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Wadeable Stream Habitat Monitoring at Chattahoochee River National Recreation Area

2021 Change Report



Looking upstream at the monitored reach on Long Island Creek (CHAT001) at Chattahoochee River National Recreation Area on May 4, 2021.

NPS

Wadeable stream habitat monitoring at Chattahoochee River National Recreation Area: 2021 change report

Science Report NPS/SR—2025/263

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Abstract

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. Streams chosen for assessment were specifically targeted for management interest or to provide a context for similar-sized stream(s) within the park. This report describes the status and trends of in-stream and riparian habitat conditions in 13 wadeable stream reaches at Chattahoochee River National Recreation Area (CHAT) between two survey periods (2017 and 2021).

In-stream habitats were primarily characterized by high-energy conditions, dominated by riffles and runs. A decline in pool habitat was observed in many reaches, reducing habitat complexity and limiting aquatic organism diversity. Additionally, fine sediment deposition was noted in several reaches, which negatively impacts aquatic life and water quality. Large woody debris (LWD) played a crucial role in creating diverse habitats and stabilizing streambanks. However, LWD dynamics, including recruitment and retention, varied among reaches.

Geomorphic processes, such as bank erosion, channel incision, and knickpoint migration, were evident in many reaches. These processes were linked to historical land use practices and ongoing disturbances, such as urbanization and altered hydrology. All the monitored stream reaches are recovering from a legacy of poor land use and responding to varying amounts of impervious surface cover in their watersheds. The streams at Chattahoochee River National Recreation Area display characteristics of streams in Stage III (widening via bank slumping) or Stage IV (aggradation and planform adjustment) of stream evolution (Schumm et al. 1984) as they work to establish a new equilibrium following the above-mentioned land use impacts.

Management concerns included trail erosion, mass wasting, infrastructure damage from treefalls, and sediment delivery from adjacent hillslopes. Trail erosion can degrade visitor experiences and increase maintenance costs. Treefalls have contributed entire trees to one stream channel, and while LWD is beneficial for habitat, entire mature trees may pose risks to downstream infrastructure, particularly if mobilized during high-flow events. Sediment delivery from hillslope upstream erosion can degrade water quality, smother benthic organisms, and fill in pools.

Continued monitoring and potential management interventions, such as LWD placement, bank stabilization, and sediment source control, may be necessary to mitigate these issues and maintain the ecological integrity of these valuable stream ecosystems. Further research on flow regime and macroinvertebrate community structure is necessary to better understand how these streams and associated habitat are changing through time.

List of Acronyms

ANOVA: Analysis of variance

B: Sand/gravel bar

Be: Bench

Bf: Bankfull

BM: Benchmark

Bo: Boulder

Br: Bedrock

BSi: Bank stability index

C: Cobble bar

CHAT: Chattahoochee National Recreation Area

Cl: Clay bar

CONG: Congaree National Park

CV: Coefficient of variation

DEM: Digital elevation model

EES: Elevated entrenched surface

FP: Floodplain

FPM: Floodplain margin

GCU: Geomorphic channel unit

GIS: Geographic information system

Gl: Glide

HOBE: Horseshoe Bend National Military Park

Is: Vegetated island

KEMO: Kennesaw Mountain National Battlefield Park

LWD: Large woody debris

LT: Low terrace

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 Inventory and Monitoring Network

Sl: Slump

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 with insight into the status of and trends in stream and near-channel habitat conditions (McDonald et al. 2018a). Wadeable stream assessments are implemented at five SECN inland parks with wadeable streams. These parks include Horseshoe Bend National Military Park, Kennesaw Mountain National Battlefield, 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 or 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.

In 2017, (June 8–16) data were collected at Chattahoochee National Recreation Area (CHAT) to characterize the in-stream and riparian habitat of 14 stream reaches (CHAT001–CHAT014). These data, along with the analysis of remotely-sensed geographic information system (GIS) data, are presented in a baseline report (McDonald et al. 2019) that describes and compares the watershed-, reach-, and transect-scale characteristics of the surveyed reaches. Thirteen of these streams were resurveyed in 2021 (May 6–13) to determine the amount of change that has occurred on each reach (CHAT007 was excluded due to safety concerns described herein). This report compares the results of the 2021 resurveys to the initial 2017 baseline surveys.

Basin Characteristics

The watersheds draining to the surveyed stream reaches at Chattahoochee River NRA range from small, mostly forested first-order watersheds to large, mostly developed third-order watersheds. Based on the geomorphic and land cover characteristics of the watersheds, five of the watersheds likely have a flashy flow regime (first-order: CHAT003; second-order: CHAT004 and CHAT011; third-order: CHAT001 and CHAT013), five watersheds likely have a moderately flashy flow regime (first-order: CHAT002 and CHAT009; second-order: CHAT005, CHAT008, and CHAT010) and the remaining three watersheds (first-order: CHAT006 and CHAT012, second-order: CHAT014) likely have less flashy flow regimes. Stream gage data are needed to confirm these interpretations of each watershed's flow regime. Additionally, it should be noted that these inferred flow regimes should not be interpreted as positive or negative. More research is needed to understand the ecological impacts of each stream's flow regime.

Habitat Characteristics

Based on bed sediment and geomorphic channel units (GCU), in-stream habitat for 10 of the reaches was classified as high energy (first-order: CHAT002, CHAT003, CHAT009, and CHAT012; second-order: all excluding CHAT014; third-order: CHAT001). The habitat for one third-order reach (CHAT013) was classified as moderate energy and the habitat for two reaches was classified as low energy (first-order: CHAT006; second-order: CHAT014). A common change observed in the majority of the monitored reaches was a loss of pool habitat which coincided with increases in run and/or glide habitat. Another change was that mean bed sediment was observed to have coarsened in most reaches while the lowest bed sediment size classes included more fine sediment. More research is necessary to determine the permanence of these fine sediments within the stream. If fine sediment deposition is episodic and related to large events, then habitat may shift back from mostly run or glide to pools as the fines are winnowed from the reach by subsequent smaller events.

Generally, when present, large woody debris (LWD) were important for step and pool creation and thereby increasing the diversity of in-stream habitat. Given the high energy and flashy classification of most of the reaches, LWD serves to dissipate energy and trap additional organic material and sediment that would otherwise be transported downstream. Based on the GCUs, bed sediment, and LWD characteristics of the surveyed streams, in-stream habitat classifications (scale of "good" to "poor") did not change for the majority (9 out of 13) of the reaches. Three reaches were downgraded: 1) CHAT002 from "good" to "fair to good;" CHAT004 from "good" to "fair to good;" and CHAT013 from "fair to good" to "fair." In-stream habitat classifications were downgraded due to a fining of the lower size classes in the pebble count data and a general homogenization of GCU within each reach to one dominated by run habitat. One reach (CHAT011) was upgraded from "fair to good" to "good" due to a reduction in the amount of run habitat within the reach, a coarsening of pebble count results, and a large increase in LWD per channel area.

Overall, in subsequent surveys, habitat classification for each reach may improve if: (1) there is an increase in stable (non-mobile) in-channel (non-bridging) LWD, (2) there is a reduction in the amount of fine sediment delivered to the reach, and/or (3) habitat (GCU) diversity increases. Conversely, habitat may degrade if: (1) LWD is transported out of the reach, (2) there is an increase in the amount of fine sediment added to and stored within the bed of the stream, and/or (3) habitat diversity decreases due to the previous two mechanisms.

Geomorphic Characteristics

All the reaches are recovering from a legacy of poor land use and responding to varying amounts of impervious surface cover in their watersheds. In general, streams at Chattahoochee River NRA display characteristics of streams in Stage III (widening via bank slumping) or Stage IV (aggradation and planform adjustment) of stream evolution (Schumm et al. 1984) as they work to establish a new equilibrium following the above-mentioned land use impacts. Bank undercutting and slumping was observed at all the streams at Chattahoochee River NRA. In the larger streams, slump blocks (e.g., the portions of bank that slumped in the channel) are usually eroded and the sediment is transported downstream. In the smaller streams, and lower energy portions of the larger streams, these slump blocks can become sediment sinks if they become stabilized (i.e., by vegetation). These stabilized slump blocks are referred to herein as elevated entrenched surfaces and were observed at or near the bankfull level of each of the monitored reaches excluding the lower energy streams (CHAT006 and

CHAT014). Six of the 13 streams are (or will soon be) impacted by the headward migration of a knickpoint (four first-order and two second-order streams). Where resistant bed material is lacking, knickpoints (defined as abrupt increases in stream slope) are often associated with stream bed incision.

Management Concern

Out of the 13 streams surveyed, three have potential management concerns (CHAT012, CHAT013, and CHAT014). Cabin Creek (CHAT012) and Long Island Creek (CHAT013) are eroding into a trail along the stream. Trail erosion at CHAT012 is a concern but will not be a great hazard to visitors once the trail fails (banks are relatively low). The bank at CHAT013 is relatively high (greater than 1.5 meters [4.9 feet {ft}]) and bank failure will create hazardous conditions along this section of trail. Since the 2017 surveys, a social trail developed allowing visitors to navigate farther from the eroding trail at CHAT013. Erosion rates for both stream reaches have yet to be determined. A significant tree fall occurred at the upper section of the reach at CHAT013 recruiting whole trees to the stream. Some of these pieces of large wood could potentially become a threat to downstream infrastructure (such as the bridge across Long Island Creek near the Whitewater parking lot) if these pieces are transported that far downstream. At CHAT014, fine sediments and sands are being eroded from a large hillslope approximately 50 meters (164 ft) from the river right bank along the monitored reach. This sediment buried one of the SECN benchmarks and sandy sediments are likely being contributed to the stream.

The following bullet points are intended to provide park managers with a brief description of each wadeable stream reach surveyed at Chattahoochee River NRA during 2021 regarding: (1) watershed characteristics (i.e., land use land cover, slope, and relief); (2) in-stream habitat conditions (i.e., high versus low energy GCUs, bed material, prevalence of LWD); (3) how the habitat was classified (i.e., "good," "fair to good," "fair," "fair to poor," or "poor") based on professional judgement of diversity of GCUs, LWD content, and bed material; and (4) general channel condition (i.e., bank conditions, degree of entrenchment, presence of knickpoints, or planform changes).

Headwater Streams (First-Order)

CHAT002—"Undercut Creek"

- Steep and forested watershed with no change in LULC since 2016 (Dewitz 2023)
- High energy in-stream habitat, loss of pools since 2017. Bed material coarsened in the larger size classes, but fine sediments were observed with more frequency than in 2017. LWD volume remained high
- Habitat downgraded to "fair to good"
- Flood chute on river left had become more prominent and channel incision was observed in the bottom of the reach, below where the flood chute rejoins the stream channel.
- Downstream knickpoint

CHAT003—"Steep Draw Creek"

- Steep and forested watershed with no change in LULC since 2017 surveys (Dewitz 2023)
- Very high energy habitat (riffle/run), and loss of pools since 2017. Coarse bed sediment (little change from 2017), introduction of fine sediments. Lower amount and volume of LWD
- Habitat classification remains "fair"
- Entrenched, bank slumping observed. Channel widening in the downstream portion of the reach.
- Downstream knickpoint

CHAT006—"Three Mind Creek"

- Watershed has relatively low slope and relief and a high amount of development (No change in watershed characteristics since 2017)
- Habitat shifted to majority run (loss of riffles and pools). Bed sediment slightly coarsened, with fining in the smallest size classes. Large increase in LWD volume due to tree fall event.
- Habitat remains classified as "poor"
- Significant channel aggradation was observed in the downstream portion of the reach related to the development of a downstream LWD jam since 2017. If this jam is blown out it is likely that the bed infill will erode, and the lower portion of the reach will again become entrenched.
- Lateral migration of the stream channel on river left was observed on the farthest upstream transect.

CHAT009—Fox Creek

- Watershed has relatively low slope and relief and is mostly forested (No change in LULC since 2016)
- Pool habitat was lost to the development of riffles and runs. Bed sediment coarsened, though fine sediments were observed. Increase in LWD volume.
- Habitat remains classified as "fair"
- Extensive slumping, the development of elevated entrenched surfaces, and channel incision were observed within the reach.

CHAT012—Cabin Creek

- Steep and forested watershed, but slight increase in development within the watershed since 2016 (Dewitz 2023).
- Pool habitat lost to increases in runs and riffles, bed sediment slightly coarser and fines introduced. Increase in LWD volume.
- Habitat remains classified as "fair"

- Channel incision was observed within the reach.
- Incoming drainage from the trail on river left caused bank slumping and the development of an elevated entrenched surface, which further threatens to erode the trail.

Medium-Sized (Second-Order) Streams

CHAT004—Crayfish Creek

- Steep and developed watershed. Slight loss of forest cover to development within the watershed since 2016 (Dewitz 2023).
- Mixture of GCUs, pools converted to runs and glides. Bed material slightly coarsened with some fine sediments deposited in the reach. Decrease in LWD volume.
- Habitat downgraded to "fair to good"
- Very entrenched and widening of active channel due to the development of a large cobble bar in the downstream portion of the reach.
- Extensive bank slumping and the development of elevated entrenched surfaces.
- Stream restoration effort was implemented just downstream of the monitored reach prior to the 2021 surveys and may influence the reach by the third surveys in 2024.

CHAT005—"Egg Creek"

- Steep and forested watershed (no change in LULC since 2016)
- Mixture of GCUs, pools converted to runs and glides. Bed sediment coarser in the smaller size classes, but no significant change. Increase in LWD volume.
- Habitat remains classified as "fair"
- Channel incision and widening was observed (loss of bars).
- Loss of downstream LWD step led to headward migration of a knickpoint which caused channel incision in the lower portion of the reach.

CHAT008—Mulberry Creek

- The watershed has average slope and relief (compared to the other reach watersheds) and is mostly covered by development (no change in LULC since 2016)
- Mixture of GCUs with increases in riffle, run, and glide as pools were lost. Bed sediment was significantly coarser. LWD volume more than doubled since 2017.
- Habitat remains classified as "good"
- Channel widening at the active channel level due to bar development
- Channel incision observed in the upstream portion of the reach and bank slumping (development of elevated entrenched surfaces) observed.

CHAT010—"Beaver Creek"

- The watershed has average slope and relief (compared to the other reach watersheds) and is mostly covered by development with slight increase in development (and concurrent loss of forest cover) since 2016 (Dewitz 2023).
- Deep pools were converted to glides and runs, bed sediment significantly coarser, and relatively large increases in the amount and volume of LWD within the reach
- Habitat remains classified as "good"
- The stream has multiple elevated entrenched surfaces inset within the higher-level terrace. The presence of these surfaces led to changes in the interpretation of bankfull. Additionally, the active channel was wider.
- Less measured change relative to other 2nd order streams, though some bank slumping was observed.

CHAT011—Gunby Creek

- The watershed has average slope and relief and is mostly covered by development (no change LULC since 2016)
- Increase in small pools and run converted to glide. Bed material slightly coarsened though some fine sediments were observed. Large increase in LWD frequency and volume (none were observed in 2017)
- Habitat classification upgraded to "good"
- Channel aggradation was observed in the middle portion of the reach while incision was observed in the lower portion.
- Bank slumping and the development of elevated entrenched surfaces was observed in the lower half of the reach.

CHAT014—Whitewater Creek

- The watershed has average slope and relief and is mostly covered by development (no change in watershed characteristics since 2017)
- Pool habitat decreased as both glide and run increased. Bed sediment slightly coarsened but is very fine relative to other 2nd order streams
- Habitat remains classified as "poor"
- Major changes in the interpretation of bankfull and channel full levels occurred as evidence of overbank flooding was observed on the surface that was classified as terrace in 2017.
- Little change observed in channel morphology outside of the changes in the interpretation of bankfull.
- Fine sediment and sand had been deposited on the river right floodplain from erosion of a steep hillslope. This erosion is a likely source of the fine-grained bed sediments observed.

Larger-Sized (Third-Order) Streams

CHAT001—Haw Creek

- The watershed has average slope and relief and is mostly covered by development, slight increase in the intensity of development within the watershed since 2016 (Dewitz 2023)
- Mixture of GCUs, increase in riffle run and glide while pools were smaller. Coarse bed sediment though fining occurred in the lower size classes. Decreased LWD volume
- Habitat remains classified as "fair to good"
- Significant channel widening was observed at the wetted, active channel, and channel full levels.
- The reach is influenced by bank slumping and a large amount of bank loss was observed on the river left side of the channel in the lower portion of the reach
- Cobble island in the middle portion of the reach (which continued developing since 2017) created two thread channel and increased habitat diversity

CHAT013—Long Island Creek

- The watershed has average slope and relief and is mostly covered by development (no change in LULC since 2017)
- Riffle and pool habitat lost since 2017, mostly run in 2021. Fine bed sediment relative to other 3rd order streams and fine sediments were introduced to the reach. Significant amount of LWD
- Habitat classification downgraded to "fair"
- Channel widening was observed in the upper portion of the reach due to erosion and slumping of the river left bank
- A major tree fall event significantly contributed to the erosion of the river left bank and may cause further erosion as the channel adapts to an influx of large pieces of wood
- The large wood contributed by this tree fall event could potentially threaten infrastructure (bridge across Long Island Creek near the Whitewater parking lot) if it is mobilized downstream
- The stream is eroding into a hiking trail on river right, which may also be exacerbated by the changes in the channel caused by the tree fall event

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 collected through this monitoring effort provide park staff with information regarding the physical linkage between streams and park resources.

Additionally, this monitoring program provides early warnings of changing conditions that may negatively affect visitor experiences and/or park infrastructure.

Wadeable stream monitoring is currently implemented at five SECN inland parks with wadeable streams. These parks include Horseshoe Bend National Military Park (HOBE) in Alabama, Kennesaw Mountain National Battlefield (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 NMP, Kennesaw Mountain NBP, and Chattahoochee River NRA are typical Appalachian Piedmont streams that are beginning to re-equilibrate to their modern flow and sediment regimes following poor land use practices of the late 19th and early 20th centuries (McDonald 2019, McDonald and Starkey 2018a, and 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 NHP are a mixture of Appalachian Piedmont and Coastal Plain type streams (McDonald and Starkey 2018d). 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 SECN stream habitat monitoring protocol are to:

- Determine 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 the purposes of 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 landscapes such as the Appalachian Piedmont.

The objectives of this report are to:

- Present the wadeable stream surveys completed at Chattahoochee River NRA during late spring 2021,
- Provide a comparison of the 2021 results to the 2017 "baseline" surveys,
- Describe the processes likely responsible for differences between the two surveys at each monitored reach,
- Explain why theses streams are changing and their potential trajectories of change, and
- Identify potential resource management concerns and suggest management strategies within the Resist, Accept, Direct (RAD; Lynch et al. 2021) decision-making framework.

Study Area

The hydro-climatic conditions of the study area are characterized as humid subtropical with average annual rainfall around 50 inches per year (127 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 27°F (−3°C) to a high in August of 92°F (33°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 various states of alteration that reflect multiple legacies of anthropogenic disturbance (James 2018). Beginning in the late 1800s, deforestation, increased row crop agriculture, and a 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, 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 (Schoonover et al. 2007; Mukudan et al. 2011).

In addition to the legacy effects of agriculture, many Appalachian Piedmont streams (including those draining to and through the park) have been further subjected to hydrologic alterations caused by urban/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 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). These stages include aggradation (receiving more sediment than 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).

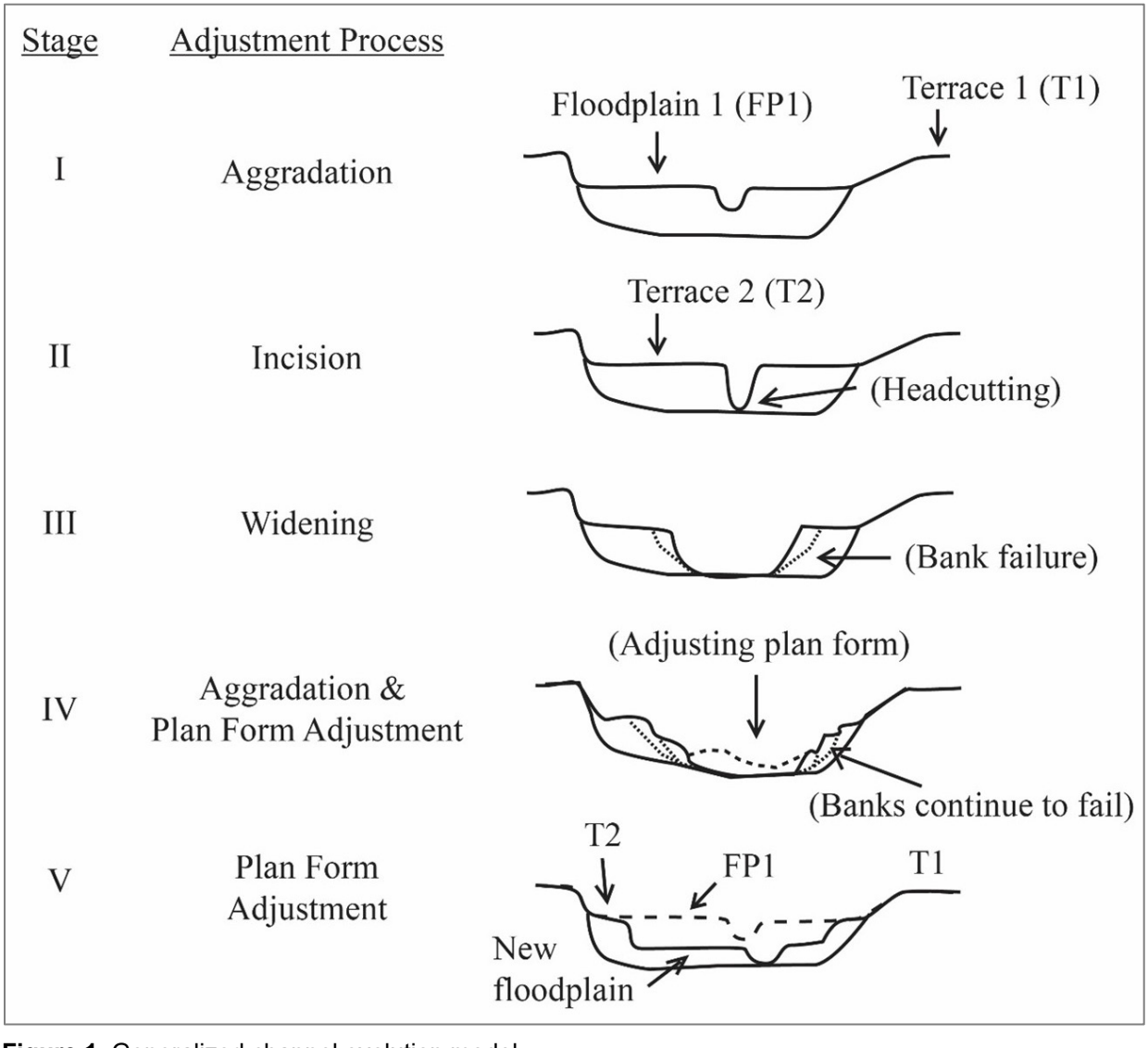


Figure 1. Generalized channel evolution model.
MODIFIED FROM SCHUMM ET AL. 1984

Chattahoochee National Recreation Area (CHAT)

The Chattahoochee River National Recreation Area covers 6,800 acres (2,752 hectares [ha]) of mixed pine/hardwood forests and wetlands buffering 48 miles (77.2 kilometers [km]) of the Chattahoochee River (Figure 2). The park consists of 16 non-contiguous management units stretching from Buford Dam to north Atlanta, Georgia, the Southeast's largest metropolitan area (U.S. Census Bureau 2010). The Chattahoochee River is utilized for recreation, power generation, as a water supply, and for wastewater assimilation for the greater metropolitan Atlanta area. This section of the Chattahoochee River is highly regulated by flows from Buford Dam, which was completed in 1957. Chattahoochee River NRA offers green space and water-based recreational opportunities for the Atlanta metropolitan area and was designated as America's first official National Water Trail in 2012.

The Upper Chattahoochee River's position in a relatively stable fault zone has resulted in a long and narrow watershed (Burkholder et al. 2010). Many small tributaries feed the mainstem along the Chattahoochee River NRA-authorized area. Flow alteration associated with the impoundment and release of water for power generation has a pronounced effect on the flow patterns of the Chattahoochee River and its tributaries. The majority of the tributaries flowing through CHAT management units are small, lower-order (first- to third-order) streams heavily impacted by the direct and indirect effects of urbanization. Changes in the watersheds outside and upstream of the park have led to higher peak flows and lower base flow in the streams that run through the park (Gregory et al. 2012; Starkey 2015). These altered stormflow regimes potentially threaten park infrastructure (e.g., parking lots, bridges, and trails) due to increased channel instability. Stormwater discharges from the urban areas that feed into park streams also impact water quality by increasing the temperature, turbidity, and bacterial and heavy metal loads. Stream habitat and water quality are also influenced by utility rights-of-way that commonly cross the wadeable and non-wadeable streams in the park. Within the park, stream bank conditions are often impacted by visitors using bicycle and foot trails.

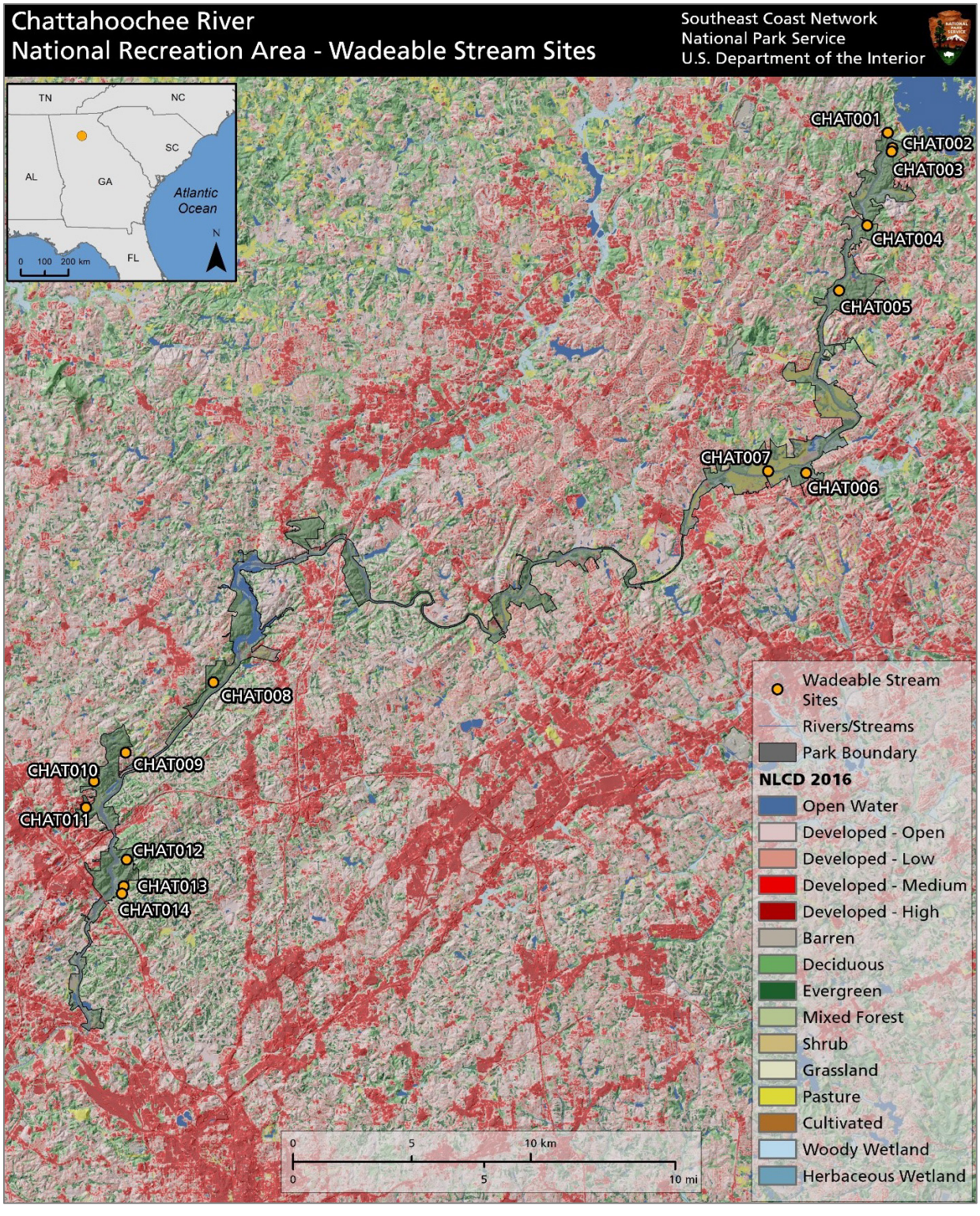


Figure 2. Map showing Chattahoochee National Recreation Area and its wadeable stream reaches (CHAT001–CHAT014). Land use/land cover (NLCD 2016 dataset; Dewitz 2023) and perennial streams (derived from a 10 meter [32.8 ft] digital elevation model; data available from the U.S. Geological Survey) in the vicinity of the park are also shown. See McDonald and Starkey (2018b) for explanations of site selection.

NPS

Previous Survey and Current Interpretations

From June 8–16, 2017, data were collected at Chattahoochee National Recreation Area (CHAT) to characterize the in-stream and riparian habitat of 14 stream reaches (CHAT001–CHAT014). These data, along with the analysis of remotely-sensed geographic information system (GIS) data, are presented in a baseline report (McDonald et al. 2019) that describes and compares the watershed-, reach-, and transect-scale characteristics of the surveyed reaches. These surveys were the first implementation of the SECN Wadeable Stream Habitat Monitoring Protocol (McDonald et al. 2018a).

McDonald et al. (2019) determined watershed characteristics and land use land cover for the 14 monitored reaches from GIS analysis. This data led to the hypothesis that the majority of the watersheds (9 of 14) likely have a flashy flow regime (three first-order, four second-order, and both third-order watersheds), while the remaining five watersheds likely have less flashy flow regimes because they had lower slope/relief and/or low amounts of development.

It was observed that all surveyed stream reaches were within channel evolution model Stage 3 (Figure 1). The streams are actively widening as the stream beds have stopped downcutting having reached local (often pre-disturbance) baselevel controls (e.g., bedrock or large boulders). A few streams might even be classified as (or at least transitioning into) Stage 4 (e.g., CHAT001 [third-order stream] and CHAT002 [first-order stream]).

Channel widening was observed to be caused by bank undercutting leading to bank failure (i.e., slumping) and tree falls breaking off chunks of the bank. In the larger streams, slump blocks (e.g., the portions of bank that slumped in the channel) are usually eroded and the sediment is transported downstream. In the smaller streams, and lower energy portions of the larger streams, these slumps blocks can become sediment sinks if they become stabilized (i.e., by vegetation). Many of these stabilized blocks were interpreted as representing the bankfull (or sometimes the channel full) level of the stream during the initial surveys.

To account for “bankfull” surfaces being present at multiple heights throughout a reach (or on a transect) interpretation and measurement of these inset surfaces and channel full changed during this (2021 survey). The lowest longitudinally continuous surface observed on a transect was measured as bankfull and the highest longitudinally continuous surface was measured as channel full. The term “elevated entrenched surfaces” is introduced to refer to these surfaces inset within channel full without ascribing a depositional origin to the landform implied by the term bankfull. Elevated entrenched surfaces are further defined later in this report.

Four of the streams were relatively straight entrenched reaches and have little to no interaction between the in- and out-of-channel areas (except during very large events), seven of the streams had begun to develop a meander planform inset within the entrenched channel full surface, and the other three stream reaches had developed a meandering planform. Six of the fourteen streams were dealing with the headward migration of downstream knickpoint. The rate at which these knickpoints migrate upstream is dependent on the sediment composition of the boundary layer (bed sediment), the amount of LWD available to increase bed and bank resistance, and the flashiness of the flow regime that shapes the stream. As a result of changes in bed elevation (from base level lowering or through

the process of complex response), bank undercutting and slumping is a common process occurring at every stream that was surveyed. For a detailed description of the initial survey results, see McDonald et al. 2019.

Methods

The habitat characteristics and geomorphic parameters selected to monitor are based on those collected by other federal organizations (USFS, Harrelson et al. 1994; USGS, Fitzpatrick et al. 1998; and EPA, Hughes 2000). 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. A table containing a list and definitions of variables collected under the protocol can be found in Appendix A. While summarized in this document, a list of standard operating procedures and an overview of the methods used to collect the surveys and process the data are available in McDonald et al. (2018a). A table explaining all variables explored under this monitoring protocol is provided in Appendix A.

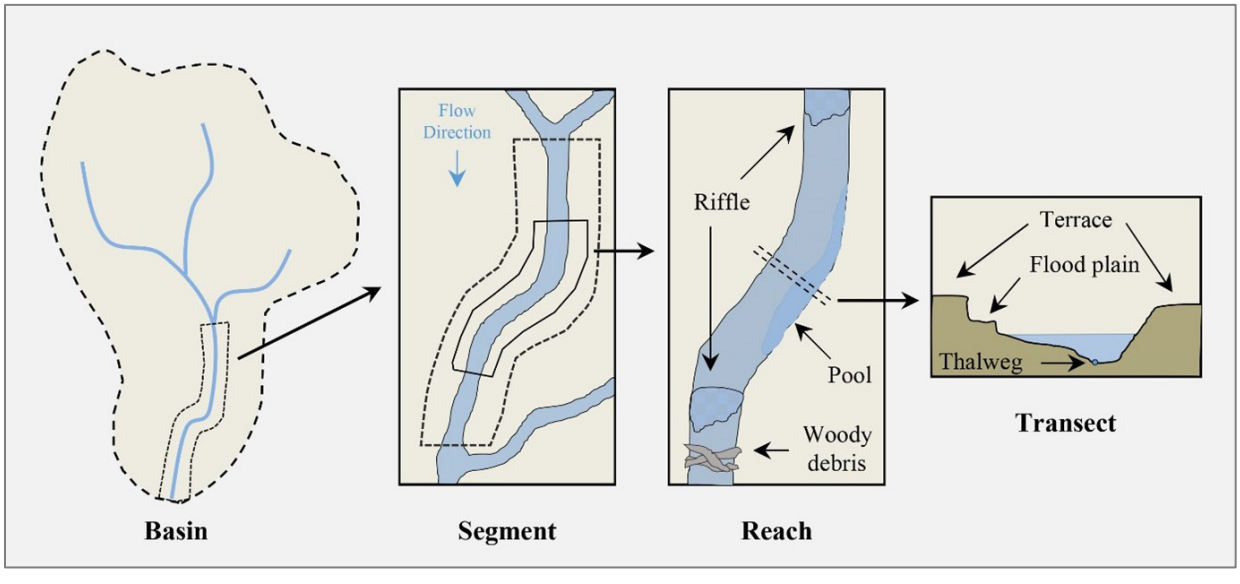


Figure 3. Spatial hierarchy of stream systems and scales of data collection.
MODIFIED FROM FITZPATRICK ET AL. 1998

Basin Characteristics

Understanding the physical characteristics of a drainage basin, as well as the land use and land cover 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 can be found 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 *Stream Habitat Assessment Basin and Segment Scale Data Summary—Version 1.1* (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 transect includes 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 and angles. As described in the "Previous Survey and Current Interpretations" section, the interpretation of bankfull and channel full were modified to account for the developmental complexity of these streams. Bankfull width was measured from the lowest longitudinally continuous surface on a transect. Bankfull height was measured to the lowest longitudinally continuous surface for that bank. This interpretation can result in different bankfull heights on the same transect. Channel full width and height were measured from the highest continuous surface on the transect. Additional surfaces inset within the channel full channel are also measured but only included in the notes for that reach. 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. A quantitative measure of bed sediment is obtained by conducting a Wolman pebble count on a representative riffle within the reach (Wolman 1954).

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 bank stability scores of "at-risk" or "unstable." This condition is consistent with expectations, given that many comparable streams in the region are currently reestablishing functional flood plains within their highly entrenched channel systems.

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 greater than 1 meter [3.3 ft] in length and greater than 10 centimeters [3.9 in] in diameter as defined in McDonald et al. 2018a), and a description of in-channel features (e.g., sand / cobble bars).

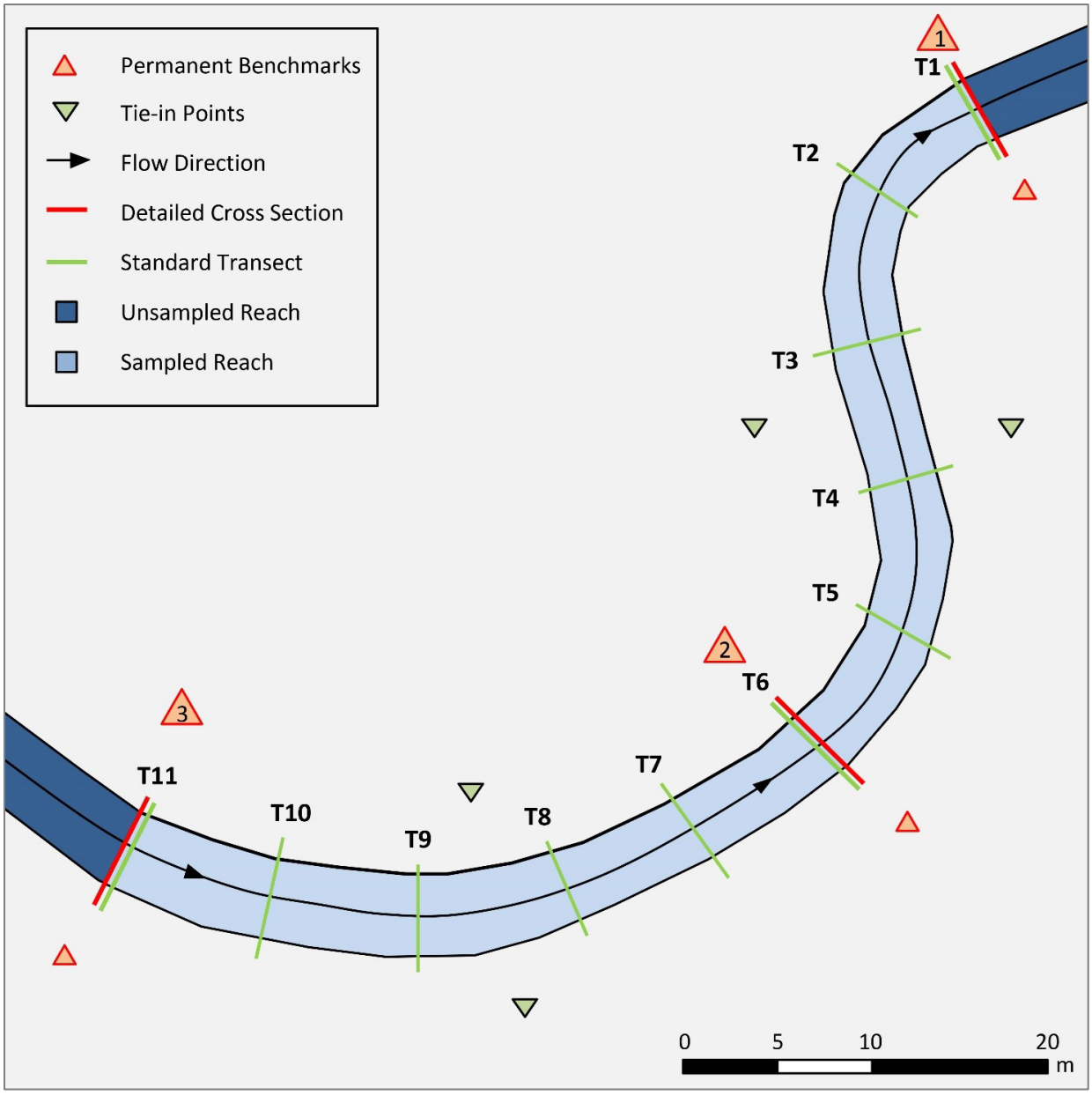


Figure 4. Example layout of stream reach with benchmarks, tie-in points, and transects.
NPS

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)1 [m—meters].

