

Lines of Evidence

The basic questions about Waubesa Wetlands (WW) that the CARPC is asking are: **How does urbanization affect WW?** and **How can urbanization be managed to avoid negative impacts to WW?**

“**Waiting for scientific certainty is neither a safe nor prudent option**” (Griggs et al. 2017). An alternative is to explore lines of evidence from multiple disciplines, as in this example for the Columbia River estuary: Diefenderfer et al. (2016) hypothesized that multiple restoration projects are benefitting juvenile salmon. In lieu of experiments with/without restoration at the landscape scale, they used **7 lines of evidence from multiple disciplines**: Ecosystem modeling, physical modeling of controlling factors, meta-analysis of restoration actions, analysis of target species data, research on critical uncertainties, literature review, and changes to the landscape. All 7 lines of evidence concurred that restoration efforts were effective in enhancing habitat for salmon. Consistent results supported policy to continue restoration.

For Waubesa Wetlands: We can test for effects of urbanization using **lines of evidence from multiple disciplines**. For lines of evidence that indicate negative impacts on downstream wetlands, we could help plan ways to avoid damages, using the literature and applying the precautionary principle where uncertainties remain (Elton et al. 2011). We could include fail-safe measures to address “perfect storms” and other uncertainties. A table (e.g., the **draft** below) could summarize our multi-disciplinary findings:

Lines of evidence	Effects on Waubesa Wetlands	Avoidance mechanisms, precautionary principle	A few references as examples in the literature
Groundwater modeling	Wells divert water from ecosystems that depend on groundwater; drier wetlands lose species; invaders appear; dry peat is vulnerable to fires	Keep wells far from WW; require 100% reuse of water by developments or >1:1 mitigation within the subwatershed	Wright et al. 2006; [Consult members of K. Potter’s county committee?]
Water quantity modeling (runoff)	Impervious surfaces increase runoff to streams/wetlands, changing hydroperiods; fens are especially vulnerable	Avoid changes to wetland hydroperiod (all critical components); require 100% capture of added runoff	NRC 2009, Azous et al. 2000, Reinelt et al. 1998, Reinelt & Taylor 2000, Schueler & Holland 2000
Water quality modeling Nutrients Pollutants Temperature	Urban runoff is warmed by impervious surfaces and carries more materials to downstream wetlands	Avoid contaminants at the source (e.g., pesticides, fertilizers); treat runoff upstream.	Azous & Horner 2000, Brabec et al. 2002, Wright et al. 2006, Dodson 2008, Lougheed et al. 2008, NRC 2009, Dugan et al. 2017
Ecosystem services	Services occur in bundles and have trade-offs; services depend on watershed location	Actually <i>measure</i> services; educate residents	Doherty et al. 2014; Arboretum Leaflets 27, 28 and 36
Biodiversity research Veg., Inverts, Amphibians, Birds, Mammals	Studies of each component show that all biota are affected by urbanization, most by declining	Avoid alterations to water quantity and quality, but also loss of buffer habitats and disturbances of noise, lights, and invasive species	Wright et al. 2002, Mantyka-Pringle et al. 2014, 2016
Climate change research	Extreme events will cause greater effects than gradual changes; a warmer climate will favor invaders, diseases, pests	Use realistic projections of storms in models, including sequence events. Use the latest data and models.	Reinelt et al. 2000, Zedler 2010; approaches for envisioning extremes in Griggs et al. 2017
Invasive species research	Invaders displace native plants & animals, also disrupt food webs & ecosystem services	Avoid introducing invaders; avoid factors that promote invasion	Refer to literature cited in the “Chain of Impacts”, also Wright et al. 2006
Cumulative impacts analyses	Acknowledge uncertainties, assess risks; address hydrology & downstream wetlands	Synergisms & interactions are hard to identify	Bedford & Preston 1988, Whigham et al. 1988, Wright et al. 2006, Lougheed et al. 2008
Policy tools	Utility for Waubesa Wetlands	Shortcomings	Examples

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Policy tools	Utility for Waubesa Wetlands	Shortcomings	Examples
Conceptual models	Display direct + indirect effects, interactions, feedbacks	Uncertain strengths of each cause-effect link	Lee et al. 2006
Adaptive management (AM)	Engage stakeholders; state policy & goals; test mgt approach; monitor outcomes; make changes based on data; improve goals & actions, repeat with new science	Requires an AM Team that can adjust policies and governance, monitor and experiment and manage with flexibility	Fischenich et al. 2012, LoSchiavo et al. 2015 Zedler 2017
Decision structures, e.g., Bayesian Decision Networking	Can prioritize management actions for adapting to climate change and urbanization	Restoration might not be a top priority in the short term for aquatic biodiversity, but it is essential in the long term	Mantyka-Pringle 2016
Safe operating space	Retaining a broad boundary well within stress thresholds helps keep ecosystems from collapsing during an era of global change. Consistent with precautionary principle.	Thresholds are uncertain; smaller systems might be more amenable to threshold-based management,	Green et al. 2017, Kelly et al. 2015
Purchase of Development Rights (PDR)	Economically: Win for the land, Win for the landowner, Win for the Town	Sounds too good to be true, but it works for the Town of Dunn.	Town of Dunn Comprehensive Plan
Watershed district (as in lake district)	Links governance to the waters that drive the regional ecosystem	For lake districts, citizens can ask; politicians must approve	http://www.uwsp.edu/cnr-ap/UWEXLakes/Pages/organizations/districts/default.aspx
Leopold's Land ethic--the basis for land care	Land Ethics embrace land care for humans, the land, wetlands and groundwater.	Needs a grass roots movement, not top down edicts	Leopold 1949, Anderson 2007, Zedler 2015

