Using Surface Hydrologic Connections to Select or Prune National Wetland Inventory Wetland Features for the National Hydrography Dataset

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INTRODUCTION

Scientists and researchers are often bound by constraints when conducting investigations. Frequently, the two variables that confine a study are time and money. For these reasons free and accessible federal databases storing water resource information are among the most widely used for querying information on aquatic ecosystems. The federally produced National Hydrography Dataset (NHD) is known as one of the most accessible and widely accepted forms of stream information in the country (Strager, 2009). Because of its availability the NHD has also been widely criticized for its inability to accurately portray the drainage network within a watershed (Baker et al., 2007; Colombo et al., 2007; and Smith and Herrmann 2005). Today, the United States Geological Survey (USGS) is working on adding good quality hydrography to The National Map. During this effort, I recommend that the USGS consider enhancing the NHD by including additional headwater streams and a sufficient Swamp/Marsh feature type within the Water Bodies feature class. By enhancing the NHD the USGS will provide a viable dataset for modeling drainage flow across the watershed and for analyzing the watershed condition.

The idea for an enhanced NHD comes at the call for scientists and managers to move away from considering streams in isolation from their surroundings, but instead to view them as working parts in the larger aquatic network (Brooks et al., 2007). Riverine wetlands work along side streams in the aquatic ecosystem and serve as both a source and a sink for stream water (Brinson et al., 1995). This class of wetland includes both floodplain and riparian wetlands, which exchange surface and subsurface water with adjacent streams (ibid). One of the most vital functions provided by riverine wetlands is floodwater detention (ibid). Working in this capacity, riverine wetlands have the ability to change downstream peak flow and redistribute sediments and other particulates leading to improved water quality conditions (ibid).

Riverine wetlands are important for modeling the watershed condition and accurately depicting watershed drainage. Researchers could better monitor and assess the quality of water coming out of the watershed if the National Wetland Inventory (NWI), a federal wetland dataset, was integrated with the NHD. Merging these two widely acceptable and used forms of aquatic data would promote better watershed reporting. However, for a clear and concise representations from of these two large datasets not all of the NWI wetland polygons can be selected for inclusion into the NHD. This project proposes a systematic method for deciding which of the NWI wetlands should be selected for inclusion and which should be omitted from the NHD.
OBJECTIVES

The goal of this project is to demonstrate a method of enhancing the NHD by adding headwater streams and NWI wetlands that have a surface water connection to the streams already provided within the dataset. This goal coincides with the goal of the NHD, which is to make available the necessary spatial data for surface waters that will allow scientists to track the direction and flow of water across the landscape (USGS, 2009 http://pubs.usgs.gov/fs/2009/3054/pdf/FS2009-3054.pdf). The actual flow of water across the landscape cannot be accurately depicted without including headwater streams. Therefore, to meet this goal, my first objective is to use high-resolution orthoimagery collected by the state of Maryland to digitize headwater streams (orders one to three) that are currently not included in the high-resolution NHD. The second objective is to use these digitized headwater streams along with NHD flowlines to maintain the necessary surface water connections with neighboring wetlands. The last objective is to provide an ecological threshold that can be applied systematically for deciding when a wetland should be included in or pruned from the NHD.

LITERATURE REVIEW

Stream maps can influence the results of chemical, nutrient and sediment transport and uptake in a watershed (Baker et al., 2007). The position, density and connectivity of streams are important attributes to consider when mapping drainage networks (Baker et al., 2007). Inaccurate water resource data have the potential to mislead water resource managers when making decisions on where to implement Total Maximum Daily Loads (TMDLs) and Best Management Practices (BMPs) (Colson, 2006). TMDLs and BMPs are two programs incorporated into the Clean Water Act that limit point source and non-point source pollution to protect the health of streams and the overall aquatic ecosystem.

