Northwest Florida, North Florida, and Peninsular Florida Bankfull Indicators

By Elizabeth J. Penrod

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Kissimmee River

(Photo credit: South Florida Water Management District)

"The answer is not in the model or in the book…..it is in the River"

– Luna B. Leopold

Abstract

This paper discusses two different methodologies for establishing Bankfull indicators in Florida stream systems. Both studies used the same methods to capture the cross-section and longitudinal view of stream dimensions surveyed. The Peninsular Florida study utilized the Florida Natural Inventory (FNAI 1990) to classify and describe the stream types they found and used in their study. The North and Northwest Florida Coastal plain study used the Natural Resources Conservation Service (NRCS), "Stream Restoration Design," engineering handbook and Rosgen "Applied River Morphology" (1996) to classify streams. Bankfull indicators were different among both studies with Peninsular Florida recognizing a total of seven applicable Bankfull indicators and North and Northwest Florida Coastal Plain only recognizing two bankfull indicators. The studies have implications to river restoration projects, water quality issues, and regional differences related between channel dimensions and hydrology.

Introduction

Streams and rivers play critical roles in the quality and supply of drinking water, they do this by ensuring a continuous flow of clean water to surface waters and recharging underground aquifers. They also protect against floods and erosion, provide food and habitat for many different species, assimilate potentially harmful nutrients, and filter pollutants. In the continental United States, over 357,000 miles of streams provide water for public drinking water systems (Streams, 2013). Freshwater streams are especially important to Florida's ecology as they are essential for many of the marshes, estuaries, lagoons, and swamps that exist in the state (IFAS, Rivers). These streams transport nutrients and sediments necessary for wetland habitats, native plants, and animals that rely on them. They also moderate salinity of brackish environments and host many migratory and local wildlife species. The state of Florida has approximately 50,000 miles of streams and rivers (SWFWMD, Water Habitats) with about 24,221 miles of those containing freshwater rivers and streams (How's my Waterway, 2020).

Water Quality History

Within the state of Florida, the Florida Department of Environmental Protection (DEP) state statistical surveys for water quality conditions across the state of Florida Rivers and Streams accounts for 11,821 miles of impaired freshwater rivers and streams (How's my Waterway, 2020). DEP defines "impaired water" by a waterbody or waterbody segment that does not meet its applicable water quality standards as set forth in Chapter 62-302 and 62-4, F.A.C. (Chapter 62-303 F.A.C.). The top reasons for these impairments in Florida rivers and streams include (greatest to least) low oxygen, bacteria/other microbes, acidity, nitrogen/phosphorous, metals, algae, aquatic weeds, degraded aquatic life, salts, murky water, and ammonia. These are in line with similar causes for water pollution under the Clean Water Act (CWA) Section 303(d), 305(b), 314, and National Pollutant Discharge Elimination System (NPDES) for national water quality of rivers and streams, including descriptions of impairments reported in the 2017 National Water Quality Inventory (USEPA, 2017). These included total phosphorus, total nitrogen, salinity, acidification, excess streambed sediments, riparian vegetative cover, riparian disturbance, and in-stream fish habitat. Out of these causes, poor biological condition is almost twice as likely in streams and rivers with excessive levels of streambed sediments and phosphorus/nitrogen. Excess sediment damage alone is estimated to cost more than $20 billion annually (Osterkamp, 2004).

It is important to note that states cannot always confidently identify these sources of pollution, however the most probable sources include agricultural activities (crop production, animal feeding operations, and grazing), hydrologic modifications (water diversions, dams, and channelization), and atmospheric deposition. In fact, it is estimated that 75% of streams within Peninsular Florida have been ditched, diverted, or otherwise damaged by land use changes altering runoff and water quality characteristics (2015, Peninsular Florida Stream Systems). To mitigate and further prevent these issues the Florida Constitution, under Article II, Section 7 requires the state to conserve and protect its natural resources and the abatement of air and water pollution. Florida legislature then passed the Florida Water Resources Act (1972), the Florida Air and Water Pollution Act (1967), and the Florida Safe Drinking Water Act (1977) to ensure Floridians the right to safe drinking water throughout the state. Florida legislature also passed the Florida Watershed Restoration Act (1999), the Clean Waterways Act (2020) and Senate Bill 64 (2021) which attempts to further increase the surface water quality within the state's waterways.

It has become increasingly imperative to safeguard Florida's water resources as the Florida Water Management Districts have estimated, between 2020 – 2040, the total statewide water usage is projected to increase by approximately 980 million gallons per day (mgd) or ~15% (EDR, 2022). This places an even greater strain on Florida's vulnerable water resources to try and keep up with anticipated demand. To prevent adverse cumulative effects of watershed development throughout Florida, scientists, engineers, and hydrologists have established different methodologies in their field to combat these complex water quality issues. This paper focuses on how different methodologies for Bankfull indicators may impact streams and therefore water quality within different hydro-physiographic regions across Florida.

