POTOMAC BASIN TRENDS IN WATER USE

Comprehensive Water Resource Plan

ICPRB
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INTRODUCTION

This pamphlet summarizes projected reported water withdrawals and consumptive use (CU) in the Potomac basin. This work, along with the results presented in the Potomac Basin Reported Water Use pamphlet and Wallace et al. (2023), addresses the technical recommendation, "Report on Basin-Wide Water Uses, Projected Demands, and Consumptive Demands" in the Potomac Basin Comprehensive Water Resources Plan (Recommendation 3.3.2 A).

The Comprehensive Water Resources Plan explains the recommendation as:

"Report On Basin-Wide Water Uses, Projected Demands, And Consumptive Demands: Effective water use planning requires consideration of upstream uses, regardless of political boundaries, to achieve multiple interstate objectives including maintaining adequate surface and ground water supplies for diverse users during times of drought and meeting flow-by requirements throughout the basin including the Potomac flow-by at Little Falls dam. To this end, a first step in planning for sustainable water uses in the basin is to develop a clear understanding of the current and anticipated future locations, amounts, and uses of surface and ground water. The ICPRB developed a basinwide database of withdrawals and consumptive use (Ducnuigeen et al. 2015).

The database was used to estimate current and future withdrawals and consumptive use for the basin above Little Falls as part of the 2015 Washington Metropolitan Area Water Supply Study: Demand and resource availability forecast for the year 2040 (Ahmed et al. 2015). With modification, the database can be expanded and used as a resource for understanding surface and ground water use, including consumptive use, in a more spatially explicit way in the basin, including the Coastal Plain, as part of a basin-wide assessment."

To address this recommendation, ICPRB staff modified and updated the Withdrawal and Consumptive Use (WCU) database discussed in Ducnuigeen et al. (2015). The resulting WCU database contains reported water withdrawal data from 2003 to 2020 for all 11 eight-digit (HUC8) watersheds in the basin, with additional data for some locations dating as far back as 1983.

This pamphlet documents the results produced using the WCU database to model historical trends in reported water withdrawals and the use of these results, in combination with CU coefficients (Table 1), to project future withdrawals and consumption. Subsequent sections include 1) the methods used to model reported water withdrawals and 2) results from the application of the modeling methods, including forecasted water withdrawals and consumption.

METHODS

The WCU database includes reported water withdrawals from the basin's jurisdictions and several other variables describing each withdrawal location, including water use type. This data needs to be considered when modeling water use in the Potomac basin as many of these descriptor variables may influence the results. Examples of these variables include water withdrawal source (i.e. river, reservoir, well, etc.) and use sector (i.e. drinking water, manufacturing, agriculture etc.). To account for these variables and ensure that they do not influence the trend being modeled, we need to determine the appropriate modeling framework. Looking at modeling frameworks implemented in other water use studies, a hierarchical structure is ideal because it accounts for factors that vary by location but are not the predictor variable being used in the model (i.e., geology, water source, water use sector, and location owner) while still producing results for the overall region (Thompson & Pindar, 2021; Nummer & Qian, 2020). As we are looking at water withdrawals over time, the predictor variable in our model is time.

Using the hierarchical structure, we applied a simple historical trend analysis to each water use sector (defined in Table 1). The hierarchical structure used in this study allows the

TABLE 1. Water use sector definitions adapted from Templin et al. (1980) and modified based on information provided by the basin jurisdictions.

SECTOR	USE DEFINITION
Aquaculture	Water used to raise and cultivate aquatic animals and plants for food, recreation, conservation, enhancement, and restoration purposes.
Commercial	Water used for sanitation, maintenance, and aesthetic purposes by commercial, institutional, and recreational facilities that exchange, buy, or sell commodities or provide services, amusement, or relaxation. Examples include office buildings, retail stores, and other commercial facilities; government, military and educational institutions; state parks, golf courses, amusement parks, campgrounds; and sport, yacht, and country clubs.
Hydroelectric	Water used to generate electrical power where water is the motive force. In general, there is little or no consumptive use in the generation process (i.e., water flowing out of a dam to turn a turbine).
Industrial	Water used for manufacturing or processing goods; washing, diluting, cooling, or transporting products; incorporating water into products; and sanitation needs within the manufacturing facility. This use category does not include mining, extraction of crude petroleum and gases, nor power generation because these are included in other categories.
Irrigation	Irrigation water uses are water applied to crops or nursery plants that are grown for human or animal consumption or used for germination, chemical application, and harvesting. Reported irrigation also includes water used for dust suppression and irrigation of public lawns, parks, and golf courses.
Livestock	Livestock water uses are water used to raise and maintain livestock and for other non-irrigation farm needs. Livestock include cattle, sheep, goats, hogs, poultry, and horses, as well as other commercially raised animals.
Mining	Water used for extracting and on-site processing of coal, ores, nonmetallic minerals, and sand and gravel. The water is primarily used for quarrying, extracting, and milling, but also indirectly for dust abatement, or may be lost by evaporation or during dewatering.
Other	Any water used for which a specific purpose could not be identified.
Thermoelectric	Water used to generate electricity with steam-driven turbine generators.
Public Water Supply	Water used by a municipality or a private water company to supply residences, commercial operations, and industries.
Self-Supplied Domestic	Water used and withdrawn directly by domestic users, often from a well. The water is used for domestic indoor household purposes (drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, etc.) and outdoor purposes (e.g., watering lawns and gardens).