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 (m)	<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

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

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 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 eleven 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).

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 will be used to calculate bankfull and channel full areas and will be used along with the bank stability index to assess the condition and stability of the reach.

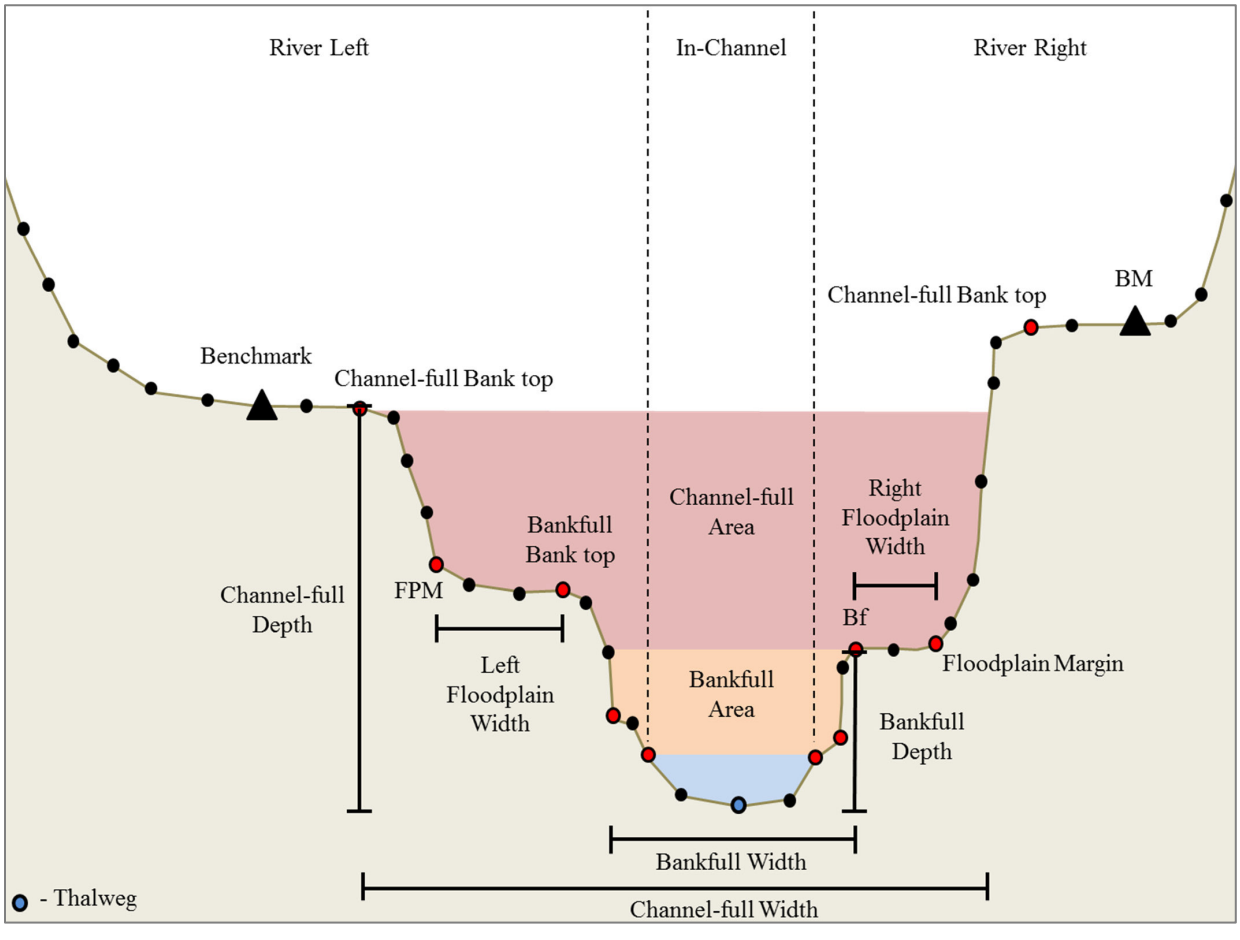


Figure 5. Hypothetical detailed transect cross-sectional survey showing the diagnostic geomorphic surfaces surveyed and the descriptive characteristics derived from the data. Bankfull area includes baseflow area (light blue) and bankfull area (orange). Channel full area includes baseflow, bankfull, and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

Statistical Analysis

The statistical significance of the difference of means between surveys (2017 and 2021) for nine variables at each monitoring site (Table 2) were tested using two-sample t-tests. These nine variables included:

1. pebble count data (millimeters),
2. thalweg depth (meters),
3. thalweg position (% distance from left bank),
4. wetted width (meters),

5. active channel width (meters),
6. channel full width (meters),
7. channel full height (meters),
8. bank angle (°), and
9. vegetative cover of the banks (%).

Table 2. Wadeable stream monitoring sites at Chattahoochee River National Recreation Area. A detailed description of each reach can be found in McDonald and Starkey (2018b).

Site Number	Park Unit	Stream Name	Lat	Long	Stream Type	Strahler Stream Order
CHAT001	Bowman Island	Haw Creek	34.158	−84.080	Large-Low Entrenchment	3
CHAT002	Bowman Island	“Undercut Creek”	34.153	−84.078	Small-Headwater	1
CHAT003	Bowman Island	“Steep Draw Creek”	34.151	−84.079	Small-Headwater	1
CHAT004	Ors Ferry	“Crayfish Creek”	34.123	−84.092	Medium-Low Entrenchment	2
CHAT005	Settles Bridge	“Egg Creek”	34.099	−84.105	Medium-Low Entrenchment	2
CHAT006	Suwanee Creek	“Three Mind Creek”	34.029	−84.124	Small-Headwater	1
CHAT007 [A]	Rogers Bridge	“Red Tail Creek”	34.032	−84.139	Medium-High Entrenchment	2
CHAT008	Johnson Ferry	Mulberry Creek	33.957	−84.395	Medium-Low Entrenchment	2
CHAT009	Cochran Shoals	Fox Creek	33.931	−84.436	Small-Headwater	1
CHAT010	Cochran Shoals	“Beaver Creek”	33.921	−84.450	Medium-Low Entrenchment	2
CHAT011	Cochran Shoals	Gunby Creek	33.911	−84.452	Medium-Low Entrenchment	2
CHAT012	Palisades	Cabin Creek	33.890	−84.436	Small-Headwater	1
CHAT013	Palisades	Long Island Creek	33.884	−84.433	Large-Low Entrenchment	3
CHAT014	Palisades	White Water Creek	33.877	−84.440	Medium-Low Entrenchment	2

[A] CHAT007 “Red Tail Creek” was excluded from monitoring in 2021 due to safety concerns, shown shaded in gray.

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 was not always equal.

In addition to the difference in means t-tests, a one-way analysis of variance (ANOVA) test was conducted to determine if there are significant differences in the nine previously mentioned variables among streams of the same order. If an ANOVA showed a significant difference, a post hoc Tukey test was used to determine where the difference occurred (i.e., which reach(es) differed significantly from the other reach(es) of the same stream order).

Results

From May 6 to May 13, 2021, 13 streams were surveyed at Chattahoochee River National Recreation Area following the methods outlined in SOP 1.2.16 *Wadeable Stream Reach-Scale Field Data Collection– Version 1.0* (McDonald et al. 2018c), and SOP 1.2.18 *Using a Total Station to Conduct a Stream Survey–Version 1.0* (McDonald et al. 2018d). Streams were selected to be representative of similar-sized streams (i.e., Strahler first-, second-, and third-order streams) in the park (Table 2). Of the 13 streams surveyed, five were classified as small-headwater streams (first-order), six were classified as medium-low entrenchment streams (second-order), and two were classified as large-low entrenchment (third-order). In this report, to compare similar sized streams, Strahler stream order is used to subdivide the results. Field surveys, in-office analyses, and statistical comparisons between monitoring years (2017 and 2021) are presented in the following sections. Results and data summary tables for each reach are provided in Appendices B through N.

Weather Conditions

Wadeable stream surveys are done as close to baseflow conditions as possible given the time frame available to do the stream surveys each year (McDonald et al. 2018a). More precipitation fell during the three-month period prior to the 2017 surveys than during the three months leading up to the 2021 surveys (Table 3). The two survey years also had the same number of large precipitation events (greater than 1 inch [in] or 2.5 centimeters [cm]) in the month leading up to the surveys. Prior to the 2017 surveys, there was one precipitation event greater than one inch (1.06 in on June 5, 2017), which occurred the day before surveys began. The 2021 surveys were scheduled to begin on May 3, 2021, but were postponed due to a frontal system which moved through North Georgia from May 3 to May 5, 2021. This frontal system produced more than an inch of precipitation for two consecutive days (2.02 in [5.13 cm] on May 4, 2021, and another 1.60 in [4.06 cm] on May 5, 2021). More precipitation also fell during the 2021 survey dates than in 2017, although neither survey year had a single precipitation event greater than 1 inch occur within the surveying timeframe.

Table 3. Amount of precipitation and number of precipitation events greater than 1 in (2.5 cm) during and in the week and month(s) prior to the 2017 and 2021 wadeable stream surveys at Chattahoochee River NRA. Data from weather co-op station GA-FS-20, Cumming, Georgia [in—inches]. One inch was chosen as the definition of a “large” event as one inch is approximately one standard deviation greater than the mean rainfall event at this station during the summer months from 2017 to 2021.

Time Frame	Length of Period	Total Precipitation (in)	Number of Events > 1 inch
6/06/2017–06/16/2017	2017 Surveys (11 Days)	0.68	0
5/30/2017–6/06/2017	One Week	2.30	1
5/06/2017–06/06/2017	One Month	8.29	3
3/06/2017–06/06/2017	Three Months	20.41	5
05/06/2021–05/13/2021	2021 Surveys (8 Days)	1.52	0
4/30/2021–5/06/2021	One Week	3.72	2
4/06/2021–5/06/2021	One Month	6.13	3
2/06/2021–5/06/2021	Three Months	15.39	5

Note that many of the results found within this report (especially related to bed sediment and geomorphic channel units) are likely related to these large precipitation events. Sediment is more likely to be introduced to streams during these large events and post-storm deposition in many cases will be ephemeral. Due to scheduling constraints on fieldwork, event-based effects and recovery rates cannot be precisely determined. In addition to the wadeable stream monitoring protocol, event-based surveys (surveying immediately before and after an event) need to be completed to determine how large-events influence these reaches.

Headwater Streams (First-Order)

This section provides a summary of the basin characteristics of the first-order study watersheds at Chattahoochee River NRA and provides the results of the surveys at each first-order reach surveyed. The results for each reach are subdivided into a reach description, habitat characteristics, and channel morphology. The results from the 2021 survey are compared to the 2017 survey in each subsection.

Basin Characteristics

Watershed characteristics were derived from GIS analyses that were conducted prior to the 2017 surveys and again in 2021 using updated park boundary and land-use and land-cover data. For an in-depth look at the 2017 basin characteristics of the first-order watersheds at Chattahoochee River NRA, see McDonald et al. (2019). The first-order watersheds range in size from 0.20 square kilometers (0.08 sq mi; CHAT006) to 0.51 square kilometers (0.20 sq mi; CHAT003 and CHAT009; Table 4). Chattahoochee River National Recreation Area manages between 35% (CHAT012) and 85% (CHAT003) of the land within these watersheds. Though the drainage areas of CHAT002 and CHAT012 are similar (within 0.02 square kilometers [0.008 sq mi]), CHAT002's watershed is much more dissected (i.e., total stream length is more than five times CHAT012's). Interestingly, CHAT002 also has a greater drainage density (TSL/DA, 1.64 km/km^2 [2.64 mi/mi^2]) than all the other first-order watersheds (0.35–1.32 km/km^2 [0.56–2.12 mi/mi^2]). The three northern sites (CHAT002, CHAT003, and CHAT006) have the highest entire stream gradients (0.0531–0.0616 m/m; Table 4). CHAT002 had the highest segment gradient (0.084 m/m) while CHAT006 had the lowest segment gradient (0.0186 m/m). The watershed with the highest average slope drains to CHAT012 (11.87°) and CHAT006 had the lowest average watershed slope (8.36°; Table 4). CHAT012 also had the least variability in slope (CV = 0.45 compared to 0.54–0.60). Basin shape indicates that CHAT002 (0.17) and CHAT006 (0.18) have long and narrow drainages and the other watersheds are more circular (0.26–0.30; Table 4). CHAT006 has the least relief (55 m [180.45 ft]) while CHAT002 and CHAT003 have the highest relief (approximately 85 meters [278.8 ft]) of the first-order watersheds. All first-order watersheds have high forest cover (73% [CHAT009] up to 86% [CHAT003]) except for CHAT006 (42%; Table 5). CHAT006 has the highest residential/suburban land cover (35% Developed Open and Low) as well as the most commercial and/or industrial land cover (24% Developed Medium and High). CHAT003 has the least developed land cover (13% Developed Open and Low).

Table 4. Watershed characteristics for the first-order streams at Chattahoochee River NRA calculated using the National Elevation Dataset (NED) 10-meter digital elevation model [km—kilometers; m—meters; SD—Standard deviation; CV—Coefficient of variation].

Basin Characteristic	CHAT002	CHAT003	CHAT006	CHAT009	CHAT012
Drainage Area (km^2)	0.32	0.51	0.20	0.51	0.30
NPS Managed Area (km^2)	0.23	0.43	0.10	0.42	0.10
NPS Managed Area (%)	71	85	49	82	35
Total Stream Length (km)	0.52	0.67	0.11	0.62	0.10
Drainage Density	1.64	1.32	0.55	1.22	0.35
Strahler Order	1	1	1	1	1
Bifurcation Ratio	1.00	1.00	1.00	1.00	1.00
Entire Stream Gradient	0.0616	0.0531	0.0537	0.0457	0.0459
Segment Gradient	0.0840	0.0385	0.0186	0.0204	0.0378
Slope - Average	9.78	11.02	8.36	8.65	11.87
Slope - Std. Dev.	5.55	5.92	4.78	5.21	5.37
Slope - CV	0.57	0.54	0.57	0.60	0.45
Basin Length (km)	1.36	1.30	1.04	1.41	1.00
Basin Shape	0.17	0.30	0.18	0.26	0.29
Basin Relief (m)	85	85	55	60	73
Basin Relief Ratio	0.062	0.066	0.053	0.043	0.073
Elevation - Std. Dev. (m)	17.2	16.6	12.3	13.5	12.6

Table 5. Changes in land use/land cover characteristics from 2016 to 2021 for the first-order streams at Chattahoochee River NRA. The data included in this table are from the National Land Cover Dataset (Dewitz 2023). Percent change from 2016 to 2021 is shown as "%Δ".

	CHAT002			CHAT003			CHAT006			CHAT009			CHAT012		
NLCD Classes	**2016**	**2021**	**% Δ**	**2016**	**2021**	**% Δ**	**2016**	**2021**	**% Δ**	**2016**	**2021**	**% Δ**	**2016**	**2021**	**% Δ**
Developed Open & Low (%)	17	17	0	17	17	0	35	35	0	18	18	−1	23	22	0
Developed Med. & High (%)	2	2	0	2	2	0	24	24	0	1	1	1	1	2	0
Forested (%)	77	77	0	77	77	0	42	42	0	81	81	0	73	73	0
Grassland (%)	0	0	0	0	0	0	0	0	0	0	0	0	3	2	−2
Cultivated (%)	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0

CHAT002—"Undercut Creek"

Reach Description

On May 6, 2021, stream survey data were collected at CHAT002. CHAT002 is on an unnamed first-order stream nicknamed "Undercut Creek" because of the extensive and deep undercuts observed during the initial assessment of the stream segment. The monitored reach on "Undercut Creek" is approximately 181 meters (594 ft) upstream of its confluence with the Chattahoochee River. CHAT002 can be accessed by following the social trail along the river left side of the Chattahoochee River and then following the creek upstream to the monitored reach. Tree falls, which have persisted since the 2017 surveys, continue to have a significant influence on the stream and a natural levee and flood chute have developed upstream of one of these tree falls (Figure 6). While these large tree falls have persisted, the tree fall upstream of T8 had rotted significantly since 2017 and no longer spans the channel. A flood chute is present in the out-of-channel area on river left, running from T9 to downstream of T4.

CHAT002's channel continues to have a low degree of entrenchment and signs of overbank flows (e.g., flow paths through the floodplain and down-valley oriented debris trails) are present. The reach surveyed was 30 meters (98.4 ft) long with 3 meters (9.8 ft) between transects. The watershed draining to CHAT002 is mostly forested (80%; Table 5) and the park manages 71% of the drainage area (0.32 km^2). Detailed transect 1 (T2) and 2 (T6) have developed small floodplains on rivers right and left, respectively (Figure 6). The flood chute, running along the river left out-of-channel area was surveyed on both detailed transects 2 (T6) and 3 (T10). Water surface slope (longitudinal profile) for this section of "Undercut Creek" increased by 0.0051 m/m (0.0341 m/m in 2017) to 0.0392 m/m in 2021. The longitudinal profile was relatively consistent with a step visible upstream of T6 and channel incision upstream of T2. The channel incision observed between T2 and T6 represents the most significant change in the longitudinal profile between surveys. Transect- and reach-scale survey results for CHAT002 can be viewed in the corresponding file of supplemental materials for this site.

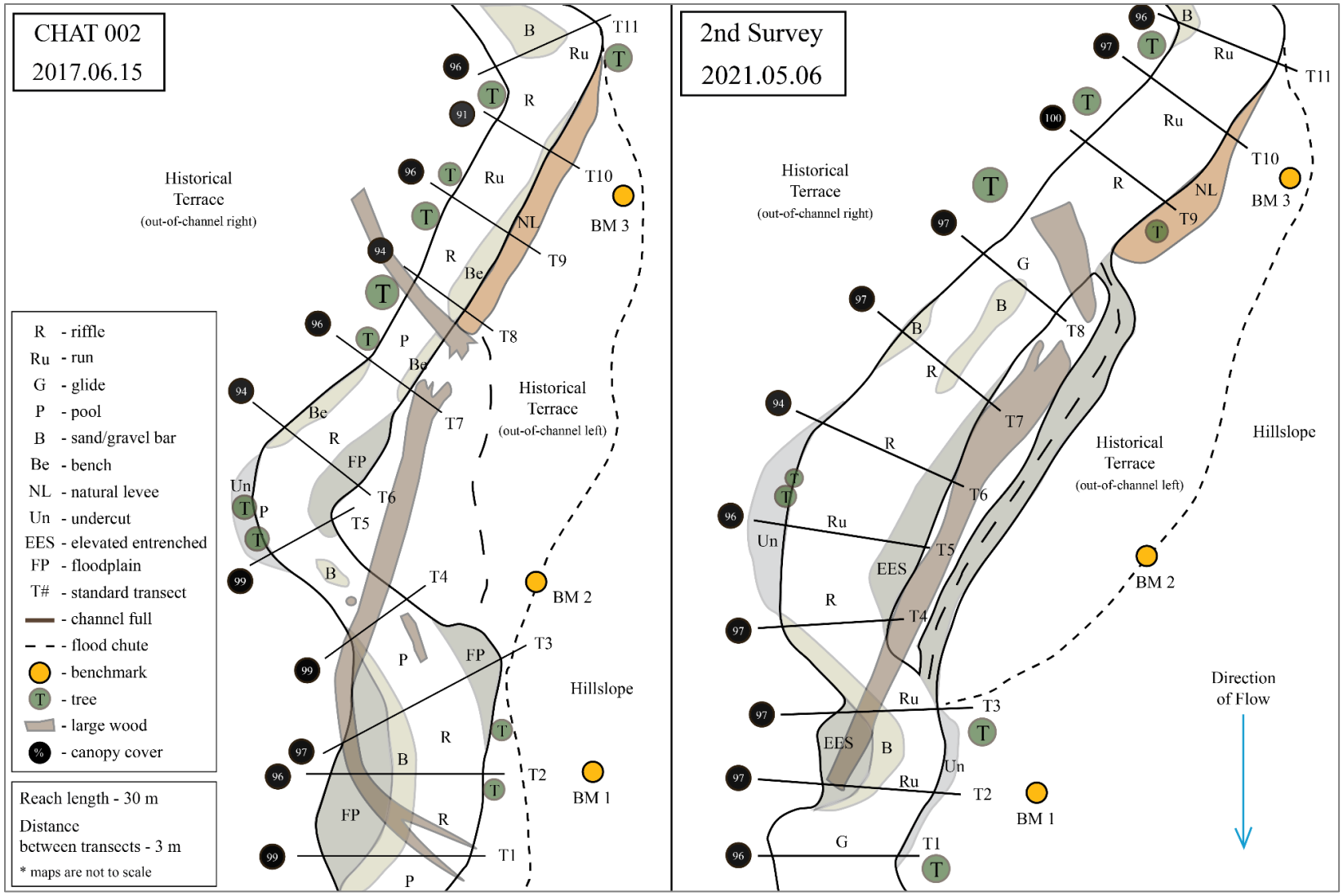


Figure 6. Reach-scale map of CHAT002. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect.

NPS

Habitat Characteristics

The geomorphic channel unit (GCU) types and distributions changed between the 2017 and 2021 surveys (Table 6). Riffles, runs, and pools were present within the surveyed reach during both survey years. The mean percentage of riffle stayed approximately the same (−6%), mean percentage of run increased (+19%), and the mean percentage of pool decreased (−22%). Three glides were observed within the reach in 2021, while none were present in 2017. A log step was observed between T8 and T9, which had not been observed during the 2017 survey. The pebble count data for CHAT002 shows a coarsening of bed sediment between the 2017 and 2021 surveys (Table 7). There was a statistically significant increase in the mean diameter of the pebbles at CHAT002 ($p = 0.004$; Table 8). While the D_{16} and larger size classes increased, the minimum and D_5 sediment classes became finer (Table 7).

Table 6. Geomorphic channel units (GCUs) observed in the area between transects during the 2017 and 2021 surveys for the first-order streams at Chattahoochee River NRA.

GCU Type	Site	Year	n [A]	Max (%)	Mean (%)	SD (%)
Riffle	CHAT002	2017	9	100	59	32
	CHAT002	2021	9	100	52	36
	CHAT003	2017	10	100	83	19
	CHAT003	2021	9	100	55	36
	CHAT006	2017	6	90	25	29
	CHAT006	2021	4	30	10	13
	CHAT009	2017	6	100	45	42
	CHAT009	2021	9	100	53	35
	CHAT012	2017	6	100	50	47
	CHAT012	2021	10	100	70	31
Run	CHAT002	2017	3	60	12	23
	CHAT002	2021	7	100	31	32
	CHAT003	2017	4	15	5	7
	CHAT003	2021	8	70	33	29
	CHAT006	2017	3	60	12	21
	CHAT006	2021	9	100	63	37
	CHAT009	2017	4	100	25	37
	CHAT009	2021	9	90	45	32
	CHAT012	2017	3	50	15	24
	CHAT012	2021	6	90	28	32
Glide	CHAT002	2017	0	0	0	0
	CHAT002	2021	3	30	7	13
	CHAT003	2017	0	0	0	0
	CHAT003	2021	0	0	0	0
	CHAT006	2017	0	0	0	0

[A] Number of transects on which the GCU type was observed.

Table 6 (continued). Geomorphic channel units (GCUs) observed in the area between transects during the 2017 and 2021 surveys for the first-order streams at Chattahoochee River NRA.

GCU Type	Site	Year	n [A]	Max (%)	Mean (%)	SD (%)
Glide (continued)	CHAT006	2021	0	0	0	0
	CHAT009	2017	0	0	0	0
	CHAT009	2021	0	0	0	0
	CHAT012	2017	0	0	0	0
	CHAT012	2021	0	0	0	0
Pool	CHAT002	2017	5	100	30	36
	CHAT002	2021	5	30	8	10
	CHAT003	2017	5	50	13	18
	CHAT003	2021	3	30	5	10
	CHAT006	2017	10	100	58	37
	CHAT006	2021	4	80	23	35
	CHAT009	2017	7	100	30	38
	CHAT009	2021	1	20	2	6
	CHAT012	2017	4	100	30	42
	CHAT012	2021	2	10	2	4
Step	CHAT002	2017	0	0	0	0
	CHAT002	2021	1	20	2	6
	CHAT003	2017	0	0	0	0
	CHAT003	2021	2	20	3	7
	CHAT006	2017	1	40	4	13
	CHAT006	2021	1	40	4	13
	CHAT009	2017	0	0	0	0
	CHAT009	2021	0	0	0	0
	CHAT012	2017	1	50	5	16
	CHAT012	2021	0	0	0	0

[A] Number of transects on which the GCU type was observed.

Table 7. Particle size distributions of bed sediment (in millimeters [mm]) from the pebble counts conducted in 2017 and in 2021 at the first-order stream sites. The subscripts indicate the percent of the sample that is smaller than the reported diameter [Min—Minimum; Max—Maximum; n—Number of measurements taken].

	CHAT002 (n = 100)		CHAT003 (n = 100)		CHAT006 (n = 100)		CHAT009 (n = 100)		CHAT012 (n = 100)	
Statistic	**2017**	**2021**	**2017**	**2021**	**2017**	**2021**	**2017**	**2021**	**2017**	**2021**
Min	2.00	< 0.06	2.00	< 0.062	2.00	< 0.06	2.00	< 0.06	2.00	< 0.06
D_5	2.00	0.36	2.00	0.06	2.00	0.06	2.00	0.06	2.00	0.41
D_{16}	6.00	14.16	5.00	11.32	3.00	3.00	6.00	20.00	5.00	18.16
D_{50}	21.50	34.00	19.50	31.50	9.50	14.00	17.50	60.50	14.50	42.50

Table 7 (continued). Particle size distributions of bed sediment (in millimeters [mm]) from the pebble counts conducted in 2017 and in 2021 at the first-order stream sites. The subscripts indicate the percent of the sample that is smaller than the reported diameter [Min—Minimum; Max—Maximum; n—Number of measurements taken].

	CHAT002 (n = 100)		CHAT003 (n = 100)		CHAT006 (n = 100)		CHAT009 (n = 100)		CHAT012 (n = 100)	
Statistic	**2017**	**2021**	**2017**	**2021**	**2017**	**2021**	**2017**	**2021**	**2017**	**2021**
Mean	29.93	42.82	39.05	41.70	10.93	14.47	23.68	63.35	22.21	62.97
D_{84}	52.48	70.00	69.16	74.00	18.00	24.84	45.32	97.84	33.32	95.68
D_{95}	85.75	114.45	144.50	102.75	23.05	33.85	63.05	159.90	75.15	192.65
Max	152.00	200.00	269.00	149.00	50.00	49.00	110.00	200.00	135.00	580.00

Table 8. Difference in means t-test results comparing CHAT002 during 2017 and 2021. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [m—meters; mm—millimeters].

Measurement	n [A]	CHAT002 in 2017	CHAT002 in 2021	P-value	Significance
Pebble Count (mm)	100	29.93	42.82	0.004	**
Thalweg Depth (m)	11	0.06	0.20	0.008	**
Thalweg Position (%)	11	42.73	42.73	1.000	–
Wetted Width (m)	11	1.52	2.42	0.002	**
Active Channel Width (m)	11	2.03	2.60	0.033	*
Channel full Width (m) [B]	11	6.78	7.62	0.565	–
Minimum Bank Height (m)	22	0.87	1.05	0.114	–
Channel full Height (m)	22	1.02	1.18	0.074	–
Bank Angle (°)	22	52.32	46.65	0.516	–
Vegetative Cover (%)	22	34.09	22.05	0.114	–

[A] Number of measurements taken.

[B] Changes due to interpretive differences between survey years.

The number of pieces of LWD increased from n = 6 in 2017 to n = 7 in 2021 (Table 9). Four of these pieces of LWD were in jams just upstream of transects 1 and 8 (Figure 6). These jams were observed during the 2017 surveys but have since rotted and no longer span the stream channel. The volume of LWD per channel area decreased slightly from 0.0105 m^3/m^2 in 2017 to 0.0097 m^3/m^2 during the 2021 survey. Like the 2017 survey, canopy cover during the 2021 survey was dense (mean canopy cover = 97%) and showed little variability (CV = 0.02; Table 10).

Table 9. Summary statistics for the large woody debris measured in 2017 and 2021 at the first-order monitoring sites at Chattahoochee River NRA (m—meters; SD—Standard deviation].

Statistic	Site	Year	n [A]	Length (m)	Diameter (m)	Volume (m^3)
Min	CHAT002	2017	6	1.20	0.10	0.0200
	CHAT002	2021	7	1.06	0.10	0.0100
	CHAT003	2017	10	1.23	0.09	0.0100
	CHAT003	2021	7	1.64	0.10	0.0200
	CHAT006	2017	2	1.10	0.19	0.0300
	CHAT006	2021	8	1.10	0.10	0.0100
	CHAT009	2017	3	1.17	0.12	0.0100
	CHAT009	2021	8	1.04	0.10	0.0100
	CHAT012	2017	2	1.10	0.10	0.0100
	CHAT012	2021	3	1.77	0.12	0.0400
Mean	CHAT002	2017	6	2.74	0.27	0.3600
	CHAT002	2021	7	3.24	0.22	0.3200
	CHAT003	2017	10	3.13	0.21	0.1600
	CHAT003	2021	7	3.65	0.17	0.1700
	CHAT006	2017	2	1.10	0.21	0.0400
	CHAT006	2021	8	4.24	0.21	0.5500
	CHAT009	2017	3	2.28	0.15	0.0400
	CHAT009	2021	8	2.03	0.13	0.0300
	CHAT012	2017	2	1.55	0.15	0.0300
	CHAT012	2021	3	2.54	0.16	0.0500
Max	CHAT002	2017	6	4.84	0.64	1.5600
	CHAT002	2021	7	11.30	0.45	1.6400
	CHAT003	2017	10	5.28	0.65	0.6600
	CHAT003	2021	7	7.07	0.40	0.8900
	CHAT006	2017	2	1.10	0.22	0.0400
	CHAT006	2021	8	12.86	0.63	4.0100
	CHAT009	2017	3	3.25	0.21	0.0800
	CHAT009	2021	8	3.31	0.23	0.0500
	CHAT012	2017	2	2.00	0.19	0.0600
	CHAT012	2021	3	3.41	0.21	0.0600
SD	CHAT002	2017	6	1.41	0.20	0.6100
	CHAT002	2021	7	3.62	0.16	0.6100
	CHAT003	2017	10	1.19	0.19	0.2400
	CHAT003	2021	7	2.25	0.10	0.3200
	CHAT006	2017	2	0.00	0.02	0.0100
	CHAT006	2021	8	4.17	0.18	1.4000
	CHAT009	2017	3	1.05	0.05	0.0400

[A] Number of pieces of LWD.

Table 9 (continued). Summary statistics for the large woody debris measured in 2017 and 2021 at the first-order monitoring sites at Chattahoochee River NRA (m—meters; SD—Standard deviation].

Statistic	Site	Year	n [A]	Length (m)	Diameter (m)	Volume (m^3)
SD (continued)	CHAT009	2021	8	0.90	0.04	0.0200
	CHAT012	2017	2	0.64	0.06	0.0300
	CHAT012	2021	3	0.82	0.05	0.0100
Sum	CHAT002	2017	6	–	–	2.1400
	CHAT002	2021	7	–	–	2.2200
	CHAT003	2017	10	–	–	1.5700
	CHAT003	2021	7	–	–	1.1900
	CHAT006	2017	2	–	–	0.0700
	CHAT006	2021	8	–	–	4.4400
	CHAT009	2017	3	–	–	0.1300
	CHAT009	2021	8	–	–	0.2100
	CHAT012	2017	2	–	–	0.0700
	CHAT012	2021	3	–	–	0.1500
Per Channel Area (m^3/m^2)	CHAT002	2017	–	–	–	0.0105
	CHAT002	2021	–	–	–	0.0097
	CHAT003	2017	–	–	–	0.0067
	CHAT003	2021	–	–	–	0.0041
	CHAT006	2017	–	–	–	0.0033
	CHAT006	2021	–	–	–	0.0126
	CHAT009	2017	–	–	–	0.0014
	CHAT009	2021	–	–	–	0.0016
	CHAT012	2017	–	–	–	0.0008
	CHAT012	2021	–	–	–	0.0015

[A] Number of pieces of LWD.

Table 10. Comparison of the variability in canopy cover in 2017 and 2021 at the first-order stream sites at Chattahoochee River NRA [SD—Standard deviation; CV—Coefficient of variation].

Site	Year	n [A]	Min (%)	Mean (%)	Max (%)	SD (%)	CV
CHAT002	2017	11	91	96	99	2	0.02
	2021	11	94	97	100	1	0.02
CHAT003	2017	11	85	91	96	3	0.04
	2021	11	90	95	99	3	0.03
CHAT006	2017	11	87	89	91	2	0.02
	2021	11	91	93	97	2	0.02
CHAT009	2017	11	93	95	100	2	0.02
	2021	11	94	97	100	2	0.02

[A] Number of transects.

Table 10 (continued). Comparison of the variability in canopy cover in 2017 and 2021 at the first-order stream sites at Chattahoochee River NRA [SD—Standard deviation; CV—Coefficient of variation].

Site	Year	n [A]	Min (%)	Mean (%)	Max (%)	SD (%)	CV
CHAT012	2017	11	85	94	99	4	0.04
	2021	11	88	96	99	3	0.03

[A] Number of transects.

Mean thalweg position (relative to the left bank) was the same in 2021 and 2017 (Table 11), but the variability in thalweg position increased from CV = 0.56 in 2017 to 0.77 in 2021. The minimum and maximum thalweg depths were higher in 2021 (+100% and +243% respectively; Table 11). Mean thalweg depth was statistically significantly deeper (+233%) in 2021 (p = 0.008; Table 8).

Table 11. Comparison of reach-scale averaged thalweg conditions in 2017 and 2021 at the first-order stream sites at Chattahoochee River NRA. Water depth measurements are in meters and position is the percent distance from the left bank1 [SD—Standard deviation; CV—Coefficient of variation].

Thalweg	Site	Year	n [B]	Min	Mean	Max	SD	CV
Depth (m)	CHAT002	2017	11	0.03	0.06	0.14	0.03	0.52
	CHAT002	2021	11	0.06	0.20	0.48	0.14	0.70
	CHAT003	2017	11	0.05	0.09	0.26	0.06	0.63
	CHAT003	2021	11	0.10	0.17	0.43	0.09	0.54
	CHAT006	2017	11	0.03	0.11	0.21	0.07	0.59
	CHAT006	2021	11	0.04	0.18	0.72	0.19	1.07
	CHAT009	2017	11	0.02	0.05	0.08	0.02	0.47
	CHAT009	2021	11	0.05	0.09	0.20	0.05	0.48
	CHAT012	2017	11	0.02	0.05	0.12	0.03	0.57
	CHAT012	2021	11	0.07	0.12	0.26	0.05	0.41
Position (%) [A]	CHAT002	2017	11	10.00	43.00	90.00	24.00	0.56
	CHAT002	2021	11	5.00	43.00	95.00	33.00	0.77
	CHAT003	2017	11	20.00	51.00	90.00	24.00	0.47
	CHAT003	2021	11	5.00	69.00	95.00	30.00	0.44
	CHAT006	2017	11	5.00	37.00	80.00	25.00	0.68
	CHAT006	2021	11	15.00	50.00	95.00	33.00	0.65
	CHAT009	2017	11	5.00	46.00	90.00	28.00	0.61
	CHAT009	2021	11	5.00	23.00	50.00	16.00	0.69
	CHAT012	2017	11	10.00	55.00	80.00	24.00	0.43
	CHAT012	2021	11	30.00	68.00	100.00	25.00	0.37

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

[B] Number of measurements.

Channel Morphology

Average wetted width at CHAT002 was 59% wider and mean active channel width increased by 28% in 2021 (Table 12). These differences were both statistically significant (p = 0.002 and 0.033, respectively; Table 8). Both the minimum and maximum wetted width values were greater than those observed during the 2017 surveys (+104% and +29%, respectively; Table 12). Though not as extreme, the same was observed regarding active channel width, as both the minimum and maximum values increased in 2021 (+17% and +11%, respectively). While mean wetted width increased, the coefficient of variation (CV) of decreased from 0.39 in 2017 to 0.25 in 2021 (Table 12).

Table 12. Comparison of reach-scale averaged width characteristics in 2017 and 2021 at the first-order stream sites at Chattahoochee River NRA [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Widths	Site	Year	n [C]	Min (m)	Mean (m)	Max (m)	SD (m)	CV
Wetted	CHAT002	2017	11	0.67	1.52	2.60	0.59	0.39
	CHAT002	2021	11	1.37	2.42	3.35	0.62	0.25
	CHAT003	2017	11	1.03	1.68	2.46	0.39	0.23
	CHAT003	2021	11	1.77	2.60	3.52	0.56	0.21
	CHAT006	2017	11	0.28	0.99	2.17	0.58	0.59
	CHAT006	2021	11	0.80	1.50	2.39	0.51	0.34
	CHAT009	2017	11	0.60	0.97	1.49	0.35	0.36
	CHAT009	2021	11	1.24	1.74	2.13	0.29	0.16
	CHAT012	2017	11	0.64	1.13	2.00	0.44	0.39
	CHAT012	2021	11	1.02	1.57	2.16	0.35	0.23
Active Channel	CHAT002	2017	11	1.20	2.03	3.02	0.54	0.27
	CHAT002	2021	11	1.40	2.60	3.35	0.61	0.24
	CHAT003	2017	11	1.20	2.21	3.49	0.67	0.30
	CHAT003	2021	11	1.93	2.94	4.21	0.62	0.21
	CHAT006	2017	11	0.86	1.41	2.04	0.43	0.31
	CHAT006	2021	11	1.92	2.62	3.79	0.63	0.24
	CHAT009	2017	11	1.33	1.86	2.66	0.43	0.23
	CHAT009	2021	11	1.98	2.44	3.47	0.44	0.18
	CHAT012	2017	11	1.00	1.38	2.10	0.32	0.23
	CHAT012	2021	11	1.49	2.02	3.24	0.55	0.27
Bankfull [A,B]	CHAT002	2017	5	2.03	2.49	3.40	0.56	0.23
	CHAT002	2021	6	3.30	4.12	5.26	0.73	0.18
	CHAT003	2017	3	1.71	2.58	3.93	1.18	0.46
	CHAT003	2021	3	2.46	4.15	5.15	1.47	0.35
	CHAT006	2017	8	2.35	3.39	4.00	0.66	0.20

[A] Statistics are based on the transects where feature is present and measurable.

[B] Large changes are due to interpretive differences between survey years.

[C] Number of measurements.