Florida Landscapes

There are three main landscape settings that make up the different stream classifications throughout Florida: highlands, flatwoods, and karst. The streams are first classified on their watershed characteristics that affect flow regimes, water source, and water quality. Within these landscape types there are fifteen stream types that present distinct assemblages of geomorphic surfaces, channel dimension, floodplain habitat, in-stream habitat, water quality, flow regime, and ecological factors that are greatly affected by thresholds along the gradients of groundwater influence, valley slope, and basin magnitude. These factors control how the landscape alters the effects of seasonal rainfall on the stream flow regime, and in turn, effects the capacity of the system to conduct geomorphic work that will affect the kind of habitats present and their scale.

Bankfull Stage

Bankfull discharge is a frequently occurring peak flow condition whose stage represents the incipient point of flooding (NTC, FWS) (Figure 1.). Furthermore, bankfull discharge is expressed as the momentary maximum of instantaneous peak flows rather than the mean daily discharge and is often related to the elevation associated with a shift in the hydraulic geometry of the channel (return period of 1-2 years). Bankfull discharge is responsible for shaping the morphology of all alluvial channels and is the fundamental principle behind stream classification. The pattern, dimensions, and profile of streams at the bankfull discharge provides a consistent refence point that can be used to compare the morphology of streams around the globe. The most important task is to correctly identify the elevation/stage of the bankfull discharge when classifying streams. Morphological variables, which are used to classify streams, are expressed as bankfull values. An example of this would be the width/depth (W/D) ratio, which is the surface width of the bankfull channel divided by the bankfull mean depth (Figure 2.).

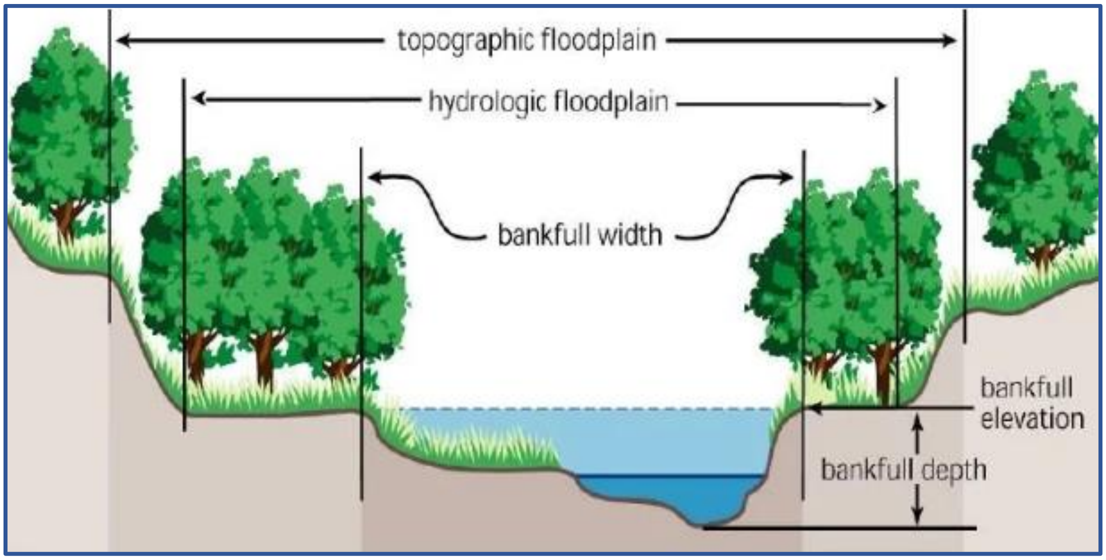


Figure 1. Bankfull Stage: incipient flooding (ASCE NC, Jennings)

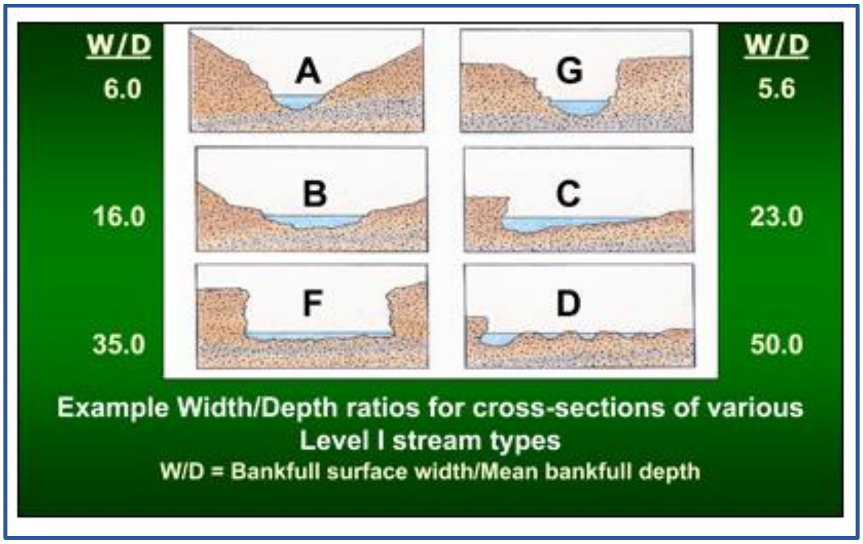


Figure 2. Width/Depth Ratio (Fundamentals of Rosgen Stream Classification System, EPA)

