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Wadeable Stream Habitat Monitoring at Ocmulgee Mounds National Historical Park

2023 Change Report



Looking upstream from Transect 4 at the monitored reach on Walnut Creek (OCMU001) at Ocmulgee Mounds National Historical Park.

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Wadeable Stream Habitat Monitoring at Ocmulgee Mounds National Historical Park: 2023 Change Report

Science Report NPS/SR—2026/443

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Abstract

This report presents findings from long-term stream habitat monitoring conducted under the Southeast Coast Network (SECN) protocol, which evaluates the status and trends of stream and near-channel conditions to inform resource management. The study focuses on a permanently established reach (OCMU001) along Walnut Creek within Ocmulgee Mounds National Historical Park, with surveys conducted in 2017, 2019, and 2023.

Baseline data collected in 2017 characterized the reach as having "poor-to-fair" in-stream habitat, despite abundant large woody debris, due to limited habitat diversity and sediment composition. The channel was smaller than expected for its watershed, likely influenced by floodwater diversion into adjacent wetlands. By 2019, substantial degradation occurred, including reduced habitat diversity, shallower thalweg depth, and increased fine sediment deposition, resulting in a downgraded habitat classification of "poor." These changes were interpreted as potentially reflecting natural variability associated with complex fluvial responses.

This 2023 resurvey indicated continued geomorphic adjustment, with persistent dominance of run habitats, further thalweg shallowing, and significant reach-wide bed aggradation. Although bed material coarsened relative to earlier surveys, it remained predominantly sandy. Increased sediment supply is evident from both in-channel and floodplain aggradation, as well as erosion and deposition patterns across transects. Notably, portions of the floodplain were eroded while other areas accumulated sediment, suggesting the influence of one or more high-magnitude hydrologic events.

Despite these changes, slight improvements in large woody debris abundance, bed material composition, and geomorphic unit heterogeneity led to an upgraded habitat classification of "poor-to-fair" in 2023. However, the extent of sediment deposition suggests recent geomorphic changes may persist, with ongoing aggradation potentially altering channel capacity and morphology over time.

No immediate management concerns were identified, but continued monitoring is recommended to determine whether observed changes represent a sustained trend. Additional analyses, including evaluation of storm events between survey periods, are needed to better understand the drivers of geomorphic change and to inform future management decisions within the park.

List of Terms or Acronyms

ANOVA: Analysis of variance

B: Sand/gravel bar

Be: Bench

Bf: Bankfull

BM: Benchmark

BSi: Bank stability index

C: Cobble bar

CHAT: Chattahoochee River National Recreation Area

CONG: Congaree National Park

CV: Coefficient of variation

DEM: Digital elevation model

FP: Floodplain

FPM: Floodplain margin

GCU: Geomorphic channel unit

GIS: Geographic information system

Gl: Glide

HOBE: Horseshoe Bend National Military Park

KEMO: Kennesaw Mountain National Battlefield Park

LT: Low terrace

LWD: Large woody debris

NED: National Elevation Dataset

NL: Natural levee

NLCD: National Land Cover Dataset

NPS: National Park Service

OCMU: Ocmulgee Mounds National Historical Park

P: Pool

R: Riffle

Ru: Run

SECN: Southeast Coast Network

SOP: Standard operating procedure

T#: Standard transect

Un: Undercut

Summary and Key Findings

The Southeast Coast Network (SECN) stream habitat monitoring protocol collects data to give park resource managers insight into the status of and trends in stream and near-channel habitat conditions (McDonald et al. 2018a). Wadeable stream assessments are implemented at the five SECN inland parks with wadeable streams. These include Horseshoe Bend National Military Park, Kennesaw Mountain National Battlefield Park, Ocmulgee Mounds National Historical Park, Chattahoochee River National Recreation Area, and Congaree National Park. Streams chosen for assessment were specifically targeted for management interest (e.g., trail erosion issues and upstream urban development) or to provide a context for similar-sized stream(s) within the park/network (McDonald and Starkey 2018a).

The objectives of the SECN stream habitat monitoring protocol are to:

- Determine status of upstream watershed characteristics (basin morphology) and trends in land cover that may affect stream habitat,
- Determine the status of and trends in benthic and near-channel habitat in selected wadeable stream reaches (e.g., bed sediment, geomorphic channel units (GCUs), and large woody debris (LWD)),
- Determine the status of and trends in cross-sectional morphology, longitudinal gradient, and sinuosity of selected wadeable stream reaches.

On September 27, 2017, data were collected at Ocmulgee Mounds National Historical Park (OCMU) to characterize the in- and near-channel habitat on a permanently monumented reach on Walnut Creek (OCMU001). These data, along with analysis of geographic information system (GIS) data, are presented in a baseline report (Cooper et al. 2019) that describes and compares the watershed-, reach-, and transect-scale characteristics of OCMU001 to selected third-order streams at Chattahoochee River National Recreation Area (CHAT001 and CHAT013) and Kennesaw Mountain National Battlefield Park (KEMO001 and KEMO002).

The channel surveyed at OCMU001 was smaller than expected, given the large size of its watershed. Cooper et al. (2019) interpreted the relatively small channel as evidence that the majority of floodwaters that come through OCMU by way of Walnut Creek do not follow this flow path. Alternatively, floodwaters are diverted into the wetlands to the southwest of OCMU001 through a power line right-of-way east of OCMU001 and a series of flood chutes and side channels.

Though the reach had a high abundance of large woody debris (LWD), based on the results of a pebble count and the type/distribution of the geomorphic channel unit (GCU) within the reach, in-stream habitat on OCMU001 was classified as “poor-to-fair” (Cooper et al. 2019). The stream did not have immediate management or safety concerns. However, exotic invasive vegetation (i.e., privet and Chinese tallow) was observed in the area surrounding and outside of the channel.

On May 8, 2019, OCMU001 was resurveyed to determine the amount and type of change that occurred within the reach since the "baseline survey" (Bateman McDonald 2020). In-stream habitat changed substantially from 2017 to 2019. In 2019, only a few non-run habitats were identified within the reach. Thalweg depth was also shallower in 2019 compared to 2017 and bed material was statistically significantly finer in 2019 compared to 2017. Due to the reduction in the diversity of in-stream habitat and the increased fining of the bed, OCMU001's in-stream habitat's classification was downgraded from "poor-to-fair" to "poor." Bateman McDonald (2020) suggested the reduction in the quality of the habitat may be a "natural" fluctuation within the stream network related more to complex response (Schumm 1973) than a permanent change in the reach and the additional fine sediment that was deposited within the reach may move through this portion of the stream network by the next survey (in 2023).

On September 12, 2023, OCMU001 was surveyed for the third time (this report). The major defining characteristics of the reach continue to be the presence of floodplains (though they were greatly altered between 2019 and 2023), lack of riffle habitat, and homogeneous channel slope throughout the reach. In-stream habitat did not change substantially from 2019 to 2023. In 2019 and 2023, only a few non-run habitats were identified within the reach. Additionally, thalweg depth continued to become shallower in 2023. Bed material was statistically significantly coarser in 2023 compared to both 2017 and 2019, though the sediment was still mostly sand. In addition to the continued shallowing of the thalweg, there was also substantial aggradation on the floodplain and out-of-channel areas surrounding the reach as well as reach-wide aggradation of the bed. All these changes indicate a substantial amount of sediment is being supplied to the reach. As in 2019, if this increased sediment supply continues, there could be substantial changes to the reach that are difficult to predict given the complex hydrologic conditions that affect the reach.

Due to increases in LWD, the coarsening of bed material, and the slight increase in the heterogeneity of GCUs, OCMU001's in-stream habitat classification was upgraded from "poor" to "poor-to-fair." The additional sediment supplied to the reach created a substantial change in bed elevation (due to reach-wide aggradation). Due to the large amount of sediment deposited within the reach, it is unlikely the changes that occurred will be undone by the next survey. While an additional survey is needed to determine if there is a trend of aggradation slowly filling up the channel, it seems likely considering the changes observed from 2017 to 2019 and from 2019 to 2023.

The major morphological changes observed within the reach included reach-wide bed aggradation, erosion of the floodplain areas on river right between T4 and T7, and aggradation of the out-of-channel area on all three detailed transects. While there was very little change on detailed transect 1 and 3 (besides the bed aggradation), detailed transect 2 had a substantial amount of change. Nearly the entire front half of the floodplain surface on river right was lost between 2019 and 2023 on detailed transect 2. Deposition of LWD on the upstream side of this surface may provide increased resistance to future change and could act as a sediment trap to allow this surface to grow upstream while protecting the surface that remains. The bed of the stream aggraded approximately 0.10 meters (0.3 feet [ft]) along the entire reach between 2019 and 2023. Additional areas of aggradation were observed on the higher "historical terrace" surfaces of each detailed cross-section. The bed

aggradation and areas of aggradation on the “historical terrace,” coupled with the loss of the floodplain, suggest a very large event (or events) influenced the reach. An analysis of the storms between each of the surveys may help elucidate the size of storm needed to influence the “historical terrace” along this reach.

Though there were substantial changes to the reach, no immediate management concerns were identified by this survey. Follow-up visits and additional analysis (proposed above) should provide much-needed context to help determine how Ocmulgee Mounds National Historical Park is likely to change in the next few years.

Introduction

The Southeast Coast Network (SECN) Stream Habitat Monitoring Protocol collects data to provide park resource managers insight into the status of, and trends in, stream and near-channel habitat conditions (McDonald et al. 2018a). The data provided through this monitoring effort provide park staff with information regarding the physical linkage between streams and park resources. Additionally, this monitoring program will provide early warnings of changing conditions that may negatively affect visitor experience and/or park infrastructure.

Wadeable stream monitoring is implemented at the five SECN inland parks with wadeable streams. These include Horseshoe Bend National Military Park (HOBE) in Alabama, Kennesaw Mountain National Battlefield Park (KEMO), Ocmulgee Mounds National Historical Park (OCMU), and Chattahoochee River National Recreation Area (CHAT) in Georgia, and Congaree National Park (CONG) in South Carolina. The streams at Horseshoe Bend National Military Park, Kennesaw Mountain National Battlefield Park, and Chattahoochee River National Recreation Area are typical Appalachian Piedmont streams beginning to re-equilibrate to their modern flow and sediment regimes following the poor land use practices of the late 19th and early 20th centuries (McDonald 2019*;* McDonald and Starkey 2018a; McDonald and Starkey 2018b). The streams at Congaree National Park are typical low gradient, blackwater, Coastal Plain streams (McDonald and Starkey 2018c) while the streams at Ocmulgee Mounds National Historical Park are a mixture of Appalachian Piedmont and Coastal Plain type streams (McDonald and Starkey 2019). Streams chosen for monitoring were specifically targeted due to management interest (e.g., trail erosion issues and upstream urban development) or to provide a context for similar-sized streams in the park (see suitability reports for each park [cited in this paragraph] for more information).

The objectives of the SECN stream habitat monitoring protocol are to:

- Determine the status of upstream watershed characteristics, including basin area, basin slope, and drainage density, and trends in land cover that may affect stream habitat,
- Determine the status of and trends in the geomorphic dimensions of selected wadeable stream reaches, including cross-sectional morphology, bank characteristics (e.g., heights, angles, and vegetative cover), and reach slope and sinuosity, and
- Determine the status of and trends in physical measures of benthic and riparian habitat features present in selected wadeable stream reaches, including the size, type, and distribution of bed sediment and large woody debris, the distribution of geomorphic channel units, and canopy cover.

For this report, wadeable streams are narrowly defined as small- to medium-sized, perennially-flowing waterbodies, with easily identifiable channel banks, that can be accessed and traversed without the use of a watercraft. The wadeable streams referred to herein do not include non-perennial channel-like features (e.g., gullies) typical of highly disturbed and gullied landscapes like the Appalachian Piedmont.

The objectives of this report are to:

- Present the wadeable stream survey completed at Ocmulgee Mounds National Historical Park during late summer 2023,
- Provide a comparison of the 2023 results to the 2019 survey, and the 2017 "baseline" survey,
- Describe the processes responsible for differences between the surveys, and
- Explain why OCMU001 is changing and its potential trajectory of change.

Study Area

The hydro-climatic conditions of the study area are characterized as humid subtropical with average annual rainfall around 46 inches (in) per year (117 centimeters [cm] per year; Wright et al. 2011). Snowfall is negligible and winters are mild; summers are hot and humid. Average monthly temperature ranges from a low in December of approximately 28°F (−2°C) to a high in July of 94°F (35°C; Wright et al. 2011). Monthly rainfall totals are distributed rather evenly from October through May due to the influence of frontal systems that sweep through the region (Lecce 2000). Convective thunderstorms influence the region from late spring through early fall. While monthly precipitation tends to be high in the summer, the high levels of evapotranspiration attenuate streamflow during this part of the year (Lins 1997).

The natural condition of rivers draining the southeastern U.S. is generally characterized by meandering channels with densely vegetated banks (Leigh 2008). Contemporary river systems in the southeastern U.S. are in variously altered states that reflect multiple legacies of anthropogenic disturbance (James 2018). Beginning in the late 1800s, deforestation, increased row crop agriculture, and a general lack of soil conservation measures caused widespread erosion of topsoil from steeply sloped upland areas in the Appalachian Piedmont region (Trimble 1969). Sediment was transported to streams and floodplains, burying productive shoal and riffle habitats. Streams in the region were transformed, from the hard-bottomed, clear-flowing streams described by early land surveyors (Bartram 1996) into conduits of turbid water and sand. As row-crop agriculture became less dominant and forest cover increased, sediment delivery to streams was reduced and streambeds began to degrade (Schumm et al. 1984). Today, streambed elevations in many of the region's small streams have returned to historic or near-historic levels though their geomorphic characteristics (width, depth, entrenchment) are quite different from early settlement conditions (Mukundan et al. 2011; Schoonover et al. 2007).

In addition to the legacy effects of agriculture, many Appalachian Piedmont streams have been further subjected to hydrologic alterations caused by urban or suburban development. Increases in impervious surface area associated with development create conditions that increase the frequency and magnitude of peak discharges (Paul and Meyer 2001). Impervious surface area is also associated with lower-than-normal base flow during dry periods due to impaired groundwater recharge (Rose and Peters 2001). These flow alterations greatly influence available in- and near-stream habitats and can have a large negative impact on the biota found within a stream (Wenger et al. 2008).

As each stream recovers from its unique history of land use and equilibrates to its current flow and sediment regime it will pass through a series of semi-predictable stages of evolution (James 2018; Schumm et al. 1984). These stages include aggradation (receiving more sediment than the flow regime can transport), degradation and narrowing (caused by a reduction in sediment and or increased runoff), further degradation and widening from unstable banks, and finally stabilization and more natural reworking of in-channel alluvium (Figure 1). The exact stage a particular stream occupies, at a given moment in time, is dependent on the location of the stream within its network and the unique history and current land use/land cover conditions of the stream's watershed. In general, streams in the Appalachian Piedmont are at the third stage of channel development (further degradation and widening) and their banks are quite unstable and subject to undercutting and slumping (Ruhlman and Nutter 1999).

