# Recovery Potential Metrics
# Summary Form

**Indicator Name:** WATERSHED PERCENT WETLANDS

**Type:** Ecological Capacity

**Rationale/Relevance to Recovery Potential:** Wetlands are key features in watershed processing of nutrients in runoff, detention of excessive runoff during extreme weather events, and act as sinks for sediment and pollutants. In addition, wetlands provide vital recharge, detention and release in their role within groundwater/surface water interactions. Absence of wetlands degrades natural processing of the pollutants mentioned and results in greater direct transport to the receiving water body of the watershed, increasing or perpetuating impairment. Greater proportion of wetland area in the watershed positively influences recovery potential in that watersheds with more wetlands have greater resilience concerning the types of impairments mentioned.

**How Measured:** Percent wetland area within the selected watershed scale.

**Data Source:** Data sources may vary considerably in source, date and accuracy of wetland/upland delineation. For land cover data including generalized wetland categories, the National Land Cover Database (NLCD) for 2006, 2001 and 1992 is accessible at http://www.mrlc.gov/finddata.php; numerous statewide land cover mapping datasets are also available from state-specific sources. NLCD or state land cover datasets are generally available but less accurate than wetland-specific mapping efforts such as National Wetlands Inventory (NWI) (see: http://www.fws.gov/wetlands/index.html). NWI data are partially available as digital coverage, are likely more accurately interpreted but may be out of date in selected areas. For watershed boundaries, numerous watershed scales have been delineated nationally as part of the Watershed Boundary Dataset (WBD) (see: http://datagateway.nrcs.usda.gov). Custom watershed boundary delineation can be done by aggregating NHDplus catchments (see: http://www.horizon-systems.com/nhdplus/) or WBD HUC12 watersheds.

**Indicator Status (check one or more)**

_______ Developmental concept.
___x__ Plausible relationship to recovery.
_______ Single documentation in literature or practice.
___x__ Multiple documentation in literature or practice.
_______ Quantification.

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**Supporting Literature (abbrev. citations and points made):**

- (Kohler et al., 2004) Unlike stormwater retention basins, a wetland cell with active plants and anaerobic sediments will have a significant retention and degradation capacity for introduced materials. Created wetlands are able to remove significant amounts of suspended solids, organic matter, nutrients, heavy metals, trace elements, pesticides, and pathogens through chemical, physical, and biological processes (Kadlec and Knight, 1996). Natural and created wetlands improved water quality of municipal wastewater (Healy and Cawley, 2002), coal mine drainage (Perry and Kleinmann, 1991), urban stormwater runoff (Mallin et al., 2002), aquaculture wastewater (Lin et al., 2002; Tilley et al., 2002) and agricultural drainage (Peverly, 1982; Kovacic et al., 2000; Moore et al., 2001) (286).
- (Kohler et al., 2004) Wetlands also have several positive aesthetics characteristics such as increasing habitat for wildlife and flora while providing improved floodwater mitigation

(Brix, 1997; Knight, 1997; Kennedy and Mayer, 2002) for drainage and stormwater management. However, the most important aspect of wetlands is their ability to improve water quality (286).

