Context Document: Wastewater Treatment or Constructed Wetlands Ecosystem Service Logic Model

Project: GEMS
http://bit.ly/NI-GEMS

Ecosystem Service Logic Models (ESLMs) are conceptual models that summarize the effects of an intervention, such as a habitat restoration project, on the ecological and social systems. Each model links changes in biophysical systems caused by an intervention to measurable socioeconomic, human well-being, and ecological outcomes. ESLMs assume that the restoration is successful and include all potentially significant outcomes for the intervention; not all outcomes will be relevant to each individual project, depending on location and environmental conditions.

The direction of an outcome (whether the restoration will have a positive or negative influence) often depends on the specific situation or is unclear due to multiple links (arrows) leading into an outcome that may have opposite effects. Thus, language like "increased" or "decreased" is not included in the models. These models are often used to consider management with or without an intervention or to compare different interventions.

This context document includes additional information about the restoration approach and details about some of the relationships in the wastewater treatment wetlands ESLM. It also includes a list of the references used to develop the ESLM and names of experts with whom we spoke to refine the model.

Treatment or Constructed Wetlands Description and Use in the Gulf of Mexico

Treatment wetlands for wastewater treatment are engineered systems designed to replicate the structure and the services often provided by wetlands in order to perform tertiary wastewater treatment, particularly phosphorus and waterborne pathogen removal, and nitrogen transformation and removal through a variety of physical, chemical, and biological mechanisms. Treatment wetlands (sometimes known as constructed wetlands) are often used to support traditional municipal and industrial wastewater treatment but can also be used for stormwater, aquaculture, and mine drainage. There are two types of treatment wetlands: free water surface (FWS) wetlands and subsurface flow (SSF) wetlands. FWS wetlands generally look like marshes and consist of multiple species of rooted emergent vegetation and standing water. FWS systems that utilize only submerged or floating vegetation are comparatively less common. Subsurface Flow Systems (SSF), on the other hand, maintain water flow below the surface.

External Factors That Influence Restoration Success

The types of pollutants entering wastewater systems is changing, and now includes chemicals and hormones from pharmaceuticals and personal care products, domestic and industrial waste, and flame retardants in addition to nutrients and suspended solids. There is not much information on how these pollutants are processed and absorbed in wetlands. As such, it remains unclear how effective treatment wetlands are at removing these pollutants in the long-term wetlands (CA Water Board 2018).

Hurricanes may also impede the benefits of treatment wetlands by damaging wetlands or catalyzing the movement of sediment and nutrients loaded into the system. At the same time, treatment wetlands also provide resilient treatment systems that recover relatively quickly following impacts from hurricanes.

Invasive species, if poorly managed, can reduce the functional capacity of constructed wetlands.

Model Notes and Clarifications

Likelihood of Flooding (Excluded): Damage from or risk due to flooding does not come up in the literature as an outcome of treatment wetlands, except in combined stormwater outflows, which are not present in the Gulf of Mexico (Tao et al. 2014). EPA guidance for constructed wetlands does include designing and planning for the likelihood of floods and avoiding building them in flood plains, but otherwise does not mention possibility of flood damage being mitigated with the presence of a constructed wetland (EPA 2015). In fact, the Texas Comission on Environmental Quality places restrictions on wastewater treatment units being built within the 100-year floodplain (30TAC §217.35) Stormwater wetlands, on the other hand, may impact flooding outcomes as they relate to stormwater events.

Invasive Species: Constructed wetlands themselves do not introduce invasive plant species, as they are almost always constructed using local and native species. However, in areas with invasive wetland species in the general vicinity, treatment wetlands offer up additional habitat for invasive species to grow and invasive animals, such as feral hogs and nutria, are drawn to constructed wetlands. In some cases, invasive species provide some of the expected benefits for pollutant removal in treatment wetlands (Gu 2006). In other cases, invasive species such as feral hogs and nutria can impede the water quality improvements expected from treatment wetlands and impact water quality that way.

Odor: The literature suggests that treatment wetlands can at times reduce odor from wastewater treatment processes (Capasso et al. 2019, Wheeler et al. 2007, Bastian 1993)

Algal Blooms (Excluded): Nitrogen species removed through nitrification-denitrification process are permanently removed from the water column, so substantial reduction in total nitrogen discharged from the constructed wetland is achieved. Long-term removal of phosphorus is achieved through accretion of new soils within the wetland cells. Although cycling of plant and microbial biomass releases some phosphorus back to the water column, long-term removal of phosphorus is achieved through the burial of organic biomass recalcitrant to microbial degradation. However, it is likely that treatment wetlands have a marginal effect on harmful algal blooms (Bastian 1993). Experts believe, however, that if scaled, a number of treatment wetlands may have a more noticeable impact on nutrient loads in water systems.

Surface and Groundwater Quality: Both types of water quality may be impacted by surface and subsurface treatment wetlands, though local and federal regulations require wetlands to be lined so as not to discharge into ground water. Internal loading, in which wetlands already have sequestered nutrients and other pollutants may affect the rate of treatment to water quality in treatment wetlands.

Mosquitoes: Though it is frequently assumed that mosquito populations will go up where there is a wetland due to permanent water, in some constructed wetlands, the population of mosquitoes may decrease as a result of increased stable predator populations to mosquito ratio. Studies also indicate that a shift in mosquito species found in treatment wetlands from strong flying species that respond to temporary pools resulting from rain events to permanent water species, which typically are found close to the permanent water habitat (personal communication with Tim Noack and Loretta Mokry).

Adjacent Habitats: Seagrasses are adversely affected by eutrophication through a variety of mechanisms, including lower light penetration due to high algae growth and direct toxicity of nitrogen compounds (Burkholder et al. 2007). Therefore, reductions in surface water nitrate loading associated with septic to sewer conversion may benefit nearby seagrass beds.

Use in Agricultural Systems: Treatment wetlands can also be used to remove pollutants from agricultural runoff and aquaculture runoff. The ESLM for a treatment wetland in either of these systems would be similar to this ESLM, but there may be differences due to the types and amounts of pollutants in the runoff water and the location of the treatment wetland. Only a few examples of these types of projects in the Gulf of Mexico coastal region were found (Millhollon et al. 2009, Tilley et al. 2002).

Nutrition for Communities: This as an expected socioeconomic outcome of restoration projects can come from two sources: changes in fish and shellfish harvesting, and changes in land-based hunting on restoration areas. For this model, the source of nutrition is mainly from changes in land-based hunting opportunities, as treatment wetlands are often closed to fishing and have marginal impacts on fishing activity elsewhere.

Experts Consulted

Tim Noack, Plummer Associates, Inc.

Loretta Mokry, Plummer Associates, Inc.

Morgan Ayers, Texas Sea Grant

Dr. Kim Jones, TAMU Kingsville

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Jaime Flores, Texas Water Resources Institute

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Wetland Solutions Inc. n.d. Featured Treatment Wetland Projects. https://www.wetlandsolutionsinc.com/projects/treatment-wetlands/.