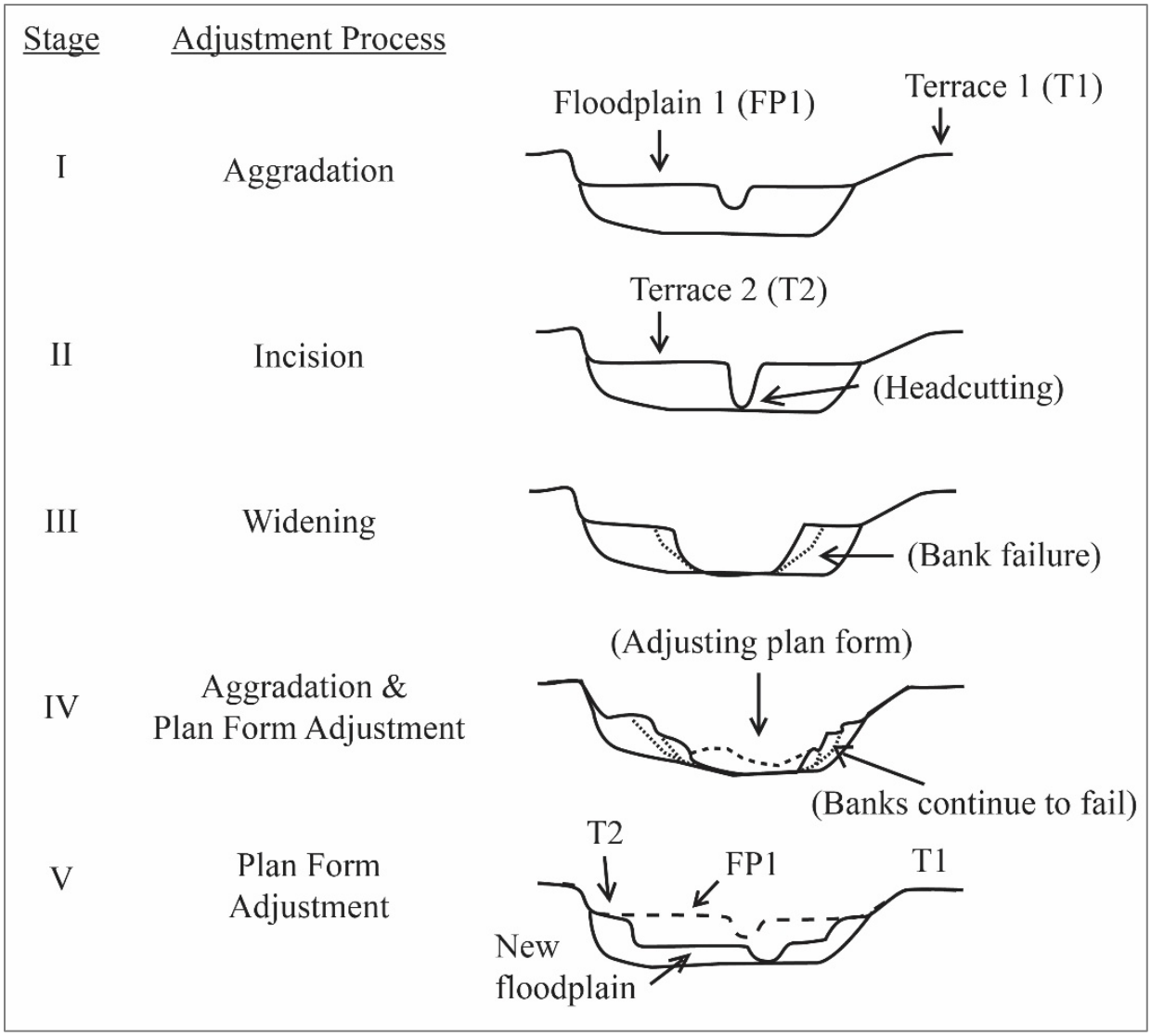


Figure 1. Generalized channel evolution model.
MODIFIED FROM SCHUMM ET AL. (1984)

Ocmulgee Mounds National Historical Park

Ocmulgee Mounds National Historical Park is located along the Ocmulgee River in the transition zone that separates the Piedmont and Coastal Plain physiographic provinces in Macon, Georgia (Figure 2). The park preserves burial and temple mounds, constructed by American Indians on the uplands overlooking the Ocmulgee River floodplain. The 702-acre (284-hectare [ha]) park is mostly surrounded by urban and suburban development. Many of the streams draining the uplands portion of the park are heavily impacted by upstream runoff from impervious surfaces and have become entrenched (McDonald and Starkey 2019).

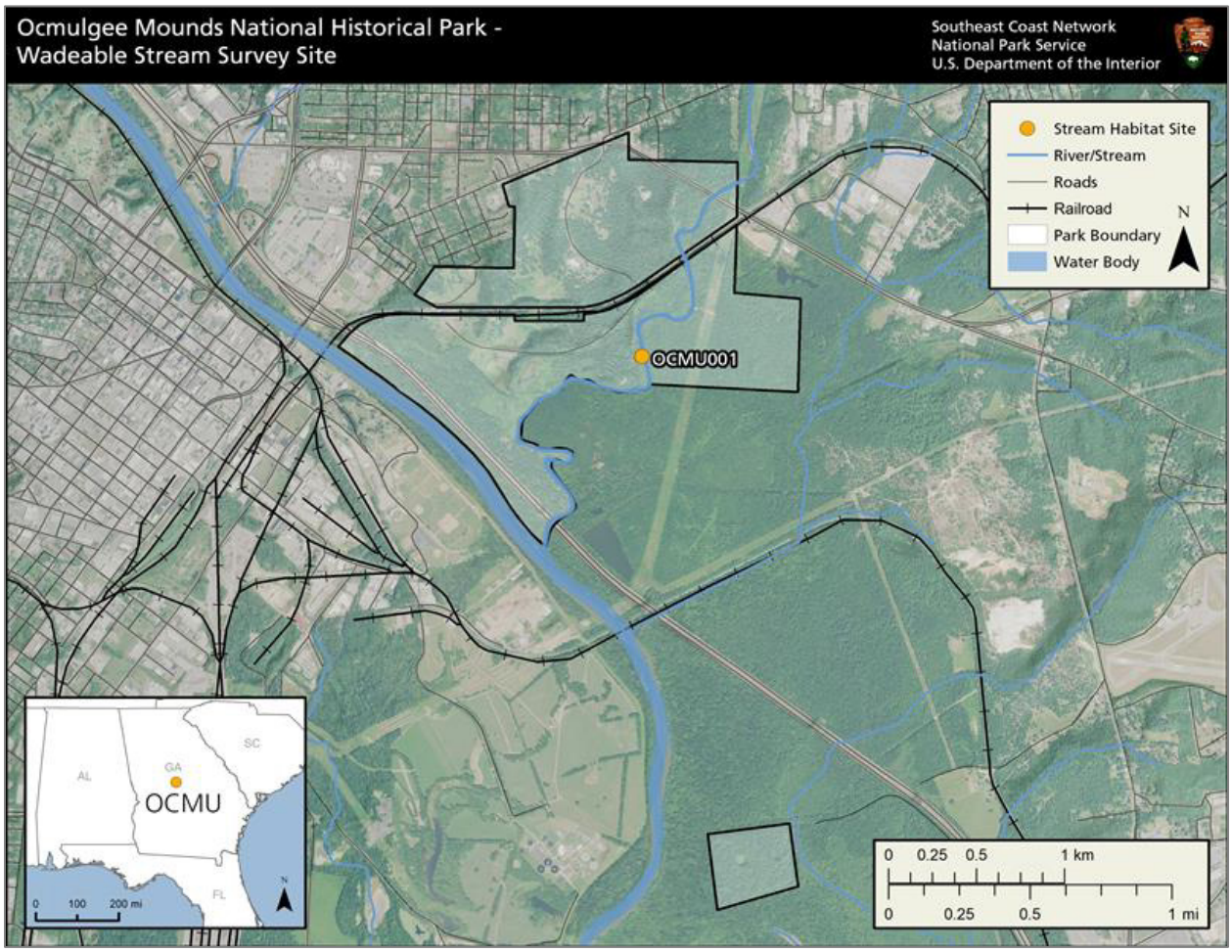


Figure 2. Map showing Ocmulgee Mounds National Historical Park and its wadeable stream site (OCMU001). Aerial imagery (National Agricultural Imagery Program, USDA NRCS 2017) and perennial streams (derived from a 10 meter (32.8 feet [ft]) digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.

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Development in eastern Macon has altered sediment delivery and streamflow inside the park's boundaries (GA DNR EPD 2007). Portions of the monument's North Plateau are rapidly eroding, and this material is deposited on the Middle and South Plateaus (KellerLynn 2013). Walnut Creek,

the park's largest perennial stream, originates outside of the park's boundaries and has several upstream areas of severe bank erosion and sedimentation (GA DNR EPD 2007). Within the boundaries of the park, Walnut Creek is an intermittently braided stream system with a distinct perennial channel (e.g., reach at OCMU001) as well as large flood chutes and side channels that spread out across the Ocmulgee River's extensive floodplain (McDonald and Starkey 2019).

Roughly 300 acres (121 ha) of the park are classified as emergent wetlands, and stream reconnaissance conducted in 2012 noted extensive beaver activity within the park along Walnut Creek, which has significantly altered flowing stream habitats in this stream corridor (M.B. Gregory, SECN Program Manager, personal observation). The monitored reach (OCMU001) is located downstream of the area that was influenced by the beavers in 2012. Although the park owns approximately 1 mile (1.6 kilometers [km]) of river frontage along the Ocmulgee River, the construction of Interstate 16 through the monument's floodplain severed its direct connection with the river.

Previous Surveys

On September 27, 2017, data were collected at Ocmulgee Mounds National Historical Park (OCMU) to characterize the in- and near-channel habitat on a permanently monumented reach on Walnut Creek (OCMU001). These data, along with analysis of geographic information system (GIS) data, are presented in a baseline report (Cooper et al. 2019) that describes and compares the watershed-, reach-, and transect-scale characteristics of OCMU001 to selected third-order streams at Chattahoochee River National Recreation Area (CHAT001 and CHAT013) and Kennesaw Mountain National Battlefield Park (KEMO001 and KEMO002).

The analysis of the GIS data found Walnut Creek's watershed at OCMU001 has low slope/relief and is covered mostly by forest and agricultural pasture. The major defining characteristics of the stream were the presence of floodplains, natural levees, lack of riffle habitat, and homogeneous channel slope throughout the reach. Though most of the watershed lies in the Appalachian Piedmont physiographic province, OCMU001 lies in the Upper Coastal Plain and is a low energy, depositional environment subject to regular flooding and slow post-flood draining.

The channel surveyed at OCMU001 was smaller than expected, given the large size of its watershed. Cooper et al. (2019) interpreted the relatively small channel as evidence that most of the floodwaters that come through the park by way of Walnut Creek do not follow this flow path. Alternatively, floodwaters are diverted into the wetlands to the southwest of OCMU001 through a power line right-of-way east of OCMU001 and a series of flood chutes and side channels.

Though the reach had a high abundance of large woody debris (LWD), based on the results of a pebble count and the type/distribution of the geomorphic channel unit (GCU) within the reach, in-stream habitat on OCMU001 was classified as "poor-to-fair" (Cooper et al. 2019). Given the complex hydrologic setting of OCMU001, Cooper et al. (2019) could not predict the site's response to changes in sediment supply and LWD; though they did not expect marked departures from this habitat classification. Finally, the stream did not have immediate management or safety concerns.

However, exotic invasive vegetation (i.e., privet and Chinese tallow) was observed in the area surrounding and outside of the channel.

On May 8, 2019, OCMU001 was resurveyed to determine the amount and type of change that occurred within the reach since the "baseline survey." In-stream habitat changed substantially from 2017 to 2019. In 2019, only a few non-run habitats were identified within the reach. Thalweg depth was also shallower in 2019 compared to 2017. Bed material was statistically significantly finer in 2019 compared to 2017. Additionally, the floodplain surfaces along detailed transects 2 (T6) and 3 (T11) had a significant amount of aggradation. Floodplain aggradation on detailed transects 2 (T6) and 3 (T11), along with the overall shallowing of average thalweg depth within the reach, indicates that a substantial amount of sediment is being supplied to the reach. If this increased sediment supply continues, there could be significant changes to the reach that are difficult to predict given the complex hydrologic conditions that characterize the reach.

Due to the continued reduction in the diversity of in-stream habitat and the increased fining of the bed, OCMU001's in-stream habitat's classification was downgraded from "poor-to-fair" to "poor." This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at Ocmulgee Mounds National Historical Park. The reduction in the quality of the habitat may be a "natural" fluctuation within the stream network related more to complex response (Schumm 1973) than a permanent change in the reach. The lack of change in the longitudinal profile supports the interpretation that the reach has not undergone a significant permanent change and the additional fine sediment that has been deposited within the reach may move through this portion of the stream network by the next round of survey.

The major morphological changes observed within the reach were observed on the detailed transects. These changes were related to bank slumping, stream bed restructuring, and floodplain aggradation. Bank slumping was interpreted to have contributed to the large observed increase in channel-full area on detailed transects 1 (T1) and 2 (T6) as well as the loss of the "bankfull" surface along river right on detailed transect 3 (T11). This bed restructuring along the detailed transects supports the interpretation that the bed along OCMU001 is highly mobile. The prevalence of slumping along all three detailed transects suggests the banks are quite unstable. Except for the high density of exotic invasive vegetation that continues to occupy the area surrounding the stream, there were no immediate management concerns identified by the survey.

Methods

The habitat characteristics and geomorphic parameters that were selected for monitoring are based on those collected by other federal organizations (USGS, Fitzpatrick et al. 1998; USEPA, Hughes et al. 2000; and USFS, Harrelson et al. 1994). The physical structure of in- and near-stream habitat has a strong influence on the biological communities and overall ecological integrity of lotic ecosystems (Newson and Newson 2000). Monitoring stream habitat not only provides an understanding of the physical suitability for aquatic species but can also identify stressors that could degrade other park resources and negatively affect visitor experiences.

The data collected as part of the SECN wadeable stream monitoring protocol are divided into three scales of analysis (Figure 3): (1) basin-scale characteristics; (2) reach-scale measurements, along and between 11 standard transects per reach; and (3) detailed cross-sectional measurements, at three of the 11 transects per reach. While summarized in this document, a list of standard operating procedures and an overview of the methods used to collect and process the survey data are available in McDonald et al. (2018a).

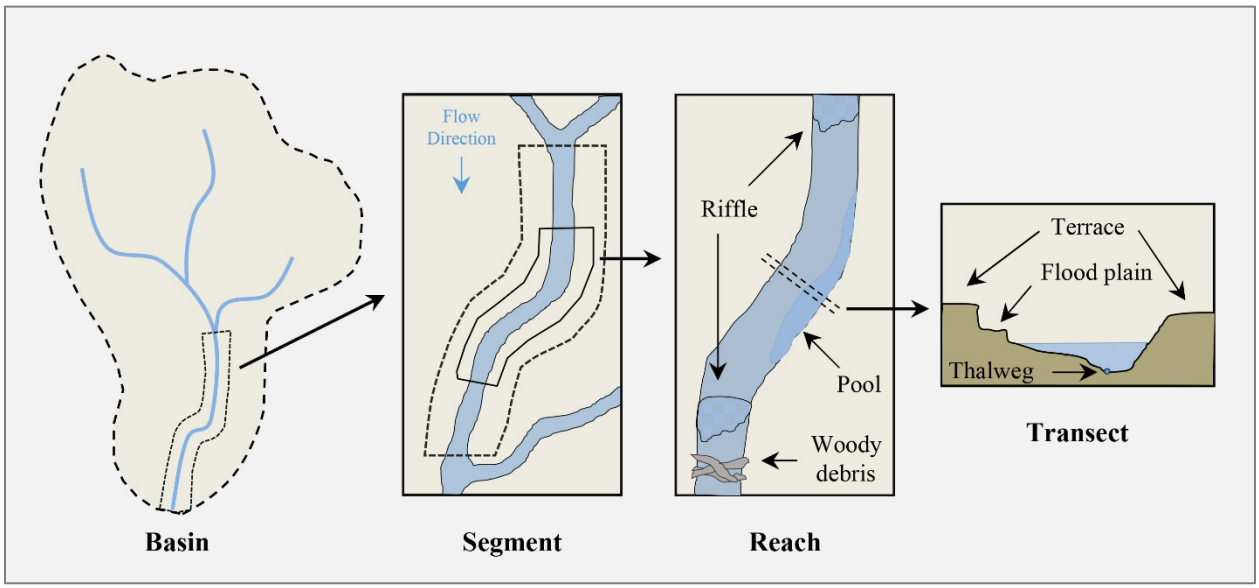


Figure 3. Spatial hierarchy of stream systems and scales of data collection. View in transect diagram is in downstream direction.

