ENHANCING HYDROLOGIC MAPPING USING LIDAR AND HIGH RESOLUTION AERIAL PHOTOS ON THE FRANCIS MARION NATIONAL FOREST IN COASTAL SOUTH CAROLINA

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Abstract—Evaluating hydrology within coastal marine terrace features has always been problematic as watershed boundaries and stream detail are difficult to determine in low gradient terrain with dense bottomland forests. Various studies have improved hydrologic detail using USGS Topographic Contour Maps (Hansen 2001, Eidson and others 2005) or Light Detection and Ranging (LIDAR) in gullied piedmont terrain (James and others 2007), and the Maryland coastal plain (Lang and others 2012). Research within Turkey Creek subwatershed near Huger, SC used LIDAR and field verification to estimate the size of the 52.4 km^2 subwatershed, but the 50-year history had estimates ranging from 32.4 to 72.6 km^2 (Amatya and others 2013).

Turkey Creek was one of 21 subwatersheds evaluated using LIDAR intended for the Plan Revision covering the 1,050 km^2 Francis Marion National Forest (FMNF). LIDAR has proven to be a valuable asset to forest planning by more accurately defining or locating many things including stream networks and watershed boundaries. LIDAR data used to map Turkey Creek were attained in February and March of 2009. Streamflow in Turkey Creek was primarily 0.05-0.28 m^3s^{-1} (somewhat below the 9-year average of 0.39 m^3s^{-1}) so most perennial and intermittent streams should contain water, but small streams and seeps are unlikely to be noticed. High-resolution ortho imagery (ESRI's World Imagery, NAIP 2013 imagery) was also helpful for image interpretation.

The mapping procedure employed both "heads-up digitizing" and DEM-based modeling. It was an iterative process of digitizing and remodeling. Hydrologic barriers were removed from the LIDAR-derived DEM so flow could be modeled. This was accomplished by first, hand digitizing streams that were clearly visible by proxy, based mostly on the linear nature of missing LIDAR ground returns due to the absorption of laser pulses by water. In flat, wet landscapes this valuable information is often lost using current methods to model ground surfaces. LIDAR-derived DEMs can "washout" stream channels in areas due to low topographic relief and/or too few laser returns to properly define ground versus low vegetation or noise returns. The "washout" effect is a result of the alogrithm selecting available stream bank or low vegetation laser returns in areas with no other laser returns (i.e. water). Errors in ground surface are especially problematic in wet areas with low, dense vegetation. When this "washout" occurs it can be difficult to model stream networks using current DEM-based modeling alone. When using current DEM-based methods in these challenging areas, a substantial amount of work is needed to provide a relatively clear path to model streams. Without a "cleared" and defined hydrologic path, the flow accumulation models often get diverted and loose channel contact. Stream paths are "cleared" using digitized line work to keep stream in its main channel. Areas of channel uncertainty, the laser point cloud in planimetric or vertical profile reveals areas with no returns and streams can be recognized if they contain water. Although not as prolific, these flow modeling issues also occur in the piedmont and mountains, and have to be recognized and dealt with. After digitizing the streams and ditches based on recognizable channels or continuous water bearing features, the stream lines were burned into a DEM and remodeled. The flow modeling tools identify only one channel, and the analyst needs to keep it in the main channel. Weighing the imagery and LIDAR derived evidence considering DEM statistics set to refresh with the current display extent (scale), using descrete colors to separate elevation detail and lack of returns from water absorbing the LIDAR pulses are all needed to digitize a refined channel location before burning in the primary channel network. Recognizing characteristic landforms with braided, meandering to linear (ditched) channels

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and their associated hydrology are helpful in making assumptions and interpretations.

Amatya and others (2013) describe improvements in the Turkey Creek boundary as more detail was acquired. This landscape analysis needs work, review, and some field verification. The flow modeling applied the median drainage size for North Carolina (NC) Coastal Flatwoods perennial or intermittent streams was about 16 ha (Russell and others 2008, Russell 2013). The 2005 WBD boundaries used 10-foot contour USGS Topographic Maps and aerial photos to remotely evaluate hydrologic details. Improvements in the National Hydrography (NHD) and Watershed Boundary Datasets (WBD) will undergo more formal review before updating. However, substantial refinement can be made by applying LIDAR detail in georeferencing streams, hydrologic boundaries and identifying modifications (e.g., ditches, dikes).

There are also instances where vegetation is so dense (e.g., pocosins, Carolina bays) that the laser pulse cannot penetrate to water, channel or ground surface and the DEM surface appears elevated. Channel margins with atypical roughness are possible signs of spoil materials from past channelization. Signs of silvicultural bedding, rutting, and wetland drainage are also noticable. Understanding the channel morphology, past activity and vegetation detail helps with interpretation. The extent and separation among perennial, intermittent and ephemeral streams is not well defined in gathering LIDAR data from one flight. However, as more LIDAR flights occur during wet and dry seasons, the successive extent of water could be related to the Turkey Creek flow duration curve and stream permanance separation may improve. Intermittent streams are estimated based on NC information (Russell 2013) using the median16 ha flow accumulation and then removing modeled streams from landscape depressions. However, data collected about flow permanance in the NC coastal plain are variable on drainage size, with 80 percent of ephemeral to intermittent streams ranging from 1.3 to 127 ha, and ephemeral to perennial from 0.1 to 72 ha. With variability likely, median data on NC stream permanence may produce reasonable landscape estimates, but for individual streams, errors of omission and commission are likely without field verification. Differences in estimated watershed size of 21 subwatersheds indicate a standard deviation of 10 percent, while modeled/digitized streams within the FMNF increased stream density averaging 179 percent (Table 1). Figure 1 presents preliminary differences between existing and modeled/digitized streams and boundaries for Turkey Creek subwatershed. Refined coastal watershed boundaries and drainage network may reduce planning errors and improve regulatory, design, mitigation and restoration decisions.

