Evaluating the impact of pumping on surface water – groundwater interaction and coastal vulnerability to salinization

1. Introduction
   1. Groundwater use
      1. Increased irrigation
      2. Increased population on the coast 🡪 increased municipal water use
      3. Water quantity is an issue, but increasingly worried about quality issues due to water use/sea level rise and saltwater intrusion.
   2. Stream depletion
      1. Salinization of estuarine streams is also a concern for water management
      2. In regions where groundwater and streams are hydraulic connected, increased groundwater withdrawal for irrigation and municipal use may reduce streamflow
   3. Salinity intrusion
   4. Climate change
      1. Over the last century, sea level along the East Coast of the United States has risen significantly, and levels have been increasing faster than the global average along much of the coast (Sallenger et al., 2012).
   5. Research questions
      1. What are the implications of pumping for coastal GW-SW interactions?
      2. If baseflow is decreased, how does this impact salinization in near-coast streams?
      3. How can we project this into the future (urbanization, sea level rise, changes in precip/ET)? Are groundwater-level and streamflow declines occurring despite an average increase in precipitation?
      4. Are we seeing these effects in the mid-Atlantic?
2. Methods
   1. Modeling
      1. Build a set of simple coupled GW-SW models to explore connectivity, pumping, and salinity front.
   2. Field data and statistical interrogation
      1. Four quantitative hydrograph-separation methods can be used in this study, the streamflow partitioning (PART) method (Rutledge 1993, 1998), the HYSEP Fixed and HYSEP Local Minimum methods developed by Pettyjohn and Henning (1979) and further discussed by Sloto and Crouse (1996), and the Base Flow Index (BFI) Standard method (Wahl and Wahl 1988, 1995). Each method uses a time series of daily mean streamflow measured at a streamgage.
3. Results
4. Discussion

Although there are many examples in the literature of the use of numerical groundwater models to determine the impact of groundwater withdrawals on streamflow, there are comparatively fewer studies that have used statistical evaluations of streamflow and baseflow records to identify groundwater-withdrawal effects; the reader is referred to Wahl and Tortorelli (1997), Burt et al. (2002), McCallum et al. (2013), Abo and Merkel (2015), Juracek (2015), Miller et al. (2015), Juracek and Eng (2017)for examples of the latter. The current understanding of groundwater and surface-water interactions and associated water-resource management issues are documented (Winter 1995;Winteretal. 1998; Sophocleous 2002; Verry 2003;Brodieet al. 2007;Anibaset al. 2011; Barlow and Leake 2012; Barthel and Banzhaf 2015; Yang et al. 2017); however, the complexities of the inter- actions are not well understood, especially in systems with observed groundwater-level declines.

Sustainable agriculture in the United States depends on appropriate management of groundwater resources. Water use in the United States in 2000 (the most recent year for which comprehensive groundwater withdrawal data have been published) was estimated at 1,544.4 billion liters per day (BL/ day) [408 billion gallons per day (Bgal/day)] and fresh- groundwater withdrawals comprising about 315.3 BL/day (83.3 Bgal/day), or approximately 20% of daily water use (Hutson et al. 2004). The majority of groundwater withdrawals were for thermoelectric power supply and irrigation (Hutson et al. 2004; Maupin and Barber 2005).

According to local groundwater modeling studies (Telis 1991; Barlow and Clark 2011; Clark et al. 2011), the current rate of freshwater withdrawals is unsustainable. The demand for groundwater resources from the allu- vial aquifer for agricultural irrigation has resulted in substantial observed declines in groundwater-level elevation over time (Barlow and Clark 2011). Groundwater withdrawals have been cited as a driving factor of streamflow depletion, which has raised concerns for the future of available groundwater resources with local, state, and regional stakeholders (Theis 1940; Barlowand Clark 2011; Barlow and Leake 2012). The quantification of observed environmental changes in groundwater-level elevation and streamflow may be done using many avail- able methods and software tools. Numerical groundwater models simulate groundwater flow and aquifer response to stresses such as groundwater withdrawals and can be useful to increase understanding of complex hydrologic systems (Clark and Hart 2009; Sahoo and Jha 2017). Numerical simulation is an oversimplification of real- world processes and many models fail to accurately rep- resent the interaction of surface water and groundwater.