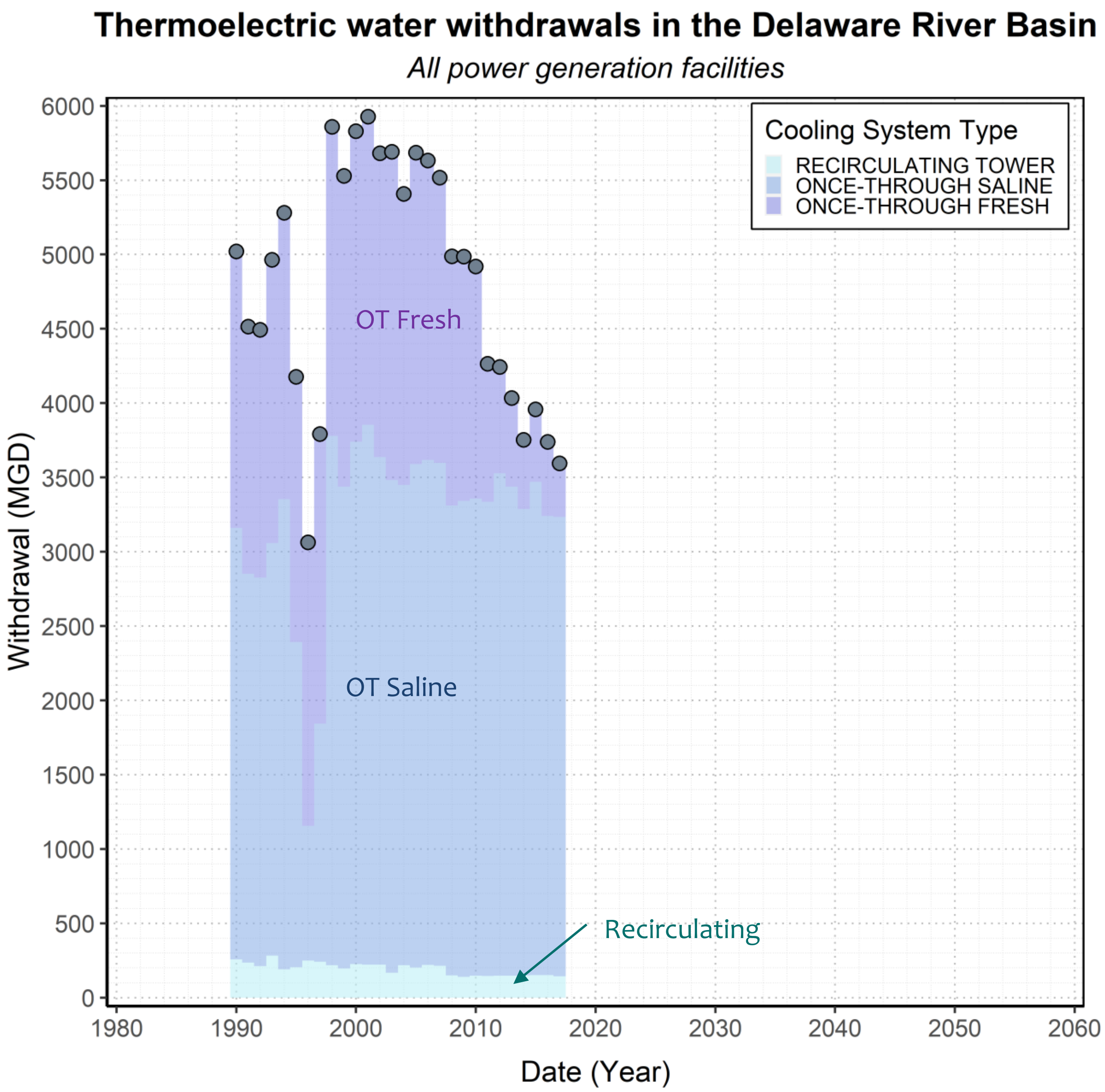

Canada
Lake Michigan
Lake Huron
Lake Ontario
Lake Erie
Atlantic Ocean
Legend
Delaware River Basin
PJM INTERCONNECTION, LLC
Installed Capacity (MW)
<= 1,000
1,000.1 - 2,500
2,500.1 - 5,000
5,000.1 - 7,500
7,500.1 - 15,000
>15,000
0 50 100 200 Miles
88°0'0"W
86°0'0"W
84°0'0"W
82°0'0"W
80°0'0"W
78°0'0"W
76°0'0"W
74°0'0"W
46°0'0"N
44°0'0"N
42°0'0"N
40°0'0"N
38°0'0"N
36°0'0"N
34°0'0"N

Power Facility Net Generation in the Delaware River Basin Categorized by AER Fuel Type