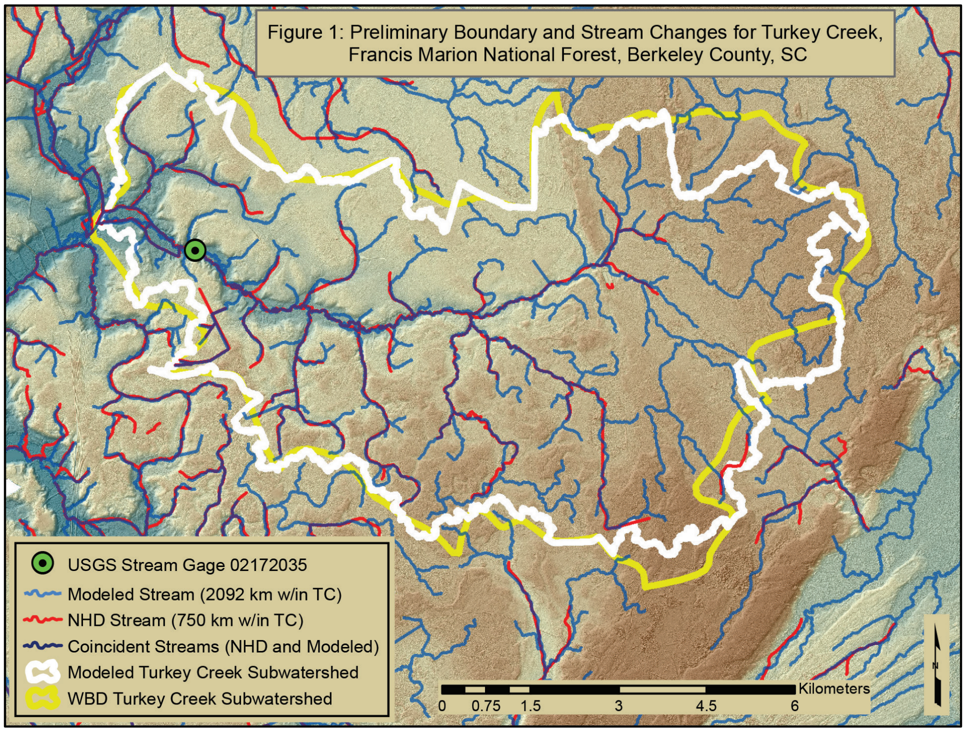

Figure 1—Preliminary boundary and stream changes for Turkey Creek, Francis Marion National Forest, Berkeley County, SC.

Table 1—Francis Marion National Forest - Estimated Change in Watershed Size and Stream Density

Subwatershed (6th Level HUC) (% NF)	WBD_GIS (km^2)	Modeled Boundary GIS (km^2)	Gain/Loss (km^2)	Estimated Boundary Based Change percentage	NHD NF Stream density (km/km^2)	Modeled NF Stream density (km/km^2)	Modeled NF stream increase over NHD (percent)
Awendaw Creek (83%)	103.9	119.6	15.6	15.1%	0.43	2.06	377%
Cane Pond Branch (79%)	43.5	52.3	8.8	20.3%	0.77	2.32	203%
Copahee Sound (0.7%)	127.3	128.5	1.2	1.0%	1.12	4.26	280%
East Branch Cooper River (8%)	75.8	84.4	8.6	11.4%	1.35	2.68	98%
Echaw Creek (72%)	114.9	124.7	9.8	8.5%	0.43	2.05	373%
French Quarter Creek (27%)	78.3	73.3	-5.0	-6.4%	0.71	2.14	202%
Gough Creek (49%)	50.4	46.5	-3.9	-7.7%	1.53	2.79	82%
Guerin Creek (44%)	161.9	157.8	-4.2	-2.6%	0.93	2.52	170%
Headwaters Wambaw Creek (93%)	87.1	80.3	-6.8	-7.8%	0.44	2.01	362%
Lower Wando River (1%)	130.9	135.1	4.2	3.2%	0.05	0.49	920%
Nicholson Creek (96%)	118.3	97.2	-21.2	-17.9%	0.89	1.98	122%
Outlet Wambaw Creek (79%)	99.5	121.1	21.7	21.8%	1.35	2.44	82%
Quinby Creek (62%)	91.8	91.8	-0.0	-0.0%	1.14	2.38	108%

Preliminary comparison of existing watershed boundary data (WBD) and hydrologic modeled boundary data with refined streams.

Preliminary comparison of existing national hydrography data (NHD) and hydrologic modeled and edited streams within the national forest (NF) areas only.

NHD stream extent on NF lands was 750 km, modeled and edited streams was 2092 km, an average increase of 179%.

Subwatersheds with low ownership have had less work and subject to higher error.

Dutart Creek - Savanna River subwatershed had insufficient LIDAR data available and was not evaluated.

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