Table 12 (continued). Comparison of reach-scale averaged width characteristics in 2017 and 2021 at the first-order stream sites at Chattahoochee River NRA [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Widths	Site	Year	n [C]	Min (m)	Mean (m)	Max (m)	SD (m)	CV
Bankfull (continued) [A,B]	CHAT006	2021	11	2.93	4.24	5.84	0.86	0.20
	CHAT009	2017	0	–	–	–	–	–
	CHAT009	2021	5	2.87	3.54	4.36	0.57	0.16
	CHAT012	2017	6	1.49	2.16	3.04	0.58	0.27
	CHAT012	2021	6	1.88	2.51	4.14	0.84	0.34
Channel full [A,B]	CHAT002	2017	11	4.14	6.78	15.48	3.61	0.53
	CHAT002	2021	11	5.18	7.62	14.00	3.11	0.41
	CHAT003	2017	11	3.34	4.67	7.42	1.12	0.24
	CHAT003	2021	11	4.44	5.89	7.72	1.03	0.18
	CHAT006	2017	11	2.43	11.16	22.07	6.24	0.56
	CHAT006	2021	11	15.55	17.59	21.20	2.05	0.12
	CHAT009	2017	11	3.56	4.67	5.74	0.86	0.18
	CHAT009	2021	11	4.71	6.70	8.08	0.85	0.13
	CHAT012	2017	11	2.45	4.02	6.33	1.15	0.29
	CHAT012	2021	11	3.40	4.96	9.20	1.70	0.34

[A] Statistics are based on the transects where feature is present and measurable.

[B] Large changes are due to interpretive differences between survey years.

[C] Number of measurements.

Bankfull widths at CHAT002 also increased between the two surveys. Six bankfull widths were measured in 2021 as opposed to five in 2017 (Table 12). Mean bankfull width increased by 65% and minimum and maximum bankfull widths also increased during the 2021 survey. This large change is due to differences in interpretation mentioned in the "Previous Surveys and Current Interpretation" section and further explained in the "Implications of Results" section. Mean channel full width increased by 12% but this difference was not statistically significant ($p = 0.565$; Table 8). Variability in channel full widths decreased from CV = 0.53 in 2017 to CV = 0.41 in 2021 (Table 12).

Mean minimum bank height (lowest bank height on a transect) in 2021 was 21% higher than in 2017 (Table 13). Mean bankfull heights were 111% higher in 2021 and more variable (CV = 0.30) than 2017 (CV = 0.16). This substantial change is also related to interpretive changes. Additionally, the minimum bankfull height in 2021 was 86% higher than in 2017 (also due to interpretative changes). Mean channel full height was 16% higher though this change was not statistically significant ($p = 0.074$; Table 8). Variability in channel full heights decreased from CV = 0.53 in 2017 to CV = 0.41 in 2021 (Table 13).

Table 13. Comparison of reach-scale averaged bank heights in 2017 and 2021 at the first-order stream sites at Chattahoochee River NRA [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Heights	Site	Year	n [E]	Min	Mean	Max	SD	CV
Minimum Bank Height (m) [A,B,D]	CHAT002	2017	22	0.29	0.87	2.34	0.43	0.49
	CHAT002	2021	22	0.54	1.05	1.53	0.27	0.26
	CHAT003	2017	22	0.23	0.91	1.39	0.31	0.33
	CHAT003	2021	22	0.31	1.06	1.61	0.28	0.26
	CHAT006	2017	22	0.34	0.51	0.84	0.12	0.23
	CHAT006	2021	22	0.25	0.47	0.93	0.18	0.38
	CHAT009	2017	22	0.67	0.97	1.19	0.14	0.14
	CHAT009	2021	22	0.35	0.97	1.34	0.25	0.26
	CHAT012	2017	22	0.25	0.52	0.82	0.15	0.29
	CHAT012	2021	22	0.38	0.70	0.94	0.15	0.22
Bankfull Height (m) [A,C,D]	CHAT002	2017	5	0.29	0.38	0.45	0.06	0.16
	CHAT002	2021	6	0.54	0.80	1.07	0.24	0.30
	CHAT003	2017	3	0.23	0.33	0.51	0.16	0.49
	CHAT003	2021	3	0.31	0.58	0.84	0.27	0.47
	CHAT006	2017	14	0.34	0.45	0.55	0.08	0.17
	CHAT006	2021	22	0.25	0.47	0.93	0.18	0.38
	CHAT009	2017	0	–	–	–	–	–
	CHAT009	2021	5	0.35	0.60	0.83	0.20	0.34
	CHAT012	2017	7	0.25	0.37	0.47	0.09	0.24
	CHAT012	2021	3	0.38	0.41	0.45	0.04	0.08
Channel full Height (m) [A,D]	CHAT002	2017	22	0.61	1.02	2.34	0.34	0.33
	CHAT002	2021	22	0.65	1.18	1.67	0.25	0.21
	CHAT003	2017	22	0.63	1.03	1.39	0.20	0.19
	CHAT003	2021	22	0.87	1.15	1.61	0.20	0.17
	CHAT006	2017	22	0.43	0.67	0.84	0.10	0.14
	CHAT006	2021	22	0.64	0.96	1.60	0.23	0.24
	CHAT009	2017	22	0.67	0.97	1.19	0.14	0.14
	CHAT009	2021	22	0.78	1.09	1.34	0.12	0.11
	CHAT012	2017	22	0.33	0.63	0.82	0.11	0.17
	CHAT012	2021	22	0.55	0.74	0.94	0.10	0.14

[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 feature is present and measurable (# in parentheses).

[D] Large changes are due to interpretive differences between survey years.

[E] Number of measurements.

The banks had the same number of undercuts from 2017 to 2021 (n = 8; Table 14). The mean depth of undercuts increased slightly (+8%) from 2017 to 2021. The largest undercut (between T5 and T6) measured 0.80 meters (2.62 ft) in 2021, an increase in depth of 18%. Bank angles were on average less steep during 2021 (47°) compared to 2017 (52°; Table 14). This difference in mean bank angle was not statistically significant (Table 8). Bank vegetation cover decreased slightly from 34% in 2017 to 22% in 2021 (Table 14). This difference in bank vegetation cover was also not statistically significant (Table 8). Bank stability scores were slightly lower (more stable) in 2021 compared to 2017 (Table 14).

Table 14. Comparison of reach-scale averaged bank characteristics in 2017 and 2021 at the first-order stream sites at Chattahoochee River NRA [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Characteristics	Site	Year	n [B]	Min	Mean	Max	SD	CV
Bank Undercut (m) [A]	CHAT002	2017	8	0.08	0.24	0.68	0.23	0.93
	CHAT002	2021	8	0.08	0.26	0.80	0.25	0.93
	CHAT003	2017	7	0.12	0.25	0.53	0.14	0.58
	CHAT003	2021	12	0.10	0.19	0.25	0.05	0.26
	CHAT006	2017	4	0.07	0.12	0.20	0.06	0.47
	CHAT006	2021	0	–	–	–	–	–
	CHAT009	2017	8	0.06	0.25	0.94	0.30	1.19
	CHAT009	2021	9	0.06	0.36	0.93	0.36	0.99
	CHAT012	2017	7	0.11	0.24	0.38	0.11	0.46
	CHAT012	2021	10	0.09	0.29	0.65	0.18	0.64
Bank Angle (°)	CHAT002	2017	22	11.50	52.32	90.00	29.68	0.57
	CHAT002	2021	22	1.80	46.65	90.50	27.78	0.60
	CHAT003	2017	22	27.10	65.79	96.90	19.63	0.30
	CHAT003	2021	22	23.70	52.69	87.40	18.93	0.36
	CHAT006	2017	22	10.70	44.44	88.10	24.40	0.55
	CHAT006	2021	22	6.80	25.25	67.00	15.13	0.60
	CHAT009	2017	22	6.90	47.14	86.50	29.44	0.62
	CHAT009	2021	22	19.30	49.73	88.10	23.69	0.48
	CHAT012	2017	22	14.50	56.70	89.20	27.17	0.48
	CHAT012	2021	22	13.40	49.10	86.90	25.48	0.52
Vegetation Cover (%)	CHAT002	2017	22	0.00	34.09	90.00	29.30	0.86
	CHAT002	2021	22	0.00	22.05	70.00	18.94	0.86
	CHAT003	2017	22	5.00	42.27	90.00	30.34	0.72
	CHAT003	2021	22	20.00	54.55	90.00	21.54	0.39
	CHAT006	2017	22	0.00	11.14	50.00	11.44	1.03

[A] Statistics are based on the transects where the features are present and measurable (# in parentheses).

[B] Number of measurements.

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

Table 14 (continued). Comparison of reach-scale averaged bank characteristics in 2017 and 2021 at the first-order stream sites at Chattahoochee River NRA [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Characteristics	Site	Year	n [B]	Min	Mean	Max	SD	CV
Vegetation Cover (%) (continued)	CHAT006	2021	22	10.00	14.55	30.00	8.00	0.55
	CHAT009	2017	22	5.00	19.77	60.00	16.44	0.83
	CHAT009	2021	22	10.00	33.18	70.00	16.15	0.49
	CHAT012	2017	22	0.00	31.36	90.00	27.95	0.89
	CHAT012	2021	22	10.00	34.09	80.00	18.69	0.55
Bank Stability [C]	CHAT002	2017	22	8.00	12.98	16.00	1.87	0.14
	CHAT002	2021	22	9.50	12.68	17.00	1.61	0.13
	CHAT003	2017	22	9.00	13.05	15.50	1.70	0.13
	CHAT003	2021	22	8.50	11.45	14.00	1.28	0.11
	CHAT006	2017	22	11.50	13.55	17.00	1.50	0.11
	CHAT006	2021	22	10.50	12.77	16.00	1.43	0.11
	CHAT009	2017	22	11.50	13.45	16.00	1.19	0.09
	CHAT009	2021	22	9.50	12.16	14.00	1.32	0.11
	CHAT012	2017	22	10.50	12.80	15.00	1.12	0.09
	CHAT012	2021	22	6.00	11.98	16.00	2.01	0.17

[A] Statistics are based on the transects where the features are present and measurable (# in parentheses).

[B] Number of measurements.

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

Detailed Transects

The detailed transects on CHAT002 were surveyed on T2 (BM1; Figure 7), T6 (BM2; Figure 8), and T10 (BM3; Figure 9). On the detailed transects, bankfull cross-sectional area was on average 25% larger in 2021 than in 2017 (Table 15). On average, channel full area was also larger (+42%) in 2021. As mentioned in the previous section, substantial changes to bankfull and channel full are related to interpretive differences (unless otherwise noted). Water surface slope (longitudinal profile) for this section of Undercut Creek was approximately the same (Figure 10; Table 15). The most significant change in longitudinal profile morphology was the channel incision between T2 and T6. There was a slight reduction in sinuosity from 1.36 in 2017 to 1.25 in 2021 (Table 15).

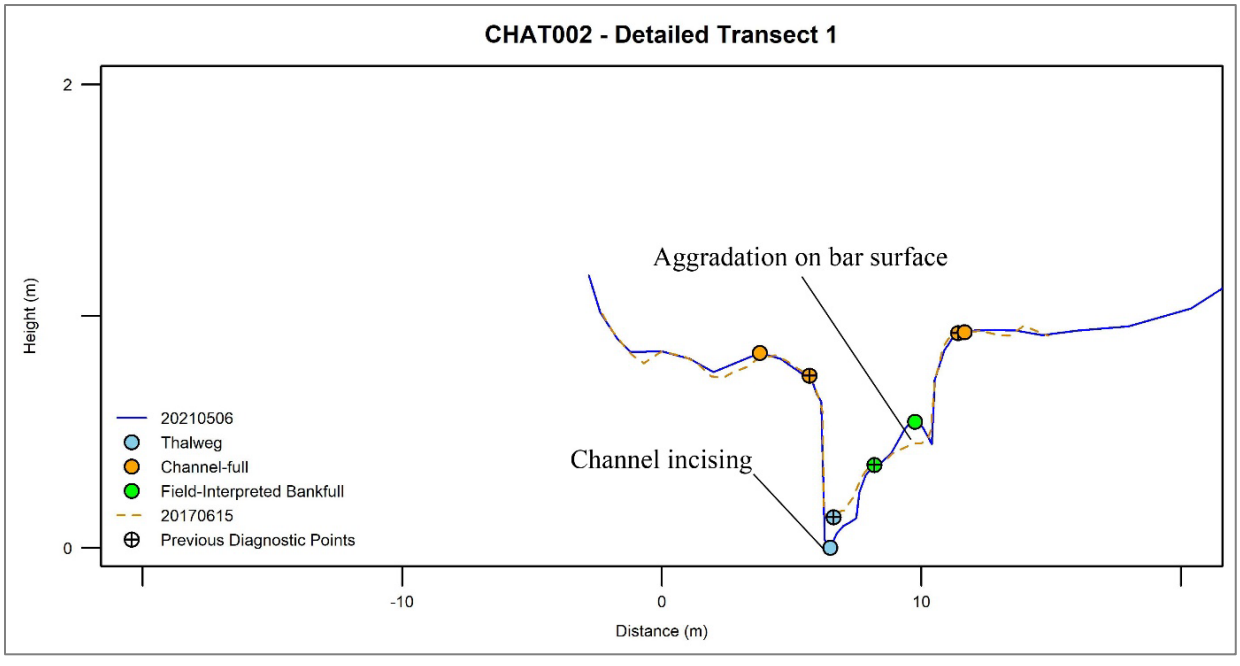


Figure 7. Differences between the 2017 and 2021 surveys of detailed transect 1 (T2) at CHAT002. View is in the downstream direction.

NPS

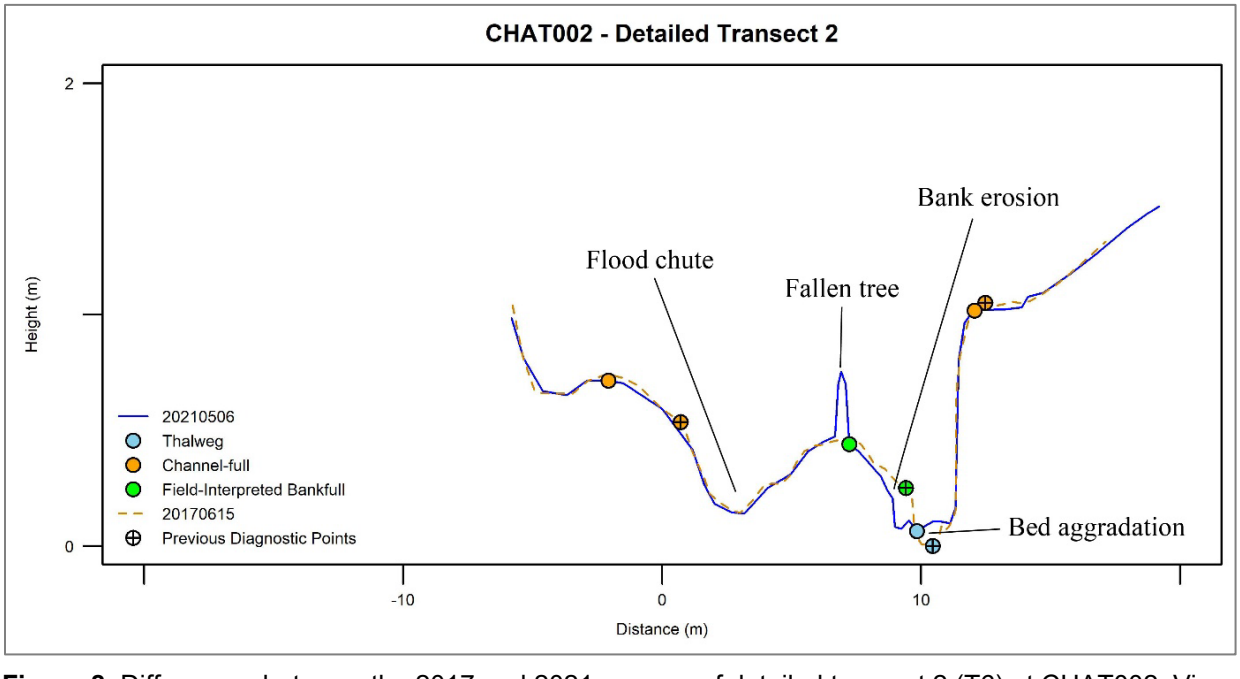


Figure 8. Differences between the 2017 and 2021 surveys of detailed transect 2 (T6) at CHAT002. View is in the downstream direction.

NPS

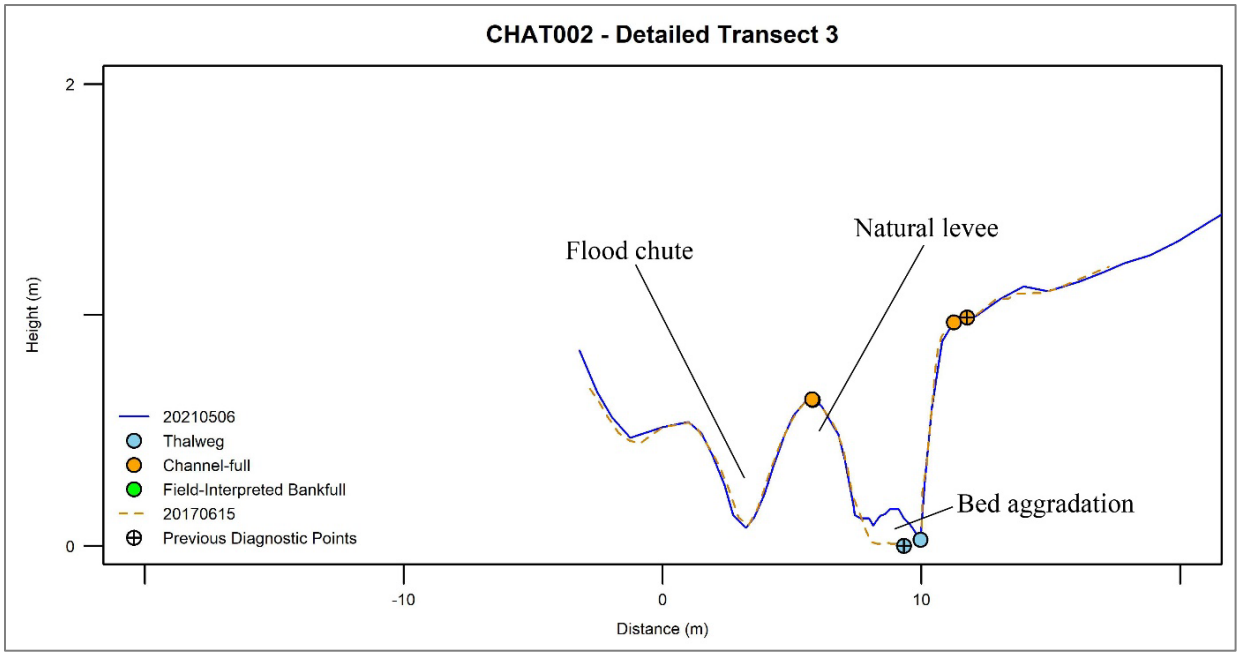


Figure 9. Differences between the 2017 and 2021 surveys of detailed transect 3 (T10) at CHAT002. View is in the downstream direction.

NPS

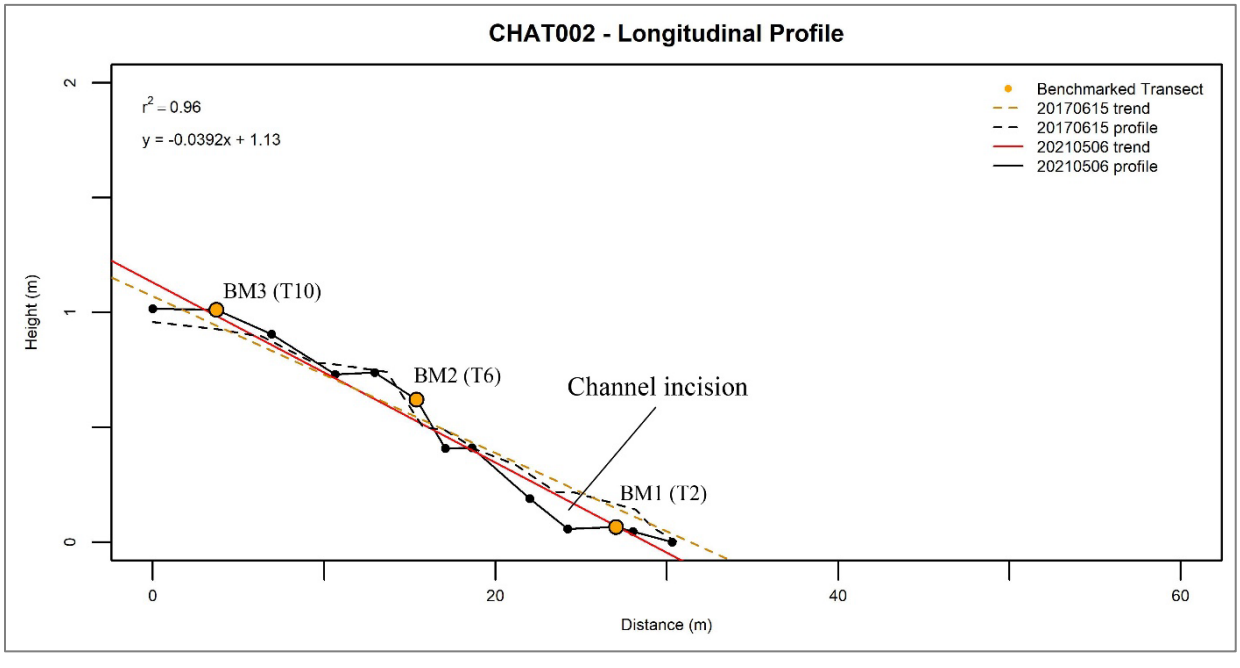


Figure 10. Longitudinal profile for CHAT002. The red line on the graph corresponds to the interpreted slope of the reach (0.0392 m/m). The r^2 value describes the strength of the 2021 trend line (interpreted slope). The "T#" in parentheses indicates the standard transect number on which the detailed transects were surveyed.

NPS

Table 15. Comparison of 2017 and 2021 reach scale and average detailed transect characteristics for the first-order streams at Chattahoochee River NRA [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)
CHAT002	2017	15	−0.0341	1.36	3	0.66	2.50	0.33	2.13	6.72	0.59
	2021	13	−0.0392	1.25	3	1.07	3.84	0.47	3.02	8.42	0.70
	Difference 2017–2021	−2	−0.0051	−0.11	–	0.41	1.34	0.15	0.90	1.70	0.11
CHAT003	2017	15	−0.0313	1.12	3	0.73	3.06	0.32	3.93	6.40	1.05
	2021	15	−0.0319	1.15	3	1.14	3.79	0.42	3.87	7.13	1.00
	Difference 2017–2021	0	−0.0006	0.03	–	0.41	0.73	0.10	−0.06	0.73	−0.04
CHAT006	2017	16	−0.0236	1.11	3	0.54	2.28	0.39	2.29	10.43	0.61
	2021	11	−0.0042	1.13	3	0.64	3.38	0.33	3.95	15.01	0.59
	Difference 2017–2021	−5	0.01936	0.02	–	0.10	1.10	−0.07	1.66	4.58	−0.02
CHAT009	2017	10	−0.0155	1.55	3	1.37	3.36	0.60	2.30	4.49	0.82
	2021	11	−0.0148	1.48	3	1.59	3.39	0.68	3.90	7.35	1.14
	Difference 2017–2021	1	−0.0007	−0.07	–	0.22	0.03	0.08	1.60	2.86	0.32
CHAT012	2017	13	−0.0234	1.44	3	0.62	2.38	0.37	1.01	3.36	0.51
	2021	13	−0.0237	1.47	3	0.84	2.74	0.53	1.64	4.97	0.73
	Difference 2017–2021	0	−0.0003	0.03	–	0.22	0.36	0.16	0.63	1.61	0.22

[A] Number of measurements for slope.

[B] Number of measurements for bankfull and channel full area, width, and depth.

The geomorphic changes observed on detailed transect 1 (T2) include the aggradation of the river right bar and floodplain coupled with stream channel incision (Figure 7). Bankfull cross-sectional area increased by 137% (Table 16). Bankfull width increased by 45% and bankfull height increased by 97%. Channel full area increased by 36% (Table 16). Channel full width increased by 45% and channel full height increased by 38%. Though some channel incision occurred (which would increase both bankfull and channel full areas), these changes are due to differences in interpretation.

Table 16. Changes to cross-sectional characteristics on detailed transect 1 (T2) at CHAT002 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	0.27	1.97	0.23
	2021	0.64	2.85	0.45
	Change 2017–2021 [A]	0.37	0.88	0.22
Channel full	2017	1.79	4.88	0.61
	2021	2.43	7.07	0.84
	Change 2017–2021 [A]	0.65	2.19	0.23

[A] Changes due to interpretive differences between survey years.

Included on detailed transect 2 (T6) are the flood chute (river left out-of-channel area), a large piece of fallen woody debris (river left bank), some erosion on the river left streambank, and bed aggradation within the stream channel (Figure 8). Bankfull cross-sectional area decreased by 27% (Table 17). Channel full area increased by 87%. This change in channel full area was related to a better interpretation of the river left channel full surface (placed on a higher more longitudinally continuous surface). The river right interpretation of channel full did not change.

Table 17. Changes to cross-sectional characteristics on detailed transect 2 (T6) at CHAT002 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	0.34	1.93	0.25
	2021	1.01	4.15	0.38
	Change 2017–2021	0.67	2.22	0.13
Channel-full	2017	2.70	10.65	0.54
	2021	4.92	13.51	0.65
	Change 2017–2021 [A]	2.23	2.86	0.11

[A] Changes due to interpretive differences between survey years.

Detailed transect 3 (T10) includes a flood chute (river left out-of-channel area), a natural levee (river left bank), significant aggradation of the streambed, and the development of a well-defined thalweg near the river right bank (Figure 9). No bankfull surfaces were identified in the field on this detailed transect. Bankfull measurements were calculated based on the reach-scale mean bankfull height.

Using the reach-scale mean bankfull height to calculate the bankfull measurements, bankfull cross-sectional area decreased by 94% (Table 18). As before, this large change is due to a change in interpretation. Channel full area decreased by 10% (Table 18). Main driver of these changes in bankfull and channel full cross-sectional area is bed aggradation (Figure 9).

Table 18. Changes to cross-sectional characteristics on detailed transect 3 (T10) at CHAT002 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.36	3.61	0.50
	2021	1.26	3.79	0.50
	Change 2017–2021	−0.10	0.17	0.00
Channel-full	2017	1.89	4.62	0.63
	2021	1.71	4.67	0.61
	Change 2017–2021	−0.18	0.05	−0.02

CHAT003—"Steep Draw Creek"

Reach Description

On June 6, 2021, stream survey data were collected at CHAT003. CHAT003 is on an unnamed first-order stream nicknamed "Steep Draw Creek" because of the steep trek into the site encountered during the initial assessment of the stream segment. The monitored reach on "Steep Draw Creek" is approximately 160 meters (525 ft) upstream from its confluence with the Chattahoochee River. CHAT003 can be accessed by following the social trail along the river left side of the Chattahoochee River, crossing "Undercut Creek" (CHAT002) and continuing over the watershed divide.

In 2021, one large tree fall was observed to be influencing the upstream transects (T9–T11; Figure 11). Additionally, an ephemeral drainage on river right, near T6, was also observed to be influencing the reach. CHAT003's channel is entrenched except for one area, between T1 and T3, that has developed elevated entrenched surfaces. A few bars and benches were observed throughout the reach. Groundwater input was observed between T4 and T5 and two cobble/boulder steps developed at T4 and T8. The cobble/boulder step at T8 was relatively steep and was producing small pockets of whitewater. The surveyed reach was 50 meters (164 ft) long with 5 meters (16.4 ft) between transects.

Water surface slope (longitudinal profile) for this section of "Steep Draw Creek" was virtually unchanged from 2017 (Table 15). The longitudinal profile is relatively consistent although some channel incision was observed downstream of T5, and a step has migrated upstream in the upper half of the reach (possibly the cobble/boulder step at T8). Channel sinuosity was low and nearly unchanged from the 2017 survey (Table 15). The detailed transects were surveyed on T1 (BM1), T6 (BM2), and T11 (BM3). Detailed transect 1 (T1) had an elevated entrenched surface on river right (identified as a floodplain in 2017) while the other two detailed transects (T6 and T11) remain

entrenched and had no floodplain or entrenched surface development (Figure 11). Survey results for CHAT003 can be viewed in the corresponding file of supplemental materials for this site.

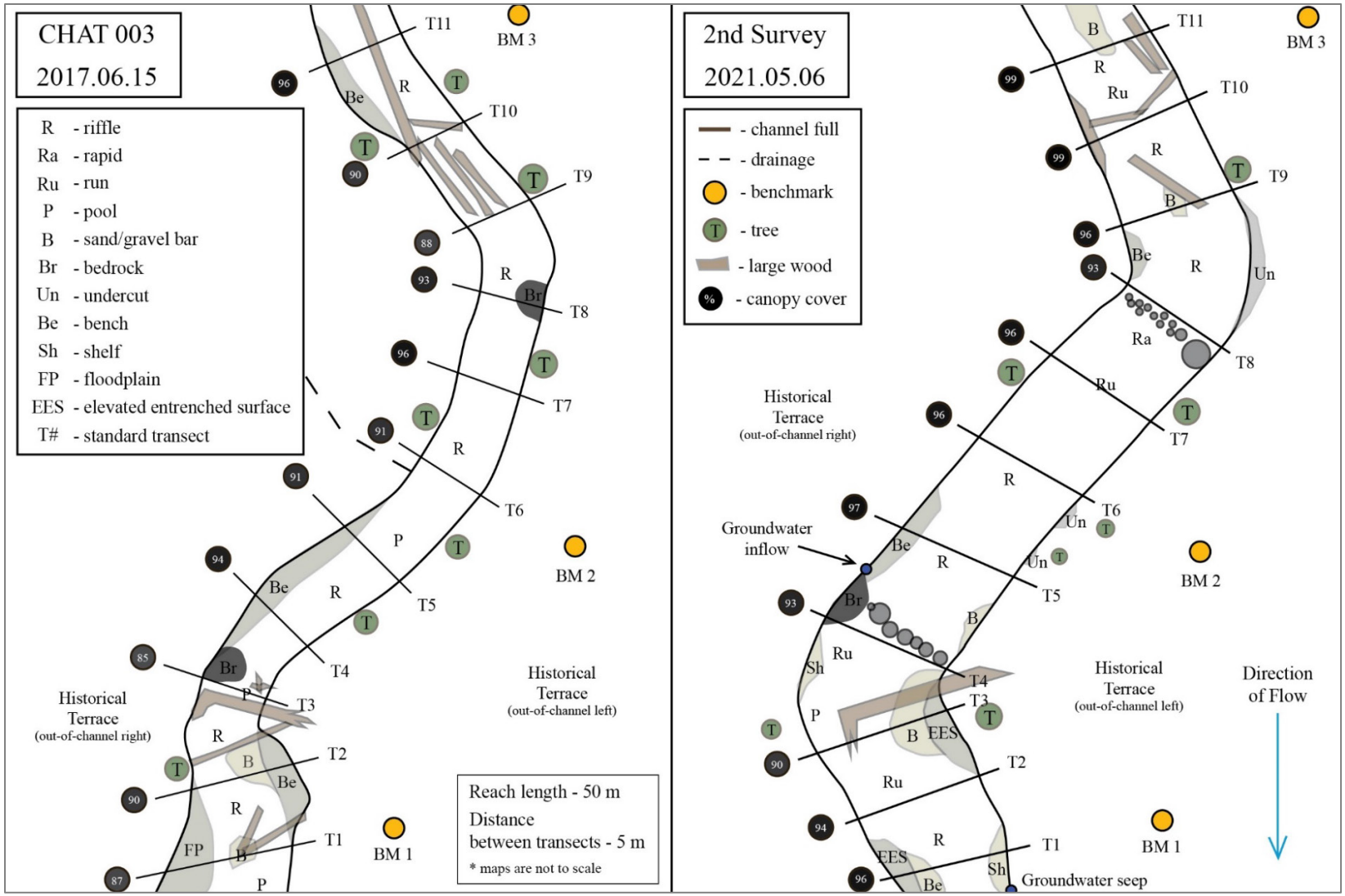


Figure 11. Reach-scale map of CHAT003. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

NPS

Habitat Characteristics

The geomorphic channel unit (GCU) types and distributions changed substantially between the surveys (Table 6). The mean percentage of riffle decreased (−28%) though the frequency of riffles was similar (n = 10 in 2017 versus n = 9 in 2021). The mean percentage of run increased (+28%) and the number of runs doubled from 4 to 8. The percentage of pool decreased (−8%) and the number of pools decreased from 5 to 3. Two steps were observed within the monitored reach in 2021, whereas none were observed in 2017.

The pebble count data for CHAT003 show a slight coarsening of the mean and intermediate sediment classes and a general fining of the smallest and largest sediment classes (Table 7). The mean diameter of the measured pebbles increased by 7% but this change was not statistically significant (p = 0.645; Table 19). Both the minimum and D_5 classes changed from sand (2.00 mm) to fine (< 0.06). There was also a substantial change in the D84 (−29%) and D95 (−45%) size classes.

Table 19. Difference in means t-test results comparing CHAT003 during 2017 and 2021. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [m—meters; mm—millimeters].

Measurement	n [A]	CHAT003 in 2017	CHAT003 in 2021	P-value	Significance
Pebble Count (mm)	100	39.05	41.70	0.645	–
Thalweg Depth (m)	11	0.09	0.17	0.029	*
Thalweg Position (%)	11	51.36	68.64	0.156	–
Wetted Width (m)	11	1.68	2.60	< 0.001	***
Active Channel Width (m)	11	2.21	2.94	0.015	*
Channel full Width (m)	11	4.67	5.89	0.015	*
Minimum Bank Height (m)	22	0.91	1.06	0.110	–
Channel full Height (m)	22	1.03	1.15	0.053	–
Bank Angle (°)	22	65.79	52.69	0.030	*
Vegetative Cover (%)	22	42.27	54.55	0.130	–

[A] Number of measurements taken.

The number of pieces of LWD decreased from 10 in 2017 to 7 in 2021 (Table 9). Six of these seven pieces of LWD were in jams just downstream of transects 4 and 11 (Figure 11). The amount of LWD per channel area decreased by 39% (Table 9). Canopy cover continued to be dense and have very little variability (Table 10).

Mean thalweg position (relative to the left bank) shifted toward the river right bank from 2017 to 2021 increasing from 51% in 2017 to 69% in 2021 (Table 11). Variability in thalweg position was very similar between the two surveys. The minimum and maximum thalweg depths were higher in 2021 (+100% and +65%, respectively; Table 11). Mean thalweg depth was statistically significantly deeper (+89%) in 2021 than 2017 (p = 0.029; Table 19).

Channel Morphology

Average wetted width at CHAT003 was 55% wider and mean active channel width was 33% wider in 2021 (Table 12). The differences in both mean wetted width and mean active channel width were statistically significant ($p < 0.001$ and $p = 0.015$, respectively; Table 19). While both wetted and active channel widths increased, both values were slightly less variable in 2021 than in 2017 (Table 12). Bankfull widths also increased. Three bankfull widths were measured in both surveys. Mean bankfull width increased by 61% (Table 12). Mean channel full width increased by 26% (Table 12) and this change was statistically significant ($p = 0.015$; Table 19).

Mean minimum bank height (lowest bank height on a transect) increased by 16% (Table 13). Bankfull heights increased by 76% and variability did not change appreciably. Mean channel full height increased by 12% (Table 13). This change in channel full height was not statistically significant ($p = 0.053$; Table 19).

The number of undercut banks increased from $n = 7$ in 2017 to $n = 12$ in 2021 (Table 14). The mean depth of undercuts decreased by 24%. Bank angles were on average less steep during 2021 (53°) compared to 2017 (66°; Table 14). This difference in mean bank angle was statistically significant ($p = 0.030$; Table 19). Bank vegetation cover increased (+13%; Table 14) but this difference was not statistically significant ($p = 0.130$; Table 19). Bank stability scores decreased (more stable) from a mean value of 13 in 2017 to 11 in 2021 (Table 14).

Detailed Transects

The detailed transects at CHAT003 were surveyed on T1 (BM1; Figure 12), T6 (BM2; Figure 13), and T11 (BM3; Figure 14). On these detailed transects, bankfull cross-sectional area was on average 44% larger and mean channel full area was approximately equal (Table 15). Water surface slope (longitudinal profile) did not change appreciably between the surveys (Figure 15). While channel slope was similar, changes can be seen. The most substantial differences were channel incision between T1 and T6 and an increase in slope above T8 (influence of the cobble/boulder step).

Detailed transect 1 (T1) showed slight bank slumping on the river left bank, a slight shift in thalweg position (towards the left bank), the loss of an in-channel bar feature, and erosion of the bar and elevated entrenched surface on river right (Figure 12). Bankfull cross-sectional area increased by 87% (Table 20). Channel full area increased by 2% (Table 20). Unlike CHAT002, this change is due to actual geomorphic change and not interpretive differences.

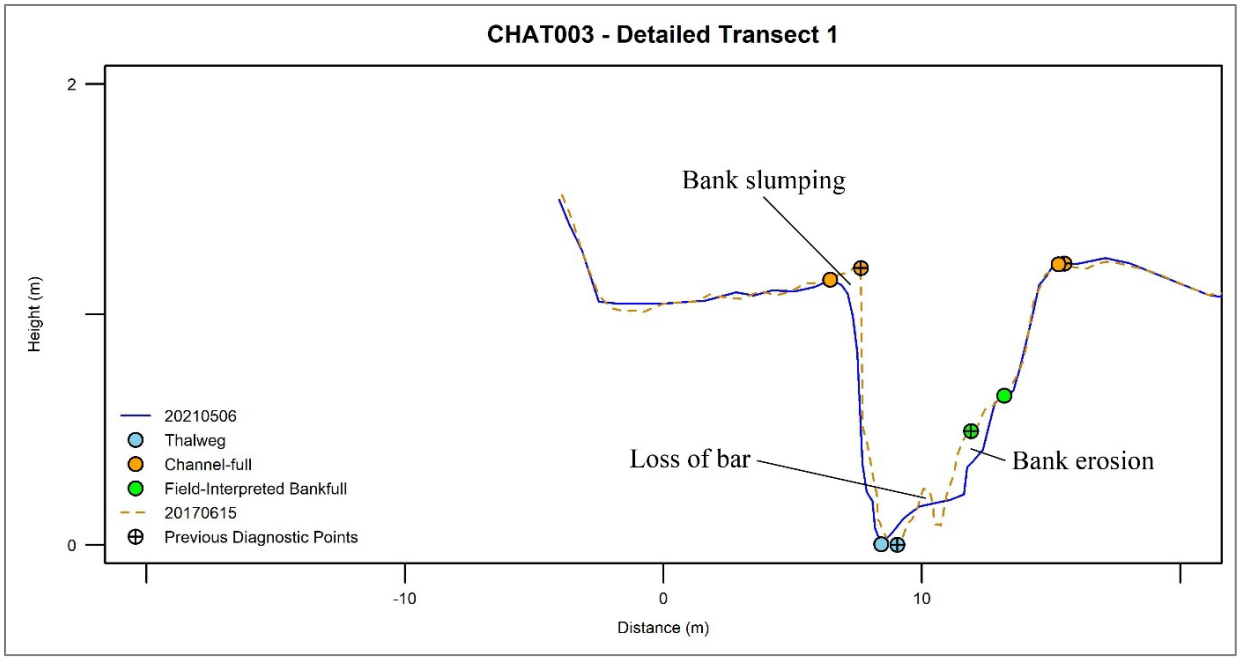


Figure 12. Differences between the 2017 and 2021 surveys of detailed transect 1 at CHAT003. View is in the downstream direction.