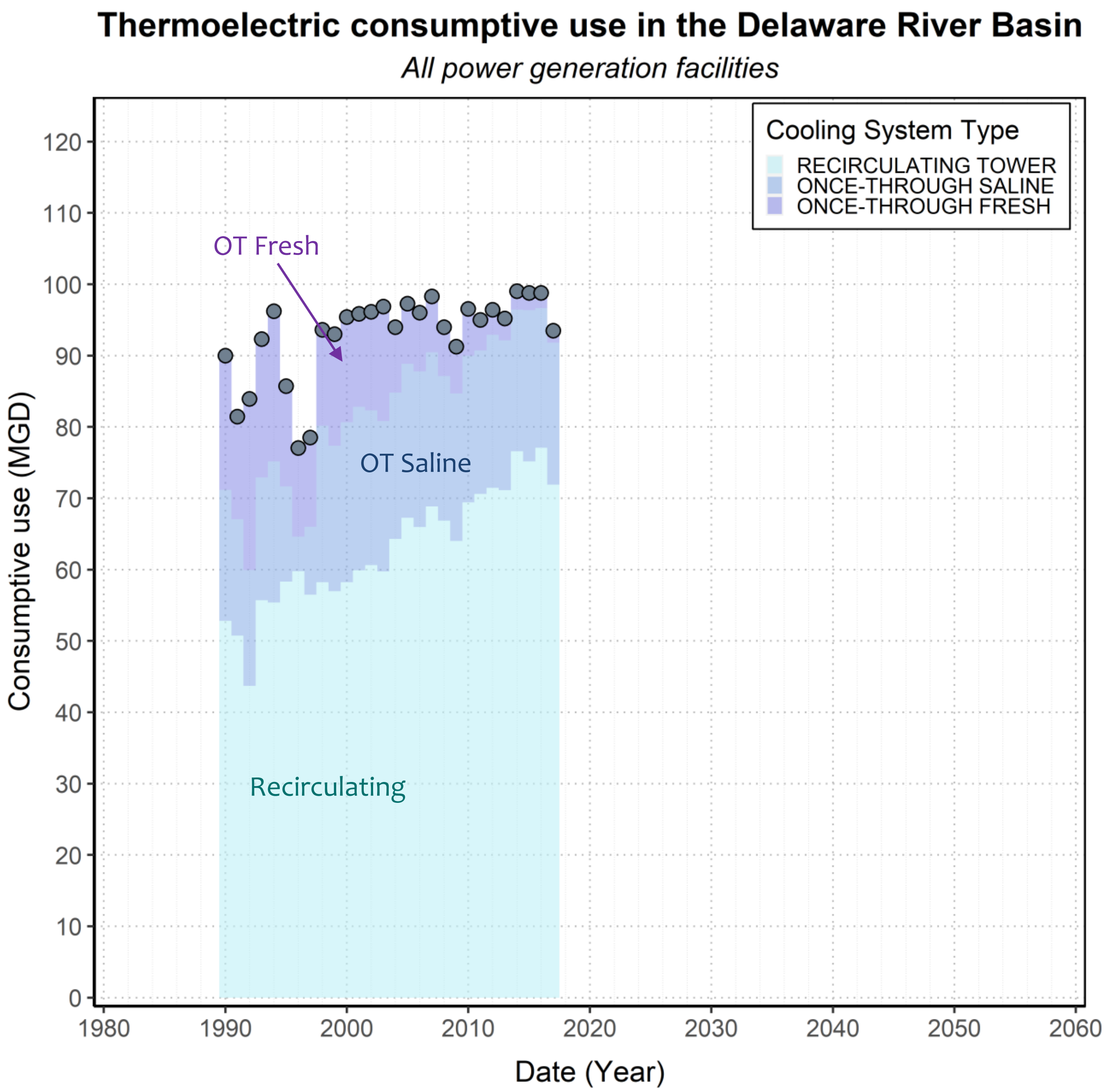


Power Facility Net Generation in the Delaware River Basin Categorized by Primary Mover Type