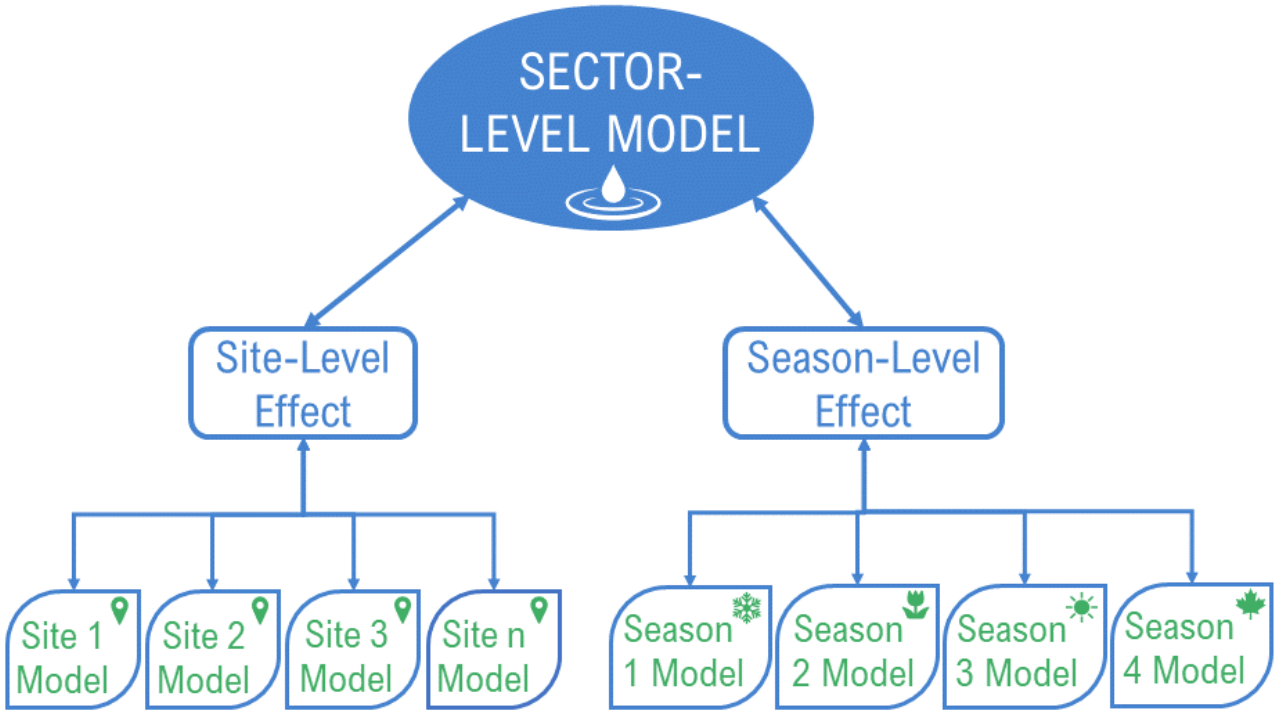

FIGURE 1. Conceptual framework of the hierarchical model for the historical trend analysis as applied to the WCU database for each water use sector.

historical model to be applied to each withdrawal location and season combination in each sector (Gelman & Hill, 2007). For this study, seasons were broken into three-month groups following Ahmed et al. (2015 and 2020). The hierarchical structure of the simple historical trends analysis applied to each sector is depicted in Figure 1.