MODIFIED FROM FITZPATRICK ET AL. 1998

Basin Characteristics

Understanding the physical characteristics of a drainage basin as well as the land use/land cover (LULC) upstream of a reach is critical to understanding changes to and differences between streams. The parameters collected for this protocol describe how dissected the watershed is (drainage density; Knighton 1998), the magnitude and duration of floods (basin shape; Gregory and Walling 1973), the rainfall-runoff potential of a watershed (average watershed slope; Hewlett and Hibbert 1967), potential sediment yield (basin relief ratio; Strahler 1957), and the amount of energy available to

move sediment through a stream network (entire stream gradient; Craig and Rankl 1978; Fitzpatrick et al. 1998). A description of these basin characteristics is in McDonald et al. (2018a).

Basin-scale measures are calculated after permanent sites have been determined. These measurements and analyses are conducted within a GIS using digital elevation models (DEMs) from the National Elevation Dataset (NED) and land cover data from the National Land Cover Database (NLCD). Instructions for the GIS basin analysis can be found in SOP 1.2.15 *Wadeable Stream Basin- and Segment-scale Data Summary—Version 1.0* (McDonald et al. 2018b).

Reach-Scale Measurements

The reach-scale characteristics of each monitored reach are measured at and between 11 equidistant transects (distance between transects is two times average wetted width; Figure 4). Reach length is 20 times average wetted width (as determined during the initial survey of the reach). Data collected at each of these transects include vegetative bank cover, presence of eroding banks, bed and bank material, channel widths (e.g., wetted, active, bankfull, and channel-full widths), water depth, and bank heights/angles. In addition to bankfull and channel-full bank heights, minimum bank height is also reported. Minimum bank height is the minimum bank height measured on each transect. This measure helps account for transects with multiple "bankfull" surfaces inset within the channel-full channel. These inset surfaces are termed "elevated entrenched surfaces" and are semi-permanent slump-cored surfaces that can become stabilized if they become vegetated. Lastly, a quantitative measure of bed sediment is obtained by conducting a Wolman pebble count on a representative riffle within the reach (Wolman 1954).

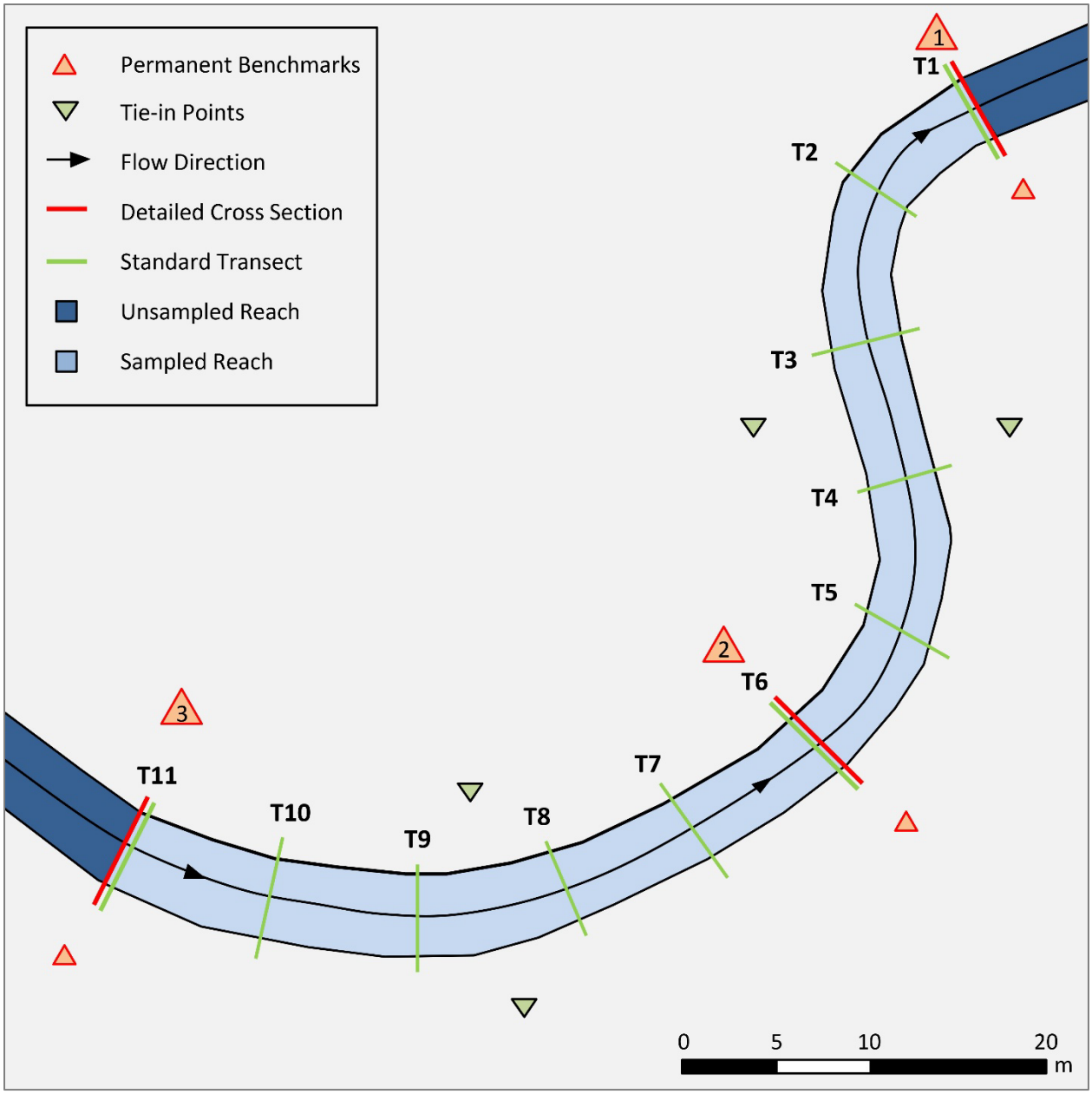


Figure 4. Example layout of stream reach with benchmarks, tie-in points, and transects.
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These data provide an understanding of the geomorphic and physical characteristics of the survey reach and are used to derive a bank stability score for the reach (Table 1). Many stream banks in the Appalachian Piedmont and in the upper portion of the Coastal Plain have a bank stability score of "at-risk" or "unstable." This condition is consistent with expectations, given that many comparable streams in the region are currently reestablishing functional floodplains within their highly entrenched channel systems.

Table 1. Bank Stability Index (BSi) from Fitzpatrick et al. (1998). A BSi score is determined by adding up the bank angle, vegetative cover, bank height, and bank sediment scores for each bank (separate score for left and right banks at each transect). Total score rankings: 4–7 stable; 8–10 at-risk; 11–15 unstable; and 16–22 very unstable.

Bank Stability Factor	Classification	Score
Angle (°)	0–30	1
	31–60	2
	>60	3
Vegetative cover (%)	>80	1
	50–80	2
	20–49	3
	<20	4
Bank Height (meters)	<1	1
	1–2	2
	2–3	3
	3–4	4
	>4	5
Type of Bank Sediment	Bedrock, artificial	1
	Boulder, cobble	3
	Clay	4
	Silt	5
	Sand	8
	Gravel/Sand	10

To understand in-stream and near-channel habitats, measurements are also taken between each transect. These between-transect measurements include: canopy cover, the amount and type of in-stream habitat (e.g., high-energy riffles vs. low-energy pools), an inventory of large woody debris (LWD; defined as >1 meter (3.3 ft) in length and >10 centimeters (3.9 inches [in]) in diameter as defined in McDonald et al. 2018a), and a description of in-channel features (e.g., sand/cobble bars). Using these measures of in-stream habitat, each stream's habitat is classified as "poor," "poor-to-fair," "fair," "fair-to-good," or "good." These classifications are based on (1) watershed characteristics (i.e., land use/land cover, slope, and relief); (2) in-stream habitat conditions (i.e., high versus low energy geomorphic channel units (GCUs), bed material, prevalence of LWD); and (3) general channel condition (i.e., bank conditions, degree of entrenchment, presence of knickpoints, or planform changes). These classifications are a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health on each reach.

A total station was used to measure the water surface slope at all transects and wherever there was a substantial break in slope (e.g., bottom and top of riffles). Water surface slope was used to characterize the longitudinal profile as it reflects the hydraulic gradient, captures real-time flow conditions, and is easier to reliably measure compared to channel bed or thalweg elevations.

Detailed Transect Cross-Sections

Three of the 11 standard transects (optimally T1, T6, and T11) are surveyed using a survey-grade (sub-centimeter accuracy) total station. These surveys allow lateral variability along each transect to be quantified and in- and out-of-channel changes to be monitored through time (Figure 5).

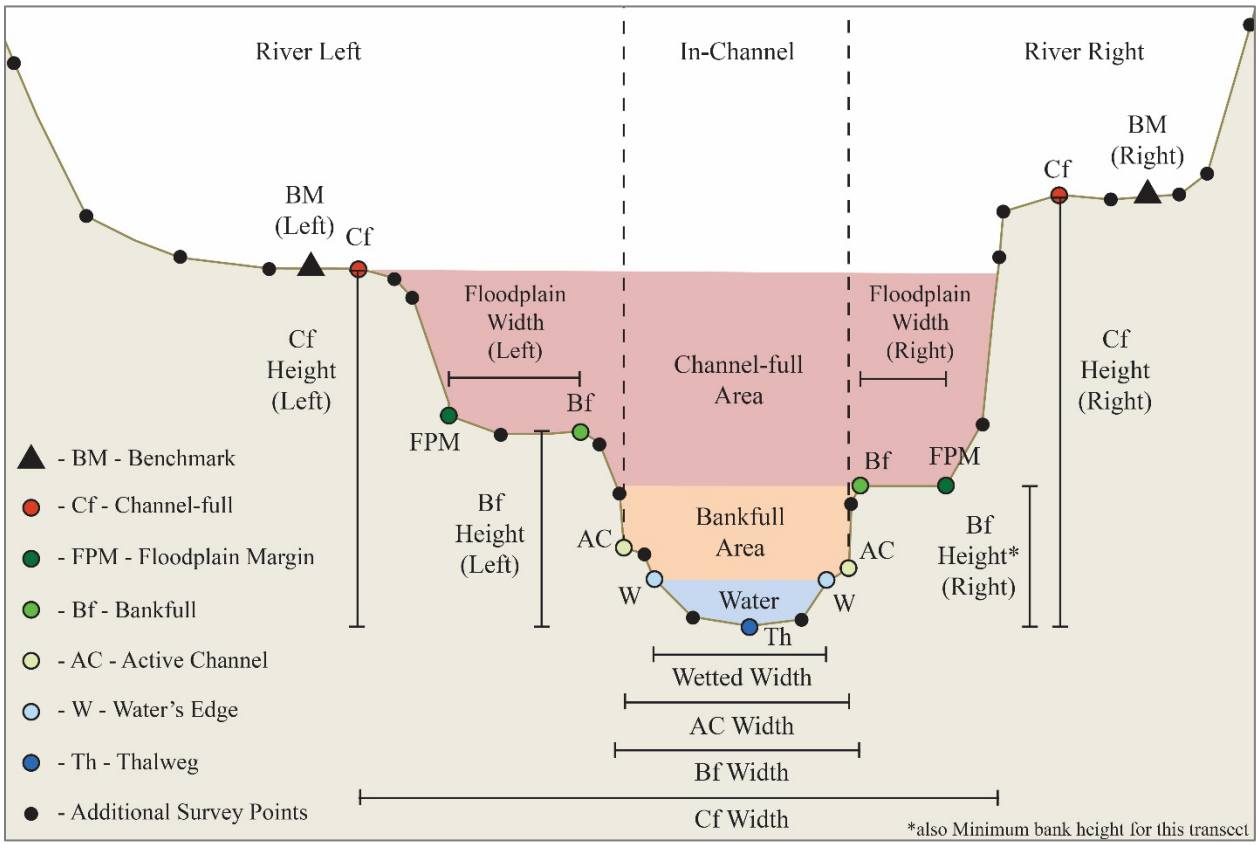


Figure 5. Hypothetical detailed transect cross-sectional survey showing the diagnostic geomorphic surfaces that should be surveyed and the descriptive characteristics that will be derived from the data. Bankfull area includes baseflow area (light blue) and bankfull area (orange). Channel-full area includes baseflow, bankfull, and channel-full (red) areas.

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Additionally, repeated surveying of channel cross-sections allows changes in streambed elevation and bank profiles to be quantitatively assessed in relation to a known point (benchmark). These data are used to calculate bankfull and channel-full areas and used along with the bank stability index to assess the condition and stability of the reach.

Statistical Analysis

Differences in mean values among surveys (2017, 2019, and 2023) for 11 variables were evaluated using analysis of variance (ANOVA). The results of the ANOVA were run through a post-hoc Tukey test to determine which years were statistically significantly different. The 11 variables tested include:

1. pebble count data (millimeters [mm]);
2. wetted width (meters [m]);
3. active channel width (m);
4. minimum bank width (m);
5. channel-full width (m);
6. thalweg depth (m);
7. minimum bank height (m);
8. channel-full height (m);
9. bank angle (°);
10. vegetative cover of the banks (%); and
11. bank stability index.

Bankfull width and height are not included in the statistical analysis because bankfull was not measured on each transect (due to lack of floodplain) and the number of bankfull measurements at each reach and between surveys was not always equal.

Results

On September 12, 2023, one stream reach on Walnut Creek (OCMU001) was surveyed following the methods outlined in SOP 1.2.16 *Wadeable Stream Reach-Scale Field Data Collection–Version 1.1* (McDonald et al. 2018c) and SOP 1.2.18 *Using a Total Station to Conduct a Stream Survey–Version 1.1* (McDonald et al. 2018d). The surveyed reach is on a fifth-order segment of the Walnut Creek stream network. Reach- and detailed transect-scale field survey results, in-office analyses, and statistical comparisons between monitoring years (2017 and 2019) are presented in the following sections. Transect-scale results and data summary tables for the 2023 survey of OCMU001 are provided in Appendix B; see Cooper et al. (2019) for transect-scale results and data summary tables from the 2017 survey and Bateman McDonald (2020) for transect-scale results and data summary tables from the 2019 survey.

Weather Conditions

Wadeable stream surveys are conducted as close to baseflow conditions as possible given the time frame available each year (McDonald et al. 2018a). No rain fell on any of the survey days (Table 2). Less than 1 inch (2.5 cm) of rain was recorded in the week prior to the 2019 and 2023 surveys, and no rain was recorded the week prior to the 2017 survey. The least amount of rainfall was recorded the month prior to the 2023 survey and no events greater than 1 inch were recorded in the month prior to the 2019 and 2023 surveys. In the three months prior to the 2023 survey, more rain was recorded than in the three months prior to the 2019 survey. The most rain was recorded in the three months prior to the 2017 survey. Though there are differences in the amount of rain in the three months prior to each survey, given the similarity of the weather conditions in the week prior to each survey, differences in baseflow conditions are not likely to explain any differences between the surveys.

Table 2. Amount of precipitation and number of precipitation events greater than 1 inch (2.5 cm) during and in the week and month(s) prior to the 2019 and 2023 wadeable stream survey at OCMU. Data from weather co-op station Macon 2.5 NNE, GA, US.