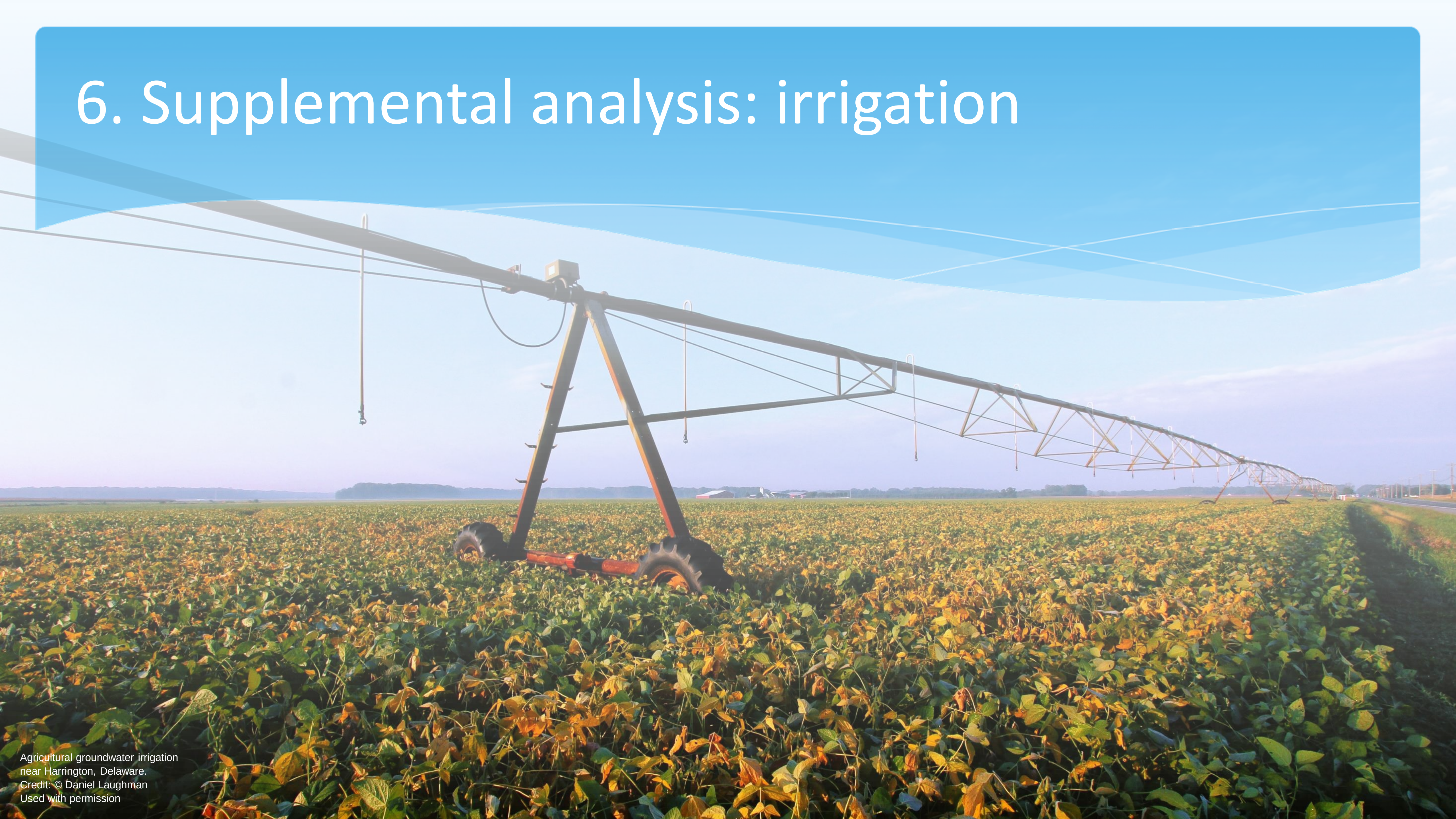


Thermoelectric water withdrawals in the Delaware River Basin
All power generation facilities
Cooling System Type
RECIRCULATING TOWER
ONCE-THROUGH SALINE
ONCE-THROUGH FRESH
OT Fresh
OT Saline
Recirculating
Withdrawal (MGD)
Date (Year)



Thermoelectric consumptive use in the Delaware River Basin
All power generation facilities
Cooling System Type
RECIRCULATING TOWER
ONCE-THROUGH SALINE
ONCE-THROUGH FRESH
OT Fresh
OT Saline
Recirculating
Consumptive use (MGD)
Date (Year)