Once the historical trends analysis produced results for each sector, the coefficients were used to predict the water withdrawals from 2025 through 2050. We then used the predicted water withdrawals to forecast the predicted CU. To forecast CU for each water use sector in the basin, annual CU factors were multiplied by the predicted withdrawal values. The CU factors used were obtained through previously published literature and are shown in Table 2.

TABLE 2. Annual consumptive use factor used in analysis and associated source.

SECTOR	CU FACTOR	SOURCE
Aquaculture	0.05	Shaffer (2009)
Commercial	0.57	Shaffer (2009)
Hydroelectric	0.00	Thompson & Pindar (2021)
Industrial	0.12	Shaffer (2009)
Irrigation	0.90	Domber & Hoffman (2004)
Livestock	0.76	Shaffer (2009)
Mining	0.10	Shaffer (2009)
Other	1.00	Withdrawal for unknown use, assume 100% CU
Thermoelectric	0.02	Shaffer (2009)
Public Water Supply	0.10	Estimated by ICPRB CO-OP section using the winter-based recharge method described in Shaffer (2009)
Self-Supplied Domestic	0.16	Horn et al. (2008)

RESULTS

Between 2025 and 2050, reported water withdrawals are predicted to increase approximately 110 MGD or about 2.5 percent. In 2025, about 4,220 MGD of water is predicted to be withdrawn from the Potomac basin. In 2050 predicted water withdrawals in the basin are approximately 4,330 MGD. However, CU is predicted to decrease between 2025 and 2050 by about 70 MGD or about 30 percent. The predicted consumption of water in 2025 is approximately 235 MGD while the predicted consumption in 2050 is about 165 MGD.

DISCUSSION

Results from the application of the hierarchical structure and a simple historical trend analysis indicate an overall increase of about 2.5 percent in reported water withdrawals from 2025 to 2050 in the basin while associated CU is anticipated to decrease by about 30 percent over the same period. This difference in trends between predicted withdrawals and consumption can be attributed to the fact that different sectors have different CU coefficients (or the amount of water that is not returned to the watershed). For example, the Public Water Supply sector is expected to increase withdrawals by about 170 MGD, but this equates to an increase in consumption of approximately 2 MGD. On the other hand, the Other sector has an assumed consumption rate of 100 percent and is expected to have a decrease in withdrawals of just under 90 MGD.

Additional work should be done to clearly identify uses, CU factors, and future trends in the Other sector.

Excluding the Other sector from the overall quantification of predicted withdrawals and consumption between 2025 and 2050, predicted withdrawals increase from about 4,130 MGD in 2025 to nearly 4,330 MGD in 2050, approximately 5 percent. Additionally, predicted consumption in 2025 is estimated at approximately 145 MGD and is expected to increase by about 20 MGD to almost 165 MGD in 2050. With the Other sector excluded from calculations the predicted increase in consumption in the basin is about 10 percent of the predicted increase in withdrawals.

The basin will see an increase of almost 5% in water withdrawals between 2025 and 2050, based on trends in state reported data whose use sector information is clearly defined.

Decreases are also predicted in the withdrawals of the Self-Supplied Domestic, Irrigation, and Commercial sectors. However, these decreases are much smaller the Other sector, ranging from about a 13 percent decrease in the Self-Supplied Domestic sector to about a 1 to 2 percent decrease in the Irrigation and Commercial sectors. Increases in withdrawals and associated consumption are predicted for 2025 to 2050 for the Aquaculture, Industrial, Livestock, Mining, thermoelectric, and Public Water Supply

TABLE 3. Predicted water withdrawals and associated consumptive use (MGD) by sector for every 5 years from 2025-2050 in the Potomac basin.