Time Frame	Length of Period	Total Precipitation (inches)	Number of Events >1 inch
9/27/2017	Day of Survey	0	0
9/20/2017–9/26/2017	One Week	0	0
8/28/2017–9/26/2017	One Month	6.92	2
6/26/2017–9/26/2017	Three Months	18.91	4
5/8/2019	Day of Survey	0	0
5/1/2019–5/7/2019	One Week	0.86	0
4/8/2019–5/7/2019	One Month	3.28	0
2/7/2019–5/7/2019	Three Months	8.54	1
9/12/2023	Day of Survey	0	0
9/5/2023–9/11/2023	One Week	0.65	0
8/12/2023–9/11/2023	One Month	1.94	0
6/13/2023–9/11/2023	Three Months	13.99	3

Basin Characteristics

This section provides a summary of the basin characteristics of the watershed draining to OCMU001. For a more in-depth look at OCMU001's basin characteristics and how they compare to third-order watersheds at Kennesaw Mountain National Battlefield Park (KEMO) and Chattahoochee River National Recreation Area (CHAT), see Cooper et al. (2019). Approximately 240 square kilometers (92.7 square miles [mi^2]) drain to OCMU001, and Ocmulgee Mounds National Historical Park manages 0.65 square kilometers (0.25 mi^2) of the watershed (Table 3). OCMU001's watershed has low slope/relief and is covered mostly by forest and grassland/pasture (Cooper et al. 2019). The land use/land cover for OCMU001's watershed has been stable since 2017 with most of the basin covered by forest, low levels of development, and grasslands (Table 4). Though most of the watershed lies in the Appalachian Piedmont physiographic province, OCMU001's reach lies in the Upper Coastal Plain and is a low energy, depositional environment subject to regular flooding and slow recession of the floodwaters (Cooper et al. 2019).

Table 3. Watershed characteristics for OCMU001 which are calculated using the National Elevation Dataset (NED) 10-meter (32.8 ft) digital elevation model. Please refer to McDonald et al. (2018a) for definitions of the variables [km = kilometers; m = meters; CV = coefficient of variation].

Basin Characteristic	OCMU001
Drainage Area (km^2)	239.65
NPS Managed Area (km^2)	0.65
NPS Managed Area (%)	0.3%
Total Stream Length (km)	401.73
Drainage Density	1.68
Strahler Order	5
Bifurcation Ratio	2.13
Entire Stream Gradient [A]	0.0021
Segment Gradient [B]	0.0014
Slope—Average	4.87
Slope—Standard Deviation	3.52
Slope—Coefficient of Variance	0.72
Basin Length (km)	39.26
Basin Shape [C]	0.16
Basin Relief (m)	127
Basin Relief Ratio	0.003
Elevation—Standard Deviation (m)	21

[A] Entire stream gradient calculated by dividing the difference between the elevations at 10% and 85% stream length by the length of stream between those points.

[B] Segment gradient is calculated by dividing the difference in elevations at the top of the stream segment and the bottom of the stream segment by the stream length between those points.

[C] Basin Shape is calculated by dividing drainage area by squared basin length.

Table 4. Land use/land cover characteristics in 2017, 2019, and 2023 for OCMU001's watershed. The data included in this table are from the National Land Cover Dataset.

Variable	2017	2019	2023
Developed—Open & Low (%)	15	15	15
Developed—Medium & High (%)	2	2	2
Forested (%)	62	62	62
Grassland (%)	13	14	13
Wetland (%)	4	4	4

Reach Description

OCMU001 is located on Walnut Creek approximately 400 meters (1,312 ft) south of the railroad tunnel on the main park road. There is a social trail along the hilltop in the vicinity of OCMU001, though tree falls continue to block most of this trail. In 2023, similar to 2017 and 2019 (Cooper et al. 2019; Bateman McDonald 2020), OCMU001 had a sandy bed throughout the survey reach and the channel had a low degree of entrenchment. The floodplains observed in 2017 and 2019, between T3 and T8 on river right and between T6 and the upper extent of the reach on river left, have reduced in size since the last survey (Figure 6). A natural levee continues to develop along the channel-side edge of the upstream floodplain (on river left) but had been eroded from the edge of the downstream (river right) floodplain. Two well-developed ephemeral side channels enter the reach on river left between T2 and T3 and between T4 and T5. The reach surveyed was 110 meters (360.9 ft) long with 11 meters (36 ft) between transects.

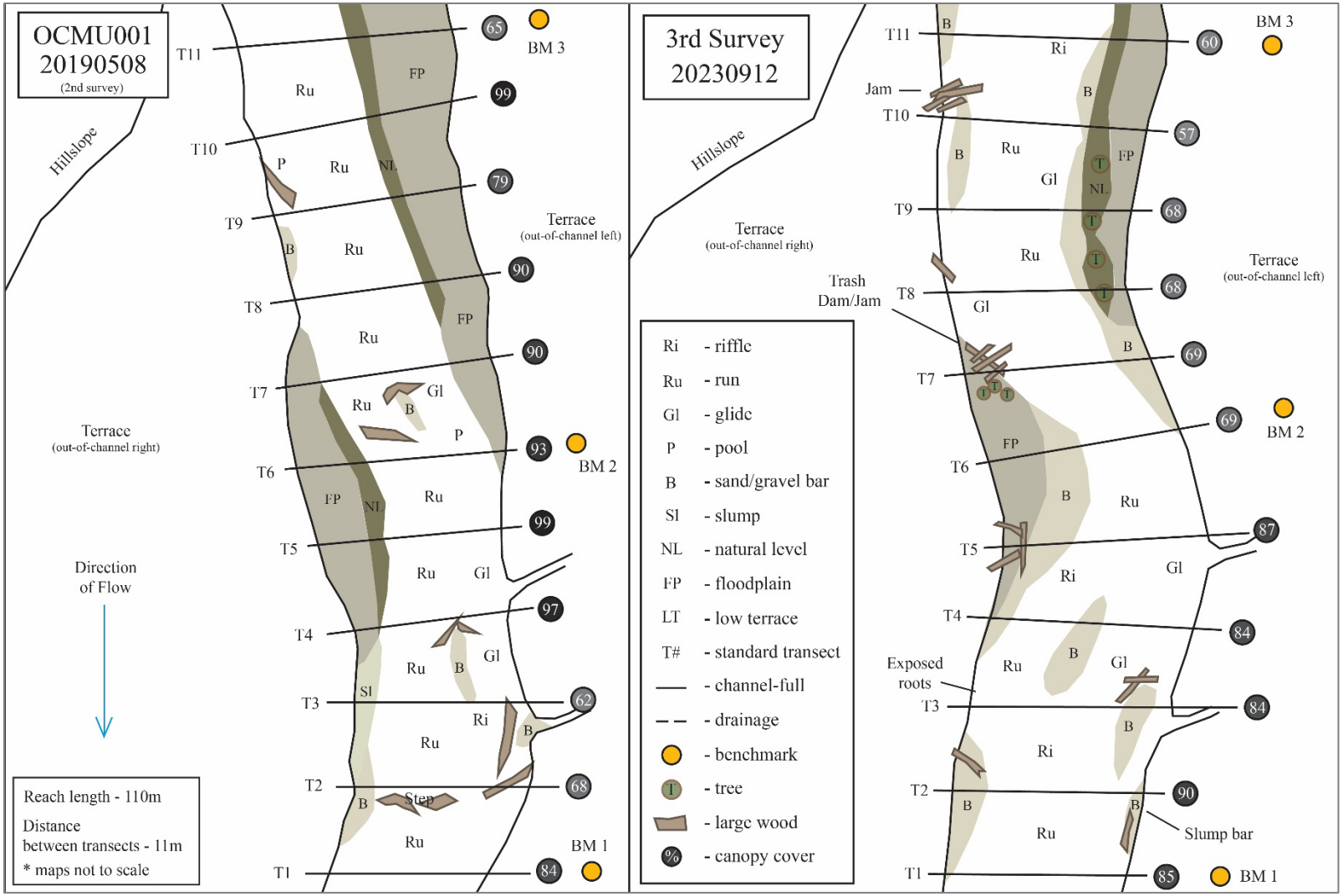


Figure 6. Reach-scale map of OCMU001. Important geomorphic surfaces and in-channel features are labeled to provide context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect.

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Habitat Characteristics

The frequency and distribution of geomorphic channel units (GCUs) observed at OCMU001 in 2023 were similar to 2019 (Table 5). During 2017, the GCUs in the Walnut Creek reach were mostly run but with glides and pools making up a substantial portion of the habitat. During 2019 and 2023, most of the habitat was run with a large decrease (-20%) in glide and pool compared to 2017. One small riffle area was observed in 2019, and two riffles were observed in 2023. In 2017, no riffles were identified within the reach so the pebble count was done just upstream of OCMU001 at the nearest riffle (Cooper et al. 2019). The main difference between 2019 and 2023 in-stream habitats was that no step habitat was observed in 2023. Bed sediment in the representative riffle in 2023 was coarser than the sampled sediment in 2019 and 2017 (Table 6). Mean sediment size in 2023 differed significantly from both 2017 and 2019 (Table 6). Almost all quartiles (i.e., D_{16}, D_{50}, etc.) were coarser in 2023 compared to 2017 and 2019 (Table 7).

Table 5. Geomorphic channel units (GCUs) observed in the area between transects during the 2017, 2019, and 2023 surveys at OCMU001 [SD = standard deviation].

GCU Type	Year	Frequency	Max (%)	Mean (%)	SD (%)
Riffle	2017	0	0	0	0
	2019	1	5	5	–
	2023	2	5	5	0
Run	2017	9	90	68	23
	2019	10	100	88	13
	2023	10	95	78	14
Glide	2017	2	60	48	18
	2019	3	30	27	6
	2023	7	40	21	12
Pool	2017	10	50	28	14
	2019	3	10	8	3
	2023	8	10	9	2
Step	2017	1	20	20	–
	2019	1	10	10	–
	2023	0	0	0	0

Table 6. Difference in ANOVA and post-hoc Tukey test results comparing the 2017, 2019, and 2023 surveys of OCMU001. [mm = millimeters; m = meters].

Measurement	Difference 2023–2019	P-Value	Significance	Difference 2023–2017	P-Value	Significance	Difference 2019–2017	P-Value	Significance
Mean Particle Diameter (mm)	2.42	<0.001	p-value < 0.001	1.23	0.050	p-value < 0.05	−1.19	0.062	not significant
Wetted Width (m)	−0.15	0.916	not significant	0.66	0.214	not significant	0.81	0.103	not significant
Active Channel Width (m)	2.57	<0.001	p-value < 0.001	2.59	<0.001	p-value < 0.001	0.02	0.999	not significant
Minimum Bank Width (m)	2.19	0.015	p-value < 0.05	2.02	0.025	p-value < 0.05	−0.17	0.972	not significant
Channel-full Width (m)	−0.61	0.939	not significant	1.18	0.792	not significant	1.79	0.588	not significant
Thalweg Depth (m)	−0.08	0.132	not significant	−0.14	0.004	p-value < 0.01	−0.06	0.305	not significant
Minimum Bank Height (m)	−0.03	0.969	not significant	−0.01	0.993	not significant	0.01	0.991	not significant
Channel-full Height (m)	−0.01	0.942	not significant	0.04	0.628	not significant	0.05	0.427	not significant
Bank Angle (°)	6.73	0.487	not significant	−5.69	0.597	not significant	−12.41	0.094	not significant
Veg. Cover (%)	−15.68	0.101	not significant	−16.59	0.078	not significant	−0.91	0.992	not significant
Bank Stability Index	−0.07	0.989	not significant	−0.98	0.107	not significant	−0.91	0.143	not significant

Table 7. Particle size distributions of bed sediment (in millimeters [mm]) from the pebble counts conducted during 2017, 2019, and 2023 at OCMU001. The subscripts indicate the percentage of the sample that is smaller than the reported diameter.

Site	Year	n	Min	D_5	D_{16}	D_{50}	Mean	D_{84}	D_{95}	Max
OCMU001	2017	100	0.06	0.06	0.06	4.00	4.54	8.00	11.05	21.00
	2019	100	0.06	0.06	1.00	3.00	3.36	6.00	8.05	11.00
	2023	100	0.06	0.06	2.00	5.50	5.77	9.00	12.00	29.00

The number of pieces of LWD was greater in 2023 (n = 57) than in previous surveys in 2017 (n = 24) and 2019 (n = 49; Table 8). This increase in the number of pieces of LWD led to an increase in the total volume of LWD per channel area from 0.0010 m^3/m^2 in 2017 to 0.0024 m^3/m^2 in 2023. Mean canopy cover in 2023 was much higher than 2017 and 2019 (Table 9). In fact, the minimum canopy cover in 2023 was equal to the mean canopy cover in 2019 (57%). Additionally, the variance (CV) in canopy cover in 2023 was 75% lower than 2019.

Table 8. Summary statistics for the large woody debris measured in 2017, 2019, and 2023 at OCMU001 [m = meters].

Statistic	Year	n	Length (m)	Diameter (m)	Volume (m^3)
Mean	2017	24	2.48	0.21	0.09
	2019	49	2.61	0.18	0.09
	2023	57	2.71	0.18	0.09
Max	2017	24	7.50	0.37	0.24
	2019	49	7.48	0.67	1.45
	2023	57	6.90	0.46	0.85
Standard Deviation (SD)	2017	24	1.75	0.07	0.07
	2019	49	1.40	0.11	0.21
	2023	57	1.44	0.07	0.12
Per Channel Area (m^3/m^2)	2017	24	–	–	0.0010
	2019	49	–	–	0.0021
	2023	57	–	–	0.0024

Table 9. Variability in canopy cover in 2017, 2019, and 2023 at OCMU001. [SD = standard deviation; CV = coefficient of variation].

Site	Year	n	Min (%)	Mean (%)	Max (%)	SD (%)	CV
OCMU001	2017	11	16	58	85	25	0.44
	2019	11	6	57	100	36	0.62
	2023	11	57	75	90	11	0.15

Mean thalweg depth in 2023 was 24% lower than 2019 and 35% lower than 2017 (Table 10). Additionally, the maximum thalweg depth in 2023 was shallower than the mean thalweg depth in 2019. While the difference between mean thalweg depth in 2023 and 2019 was not statistically significant, the difference between the mean thalweg depth in 2023 compared to 2017 was statistically significant (Table 10). Mean thalweg position in the three survey years was similar (Table 10).

Table 10. Reach-scale averaged thalweg conditions in 2017, 2019, and 2023 at OCMU001. [SD = standard deviation; CV = coefficient of variation].

Thalweg	Year	n	Min	Mean	Max	SD	CV
Depth (m)	2017	11	0.21	0.40	0.66	0.14	0.35
	2019	11	0.20	0.34	0.46	0.07	0.21
	2023	11	0.20	0.26	0.32	0.04	0.15
Position (%) [A]	2017	11	5	55	95	35	0.63
	2019	11	5	53	95	40	0.76
	2023	11	5	45	90	31	0.69

[A] Position is percent distance from left active channel bank.

Channel Morphology

Wetted widths were on average wider during 2019 compared to 2017 and 2023 (Table 11). The differences in mean wetted width between survey years were not statistically significant (Table 11). Mean active channel widths were similar in 2017 and 2019 but were approximately 30% wider in 2023 (Table 11). This difference in mean active channel width was statistically significant (Table 11). One more bankfull width was measured in 2019 and 2023 (n = 10) than in 2017 (n = 9; Table 11). Bankfull widths were on average approximately 20% wider in 2023 than 2017 and 2019. Differences in bankfull width were not statistically compared because bankfull features were absent at some transects, limiting comparability among survey years. Mean channel-full width was slightly wider in 2019 compared to 2017 and 2023 (Table 11). The differences in mean channel-full width between the survey years were not statistically significant (Table 11).