- (Kohler et al., 2004) Our study showed that this golf course does not reduce quality of its water compared to water entering the golf course or water in the larger Cuppy–McClure watershed. The created wetland system in our study was efficient at improving water quality (296).
- (Kohler et al., 2004) Overall, our system demonstrated that created wetlands on golf courses can be used to filter golf course tile drains as well as runoff from areas adjacent to the course. However, to insure maximum water quality improvement, wetlands should be sized to maximize water holding during storm events and to minimize outputs during nonstorm periods (296).
- (Kohler et al., 2004) While nutrients and pesticide management is largely handled by soils on the course; the use of created wetlands offers a means of containing these materials if they do migrate into the drainage water (287).
- (Kohler et al., 2004) The wetland efficiently removed N-NO3/NO2 and NNH3, removing an estimated 97% of N-NO3/NO2 and 100% of N-NH3 (Table 5). These results are similar with those of Kao andWu (2001) and Kao et al. (2001) who found wetlands to be greater that 80% efficient at nitrogen removal during storm events (291).
- (Kohler et al., 2004) P mass reductions of 70% (Kao et al., 2001) and 59% (Kao and Wu, 2001) have been previously reported as water passed though a constructed wetland during a storm event (292).
- (Kohler et al., 2004) However, COD and TOC were reduced by wetlands during storm events. Reductions from the UI to the GCO were 90% for COD and 91% for TOC (Table 5), which is similar to that found by Kao et al. (2001) and Kao and Wu (2001) (292-293).
- (Kohler et al., 2004) Mass loading removal of dissolved solids was 59%, indicating that the wetlands were effective at removing dissolved solids during storm events (Table 5). However, mass loading removal of suspended solids was 0% in our study (Table 5), whereas other researchers found higher removal efficiencies of suspended solids during storm events (Kao and Wu, 2001; Moore et al., 2002) (293).
- (Kohler et al., 2004) The wetlands reduced Cl and Na to below UI levels as water exited the course at GCO. Mass loading removal efficiency was 77% for Cl and 85% for Na during storm events (Table 5) (293).
- (Kohler et al., 2004) Wetlands are generally efficient at Mn removal (Stark et al., 1994; Kadlec and Knight, 1996) and removal efficiency of Mn in our study was 51% (Table 5). The wetlands had a limited effect on Al, Ca, Fe, Mg, Si, and SO4 (Table 2) (293).
- (Kohler et al., 2004) The golf course's impact on wetland water quality can be summarized by comparing parameters at the UI and the GCO. During storm events, 11 of the 17 measured parameters (NO3/NO2, NH3, P, COD, TOC, dissolved solids, Ca, Cl, Mg, Mn, and Na) had higher mass loading entering the course at the UI than leaving the golf course at the GCO (Table 5). Thus, during storm events the mass of most of the parameters decreased as water flowed through the wetland system (293).
- (Kohler et al., 2004) The wetlands reduced the NNO3/NO2 concentration by as much as 95% (Table 3). This is similar to other reports (Comin et al., 1997; Burgoon, 2001; Kao et al., 2002) and is in agreement with Baker's (1998) conclusion that wetlands are proficient at nitrate removal (294).
- (Kohler et al., 2004) However, after moving through that wetland system, the nutrient concentrations were extremely low (<1 mg/L) (Mallin et al., 2002), which concurred with our study (294).
- (Kohler et al., 2004) Thus, our results are in agreement with Brix (1994) that most created wetlands are able to remove P from water with most wetlands producing effluents with <1 mg/L total P. Overall, low (<0.07 mg/L) levels of phosphorus have been found in golf course wetlands (Mallin and Wheeler, 2000; Mallin et al., 2002), and our findings are in agreement (294).