Sector	2025		2030		2035		2040		2045		2050	
	With	CU	With	CU	With	CU	With	CU	With	CU	With	CU
Aquaculture	28.48	1.42	27.70	1.38	27.59	1.38	28.57	1.43	29.56	1.48	30.55	1.53
Commercial	8.51	4.85	8.32	4.74	8.24	4.69	8.23	4.69	8.28	4.72	8.38	4.77
Hydroelectric	1,222.39	0.00	1,222.39	0.00	1,222.39	0.00	1,222.39	0.00	1,222.39	0.00	1,222.39	0.00
Industrial	21.95	2.63	21.92	2.63	21.97	2.64	22.11	2.65	22.32	2.68	22.62	2.71
Irrigation	22.82	20.54	22.75	20.48	22.71	20.44	22.68	20.41	22.67	20.40	22.67	20.40
Livestock	0.58	0.44	0.59	0.45	0.60	0.45	0.61	0.46	0.63	0.48	0.64	0.49
Mining	52.75	5.27	57.16	5.72	61.57	6.16	65.98	6.60	70.39	7.04	74.80	7.48
Other	88.79	88.79	66.26	66.26	43.72	43.72	21.19	21.19	3.04	3.04	0.24	0.24
Thermoelectric	2,098.50	41.97	2,098.42	41.97	2,098.39	41.97	2,098.37	41.97	2,098.37	41.97	2,098.37	41.97
Public Water Supply	676.05	67.60	696.43	69.64	723.11	72.31	756.55	75.66	797.53	79.75	847.04	84.70
Self-Supplied Domestic	0.15	0.02	0.14	0.02	0.14	0.02	0.14	0.02	0.14	0.02	0.13	0.02
Basin Total	**4,220.97**	**233.53**	**4,222.08**	**213.29**	**4,230.43**	**193.78**	**4,246.82**	**175.08**	**4,275.32**	**161.58**	**4,327.83**	**164.31**

sectors with the greatest increase predicted in the Livestock and Mining sectors at about 10 percent and 40 percent respectively. Because the model is applied to each sector separately, predicted changes in withdrawal and CU vary from sector to sector.

This basin-wide increase in withdrawals between 2025 and 2050 is not expected to be uniform across the basin. Some HUC8 watersheds are predicted to experience increases of up to 23 percent (the Middle Potomac-Catoctin watershed) while other areas are estimated to have a decrease in withdrawals of up to 9 percent (the Lower Potomac watershed). Figure 2 shows the expected percent change in water withdrawals for all 11 HUC8 watersheds in the basin between 2025 and 2050 with the greatest increase being shown in dark blue and the greatest decrease being shown in yellow.