Table 11. Reach-scale width characteristics in 2017, 2019, and 2023 at OCMU001. [m = meters; SD = standard deviation; CV = coefficient of variation].

Width	Year	n	Min (m)	Mean (m)	Max (m)	SD (m)	CV
Wetted	2017	11	5.82	7.20	8.67	0.98	0.14
	2019	11	6.30	8.01	9.13	0.88	0.11
	2023	11	6.80	7.86	9.16	0.84	0.11
Active Channel	2017	11	5.82	8.41	11.16	1.37	0.16
	2019	11	6.42	8.43	9.41	0.83	0.10
	2023	11	8.51	11.00	15.13	1.84	0.17

Table 11 (continued). Reach-scale width characteristics in 2017, 2019, and 2023 at OCMU001. [m = meters; SD = standard deviation; CV = coefficient of variation].

Width	Year	n	Min (m)	Mean (m)	Max (m)	SD (m)	CV
Bankfull	2017	9	7.21	10.98	13.25	1.84	0.17
	2019	10	7.87	10.63	12.10	1.26	0.12
	2023	10	9.49	12.98	16.84	2.24	0.17
Channel-Full	2017	11	10.45	18.27	23.01	4.62	0.25
	2019	11	11.91	20.06	25.50	4.06	0.20
	2023	11	12.39	19.45	25.03	3.99	0.21

Mean minimum bank height (lowest bank height on a transect), mean bankfull height, and mean channel-full height were similar in all three survey years (Table 12). The differences in mean channel-full height between the survey years were not statistically significant (Table 12). Variability in all the bank height metrics was low in all three survey years (Table 12).

Table 12. Reach-scale averaged bank heights in 2017, 2019, and 2023 at OCMU001. [m = meters; SD = standard deviation; CV = coefficient of variation].

Height	Year	n	Min (m)	Mean (m)	Max (m)	SD (m)	CV
Minimum Bank Height [A, B] (m)	2017	22	0.77	1.28	1.88	0.31	0.25
	2019	22	0.72	1.29	1.91	0.37	0.28
	2023	22	0.78	1.26	1.77	0.35	0.28
Bankfull Height [A, C] (m)	2017	12	0.77	1.04	1.32	0.18	0.17
	2019	12	0.72	1.00	1.35	0.19	0.20
	2023	12	0.78	0.99	1.24	0.16	0.16
Channel-full Height [A] (m)	2017	22	1.28	1.56	1.88	0.14	0.09
	2019	22	1.42	1.62	1.91	0.11	0.07
	2023	22	1.20	1.60	1.86	0.17	0.11

[A] Above thalweg.

[B] This height refers to the lowest bank height on either side (bankfull or channel-full).

[C] Statistics are based on the transects where the feature is present (reported in “n” field).

One fewer undercut was observed in 2023 compared to 2017 and 2019 (Table 13). The mean horizontal depth of undercut during 2017 and 2023 was much less than in 2019. The vertical height of the undercut observed in 2023 was greater than the undercuts in 2017 and less than one of the 2019 undercuts. Bank angles were on average less steep during 2019 compared to 2017 and 2023 (Table 13). The differences in bank angles between the survey years were not statistically significant (Table 13). Bank vegetation cover in 2023 was less than in 2019 and 2017 (Table 13) though these differences were not statistically significant (Table 13). Mean bank stability scores in all survey years

fell on the lower end of unstable, while the minimum (most stable) scores in all three survey years were classified as “at-risk” (Table 13).

Table 13. Reach-scale averaged bank characteristics in 2017, 2019, and 2023 at OCMU001. [m = meters; SD = standard deviation; CV = coefficient of variation].

Bank Characteristic	Year	n	Min (m)	Mean (m)	Max (m)	SD (m)	CV
Bank Undercut (horizontal depth [m]) [A]	2017	2	0.05	0.10	0.14	0.06	0.67
	2019	2	0.08	0.52	0.95	0.62	1.19
	2023	1	0.14	0.14	0.14	–	–
Bank Undercut (vertical height [m]) [A]	2017	2	0.33	0.40	0.47	0.10	0.25
	2019	2	0.68	1.19	1.69	0.71	0.60
	2023	1	0.95	0.95	0.95	–	–
Bank Angle (°)	2017	22	23	49	85	20	0.41
	2019	22	12	36	61	13	0.35
	2023	22	4	43	85	24	0.55
Vegetation Cover (%)	2017	22	10	58	100	30	0.51
	2019	22	20	57	90	20	0.36
	2023	22	0	41	90	24	0.59
Bank Stability [B]	2017	22	9	12	15	2	0.15
	2019	22	10	12	14	1	0.10
	2023	22	10	12	14	2	0.13

[A] Statistics are based on the transects where feature is present (reported in “n” field).

[B] Bank stability score rankings: 4–7 stable; 8–10 at-risk; 11–15 unstable; and 16–22 very unstable.

Detailed Transects

The detailed transects were surveyed on T1 (BM1; Figure 7), T6 (BM2; Figure 8), and T11 (BM3; Figure 9). Average bankfull area increased by 12% from 2019 to 2023 and increased by 36% since 2017 (Table 14). This increase in bankfull area was driven by a 34% increase in mean bankfull width since 2017. There was only a minor (approximately 1%) increase in channel-full area from 2019 to 2023 (Table 14). Overall, the mean channel-full area has increased by 23% since 2017.

Water surface slope (longitudinal profile) for this section of Walnut Creek was approximately 18% lower in 2023 compared to 2019 (Figure 10; Table 14). Unlike previous surveys, in 2023 there were no steps in the bed of the stream creating small increases in slope. Additionally, the results of the longitudinal profile survey show the effects of reach-wide aggradation (Figure 10). The reach is relatively straight, and sinuosity did not change appreciably since 2019 (Table 14).

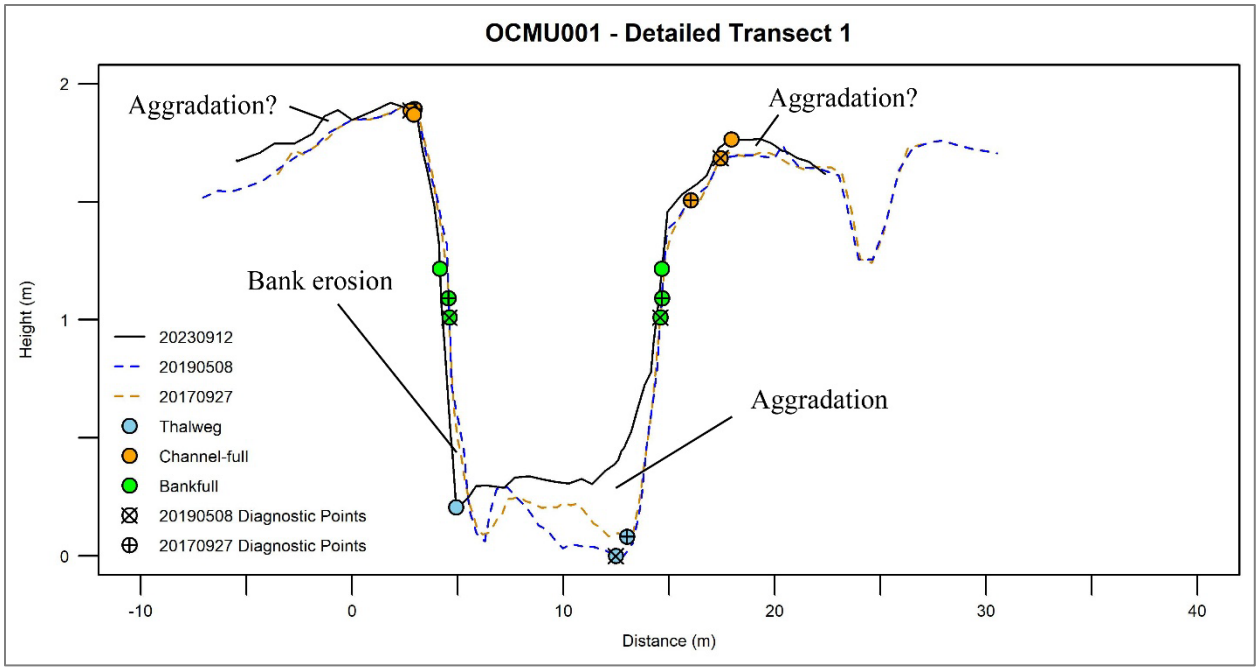


Figure 7. Differences between 2017, 2019, and 2023 surveys of detailed transect 1 (T1) at OCMU001. The view is in the downstream direction.

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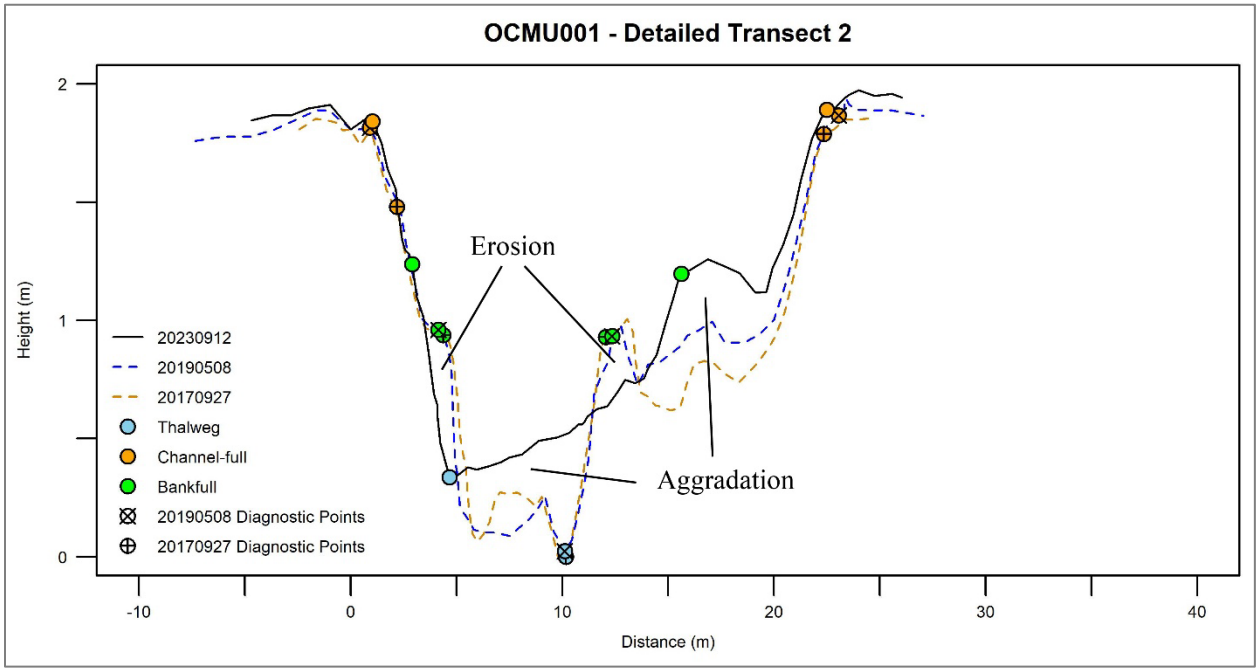


Figure 8. Differences between 2017, 2019, and 2023 surveys of detailed transect 2 (T6) at OCMU001. The view is in the downstream direction.

NPS / SECN

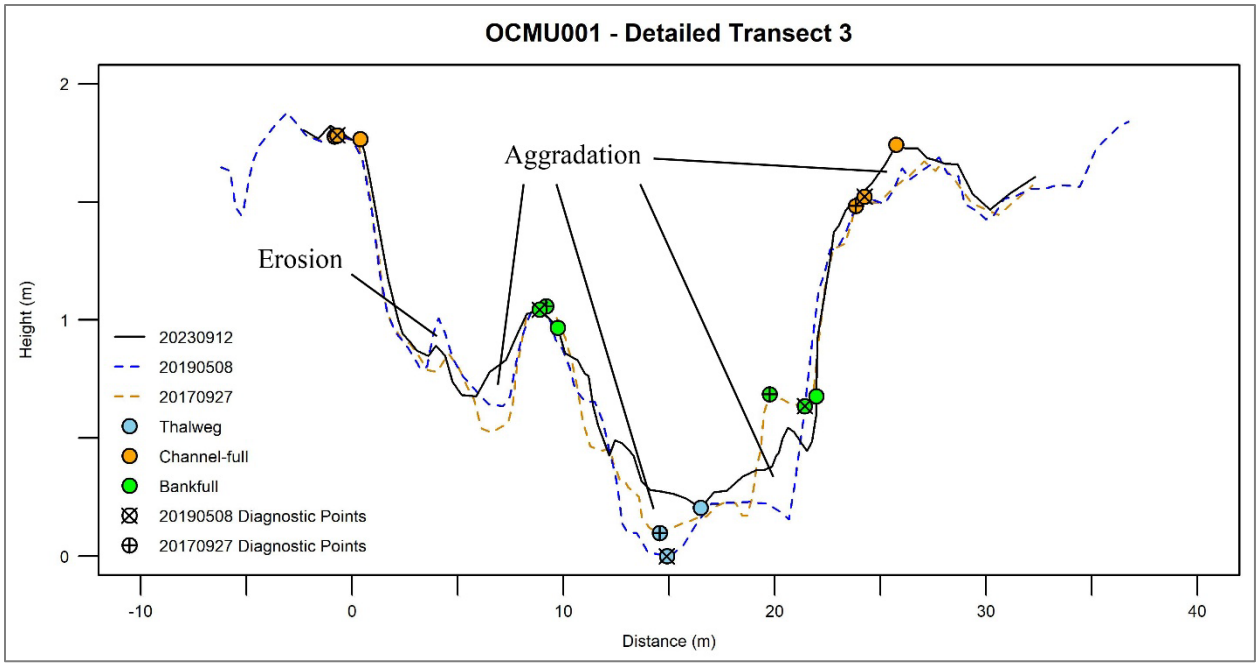


Figure 9. Differences between 2017, 2019, and 2023 surveys of detailed transect 3 (T11) at OCMU001. The view is in the downstream direction.

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Table 14. Comparison of 2017, 2019, and 2023 average detailed transect characteristics at OCMU001 [m = meters].

Site	Year	n [A]	Slope	Sinuosity	n [B]	Bankfull Area (m^2)	Bankfull Width (m)	Bankfull Height (m)	Channel-full Area (m^2)	Channel-full Width (m)	Channel-full Height (m)
OCMU001	2017	11	0.0018	1.15	3	4.46	8.27	0.69	16.03	18.11	1.43
	2019	11	0.0017	1.04	3	5.40	8.91	0.78	19.54	19.63	1.67
	2023	13	0.0014	1.07	3	6.05	11.12	0.75	19.67	20.37	1.53
Difference	2017–2019	–	0.0001	0.10	–	−0.94	−0.63	−0.10	−3.51	−1.52	−0.24
	2019–2023	–	0.0003	−0.03	–	−0.65	−2.21	0.03	−0.13	−0.74	0.13
	2017–2023	–	0.0004	0.07	–	−1.59	−2.85	−0.07	−3.64	−2.26	−0.10

[A] Number of measurements taken for slope and sinuosity.

[B] Number of measurements taken for bankfull and channel-full area, width, and height.