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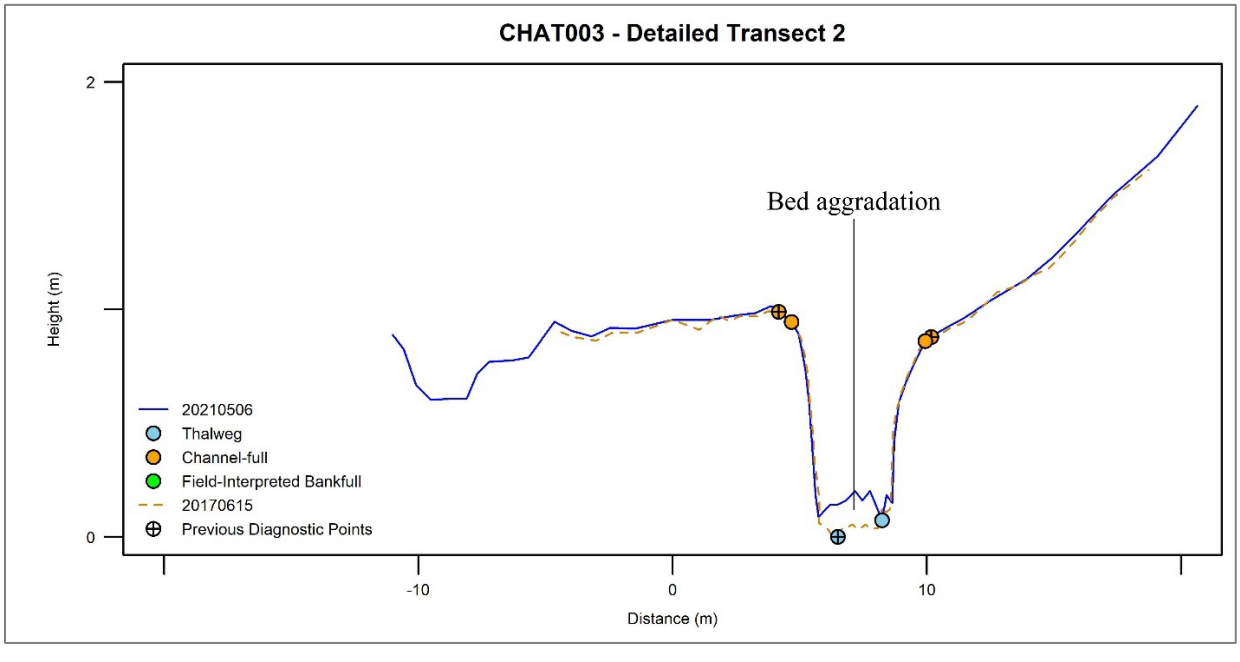


Figure 13. Differences between the 2017 and 2021 surveys of detailed transect 2 at CHAT003. View is in the downstream direction.

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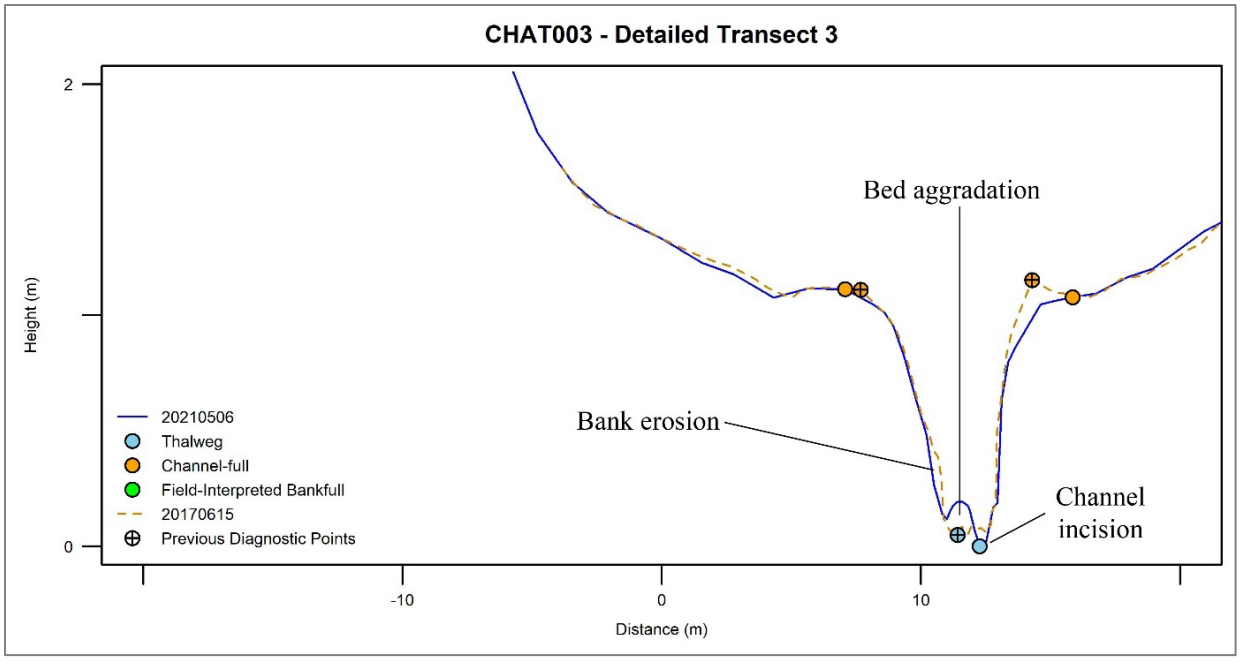


Figure 14. Differences between the 2017 and 2021 surveys of detailed transect 3 at CHAT003. View is in the downstream direction.

NPS

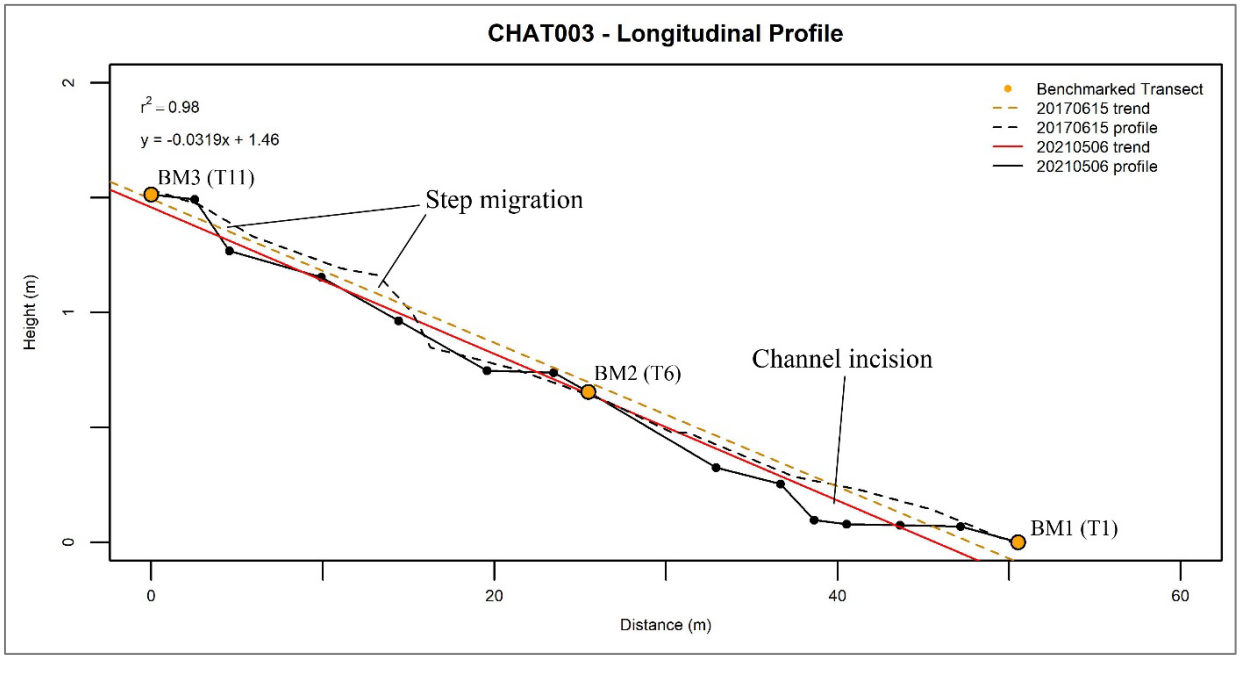


Figure 15. Longitudinal profile for CHAT003. The red line on the graph corresponds to the interpreted slope of the reach (0.0319 m/m). The r^2 value describes the strength of the 2021 trend line (interpreted slope). The "T#" in parentheses indicates the transect number on which the detailed transects were surveyed.

NPS

Table 20. Changes to cross-sectional characteristics on detailed transect 1 at CHAT003 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.21	4.15	0.49
	2021	2.26	5.61	0.64
	Change 2017–2021	1.05	1.46	0.15
Channel full	2017	5.51	7.56	1.20
	2021	5.64	8.27	1.15
	Change 2017–2021	0.12	0.71	−0.05

Detailed transect 2 (T6) had bed aggradation (incipient midchannel bar formation) and thalweg migration to the river right side of the channel (Figure 13). Bankfull cross-sectional area increased by 31% (Table 21). This change is due to the higher bed sediments forcing stormflow waters up into the wider areas of the channel closer to channel full. Channel full area decreased by 11% due to the aggradation of the bed.

Table 21. Changes to cross-sectional characteristics on detailed transect 2 at CHAT003 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	0.55	2.93	0.24
	2021	0.72	3.21	0.31
	Change 2017–2021	0.17	0.28	0.07
Channel full	2017	2.87	5.17	0.88
	2021	2.54	4.92	0.79
	Change 2017–2021	−0.33	−0.24	−0.09

Detailed transect 3 (T10) had slight erosion of the river left bank, bed aggradation (incipient bar formation), and both thalweg migration (toward the river right side) and incision (Figure 14). Bankfull cross-sectional area was very similar between the two surveys (Table 22). Channel full area also did not change appreciably between the surveys. Though bankfull and channel full widths and heights changed, the development of the incipient mid-channel bar kept cross-sectional areas relatively similar between the surveys.

Table 22. Changes to cross-sectional characteristics on detailed transect 3 at CHAT002 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	0.43	2.11	0.24
	2021	0.44	2.56	0.31
	Change 2017–2021	0.01	0.44	0.07
Channel full	2017	3.40	6.47	1.06
	2021	3.43	8.20	1.08
	Change 2017–2021	0.03	1.73	0.02

CHAT006—"Three Mind Creek"

Reach Description

On May 08, 2021, stream survey data were collected at CHAT006. CHAT006 is on an unnamed first-order stream nicknamed "Three Mind Creek" because three distinctive sections were observed during the initial survey (highly entrenched upstream, low banks and wide floodplain in the middle, and becoming increasingly entrenched downstream). The monitored reach on "Three Mind Creek" is positioned on the transition from the middle not entrenched section to the increasingly entrenched downstream section. CHAT006 is approximately 325 meters (1,066 ft) upstream of its confluence with Suwanee Creek. CHAT006 can be accessed by following the trail at the end of Chattahoochee Drive down to within 50 meters (164 ft) of the stream.

The reach surveyed was 20 meters (65.6 ft) long with 2 meters (6.6 ft) between transects. The most distinguishing characteristic of "Three Mind Creek" during the initial survey (2017) was a large change in slope (knickpoint) above T3 and the transition to an entrenched channel below this change in slope (Figure 16). Since the 2017 survey, the entrenched area below T4 infilled due to the development of a large wood jam just downstream of the monitored reach. In 2021, the longitudinal profile was relatively flat throughout the reach, with a slight change in slope at the (now filled in) knickpoint between T3 and T4. Detailed transects were surveyed on T1 (BM1), T6 (BM2), and T11 (BM3). Substantial change was observed on detailed transects 1 (T1) and 3 (T11), including aggradation and channel migration. Survey results for CHAT006 can be viewed in the corresponding file of supplemental materials for this site.

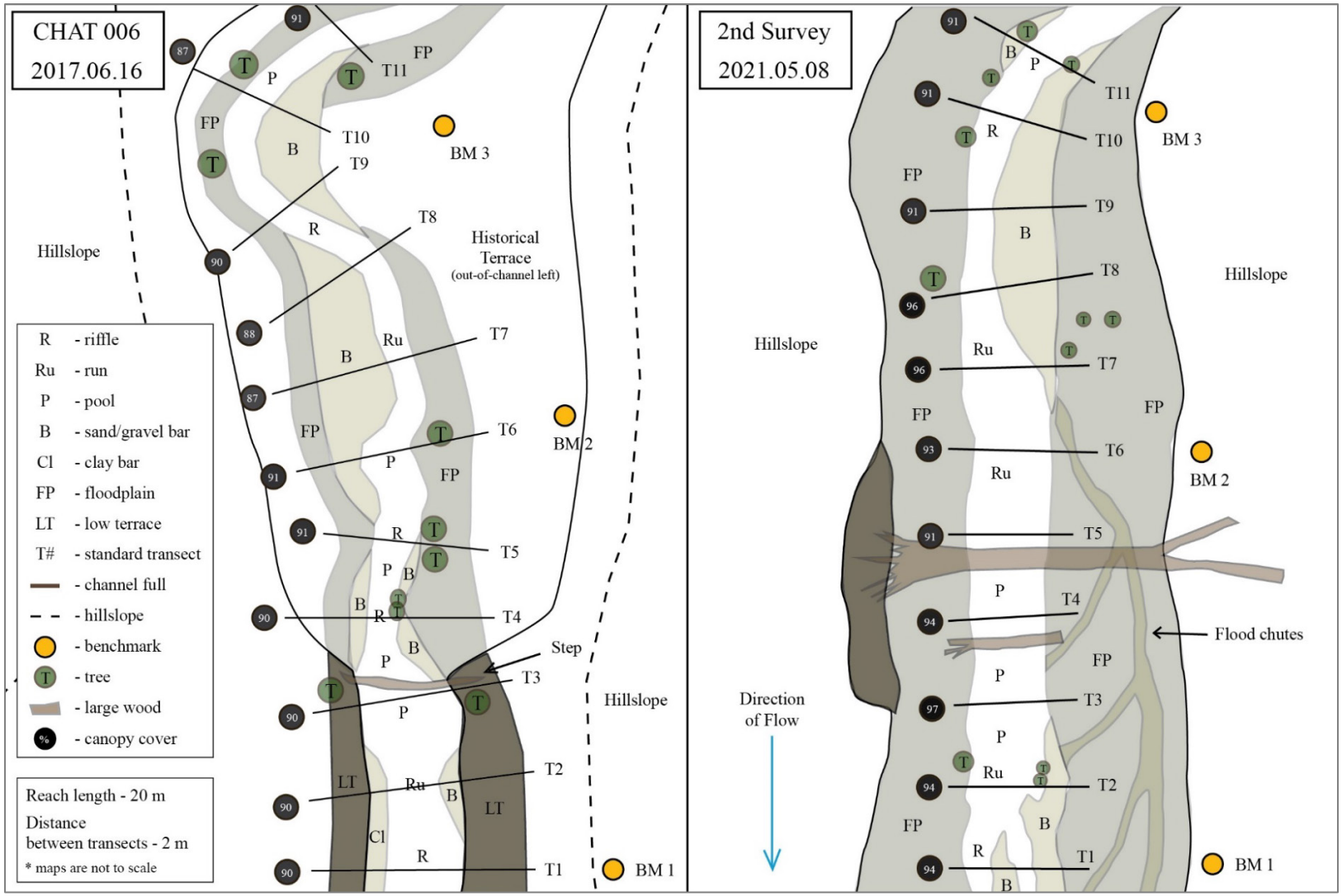


Figure 16. Reach-scale map of CHAT006. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

NPS

Habitat Characteristics

The geomorphic channel unit (GCU) types and distributions changed between the 2017 and 2021 surveys (Table 6). Riffles, runs, pools, and one step were present within the surveyed reach during both survey years. The mean percentage of riffle decreased (−15%) and the frequency of riffles along transects also decreased. The mean percentage of run greatly increased (+51%) and the number of observed runs tripled from 3 to 9. The percentage of pool greatly decreased (−35%) and the number of pools decreased from 10 to 4. One log step was observed within the monitored reach during both survey years, although during the 2021 survey it was classified as a "mixed" step (comprised of both large woody debris and organics). This step was observed just upstream of transect 3 during both survey years.

The pebble count data for CHAT006 shows the bed sediment has coarsened between the surveys (Table 7). There was a statistically significant increase (+32%) in the mean diameter of the pebbles measured at CHAT006 ($p = 0.010$; Table 23). The minimum observed value and the D_5 decreased, but the D_{50}, D_{84}, and D_{95} particle sizes all increased (Table 7).

Table 23. Difference in means t-test results comparing CHAT006 during 2017 and 2021. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [m—meters; mm—millimeters].

Measurement	n [A]	CHAT006 in 2017	CHAT006 in 2021	P-value	Significance
Pebble Count (mm)	100	10.93	14.47	0.010	**
Thalweg Depth (m)	11	0.11	0.18	0.299	–
Thalweg Position (%)	11	36.82	50.00	0.301	–
Wetted Width (m)	11	0.99	1.50	0.041	*
Active Channel Width (m)	11	1.41	2.62	< 0.001	***
Channel full Width (m)	11	11.16	17.59	0.007	**
Minimum Bank Height (m)	22	0.51	0.47	0.406	–
Channel full Height (m)	22	0.67	0.96	< 0.001	***
Bank Angle (°)	22	44.44	25.25	0.003	**
Vegetative Cover (%)	22	11.14	14.55	0.259	–

[A] Number of measurements taken.

The number of pieces of large woody debris (LWD) observed at CHAT006 increased from two to eight (Table 9). Four of these eight pieces of LWD were in a jam (step) just upstream of transect 3 (Figure 16). The largest piece of LWD was a channel-spanning fallen tree between T4 and T5. The amount of LWD per channel area nearly quadrupled from 0.0033 m^3/m^2 to 0.0126 m^3/m^2. Canopy cover continued to be dense (mean canopy cover = 93%; Table 10) and had very little variability (CV = 0.02).

Mean thalweg position (relative to the left bank) shifted toward the middle of the channel increasing from 37% in 2017 to 50% in 2021 (Table 11). Variability in thalweg position was very similar between the two surveys. While the minimum thalweg depth was similar, maximum thalweg depth

increased by 243%. Mean thalweg depth increased by 64% but this increase was not statistically significant ($p = 0.299$; Table 23).

Channel Morphology

There was statistically significant increase in both wetted width (+52%; $p = 0.041$) and active channel width (+86%; $p < 0.001$; Table 23). While both wetted and active channel widths increased, both values were less variable in 2021 than in 2017 (Table 12). Bankfull width also increased. The number of bankfull width measurements increased from eight in 2017 to eleven in 2021 because of the infilling of the entrenched channel below T4. Mean bankfull width increased by 24% (Table 12). Variability in bankfull width was unchanged continuing to be relatively low (Table 12). There was a statistically significant increase (+58%) in mean channel full width ($p = 0.007$; Table 23). There was also a substantial reduction (−79%) in variability in channel full widths (Table 12). Unlike CHAT002, the statistically significant increase in channel full was due to geomorphic change (infilling of entrenched channel leading to connection of the channel to its floodplain) not interpretive differences.

There was a slight (−8%) reduction in mean minimum bank height (lowest bank height on a transect; Table 13). The number of bankfull height measurements was higher in 2021 ($n = 22$) than in 2017 ($n = 14$). These added measurements did not greatly affect the mean value though variability in bankfull height more than doubled (Table 13). There was a statistically significant (+43%) increase in mean channel full height ($p < 0.001$; Table 23). This statistically significant increase in mean channel full height was influenced by the previously mentioned infilling of the channel below T4.

No undercut banks were measured during the 2021 survey, whereas four bank undercuts were measured in 2017 (Table 14). There was statistically significant reduction (−43%) in bank angle ($p = 0.003$; Table 23). The percentage of bank vegetation cover increased between the two survey periods but remained relatively low and this change was not statistically significant ($p = 0.259$; Table 23). Bank stability scores decreased (more stable) from a mean value of 13.55 to 12.77 (Table 14).

Detailed Transects

The detailed transects at CHAT006 were surveyed on T1 (BM1; Figure 17), T6 (BM2; Figure 18), and T11 (BM3; Figure 19). Substantial change was observed on detailed transects 1 and 3 (top and bottom of the monitored reach). On average, bankfull area increased by 19% and channel full area increased by 72% (Table 15). Water surface slope (longitudinal profile) for this section of Three Mind Creek decreased substantially from 0.0236 m/m to 0.0042 m/m (Figure 20; Table 15). This major change in water surface slope was caused by substantial aggradation downstream of T4. As mentioned earlier, sediment built up behind a mixed jam (woody debris and organics) just downstream of the monitored reach has led to the area between T1 and T4 to aggrade (Figure 20).

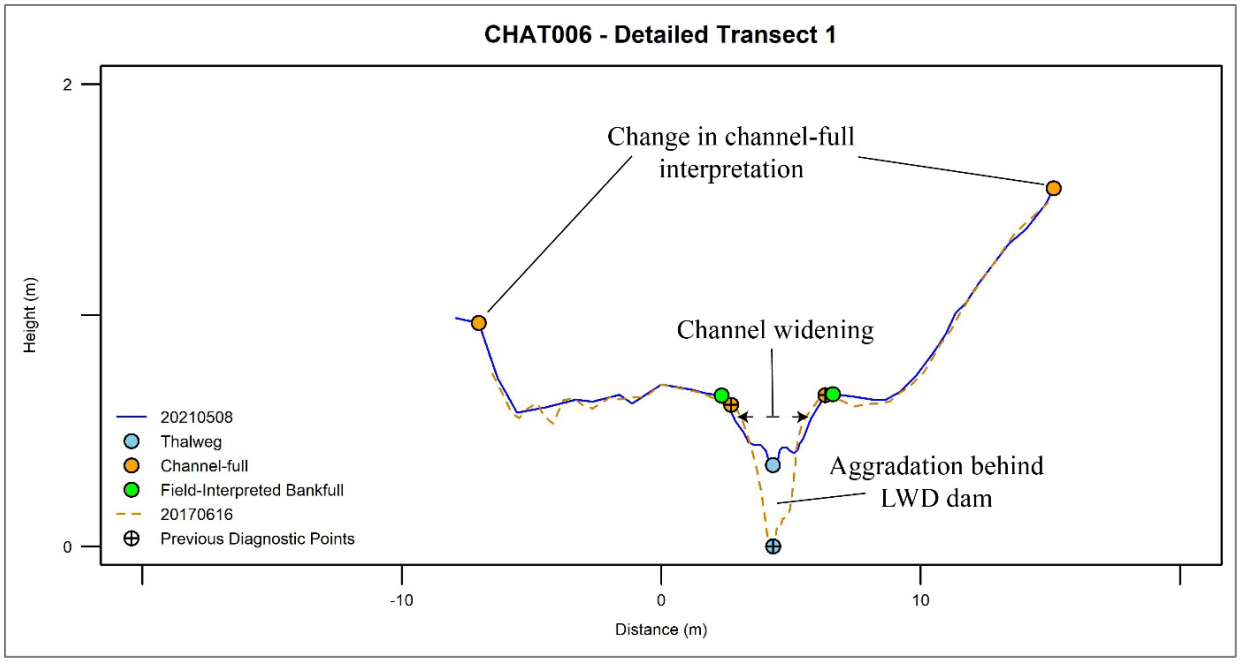


Figure 17. Differences between the 2017 and 2021 surveys of detailed transect 1 at CHAT006. View is in the downstream direction.

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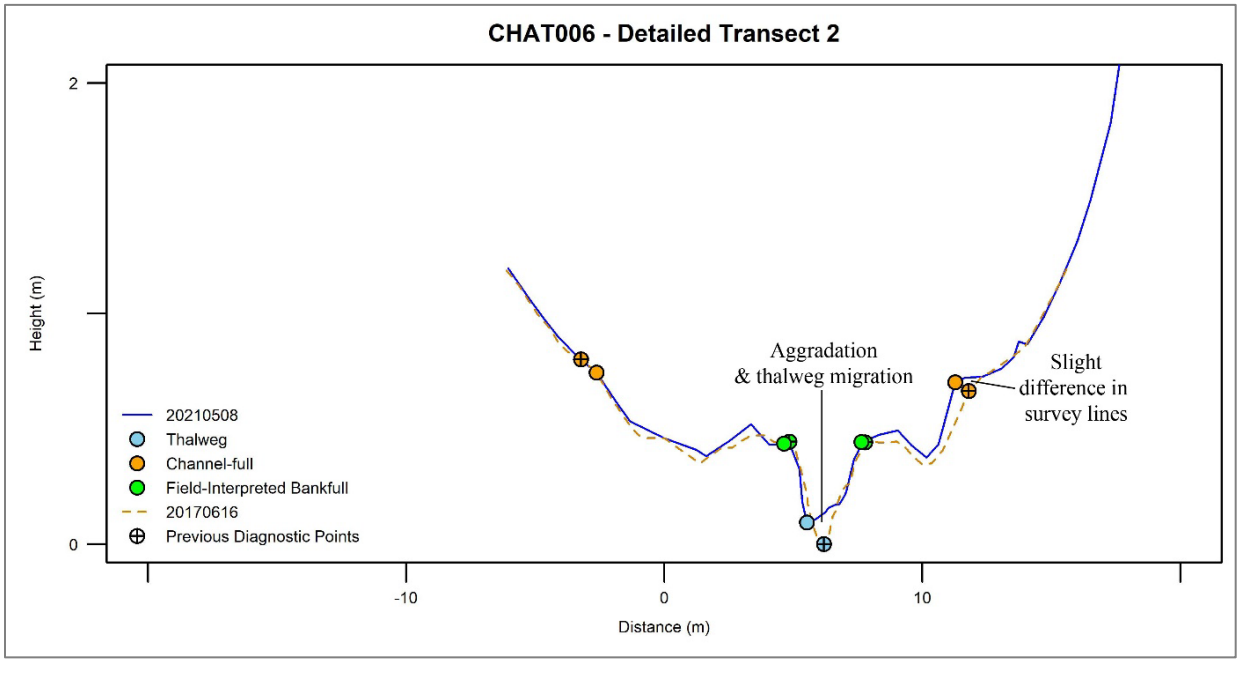


Figure 18. Differences between the 2017 and 2021 surveys of detailed transect 2 at CHAT006. View is in the downstream direction.

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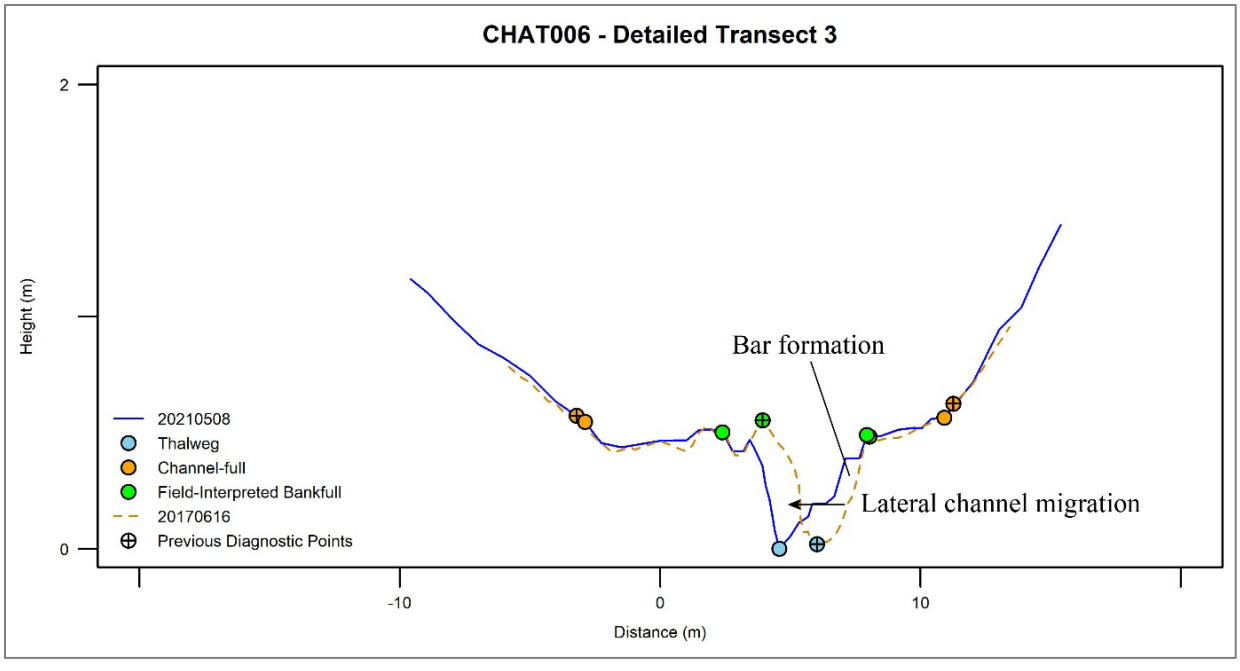


Figure 19. Differences between the 2017 and 2021 surveys of detailed transect 3 at CHAT006. View is in the downstream direction.

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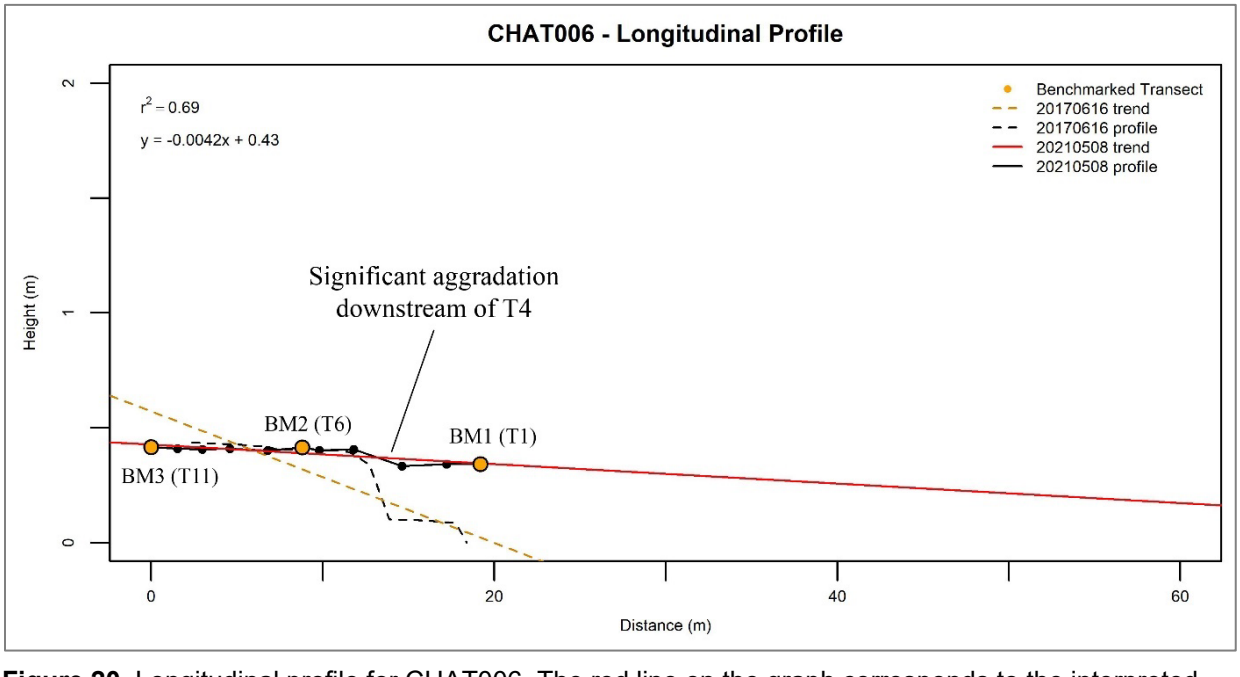


Figure 20. Longitudinal profile for CHAT006. The red line on the graph corresponds to the interpreted slope of the reach (0.0042 m/m). The r^2 value describes the strength of the 2021 trend line (interpreted slope). The "T#" in parentheses indicates the transect number on which the detailed transects were surveyed.

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Detailed transect 1 (T1) showed a slight widening of the bankfull channel, a change in thalweg position, and substantial bed aggradation (Figure 17). Bankfull cross-sectional area on detailed transect 1 (T1) decreased by 15% (Table 24). Channel full area on detailed transect 1 (T1) greatly increased (+595%) driven by the necessary change in interpretation of geomorphic surfaces because of the infilling of the formerly entrenched channel (Table 24). While there was a substantially increase in channel full width (+465%), channel full height did not change.

Table 24. Changes to cross-sectional characteristics on detailed transect 1 at CHAT006 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	0.48	1.84	0.45
	2021	0.41	3.21	0.23
	Change 2017–2021	−0.08	1.37	−0.22
Channel full	2017	0.87	3.22	0.61
	2021	6.05	18.20	0.61
	Change 2017–2021 [A]	5.18	14.98	0.00

[A] Changes due to interpretive differences between survey years (caused by reconnection of channel to floodplain).

Detailed transect 2 (T6) showed less change than detailed transects 1 (T1) and 3 (T11) but displays thalweg migration to the river left side of the channel and some aggradation of the streambed (Figure 18). Neither bankfull cross-sectional area nor channel full area changed appreciably (Table 25). The differences in widths and heights could be related to slightly differences in survey line as opposed to “true” geomorphic change.

Table 25. Changes to cross-sectional characteristics on detailed transect 2 at CHAT006 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	0.41	2.13	0.35
	2021	0.43	2.32	0.28
	Change 2017–2021	0.02	0.20	−0.07
Channel full	2017	3.70	14.02	0.66
	2021	3.81	13.64	0.61
	Change 2017–2021	0.12	−0.38	−0.06

Detailed transect 3 (T11) shows lateral migration of the stream channel toward river left, slight incision (lowering of thalweg), and the development of a bar surface on the river right side of the channel (Figure 19). Bankfull cross-sectional area increased by 49% (Table 26). The observed increase in bankfull width was driven by the lateral migration of the channel, which shifted the bankfull diagnostic point on river left (Figure 19). Channel full area on detailed transect 3 decreased by 13% (Table 26). While there was a slight reduction in channel full width (−6%), channel full height did not change.

Table 26. Changes to cross-sectional characteristics on detailed transect 3 at CHAT002 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	0.72	2.87	0.38
	2021	1.07	4.60	0.47
	Change 2017–2021	0.36	1.73	0.09
Channel full	2017	2.31	14.06	0.55
	2021	2.00	13.20	0.55
	Change 2017–2021	−0.32	−0.86	0.00

CHAT009—"Fox Creek"

Reach Description

On May 13, 2021, stream survey data were collected at CHAT009. CHAT009 is on a portion of Fox Creek (a first-order stream near the Sope Creek Hiking Trail). Fox Creek is accessed using the Sope Creek Hiking Trail to get to within 50 meters (164 ft) of the monitored reach. CHAT009 is approximately 175 meters (574 ft) upstream of a culvert that runs under the adjacent apartment complex and empties into Sope Creek. The reach surveyed was 20 meters (65.6 ft) long with 2 meters (6.6 ft) between transects.

The monitored portion of Fox Creek is characterized by an abundance of low, potentially slump-cored (i.e., an erosional surface as opposed to a depositional "point-bar" type surface), benches and elevated entrenched surfaces along the sides of the channel at T1, T2, T5, and T8 through T11 (Figure 21). More areas of riffle have developed than were observed during the initial survey in 2017. Water surface slope (longitudinal profile) for this section of Fox Creek was 0.0148 m/m (Table 5). The longitudinal profile was relatively flat with only one slight increase in slope showing possible knickpoint migration since the 2017 survey (between T4 and T6). The detailed transects were surveyed on T3 (BM1), T8 (BM2), and T11 (BM3). No floodplains were surveyed on any of the detailed transects during the initial surveys, but during 2021 elevated entrenched surfaces on all three detailed transects were identified as bankfull. Channel incision and/or erosion was also observed on each detailed transect. Survey results for CHAT009 can be viewed in the corresponding file of supplemental materials for this site.

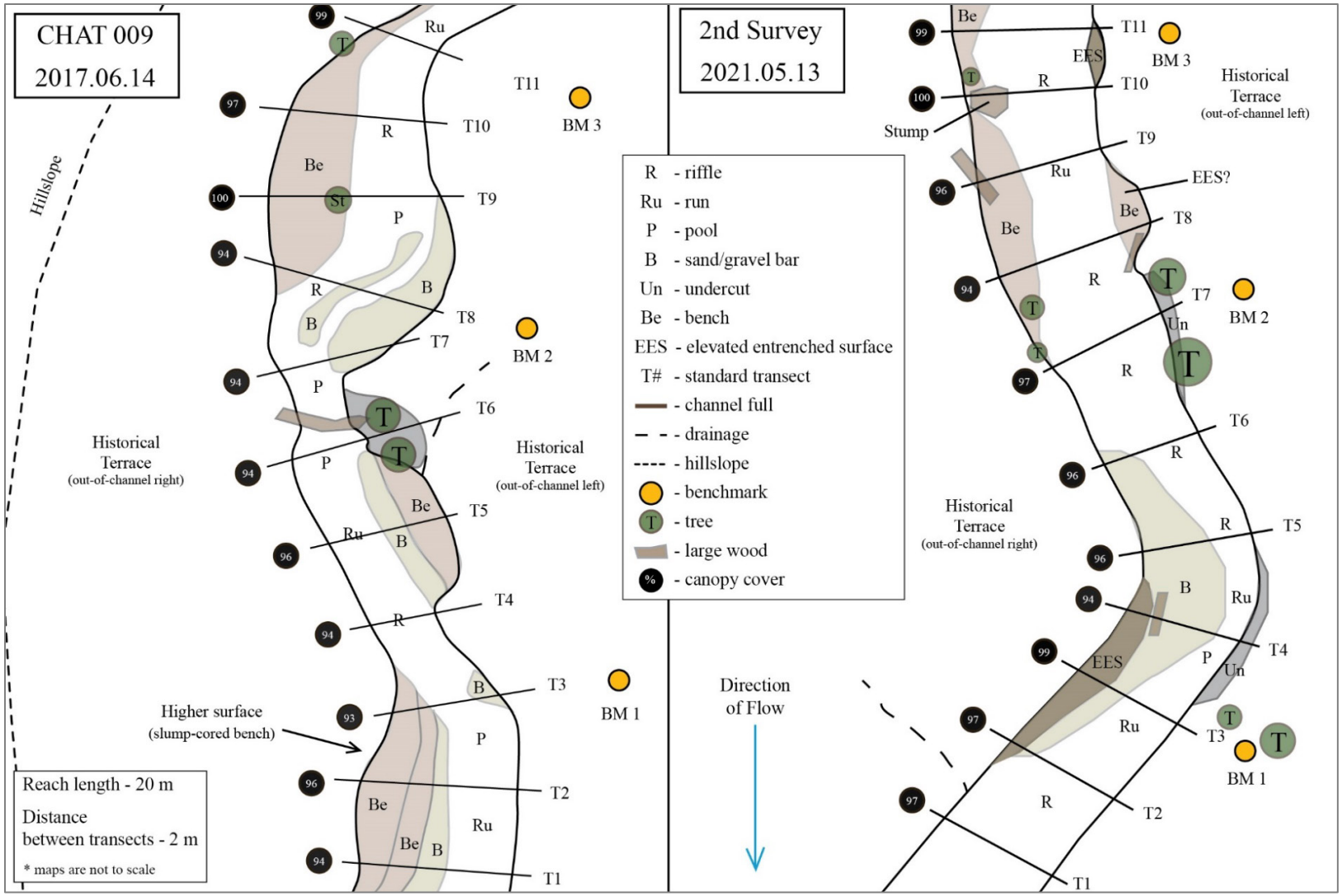


Figure 21. Reach-scale map of CHAT009. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

NPS

Habitat Characteristics

The geomorphic channel unit (GCU) types and distributions changed between the 2017 and 2021 surveys (Table 6). Riffles, runs, pools, and one step were present within the surveyed reach during both survey years. The mean percentage of riffle increased (+18%) and the frequency of riffles along transects also increased. The mean percentage of run greatly increased (+20%) and the number of observed runs also increased. The percentage of pool greatly decreased (−28%) and the number of pools also decreased from 7 to 1. No glide or steps were observed within the reach during either survey years.