6. Supplemental analysis: irrigation



Agricultural groundwater irrigation near Harrington, Delaware.
Credit: © Daniel Laughman
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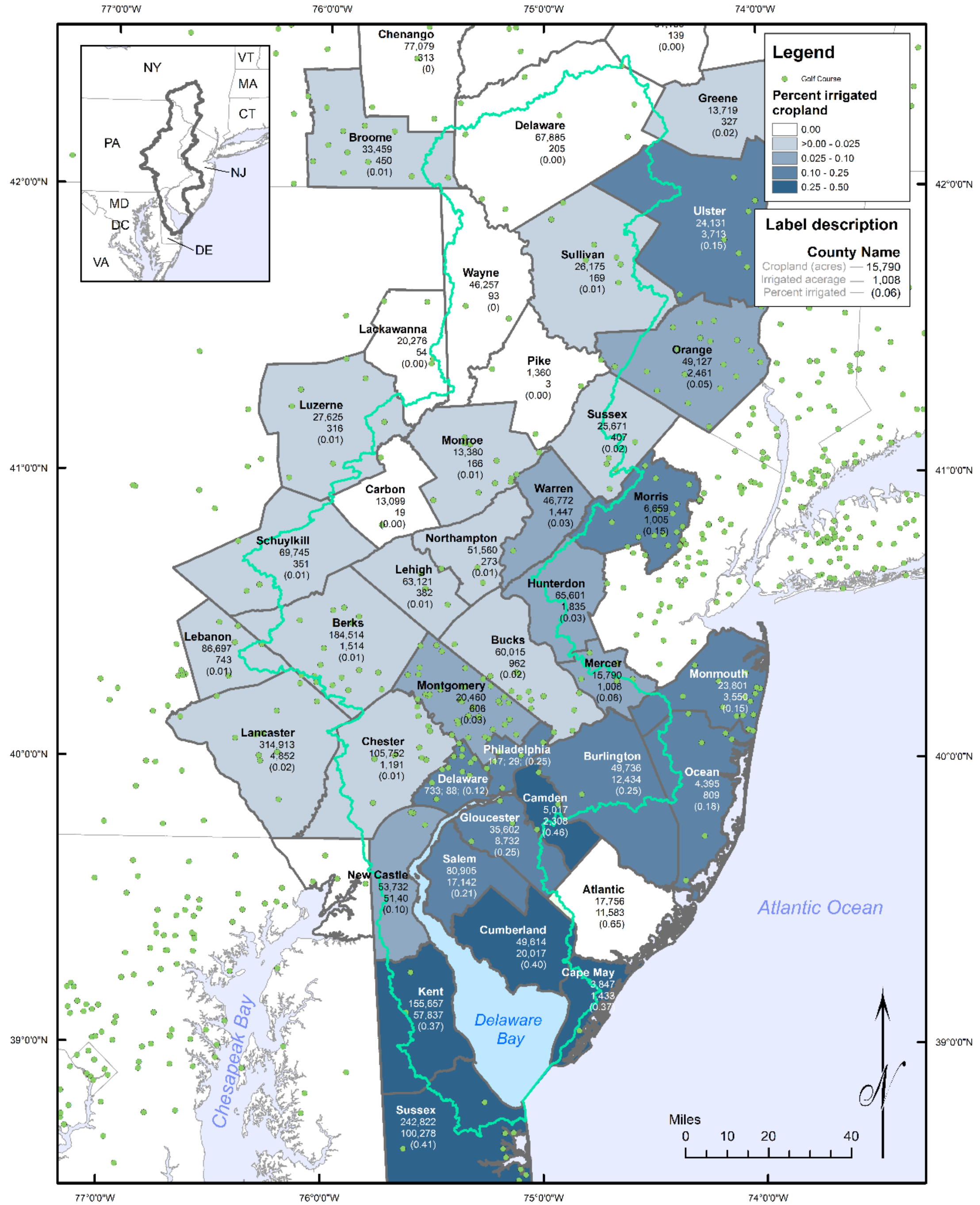
