Appendix E. Summary of Literature Added to the Wetland Literature Review Database

The initial and primary focus of the literature review was to identify supporting research and/or data to differentiate amongst the wetland BMP types. The WEP2016 provided a comprehensive review of the literature describing wetland functions on nutrient and sediment retention.

Prepared by the Center for Watershed Protection, Inc.

Doherty, J. M., Miller, J. F., Prellwitz, S. G., Thompson, A. M., Loheide II, S. P., & J. B. Zedler. (2014). Hydrologic Regimes Revealed Bundles and Tradeoffs Among Six Wetland Services. *Ecosystems, 17*: 1026–1039. DOI: 10.1007/s10021-014-9775-3.

> This study evaluates the relationships between a variety of ecosystem services within three swales treating stormwater from an urban watershed in Wisconsin. Comprehensive sampling was conducted to measure the following six variables: peak flow reduction, outflow volume reduction, plant biomass, species richness, surface soil stability, and nutrient and sediment removal efficiency. The study concludes that hydrologic regime is a key determinant of the overall ecosystem services provided by wetlands, while net primary productivity is a potentially misleading indicator of overall ecosystem services.

Filoso, S., Smith, S. M. C., Williams, M. R., & M. A. Palmer. (2015). The Efficacy of Constructed Stream-Wetland Complexes at Reducing the Flux of Suspended Solids to Chesapeake Bay. *Environmental Science & Technology, 49*(15): 8986–8994. DOI: 10.1021/acs.est.5b00063.

> This study monitored the TSS retention effectiveness of two restored, nontidal, lowland valley stream reaches (forming stream-wetland complexes) in Maryland's Coastal Plain using a mass-balance approach. There was no statistically significant difference in the TSS load entering the reach and the TSS load leaving the reach, which indicates that these stream-wetland systems do not significantly lessen TSS loadings to tidal waters. The high variability of TSS retention documented in this study suggests that the TSS retention efficiency of these systems is dependent on: 1) the amount of TSS originating upstream, 2) system design characteristics, and 3) the frequency and magnitude of storm events.

Gumiero, B., Mant, J., Hein, T., Elso, J., & B. Boz. (2013). Linking the Restoration of Rivers and Riparian Zones/Wetlands in Europe: Sharing Knowledge through Case Studies. *Ecological Engineering, 56*: 36–50. DOI: 10.1016/j.ecoleng.2012.12.103.

> This meta-analysis assesses the loss of wetlands in Europe and evaluates how various policies have resulted in wetland re-establishment. The meta-analysis includes data from nine case studies. Only the results from one of those studies (Tockner et al., 2001) was included in the database as its own entry (meaning it is double-counted). Each case study highlights how different localities balance conservation, agriculture, socioeconomic needs, and policy drivers. The discussion concludes that hydrology is the most important determinant of wetland health, meaning that water management is the key to effective wetland restoration.

Kreiling, R. M., Schubauer-Berigan, J. P., Richardson, W. B., Bartsch, L. A., Hughes, P. E., Cavanaugh, J. C., & E. A. Strauss. (2013). Wetland Management Reduces Sediment and Nutrient Loading to the Upper Mississippi River. *Journal of Environmental Quality*. DOI: 10.2134/jeq2012.0248.

> This study measured the nutrient retention efficiencies of a marsh complex in Mississippi using a mass-balance approach. The marsh complex was an effective sediment trap, retaining approximately 75% of the sediment load entering the complex. While both nitrogen (N) and phosphorus (P) were retained in the marsh complex (although more P was retained than N), there was a net export of ammonium and soluble reactive phosphorus. Because the inlet of the most upstream section of the marsh complex was too high to intercept baseflow (it only intercepted strong storms and spring thaw), the nutrients and sediment in baseflow went directly into the adjacent river. Diverting more of the inflow into the marsh complex prior to it entering the adjacent river by lowering the inlet would further increase nutrient and sediment retention.