The pebble count data for CHAT009 shows a coarsening of the bed sediment between the 2017 and 2021 surveys (Table 7). There was a statistically significant coarsening (+167%) of the measured mean diameter of the pebbles ($p < 0.001$; Table 27). The minimum observed value and the D_5 decreased, but the D_{50}, D_{84}, and particle sizes all greatly increased from their 2017 values (Table 7).

Table 27. Difference in means t-test results comparing CHAT009 during 2017 and 2021. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [m—meters; mm—millimeters].

Measurement	n [A]	CHAT009 in 2017	CHAT009 in 2021	P-value	Significance
Pebble Count (mm)	100	23.68	63.35	< 0.001	***
Thalweg Depth (m)	11	0.05	0.09	0.008	**
Thalweg Position (%)	11	46.36	23.18	0.031	*
Wetted Width (m)	11	0.97	1.74	< 0.001	***
Active Channel Width (m)	11	1.86	2.44	0.005	**
Channel full Width (m) [B]	11	4.67	6.70	< 0.001	***
Minimum Bank Height (m)	22	0.97	0.97	0.890	–
Channel full Height (m)	22	0.97	1.09	0.003	**
Bank Angle (°)	22	47.14	49.73	0.749	–
Vegetative Cover (%)	22	19.77	33.18	0.009	**

[A] Number of measurements taken.

[B] Changes due to interpretive differences between survey years.

The number of pieces of large woody debris (LWD) observed at CHAT009 increased from 3 to 8 and were evenly distributed throughout the reach (Table 9). The mean length of LWD and mean diameter of LWD did not change appreciably between the surveys. The volume of LWD per channel area was similar, increasing slightly from 0.0014 m^3/m^2 to 0.0016 m^3/m^2. Canopy cover continued to be very dense and have very little variability (CV = 0.02; Table 10).

Mean thalweg position (relative to the left bank) shifted toward river left decreasing from 46% to 23% (Table 11). While the minimum thalweg depth was similar, maximum thalweg depth increased by 150%. Additionally, there was a statistically significant (80%) increase in mean thalweg depth ($p = 0.003$; Table 27).

Channel Morphology

There was a statistically significant increase in both mean wetted width (+80%) and mean active channel width (+31%) between the survey years ($p < 0.001$ and $p = 0.005$, respectively; Table 27). Both minimum wetted width and maximum wetted width were greater in 2021 (+107% and +43%, respectively; Table 12). The same was observed for active channel width, as both the minimum and maximum values increased from those observed during the 2017 surveys (+49% and 30%, respectively). While both wetted and active channel widths increased, both metrics were less variable in 2021 than in 2017 (Table 12). The number of bankfull width measurements increased from zero in 2017 to five in 2021 due to the change in how elevated entrenched surfaces were interpreted. The change in surface interpretation also led to a statistically significant (43%) increase in mean channel full width ($p < 0.001$; Table 27).

Mean minimum bank height (lowest bank height on a transect) in 2021 did not change from the 2017 value (Table 13). Five bankfull height measurements were taken during the 2021 (Table 13). Mean channel full height was statistically significantly higher (+12%) in 2021 and this change can again be attributed to the change in surface interpretation ($p = 0.003$; Table 27).

One more undercut bank was measured at CHAT009 during the 2021 survey (Table 14). The mean depth of bank undercuts increased by 44% and variability in bank undercut depths remained high but decreased slightly in 2021. CHAT009 was the only monitored first-order stream that showed an increase in mean bank angle though this increase was not statistically significant ($p = 0.749$; Table 27). There was also a statistically significant (13%) increase in bank vegetation cover ($p = 0.009$; Table 27). Bank stability scores decreased (more stable) from a mean value of 13.5 in 2017 to 12.0 in 2021 (Table 14).

Detailed Transects

The detailed transects on CHAT009 were surveyed on T3 (BM1; Figure 22), T8 (BM2; Figure 23), and T11 (BM3; Figure 24). There were changes in the interpretation of geomorphic surfaces on each detailed transect, as each had an elevated entrenched surface that was identified as an indicator of bankfull level during the 2021 survey. Some channel incision and/or erosion was also observed on each detailed transect. These interpretive and geomorphic changes led to an increase in both mean bankfull area and mean channel full area of 18% and 70%, respectively (Table 15). Change in water surface slope (longitudinal profile) for this section of Fox Creek was negligible (Figure 25; Table 15). This change in water surface slope (0.0004 m/m) falls well within the surveying equipment's range of error. On the longitudinal profile, the change in slope seen between T5 and T7 may indicate knickpoint migration, as there was a similar change in slope between T3 and T4 in 2017. Sinuosity did not change appreciably between the survey years (Table 15).

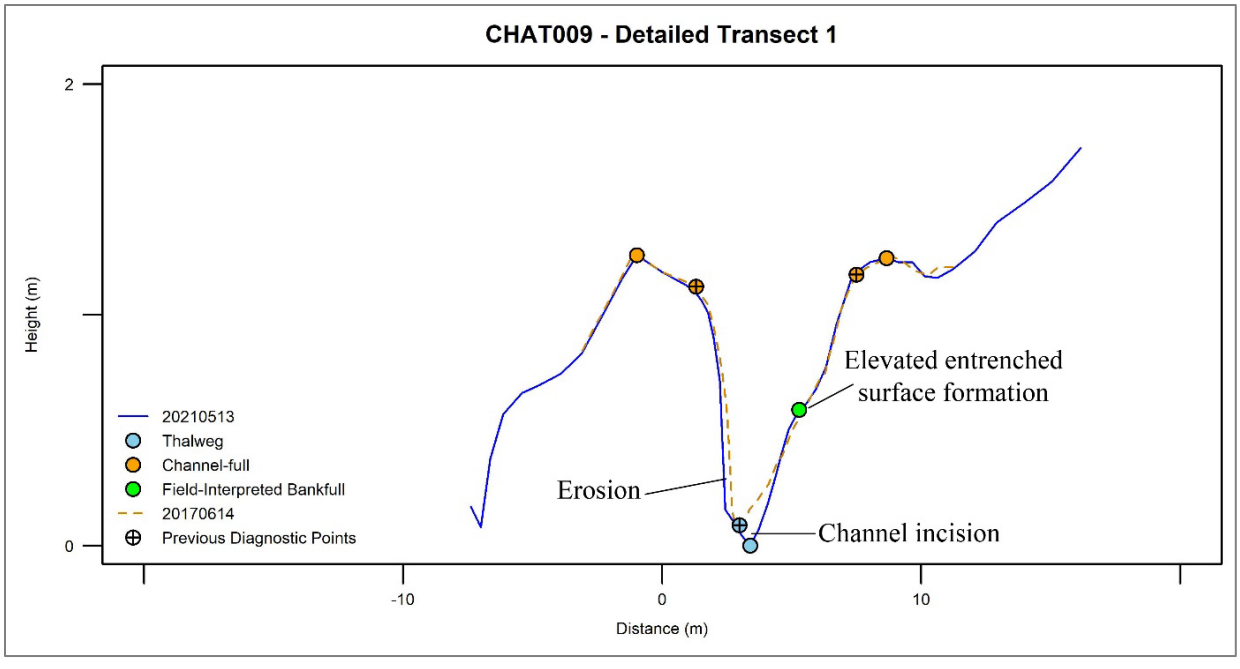


Figure 22. Differences between the 2017 and 2021 surveys of detailed transect 1 at CHAT009. View is in the downstream direction.

NPS

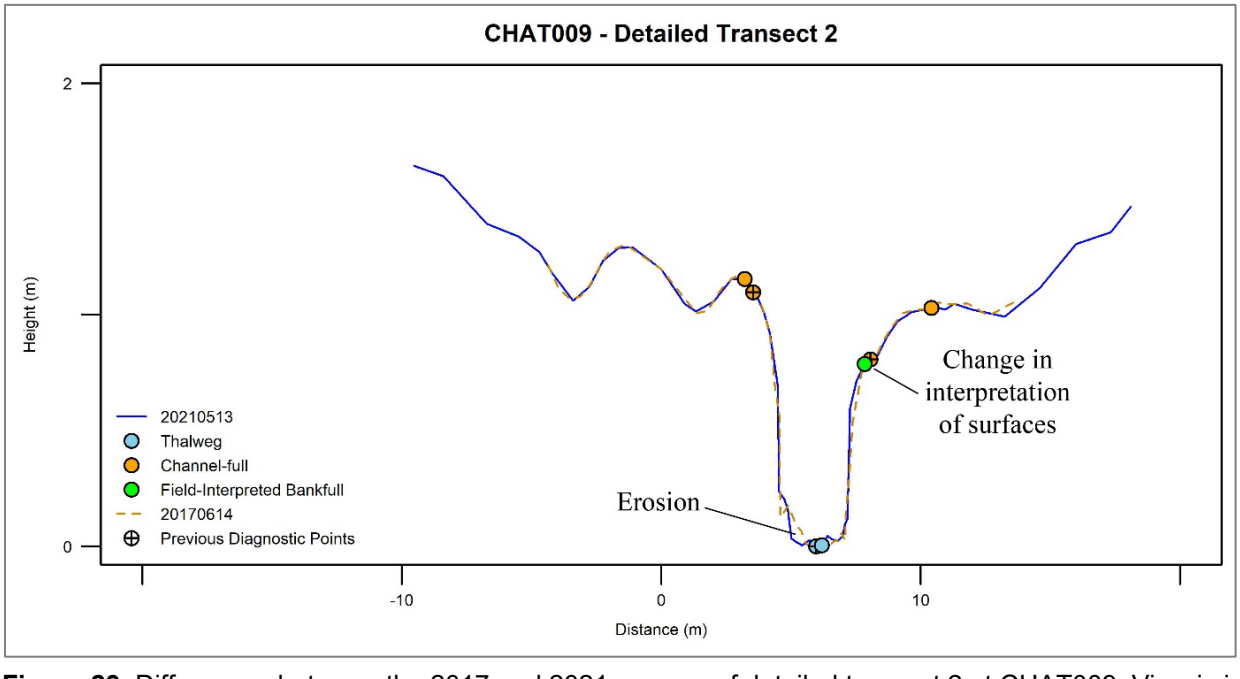


Figure 23. Differences between the 2017 and 2021 surveys of detailed transect 2 at CHAT009. View is in the downstream direction.

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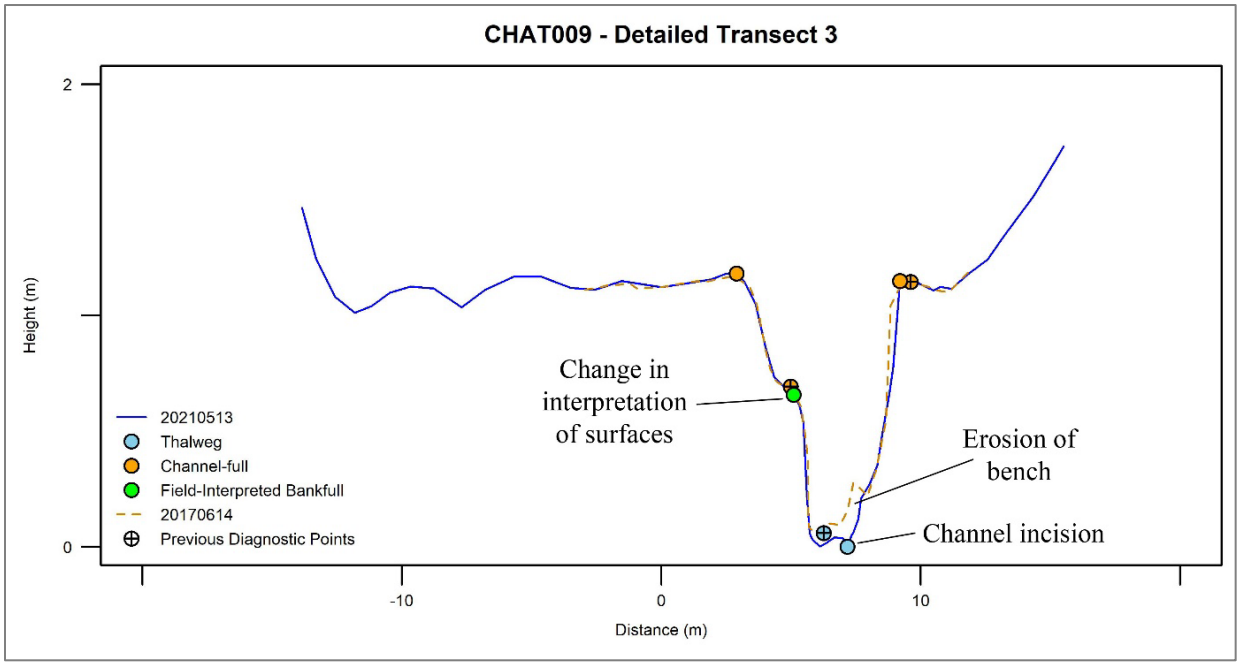


Figure 24. Differences between the 2017 and 2021 surveys of detailed transect 3 at CHAT009. View is in the downstream direction.

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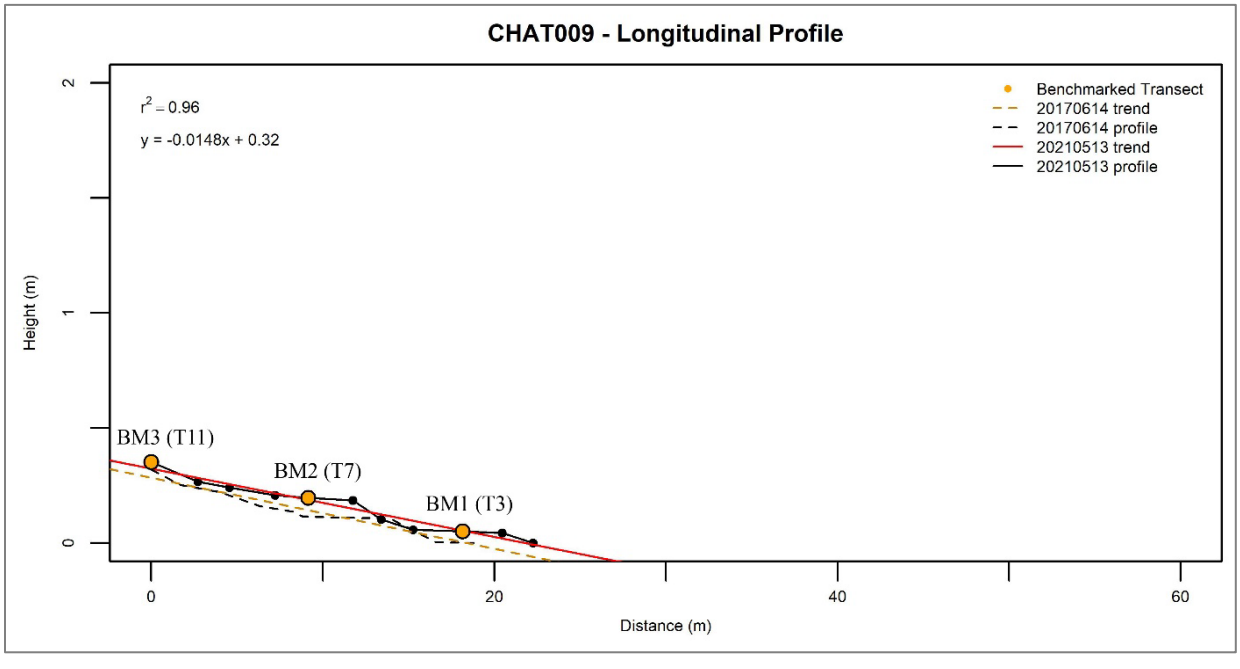


Figure 25. Longitudinal profile for CHAT009. The red line on the graph corresponds to the interpreted slope of the reach (0.0148 m/m). The r^2 value describes the strength of the 2021 trend line (interpreted slope). The "T#" in parentheses indicates the standard transect number on which the detailed transects were surveyed.

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Detailed transect 1 (T3) displays slight changes in interpretation of bankfull and channel full surfaces as the elevated entrenched surface on the river right side of the channel was identified as bankfull in 2021 (Figure 22). The cross-section also displays some erosion of the river left bank and slight channel incision. There were slight increases in both bankfull cross-sectional area (+28%) and channel full area (+38%) due to these interpretive and geomorphic changes (Table 28).

Table 28. Changes to cross-sectional characteristics on detailed transect 1 at CHAT009 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.46	3.56	0.60
	2021	1.64	3.68	0.66
	Change 2017–2021	0.18	0.12	0.06
Channel-full	2017	1.58	3.72	0.63
	2021	4.13	6.02	1.15
	Change 2017–2021 [A]	2.55	2.30	0.52

[A] Changes due to interpretive differences between survey years.

Only a small amount of geomorphic change (slight erosion on river left) occurred on detailed transect 2 (T6; Figure 23). Most of the change observed was due to the inclusion of the elevated entrenched surface on river right as bankfull. This change caused bankfull cross-sectional area to increase by 70% and channel full area to increase by 48% (Table 29).

Table 29. Changes to cross-sectional characteristics on detailed transect 2 at CHAT009 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.18	2.79	0.50
	2021	2.01	3.42	0.77
	Change 2017–2021 [A]	0.83	0.64	0.27
Channel full	2017	2.14	3.78	0.81
	2021	3.17	6.54	1.03
	Change 2017–2021 [A]	1.03	2.76	0.22

[A] Changes due to interpretive differences between survey years.

Like the other two detailed transects, most the change observed on detailed transect 3 (T11) was due to a change in interpretation of the elevated entrenched surface on river left (Figure 24). The geomorphic change that occurred was related to thalweg incision and migration toward river right which eroded the bench observed there in 2017 (Figure 24). These changes led to an increase of bankfull cross-sectional area of 46% and a substantial (+161%) increase in channel full area (Table 30).

Table 30. Changes to cross-sectional characteristics on detailed transect 3 at CHAT009 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.12	3.23	0.50
	2021	1.64	3.68	0.66
	Change 2017–2021	0.52	0.45	0.16
Channel full	2017	1.58	3.72	0.63
	2021	4.13	6.02	1.15
	Change 2017–2021 [A]	2.55	2.30	0.52

[A] Changes due to interpretive differences between survey years.

CHAT012—"Cabin Creek"

Reach Description

On May 13, 2021, stream survey data were collected at CHAT012. CHAT012 is on Cabin Creek (a first-order stream in the Palisades unit). Cabin Creek is accessed by taking the first hiking trail on Indian Trail NW down to the reach. The reach surveyed was 20 meters (65.6 ft) long with 2 meters (6.6 ft) between transects.

Cabin Creek's left bank was actively eroding into the trail between T5 and T7, this erosion was also observed during the 2017 survey (Figure 26). Elevated entrenched surfaces interpreted as developing floodplains in 2017 were observed on the inside of meanders throughout the monitored reach. These elevated entrenched surfaces also had bars developing into the stream channel. The step observed on T3 during the 2017 survey was no longer present during the 2021 survey. Water surface slope (longitudinal profile) for this section of Cabin Creek was 0.0237 m/m (Table 5). Two changes in slope can be seen in the longitudinal profile, the first being upstream of T2 and the second being upstream of T6. The detailed transects were surveyed on T1 (BM1), T6 (BM2), and T9 (BM3). Each detailed transect showed evidence of channel incision. Detailed transects 2 (T6) and 3 (T9) showed channel widening and bar formation was observed on detailed transects 1 (T1) and 3 (T9). Survey results for CHAT012 can be viewed in the corresponding file of supplemental materials for this site.

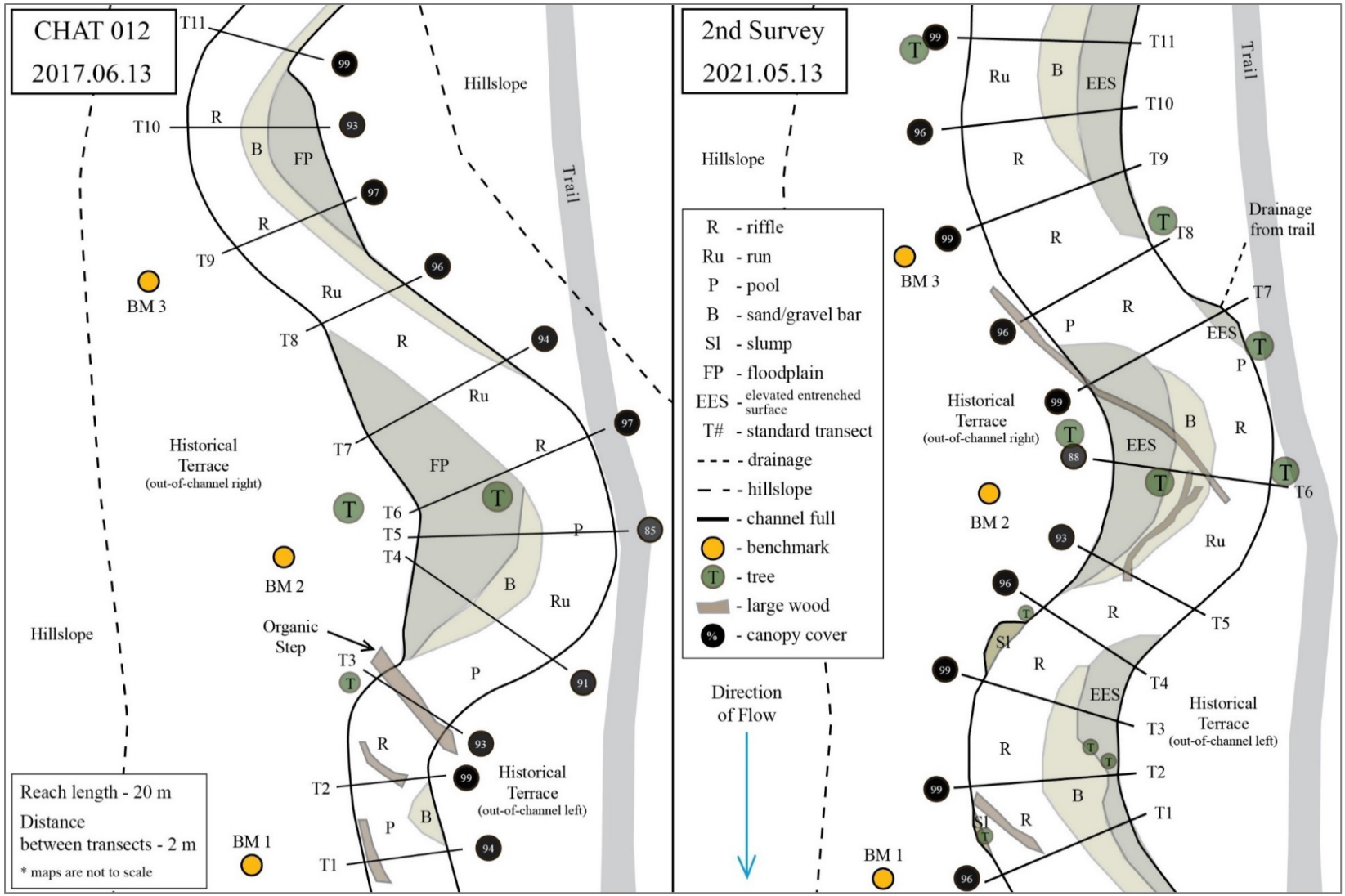


Figure 26. Reach-scale map of CHAT012. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

NPS

Habitat Characteristics

The geomorphic channel unit (GCU) types and distributions changed between the 2017 and 2021 surveys (Table 6). Riffles, runs, and pools were present within the surveyed reach during both survey years. The one step that was observed during the 2017 survey was not present in 2021. The mean percentage of riffle increased (+20%) and the frequency of riffles along transects increased (Table 6). The mean percentage of run increased (+13%) and the number of observed runs doubled. The mean percentage of pool greatly decreased (−28%) and the number of pools decreased from four to two.

The pebble count data for CHAT012 suggests that bed sediment has changed substantially between the surveys (Table 7). There was a statistically significant increase (+184%) in the mean diameter of the measured pebbles ($p < 0.001$; Table 31). The minimum observed value and the D_5 decreased, but the D_{16}, D_{50}, D_{84}, and D_{95} particle sizes all increased from their 2017 values (Table 7). The largest pebble measured during the 2021 survey was also much larger than the 2017 maximum (+330% Table 7).

Table 31. Difference in means t-test results comparing CHAT012 during 2017 and 2021. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [m—meters; mm—millimeters].

Measurement	n [A]	CHAT012 in 2017	CHAT012 in 2021	P-value	Significance
Pebble Count (mm)	100	22.21	62.97	< 0.001	***
Thalweg Depth (m)	11	0.05	0.12	< 0.001	***
Thalweg Position (%)	11	55.45	67.73	0.254	–
Wetted Width (m)	11	1.13	1.57	0.019	*
Active Channel Width (m)	11	1.38	2.02	0.004	**
Channel full Width (m)	11	4.02	4.96	0.147	–
Minimum Bank Height (m)	22	0.52	0.70	< 0.001	***
Channel full Height (m)	22	0.63	0.74	< 0.001	***
Bank Angle (°)	22	56.70	49.10	0.344	–
Vegetative Cover (%)	22	31.36	34.09	0.706	–

[A] Number of measurements taken.

The number of pieces of large woody debris (LWD) increased from two in 2017 to three in 2021 (Table 9). The volume of LWD per channel area nearly doubled from 0.0008 m^3/m^2 to 0.0015 m^3/m^2. Canopy cover continued to be dense and have very little variability (Table 10).

Mean thalweg position (relative to the left bank) shifted farther toward river right increasing from 55% to 68% (Table 11). Variability in thalweg position decreased slightly between the two surveys. The minimum, mean, and maximum thalweg depths all increased (+250%, +140%, and +117%, respectively; Table 11). Additionally, the increase in mean thalweg depth was statistically significant ($p < 0.001$; Table 31).

Channel Morphology

Average wetted width at CHAT012 was 39% greater and mean active channel width was 46% greater in 2021 (Table 12). The increases in both the mean wetted width and mean active channel width were statistically significant ($p = 0.019$ and $p = 0.004$, respectively; Table 23). The minimum and maximum wetted widths were greater than those measured in 2017 (+59% and +8%, respectively). The same was observed regarding active channel width, as both the minimum and maximum measurements increased in 2021 (+49% and +54%, respectively). The coefficient of variation (CV) of wetted widths at CHAT012 decreased in 2021. Variation in active channel widths was similar between the two survey periods. Bankfull width also increased between the two surveys. Six bankfull width measurements were taken in both the 2017 and 2021 surveys. Mean bankfull width increased by 16% and variability in bankfull width increased from CV = 0.27 to CV = 0.34 (Table 12). Mean channel full width increased by 23%, but this increase was not statistically significant ($p = 0.147$; Table 31).

There was a statistically significant (+35%) increase in mean minimum bank height (lowest bank height on a transect) in 2021 ($p < 0.001$; Table 31). The number of bankfull height measurements taken was higher in 2017 ($n = 7$) than in 2021 ($n = 3$) and mean bankfull height slightly increased (+11%; Table 13). There was also a substantial reduction in the variability (CV) of bankfull heights. Mean channel full height was statistically significantly higher (+17%) in 2021 ($p < 0.001$; Table 31).

The number of undercut banks increased from $n = 7$ to $n = 10$ (Table 14). The mean depth of these undercuts also increased (+21%). Bank angles were less steep on average during 2021 (49.10°) compared to 2017 (56.70°; Table 14), but this difference was not statistically significant ($p = 0.344$; Table 31). The percentage of bank vegetation cover increased slightly between the two survey periods but was not statistically significant ($p = 0.706$; Table 23). Bank stability scores decreased (more stable) from a mean value of 13 in 2017 to 12 in 2021 (Table 14).

Detailed Transects

The detailed transects on CHAT012 were surveyed on T1 (BM1; Figure 27), T6 (BM2; Figure 28), and T9 (BM3; Figure 29). Channel incision occurred along each detailed transect and bank erosion and channel widening were visible on detailed transects 2 (T6) and 3 (T9). On the detailed transects, bankfull cross-sectional area was on average 11% larger in 2021 than in 2017 and mean channel full area increased by 62% (Table 15). Like the other reaches, there were some modifications to how bankfull and channel full surfaces were interpreted and some of the changes recorded in the tables is a result of this modification.

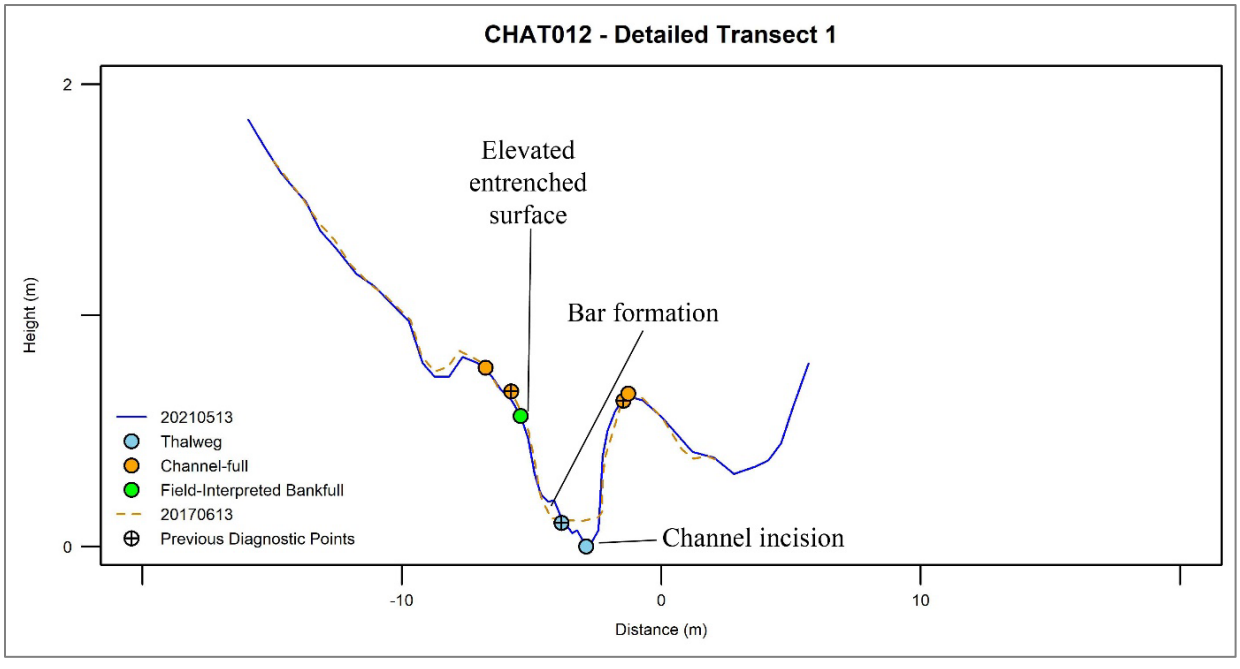


Figure 27. Differences between the 2017 and 2021 surveys of detailed transect 1 at CHAT012. View is in the downstream direction.

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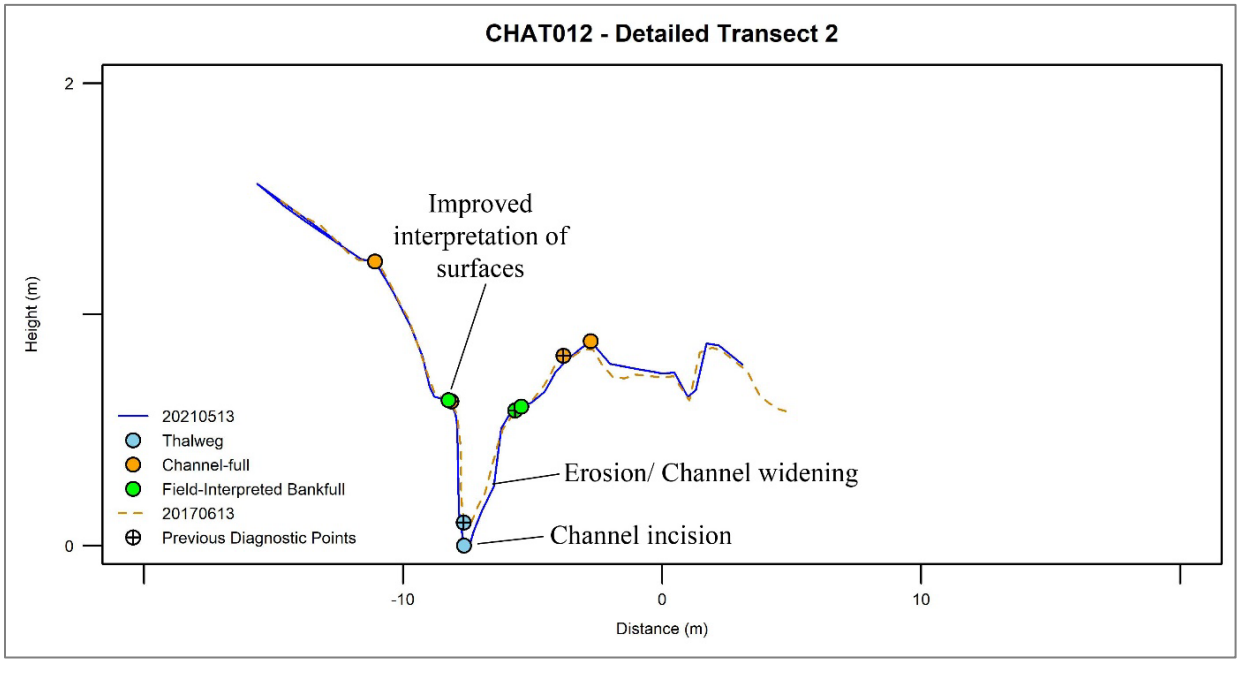


Figure 28. Differences between the 2017 and 2021 surveys of detailed transect 2 at CHAT012. View is in the downstream direction.

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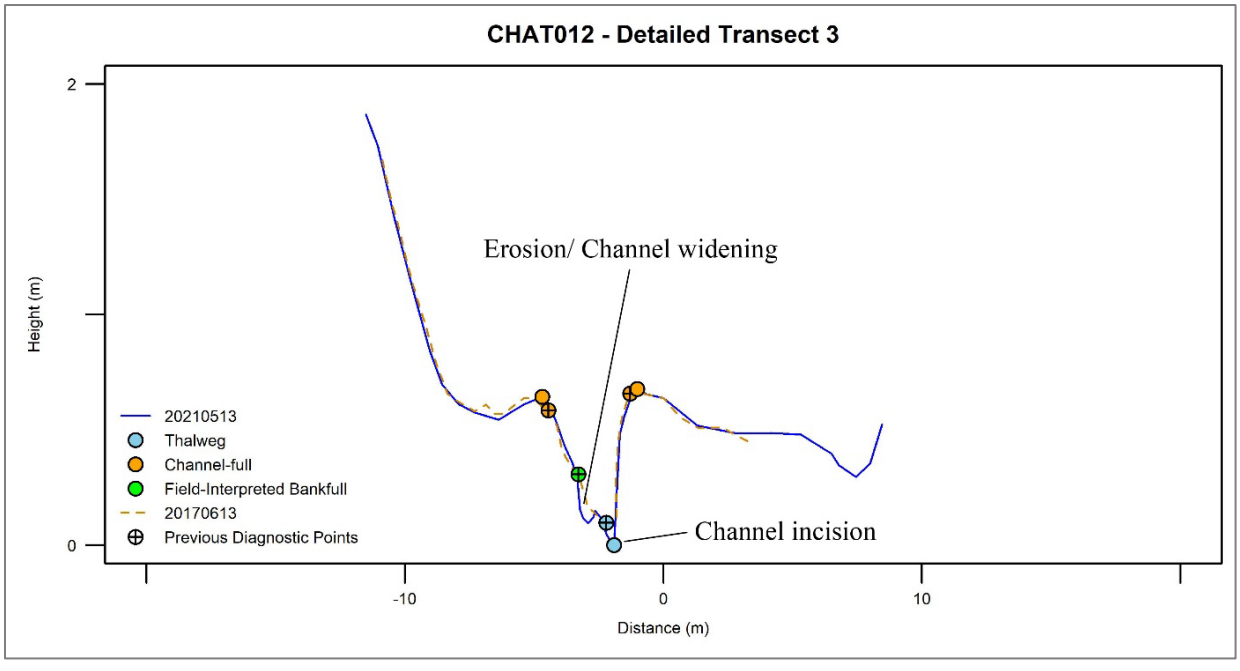


Figure 29. Differences between the 2017 and 2021 surveys of detailed transect 3 at CHAT012. View is in the downstream direction.

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Water surface slope (longitudinal profile) for this section of Cabin Creek was similar between the two surveys, slightly increasing from 0.234 m/m to 0.0237 m/m (Figure 30; Table 15). The 0.0003 m/m change in slope is negligible as it falls within the error range of the surveying equipment. Sinuosity at CHAT012 continued to be the highest among the surveyed first-order streams (Table 15).