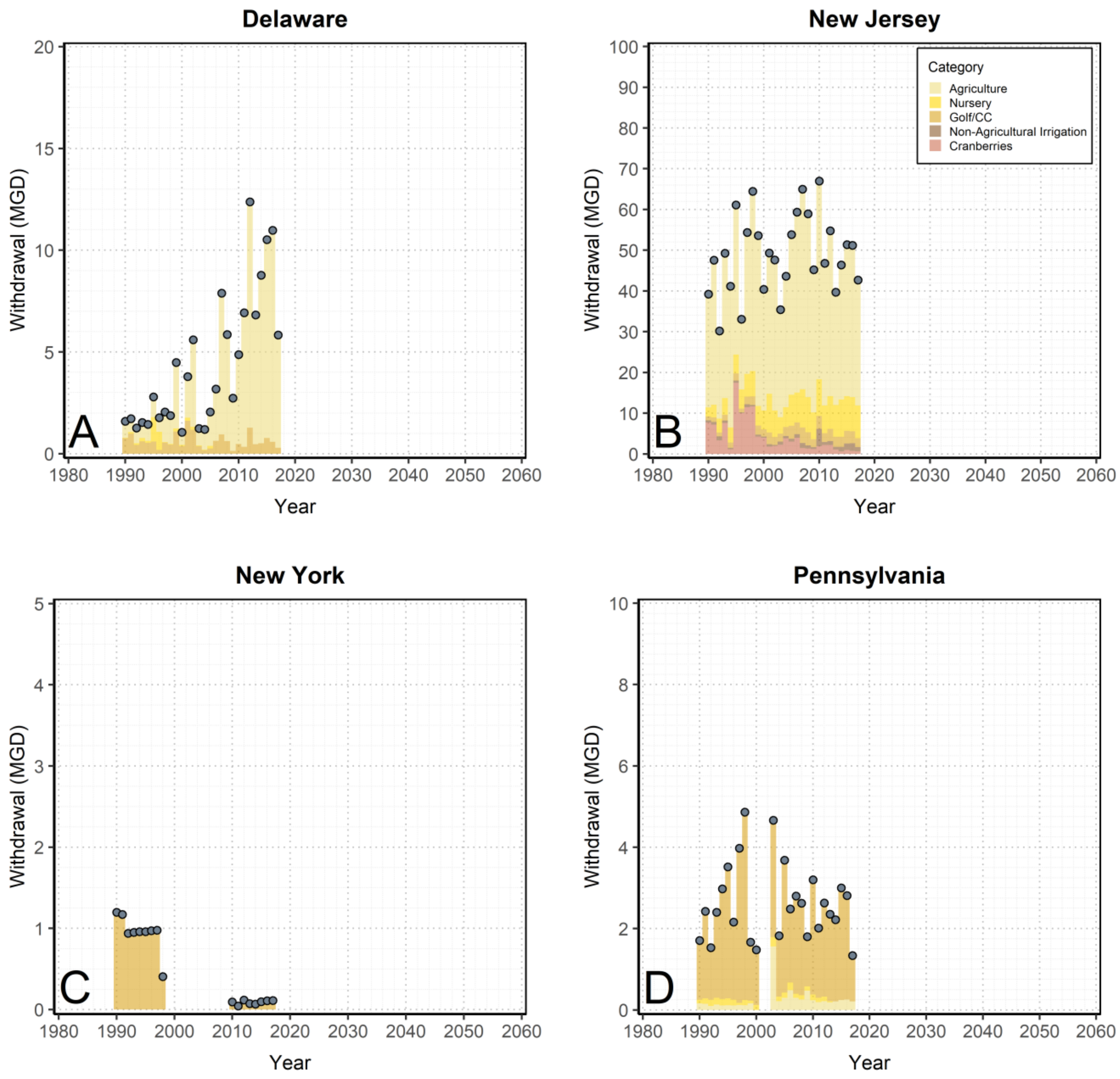
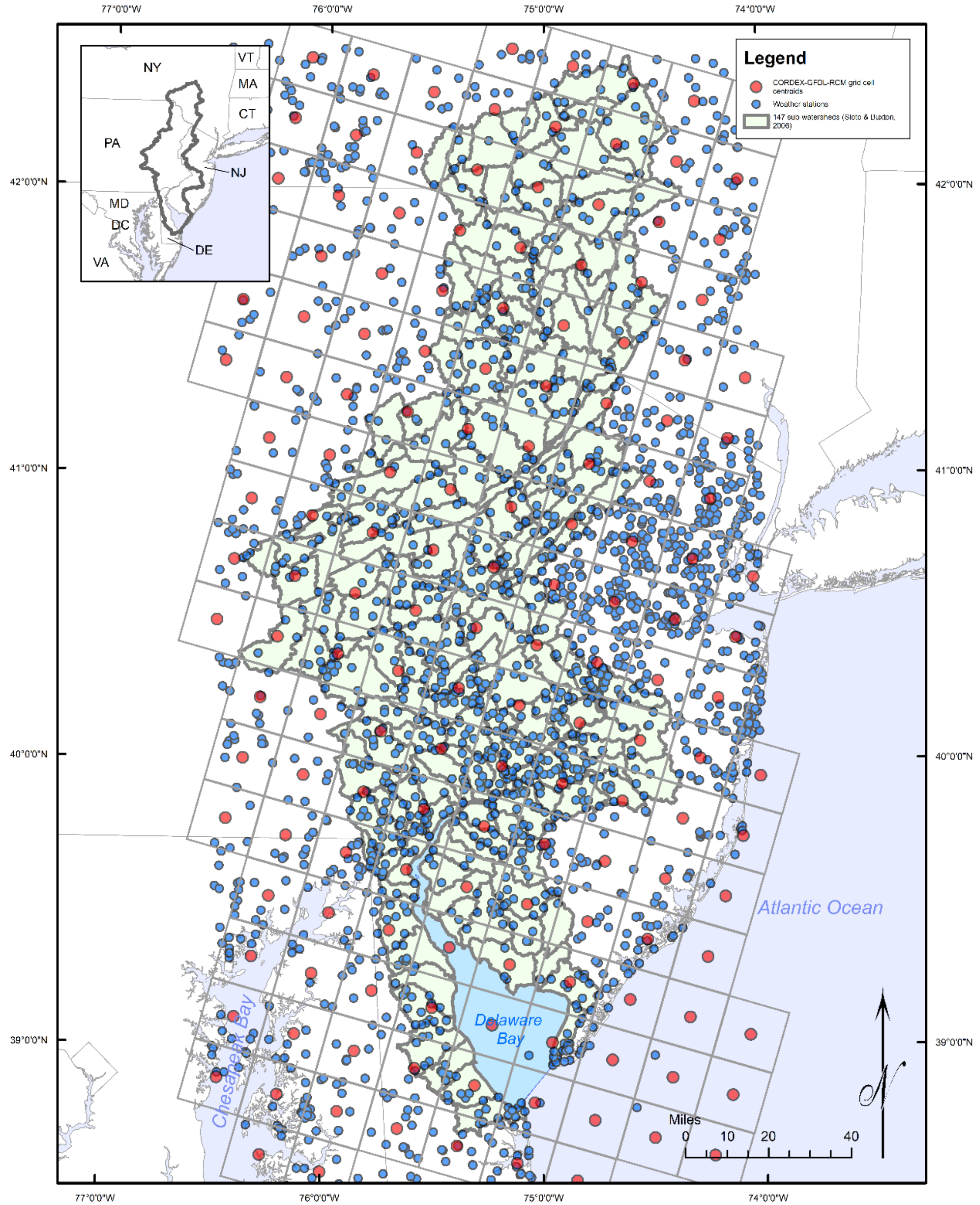
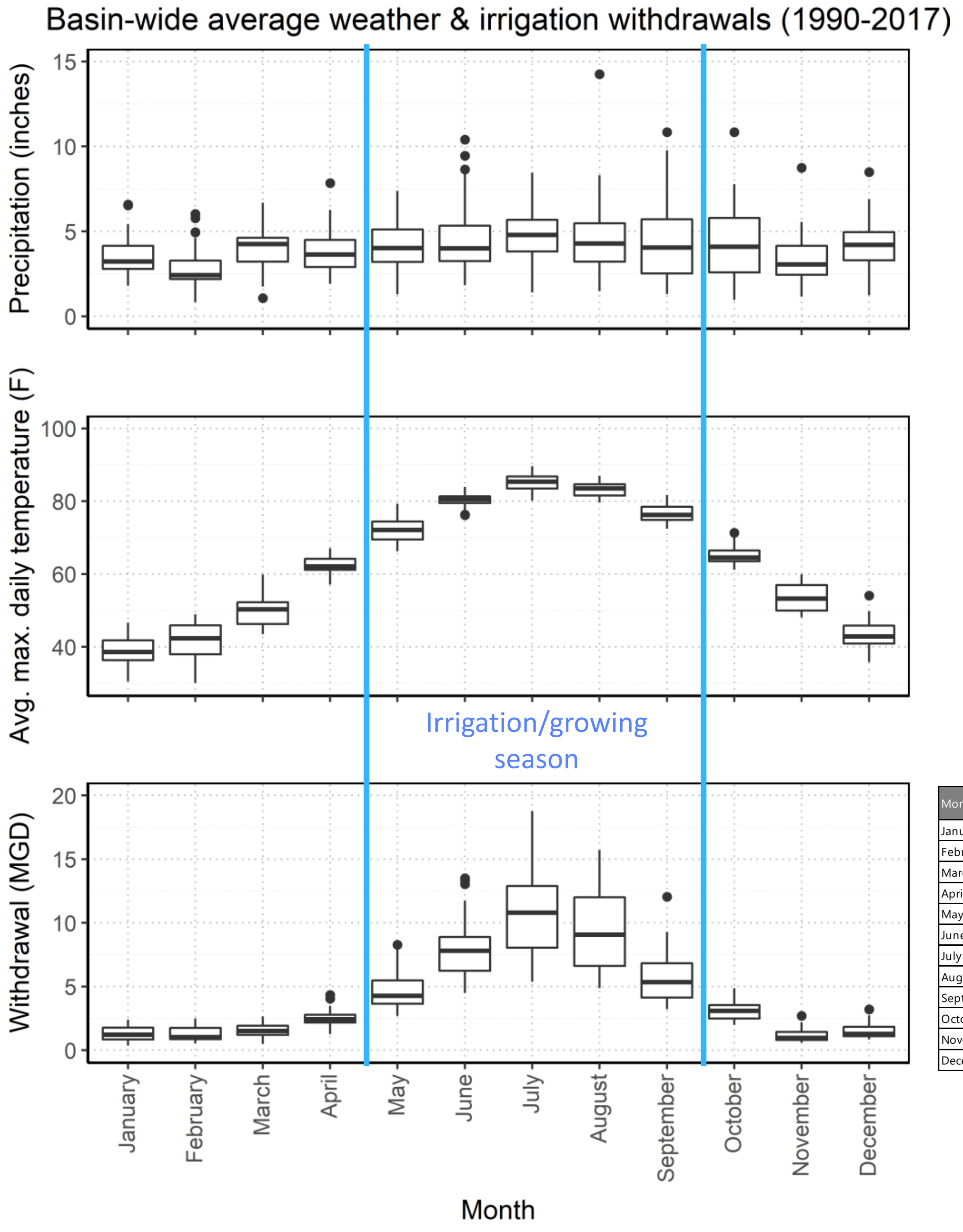