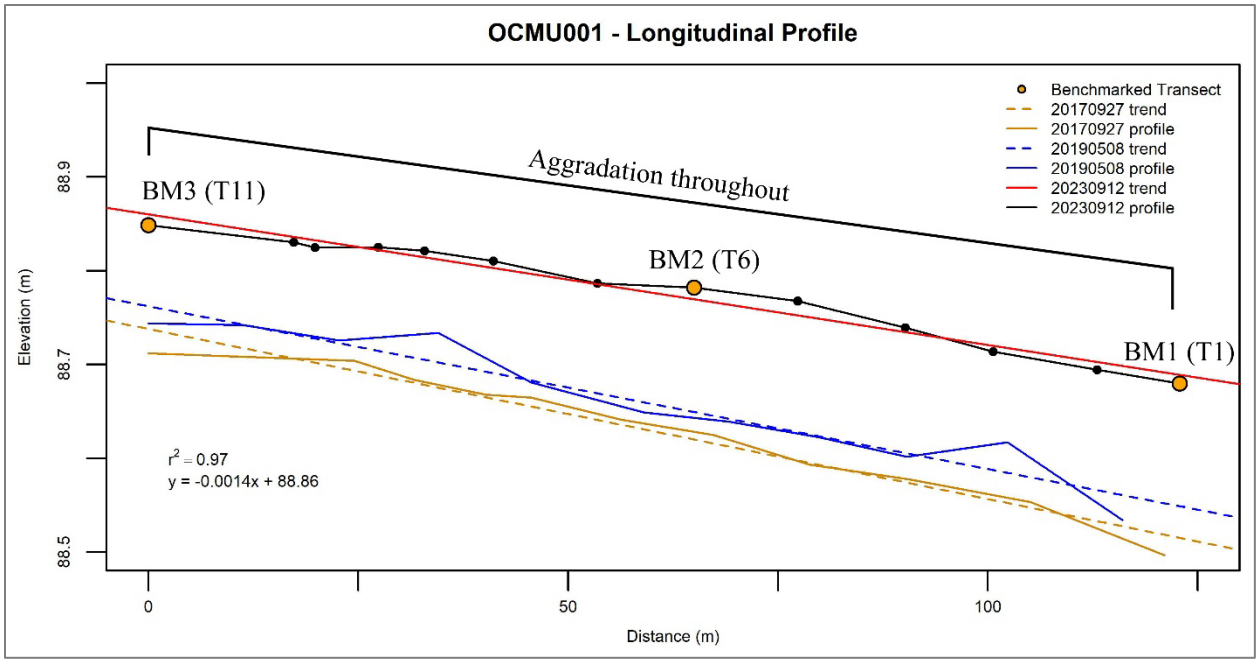


Figure 10. Longitudinal profile for OCMU001. The red line on the graph corresponds to the slope of the reach in 2023 (0.0014 m/m). The r^2 value describes the strength of the 2023 trend line (interpreted slope). The "T#" in parentheses indicates the standard transect number on which the detailed transects were surveyed.

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Detailed transect 1 (T1) continues to be entrenched and no bankfull surfaces were identified (Figure 7). For changes in bankfull morphology to be calculated, average bankfull height from the 2019 survey was used to estimate bankfull cross-sectional area and bankfull width. Bankfull cross-sectional area on detailed transect 1 in 2023 was similar to 2017 and 4% larger than 2019 (Table 15). The bed on detailed transect 1 (T1) has aggraded substantially since 2019 and the thalweg has migrated to river left (Figure 7). Channel-full area on detailed transect 1 decreased by approximately 4% since 2019 though channel-full area was 16% greater in 2023 compared to 2017 (Table 15). In addition to the aggradation observed on the bed of channel, it appears there has been some aggradation of the out-of-channel area on both sides of the channel.

Table 15. Changes to cross-sectional characteristics on detailed transect 1 at OCMU001 [m = meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	8.48	10.11	1.01
	2019	8.13	9.98	1.01
	2023	8.43	10.50	1.01
Change	2017–2019	0.36	0.13	0.00
	2019–2023	−0.30	−0.52	0.00
	2017–2023	0.06	−0.40	0.00

Table 15 (continued). Changes to cross-sectional characteristics on detailed transect 1 at OCMU001 [m = meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Channel-full	2017	12.94	12.04	1.43
	2019	15.67	13.89	1.68
	2023	14.97	14.71	1.56
Change	2017–2019	−2.73	−1.85	−0.26
	2019–2023	0.71	−0.82	0.13
	2017–2023	−2.02	−2.67	−0.13

Bankfull cross-sectional area on detailed transect 2 (T6) increased by 73% from 2019 to 2023 and 152% from 2017 to 2023 (Table 16). These changes to bankfull area were associated with erosion of the small "bankfull" surface on river left and the small natural levee that had developed on river right. These changes were slightly offset by substantial aggradation of the channel bed but erosion of the banks on both sides of the channel caused bankfull width to increase by 76% since 2019. In addition to bed aggradation, a large amount of sediment was deposited on river right along the bank to form a new bankfull surface. Though there was a substantial increase in bankfull area on detailed transect 2, channel-full area decreased by 11% from 2019 to 2023. This decrease is due to the aggradation observed within the channel and on the newly formed bankfull surface.

Table 16. Changes to cross-sectional characteristics on detailed transect 2 at OCMU001.

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	2.56	6.38	0.62
	2019	3.73	6.89	0.70
	2023	6.45	12.23	0.78
Change	2017–2019	−1.17	−0.51	−0.08
	2019–2023	−2.72	−5.34	−0.08
	2017–2023	−3.89	−5.85	−0.16
Channel-full	2017	15.76	19.34	1.48
	2019	21.98	21.56	1.79
	2023	19.65	21.13	1.50
Change	2017–2019	−6.22	−2.21	−0.31
	2019–2023	2.32	0.43	0.29
	2017–2023	−3.89	−1.79	−0.02

Bankfull cross-sectional area on detailed transect 3 (T11) decreased by 25% from 2019 to 2023 though bankfull cross-sectional area was still 40% larger in 2023 compared to 2017 (Table 17). This reduction in bankfull area was due to bed aggradation on both sides of the channel (Figure 10). On the other hand, channel-full area on detailed transect 3 increased by ~16% from 2019 to 2023 and

~26% from 2017 to 2023 (Table 17). This increase in channel-full area was caused by aggradation on the river right bank top which led to an increase in channel-full height and width. Though there was some aggradation in the bank channel portion of the river left floodplain, some of this area was also eroded between 2019 and 2023 (Figure 11).

Table 17. Changes to cross-sectional characteristics on detailed transect 3 at OCMU001 [m = meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	2.34	8.34	0.43
	2019	4.34	9.86	0.64
	2023	3.27	10.63	0.47
Change	2017–2019	−2.00	−1.52	−0.21
	2019–2023	1.07	−0.78	0.16
	2017–2023	−0.93	−2.30	−0.05
Channel-full	2017	19.38	22.94	1.38
	2019	20.97	23.45	1.52
	2023	24.39	25.28	1.54
Change	2017–2019	−1.59	−0.51	−0.14
	2019–2023	−3.42	−1.83	−0.01
	2017–2023	−5.01	−2.34	−0.15

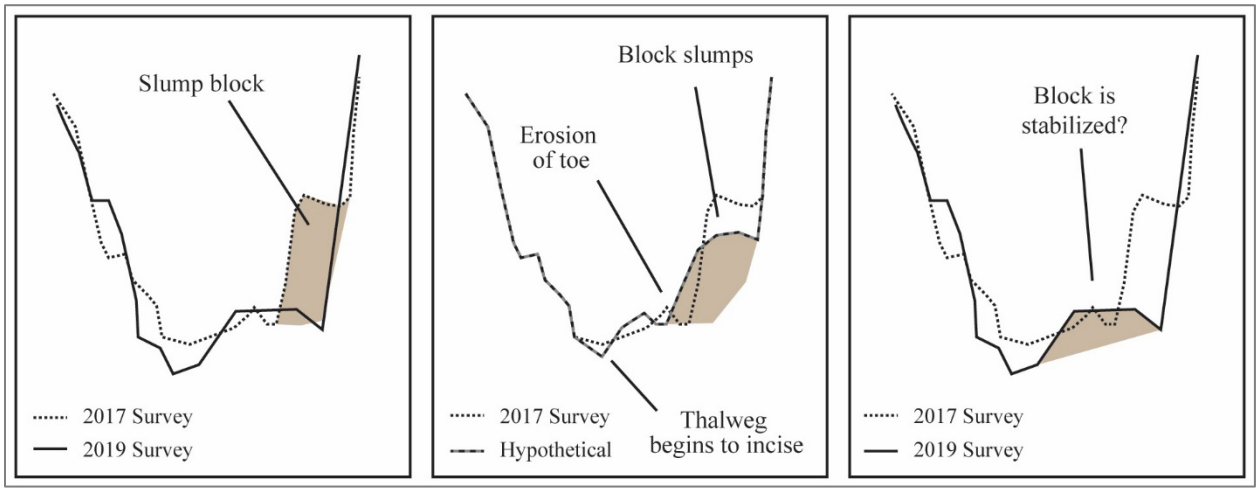


Figure 11. Hypothesized process by which the "floodplain" surface on detailed transect 3 (T11) slumped into the channel and contributed to thalweg incision.

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Implications and Synthesis of Results

The reach surveyed on Walnut Creek (OCMU001) is within 100 meters (328 ft) of a social trail with a treefall (downed tree) on it since at least 2019. Even if visitors make it past the treefall, visitors are not expected to interact with the stream along the surveyed reach (no obvious trails down to the stream). In-stream habitat did not change substantially from 2019 to 2023 (Table 5). The reach is still covered mostly in run habitat but unlike 2019, there was an increase in the frequency of glide and pool habitats as well as one additional riffle habitat (though the overall percentage of glides and pools are still much lower in 2023). Bed material was statistically significantly coarser in 2023 compared to both 2017 and 2019 (Table 6). In addition to the changes observed in the frequency of GCUs and mean diameter of bed sediment, the number of pieces of LWD and volume of LWD per channel area increased in 2023 (Table 8).

The abundance of LWD and the coarsening of bed material are positive benthic macroinvertebrate habitat attributes, yet the lack of habitat heterogeneity continues to be a negative driver of macroinvertebrate biodiversity (Allan and Castillo 2007). Additionally, as identified by Cooper et al. (2019), while bed sediment has gotten coarser, the high amount of sandy and fine sediment that make up the bed material suggests bed sediment is highly mobile which puts further stress on any benthic organisms. Due to increases in LWD, the coarsening of bed material, and the slight increase in the heterogeneity of GCUs, OCMU001's in-stream habitat classification was upgraded from "poor" to "poor-to-fair." As mentioned earlier, this classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at Ocmulgee Mounds National Historical Park. Unlike in 2019, the additional sediment supplied to the reach did create a substantial change in bed elevation (due to aggradation). Due to the large amount of sediment deposited within the reach, it is unlikely changes that occurred will be undone by the next survey. While an additional survey is needed to determine if there is a trend of aggradation slowly filling up the channel, it seems likely considering the changes observed from 2017 to 2019 and 2019 to 2023.

There were a few interesting reach-scale morphologic changes that occurred along OCMU001 between 2019 and 2023. Changes observed in active channel width were statistically significant and bankfull width increased by 20%. These changes were due to erosion of the elevated entrenched surface between T4 and T7 on river right. Additionally, erosion of the elevated entrenched surface on river left upstream of T7 contributed to the increases in active channel width and bankfull width. These changes to active channel width and bankfull width show how unstable the elevated entrenched surfaces can be. While the elevated entrenched surface on river left only had grasses growing on it, the surface on river right had small trees growing on it before it was eroded away. This occurrence shows the major difference between Walnut Creek at OCMU001 and the other Appalachian Piedmont-type streams monitored by the Southeast Coast Network (e.g., at HOBE, KEMO, and CHAT). The high percentage of sand supplied to OCMU001 can lead to large and sudden changes in the morphology of these upper Coastal Plain streams.

The major morphological changes observed within the reach included reach-wide bed aggradation, erosion of the elevated entrenched areas on river right between T4 and T7, and aggradation of the out-of-channel area on all three of the detailed transects. While there was very little change on detailed transects 1 and 3 (besides the bed aggradation), detailed transect 2 had a substantial change. Nearly the entire front half of the floodplain surface on river right was lost between 2019 and 2023 on detailed transect 2. Deposition of LWD on the upstream side of this surface may provide increased resistance to future change and could act as sediment trap to allow this surface to grow upstream while protecting the surface that remains. It is uncertain whether the floodplain surface was gradually eroded or if a single high flow event (or multiple events in quick succession) caused the surface to become fully saturated allowing the surface to become detached from the bank and move downstream as a more solid plug of sediment.

The longitudinal profile shows the large amount of sediment deposited within the reach since 2019 (Figure 10). The bed of the stream aggraded approximately 0.10 meters (0.33 ft) along the entire reach between 2019 and 2023. Additional areas of aggradation were observed on the higher "historical terrace" surfaces of each of the detailed cross-sections (Figures 7–9). The bed aggradation and areas of aggradation on the "historical terrace," coupled with the loss of the floodplain, suggest a large event (or events) influenced the reach. An analysis of the storms between each of the surveys may help elucidate the size of storm needed to influence the "historical terrace" along this reach.

The highly mobile and dynamic nature of sediment within this reach was observed during the 2019 (second) survey. In 2019, the evidence of highly mobile sediment included floodplain aggradation on detailed transects 2 (T6) and 3 (T11) and an overall shallowing of average thalweg depth within the reach (Bateman McDonald 2020). Filling in the glides and pools observed in 2017 and general aggradation of the bed since that first survey coupled with the complex hydrologic regime (explained in the next paragraph) may indicate this reach is becoming filled in and an upstream avulsion may occur.

In the baseline report, Cooper et al. (2019) identified the reach's complex hydrologic regime and the size of this stream does not reflect the size of its watershed. The reach on Walnut Creek is approximately the same size as the reach surveyed on Haw Creek (CHAT001) at Chattahoochee River National Recreation Area yet OCMU001's watershed is 27 times larger than Haw Creek's watershed (Cooper and Bateman McDonald 2025). Cooper et al. (2019) identified the likely reason for Walnut Creek's relatively small size. It appears most of the stormflow into the park and underneath the railroad bridge gets diverted into a powerline cut just upstream of OCMU001 during large storm events. One of the 2023 surveyors (C. Stephen Cooper) walked to the location where Walnut Creek enters the power line easement and found a wide sandy ephemeral channel running down the power line cut. An estimate by Mr. Cooper suggests the surface this ephemeral channel flows over is at a similar height above Walnut Creek as the "historical terrace" on OCMU001. In addition to the storm analysis suggested above, a rapid geomorphic assessment of channel bed conditions between the powerline cut and OCMU001 coupled with a quick survey of channel bank conditions leading into the powerline cut will help determine whether an avulsive event is likely.

There were no immediate management concerns identified by this survey. A few follow-up visits and an additional analysis (proposed above) should provide much-needed context to help determine how Ocmulgee Mounds National Historical Park is likely to change in the next few years.

Conclusion

Walnut Creek's watershed at OCMU001 has low slope/relief and is covered mostly by forest and agricultural pasture. The major defining characteristics of the reach are the presence of floodplains (though they were greatly altered between 2019 and 2023), lack of riffle habitat, and homogeneous channel slope throughout the reach. In-stream habitat did not change substantially from 2019 to 2023. In 2019 and 2023, only a few non-run habitats were identified within the reach. Additionally, thalweg depth continued to get shallower in 2023. Bed material was statistically significantly coarser in 2023 compared to 2017 and 2019, though the sediment was mostly sand. In addition to the continued shallowing of the thalweg, there was also substantial aggradation on the floodplain and out-of-channel areas surrounding the reach as well as reach-wide aggradation of the bed. These changes indicate a substantial amount of sediment is being supplied to the reach. As mentioned in 2019, if this increased sediment supply continues, there could be substantial changes to the reach that are difficult to predict given the complex hydrologic conditions that affect the reach.