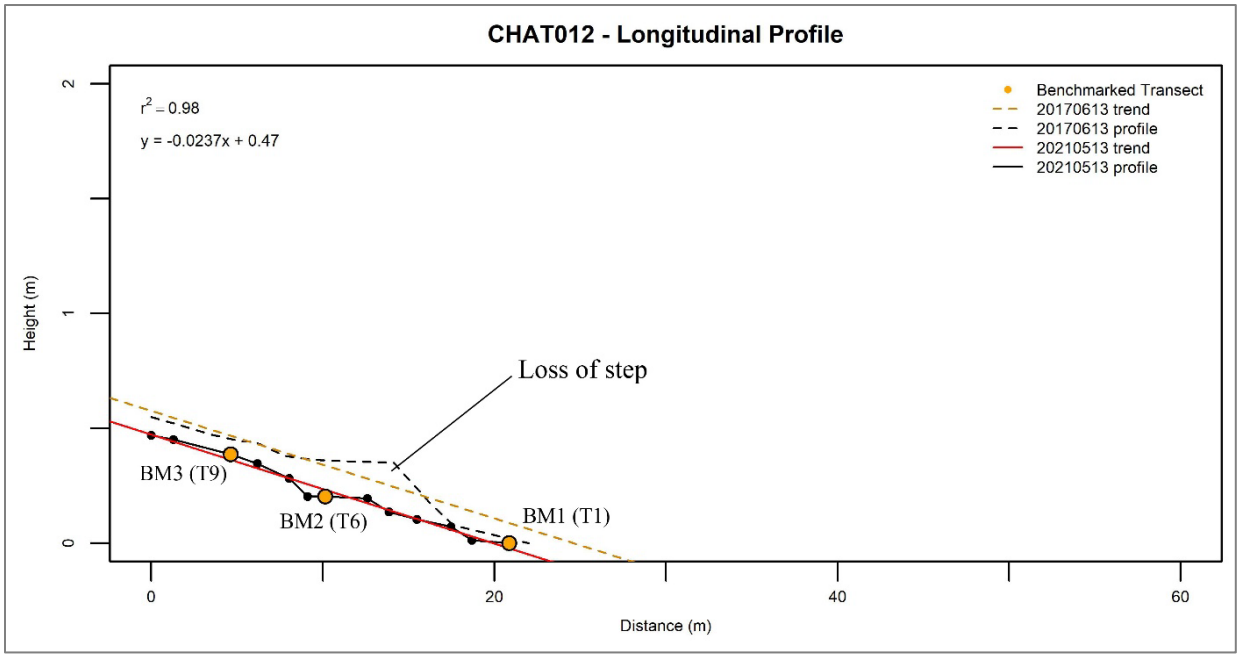


Figure 30. Longitudinal profile for CHAT012. The red line on the graph corresponds to the interpreted slope of the reach (0.0237 m/m). The r^2 value describes the strength of the 2021 trend line (interpreted slope). The "T#" in parentheses indicates the standard transect number on which the detailed transects were surveyed.
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The cross-section measured along detailed transect 1 (T1) shows a change in interpretation of the bankfull surface on river left (now on an elevated entrenched surface), bar development on river left, thalweg migration toward river right, and channel incision (Figure 27). Bankfull cross-sectional area decreased by 19% and channel full area increased by 11% (Table 32). Though the channel incised, and bank heights increased, the development of the bar within the channel offset some of the gains in bankfull area.

Table 32. Changes to cross-sectional characteristics on detailed transect 1 at CHAT012 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.03	3.34	0.41
	2021	1.24	3.56	0.57
	Change 2017–2021 [A]	0.21	0.22	0.16
Channel-full	2017	1.47	4.14	0.53
	2021	1.63	4.74	0.66
	Change 2017–2021	0.16	0.60	0.13

[A] Changes due to interpretive differences between survey years.

Detailed transect 2 (T6) showed bank erosion and channel widening as well as channel incision (Figure 28). Interpretation of the bankfull level on river left improved between surveys and the

channel full diagnostic point was moved upslope to a more appropriate position. In addition to the interpretive change, the thalweg incised contributing to an increase of bankfull cross-sectional area of 39% (Table 33). While bankfull area increased due to channel incision, the substantial (+216%) increase in channel full area was related to the new interpretation of river left channel full (Table 33).

Table 33. Changes to cross-sectional characteristics on detailed transect 2 at CHAT012 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	0.56	2.23	0.47
	2021	0.78	2.65	0.60
	Change 2017–2021	0.21	0.42	0.13
Channel full	2017	0.69	3.02	0.52
	2021	2.18	6.72	0.88
	Change 2017–2021 [A]	1.49	3.71	0.36

[A] Changes due to interpretive differences between survey years.

Detailed transect 3 (T9) showed bank erosion and channel widening, incipient bar formation, and channel incision (Figure 29). Bankfull cross-sectional area increased by 25% and channel full area increased by 28% (Table 34). While there were slight modifications in how bankfull and channel full were interpreted, a large portion of the change observed on this transect is related to bank erosion and channel incision.

Table 34. Changes to cross-sectional characteristics on detailed transect 3 at CHAT012 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	0.24	1.48	0.21
	2021	0.30	1.59	0.30
	Change 2017–2021	0.06	0.12	0.09
Channel full	2017	0.87	2.93	0.49
	2021	1.11	3.46	0.64
	Change 2017–2021	0.23	0.54	0.16

Between Site Comparisons of First-Order Streams

The following section describes the statistical significance of the between site differences in terms of bed sediment (pebble count), thalweg depth, wetted width, active channel width, channel full width, channel full height, and bank angle.

In both survey years, bed sediment at CHAT006 was statistically significantly finer than the other first-order streams (Table 35). Like in 2017, CHAT003's bed sediment is statistically significantly different from CHAT009 and CHAT012's bed sediment in 2021. Unlike 2017, CHAT003's bed

sediment is now statistically significantly finer than CHAT009 and CHAT012's bed sediment. Additionally, CHAT009 and CHAT012's bed sediment is also statistically significantly coarser than CHAT002's bed sediment. CHAT002 and CHAT003, as well as CHAT009 compared to CHAT012, continue to have statistically similar-sized bed sediment.

Mean thalweg depth increased at each of the monitored first-order streams between the 2017 and 2021 surveys (Table 11). While mean thalweg depth at CHAT006 was statistically significantly deeper than CHAT009 and CHAT012 during 2017, this was no longer true for the 2021 survey data (Table 36). No statistically significant differences were found between the mean thalweg depths of any of the monitored first-order streams during 2021. Comparisons in mean thalweg position between different streams do not reflect any management concerns (Table 37).

Table 35. Significance of the differences in means in the pebble counts of the first-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Pebble Count 2017 (mm)	Pebble Count 2021 (mm)	P-value [B] 2017	P-value [C] 2021	Significance 2017	Significance 2021
CHAT003–CHAT002	100	9	−1	0.168	1.000	–	–
CHAT006–CHAT002	100	−19	−28	< 0.001	< 0.001	***	***
CHAT009–CHAT002	100	−6	21	0.524	0.009	–	**
CHAT012–CHAT002	100	−8	20	0.320	0.011	–	*
CHAT006–CHAT003	100	−28	−27	< 0.001	< 0.001	***	***
CHAT009–CHAT003	100	−15	22	0.002	0.005	**	**
CHAT012–CHAT003	100	−17	21	< 0.001	0.006	***	**
CHAT009–CHAT006	100	13	49	0.017	< 0.001	*	***
CHAT012–CHAT006	100	11	49	0.046	< 0.001	*	***
CHAT012–CHAT009	100	−1	0	0.997	> 0.999	–	–

[A] Number of pebbles.

[B] $F(4, 100) = 12.95$, $p < 0.001$.

[C] $F(4, 100) = 20.66$, $p < 0.001$.

Table 36. Significance of the differences in mean thalweg depths of the first-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Thalweg Depth 2017 (m)	Thalweg Depth 2021 (m)	P-value [B] 2017	P-value [C] 2021	Significance 2017	Significance 2021
CHAT003–CHAT002	11	0.03	−0.02	0.446	0.989	–	–
CHAT006–CHAT002	11	0.05	−0.02	0.088	0.994	–	–
CHAT009–CHAT002	11	−0.01	−0.10	0.964	0.258	–	–
CHAT012–CHAT002	11	−0.01	−0.07	0.993	0.601	–	–
CHAT006–CHAT003	11	0.02	0.00	0.897	1.000	–	–
CHAT009–CHAT003	11	−0.05	−0.08	0.145	0.520	–	–
CHAT012–CHAT003	11	−0.04	−0.05	0.228	0.867	–	–
CHAT009–CHAT006	11	−0.06	−0.08	0.017	0.475	*	–
CHAT012–CHAT006	11	−0.06	−0.05	0.031	0.834	*	–
CHAT012–CHAT009	11	0.00	0.03	0.999	0.974	–	–

[A] Number of measurements for thalweg depth.

[B] $F(4, 11) = 4.08$, $p = 0.006$.

[C] $F(4, 11) = 1.43$, $p = 0.238$.

Table 37. Significance of the differences in mean thalweg positions of the first-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	N [A]	Thalweg Position 2017 (%)	Thalweg Position 2021 (%)	P-value [B] 2017	P-value [C] 2021	Significance 2017	Significance 2021
CHAT003–CHAT002	11	9	26	0.927	0.212	–	–
CHAT006–CHAT002	11	−6	7	0.981	0.973	–	–
CHAT009–CHAT002	11	4	−20	0.997	0.487	–	–
CHAT012–CHAT002	11	13	25	0.756	0.243	–	–
CHAT006–CHAT003	11	−15	−19	0.654	0.534	–	–
CHAT009–CHAT003	11	−5	−45	0.990	0.004	–	**
CHAT012–CHAT003	11	4	−1	0.995	> 0.999	–	–
CHAT009–CHAT006	11	10	−27	0.898	0.184	–	–
CHAT012–CHAT006	11	19	18	0.417	0.582	–	–
CHAT012–CHAT009	11	9	45	0.913	0.005	–	**

[A] Number of measurements for thalweg position.

[B] $F(4, 11) = 0.93$, $p = 0.455$.

[C] $F(4, 11) = 4.97$, $p = 0.002$.

Mean wetted width at CHAT002 and CHAT003 during 2021 were both statistically significantly wider than the measures observed during 2017. The 2021 mean wetted widths at CHAT002 and CHAT003 were statistically significantly wider than each of the other first-order streams (Table 38). During 2017, the only statistically significant differences in mean wetted width between the first-order streams were that CHAT003 was statistically significantly wider than CHAT009 and CHAT006.

The 2021 mean active channel width of all the first-order streams was statistically significantly wider than their 2017 means (Tables 8 [002], 19 [003], 23 [006], 27 [009], and 31 [012]). This general widening among the monitored streams caused a general convergence of their means making them less statistically significantly different from each other. In 2017, CHAT002's active channel was significantly wider than CHAT006 and CHAT012, but the differences between these sites were no longer statistically significant (Table 39). Similarly, mean active channel width at CHAT003 during 2017 was significantly wider than CHAT006 and CHAT012, but was only significantly wider than CHAT012 in 2021.

Like 2017, CHAT006 continued to have a statistically significantly wider channel full width than all the other first-order streams (Table 40). These differences were even greater in 2021 due to modifications in channel full surface interpretations and geomorphic changes on CHAT006. Though the difference between CHAT002 and CHAT012's channel full width became smaller in 2021, this difference is now statistically significant (Table 40).

Mean channel full height at CHAT012 was statistically significantly lower than all the other first-order streams during 2021 (Table 41). The only difference in 2017 was that the mean channel full height at CHAT012 was not significantly lower than CHAT006's channel full height. CHAT006's channel full height continued to be lower than all the other first-order streams (except for CHAT012) but lost the statistical significance of the difference to CHAT009.

No statistically significant differences were observed in mean bank angle between the first-order streams during 2017 (Table 42). Mean bank angle at CHAT006 decreases between the two survey periods and during 2021, CHAT006's mean bank angle was statistically significantly lower than of all other first-order stream mean bank angles. Comparisons in mean bank vegetative cover between different streams do not reflect any management concerns (Table 43).

Table 38. Significance of the differences in mean wetted widths of the first-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Wetted Width 2017 (m)	Wetted Width 2021 (m)	P-value [B] 2017	P-value [C] 2021	Significance 2017	Significance 2021
CHAT003–CHAT002	11	0.15	0.17	0.943	0.913	–	–
CHAT006–CHAT002	11	−0.54	−0.92	0.082	< 0.001	–	***
CHAT009–CHAT002	11	−0.55	−0.68	0.068	0.014	–	*
CHAT012–CHAT002	11	−0.39	−0.85	0.324	0.001	–	**
CHAT006–CHAT003	11	−0.69	−1.10	0.012	< 0.001	*	***
CHAT009–CHAT003	11	−0.71	−0.85	0.010	0.001	**	**
CHAT012–CHAT003	11	−0.55	−1.03	0.074	< 0.001	–	***
CHAT009–CHAT006	11	−0.02	0.25	> 0.999	0.752	–	–
CHAT012–CHAT006	11	0.14	0.07	0.954	0.997	–	–
CHAT012–CHAT009	11	0.16	−0.18	0.932	0.911	–	–

[A] Number of measurements for wetted width.

[B] $F(4, 11) = 4.99$, $p = 0.002$.

[C] $F(4, 11) = 12.32$, $p < 0.001$.

Table 39. Significance of the differences in mean active channel widths of the first-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Active Channel Width 2017 (m)	Active Channel Width 2021 (m)	P-value [B] 2017	P-value [C] 2021	Significance 2017	Significance 2021
CHAT003–CHAT002	11	0.18	0.34	0.906	0.624	–	–
CHAT006–CHAT002	11	−0.62	0.03	0.038	> 0.999	*	–
CHAT009–CHAT002	11	−0.17	−0.16	0.925	0.968	–	–
CHAT012–CHAT002	11	−0.65	−0.58	0.025	0.142	*	–
CHAT006–CHAT003	11	−0.80	−0.32	0.003	0.693	**	–
CHAT009–CHAT003	11	−0.35	−0.50	0.451	0.260	–	–
CHAT012–CHAT003	11	−0.83	−0.92	0.002	0.004	**	**
CHAT009–CHAT006	11	0.44	−0.18	0.228	0.944	–	–
CHAT012–CHAT006	11	−0.03	−0.61	> 0.999	0.112	–	–
CHAT012–CHAT009	11	−0.48	−0.42	0.168	0.425	–	–

[A] Number of measurements for active channel width.

[B] $F(4, 11) = 6.24$, $p < 0.001$.

[C] $F(4, 11) = 3.78$, $p = 0.009$.

Table 40. Significance of the differences in mean channel full widths of the first-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–"not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Channel full Width 2017 (m)	Channel full Width 2021 (m)	P-value [B] 2017	P-value [C] 2021	Significance 2017	Significance 2021
CHAT003–CHAT002	11	−2.11	−1.73	0.574	0.235	–	–
CHAT006–CHAT002	11	4.38	9.97	0.026	< 0.001	*	***
CHAT009–CHAT002	11	−2.11	−0.92	0.577	0.794	–	–
CHAT012–CHAT002	11	−2.76	−2.66	0.307	0.017	–	*
CHAT006–CHAT003	11	6.49	11.70	< 0.001	< 0.001	***	***
CHAT009–CHAT003	11	0.00	0.81	> 0.999	0.863	–	–
CHAT012–CHAT003	11	−0.65	−0.94	0.991	0.784	–	–
CHAT009–CHAT006	11	−6.48	−10.89	< 0.001	< 0.001	***	***
CHAT012–CHAT006	11	−7.14	−12.64	< 0.001	< 0.001	***	***
CHAT012–CHAT009	11	−0.65	−1.74	0.990	0.227	–	–

[A] Number of measurements for channel full width.

[B] $F(4, 11) = 8.54$, $p < 0.001$.

[C] $F(4, 11) = 78.64$, $p < 0.001$.

Table 41. Significance of the differences in mean channel full heights of the first-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Channel full Height 2017 (m)	Channel full Height 2021 (m)	P-value [B] 2017	P-value [C] 2021	Significance 2017	Significance 2021
CHAT003–CHAT002	22	0.01	−0.03	> 0.999	0.980	–	–
CHAT006–CHAT002	22	−0.35	−0.22	< 0.001	0.002	***	**
CHAT009–CHAT002	22	−0.05	−0.09	0.905	0.507	–	–
CHAT012–CHAT002	22	−0.39	−0.44	< 0.001	< 0.001	***	***
CHAT006–CHAT003	22	−0.36	−0.19	< 0.001	0.013	***	*
CHAT009–CHAT003	22	−0.06	−0.06	0.818	0.841	–	–
CHAT012–CHAT003	22	−0.40	−0.41	< 0.001	< 0.001	***	***
CHAT009–CHAT006	22	0.29	0.13	< 0.001	0.182	***	–
CHAT012–CHAT006	22	−0.05	−0.22	0.939	0.002	–	**
CHAT012–CHAT009	22	−0.34	−0.35	< 0.001	< 0.001	***	***

[A] Number of measurements for channel full height.

[B] $F(4, 22) = 22.13$, $p < 0.001$.

[C] $F(4, 22) = 19.62$, $p < 0.001$.

Table 42. Significance of the differences in mean bank angles of the first-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Bank Angle 2017 (°)	Bank Angle 2021 (°)	P-value [B] 2017	P-value [C] 2021	Significance 2017	Significance 2021
CHAT003–CHAT002	22	13.5	6.0	0.441	0.902	–	–
CHAT006–CHAT002	22	−7.9	−21.4	0.858	0.019	–	*
CHAT009–CHAT002	22	−5.2	3.1	0.966	0.991	–	–
CHAT012–CHAT002	22	4.4	2.5	0.981	0.996	–	–
CHAT006–CHAT003	22	−21.3	−27.4	0.062	0.001	–	**
CHAT009–CHAT003	22	−18.6	−3.0	0.138	0.993	–	–
CHAT012–CHAT003	22	−9.1	−3.6	0.783	0.985	–	–
CHAT009–CHAT006	22	2.7	24.5	0.997	0.005	–	**
CHAT012–CHAT006	22	12.3	23.8	0.536	0.006	–	**
CHAT012–CHAT009	22	9.6	−0.6	0.749	> 0.999	–	–

[A] Number of measurements for bank angle.

[B] $F(4, 22) = 2.26$, $p = 0.068$.

[C] $F(4, 22) = 5.25$, $p < 0.001$.

Table 43. Significance of the differences in mean bank vegetative cover percentages of the first-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Vegetative Cover 2017 (%)	Vegetative Cover 2021 (%)	P-value [B] 2017	P-value [C] 2021	Significance 2017	Significance 2021
CHAT003–CHAT002	22	8	33	0.798	< 0.001	–	***
CHAT006–CHAT002	22	−23	−7	0.019	0.605	*	–
CHAT009–CHAT002	22	−14	11	0.297	0.213	–	–
CHAT012–CHAT002	22	−3	12	0.996	0.150	–	–
CHAT006–CHAT003	22	−31	−40	0.000	< 0.001	***	***
CHAT009–CHAT003	22	−23	−21	0.023	< 0.001	*	***
CHAT012–CHAT003	22	−11	−20	0.573	0.001	–	**
CHAT009–CHAT006	22	9	19	0.765	0.005	–	**
CHAT012–CHAT006	22	20	20	0.053	0.003	–	**
CHAT012–CHAT009	22	12	1	0.514	1.000	–	–

[A] Number of measurements for vegetative cover.

[B] $F(4, 22) = 5.61$, $p < 0.001$.

[C] $F(4, 22) = 16.85$, $p < 0.001$.

Medium-Sized (Second-Order) Streams

This section provides a summary of the basin characteristics of the second-order study watersheds at Chattahoochee River National Recreation Area and provides the results of the surveys at each second-order reach surveyed. The results for each reach are subdivided into a reach description, habitat characteristics, and channel morphology. The results from the 2021 survey are compared to the 2017 survey within each subsection.

Basin Characteristics

The second-order watersheds range in size from 0.77 square kilometers (0.30 sq mi; CHAT005) to 2.67 square kilometers (1.03 sq mi; CHAT014; Table 44). Chattahoochee River National Recreation Area manages between 0.4% (CHAT004) and 87% (CHAT005) of these watersheds. CHAT007 and CHAT014 have the highest drainage densities of the second-order streams (2.06 km/km^2 and 2.00 km/km^2, respectively). CHAT005 has a higher drainage density than CHAT004 (1.24 km/km^2 versus 1.18 km/km^2) even though CHAT004's watershed (1.39 square kilometers [0.54 sq mi]) is almost twice the size of CHAT005's watershed (0.77 square kilometers [0.30 sq mi]). Bifurcation ratios indicate that CHAT007 and CHAT014 (both 1.25) have a lot more first-order streams in their watersheds than the other second-order streams. CHAT005 has the steepest entire stream gradient (0.0435 m/m) while CHAT007 (0.0160 m/m) and CHAT014 (0.0167 m/m) have the lowest (Table 21). CHAT007 also has the lowest segment gradient (0.0059 m/m) while CHAT010 has the highest segment gradient (0.0279 m/m). CHAT007 has the lowest average watershed slope (3.82°) and the most variable watershed slope (CV = 0.89). Basin shape indicates that the watersheds draining to CHAT007 (0.18) and CHAT011 (0.15) are longer and narrower than the other second-order watersheds (range from 0.20 [CHAT008] to 0.39 [CHAT005]). All seven second-order streams have approximately the same amount of relief (range from 70 meters [230 ft; CHAT008] to 80 meters [262 ft; CHAT014]) though CHAT005 is almost twice as steep (basin relief ratio = 0.051 compared to 0.024 [CHAT014] up to 0.032 [CHAT004]) because its watershed is so much smaller than the other second-order watersheds.

Table 44. Watershed characteristics for the second-order streams at Chattahoochee River National Recreation Area calculated using the National Elevation Dataset (NED) 10-meter digital elevation model [km—kilometers; m—meters; SD—standard deviation; CV—coefficient of variation].

Basin Characteristic	CHAT004	CHAT005	CHAT007	CHAT008	CHAT010	CHAT011	CHAT014
Drainage Area (km^2)	1.39	0.77	2.35	1.65	2.01	1.01	2.67
NPS Managed Area (km^2)	0.16	0.67	0.85	0.36	0.27	0.15	0.01
NPS Managed Area (%)	12	87	36	22	13	15	0.4
Total Stream Length (km)	1.64	0.95	4.84	2.71	2.72	1.63	4.22
Drainage Density	1.18	1.24	2.06	1.64	1.36	1.62	1.58
Strahler Order	2	2	2	2	2	2	2
Bifurcation Ratio	2.00	2.00	1.25	1.50	1.50	2.00	1.25
Entire Stream Gradient	0.0232	0.0435	0.0160	0.0264	0.0217	0.0328	0.0167
Segment Gradient	0.0135	0.0158	0.0059	0.0155	0.0279	0.0179	0.0145
Slope—Average	8.30	8.38	3.82	6.78	5.39	7.47	8.05
Slope—Std. Dev.	5.40	4.37	3.41	4.64	4.06	5.23	4.88

Table 44 (continued). Watershed characteristics for the second-order streams at Chattahoochee River National Recreation Area calculated using the National Elevation Dataset (NED) 10-meter digital elevation model [km—kilometers; m—meters; SD—standard deviation; CV—coefficient of variation].

Basin Characteristic	CHAT004	CHAT005	CHAT007	CHAT008	CHAT010	CHAT011	CHAT014
Slope—CV	0.65	0.52	0.89	0.68	0.75	0.70	0.61
Basin Length (km)	2.32	1.40	3.58	2.85	2.86	2.61	3.33
Basin Shape	0.26	0.39	0.18	0.20	0.25	0.15	0.24
Basin Relief (m)	74	71	74	70	70	76	80
Basin Relief Ratio	0.032	0.051	0.021	0.025	0.025	0.029	0.024
Elevation—Std. Dev. (m)	14.4	14.1	16.3	14.6	12.3	17.8	14.5

Except for CHAT005, CHAT010, and CHAT011, the second-order watersheds are a mixture of residential or suburban development and forest (Table 45). CHAT005 is mostly forested (83%) while CHAT011 has the least amount of forest cover (19%). CHAT011's watershed has the highest commercial and/or industrial land cover (43% developed medium and high). CHAT010 is mostly residential/suburban (69%) with some (27%) forest cover.

Table 45. Changes in land use/land cover characteristics from 2016 to 2021 for the second-order streams at Chattahoochee River NRA. The data included in this table are from the National Land Cover Dataset (Dewitz 2023). Percent change from 2016 to 2021 is shown as "%Δ."

	CHAT004			CHAT005			CHAT007			CHAT008			CHAT010			CHAT011			CHAT014		
NLCD Classes	**2016**	**2021**	**% Δ**	**2016**	**2021**	**% Δ**	**2016**	**2021**	**% Δ**	**2016**	**2021**	**% Δ**	**2016**	**2021**	**% Δ**	**2016**	**2021**	**% Δ**	**2016**	**2021**	**% Δ**
Developed Open & Low (%)	34	35	0	9	9	0	29	29	0	54	54	0	66	66	0	31	30	−2	47	47	0
Developed Med. & High (%)	23	26	3	4	4	0	4	5	1	9	10	0	5	10	4	52	53	2	4	5	1
Forested (%)	37	35	−2	84	84	0	38	37	0	32	32	0	27	24	−3	17	17	0	47	46	−1
Grassland (%)	2	1	0	3	3	0	2	0	−2	0	0	0	0	0	0	0	0	0	0	1	0
Cultivated (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

CHAT004—"Crayfish Creek"

Reach Description

On May 7, 2021, stream survey data were collected at CHAT004. CHAT004 is on a second-order stream named Crayfish Creek. The monitored reach on Crayfish Creek is approximately 375 meters (1,230 ft) upstream of its confluence with the Chattahoochee River and approximately 1 kilometer (0.62 mi) downstream of a shopping center on GA Highway 20. CHAT004 is accessed from the parking lot off the eastbound lanes of GA Highway 20, on the south side of the Chattahoochee River. The reach surveyed was 70 meters (230 ft) long with 7 meters (23 ft) between transects. Shortly after CHAT004 was resurveyed in 2021, a stream restoration effort was executed on Crayfish Creek, whose upstream end is approximately 30 meters (98 ft) downstream of the monitored reach.

Crayfish Creek is fairly entrenched and has a few areas of bedrock that influence the reach (Figure 31). There is a developed, vegetated floodplain along river right on transects 1 through 3. Between T1 and T4, there is a very large and well-developed cobble bar that has a small secondary drainage channel along river left. The stream channel is widening through bank slumping and there are elevated entrenched surfaces at or near the bankfull level throughout the reach. Additionally, there are some lower bars on alternating sides of the channel beginning upstream of T5. Throughout the reach, there are trees in danger of falling into the stream channel via bank erosion and undercutting. The detailed transects were surveyed on T1 (BM1), T5 (BM2), and T9 (BM3). The flat out-of-channel area on river right on detailed transect 1 (T1) was interpreted as a low terrace in 2017 because a lower (interpreted as bankfull) surface was observed immediately downstream. During the 2021 survey, this "low terrace" surface was reinterpreted as bankfull as there was evidence of deposition on this surface. The lower surface was reinterpreted as an elevated entrenched surface though it is not in the reach so was not measured. Detailed transect 2 (T5) and 3 (T9) are entrenched and show evidence of bank erosion and channel incision. Water surface slope (longitudinal profile) for this section of Crayfish Creek was 0.0099 m/m. The longitudinal profile shows there are two sections with higher slope, one at the large cobble bar and riffle downstream of T4 and the other a riffle at T9. Survey results for CHAT004 can be viewed in the corresponding file of supplemental materials for this site.

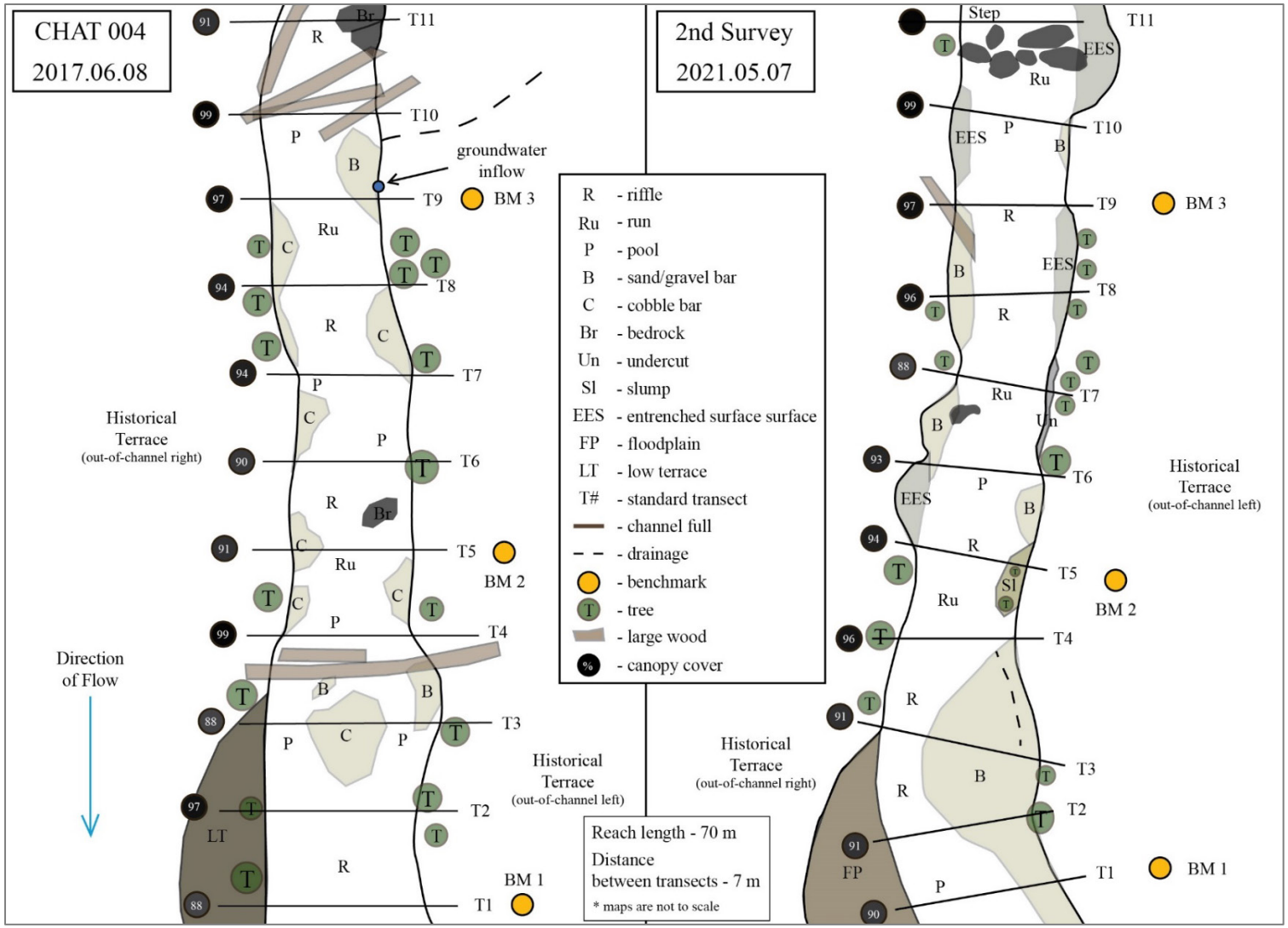


Figure 31. Reach-scale map of CHAT004. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

NPS

Habitat Characteristics

The geomorphic channel unit (GCU) types and distributions changed between the 2017 and 2021 surveys (Table 46). Riffles, runs, and pools were present within the surveyed reach during both survey years and glides were observed during the 2021 survey. The frequency of riffles within the reach increased from n = 8 to n = 10, but the mean percentage of riffle decreased 6%. The mean percentage of run increased (+20%), while the mean percentage of pool decreased (−30%) in 2021. No glides were observed within the reach in 2017, while five were observed in 2021. The mean percentage of glide was 11%. No steps were observed within the monitored reach at CHAT004 during either survey year.

Table 46. Geomorphic channel units (GCUs) observed in the area between transects during the 2017 and 2021 surveys for the second-order streams at Chattahoochee River NRA.

GCU Type	Site	Year	n [A]	Max (%)	Mean (%)	SD (%)
Riffle	CHAT004	2017	8	95	39	36
	CHAT004	2021	10	80	33	22
	CHAT005	2017	8	80	44	29
	CHAT005	2021	8	100	50	41
	CHAT007	2017	5	80	24	30
	CHAT007	2021	–	–	–	–
	CHAT008	2017	7	100	41	39
	CHAT008	2021	8	100	51	35
	CHAT010	2017	5	100	30	37
	CHAT010	2021	6	90	32	35
	CHAT011	2017	5	100	42	50
	CHAT011	2021	6	100	47	45
	CHAT014	2017	3	40	8	15
	CHAT014	2021	4	50	12	19
Run	CHAT004	2017	6	80	27	31
	CHAT004	2021	10	90	47	23
	CHAT005	2017	4	75	14	25
	CHAT005	2021	7	70	27	23
	CHAT007	2017	10	70	45	20
	CHAT007	2021	–	–	–	–
	CHAT008	2017	3	70	11	22
	CHAT008	2021	8	80	26	26
	CHAT010	2017	4	100	20	36
	CHAT010	2021	8	80	33	30
	CHAT011	2017	3	100	28	45
	CHAT011	2021	2	60	12	25
	CHAT014	2017	2	100	16	35

[A] Number of transects on which the GCU type was observed.

Table 46 (continued). Geomorphic channel units (GCUs) observed in the area between transects during the 2017 and 2021 surveys for the second-order streams at Chattahoochee River NRA.

GCU Type	Site	Year	n [A]	Max (%)	Mean (%)	SD (%)
Run (continued)	CHAT014	2021	7	100	42	43
Glide	CHAT004	2017	0	0	0	0
	CHAT004	2021	5	50	11	16
	CHAT005	2017	0	0	0	0
	CHAT005	2021	4	50	12	18
	CHAT007	2017	0	0	0	0
	CHAT007	2021	–	–	–	–
	CHAT008	2017	0	0	0	0
	CHAT008	2021	2	70	11	24
	CHAT010	2017	0	0	0	0
	CHAT010	2021	4	60	17	26
	CHAT011	2017	0	0	0	0
	CHAT011	2021	4	100	28	39
	CHAT014	2017	0	0	0	0
	CHAT014	2021	4	50	12	18
Pool	CHAT004	2017	8	100	35	37
	CHAT004	2021	4	20	5	7
	CHAT005	2017	8	100	41	38
	CHAT005	2021	3	30	6	11
	CHAT007	2017	8	65	32	26
	CHAT007	2021	–	–	–	–
	CHAT008	2017	7	100	49	39
	CHAT008	2021	6	30	12	12
	CHAT010	2017	7	100	50	44
	CHAT010	2021	5	70	19	24
	CHAT011	2017	3	100	30	48
	CHAT011	2021	6	30	13	13
	CHAT014	2017	8	100	76	41
	CHAT014	2021	7	80	34	30
Step	CHAT004	2017	0	0	0	0
	CHAT004	2021	0	0	0	0
	CHAT005	2017	1	20	2	6
	CHAT005	2021	2	30	5	11
	CHAT007	2017	0	0	0	0
	CHAT007	2021	–	–	–	–
	CHAT008	2017	0	0	0	0
	CHAT008	2021	0	0	0	0

[A] Number of transects on which the GCU type was observed.

Table 46 (continued). Geomorphic channel units (GCUs) observed in the area between transects during the 2017 and 2021 surveys for the second-order streams at Chattahoochee River NRA.

GCU Type	Site	Year	n [A]	Max (%)	Mean (%)	SD (%)
Step (continued)	CHAT010	2017	0	0	0	0
	CHAT010	2021	0	0	0	0
	CHAT011	2017	0	0	0	0
	CHAT011	2021	0	0	0	0
	CHAT014	2017	0	0	0	0
	CHAT014	2021	0	0	0	0

[A] Number of transects on which the GCU type was observed.

The pebble count data for CHAT004 shows a slight coarsening of the bed sediment between the surveys (Table 47). The mean diameter of the pebbles increased by 10%, but this increase was not statistically significant ($p = 0.477$; Table 48). The D_5 size interval decreased to < 0.06 indicating a fining of this size class from sand-sized (2 mm) to silt and clay. There was a slight coarsening of the other size classes (except for the maximum pebble which decreased by 20%; Table 47).

The number of pieces of large woody debris (LWD) increased from n = 10 to n = 15 (Table 49). These pieces of LWD were distributed mainly in the upper half of the reach. Despite the increase in pieces of LWD, the volume of LWD per channel area decreased substantially from 0.0067 m^3/m^2 in 2017 to 0.0023 m^3/m^2 during the 2021 survey (Table 49). This large decrease in volume was related to the increase in channel full area that resulted from the reinterpretation of the bottom portion of the reach along with the smaller size of the LWD measured in 2021. Canopy cover did not change and continued to be dense (mean canopy cover = 94%; Table 50) and have very little variability (CV = 0.04).

Mean thalweg position (relative to the left bank) shifted slightly toward river right between surveys, increasing from 39% to 53% (Table 51). Variability (CV) in thalweg position was similar between the two survey years. Mean thalweg depth was slightly deeper (+19%) in 2021, but this increase was not statistically significant ($p = 0.339$; Table 48).

Table 47. Particle size distributions of bed sediment (in millimeters [mm]) from the pebble counts conducted in 2017 and in 2021 at the second-order stream sites. The subscripts indicate the percent of the sample that is smaller than the reported diameter [Min—Minimum; Max—Maximum; n—Number of measurements taken].

	CHAT004 (n = 100)		CHAT005 (n = 100)		CHAT007 (n = 100)		CHAT008 (n = 100)		CHAT010 (n = 100)		CHAT011 (n = 100)		CHAT014 (n = 100)	
Statistic	**2017**	**2021**	**2017**	**2021**	**2017**	**2021**	**2017**	**2021**	**2017**	**2021**	**2017**	**2021**	**2017**	**2021**
Min	< 0.06	< 0.06	< 0.06	< 0.06	< 0.06	–	2.00	< 0.06	2.00	< 0.06	2.00	< 0.06	2.00	< 0.06
D_5	2.00	0.06	1.90	5.05	1.90	–	2.00	9.00	2.00	20.00	3.95	0.36	2.00	0.16
D_{16}	5.00	10.16	2.00	15.00	2.00	–	9.00	25.16	6.84	34.32	7.84	19.00	6.00	6.16
D_{50}	37.50	44.00	19.50	35.00	8.00	–	34.50	41.50	28.00	59.00	21.00	43.50	13.00	18.00
Mean	50.82	55.66	37.83	42.73	8.44	–	40.73	50.58	41.82	65.75	34.23	56.99	13.87	19.51
D_{84}	93.12	101.68	80.48	73.56	14.00	–	76.64	86.00	73.00	101.84	54.16	93.68	20.00	33.00
D_{95}	140.50	165.80	130.50	109.95	19.00	–	100.50	127.90	112.75	129.55	102.55	150.60	31.00	46.90
Max	250	200	178	149	30	–	130	159	190	196	330	370	47	98

Table 48. Difference in means t-test results comparing CHAT004 during 2017 and 2021. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [m—meters; mm—millimeters].

Measurement	n [A]	CHAT004 in 2017	CHAT004 in 2021	P-value	Significance
Pebble Count (mm)	100	50.82	55.66	0.477	–
Thalweg Depth (m)	11	0.16	0.19	0.339	–
Thalweg Position (%)	11	39.09	53.18	0.282	–
Wetted Width (m)	11	3.16	2.78	0.212	–
Active Channel Width (m)	11	3.93	4.42	0.469	–
Channel full Width (m) [B]	11	6.35	10.13	< 0.001	***
Minimum Bank Height (m)	22	1.67	1.74	0.594	–
Channel full Height (m) [B]	22	1.67	2.05	0.001	**
Bank Angle (°)	22	67.29	58.53	0.089	–
Vegetative Cover (%)	22	39.77	45.91	0.378	–

[A] Number of measurements taken during each survey year.

[B] Changes due to interpretive differences between survey years.

Table 49. Summary statistics for the large woody debris measured in 2017 and 2021 at the second-order monitoring sites at Chattahoochee River NRA (m—meters; SD—Standard deviation].

Statistic	Site	Year	n [A]	Length (m)	Diameter (m)	Volume (m^3)
Min	CHAT004	2017	10	2.00	0.10	0.02
	CHAT004	2021	15	1.59	0.10	0.01
	CHAT005	2017	11	1.02	0.09	0.01
	CHAT005	2021	8	1.22	0.10	0.01
	CHAT007	2017	11	1.54	0.09	0.01
	CHAT007	2021	–	–	–	–
	CHAT008	2017	6	1.45	0.12	0.02
	CHAT008	2021	11	1.72	0.10	0.02
	CHAT010	2017	12	1.02	0.10	0.01
	CHAT010	2021	16	1.62	0.11	0.02
	CHAT011	2017	0	–	–	–
	CHAT011	2021	9	1.45	0.11	0.04
	CHAT014	2017	2	3.75	0.15	0.09
	CHAT014	2021	12	1.10	0.11	0.01
Mean	CHAT004	2017	10	3.57	0.23	0.30
	CHAT004	2021	15	3.44	0.17	0.11
	CHAT005	2017	11	2.37	0.16	0.06
	CHAT005	2021	8	2.98	0.20	0.13
	CHAT007	2017	11	3.51	0.23	0.16
	CHAT007	2021	–	–	–	–

[A] Number of pieces of LWD.