Irrigation water withdrawals from the Delaware River Basin states



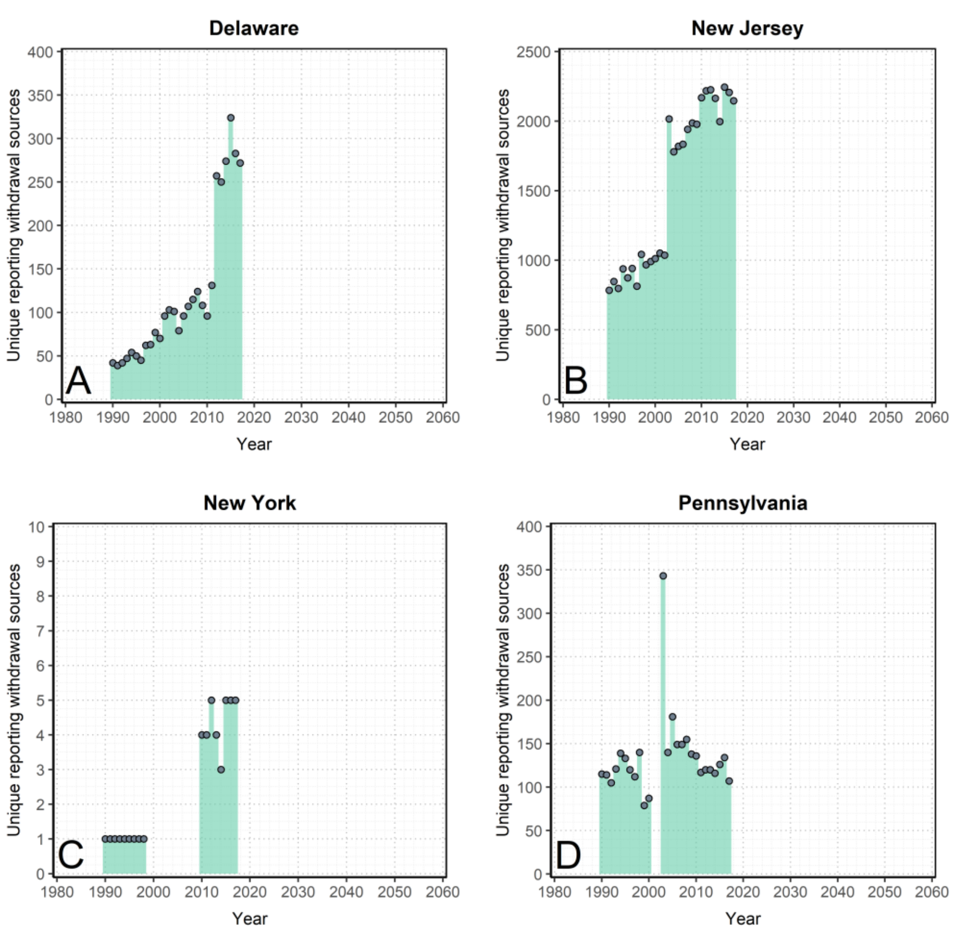


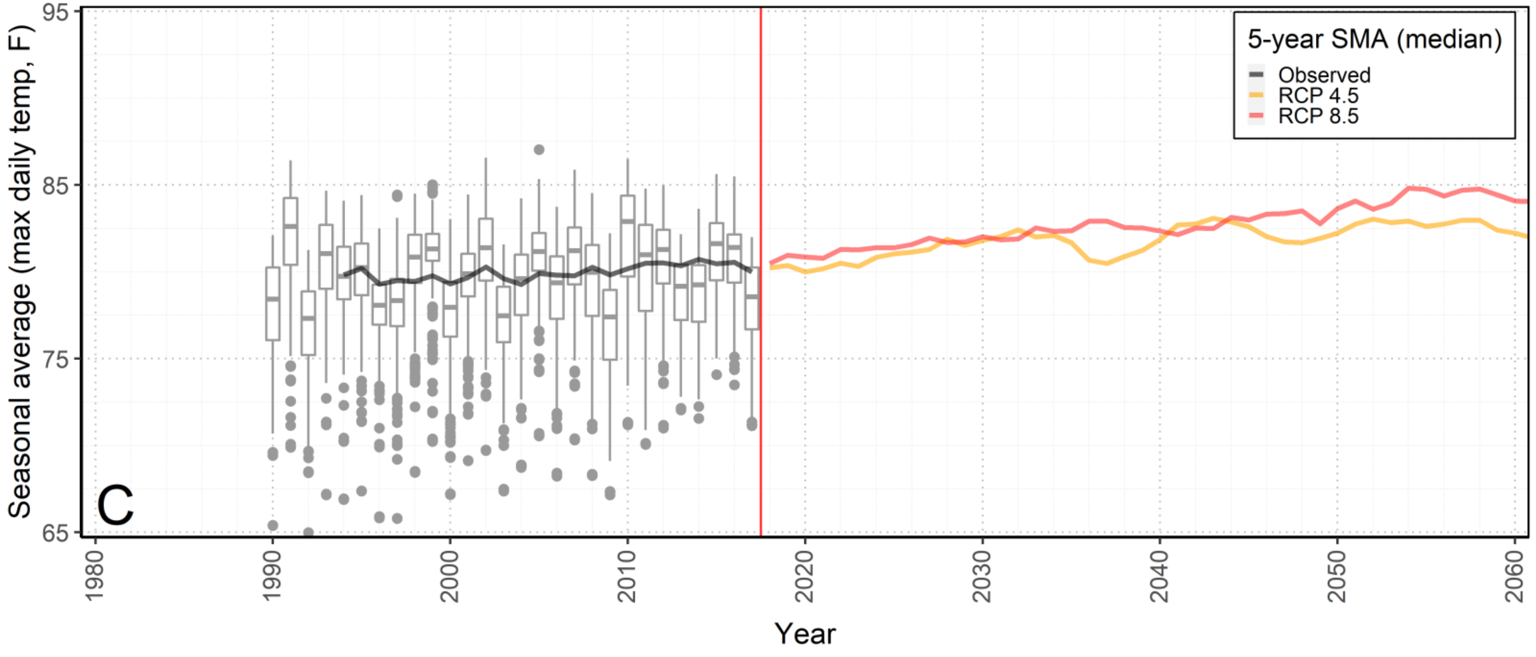


Month	Median MGD	Percent
January	1.235	2.52%
February	1.044	2.13%
March	1.531	3.13%
April	2.452	5.01%
May	4.285	8.75%
June	7.817	15.96%
July	10.804	22.06%
August	9.078	18.53%
September	5.357	10.94%
October	3.095	6.32%
November	0.978	2.00%
December	1.301	2.66%

56.6% (June–August)
76.2% (May–September)
87.6% (April–October)
92.7% (March–November)

Irrigation reporting water sources in the Delaware River Basin states





SIMPLIFY

CALIBRATE

PROJECT

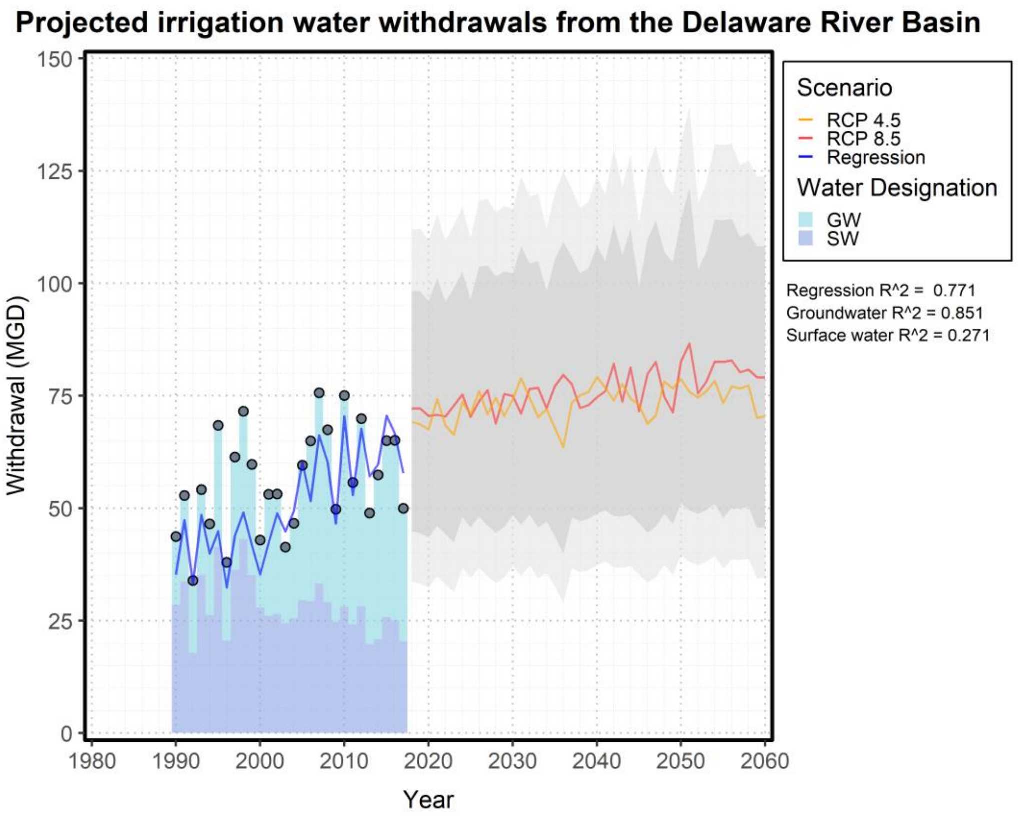
Constant Temperature Precipitation No. Sources