Due to increases in LWD, the coarsening of bed material, and the slight increase in the heterogeneity of GCUs, OCMU001's in-stream habitat classification was upgraded from "poor" to "poor-to-fair." This classification is a generalized interpretation of in-stream habitat and additional work is needed to determine how flow (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect biodiversity and stream health at Ocmulgee Mounds National Historical Park. The additional sediment supplied to the reach created a substantial change in bed elevation (due to aggradation). Due to the large amount of sediment deposited within the reach, it is unlikely changes that occurred will be undone by the next survey. While an additional survey is needed to determine if there is a trend of aggradation slowly filling up the channel, it seems likely considering the changes observed from 2017 to 2019 and 2019 to 2023.

The major morphological changes observed within the reach included reach-wide bed aggradation, erosion of the floodplain areas on river right between T4 and T7, and aggradation of the out-of-channel area on all three detailed transects. While there was little change on detailed transects 1 and 3 (besides the bed aggradation), detailed transect 2 had a substantial change. Nearly the entire front half of the floodplain surface on river right was lost between 2019 and 2023. Deposition of LWD on the upstream side of this surface may provide increased resistance to future change and could act as a sediment trap to allow this surface to grow upstream while protecting the surface that remains. The bed of the stream aggraded approximately 0.10 meters (.33 ft) along the reach between 2019 and 2023. Additional areas of aggradation were observed on the higher "historical terrace" surfaces of each of the detailed cross-sections. The bed aggradation and areas of aggradation on the "historical terrace," coupled with the loss of the floodplain, suggest a large event (or events) influenced the reach. An analysis of the storms between each of the surveys may help elucidate the size of storm needed to influence the "historical terrace" along this reach.

Though there were substantial changes to the reach, there were no immediate management concerns identified by this survey. A few follow-up visits and an additional analysis (proposed above) should provide much-needed context to determine how the park is likely to change in the next few years.

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Appendix A. Explanation of Variables

Table 18 contains information about the variables collected using the SECN Wadeable Stream Habitat Monitoring Protocol.

Table 18. Definitions of the variables used in this report.

Variable	Variable Scale	Description
Drainage Area	Basin	The topographical area to which precipitation, sediment, and dissolved constituents are funneled to a common outlet point along a given stream channel (Dunne and Leopold 1978).
Total Stream Length	Basin	The sum of the length of perennial streams within a watershed.
Drainage Density	Basin	The ratio of total stream length to drainage area.
Basin Length	Basin	The length of the line that bisects a watershed running from outlet to drainage divide.
Basin Shape	Basin	Drainage area divided by basin length squared (Horton 1932).
Average Watershed Slope	Basin	Within watershed, average of the slope values of each pixel of a digital elevation model.
Standard Deviation of Slope	Basin	Within watershed, standard deviation of the slope values of each pixel of a digital elevation model.
Basin Relief	Basin	Within watershed, maximum elevation minus minimum elevation.
Standard Deviation of Elevation	Basin	The standard deviation of elevation within a watershed.
Basin Relief Ratio	Basin	A ratio calculated by dividing basin relief by basin length.
Entire Stream Gradient	Basin	The difference in elevation at 85% and 10% of the main stem stream length divided by the stream length between the two points (Fitzpatrick et al. 1998).
Segment Gradient	Basin	The difference in elevation between the upstream extent of the stream segment and the downstream extent of the stream segment, divided by the length of the stream segment.
Strahler Stream Order	Basin	A stream ordering system where order increases when two orders of the same magnitude join.
Bifurcation Ratio	Basin	The ratio of streams in a given Strahler order to streams in the next highest order (e.g., number of first order streams/number of second order streams).
Land Use/Land Cover	Basin	Land use/land cover is derived from the NLCD dataset.
Geomorphic Channel Units	Reach	Geomorphic channel units are a way to classify in-channel habitat (e.g., riffles and pools).
Large Woody Debris	Reach	Pieces of woody material that have a diameter greater than 0.1 m and are 1 m or longer.

[A] collected at each standard transect (11 measurements).

[B] calculated at each detailed transect (3 per reach) using survey data collected using a total station.

Table 18 (continued). Definitions of the variables used in this report.

Variable	Variable Scale	Description
Pebble Count	Reach	The size and distribution of 100 particles (pebble count) from a representative riffle (Wolman 1954).
Canopy Closure	Reach [A]	The average of four measurements (looking upstream, downstream, and at each bank) taken using a spherical densiometer.
Reach Sinuosity	Reach	Sinuosity is calculated by dividing reach length by valley length.
Longitudinal Profile	Reach	The gradient of the line that connects the tops of the steps and riffles within a reach (channel slope).
Wetted Width	Transect [A]	Wetted channel width is measured where water is flowing (including undercuts).
Active Channel Width	Transect [A]	Active channel width is measured to the beginning of vegetation within the stream channel.
Bankfull Width	Transect [A, B]	Bankfull widths should only be measured if there is a floodplain (or incipient floodplain) present.
Bankfull Height	Transect [A, B]	The height of the channel bank where a floodplain is present.
Bankfull Area	Transect [B]	The cross-sectional area of a stream channel at bankfull stage (height) measured perpendicular to flow.
Bankfull Perimeter	Transect [B]	The length of the contact between the stream of flowing water and its containing channel, measured at a section perpendicular to streamflow at bankfull discharge.
Bankfull Hydraulic Radius	Transect [B]	A measure of hydraulic efficiency defined by the ratio between bankfull area and bankfull perimeter.
Channel-full Width	Transect [A, B]	Channel-full widths are measured from the top of the lowest bank that is not a floodplain.
Channel-full Height	Transect [A, B]	The height of the channel bank where a floodplain is not present (channel-full height is also measured where a floodplain is inset within an entrenched channel).
Channel-full Area	Transect [B]	The cross-sectional area of a stream channel at bankfull stage measured perpendicular to flow.
Channel-full Perimeter	Transect [B]	The length of the contact between the stream of flowing water and its containing channel, measured at a section perpendicular to streamflow at channel-full discharge.
Channel-full Hydraulic Radius	Transect [B]	A measure of hydraulic efficiency defined by the ratio between channel-full area and channel-full perimeter.
Thalweg Position	Transect [A]	The position of the thalweg as a percent distance of the wetted width from left water's edge.
Thalweg Depth	Transect [A]	The greatest depth of water along a transect.
Dominant Particle Size	Transect [A]	A visual estimate of the dominant sediment size along a transect.
Dominant Habitat	Transect [A]	A visual estimate of the dominant geomorphic channel unit along a transect.

[A] collected at each standard transect (11 measurements).

[B] calculated at each detailed transect (3 per reach) using survey data collected using a total station.

Table 18 (continued). Definitions of the variables used in this report.

Variable	Variable Scale	Description
In-channel Features	Transect [A]	A description of the in-channel features (e.g., bars or islands) that are present along a transect.
Floodplain Width	Transect [A]	The width(s) of floodplain(s) present along rivers left and/or right.
Bank Undercut	Transect [A]	Where the bank overhangs the channel due to lateral erosion at the base of the bank.
Bank Angle	Transect [A]	The dominant bank angle from active channel boundary to the top of the bank.
Bank Sediment	Transect [A]	The dominant sediment composition of the channel banks.
Bank Erosion	Transect [A]	The presence of and type of erosion (e.g., lateral or slump) that is observed on the channel banks.
Bank Cover	Transect [A]	A visual estimate of the percent of the channel banks that has vegetative cover.

[A] collected at each standard transect (11 measurements).

[B] calculated at each detailed transect (3 per reach) using survey data collected using a total station.

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Appendix B. Survey Results for OCMU001

Figures 12 through 59 and Tables 19 through 25 show survey sites and results.

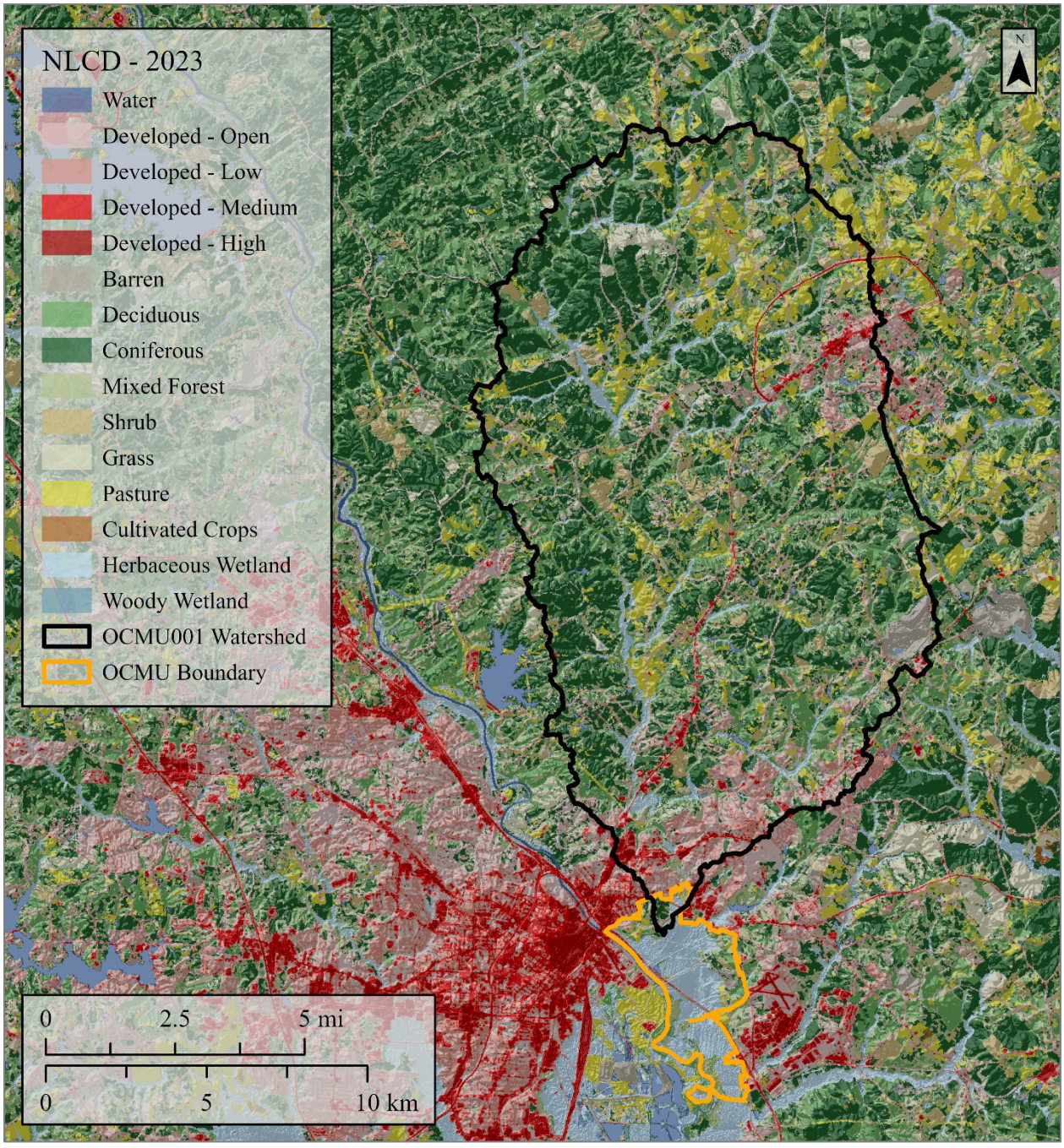


Figure 12. Map showing the watershed draining to OCMU001 at Ocmulgee Mounds National Historical Park. The land use/land cover (NLCD 2011 in Homer et al. 2015), road network (U.S. Census Bureau 2011), and perennial streams (derived from a 10-meter [32.8 ft] digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown.

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Figure 13. OCMU001 looking upstream from T1 (detailed transect 1).
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Figure 14. OCMU001 looking downstream on T1 (detailed transect 1).
NPS / SECN



Figure 15. OCMU001 looking at the left bank on T1 (detailed transect 1).
NPS / SECN



Figure 16. OCMU001 looking at the right bank on T1 (detailed transect 1).
NPS / SECN



Figure 17. OCMU001 looking upstream from T2.
NPS / SECN



Figure 18. OCMU001 looking downstream on T2.
NPS / SECN



Figure 19. OCMU001 looking at the left bank on T2.
NPS / SECN



Figure 20. OCMU001 looking at the right bank on T2.
NPS / SECN



Figure 21. OCMU001 looking upstream from T3.
NPS / SECN



Figure 22. OCMU001 looking downstream on T3.
NPS / SECN



Figure 23. OCMU001 looking at the left bank on T3.
NPS / SECN



Figure 24. OCMU001 looking at the right bank on T3.
NPS / SECN



Figure 25. OCMU001 looking upstream from T4.
NPS / SECN



Figure 26. OCMU001 looking downstream on T4.
NPS / SECN



Figure 27. OCMU001 looking at the left bank on T4.
NPS / SECN



Figure 28. OCMU001 looking at the right bank on T4.
NPS / SECN



Figure 29. OCMU001 looking upstream from T5.
NPS / SECN



Figure 30. OCMU001 looking downstream on T5.
NPS / SECN



Figure 31. OCMU001 looking at the left bank on T5.
NPS / SECN



Figure 32. OCMU001 looking at the right bank on T5.
NPS / SECN



Figure 33. OCMU001 looking upstream on T6 (detailed transect 2).
NPS / SECN



Figure 34. OCMU001 looking downstream on T6 (detailed transect 2).
NPS / SECN



Figure 35. OCMU001 looking at the left bank on T6 (detailed transect 2).
NPS / SECN



Figure 36. OCMU001 looking at the right bank on T6 (detailed transect 2).
NPS / SECN



Figure 37. OCMU001 looking upstream from T7.
NPS / SECN



Figure 38. OCMU001 looking downstream on T7.
NPS / SECN



Figure 39. OCMU001 looking at the left bank on T7.
NPS / SECN



Figure 40. OCMU001 looking at the right bank on T7.
NPS / SECN



Figure 41. OCMU001 looking upstream from T8.
NPS / SECN



Figure 42. OCMU001 looking downstream on T8.
NPS / SECN



Figure 43. OCMU001 looking at the left bank on T8.
NPS / SECN



Figure 44. OCMU001 looking at the right bank on T8.
NPS / SECN



Figure 45. OCMU001 looking upstream from T9.
NPS / SECN



Figure 46. OCMU001 looking downstream on T9.
NPS / SECN



Figure 47. OCMU001 looking at the left bank on T9.
NPS / SECN



Figure 48. OCMU001 looking at the right bank on T9.
NPS / SECN



Figure 49. OCMU001 looking upstream from T10.
NPS / SECN



Figure 50. OCMU001 looking downstream on T10.
NPS / SECN



Figure 51. OCMU001 looking at the left bank on T10.
NPS / SECN



Figure 52. OCMU001 looking at the right bank on T10.
NPS / SECN



Figure 53. OCMU001 looking upstream on T11 (detailed transect 3).
NPS / SECN



Figure 54. OCMU001 looking downstream on T11 (detailed transect 3).
NPS / SECN



Figure 55. OCMU001 looking at the left bank on T11 (detailed transect 3).
NPS / SECN



Figure 56. OCMU001 looking at the right bank on T11 (detailed transect 3).
NPS / SECN

Table 19. Geomorphic channel units (GCU) observed in the area between transects at OCMU001. [SD = standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1–2	0	90	0	10	0
2–3	5	85	0	10	0
3–4	5	80	10	5	0
4–5	0	95	0	5	0
5–6	0	80	10	10	0
6–7	0	90	10	0	0
7–8	0	70	20	10	0
8–9	0	75	25	0	0
9–10	0	60	30	10	0
10–11	0	50	40	10	0

Table 19 (continued). Geomorphic channel units (GCU) observed in the area between transects at OCMU001. [SD = standard deviation].

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
Frequency	2	10	7	8	0
Max (%)	5	95	40	10	0
Mean (%)	1	78	15	7	0
Median (%)	0	80	10	10	0
SD (%)	2	14	14	4	0

Table 20. Characteristics of the large woody debris observed at OCMU001 [m = meters].