Table 49 (continued). Summary statistics for the large woody debris measured in 2017 and 2021 at the second-order monitoring sites at Chattahoochee River NRA (m—meters; SD—Standard deviation].

Statistic	Site	Year	n [A]	Length (m)	Diameter (m)	Volume (m^3)
Mean (continued)	CHAT008	2017	6	3.62	0.20	0.18
	CHAT008	2021	11	4.45	0.18	0.22
	CHAT010	2017	12	2.97	0.19	0.12
	CHAT010	2021	16	4.54	0.18	0.16
	CHAT011	2017	0	–	–	–
	CHAT011	2021	9	4.89	0.21	0.19
	CHAT014	2017	2	4.35	0.23	0.18
	CHAT014	2021	12	3.07	0.16	0.07
Max	CHAT004	2017	10	6.63	0.60	1.61
	CHAT004	2021	15	7.11	0.34	0.65
	CHAT005	2017	11	4.18	0.26	0.22
	CHAT005	2021	8	7.72	0.28	0.44
	CHAT007	2017	11	11.15	0.36	0.42
	CHAT007	2021	–	–	–	–
	CHAT008	2017	6	5.53	0.43	0.74
	CHAT008	2021	11	6.70	0.59	1.62
	CHAT010	2017	12	5.70	0.36	0.58
	CHAT010	2021	16	17.70	0.28	1.01
	CHAT011	2017	0	–	–	–
	CHAT011	2021	9	7.25	0.28	0.45
	CHAT014	2017	2	4.95	0.30	0.27
	CHAT014	2021	12	9.38	0.27	0.24
SD	CHAT004	2017	10	1.89	0.16	0.52
	CHAT004	2021	15	1.94	0.07	0.16
	CHAT005	2017	11	1.00	0.06	0.06
	CHAT005	2021	8	2.23	0.07	0.14
	CHAT007	2017	11	2.76	0.08	0.15
	CHAT007	2021	–	–	–	–
	CHAT008	2017	6	1.83	0.12	0.28
	CHAT008	2021	11	1.63	0.14	0.47
	CHAT010	2017	12	1.27	0.08	0.16
	CHAT010	2021	16	3.90	0.06	0.24
	CHAT011	2017	0	–	–	–
	CHAT011	2021	9	2.05	0.06	0.15
	CHAT014	2017	2	0.85	0.11	0.13
	CHAT014	2021	12	2.49	0.06	0.07

[A] Number of pieces of LWD.

Table 49 (continued). Summary statistics for the large woody debris measured in 2017 and 2021 at the second-order monitoring sites at Chattahoochee River NRA (m—meters; SD—Standard deviation].

Statistic	Site	Year	n [A]	Length (m)	Diameter (m)	Volume (m^3)
Sum	CHAT004	2017	10	–	–	2.96
	CHAT004	2021	15	–	–	1.61
	CHAT005	2017	11	–	–	0.65
	CHAT005	2021	8	–	–	1.05
	CHAT007	2017	11	–	–	1.80
	CHAT007	2021	–	–	–	–
	CHAT008	2017	6	–	–	1.06
	CHAT008	2021	11	–	–	2.37
	CHAT010	2017	12	–	–	1.40
	CHAT010	2021	16	–	–	2.57
	CHAT011	2017	0	–	–	–
	CHAT011	2021	9	–	–	1.70
	CHAT014	2017	2	–	–	0.35
	CHAT014	2021	12	–	–	0.82
Per Channel Area (m^3/m^2)	CHAT004	2017	–	–	–	0.0067
	CHAT004	2021	–	–	–	0.0023
	CHAT005	2017	–	–	–	0.0023
	CHAT005	2021	–	–	–	0.0032
	CHAT007	2017	–	–	–	0.0063
	CHAT007	2021	–	–	–	–
	CHAT008	2017	–	–	–	0.0027
	CHAT008	2021	–	–	–	0.0036
	CHAT010	2017	–	–	–	0.0023
	CHAT010	2021	–	–	–	0.0026
	CHAT011	2017	–	–	–	–
	CHAT011	2021	–	–	–	0.0054
	CHAT014	2017	–	–	–	0.0011
	CHAT014	2021	–	–	–	0.0004

[A] Number of pieces of LWD.

Table 50. Comparison of the variability in canopy cover in 2017 and 2021 at the second-order stream sites at Chattahoochee River NRA [SD—Standard deviation; CV—Coefficient of variation].

Site	Year	n [A]	Min (%)	Mean (%)	Max (%)	SD (%)	CV
CHAT004	2017	11	88	94	99	4	0.04
	2021	11	88	94	99	4	0.04
CHAT005	2017	11	85	91	97	4	0.04
	2021	11	88	93	97	3	0.03
CHAT007	2017	11	82	88	93	4	0.05
	2021	11	–	–	–	–	–
CHAT008	2017	11	90	93	96	2	0.03
	2021	11	90	93	99	3	0.03
CHAT010	2017	11	79	90	97	6	0.06
	2021	11	79	92	99	7	0.07
CHAT011	2017	11	90	92	97	3	0.03
	2021	11	88	91	94	2	0.03
CHAT014	2017	11	88	94	99	4	0.04
	2021	11	87	93	100	4	0.04

[A] Number of transects.

Table 51. Comparison of reach-scale averaged thalweg conditions in 2017 and 2021 at the second-order stream sites at Chattahoochee River NRA. Water depth measurements are in meters and position is the percent distance from the left bank1 [SD—Standard deviation, CV—Coefficient of variation].

Thalweg	Site	Year	n [B]	Min	Mean	Max	SD	CV
Depth (m)	CHAT004	2017	11	0.09	0.16	0.34	0.08	0.49
	CHAT004	2021	11	0.10	0.19	0.33	0.07	0.38
	CHAT005	2017	11	0.04	0.10	0.28	0.07	0.72
	CHAT005	2021	11	0.06	0.23	0.56	0.15	0.66
	CHAT007	2017	11	0.09	0.16	0.29	0.07	0.42
	CHAT007	2021	–	–	–	–	–	–
	CHAT008	2017	11	0.06	0.19	0.64	0.18	0.94
	CHAT008	2021	11	0.11	0.19	0.46	0.10	0.51
	CHAT010	2017	11	0.08	0.28	0.61	0.17	0.60
	CHAT010	2021	11	0.10	0.30	0.74	0.20	0.65
	CHAT011	2017	11	0.03	0.16	0.51	0.18	1.11
	CHAT011	2021	11	0.12	0.30	0.64	0.19	0.63
	CHAT014	2017	11	0.03	0.25	0.48	0.16	0.64
	CHAT014	2021	11	0.15	0.33	0.67	0.16	0.50

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

[B] Number of measurements.

Table 51 (continued). Comparison of reach-scale averaged thalweg conditions in 2017 and 2021 at the second-order stream sites at Chattahoochee River NRA. Water depth measurements are in meters and position is the percent distance from the left bank1 [SD—Standard deviation, CV—Coefficient of variation].

Thalweg	Site	Year	n [B]	Min	Mean	Max	SD	CV
Position [A] (%)	CHAT004	2017	11	5	39	75	24	0.60
	CHAT004	2021	11	5	53	95	35	0.65
	CHAT005	2017	11	25	65	95	22	0.34
	CHAT005	2021	11	0	48	95	29	0.61
	CHAT007	2017	11	10	53	95	28	0.53
	CHAT007	2021	–	–	–	–	–	–
	CHAT008	2017	11	10	50	90	24	0.47
	CHAT008	2021	11	5	36	80	28	0.78
	CHAT010	2017	11	25	67	90	17	0.25
	CHAT010	2021	11	25	65	95	27	0.41
	CHAT011	2017	11	5	47	90	22	0.48
	CHAT011	2021	11	10	49	95	33	0.66
	CHAT014	2017	11	25	61	95	24	0.39
	CHAT014	2021	11	5	90	95	35	0.58

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

[B] Number of measurements.

Channel Morphology

Mean wetted width at CHAT004 was slightly narrower during the 2021 survey (−12%) but this slight decrease was not statistically significant ($p = 0.212$; Table 48). Mean active channel width was 12% wider in 2021 but, like mean wetted width, this change was not statistically significant ($p = 0.469$; Table 48). Variability of both wetted and active channel width was slightly higher during the 2021 survey (Table 52). No bankfull width measurements were taken during the 2017 surveys. Seven bankfull width measurements were taken during the 2021 survey, as the survey crew observed that the 2017 “low terrace” near T1 was actually a depositional floodplain (bankfull surface). In 2021, elevated entrenched surfaces also developed along some of the upstream transects and were measured as bankfull surfaces as well. Mean bankfull width was 5.36 meters (17.6 ft; Table 52) and variability in bankfull widths was relatively low (CV = 0.24). There was a statistically significant (+60%) increase in mean channel full width ($p < 0.001$; Table 48). Both the minimum and maximum channel full width values were wider in 2021 than in 2017 (Table 52). Variability in channel full width was similar between the two surveys.

Table 52. Comparison of reach-scale averaged width characteristics in 2017 and 2021 at the second-order stream sites at Chattahoochee River NRA [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Widths	Site	Year	n [A]	Min (m)	Mean (m)	Max (m)	SD (m)	CV
Wetted	CHAT004	2017	11	2.03	3.16	4.13	0.65	0.21
	CHAT004	2021	11	1.64	2.78	3.95	0.73	0.26
	CHAT005	2017	11	0.85	1.94	2.96	0.69	0.35
	CHAT005	2021	11	1.72	2.71	3.97	0.69	0.26
	CHAT007	2017	11	1.13	1.74	2.78	0.55	0.31
	CHAT007	2021	–	–	–	–	–	–
	CHAT008	2017	11	1.56	2.57	3.63	0.69	0.27
	CHAT008	2021	11	2.26	3.28	4.56	0.80	0.24
	CHAT010	2017	11	1.46	3.30	4.70	0.90	0.27
	CHAT010	2021	11	1.72	4.12	6.19	1.29	0.31
	CHAT011	2017	11	1.73	2.96	4.32	0.92	0.31
	CHAT011	2021	11	3.26	4.03	4.92	0.62	0.16
	CHAT014	2017	11	1.10	2.66	4.61	1.19	0.45
	CHAT014	2021	11	1.52	3.17	4.55	0.93	0.29
Active Channel	CHAT004	2017	11	2.03	3.93	7.13	1.26	0.32
	CHAT004	2021	11	2.15	4.42	8.00	1.80	0.41
	CHAT005	2017	11	2.01	2.73	3.65	0.59	0.22
	CHAT005	2021	11	2.27	3.15	4.80	0.75	0.24
	CHAT007	2017	11	2.02	3.25	4.25	0.72	0.22
	CHAT007	2021	–	–	–	–	–	–
	CHAT008	2017	11	3.21	4.21	6.74	1.06	0.25
	CHAT008	2021	11	3.93	5.23	6.79	1.00	0.19
	CHAT010	2017	11	2.50	4.13	5.46	0.96	0.23
	CHAT010	2021	11	4.00	5.50	7.60	1.14	0.21
	CHAT011	2017	11	3.25	4.04	5.27	0.66	0.16
	CHAT011	2021	11	4.26	4.56	4.86	0.20	0.04
	CHAT014	2017	11	2.63	3.46	5.51	0.93	0.27
	CHAT014	2021	11	2.13	3.83	4.86	0.88	0.23
Bankfull [A,B]	CHAT004	2017	0	–	–	–	–	–
	CHAT004	2021	7	3.83	5.36	7.50	1.25	0.23
	CHAT005	2017	2	3.16	3.36	3.55	0.28	0.08
	CHAT005	2021	5	3.26	3.60	4.27	0.41	0.11
	CHAT007	2017	7	2.31	3.66	4.82	0.89	0.24
	CHAT007	2021	–	–	–	–	–	–

[A] Statistics are based on the transects where feature is present and measurable.

[B] Large changes are due to interpretive differences between survey years.

[C] Number of measurements.

Table 52 (continued). Comparison of reach-scale averaged width characteristics in 2017 and 2021 at the second-order stream sites at Chattahoochee River NRA [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Widths	Site	Year	n [A]	Min (m)	Mean (m)	Max (m)	SD (m)	CV
Bankfull (continued) [A,B]	CHAT008	2017	6	3.37	4.95	6.38	1.04	0.21
	CHAT008	2021	10	5.15	7.18	8.98	1.18	0.16
	CHAT010	2017	5	3.41	5.40	8.35	1.97	0.36
	CHAT010	2021	11	6.12	8.76	12.10	1.88	0.21
	CHAT011	2017	5	4.20	4.61	5.26	0.39	0.09
	CHAT011	2021	7	5.29	6.12	6.96	0.65	0.11
	CHAT014	2017	3	3.84	4.18	4.45	0.31	0.07
	CHAT014	2021	11	5.45	8.21	10.46	1.86	0.23
Channel full [A,B]	CHAT004	2017	11	4.65	6.35	9.11	1.66	0.26
	CHAT004	2021	11	7.69	10.13	14.90	2.40	0.24
	CHAT005	2017	11	4.91	5.62	6.44	0.45	0.08
	CHAT005	2021	11	5.19	6.51	8.60	0.99	0.15
	CHAT007	2017	11	3.50	5.68	7.51	1.23	0.22
	CHAT007	2021	–	–	–	–	–	–
	CHAT008	2017	11	5.79	7.96	10.96	1.74	0.22
	CHAT008	2021	11	9.36	13.10	16.85	2.41	0.18
	CHAT010	2017	11	4.52	8.77	11.78	2.20	0.25
	CHAT010	2021	11	9.22	15.69	19.58	3.20	0.20
	CHAT011	2017	11	5.55	7.30	9.16	1.30	0.18
	CHAT011	2021	11	5.89	7.94	9.57	1.17	0.15
	CHAT014	2017	11	4.75	6.37	8.50	1.39	0.22
	CHAT014	2021	8	27.86	38.08	50.10	6.25	0.16

[A] Statistics are based on the transects where feature is present and measurable.

[B] Large changes are due to interpretive differences between survey years.

[C] Number of measurements.

Mean minimum bank height (lowest bank height on a transect) increased slightly (+4%) in 2021 (Table 53). This slight increase was not statistically significant ($p = 0.594$; Table 48). Mean bankfull height was 1.09 meters (ft) and the CV was 0.26 (no bankfull height measurements were taken in 2017; Table 53). There was a statistically significant (+23%) increase in mean channel full height ($p = 0.001$; Table 48). This increase is partly driven by the change in interpretation of the floodplain surface in the downstream portion of the reach. Variability in channel full height decreased from CV = 0.27 to CV = 0.11 (Table 53).

Table 53. Comparison of reach-scale averaged bank heights in 2017 and 2021 at the second-order stream sites at Chattahoochee River NRA [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Heights	Site	Year	n [D]	Min	Mean	Max	SD	CV
Minimum Bank Height (m) [A,B]	CHAT004	2017	22	0.84	1.67	2.23	0.45	0.27
	CHAT004	2021	22	0.67	1.74	2.36	0.52	0.30
	CHAT005	2017	22	0.57	1.21	1.59	0.26	0.22
	CHAT005	2021	22	0.50	1.21	2.17	0.38	0.31
	CHAT007	2017	22	0.37	1.37	4.30	0.99	0.72
	CHAT007	2021	–	–	–	–	–	–
	CHAT008	2017	22	0.38	1.18	1.95	0.50	0.42
	CHAT008	2021	22	0.64	1.32	1.91	0.42	0.32
	CHAT010	2017	22	0.52	1.33	1.94	0.42	0.32
	CHAT010	2021	22	0.69	1.40	1.90	0.34	0.24
	CHAT011	2017	22	0.33	2.77	10.54	3.69	1.33
	CHAT011	2021	22	0.46	1.15	1.83	0.42	0.36
	CHAT014	2017	22	0.43	1.07	1.47	0.29	0.28
	CHAT014	2021	22	0.83	1.13	1.50	0.20	0.18
Bankfull Height (m) [A,C]	CHAT004	2017	0	–	–	–	–	–
	CHAT004	2021	7	0.67	1.09	1.58	0.29	0.27
	CHAT005	2017	2	0.57	0.58	0.59	0.01	0.02
	CHAT005	2021	5	0.50	0.73	1.13	0.25	0.34
	CHAT007	2017	7	0.37	0.54	0.78	0.14	0.26
	CHAT007	2021	–	–	–	–	–	–
	CHAT008	2017	6	0.38	0.64	1.03	0.27	0.43
	CHAT008	2021	9	0.64	0.85	1.09	0.14	0.17
	CHAT010	2017	5	0.52	0.69	0.99	0.18	0.26
	CHAT010	2021	11	0.69	1.19	1.62	0.28	0.24
	CHAT011	2017	5	0.33	0.39	0.53	0.08	0.20
	CHAT011	2021	7	0.46	0.74	1.11	0.24	0.33
	CHAT014	2017	3	0.43	0.54	0.65	0.11	0.21
	CHAT014	2021	22	0.83	1.13	1.50	0.20	0.18
Channel full Height (m) [A]	CHAT004	2017	22	0.84	1.67	2.23	0.45	0.27
	CHAT004	2021	22	1.62	2.05	2.48	0.23	0.11
	CHAT005	2017	22	1.02	1.28	1.59	0.17	0.13
	CHAT005	2021	22	1.00	1.39	2.17	0.28	0.20
	CHAT007	2017	22	0.56	1.63	4.30	1.00	0.61

[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 feature is present and measurable (# in parentheses).

[D] Number of measurements.

Table 53 (continued). Comparison of reach-scale averaged bank heights in 2017 and 2021 at the second-order stream sites at Chattahoochee River NRA [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Heights	Site	Year	n [D]	Min	Mean	Max	SD	CV
Channel full Height (m) (continued) [A]	CHAT007	2021	–	–	–	–	–	–
	CHAT008	2017	22	0.66	1.36	1.95	0.38	0.28
	CHAT008	2021	22	1.39	1.67	1.94	0.14	0.08
	CHAT010	2017	22	0.80	1.45	1.94	0.29	0.20
	CHAT010	2021	22	1.13	1.58	1.94	0.26	0.16
	CHAT011	2017	22	0.59	3.13	10.54	3.59	1.15
	CHAT011	2021	18	0.98	1.39	1.83	0.23	0.17
	CHAT014	2017	22	0.61	1.13	1.47	0.23	0.20
	CHAT014	2021	17	1.16	1.39	1.65	0.15	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 feature is present and measurable (# in parentheses).

[D] Number of measurements.

Two fewer bank undercuts were measures in 2021 (n = 11; Table 54). The mean depth of bank undercuts doubled (0.20 meters [ft] in 2017 to 0.40 meters [ft] in 2021). Bank angles were on average less steep during 2021 (mean bank angle = 59°) compared to 2017 (67°), but this decrease was not statistically significant (p = 0.089; Table 48). Bank vegetation cover increased slightly from 40% in 2017 to 46% in 2021 (Table 54). This difference was also not statistically significant (p = 0.378; Table 48). Bank stability scores were slightly lower (more stable) in 2021 compared to 2017 (Table 54).

Table 54. Comparison of reach-scale averaged bank characteristics in 2017 and 2021 at the second-order stream sites at Chattahoochee River NRA [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Characteristics	Site	Year	n [A]	Min	Mean	Max	SD	CV
Bank Undercut (m)	CHAT004	2017	13	0.11	0.20	0.41	0.09	0.44
	CHAT004	2021	11	0.15	0.40	1.30	0.32	0.79
	CHAT005	2017	8	0.14	0.38	0.92	0.33	0.86
	CHAT005	2021	8	0.17	0.40	0.75	0.23	0.58
	CHAT007	2017	3	0.11	0.17	0.27	0.09	0.51
	CHAT007	2021	–	–	–	–	–	–
	CHAT008	2017	8	0.07	0.24	0.58	0.19	0.78
	CHAT008	2021	5	0.19	0.27	0.55	0.16	0.57
	CHAT010	2017	7	0.07	0.27	0.52	0.16	0.59

[A] Number of measurements.

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

Table 54 (continued). Comparison of reach-scale averaged bank characteristics in 2017 and 2021 at the second-order stream sites at Chattahoochee River NRA [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Characteristics	Site	Year	n [A]	Min	Mean	Max	SD	CV
Bank Undercut (m) (continued)	CHAT010	2021	4	0.14	0.29	0.38	0.11	0.38
	CHAT011	2017	7	0.05	0.15	0.42	0.13	0.87
	CHAT011	2021	9	0.10	0.33	0.85	0.23	0.70
	CHAT014	2017	9	0.05	0.15	0.27	0.08	0.52
	CHAT014	2021	4	0.13	0.20	0.37	0.11	0.57
Bank Angle (°)	CHAT004	2017	22	33.90	67.29	92.40	15.19	0.23
	CHAT004	2021	22	27.10	58.53	90.60	18.03	0.31
	CHAT005	2017	22	13.20	48.86	104.60	27.09	0.55
	CHAT005	2021	22	19.80	50.22	90.50	25.88	0.52
	CHAT007	2017	22	21.70	50.14	82.20	18.25	0.36
	CHAT007	2021	–	–	–	–	–	–
	CHAT008	2017	22	10.60	55.77	90.00	27.64	0.50
	CHAT008	2021	22	13.60	49.95	91.30	24.21	0.48
	CHAT010	2017	22	8.80	49.92	89.90	31.33	0.63
	CHAT010	2021	22	3.40	46.53	99.20	29.70	0.64
	CHAT011	2017	22	7.70	58.95	98.80	30.55	0.52
	CHAT011	2021	22	7.30	45.62	82.20	24.38	0.53
	CHAT014	2017	22	9.40	59.19	90.90	28.63	0.48
	CHAT014	2021	22	3.30	43.84	82.80	23.64	0.54
Vegetation Cover (%)	CHAT004	2017	22	0.00	39.77	95.00	26.34	0.66
	CHAT004	2021	22	10.00	45.91	80.00	18.69	0.41
	CHAT005	2017	22	0.00	27.50	50.00	17.03	0.62
	CHAT005	2021	22	10.00	40.91	80.00	18.75	0.46
	CHAT007	2017	22	0.00	15.45	90.00	21.21	1.37
	CHAT007	2021	–	–	–	–	–	–
	CHAT008	2017	22	5.00	37.05	80.00	23.89	0.64
	CHAT008	2021	22	10.00	38.64	70.00	16.42	0.42
	CHAT010	2017	22	5.00	29.55	70.00	20.81	0.70
	CHAT010	2021	22	0.00	31.82	60.00	15.32	0.48
	CHAT011	2017	22	5.00	41.36	80.00	23.71	0.57
	CHAT011	2021	22	20.00	48.18	80.00	18.93	0.39
	CHAT014	2017	22	0.00	29.32	70.00	22.64	0.77
	CHAT014	2021	22	0.00	25.00	60.00	15.58	0.62

[A] Number of measurements.

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

Table 54 (continued). Comparison of reach-scale averaged bank characteristics in 2017 and 2021 at the second-order stream sites at Chattahoochee River NRA [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Characteristics	Site	Year	n [A]	Min	Mean	Max	SD	CV
Bank Stability [B]	CHAT004	2017	22	10.50	13.23	17.00	1.65	0.12
	CHAT004	2021	22	9.00	12.61	16.00	1.71	0.14
	CHAT005	2017	22	10.50	12.84	15.50	1.31	0.10
	CHAT005	2021	22	9.50	12.00	15.00	1.73	0.14
	CHAT007	2017	22	9.00	12.86	16.50	1.83	0.14
	CHAT007	2021	–	–	–	–	–	–
	CHAT008	2017	22	9.00	13.43	16.00	1.61	0.12
	CHAT008	2021	22	10.50	12.95	16.00	1.27	0.10
	CHAT010	2017	22	8.00	12.36	15.00	2.38	0.19
	CHAT010	2021	22	11.50	13.41	16.00	1.12	0.08
	CHAT011	2017	22	9.00	12.52	17.50	2.33	0.19
	CHAT011	2021	22	6.00	11.05	13.50	1.89	0.17
	CHAT014	2017	22	9.00	13.77	16.00	1.78	0.13
	CHAT014	2021	22	11.50	13.82	16.00	1.05	0.08

[A] Number of measurements.

[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 on CHAT004 were surveyed on T1 (BM1; Figure 32), T5 (BM2; Figure 33), and T9 (BM3; Figure 34). On the detailed transects, bankfull cross-sectional area was on average 115% larger in 2021 (Table 55). On average, channel full area was also larger (+83%; Table 55). These increases are driven by the major improvement in the interpretation of geomorphic surfaces at detailed transect 1 (T1; Figure 32). Water surface slope (longitudinal profile) for this section of Crayfish Creek was 0.0099 m/m in 2021 and 0.0114 m/m in 2017 (Figure 35; Table 55). While overall water surface slope decreased slightly, the longitudinal profile of the reach displays aggradation in the downstream portion of the reach (between T4 and T2) and downcutting in the upstream portion of the reach. Sinuosity continued to be low within the surveyed reach (Table 55).

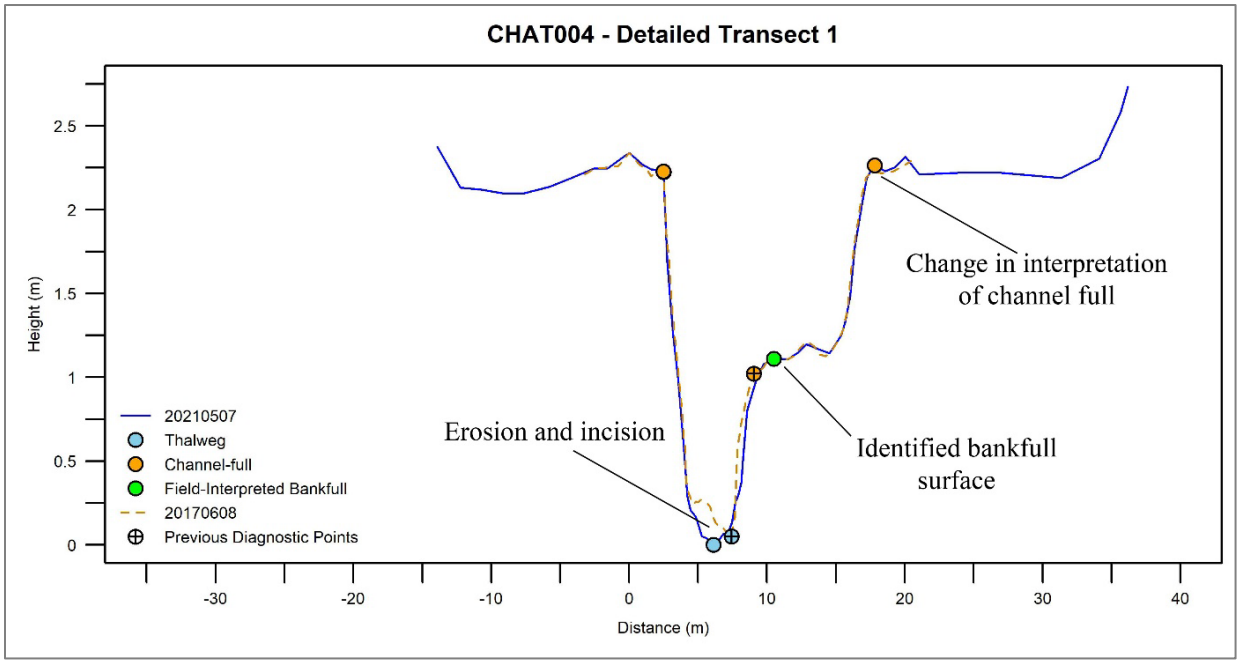


Figure 32. Differences between the 2017 and 2021 surveys of detailed transect 1 (T2) at CHAT004. View is in the downstream direction.

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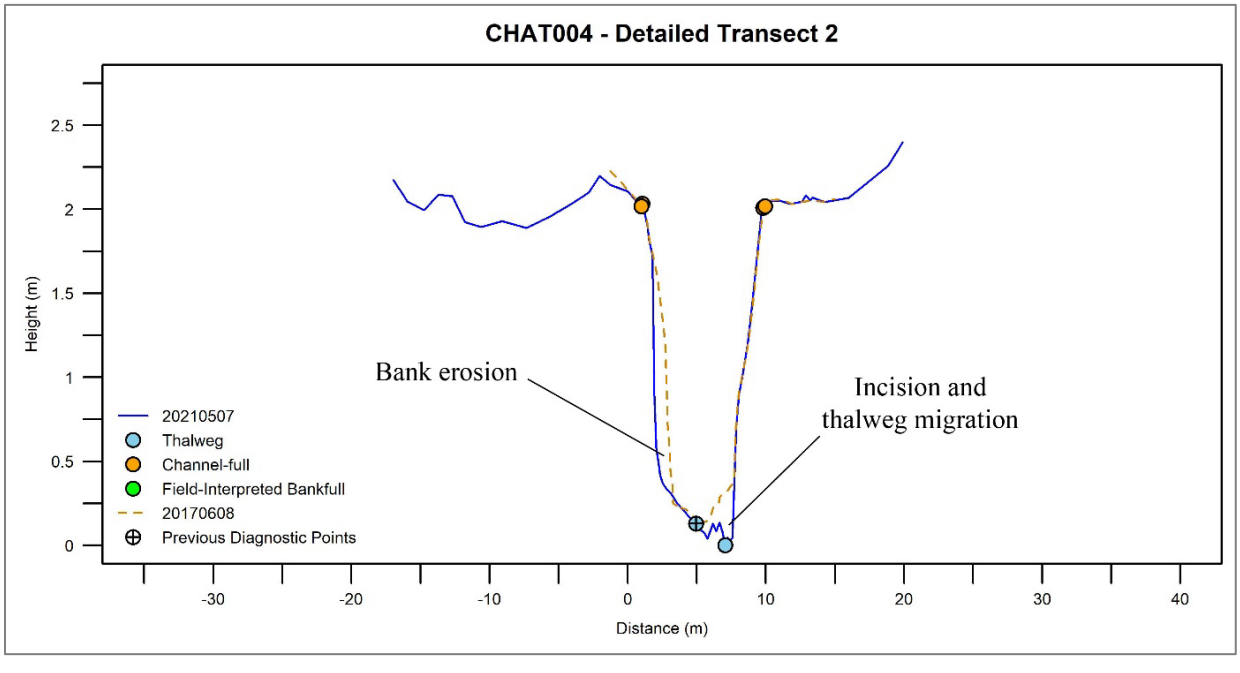


Figure 33. Differences between the 2017 and 2021 surveys of detailed transect 2 (T6) at CHAT004. View is in the downstream direction.

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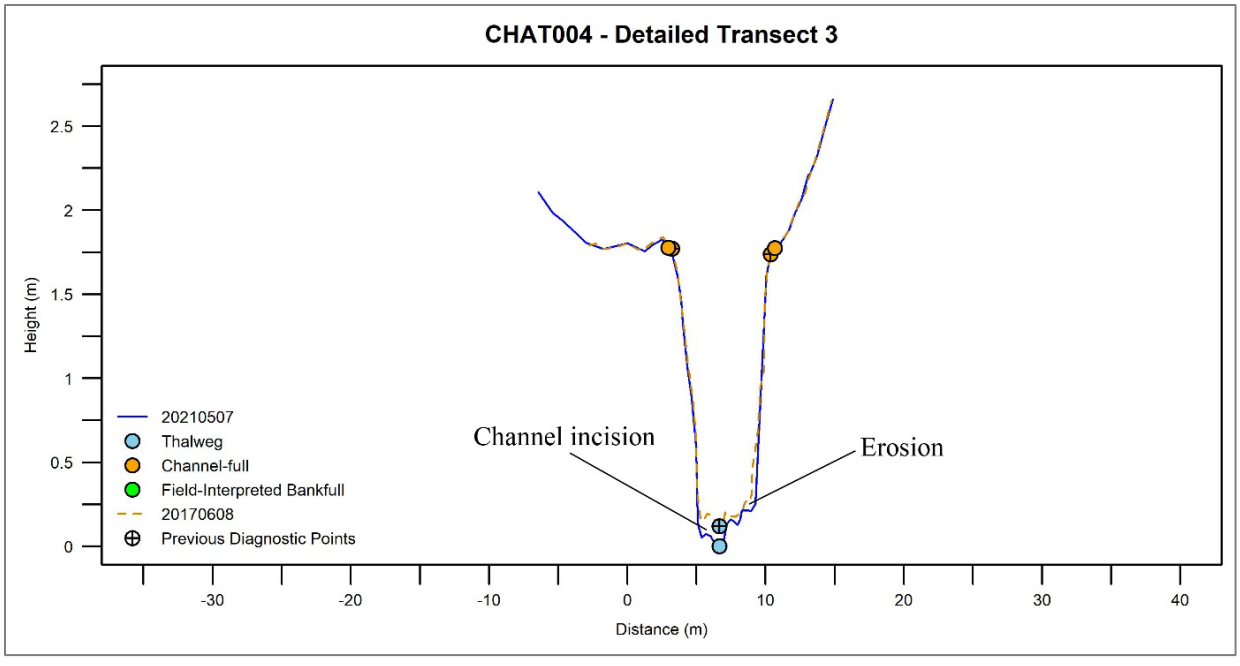


Figure 34. Differences between the 2017 and 2021 surveys of detailed transect 3 (T10) at CHAT004. View is in the downstream direction.

NPS

Table 55. Comparison of 2017 and 2021 reach scale and average detailed transect characteristics for the second-order streams at Chattahoochee River NRA [m—meters].

Site	Year	n [A]	Slope	Sinuosity	n [B]	Bankfull Area (m^2) [C]	Bankfull Width (m) [C]	Bankfull Height (m) [C]	Channel full Area (m^2) [C]	Channel full Width (m) [C]	Channel full Height (m) [C]
CHAT004	2017	13	−0.0114	1.02	3	1.89	4.44	0.56	7.37	7.05	0.56
	2021	17	−0.0099	1.03	3	4.06	6.06	0.96	13.46	10.55	2.01
	Difference 2017–2021	4	0.00151	0.01	–	2.16	1.62	0.40	6.09	3.50	1.45
CHAT005	2017	17	−0.0124	1.13	3	1.62	3.83	0.58	4.22	5.31	1.16
	2021	15	−0.0147	1.12	3	1.42	3.68	0.52	4.61	5.57	1.22
	Difference 2017–2021	−2	−0.0023	−0.01	–	−0.20	−0.15	−0.06	0.39	0.26	0.07
CHAT007	2017	14	−0.0049	1.12	3	1.22	3.69	0.50	4.24	7.36	1.01
	2021	–	–	–	–	–	–	–	–	–	–
	Difference 2017–2021	–	–	–	–	–	–	–	–	–	–
CHAT008	2017	12	−0.0142	1.10	3	1.34	5.09	0.34	5.04	7.52	0.78
	2021	13	−0.0138	1.07	3	3.13	6.71	0.72	11.26	12.81	1.53
	Difference 2017–2021	1	0.00042	−0.03	–	1.79	1.62	0.38	6.22	5.29	0.75
CHAT010	2017	12	−0.0106	1.36	3	2.04	5.05	0.59	6.35	7.88	1.23
	2021	15	−0.0123	1.30	3	5.13	7.60	1.08	8.98	11.83	1.47
	Difference 2017–2021	3	−0.0017	−0.06	–	3.09	2.56	0.49	2.63	3.95	0.24

[A] Number of measurements for slope.

[B] Number of measurements for bankfull and channel full area, width, and depth.

[C] Large changes due to interpretive differences between survey years.

Table 55 (continued). Comparison of 2017 and 2021 reach scale and average detailed transect characteristics for the second-order streams at Chattahoochee River NRA [m—meters].

Site	Year	n [A]	Slope	Sinuosity	n [B]	Bankfull Area (m^2) [C]	Bankfull Width (m) [C]	Bankfull Height (m) [C]	Channel full Area (m^2) [C]	Channel full Width (m) [C]	Channel full Height (m) [C]
CHAT011	2017	11	−0.0087	1.06	3	0.85	4.25	0.28	4.96	7.55	0.96
	2021	11	−0.0088	1.02	3	2.55	5.65	0.61	7.32	9.52	1.27
	Difference 2017–2021	0	−0.0001	−0.04	–	1.70	1.40	0.33	2.36	1.97	0.31
CHAT014	2017	14	−0.0026	1.50	3	1.15	3.92	0.47	2.84	5.73	0.85
	2021	12	−0.0025	1.45	3	2.41	4.64	0.75	8.43	26.29	1.21
	Difference 2017–2021	−2	0.00011	−0.05	–	1.25	0.73	0.28	5.60	20.56	0.37

[A] Number of measurements for slope.

[B] Number of measurements for bankfull and channel full area, width, and depth.

[C] Large changes due to interpretive differences between survey years.

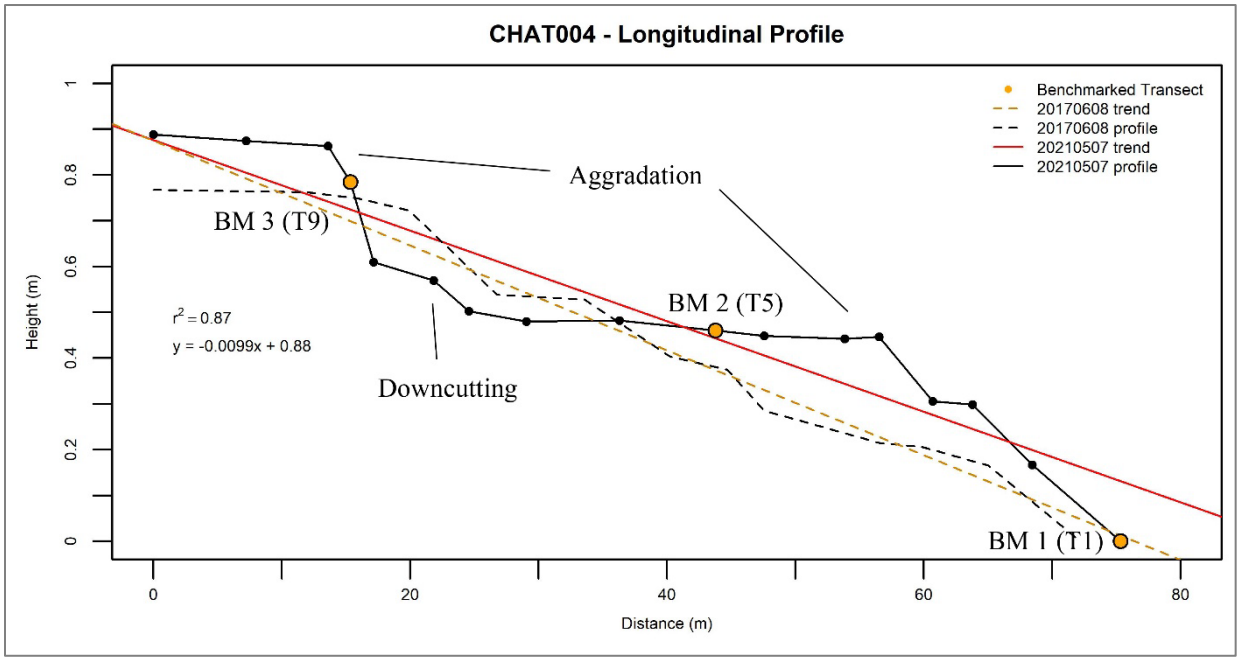


Figure 35. Longitudinal profile for CHAT004. The red line on the graph corresponds to the interpreted slope of the reach (0.0392 m/m). The r^2 value describes the strength of the 2021 trend line (interpreted slope). The "T#" in parentheses indicates the standard transect number on which the detailed transects were surveyed.
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The cross-sections at detailed transect 1 (T1) were fairly similar between the survey years (Figure 32), though slight incision, thalweg migration (away from river right), and erosion was evident. An improvement in the interpretation of the bankfull and channel full surfaces occurred during the 2021 survey as the lower out-of-channel surface (identified as channel full in 2017) was correctly identified as the bankfull surface in 2021. Related to this new interpretation, bankfull cross-sectional area increased by 197% and channel full area increased by 365% (Table 56).