Bankfull Stage Indicators

Physical indicators such as floodplains, depositional bars, changes in vegetation, breaks in slope, etc., are relied on to represent the flooded area of the stream at the bankfull discharge (NCTC, USFWS). It is important to note that there are many bankfull indicators, but each individual indicator cannot always be relied on for all stream types in all climates. It is strongly encouraged to visit stream gaging stations that bankfull elevations can be calibrated to a known discharge and return period to better recognize features associated with bankfull flows. Areas that should be avoided when determining bankfull flow include bedrock outcroppings, braided channels, logjams/fallen trees, human-made impacts, hard meander bends, and tributaries/springs.

There are four basic principles for use of bankfull stage indicators (Rosgen, 1996): (1) seek indicators in locations appropriate for specific stream type, (2) know the recent flood & drought history of the area to avoid any misleading spurious indicators, (3) use multiple indicators wherever possible for reinforcement of a common stage of elevation, and (4) where possible, calibrate field-determined bankfull stage elevation and any corresponding bankfull channel dimensions to known recurrence interval discharges at gage stations. Some common bankfull stage indicators include floodplains, slope breaks or change in particle size distribution, highest active depositional feature, staining of rocks, evidence of an inundation feature, lichens and certain riparian vegetation species, and exposed root hairs below an intact soil layer indicating exposure of erosive flow.

Methods

Characterization of Study Areas – Physiography, Geological Context, Rainfall Patterns

Peninsular Florida (Figure 3.) presents unique combinations of climatic and physical conditions compared to the northern temperate regions. Differences include karst bedrock (variably mantles by sand and clay), low relief and proximity to sea level, distinct annual dry and wet seasons, fire as a major ecological process, large pulses of water and wind from cyclonic storms, and hot to mild temperatures. Peninsular Florida is also topographically low and geologically young with many wetlands, springs, lakes, and streams. The Northwest Florida Coastal Plain has a greater topographic relief (elevations 75 – 600 feet above sea level), coarse-textured soils, 18 – 40 inches of rainfall runoff annually, and a higher drainage density compared to the North Florida Coastal Plain. The North Florida Coastal Plain has low relief (elevations less than 100 feet above sea level), water tables are typically higher, predominantly coarse, and sandy soils with organic soils coinciding, and an average rainfall runoff of 8 – 18 inches annually.

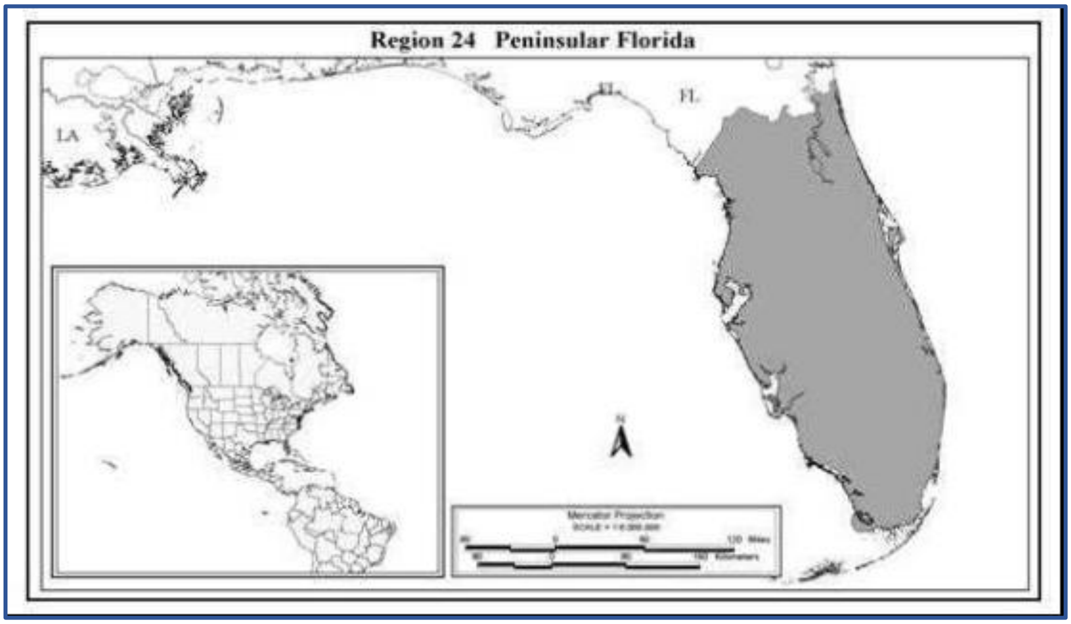
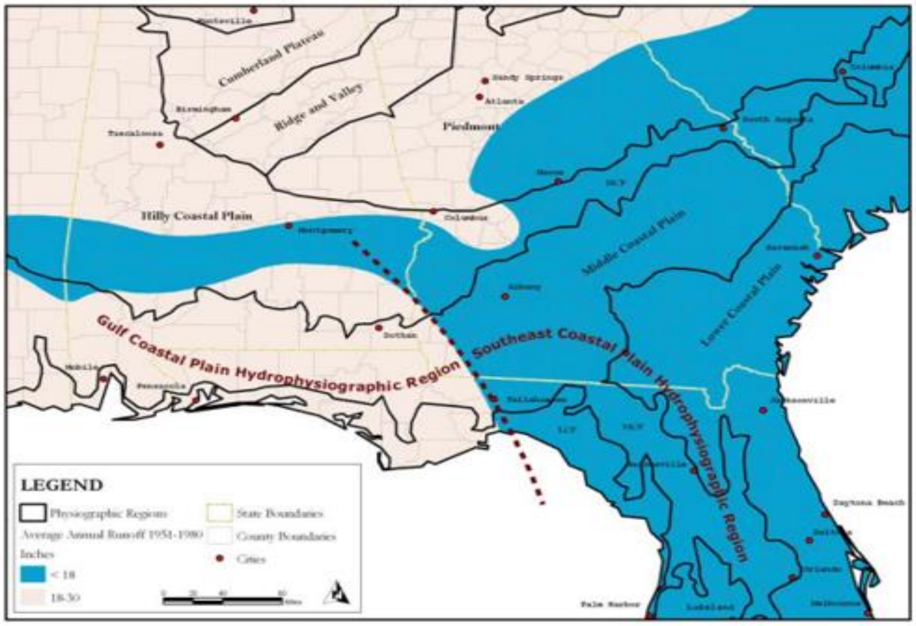