- (Kohler et al., 2004) This However, reductions in parameter concentration between the GCT and the GCO were as high as 59%, indicating the wetlands are having a positive affect on golf course tile water, most likely from dilution (Sriyaraj and Shutes, 2001) (295).
- (Norton and Fisher 2000) Johnston et al. (1990) determined that proximity of herbaceous wetlands to streams in a nine-county region surrounding Minneapolis significantly influenced nitrate and dissolved P during base flow as well as ammonium, nitrate, and TP during storm flow (339).
- (Kohler et al., 2004) Passage though the wetlands reduced dissolved solids concentration by as much as 53% (Table 3). This is in contrast to Kadlec and Knight (1996) who report that dissolved solids generally are not affected by wetlands. In contrast to our findings with dissolved solids, the wetland had little effect on suspended solids concentration during nonstorm events (295).
- (Kohler et al., 2004) This is similar to other work that found potassium concentration increases as water passes through a wetland (Peverly, 1982) and that natural wetlands often export potassium (Richardson, 1989) (292).
- (Norton and Fisher 2000) In the Choptank, forest cover was strongly associated with low TN and NO3_ concentrations. Within first order streams, the conduits of water from terrestrial to aquatic systems, the presence of forested stream banks also had a strong relationship with low stream N. In addition, the amount of riparian wetlands and degree of ‘wetness’ was inversely correlated with stream N in the Choptank basin. In contrast, forest cover in the Chester basin did not have a strong impact on stream nutrients regardless of landscape position and/or flooding regime. Hydrologic characteristics, rather than land cover, had the strongest effect on predicting Chester stream nutrient concentrations (359).
- (Brydon et al. 2006) Numerous studies have shown that metal retention in wetlands is highly variable but generally falls into the 25-50% removal rates for metals such as Cr, Ni, Cu, Pb, and Zn (Birch et al. 2004), (Mal lin et al. 2002). In contrast Fe and Mn are generally released from sediments in wetlands and the outflow water usually has significantly higher concentrations than the inflowing water (Birch et al. 2004; Brydon 2004; Goulet and Pick 2001) (147-148).
- (Brydon et al. 2006) The uptake of excess nutrients by plants is another service provided by wetlands. This can have some very positive effects since it will reduce the eutrophication risk downstream. Usually the nutrient uptake efficiency in wetland for TN, TP and ammonia and nitrate is in the order of 10-20%. Increased wetland size and water residence time can improve nutrient reduction significantly. (148).
- (Brydon et al. 2006) Pathogen removal in wetlands has been reported to range between 30% and 90% but is obviously less efficient during high flow events (Birch et al. 1004) (148).
- (Brydon et al. 2006) Water detention and water storage during storm events, and water release during dry periods, are some of the main functions wetlands can provide in order to help reduce peak flow and increase low flow runoff into streams. However, wetlands can also be effective in retaining and remediating contaminants. In the present example it was shown that dissolved and bio-available metals in the water column were significantly reduced as the water moves through a constructed wetland (152).
- (Moreno et al. 2007) New interest is arising now in restoring and creating wetlands to buffer non-point source pollution at watershed scale (Raisen and Mitchell, 1995; Mitsch and Gosselink, 2000) because nutrients are responsible for eutrophication of natural aquatic ecosystems in river basins and coastal seas (Goldman and Horne, 1983) (103).
- (Pavel et al. 1996) In many areas of the Atlantic Coastal Plain, riparian wetlands border intensively managed agricultural fields and may act as important biological filters with the potential to remove nutrients, such as $NO_3^-$, as they move with groundwater through this zone (2798).
- (Pavel et al. 1996) Several studies, conducted in the Coastal Plain of Eastern and Southern U.S.A., have indicated that riparian wetlands effectively remove $NO_3^-$ from groundwater flowing from beneath agricultural fields before it can enter into nearby

streams. Reductions in groundwater $NO_3^-$ concentrations of up to 90% have been measured by Jacobs and Gilliam (1985) in North Carolina, by Lowrance *et al.* (1984) in Georgia, and by Peterjohn and Correll (1984) in Maryland. In Virginia, Snyder (1995) observed that elevated $NO_3^-$ concentrations in groundwater moving from beneath an upland agricultural field (located in the Nomini Creek watershed) and then under a riparian forest was reduced by 48% before entering a stream bordering the field (2798).