References Cited (listed on next page)

- Anderson, M. 2007. Groundwater ethics (Abstract). Geological Society of 'America Mtg. https://gsa.confex.com/gsa/2007AM/finalprogram/abstract_127305.htm
- Azous, A., and R. R. Horner, eds. 2000. *Wetlands and Urbanization: Implications for the Future*. CRC Press, Boca Raton, FL.
- Azous, A., L. Reinelt, and J. Burkey. 2000. Managing wetland hydroperiod: Issues and concerns. P. 287-298 IN Azous & Horner (2000).
- Bedford, B., and E. Preston. 1988. Developing the scientific basis for assessing cumulative effects of wetland loss and degradation on landscape functions: Status, perspectives and prospects. *Environmental Management* 12(5):751-771.
- Brabec, E., S. Schulte, and P. L. Richards. 2002. Impervious surfaces and water quality: A review of Current literature and its implications for watershed planning. *Journal of Planning Literature* 16(4): 499–514.
- Diefenderfer, H. L., G. Johnson, R. M. Thom, K. Buenau, L. Weitkamp, C. Woodly, A. Borde, and R. Knapp. 2016. Evidence-based evaluation of the cumulative effects of ecosystem restoration. *Ecosphere* 7(3): e01242.
- Doherty, J. M., J. F. Miller, S. Prellwitz, A. M. Thompson, S. Loheide, and J. B. Zedler. 2014. Bundles and tradeoffs among six wetland services were associated with hydrologic regime. *Ecosystems* 17(6):1026-1039.
- Dodson, S. I. 2008. Biodiversity in southern Wisconsin storm-water retention ponds: Correlations with watershed cover and productivity, *Lake and Reservoir Management*, 24:4, 370-380, DOI: 10.1080/07438140809354847
- Elton, Elyssa, L. Del Giudice, K. Montgomery and L. Roberti. 2011. *The impacts of urbanization on the hydrology of wetlands: a literature review*. Toronto and Region Conservation Authority, Downsview, Ontario, Canada.
- Fischenich, C., C. Vogt (and 12 more authors). 2012. The application of adaptive management to ecosystem restoration projects. EBA Technical Notes Collection. ERDC TN-EMRRP-EBA-10. Vicksburg, MS: U.S. Army Engineer Research and Development. <http://el.ercd.usace.army.mil/elpubs/pdf/eba10.pdf>.
- Green, A, P. Alcorlo, ETHM Peeters, EP Morris, JL Espinar, MA Bravo-Utrera, J Bustamante, R Díaz-Delgado6, AA Koelmans, R Mateo, WM Mooij, M Rodriguez-Rodriguez, EH van Nes, and M Scheffer. 2017. Creating a *safe operating space* for wetlands in a changing climate. *Frontiers Ecol Environ* 15(2): 99–107, doi:10.1002/fee.1459
- Griggs, G, J. Árvai, D Cayan, and 6 more authors (California Ocean Protection Council Science Advisory Team Working Group). *Rising Seas in California: An Update on Sea-Level Rise Science*. California Ocean Science Trust, April 2017.
- Kelly RP, Erickson AL, Mease LA, et al. 2015. Embracing thresholds for better environmental management. *Philos T R Soc B* 370: 20130276.
- LoSchiavo, A.J., R.G. Best, R.E. Burns, S. Gray, M. C. Harwell, E.B. Hines, A.R. McLean, T. St. Clair, S. Traxler, and J.W. Vearil. 2013. Lessons learned from the first decade of adaptive management in comprehensive Everglades Restoration. *Ecology and Society* 18: 70. doi.org/10.5751/ES-06065-180470.
- Mantyka-Pringle, C.S., T.G. Martin, D. B. Moffatt, S. Linke and J.R. Rhodes. 2014. Understanding and predicting the combined effects of climate change and land-use change on freshwater macroinvertebrates and fish. *Journal of Applied Ecology* 51:572–581.
- Mantyka-Pringle, C.S., T.G. Martin, D.B. Moffatt, J. Udy, J. Olley, N. Saxton, F. Sheldon, S.E. Bunn, J.R. Rhodes. 2016. Prioritizing management actions for the conservation of freshwater biodiversity under changing climate and land-cover. *Biological Conservation* 197: 80–89.
- Reinelt, L., R. Horner, A. Azous. 1998. Impacts of urbanization on palustrine (depressional freshwater) wetlands—research and management in the Puget Sound region. *Urban Ecosystems* 2: 219-236.
- Reinelt, L., and B. Taylor. 2000. Effects of watershed development on hydrology. P. 221-235 IN Azous and Horner 2000.
- Whigham, D. F., C. Chitterling, and B. Palmer. 1988. Impacts of freshwater wetlands on water quality: a landscape perspective. *Environmental Management* 12:663-671.
- Wright, T., J. Tomlinson, T. Schueler and K. Capiella. *Direct and indirect impacts of urbanization on wetland quality*. 2006. *Wetlands and Watersheds: Article 1*. Maryland: Centre for Watershed Protection.
- Zedler, J. B. 2010. How frequent storms affect wetland vegetation: A preview of climate change impacts. *Frontiers in Ecology and the Environment* 8:540-547.
- Zedler, J. 2015. A wetland ethic? *National Wetlands Newsletter* 37(4):17-18.
- Zedler, J. B. 2017. What's new in the adaptive management and restoration of estuaries and coasts? *Estuaries and Coasts* 40: 1-21. DOI 10.1007/s12237-016-0162-5