Figure 3. Peninsular Florida (Peninsular Florida)

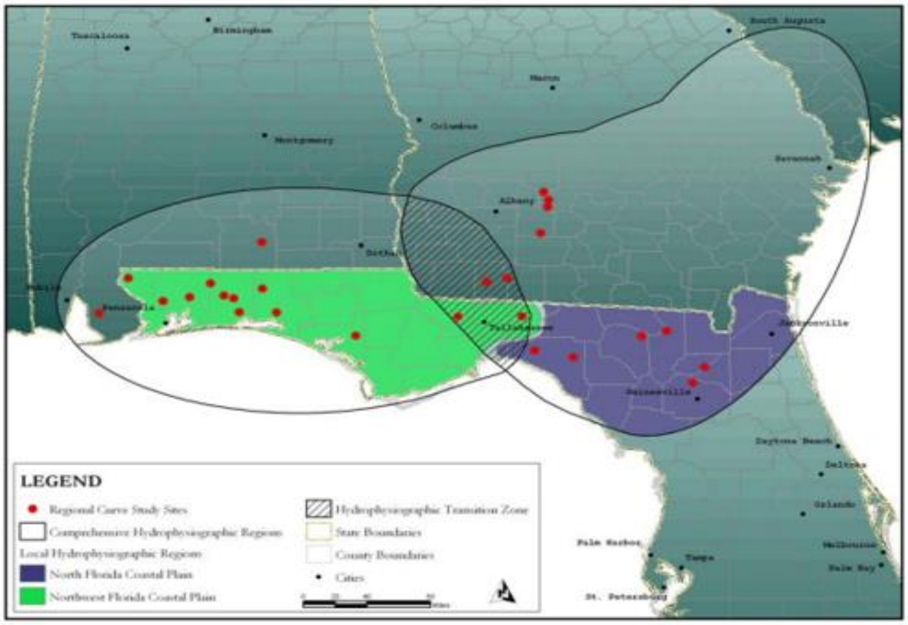
Gage & Ungaged Sites

Fourteen gage sites were selected for the Northwest Florida Coastal Plain region and twelve sites were selected for the North Florida Coastal Plain region (six of these sites are from data collected in the Georgia Coastal Plain and two site in the Alabama Coastal Plain) (Figure 4.). Recently and currently active, non-tidal, and rural USGS gages within the Florida Panhandle Coastal Plain, with a drainage of less the 500 square miles, were considered for inclusion. Forty-six USGS gaged and thirty-four un-gaged streams were visited and many of them were rejected due to them not meeting the inclusion criteria: (1) site was characterized by an anastomosed channel or swampland with no defined channel, (2) site was characterized by incision and unstable banks, (3) site consisted of a limestone or gravel bed stream. Of the three un-gaged and twenty-three USGS gages selected, only ten are active, continuous discharge gages (Figure 5.). Five gages are discontinued, but have continuous discharge data, and eight sites were discontinued and only measured peak discharge. Two sites in the study had new bridges installed with no gage discharge estimates.