The presence and condition of headwater streams within a watershed are the most important factor in determining the health of aquatic ecosystems (Brooks et al., 2009). Headwater streams can drain up to 85 percent of the total land area within a watershed (Colson, 2006; Brooks et al., 2009). Yet, many of these systems go undocumented and remain absent from the NHD (Colson, 2006). The absent streams have been the impetus for criticism. Researchers state that the NHD does not supply the data necessary to accurately map drainage networks within a watershed (Baker et al., 2007; Colombo et al., 2007; and Smith and Herrmann 2005).

Working from the concept that the headwater streams of a river system directly affect downstream water quality, Strager et al. (2008) set out to create a spatially explicit model for assessing the cumulative impacts of upstream mining activity. Strager et al. used the high resolution NHD stream data to calculate mining intensity for a given drainage area. Measures of mining intensity were based on streams that drained mine outcroppings and upstream mining areas. By using the high resolution NHD to build their spatially explicit model, Strager et al. assumed they had adequate headwater stream representation. This assumption severely weakened their results because an estimated 80 percent of the headwater streams were not documented in the NHD (Colson, 2006).

Designing a sampling method from a complete sample frame is fundamental to achieving good results (Kentula, 2007). Therefore, when using the NHD to create spatially explicit models or to select stream sample points it is essential that researchers recognize the effect that this incomplete dataset has on their results. Reinhardt et al. (2007) employed the high resolution NHD flowlines to collect a random sample of approximately 1 sample per 1 km of reach. When validating the results of the stream network they found that “the hydrographic layer omitted many headwater intermittent streams” (p. 527) and therefore did not provide an adequate sampling frame to conduct their study. To correct for the inaccurate representation of...
the true stream network Reinhardt et al. tried many approaches including digitizing upstream areas with county soil survey maps and deriving the upstream network with Digital Elevation Models (DEMs). They discovered the best approach was to correct for the stream network manually by using crenulations in contours drawn on existing topographic maps and employing a set of “rules for extending the streams headward” (p. 529).

Undocumented headwater streams do not just compromise the integrity of research results, but also put the protection of these valuable stream reaches in jeopardy (Hanson, 2001). For many states only the streams included in federal databases are considered for protection through the implementation of TMDLs and BMPs (ibid). The same federal databases are also incredibly important to the protection of wetlands. A wetland that appears to be cut off from surface waters are vulnerable to destruction because of wavering federal protection under the Clean Water Act after the 2001 U.S. Supreme Court’s decision in Solid Waste Agency of Northern Cook County (SWANCC) (Downing et al., 2003). Incomplete stream data cause the majority of wetlands associated with headwater streams to appear on a digital NHD map as isolated wetlands. Consequently, extensive stream mapping errors within the NHD should raise a red flag for federal regulatory applications, an application for which the dataset was not intended (Colson, 2008).

Documenting the surface water connection of riverine wetlands to neighboring streams is important for modeling water quality. In fact, wetlands adjacent to headwater streams have been found to be critical components to the overall water quality of the main river channel and watershed outputs (Baker et al., 2007). Wetlands bordering headwater streams are some of least understood yet most important to water quality considerations. One of the many ecosystem services provided by wetlands is their ability to filter water impurities as they flow across them in the landscape (Mitsch and Gosselink). The mere presence of wetlands in the landscape automatically “modifies and changes” the physical and chemical properties of the surrounding environment making them important components for modeling water quality (Mitsch and Gosselink, 2000, p.108). Thus providing a comprehensive dataset that includes headwater streams and their associated wetlands will give data users the ability to accurately model the watershed condition.

STUDY AREA

I chose a HUC 14 watershed, number 05020006010112, in western Maryland as my study area (Figure 1). The watershed makes up part of the Deep Creek Lake HUC 8 watershed. It was selected due to the larger number of wetlands (147) and stream segments (30) found within it. The watershed is situated within Garrett County. Garrett County is 678 square miles (433,920 acres) in size and has a population that is just under 30,000 (Garrett County Maryland Brief Economic Fact Sheet, 2008-2009, http://www.choosemaryland.org/Resources/pdffiles/briefeconomicfacts/GarrettBEF.pdf). The watershed takes up two percent of the total land area in Garrett County.