Kreiling, R. M., Thoms, M. C., & W. B. Richardson. (2018). Beyond the Edge: Linking Agricultural Landscapes, Stream Networks, and Best Management Practices. *Journal of Environmental Quality, 47*: 42–53. DOI: 10.2134/jeq2017.08.0319.

> Using a case study of the Fox Basin (which drains to Lake Michigan) in Wisconsin, this paper presents a framework for the interdisciplinary management of agricultural and riverine landscapes. The proposed framework is composed of three primary components: 1) ecosystems approach, 2) resilience thinking, and 3) strategic adaptive management. The ecosystems approach and resilience thinking are both conceptual components, while strategic adaptive management provides operational and logistical direction to the framework.

Land, M., Granéli, W., Grimvall, A., Hoffmann, C. C., Mitsch, W. J., Tonerski, K. S., & J. T. A. Verhoeven. (2016). How Effective are Created or Restored Freshwater Wetlands for Nitrogen and Phosphorus Removal? A Systematic Review. *Environmental Evidence, 5*(9). DOI: 10.1186/s13750-016-0060-0.

> This meta-analysis systematically reviewed nutrient removal rates by wetlands from a total of 2013 wetlands from 93 studies. Only the results from two of those studies (Jordan et al., 2003 and Ardón et al., 2010) were included in the database as their own entries (meaning they are double-counted). The TN removal efficiency of the evaluated wetlands was significantly correlated with both hydrologic loading rate and air temperature, while the TP removal efficiency of those wetlands was significantly correlated with TP concentration at the inlet, hydrologic loading rate, air temperature, and wetland area. The results indicate that both created and restored wetlands significantly reduce the transport of TN and TP in wastewater, urban runoff, and agricultural runoff. However, restored wetlands on previously-agricultural land were significantly less effective at TP removal than other types of wetlands. Additionally, wetlands with hydrologic loading rates that are driven by precipitation are significantly less effective at TP removal than their controlled-hydrologic-loading-rate counterparts.

Mitsch, W. J., Zhang, L., Stefanik, K. C., Nahlik, A. M., Anderson, C. J., Bernal, B., Hernandez, M., & K. Song. (2012). Creating Wetlands: Primary Succession, Water Quality Changes, and Self-Design over 15 Years. *Bioscience, 62*(3): 237–250. DOI: 10.1525/bio.2012.62.3.5.

This study monitored a pair of one-hectare, created riverine wetlands (one planted and one unplanted) for their first 15 years and compared them to a natural wetland (all located within the Oletangy River Wetland Research Park in Columbus, Ohio). Monitoring was conducted to evaluate vegetative succession, soil development, water quality conditions, and nutrient dynamics (specifically for carbon and nitrogen). While the planted wetland had higher vegetative diversity, the unplanted wetland was more productive. Both wetlands' soils became hydric within a few years of creation, and soil organic carbon nearly tripled in the 15-year study period. Both wetlands had similar nutrient removal and carbon retention rates. This study was ultimately removed from the database as an update to the study was published and included instead (Mitsch et al., 2014).

Mitsch, W. J., Zhang, L., Waletzko, E., & B. Bernal. (2014). Validation of the Ecosystem Services of Created Wetlands: Two Decades of Plant Succession, Nutrient Retention, and Carbon Sequestration in Experimental Riverine Marshes. *Ecological Engineering, 72*: 11–24. DOI: 10.1016/j.ecoleng.2014.09.108.

This study monitored a pair of one-hectare, created riverine wetlands (one planted and one unplanted) for their first 20 years and compared them to a natural wetland (all located within the Oletangy River Wetland Research Park in Columbus, Ohio). The primary inflow to the wetlands was water pumped from the adjacent Oletangy River. Monitoring was conducted to evaluate nitrogen and phosphorus budgets, vegetative structure and function, and carbon dynamics. The planted wetland retained significantly more TP than the unplanted wetland, while the unplanted wetland retained significantly more TN than the planted wetland. Overall, nutrient retention decreased over time. Both created wetlands sequestered more carbon than the reference natural wetland.