Intersection of the Southeast and Gulf Coastal Plains with Average Annual Rainfall Runoff from 1951 – 1980 along the Florida Panhandle (modified from Gerbert et al., 1987, and Miller and Robinson, 1994)

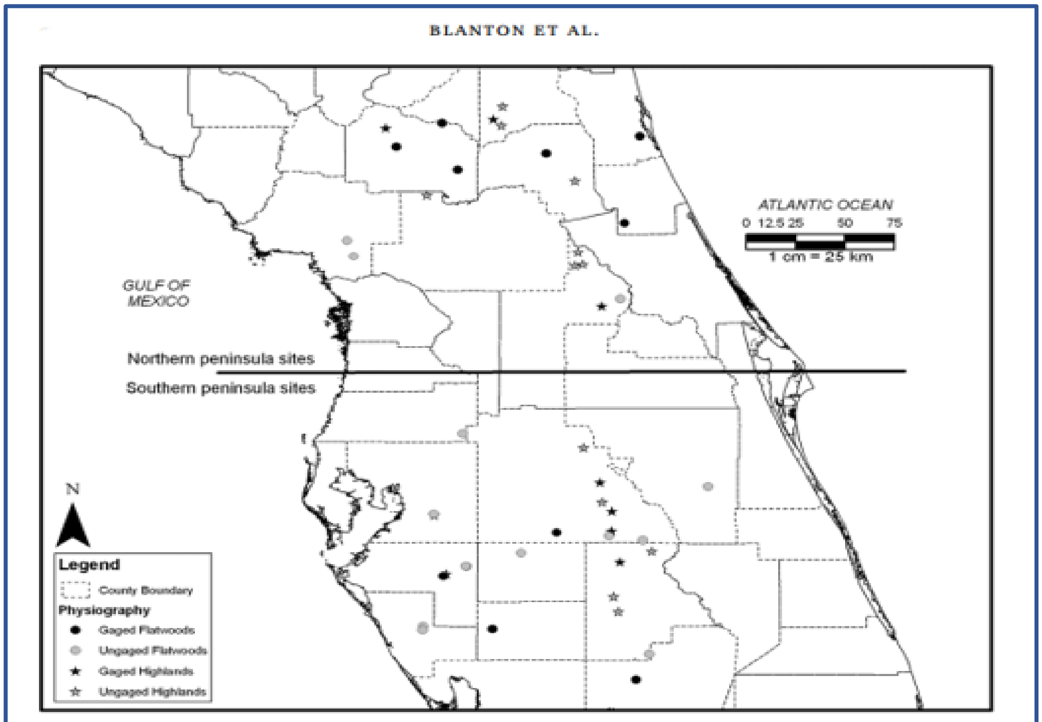
Figure 4. Northwest Florida Coastal Plain (Metcalf et al., 2009)



North and Northwest Florida Coastal Plain Hydro-physiographic Regions

Figure 5. North Florida Coastal Plain (Metcalf et al., 2009)

Out of forty – fifty gaged/un-gaged sites, twenty-seven gaged and fifty-two un-gaged sites were selected. These were selected based on the following inclusionary criteria: (1) at least ten years of continuous or peak discharge measurements, (2) no reaches or basins with water control structures, canals, or ditches less than twenty percent of basin is impervious, less than twenty percent of basin is ditched, less than ten percent of basin is mined, no major roads, and no significant land use changes during or since the gaging period. Forty-five streams were surveyed, of these seventeen sites were gaged and 28 sites were un-gaged. These were further divided into subsets based on physiography, floodplain, and geography. Twenty-five sites drain a flatwoods physiography, while twenty drain a highlands physiography. Nineteen of the sites are in northern portions of the peninsula, while twenty-six are in the southern portion of the peninsula (Figure 6.). Twenty-three sites had a wetland floodplain (eleven of these were dominated by cypress (*Taxodium spp.*)) and twenty-two had an upland floodplain.



Peninsular Florida study sites. Filled shapes are gaged sites, and hollow shapes are ungaged. Circles are in the flatwoods and triangles are in the highlands.

Figure 6. Peninsular Florida study sites (Blanton et al., 2010)

Stream Types

Out of the different stream types within Peninsular Florida (Alluvial streams, Blackwater streams, Seepage streams, and Spring-run streams) blackwater streams (Figure 7.); originate in sandy lowlands where wetlands slowly discharge tannic waters due to the channel; generally acidic waters; were the predominate stream type. Flow duration curves ranged from less than one year to 1.44 years.