METHODS

Digital data was downloaded and added as layers into an ArcGIS 9.3 project (Table 1). High-resolution orthoimagery was used to identify headwater streams. Using the high resolution NHD flowline as a base, headwater streams stemming from the NHD flowline were digitized first.

The standards set by USGS for where a stream begins were also employed in these methods. The standard states that a stream begins where the channel becomes most evident as a stream (Colson, 2006; Smith and Herrmann, 2006). In order for a stream within the
Figure 1: Map of HUC 14 (number 0502006010112) chosen as the study area and set within Maryland county boundaries.

Table 1: Data Layers used in the GIS.

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<td>Streams, rivers, water bodies</td>
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<td>Vector points, lines and polygons at 1:24K (2001 – present) and 1:100K (1999 – present)</td>
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<td>Drainage Area</td>
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orthoimagery to be considered and digitized, the segment must also be primarily or secondarily connected to the NHD flowline. In other words, if a stream was identified on the orthoimagery map and was obviously connected to the NHD flowline (through a visually defined channel) then it was considered as a primary stream to that NHD flowline. If an identified stream was connected to the primary stream then it was considered a secondary stream to the NHD flowline (Figure 2).

Next, a 100-foot buffer was created around the NHD flowlines and digitized streams. This size buffer was chosen because the Maryland Conservation Reserve and Enhancement Program (CREP) provides monetary incentives for enhancing and reserving up to 100 feet of vegetated buffer along a streamside because of their importance to water quality and other ecosystem services (Maryland Department of Agriculture, 2004). NWI wetland polygons were individually selected and zoomed in on and their surface water connection to streams was evaluated. A surface water connection was established if the wetland's land area or its drainage area: (1) overlapped with the NHD flowline or its 100ft buffer, or (2) overlapped with the digitized stream or its 100ft buffer. To be deemed as having no surface water connection meant that neither the wetland area nor its drainage area came in contact with a stream or its 100ft buffer (Figures 3a, 3b, 3c, and 3d). A new attribute field was added to the NWI attribute table so that hydrologic connections could be recorded.

As noted above, when managing water quality within a watershed it is extremely important to know whether there are adjacent wetlands present. Therefore, if a particular wetland was determined to have a surface water connection to the neighboring stream then it did not get pruned from the database. Keeping these wetlands and their attributes in the NHD is critical for hydrologic and biogeochemical flow analyses. Conversely, if the wetland or its

Figure 2: Orange primary and secondary digitized streams connected to NHD Flowline in blue.
**Figure 3:** Four examples to explain surface water connection

**Figure 3a:** A surface water connection is established by the NWI wetland with its much larger drainage area crossing both the blue NHD Flowline and the red 100ft buffer.

**Figure 3b:** A surface water connection is established by the NWI wetland and its drainage area’s intersection with the orange digitized stream and its red 100ft buffer.

**Figure 3c:** A surface water connection is established by the NWI wetland and its much larger drainage area crossing the red 100ft buffer.

**Figure 3d:** No surface water connection has been established.
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A NWI wetland can only be pruned from the dataset if it could not establish a surface water connection with neighboring streams and therefore is assumed to be less important for water quality investigations.

The methods for selecting wetlands for inclusion into the NHD were repeated using medium resolution NHD flowlines. Streams were not digitized for the medium resolution NHD. Therefore, a NWI wetland established a surface water connection to neighboring streams if its land area or its associated drainage area came into contact with the NHD flowline or its 100ft buffer.

RESULTS

Twenty-one stream segments were found to be missing from the stream network of NHD flowlines (Figure 4). These streams were digitized from the high-resolution orthoimagery and added to enhance the high resolution NHD. The surface water connections of 145 wetlands were examined in this study. Fifty-one NWI wetlands were represented in whole or in part by the 7 polygons within the Swamp/Marsh feature type of the high resolution NHD (Figure 5). The digitized streams provided a surface water connection to 26 NWI wetlands (29 percent of the sample), indicating the importance of adding tributaries from the orthoimagery to the high resolution NHD.