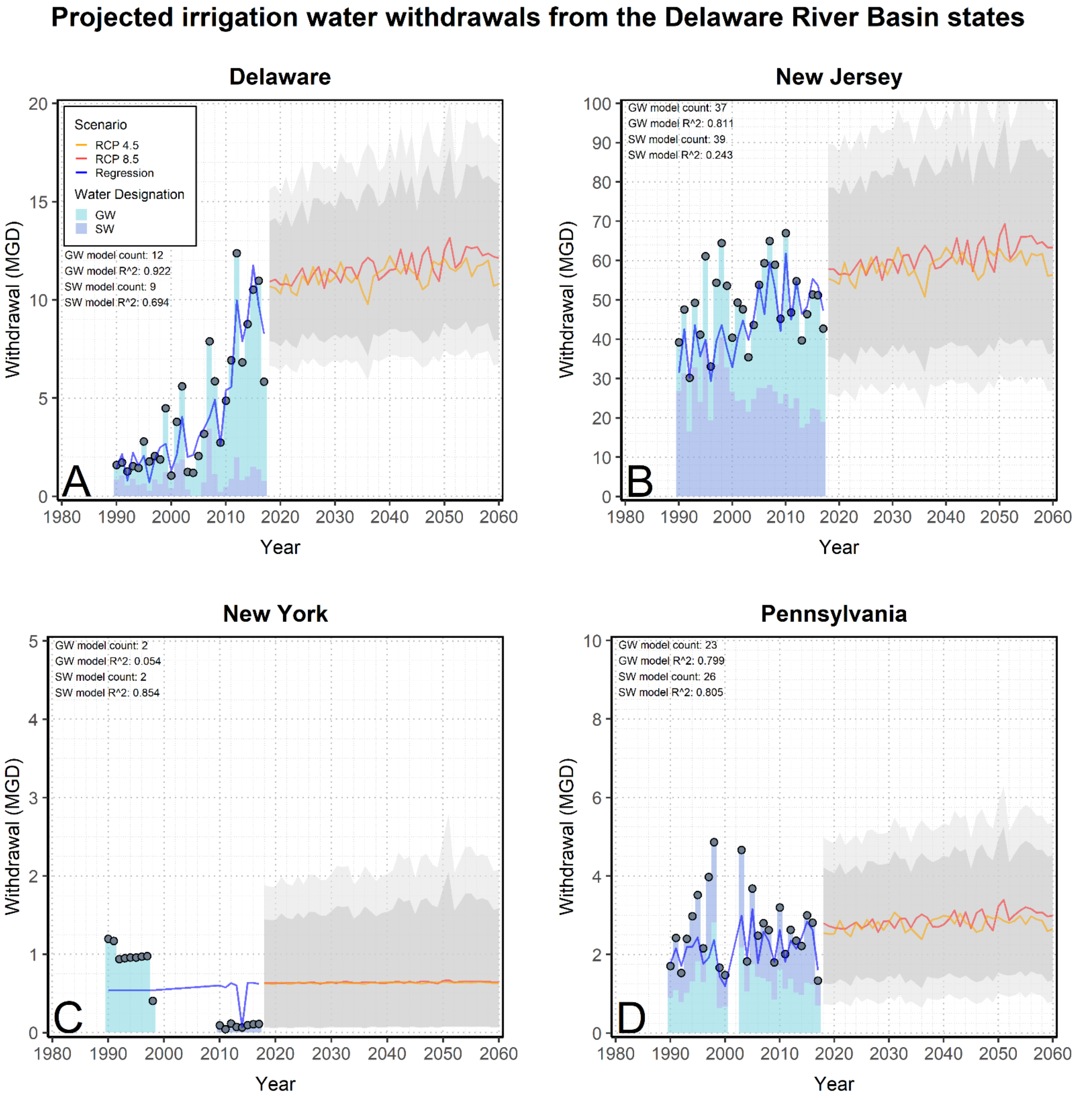
$$W_{i,j,t} = \alpha_j + \beta_j T_{i,t} + \gamma_j P_{i,t} + \delta_j S_{i,j,t}$$

$$W_{i,j,t} = \alpha_j^* + \beta_j T_{i,t}$$

where,

$W_{i,j,t}$	=	The annual withdrawal from subbasin *i* at year *t*, where *j* is either GW or SW
$\alpha, \beta, \gamma, \delta$	=	Constants from a linear regression, where *j* is either GW or SW
$T_{i,t}$	=	Seasonal average daily max temperature (°F) for subbasin *i*, at year *t*
$P_{i,t}$	=	Seasonal total precipitation (inches) for subbasin *i*, at year *t*
$S_{i,j,t}$	=	The number of sources resulting in the annual withdrawal for $W_{i,j,t}$


Projected irrigation water withdrawals from the Delaware River Basin
Scenario
RCP 4.5
RCP 8.5
Regression
Water Designation
GW
SW
Regression R^2 = 0.771
Groundwater R^2 = 0.851
Surface water R^2 = 0.271
Withdrawal (MGD)
Year


Projected irrigation water withdrawals from the Delaware River Basin states
Delaware
Scenario
RCP 4.5
RCP 8.5
Regression
Water Designation
GW
SW
GW model count: 12
GW model R^2: 0.922
SW model count: 9
SW model R^2: 0.694
A
New Jersey
GW model count: 37
GW model R^2: 0.811
SW model count: 39
SW model R^2: 0.243
B
New York
GW model count: 2
GW model R^2: 0.054
SW model count: 2
SW model R^2: 0.854
C
Pennsylvania
GW model count: 23
GW model R^2: 0.799
SW model count: 26
SW model R^2: 0.805
D
Withdrawal (MGD)
Year

7. Next Steps

- Interactive online data platform (Power BI)
- Groundwater availability
  - 147 HUC scale
  - SEPA GWPA scale
- Surface Water availability
  - Consider effects of climate change
  - Consider reservoir operations
  - Consider the Drought of Record

8. Questions

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