Figure 7. Blackwater stream type (Cellon Creek, San Felasco Hammock Preserve State Park, FL)

North Florida and Northwest Florida Coastal Plain only selected stream types that were single threaded channels, excluding any multiple thread channels (anastomosing streams, DA stream type). Both have level II Rosgen E5 and C5 stream types (Figure 8.). This decision was made because bankfull sediment transport only occurs in the active channel. Other floodplain features act as sediment and water sinks and therefore could not convey part of the effective bankfull discharge. The entrenchment ratios were very large for all streams; the largest entrenchment ration was 35.9, compared to the smallest being 3.7. Flow duration curves ranged from 1 to 1.4 years.

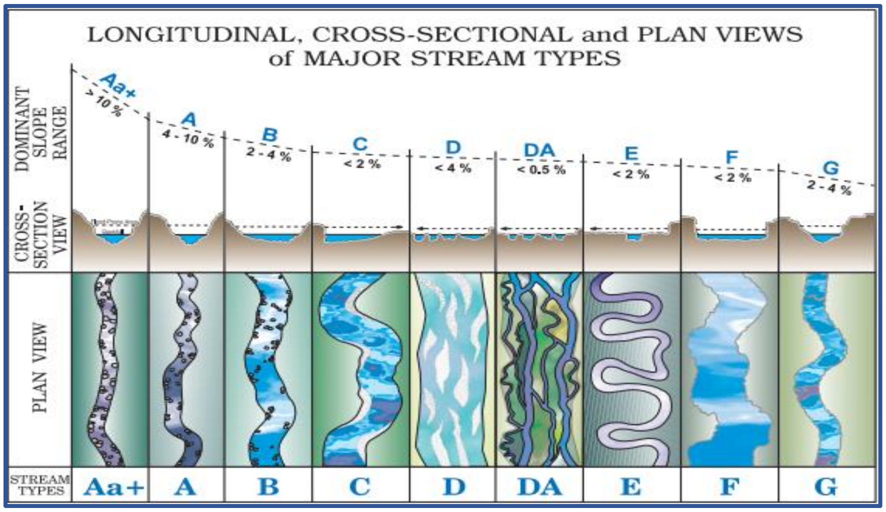


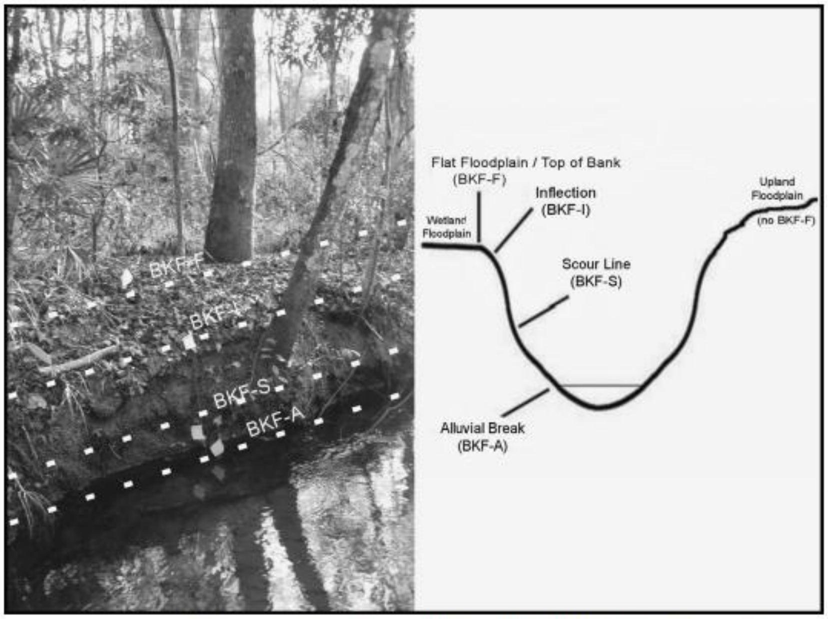
Figure 8. Plan views of major stream types (Rosgen, 1994, 1996)

Results & Discussion

Bankfull Indicators

Bankfull indicators surveyed during each refence reach within the Peninsular Florida study includes: Top of bank (TOB), Elevation of the flat floodplain or position on the bank where slope first becomes level (BKF-F), Inflection or break in slope of bank (BKF-I), Top of point bar (BKF-TOPB), Top of scour or undercuts in the bank (BKF-S), and Bottom of moss collars (BKF-M), and Alluvial break (BKF-A) (Figure 9. & Table 1). The two most reliable bankfull indictors were found for Peninsular Florida streams: 1) BKF-F, the elevation of the flat floodplain or position on the bank where the slope first becomes level, should be used for streams with a wetland floodplain or those with a broad valley; and 2) BKF-I (present at 100% of sites and most reliable indicator), the inflection or break in slope of the bank, should be used for streams without a wetland floodplain or those with a confined valley (Blanton et al.).

Bankfull Indicators in Small Blackwater Streams



Various field indicators of bankfull stage: flat floodplain (BKF-F), inflection (BKF-I), scour (BKF-S), moss (BKF-M), and alluvial break (BKF-A). Photograph is at South Fork Black Creek in Clay County at Camp Blanding. This site has a wetland floodplain (BKF-F is same as top of bank).