- (Pavel et al. 1996) Processes responsible for removing $NO_3^-$ from groundwater as it moves through the riparian buffer zones include denitrification, plant uptake, and assimilative $NO_3^-$ reduction by microbes (Simmons *et al.,* 1992) (2799).
- (Brody and Highfield 2007) Conger (1971) showed that the ability of wetlands to store water significantly reduced peak flows for recurrence intervals up to 100 years. Novitski (1979) studied four different types of wetlands and found that each had a negative effect on flood flows. Novitski (1985) concluded that basins with as little as 5% lake and wetland area might lead to 40-60% lower flood peaks (415).
- (Brody and Highfield 2007) More recent research utilizing simulation models also demonstrates the flood reducing role of wetlands. Ammon et al. (1981) modeled the effects of wetlands on both water quantity and quality of Chandler Marsh in South Florida. Results showed that maximum flood peak attenuation is higher with increasing areas of marsh. The authors concluded that Chandler Slough Marsh increases storm water detention times, changes run-off regimes from surface to increased subsurface regimes, and is ‘‘moderately effective as a water quantity control unit’’ (p. 326). Ogawa and Male (1986) also developed a simulation model to explore the potential of wetlands as a flood mitigation strategy. Using four scenarios of downstream wetland encroachment ranging from 25 to 100% loss, the authors found that increased encroachment resulted in significant increases in peak flow (415).
- (Rodgers et al. 2009) Surface waters entering wetlands often contain sediment and associated nutrients, particularly P. As this water is stored, a portion of the sediment and associated nutrients is trapped (Mitsch et al., 1979; Johnston et al., 1984; Lowrance et al., 1986; Cooper et al., 1987; Hupp and Bazemore, 1993; Johnston, 1991; Hupp et al., 1993; Kleiss, 1996; Craft and Casey, 2000; Wilson et al., 2005). However, during large storm events erosion of sediment can transform wetlands into temporary sources of sediment and nutrients (Phillips, 1989; Kleiss, 1996; Jordan et al., 2003; Wilson et al., 2005). Under anoxic conditions, P bound to wetland sediment may be released (Roden and Edmonds, 1997; Bridgham et al., 2001) (629).
- (Jordan et al. 2003) Preserving or restoring wetlands may help reduce nonpoint-source pollution. Wetlands can act as filters removing particulate material, as sinks accumulating nutrients, or as transformers converting nutrients to different forms, such as gaseous compounds of nitrogen (N) and carbon (C) (Richardson, 1989). Recent research has shown that constructed or restored wetlands can remove sediments and nutrients from nonpoint sources, including agricultural discharges (e.g., Fleischer et al., 1994; Mitsch, 1994; Raisin and Mitchell, 1995; Whigham, 1995; Jordan et al., 1999). Widespread restoration of wetlands has been suggested as part of a plan for reducing nitrogen releases from the Mississippi River basin (Mitsch et al., 2001).
- (Johnston et al.1990) 'Cumulative impact,' the incremental effect of an impact added to other past, present and reasonably foreseeable future impacts, has been an area of increasing concern to regulatory agencies because the piece-meal loss of wetlands over time has seriously depleted wetland resources (Williamson et al. 1986; Preston & Bedford 1988) (105) (1534).
- (Johnston et al.1990) Our results indicate the importance of considering wetland position in the landscape when evaluating cumulative function. All wetlands in a watershed do not behave alike with regard to water quality function, which may explain why previous attempts to relate percent wetland to drainage basin water quality have generally been unsuccessful (Whigham & Chitterling 1988). Wetland extent (PC 1) was related to decreased concentrations of only three of the time-weighted variables on an annual basis, none of which were nutrients: chloride, lead, and specific conductance. PC2, which

was related to wetland proximity, helped to explain decreased concentrations of five annual time-weighted variables (LGSPCND, LOGFCOL, FRDP, SQRTNO3, and TSIS) and three additional flow-weighted variables (NH4, NOX, and TP). Therefore, the position of wetlands in the watershed appears to have a substantial effect on water quality, particularly with regard to sediment and nutrients (136).

- (Brody et al. 2007) Ogawa and Male (1986) also developed a simulation model to explore the potential of wetlands as a flood mitigation strategy. Using four scenarios of downstream wetland encroachment ranging from 25 to 100% loss, the authors found that increased encroachment resulted in significant increases in peak flow.
- (Brody et al. 2007) For example, recent findings demonstrate that wetlands are able to absorb and hold greater amounts of floodwater than previously thought. Based on an experiment that involved constructing wetlands along the Des Plaines River in Illinois, it was found that a marsh of only 5.7 acres could retain the natural run-off of a 410-acre watershed. This study estimated that only 13 million acres of wetlands (3% of the upper Mississippi watershed) would have been needed to prevent the catastrophic flood of 1993 (Godschalk et al. 1999).
- (Brydon, Roa, Brown and Schreier 2006) wetlands have many functions that are of great advantage to watershed management. Wetlands moderate stream-flow and can retain large quantities of storm-water. They tend to have high capacities for contaminant removal and carbon accumulation.
- (Brydon, Roa, Brown and Schreier 2006) Incorporating wetlands into watershed management plans is rapidly emerging as an innovative way of providing multiple functions which include flood control, stream-flow moderation, groundwater recharge, sediment detention, pollutant retention and phytoremediation.