LWD ID	Length (m)	Diameter (m)	Volume (m^3)	Transect Interval	Function	Position
1	1.16	0.18	0.03	10	None	Jam
2	2.52	0.24	0.11	10	Organic Trap, Jam	Jam
3	3.35	0.10	0.03	10	Organic Trap, Jam	Jam
4	1.95	0.20	0.06	10	Organic Trap, Jam	Jam
5	2.09	0.14	0.03	10	Jam	Jam
6	1.51	0.12	0.02	10	Jam	Jam
7	2.19	0.11	0.02	10	Bank Protection	Jam
8	4.39	0.16	0.09	10	Bank Protection	Jam
9	2.72	0.20	0.09	10	Bank Protection	Jam
10	1.56	0.19	0.04	10	Organic Trap, Jam	Jam
11	2.39	0.18	0.06	10	None	Jam
12	1.71	0.12	0.02	10	Bank Protection	Jam
13	1.58	0.21	0.05	10	Jam	Jam
14	1.40	0.19	0.04	10	Jam	Jam
15	1.57	0.29	0.10	10	Organic Trap, Jam	Jam
16	1.60	0.13	0.02	10	None	Buried
17	1.51	0.13	0.02	10	None	Free
18	5.17	0.20	0.16	10	None	Free
19	1.26	0.18	0.03	10	None	Free
20	2.19	0.24	0.10	10	None	Free
21	1.29	0.18	0.03	9	None	Buried
22	4.61	0.21	0.16	9	Jam	Jam
23	2.03	0.17	0.05	9	Jam	Jam
24	1.46	0.11	0.01	8	None	Buried
25	3.31	0.16	0.07	8	Jam	Ramp
26	4.32	0.17	0.10	8	None	Free

Table 20 (continued). Characteristics of the large woody debris observed at OCMU001 [m = meters].

LWD ID	Length (m)	Diameter (m)	Volume (m3)	Transect Interval	Function	Position
27	2.86	0.12	0.03	7	None	Free
28	6.34	0.25	0.31	7	None	Free
29	4.00	0.26	0.21	7	Bank Protection, Organic Trap	Jam
30	1.62	0.19	0.05	7	Bank Protection, Organic Trap	Jam
31	2.08	0.15	0.04	7	Bank Protection, Organic Trap	Jam
32	5.12	0.46	0.85	7	Organic Trap	Jam
33	2.07	0.22	0.08	7	Organic Trap, Jam	Jam
34	5.07	0.13	0.07	6	None	Free
35	2.23	0.15	0.04	6	None	Free
36	3.23	0.21	0.11	6	Organic Trap	Jam
37	4.11	0.15	0.07	6	None	Free
38	3.15	0.16	0.06	6	None	Free
39	6.61	0.14	0.10	5	Organic Trap	Buried
40	2.31	0.10	0.02	5	None	Free
41	6.90	0.21	0.24	4	None	Free
42	1.15	0.26	0.06	4	Organic Trap	Jam
43	2.26	0.42	0.31	4	Organic Trap	Jam
44	2.33	0.12	0.03	4	Organic Trap	Jam
45	1.44	0.11	0.01	4	Organic Trap	Jam
46	2.62	0.15	0.05	4	Sediment Trap	Buried
47	1.12	0.14	0.02	4	Sediment Trap, Jam	Buried
48	3.96	0.25	0.19	3	Jam, Organic Trap	Buried
49	2.06	0.11	0.02	3	Jam	Jam
50	1.84	0.12	0.02	3	Jam	Jam
51	2.98	0.29	0.20	3	Jam, Organic Trap	Jam
52	3.01	0.13	0.04	3	Jam, Organic Trap	Jam
53	1.86	0.20	0.06	2	Pool Formation	Buried
54	4.11	0.21	0.14	1	Organic Trap, Sediment Trap	Buried
55	1.99	0.24	0.09	1	Bank Protection	Jam
56	1.20	0.14	0.02	1	Bank Protection	Buried
57	1.81	0.12	0.02	1	Jam, Organic Trap	Buried

Table 21. Variability of canopy cover observed at OCMU001. [CV = coefficient of variation; SD = standard deviation].

Transect	Canopy Cover (%)
1	85
2	90
3	84
4	84
5	87
6	69
7	69
8	68
9	68
10	57
11	60
Min (%)	57
Max (%)	90
Mean (%)	75
Median (%)	69
SD (%)	11
CV	0.15

Table 22. Average reach-scale bank characteristics at OCMU001. [m = meters; L = left bank; R = right bank; SD = standard deviation; CV = coefficient of variation].

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)	SD (L)	SD (R)	CV (L)	CV (R)
Bank Height [A] (m)	11	11	0.78	0.86	1.77	1.65	1.31	1.22	1.16	1.24	0.43	0.26	0.33	0.22
Bankfull Height [A, B] (m)	6	6	0.78	0.86	1.16	1.24	0.95	1.04	0.96	0.98	0.15	0.16	0.16	0.16
Channel-full Height [A, B] (m)	11	11	1.47	1.20	1.86	1.70	1.70	1.50	1.72	1.52	0.11	0.17	0.06	0.11
Water Depth at Base [C] (m)	11	11	−0.29	−0.31	0.15	0.03	−0.07	−0.15	0.00	−0.20	0.14	0.13	–	–
Bank Undercut [B] (m)	1	0	0.14	0.00	0.14	0.00	0.14	–	0.14	–	–	–	–	–
Bank Angle (°)	11	11	17	4	85	73	50	36	37	34	27	19	0.54	0.53
Vegetation Cover (%)	11	11	20	0	80	90	48	34	50	30	19	27	0.40	0.79
Bank Stability [D]	11	11	At-Risk	At-Risk	Unstable	Unstable	Unstable	Unstable	Unstable	Unstable	1.43	1.45	0.13	0.12

[A] Above thalweg.

[B] Statistics are based on the transects where feature is present.

[C] A negative number indicates base of bank is above the water surface.

[D] See Table 1 for explanation of scores.

Table 23. Cross-sectional characteristics for detailed transect 1 at OCMU001 [m = meters].

Type	Area (m2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	8.43	11.23	0.75	10.50	1.01	10.40
Channel-full	14.97	15.73	0.95	14.71	1.56	9.44
Ratio	1.78	1.40	1.27	1.40	1.54	0.91

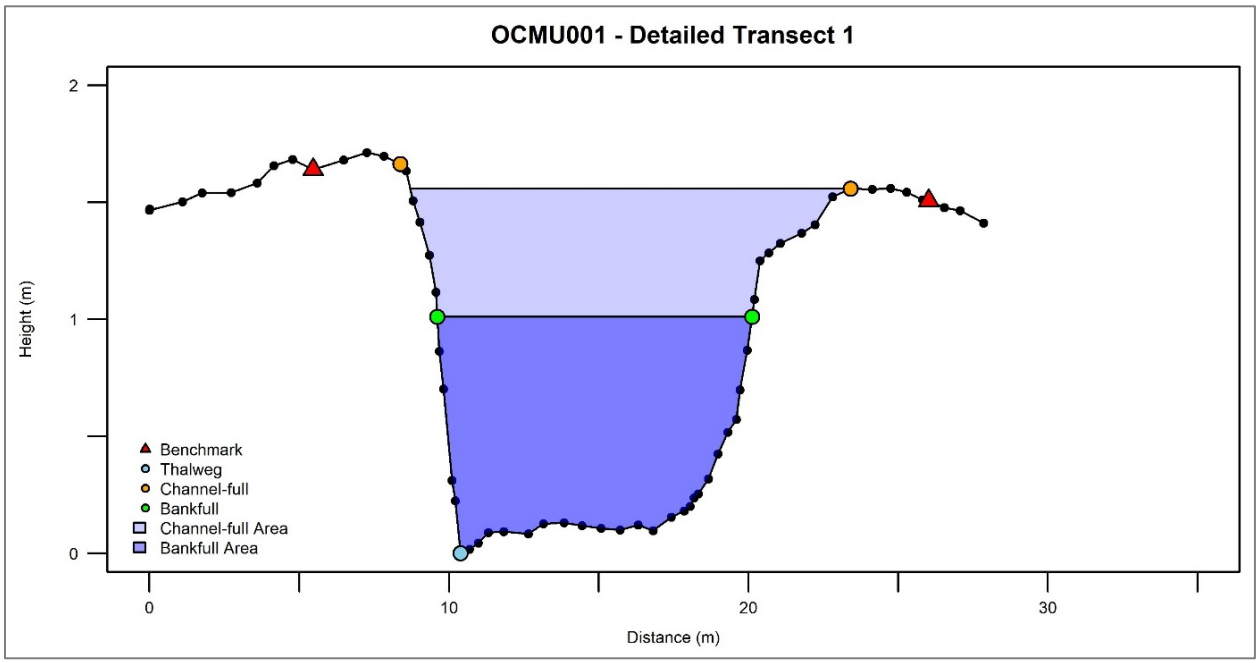


Figure 57. Detailed transect 1 at OCMU001. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Additionally, the channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue). If no bankfull surfaces were present at the cross-section, bankfull area was interpolated by determining hydraulic radius when the water surface is at the reach averaged bankfull height above thalweg.

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Table 24. Cross-sectional characteristics for detailed transect 2 at OCMU001 [m = meters].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	6.45	12.51	0.52	12.23	0.78	15.68
Channel-full	19.65	21.70	0.91	21.13	1.50	14.05
Ratio	3.05	1.73	1.76	1.73	1.93	0.90

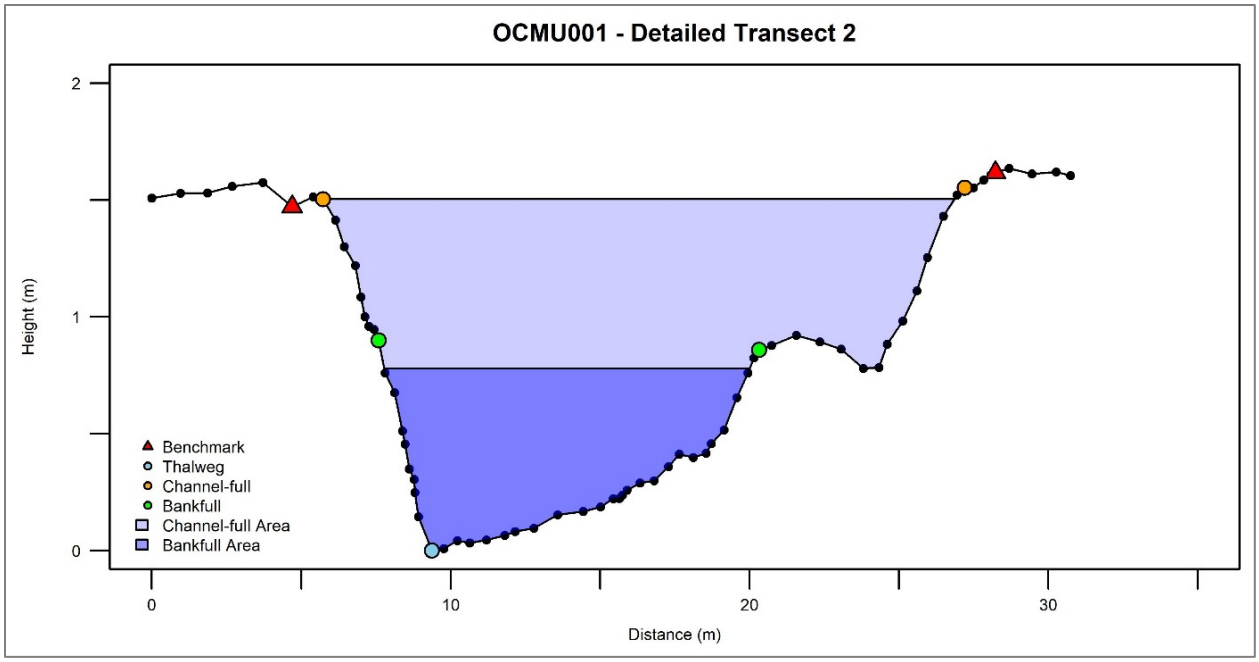


Figure 58. Detailed transect 2 at OCMU001. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue). When bankfull height above thalweg was greater than the lowest out-of-channel surface (LooC), bankfull area was interpolated using LooC height to determine the hydraulic radius at this height.

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Table 25. Cross-sectional characteristics for detailed transect 3 at OCMU001 [m = meters].

Type	Area (m^2)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
Bankfull	3.27	10.84	0.30	10.63	0.47	22.54
Channel-full	24.39	26.09	0.93	25.28	1.54	16.45
Ratio	7.45	2.41	3.09	2.38	3.26	0.73

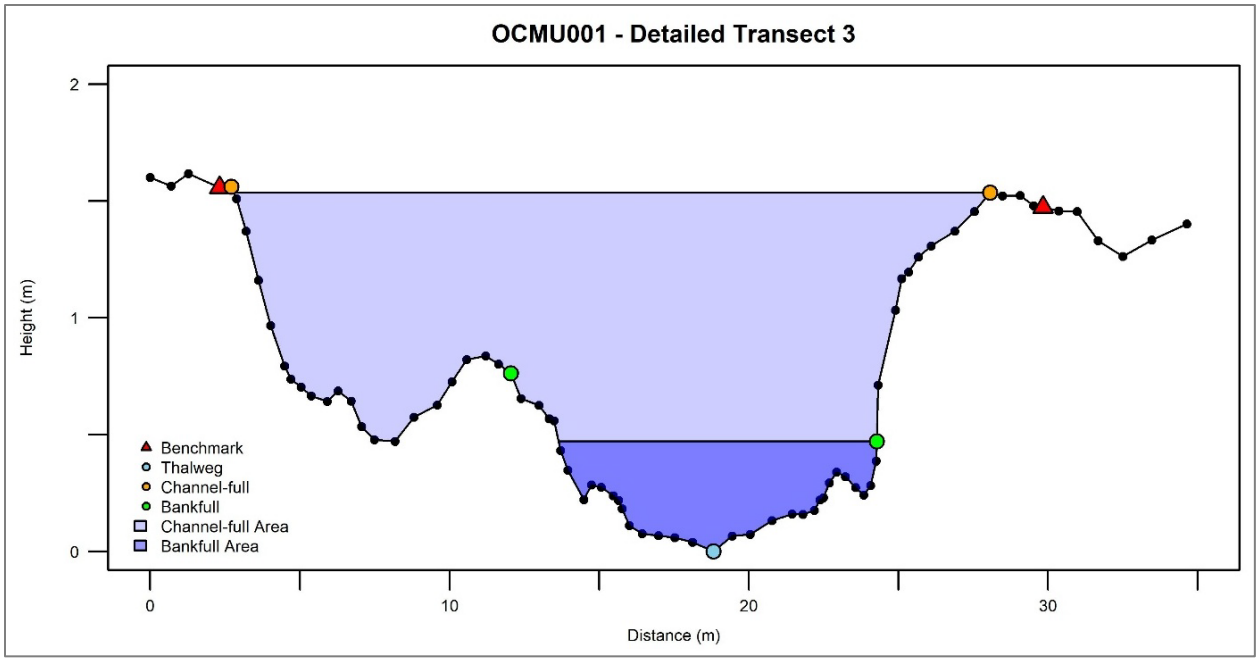


Figure 59. Detailed transect 3 at OCMU001. The surveyed locations of the left and right benchmarks, channel-full bank-tops, and interpreted bankfull bank height are shown on the figure. Channel-full (light blue) and bankfull (dark blue) cross-sectional areas are also included (channel-full cross-sectional area equals light blue plus dark blue). When bankfull height above thalweg was greater than the lowest out-of-channel surface (LooC), bankfull area was interpolated using LooC height to determine the hydraulic radius at this height.

NPS / SECN

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