Figure 9. Bankfull Indicators Peninsular Florida (Blanton et al., 2010)

Table 1. Prevalence of field bankfull indicators. Legend: + = Bankfull indicator present; - = Bankfull indicator not present.

Site ID	Flat floodplain (BKF-F)	Inflection (BKF-I)	Top of point bar (BKF-TOPB)	Scour (BKF-S)	Moss (BKF-M)	Alluvial break (BKF-A)
NFU1	-	+	+	+	-	+
NFU2	-	+	-	+	+	+
NFU3	-	+	-	+	-	+
NFWC1	+	+	-	+	-	+
NFWC2	+	+	-	+	-	+
NFWC3	+	+	-	+	-	+
NFWC4	+	+	-	+	-	+
NFWC5	+	+	+	+	-	+
NFWC6	+	+	-	-	-	+
NHU1	+	+	-	+	-	+
NHU2	-	+	-	+	+	+
NHU3	+	+	-	+	-	+
NHU4	+	+	-	+	-	+
NHU5	-	+	-	+	-	+

Table 1. Continued						
NHW1	+	+	-	+	+	+
NHW2	+	+	-	+	-	+
NHW3	+	+	-	+	-	+
NHW4	+	+	-	+	-	+
NHWC1	+	+	-	-	-	-
SFU1	+	+	-	+	+	-
SFU2	+	+	-	+	+	-
SFU3	+	+	-	+	+	-
SFU4	-	+	-	+	-	+
SFU5	+	+	+	-	-	-
SFU6	+	+	-	-	-	-
SFU7	+	+	+	+	+	+
SFU8	+	+	-	+	-	+
SFU9	+	+	+	+	-	+
SFW1	+	+	-	+	-	+
SFW2	+	+	-	+	-	+
SFW3	+	+	-	-	-	+
SFW4	+	+	-	+	-	+
SFWC1	+	+	-	-	-	-
SFWC2	+	+	-	+	+	+
SFWC3	+	+	+	+	-	-
SHU1	+	+	-	+	-	+
SHU2	+	+	-	+	-	+
SHU3	+	+	-	-	-	+
SHU4	+	+	-	+	-	+
SHW1	+	+	-	+	-	+
SHW2	+	+	-	+	-	+
SHW3	+	+	-	+	-	-
SHW4	+	+	-	+	-	+
SHWC1	+	+	-	+	-	+
Percentages of sites at which bankfull indicator is present:	87%	100%	13%	84%	18%	78%

Table 1. Prevalence of field bankfull indicators (Blanton et al., 2010)

North and Northwest Florida Coastal Plain Bankfull indicators that had the most prevalence within the study reaches were the top of bank or a lower bench/bar feature (Table 2.). The floodplain width was not considered bankfull because of signs of water storage and thick vegetation. Sediment transport typically occurred within the main channel of the study reaches.

Table 2. Bankfull Classification Characteristics of Study Reaches

Stream Name	Entrenchment Ratio	Width/Depth Ratio	Sinuosity	Water Surface Slope (ft/ft)	Channel Material (D50 mm)	Bank Height Ratio	Rosgen Stream Type
Alaqua Creek near Portland,FL	33.1	6.2	1.58	0.00011	0.71	1	E5
Baggett Creek near Milligan,FL	33	7	2.42	0.0022	0.75	1	E5
Barnetts Creek near Thomasville,GA	26	7.4	1.1	0.0026	1.21	1.1	C5
Bear Creek near Youngstown,FL	20.6	8.9	1.36	0.00023	1.32	1	E5
"Big Coldwater Creek near Milton, FL"	9.4	24.3	1.18	0.00037	0.5	1	C5c
"Brushy Creek near Walnut Hill, FL"	10.5	8.2	1.57	0.00078	1.99	1.1	E5
Caney Creek near Monticello,FL	3.8	6.1	1.12	0.00047	0.4	1.1	E5
Deep Creek near SuwanneeValley,FL	10.6	6	1.31	0.00021	0.65	1	E5
"Econfina River near Perry,FL"	>50	5.3	1.32	0.0002	0.61	1	E5
"Fenholloway River near Foley, FL"	6.8	4.2	1.11	0.0008	0.59	1.5	E5
"Fish River near Silverhill, AL"	6.6	9.7	1.51	0.00058	0.15	1	E5
Juniper Creek near Niceville,FL	21.5	11.7	1.34	0.00056	0.81	1	C5c
"Little Double Bridges Creek near Enterprise,AL"	6.5	10.1	1.25	0.00128	0.43	1	C5
Little River near Ashburn, GA	10	19.4	1.1	0.0004	0.34	1	E5