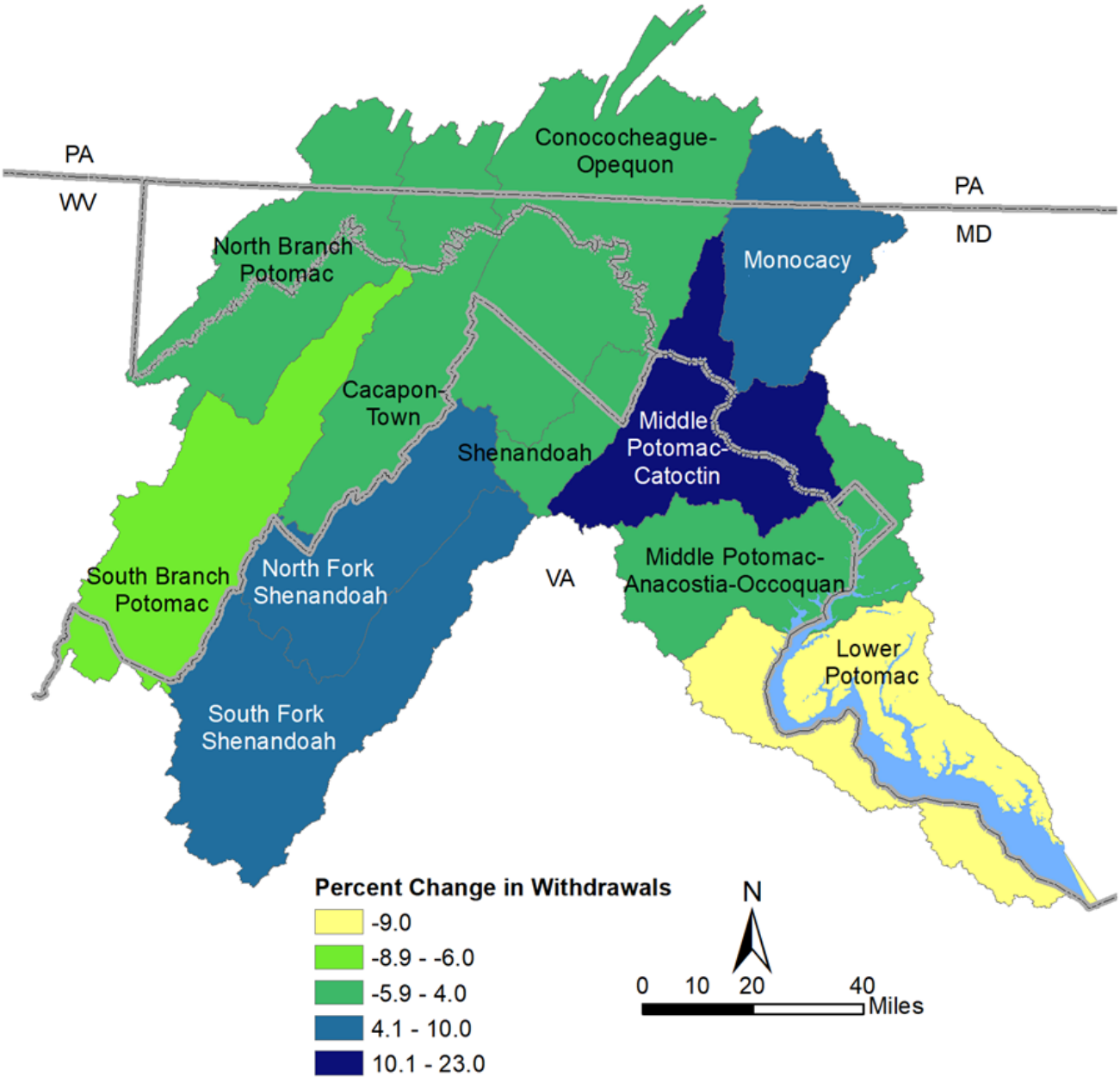

FIGURE 2. Map of the expected percent change in water withdrawals from 2025 to 2050 in the Potomac basin by HUC8.

The model structure developed in this study accounts for variables that differ by water withdrawal location and may otherwise impact the predicted withdrawal values. While the same general trend analysis was used for all sectors in this study, the hierarchical structure can easily be added to sector-specific models that incorporate predictor variables influential for a given sector and therefore further improve projection accuracy. An example of this would be combining a model predicting the water withdrawals of the Public Water Supply sector (which may include population as a predictor, Warziniack et al., 2022) with the hierarchical structure presented in this pamphlet. Additional work performed to forecast future reported water withdrawals and consumption in the Potomac basin will aim to improve the general trend analysis applied to each sector using the hierarchical framework and customize the model for individual sectors.

While ICPRB aims to predict reported water withdrawals using more sector-specific models in the future, these statistical approaches do not consider societal or policy changes. Such changes are difficult, if not impossible, to accurately anticipate given the inherently variable nature of policy will and society value. Another goal of future work may be to incorporate these societal and policy changes into the predictions where possible. In addition to incorporating unforeseen changes that influence water withdrawals, ICPRB aims to produce sector-specific and potentially location-specific CU factors unique to the basin.

Furthermore, the 2023 update to the Potomac Basin Comprehensive Water Resources Plan established new and updated goals regarding reported water withdrawal and CU in the basin.

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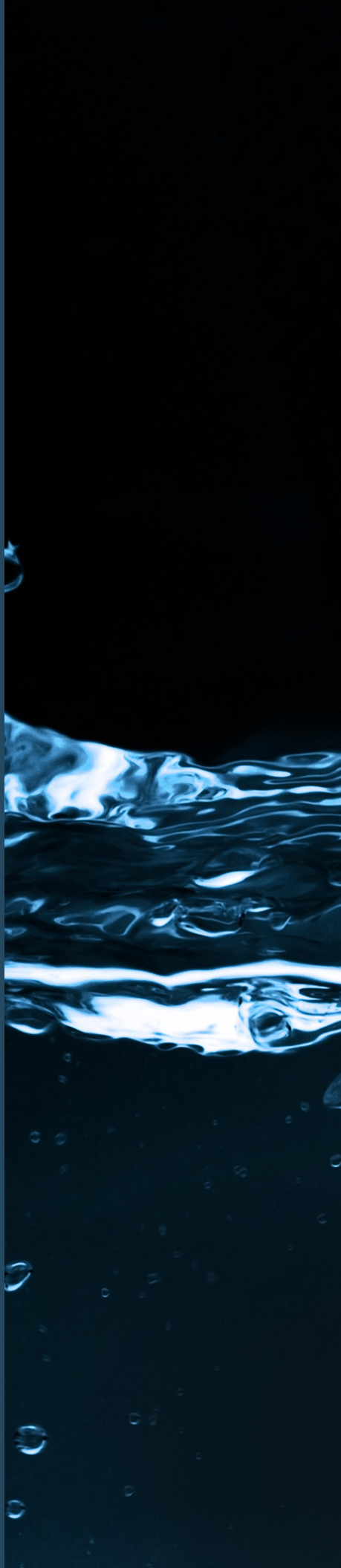

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