To stay true to the objective to maintain the necessary surface water connections between wetlands and streams 4 wetlands were pruned from the high resolution Swamp/Marsh feature type. The remaining 47 wetlands were joined by an additional 44 NWI wetlands that were also determined to have a surface water connection. In total, there were 91 wetlands and
51 stream segments selected for inclusion into the enhanced high resolution NHD. Figure 6 visually displays the enhanced NHD.

**Figure 5:** The NWI wetlands that were represented in all or in part by the 7 Swamp/Marsh feature type polygons, which are displayed in light green. The NWI wetlands not documented in the high resolution NHD are shown in dark green.

**Figure 6:** Visual representation of the enhanced high resolution NHD within the study watershed. The enhanced NHD includes digitized streams (orange), 91 NWI wetlands (green) and high resolution NHD Flowline (blue).

The medium resolution NHD had three polygons for the Swamp/Marsh feature type. These three polygons represented all or part of 24 NWI wetland polygons (Figure 7). Thirteen wetlands were pruned from the Swamp/Marsh feature type of the medium resolution NHD. Thirty-seven NWI wetlands not represented in the Swamp/Marsh feature type were found to have a surface water connection to the flowlines. In total, 48 wetlands are recommended for inclusion into the medium resolution NHD. These could be amalgamated and simplified to suit the intended viewing scale of 1:100,000. Figure 8 visually displays the enhanced medium resolution NHD.
Figure 7: The NWI wetlands (light green) that were represented in all or in part by the 3 polygons of the Swamp/Marsh feature type (dark green).

Figure 8: Visual representation of the enhanced medium resolution NHD, which includes 48 NWI wetlands (green) and 3 medium resolution NHD flowlines (blue).
CONCLUSION

To enhance the high resolution NHD 21 lower order streams were digitized. In total, 91 wetlands were selected for inclusion into the enhanced high resolution NHD because of their surface water connection to neighboring NHD flowlines or digitized streams. Only four wetlands already represented in the high resolution NHD water bodies feature were pruned from the dataset for their lack of surface water connection. For the medium resolution NHD 48 wetlands are suggested for inclusion and 13 wetlands should be pruned to maintain a surface water connection between streams and wetlands.

The methods described by this project can be used to enhance the NHD by adding headwater streams and surface water connected wetlands to the dataset. Adding these data to the NHD will allow the dataset to more accurately portray the flow of water across the landscape. As cited above, headwater streams are critical components of the drainage network and therefore must be included to the NHD flowline feature class. I do not assert that my methods for incorporating headwater streams are the most accurate or that they should be adopted by the USGS. Instead, my methods are intended to demonstrate that there are easily identifiable streams that should be represented in the NHD. Without additional streams, approximately 30 percent of the wetlands with a surface water connection appear isolated from the stream network. However, establishing a viable method for incorporating these streams was outside the scope of this project. Yet a brief literature review on the subject suggests that there is quite a bit of published research on deriving stream networks from a variety of digital data sources that should be considered (Montomery and Foufoula-Georgou, 1993; Bischetti et al., 1998; Graham et al., 1999; Doll and Lehner, 2002; Olivera et al., 2002; and Colombo et al., 2007). Finally, I believe the methods described above create a viable and systematic approach for selecting wetlands for inclusion into the NHD. In fact, using surface water flow connectivity as a basis for wetland selection can only add to the accuracy of the dataset in portraying the flow of water across the watershed.

RECOMMENDATIONS

The unintended uses of the NHD by regulatory agencies should raise significant concerns and could be addressed by either (1) enhancing the NHD (as described above) so that it includes more headwater streams and becomes more fully representative of the waters of the United States, or (2) by making clear to its users through public outreach and product branding that the NHD is a visual abstraction of the actual stream network and will never be applicable for regulatory application because of its inherent inaccuracies.
RESOURCES


Smith, S. and M. Herrmann. 2006. Stream Mapping in Maryland...finding first order Piedmont channels. Landscape and Watershed Division, Maryland Department of Natural Resources.