Table 2. Continued							
Little River near Midway,FL	18.3	12.7	1.68	0.00018	0.38	1	C5c
Muddy Creek near Beaver Creek, FL	8.1	9.3	2.73	0.00197	1.31	1	E5
New River near Lake Butler,FL	21.3	10.3	1.23	0.00017	0.55	1.1	E5
Newell Branch near Ashburn, GA	23	24.2	1.4	0.001	0.41	1.2	C5
Newell Branch near Worth, GA	10	20.5	1.1	0.004	0.48	1.5	C5
Rocky Creek near Live Oak, FL	27.6	5.1	1.43	0.0005	0.36	1.2	E5
Seven Mile Creek near Milton, FL	18.6	11	2	0.00305	0.57	1	E5
Shoal River Near Crestview,FL	19	20.2	1.76	0.00038	0.22	1	C5c
Shoal River Near MossyHead,FL	5.3	9.4	1.54	0.00051	1.35	1.4	E5
"Tired Creek near Cairo,GA"	30	10.2	1.7	0.0006	0.3	1.3	E5
"UT to Rocky Creek, near Gainesville, FL"	17.8	5.8	1.38	0.0012	0.86	1	E5
"Warrior Creek near Sumner, GA"	22	10.7	1.1	0.0012	0.45	1.2	C5

Table 2. Bankfull Classification Characteristics of Study Reaches (Metcalf et al., 2009)

The North and Northwest Florida Coastal Plain study used, in part, the Natural Resources Conservation Service (NRCS), “Stream Restoration Design,” engineering handbook to identify certain streams and bankfull indicators. This guidance document is rather generic and typically based on climatic and physical conditions that are more applicable to areas outside of Florida. Florida’s unique combination of carbonate geology, humid subtropical climate, low relief, and sandy soils, often lead to a wide array of fluvial form / stream types, some that could be globally unique and requires a more region-specific classification system (2015, Peninsular Florida Stream Systems). The NRCS’s guidance along with Rosgen’s (1996) excluded many applicable channel types that meet Florida’s fluvial systems. That is why existing stream classification systems outside of the Peninsula may not be useful to identifying streams within the Peninsula, as only two types out of forty-eight met the Rosgen (1996) stream type criteria (Metcalf et al., 2009). This cannot be an accurate characterization of Florida streams as there are reasonably more stream types that occur within the state. This study lacked more descriptive stream types that should have been based on their landscape associations, habitats, dimension, and hydrology. The North and Northwest Florida Coastal Plain study also conducted eight of their study sites outside of the state of Florida and the rest of their study sites were confined to extreme North Florida and the Panhandle of Florida. Thus, these relationships may not be appropriate and why in part their study lacked the bankfull indicators that the Peninsular study found based off applicable relationships between different geological context, physiography, and rainfall patterns that pertain specifically to Peninsular Florida and not any other region types (Fernald & Purdum, 1992). The Peninsular Florida study may be a more applicable approach to establishing bankfull indicators within Florida as they used the Florida Natural Areas Inventory (FNAI, 1990) guide to categorize/classify landscape settings and water sources that Florida ecologists had already established based on water quality, faunal metrics, and sediment type (Blanton et al., 2010). This allowed the Peninsular study to examine alluvial, blackwater, seepage, spring-run, and more stream types for their study sites as well as access to more gage/ungaged sites that contained critical historic/current discharge data needed for establishing accurate bankfull indicators.

Conclusion

This paper examined two different methodologies for identifying bankfull indicators in Florida streams. The findings for the North and Northwest Florida Coastal Plain study were found to be very limiting in stream types (two) and bankfull indicators (two). This was due to their study following methodologies set by the NRCS “Stream Restoration Design” engineering handbook and Rosgen (1996) major stream types classification system. The Peninsular Florida study was able to identify more stream types (four) and more bankfull indicators (six). This was because their study used methodologies created by FNAI to classify relevant stream types and comparing several bankfull indicators in a systematic way, using prevalence, relations to hydrology, and a slopes comparison.

Areas to consider further research on:

- More discharge data is needed, specifically in the North Florida Coastal Plain. This research is needed because of the lack of gage/ungaged USGS stations used in either study to determine if there are more or less bankfull indicators associated within this area of Florida.
- More USGS gages should be established in natural reaches and existing gages should be updated so that current discharge data can be analyzed. This is needed to give a more accurate picture of what historic and current discharge rates are so that the most accurate bankfull indicators are established within Florida streams. Without this data it would be very difficult to restore natural stream systems.
- Additional data on identifying a more definitive break between the North and Northwest Coastal Plain regions or potentially even defining a third region. This would help establish more applicable bankfull indicators to each regions stream types.
- Other studies should be conducted throughout Florida, specifically on the southern Peninsula to understand why this area tends to have a lower than average bankfull discharge return interval (less than a year).
- Including braided channels in future studies, as many of the single-threaded channels may have been changed due to land conversions. This may give better insight into how Florida streams are changing over time and their bankfull indicators along with them.
- Long term studies on stream restoration efforts and their success rate of selected bankfull indictor(s) in design plans.

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