Annotated Bibliography of Additional Literature to Support the Wetland Rehabilitation, Enhancement and Creation Expert Panel.

Golden, H. E., Creed, I. F., Ali, G., Basu, N. B., Neff, B. P., Rains, M. C., McLaughlin, D. L., Alexander, L. C., Ameli, A. A., Christensen, J. R., Evenson, G. R., Jones, C. N., Lane, C. Rl., & M. Lang. (2017). Integrating Geographically Isolated Wetlands into Land Management Decisions. *Frontiers in Ecology and the Environment, 15*(6): 319–327. DOI: 10.1002/fee.1504.

This review paper details the environmental importance of geographically isolated wetlands (GIWs) and explains wetland connectivity in both scientific and management contexts. It also presents a variety of models available to quantify the connectivity of GIWs while recommending next steps to integrate and further improve such tools. While GIWs are often excluded from policy and management decision-making because of their apparent limited connection to downstream waters, their impacts on watersheds can be more accurately estimated as models improve.

Hansen, A. T., Dolph, C. L., Foufoula-Georgiou, E., & J. C. Finlay. (2018). Contributions of Wetland to Nitrate Removal at the Watershed Scale. *Nature Geoscience, 11*: 127–132. DOI: 10.1038/s41561-017-0056-6.

This study evaluated the effects of both wetland and cropland cover on nitrate levels by comparing high-resolution land cover data and extensive water quality sampling data within the

Minnesota River Basin (a region of the Mississippi River Basin). The results indicate that wetland cover is significantly related to nitrate concentrations under high-streamflow conditions, which is when most nitrate export takes place.

Hunt, P. G., Miller, J. O., Ducey, T. F., Lang, M. W., Szogi, A. A., & G. McCarty. (2014). Denitrification of Soils of Hydrologically Restored Wetlands Relative to Natural and Converted Wetlands in the Mid-Atlantic Coastal Plain of the USA. *Ecological Engineering, 71*: 438–447. DOI: 10.1016/j.ecoleng.2014.07.040.

This study monitored a total of 48 natural, converted, and restored wetland sites in Maryland, Virginia, and Delaware for three years to assess the soil denitrification capacity of wetlands in the Mid-Atlantic coastal plain of the United States. Soil enzyme analyses indicated that restored wetlands (NRCS Practice Standard 657 and 646) differed from both natural and converted wetlands. The results find that elevation (topographic gradient) and management approach will have an effect on denitrification.

Ducey, T. F., Miller, J. O., Lang, M. W., Szogi, A. A., Hunt, P. G., Fenstermacher, D. E., Rabenhorst, M. C., & G. W. McCarty. (2015). Soil Physiochemical Conditions, Denitrification Rates, and nosZ Abundance in North Carolina Coastal Plain Restoration Wetlands. *Journal of Environmental Quality, 44*: 1011–1022. DOI: 10.2134/jeq2014.09.0403.

This study monitored nine wetland sites in North Carolina’s coastal plain in order to assess the impact of hydrological restoration on the denitrification capacity of wetland soils. The study compared natural, restored, and historic wetlands under agricultural production (i.e., prior converted—PC—croplands). Restored wetland soils had a significantly lower concentration of the nitrate-reducing enzyme *nosZ* than natural wetland soils. Additionally, the nosZ activity rate of wetland soils varied with soil wetness (typically increasing as moisture increases).

Moreno-Mateos, D., Meli, P., Vara-Rodríguez, M. I., & J. Aronson. (2015). Ecosystem Response to Interventions: Lessons from Restored and Created Wetland Ecosystems.

This study compared the biogeochemical functionality of 628 restored and created wetlands to 499 reference wetlands from across the globe. Recovery trajectories of wetlands under various restoration/creation approaches were studies under different environmental settings. The differences amongst wetland BMP functions based on a regression analyses were small (6-7%). Surface modification and hydrological re-establishment had similar effects on wetland recovery trajectory regardless of revegetation.