Table 56. Changes to cross-sectional characteristics on detailed transect 1 (T2) at CHAT004 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.55	3.93	0.56
	2021	4.61	7.08	1.11
	Change 2017–2021 [A]	3.06	3.15	0.55
Channel full	2017	3.43	5.47	0.97
	2021	19.39	15.02	2.23
	Change 2017–2021 [A]	15.96	9.55	1.26

[A] Changes due to interpretive differences between survey years.

Detailed transect 2 (T5) was entrenched and had no in-channel features (Figure 33). The left bank eroded, the channel incised, and the thalweg shifted from mid channel toward river right between the

surveys. Because there were no bankfull surfaces identified on detailed transect 2, bankfull was estimated based on the reach-scale bankfull measurements (mean bankfull height). Bankfull cross-sectional area increased by 91% (Table 57). This change was driven by an increase in both bankfull width and height. Channel full area increased by 17%.

Table 57. Changes to cross-sectional characteristics on detailed transect 2 (T6) at CHAT004 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	2.14	4.90	0.56
	2021	4.09	6.12	0.89
	Change 2017–2021	1.95	1.22	0.33
Channel full	2017	10.73	8.63	1.88
	2021	12.25	8.94	2.02
	Change 2017–2021	1.53	0.31	0.14

Detailed transect 3 (T9) was also entrenched and had no in-channel features (Figure 34). The cross-sections were very similar between the two survey years and the channel full diagnostic points were nearly identical. While the cross-sections are similar, some channel incision occurred between the two surveys. Like detailed transect 2, there were no bankfull surfaces identified on this detailed transect, so bankfull was estimated based on the reach-scale bankfull measurements (mean bankfull height). Bankfull cross-sectional area increased by 74% (Table 58). This change was driven by an increase in both bankfull width and height. Channel full area increased by 10%.

Table 58. Changes to cross-sectional characteristics on detailed transect 3 (T10) at CHAT004 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	2.00	4.49	0.56
	2021	3.47	5.00	0.89
	Change 2017–2021	1.47	0.51	0.33
Channel full	2017	7.95	7.05	1.62
	2021	8.73	7.70	1.78
	Change 2017–2021	0.78	0.65	0.16

CHAT005—"Egg Creek"

Reach Description

On May 8, 2021, stream survey data were collected at CHAT005. CHAT005 is on an unnamed second-order stream nicknamed "Egg Creek" because fish eggs were found under a rock during the initial assessment of the stream segment. The monitored reach on "Egg Creek" is approximately 190

meters (623 ft) upstream of its confluence with the Chattahoochee River. Social trails run along both sides of the creek on the terrace that the stream channel is entrenched within (Figure 36). CHAT005 is accessed by following the utility right-of-way from the Settles Bridge parking lot to the stream and then walking upstream to the monitored reach. The reach surveyed was 50 meters (164 ft) long with 5 meters (16.4 ft) between transects.

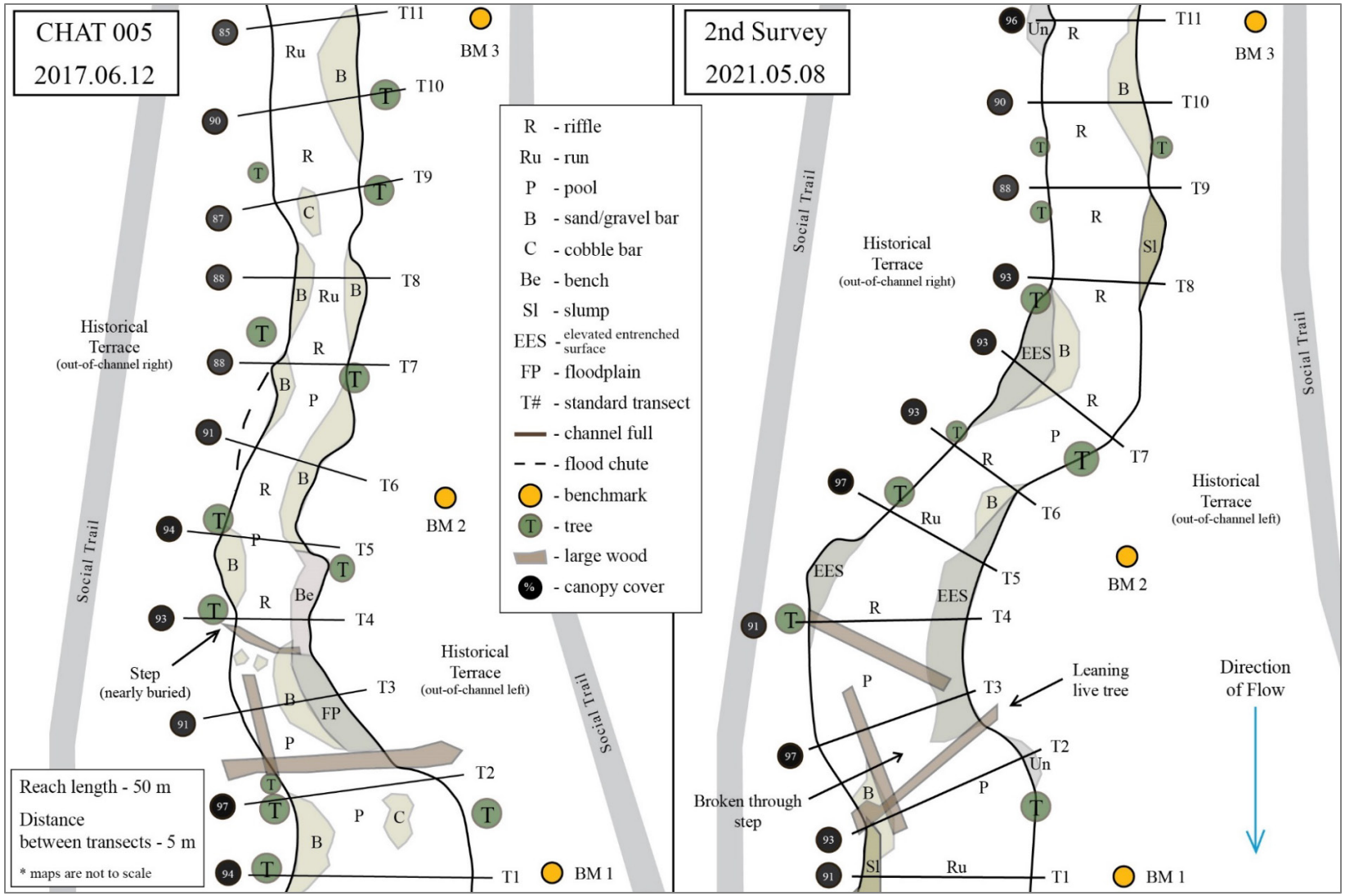


Figure 36. Reach-scale map of CHAT005. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

NPS

“Egg Creek” is slightly entrenched at the surveyed reach and becomes more entrenched downstream. During the 2017 survey, the reach was heavily influenced by a large woody debris dam near T3 (Figure 36). Since that initial survey, that LWD dam has broken through and a knickpoint has migrated upstream to the step at T4 (this step was partially buried in 2017 but was exposed in 2021). The stream banks are undercutting and slumping within the reach and elevated entrenched surfaces were observed on both sides of the stream. Habitat within the monitored reach consisted of mostly riffle and run. Many of the pools observed in 2017 were not present during the 2021 survey. The detailed transects were surveyed on T1 (BM1; Figure 37), T6 (BM2; Figure 38), and T11 (BM3; Figure 39). The detailed transects show evidence of bank erosion and channel incision occurring between the surveys. Water surface slope (longitudinal profile) for this section of “Egg Creek” was 0.0147 m/m (Table 55). The longitudinal profile shows the loss of the step at T3 and knickpoint migration upstream since the 2017 survey (above T1; Figure 40). Survey results for CHAT005 can be viewed in the corresponding file of supplemental materials for this site.

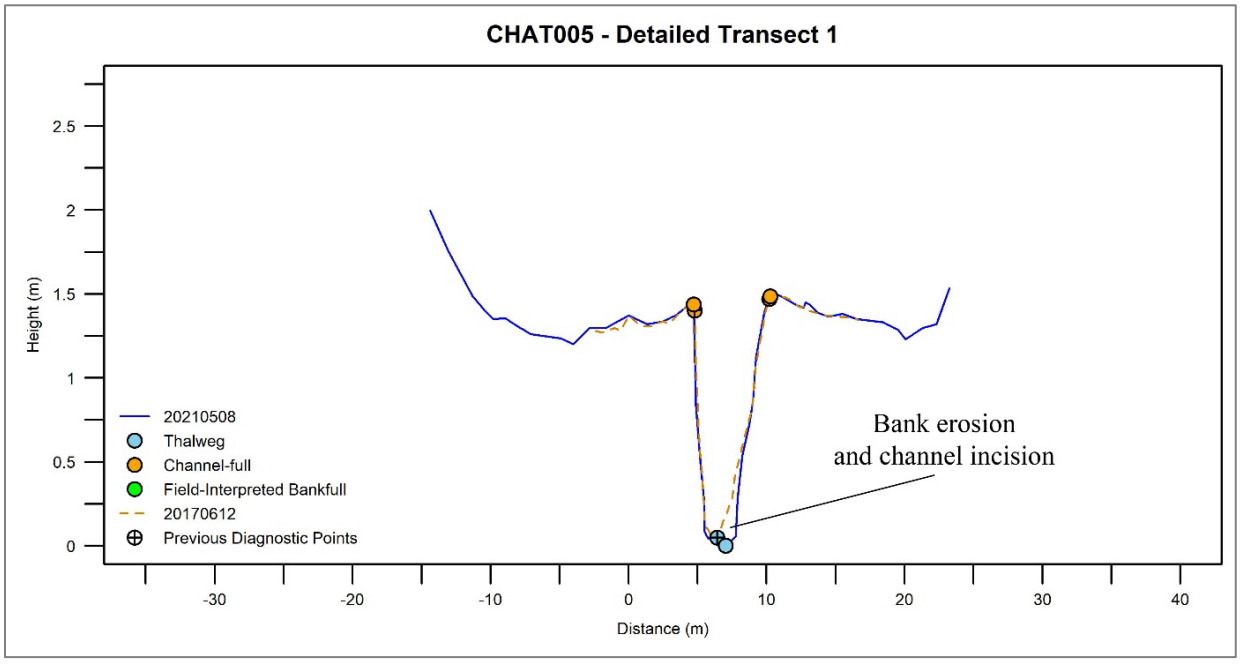


Figure 37. Differences between the 2017 and 2021 surveys of detailed transect 1 at CHAT005. View is in the downstream direction.

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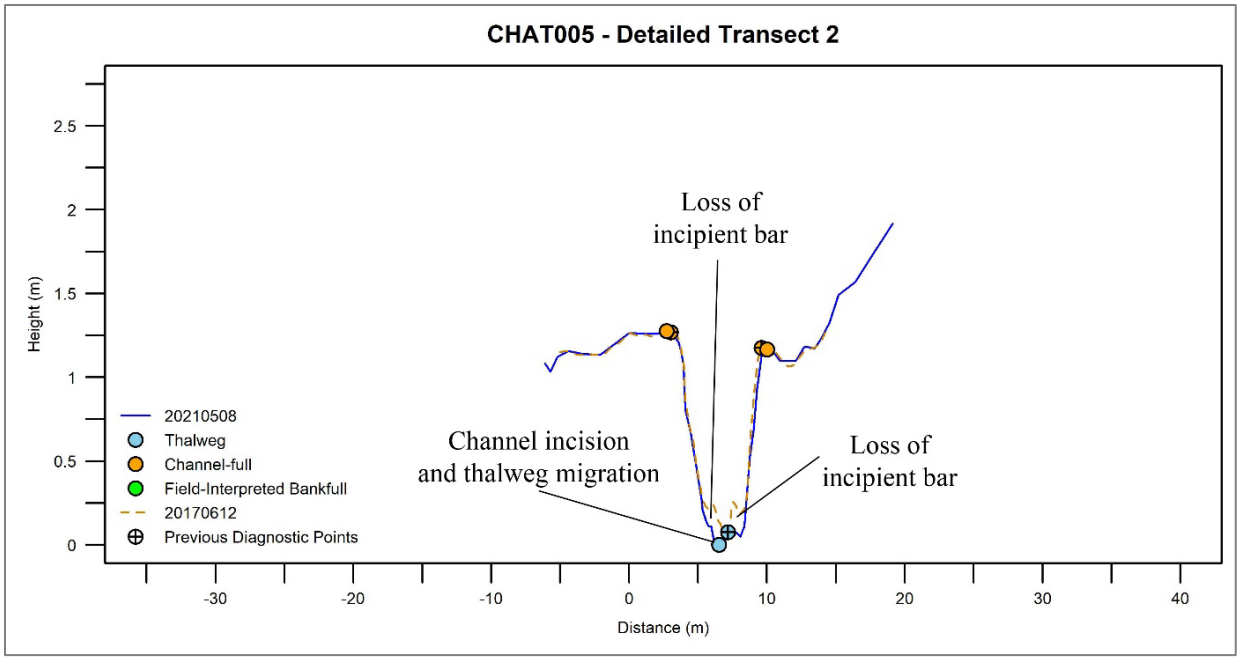


Figure 38. Differences between the 2017 and 2021 surveys of detailed transect 2 at CHAT005. View is in the downstream direction.

NPS

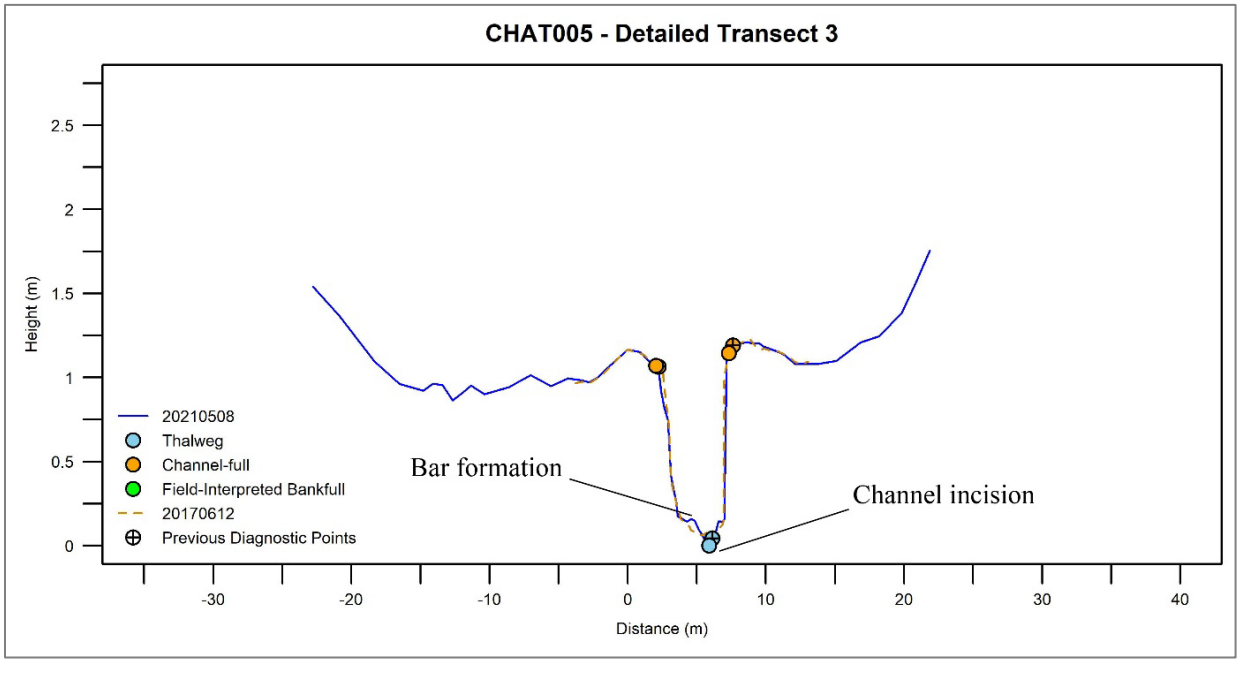


Figure 39. Differences between the 2017 and 2021 surveys of detailed transect 3 at CHAT005. View is in the downstream direction.

NPS

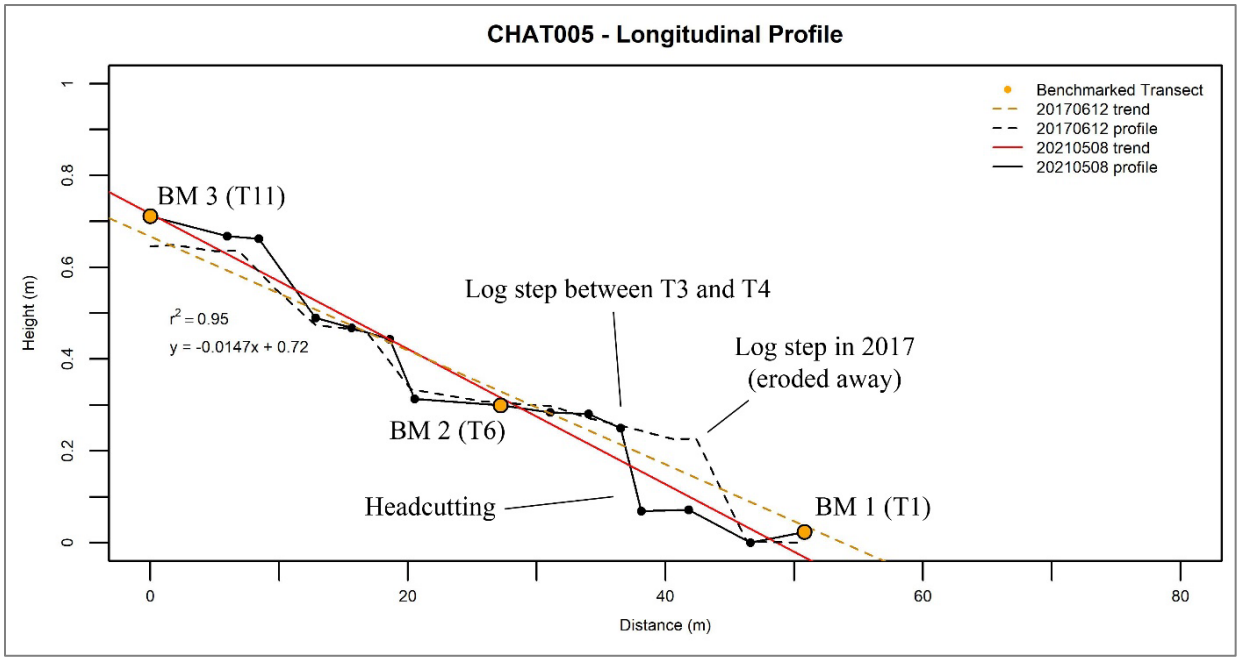


Figure 40. Longitudinal profile for CHAT005. The red line on the graph corresponds to the interpreted slope of the reach (0.0147 m/m). The r^2 value describes the strength of the 2021 trend line (interpreted slope). The "T#" in parentheses indicate the transect number on which the detailed transects were surveyed.
NPS

Habitat Characteristics

The geomorphic channel unit (GCU) types and distributions at CHAT005 changed between the 2017 and 2021 surveys (Table 46). Riffles, runs, pools, and steps were present within the surveyed reach during both survey years and glides were observed during the 2021 survey. The frequency of riffles did not change between the surveys (n = 8) and the mean percentage of riffle slightly increased (+6%; Table 46). The mean percentage of run increased (+13%), while the mean percentage of pool greatly decreased (−35%). The frequency of pools also decreased from n = 8 to n = 3. No glides were observed within the reach in 2017, while four were observed in 2021. The mean percentage of glide was 12%. One step was observed within the reach during the 2017 survey, while two were observed in 2021. The mean percentage of step remained low (Table 46).

The pebble count data for CHAT005 shows a slight coarsening of the bed sediment between the surveys. The mean diameter of the pebbles measured at CHAT005 increased by 13% (Table 47). This slight increase was not statistically significant (p = 0.374; Table 59). While the mean diameter of pebbles increased, the D_5 and maximum pebble diameters decreased (Table 47).

Table 59. Difference in means t-test results comparing CHAT005 during 2017 and 2021. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [m—meters; mm—millimeters].

Measurement	n [A]	CHAT005 in 2017	CHAT005 in 2021	P-value	Significance
Pebble Count (mm)	100	37.83	42.73	0.374	–
Thalweg Depth (m)	11	0.10	0.23	0.024	*
Thalweg Position (%)	11	65.45	47.73	0.126	–
Wetted Width (m)	11	1.94	2.71	0.016	*
Active Channel Width (m)	11	2.73	3.15	0.161	–
Channel full Width (m)	11	5.62	6.51	0.018	*
Minimum Bank Height (m)	22	1.21	1.21	0.964	–
Channel full Height (m)	22	1.28	1.39	0.118	–
Bank Angle (°)	22	48.86	50.22	0.866	–
Vegetative Cover (%)	22	27.50	40.91	0.017	*

[A] Number of measurements taken during each survey year.

The number of pieces of large woody debris (LWD) decreased from n = 11 to n = 8 (Table 49). During this survey, LWD was mostly concentrated downstream of T4 with six of the eight pieces being part of LWD jams. Despite the decrease in pieces of LWD, the volume of LWD per channel area increased from 0.0023 m^3/m^2 in 2017 to 0.0032 m^3/m^2 (Table 49). Canopy cover continued to be dense (mean canopy cover = 93%) and have very little variability (CV = 0.03; Table 50).

Mean thalweg position (relative to the left bank) shifted toward the middle of the channel between surveys, decreasing from 65% to 48% (Table 51). Variability in thalweg position increased between the two survey years (CV = 0.34 in 2017 to 0.61 in 2021). Mean thalweg depth was statistically significantly greater (+130%) in 2021 (p = 0.024; Table 59). Additionally, maximum thalweg depth doubled between the surveys (Table 51).

Channel Morphology

Mean wetted width at CHAT005 was statistically significantly wider (+40%) in 2021 (p = 0.016; Table 59), while variability in wetted width was lower during the 2021 survey. Mean active channel width was 15% wider in 2021, but this change was not statistically significant (p = 0.161; Table 59). Variability (CV) of active channel width was similar between the two surveys (Table 52). The number of bankfull widths measured increased from n = 2 to n = 5. This increase in bankfull measurements was related to the identification of elevated entrenched surfaces at the bankfull level along transects 3, 4, 5, and 7 (Figure 36). Mean bankfull width increased slightly (+7%) and variability continued to be low (CV = 0.11; Table 52). There was a statistically significant (+16%) increase in mean channel full width (p < 0.018; Table 59). Both the minimum and maximum channel full width values were wider in 2021 (Table 52). Variability in channel full width (CV) was relatively low but increased slightly.

Mean minimum bank height (lowest bank height on a transect) in 2021 was equal to the mean observed in 2017 (Table 53). Mean bankfull height increased (+26%) between the surveys. Much of

this increase was influenced by an anomalously high bankfull level on the elevated entrenched surface at T3 (Figure 36). Mean channel full height slightly increased (+9%) but this change was not statistically significant (p = 0.118; Table 59).

The same number of undercuts (n = 8) were measured during both survey years and the mean depth of these undercuts were similar (Table 54). The very slight increase in mean bank angle (+1°) was not statistically significant (p = 0.866; Table 59). Bank vegetation cover increased from 28.50% to 41% (Table 54), and this change was statistically significant (p = 0.017; Table 59). Bank stability scores were slightly lower (more stable) in 2021 (Table 54).

Detailed Transects

The detailed transects on CHAT005 were surveyed on T1 (BM1; Figure 37), T6 (BM2; Figure 38), and T11 (BM3; Figure 39). On the detailed transects, the cross-sections were relatively similar between the survey years. Mean bankfull cross-sectional area decreased by approximately 12% (Table 55). Mean channel full area was approximately 9% larger.

Water surface slope (longitudinal profile) for this section of "Egg Creek" increased by approximately 19% (+0.0023 m/m; Figure 40; Table 55). This sub-centimeter per meter difference in slope is negligible as it falls well within the margin of error of the equipment used to conduct the survey. The longitudinal profiles of the surveyed reach were similar between the survey years in the upper half of the reach, but the lower half changed substantially. In 2017, there was a large change in slope caused by a log step at T3. This change in slope was not present in the 2021 profile as that log step had blown out and the stream incised into the sediment trapped by the log step. In the 2021 profile, a change in slope is evident just upstream of T4 as another log step was present at the downstream end of the riffle between T5 and T4. There was only a slight change in sinuosity between the surveys (Table 55).

Detailed transect 1 (T1) shows bank erosion on river right, a slight shift in thalweg position, and a small amount of channel incision (Figure 37). The cross-sections are otherwise relatively similar between the survey years and the channel full diagnostic points were nearly identical. Bankfull cross-sectional area was nearly equal (Table 60). Channel full area increased by 12% due to bank erosion and channel incision (Table 60).

Table 60. Changes to cross-sectional characteristics on detailed transect 1 at CHAT005 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.22	3.22	0.58
	2021	1.21	3.05	0.52
	Change 2017–2021	0.00	−0.17	−0.06
Channel full	2017	4.55	5.18	1.35
	2021	5.10	5.33	1.44
	Change 2017–2021	0.55	0.15	0.08

Detailed transect 2 (T6) shows the loss of two incipient bars (one on each side of the channel), slight channel incision, and thalweg migration (Figure 38). Like detailed transect 1, the cross-sections are otherwise relatively similar. Bankfull cross-sectional area on detailed transect 2 (T6) decreased by 11% (Table 61). Channel full area increased 10% due to the loss of the two bars and slight channel incision.

Detailed transect 3 (T11) shows slight channel incision and slight bed aggradation on the sides of the channel which has led to incipient bar formation on river left (Figure 39). Bankfull cross-sectional area decreased by 21% (Table 62). Channel full area was similar between the two surveys, increasing by 4%.

Table 61. Changes to cross-sectional characteristics on detailed transect 2 at CHAT005 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.71	4.30	0.58
	2021	1.53	3.97	0.52
	Change 2017–2021	−0.18	−0.32	−0.06
Channel full	2017	4.33	5.86	1.10
	2021	4.78	6.28	1.17
	Change 2017–2021	0.45	0.42	0.07

Table 62. Changes to cross-sectional characteristics on detailed transect 3 at CHAT005 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.93	3.96	0.58
	2021	1.52	4.01	0.52
	Change 2017–2021	−0.42	0.05	−0.06
Channel full	2017	3.79	4.90	1.02
	2021	3.95	5.11	1.07
	Change 2017–2021	0.15	0.21	0.05

CHAT007—"Red Tail Creek" (Removed from Monitoring)

Reach Description

CHAT007 is on an unnamed second-order stream nicknamed "Red Tail Creek." CHAT007 is accessed by crossing the field near the end of Rogers Bridge Road (beyond the locked gate) and then navigating the steep descent down to the channel. CHAT007 is approximately 110 meters (361 ft) upstream of its confluence with the Chattahoochee River. In 2017, the reach was 50 meters (164 ft) long with 5 meters (16.4 ft) between transects. The results from the data collected at "Red Tail

Creek" during 2017 were not paired with any other second-order streams (McDonald et al. 2019), as it was not similar to the other monitored second-order streams.

The monitored reach on "Red Tail Creek" is extremely entrenched and is located very near the stream's confluence with the Chattahoochee River. The reach receives near-daily flow reversals due to increases in discharge in the Chattahoochee River which occur when water is released for power generation at Buford Dam. Immediately upstream of the monitored reach, the channel is even more entrenched and steep valley walls encroach directly on to the channel. Benchmarks were on T1 (BM1), T6 (BM2), and T11 (BM3).

On April 25, 2021, SECN personnel visited CHAT007 for the purpose of conducting site maintenance in preparation for the second data collection survey within the reach. During this visit, a large tree was observed to have fallen on top of BM3. This tree had to be removed by CHAT staff. BM2 was buried under approximately 0.18 meters (7 inches) of fine sediment deposition. The streambanks at CHAT014 were slumped and undercut and the stream channel was choked with muddy fine sediment deposition. SECN personnel were able to locate all benchmarks, but due to safety concerns (i.e., high, steep, slippery, and deeply undercut bank) secondary benchmarks were not installed on the river left side of the stream. Movement throughout the reach was difficult as large amounts of fine sediment had been deposited in the stream.

SECN and CHAT personnel agreed that due to the fact that this stream reach was not representative of other second-order streams managed by the park and there were safety concerns involved in accessing and accurately assessing the habitat conditions of the reach, CHAT007 was removed from this monitoring protocol.

CHAT008—Mulberry Creek

Reach Description

On May 11, 2021, stream survey data were collected at CHAT008. CHAT008 is on a portion of Mulberry Creek (a second-order stream downstream of Roswell, Georgia). CHAT008 is accessed by hiking into the site from the end of the paved road on Hyde Rd N.E. (beyond locked gate). CHAT008 is approximately 700 meters (2,297 ft) upstream of its confluence with the Chattahoochee River. The reach surveyed was 50 meters (164 ft) long with 5 meters (16.4 ft) between transects.

The monitored reach on Mulberry Creek is slightly entrenched and elevated entrenched surfaces and large gravel bars are present on both sides of the stream (Figure 41). Bar surfaces have persisted since the 2017 surveys and riffles have further developed. Some pool habitat observed in the 2017 survey was not observed during the 2021 survey (converting to run). More large woody debris was introduced to the stream channel since the 2017 survey, serving as bank protection along some parts of the reach. Water surface slope (longitudinal profile) for this section of Mulberry Creek was 0.0138 m/m (Table 20). The longitudinal profile shows the high slope areas between T3 and T6 as well as the further development of the riffles between T8 and T11 (Figure 41). Some channel aggradation was also observed within the downstream portion of the reach. The detailed transects were surveyed on T1 (BM1), T6 (BM2), and T11 (BM3). Elevated entrenched surfaces were observed on each of the detailed transects. Detailed transect 1 (T1) showed some channel incision and detailed transect 2

(T6) showed some erosion of the river right bank. Survey results for CHAT008 can be viewed in the corresponding file of supplemental materials for this site.

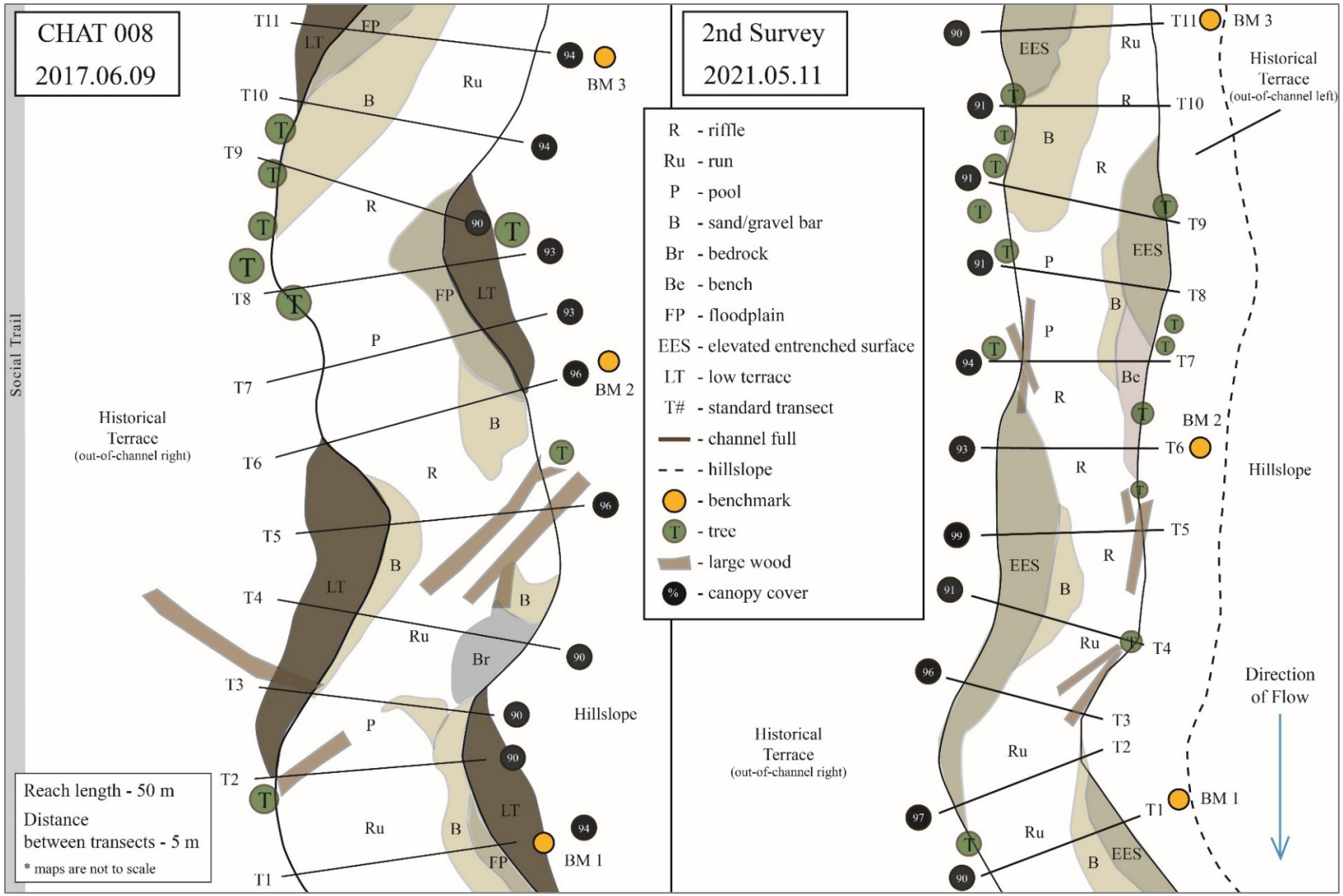


Figure 41. Reach-scale map of CHAT008. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

NPS

Habitat Characteristics

The geomorphic channel unit (GCU) types and distributions at CHAT008 changed substantially between the surveys (Table 46). Riffles, runs, and pools were present within the surveyed reach during both survey years and glides were observed during the 2021 survey. One more instance of riffle was observed during the 2021 survey (from n = 7 to n = 8) and the mean percentage of riffle increased (+10%). The number of observed runs increased from n = 3 to n = 8 and the mean percentage of run increased (+15%). The frequency of pools slightly decreased from n = 7 to n = 6. While the number of observed pools was only one fewer in 2021, there was a large reduction in the mean percentage of pool (−37%; Table 46). No glides were observed within the reach in 2017. In 2021, two glides were observed and there was a mean percentage of glide of 11%. No steps were observed within the reach during either survey.

The pebble count data for CHAT008 shows a statistically significant coarsening of the bed between the surveys (p = 0.034; Table 63). The mean diameter of the pebbles measured at CHAT008 increased by 24% (Table 47). Every sediment particle size percentile measurement was larger in 2021, excluding the minimum observed particle size which decreased from 2 millimeters to < 0.062 millimeters (Table 47).

Table 63. Difference in means t-test results comparing CHAT008 during 2017 and 2021. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [m—meters; mm—millimeters].

Measurement	n [A]	CHAT008 in 2017	CHAT008 in 2021	P-value	Significance
Pebble Count (mm)	100	40.73	50.58	0.034	*
Thalweg Depth (m)	11	0.19	0.19	0.919	–
Thalweg Position (%)	11	50.45	36.36	0.221	–
Wetted Width (m)	11	2.57	3.28	0.037	*
Active Channel Width (m)	11	4.21	5.23	0.031	*
Channel full Width (m) [B]	11	7.96	13.10	< 0.001	***
Minimum Bank Height (m)	22	1.18	1.32	0.313	–
Channel full Height (m) [B]	22	1.36	1.67	0.002	**
Bank Angle (°)	22	55.77	49.95	0.462	–
Vegetative Cover (%)	22	37.05	38.64	0.798	–

[A] Number of measurements taken during each survey year.

[B] Changes due to interpretive differences between survey years.

The number of pieces of large woody debris (LWD) observed at CHAT008 increased from n = 6 in 2017 to n = 11 in 2021 (Table 49). While LWD was well distributed throughout the reach, five pieces were contained in a jam upstream of T6 (Figure 41). The mean length of LWD at CHAT008 increased by 23% and the mean diameter slightly decreased from 0.20 meters (ft) in 2017 to 0.18 meters (ft) (Table 49). The volume of LWD per channel area at CHAT008 increased by 33% (Table 49). Canopy cover at CHAT008 did not change between the surveys, was dense (mean canopy cover = 93%), and had very little variability (CV = 0.03; Table 50).

Mean thalweg position (relative to the left bank) shifted toward the river left bank, decreasing from 50% in 2017 to 36% in 2021 (Table 51). Variability in thalweg position increased between the two survey years (CV = 0.47 in 2017 to 0.78 in 2021). Mean thalweg depth (0.19 meters [ft]; Table 51) did not change between the survey years, but measurements were far less variable in 2021 (CV = 0.51) than in 2017 (CV = 0.94).

Channel Morphology

Average wetted width at CHAT008 was statistically significantly wider (+28%) during the 2021 survey ($p = 0.037$; Table 63). Variability of wetted width measurements was similar in the two survey years. Mean active channel width was 24% wider in 2021 compared to 2017 (Table 52) and this change was statistically significant ($p = 0.031$; Table 63). Variability of active channel widths decreased slightly between the two surveys (Table 52). The number of measured bankfull widths increased from n = 6 in 2017 to n = 10 during the 2021 survey (Table 45). This increase in measured bankfull widths is due to the reinterpretation of elevated entrenched surfaces and channel full. Elevated entrenched surfaces were observed along every transect excluding T7, where a bench was observed. (Figure 41). Mean bankfull width increased by 45% and there was a slight reduction in the variability of the measurements (Table 52). The modification to the interpretation of channel full led to a statistically significant increase (+64%) in mean channel full width ($p < 0.001$; Table 63). Variability in channel full widths was relatively low and slightly decreased in 2021 (Table 52).

Mean minimum bank height at CHAT008 (lowest bank height on a transect) was 12% higher and 24% less variable in 2021 (Table 53). Mean bankfull height increased by 31%. Bankfull height measurements were also 60% less variable. There was a statistically significant increase (+23%) in mean channel full height ($p = 0.002$; Table 63). Like channel full widths, this significant increase in mean channel full height was influenced by the change in interpretation of bankfull and channel full. There was a 70% decrease in channel full height variability between the surveys (Table 53).

The number of undercut banks decreased from n = 8 in 2017 to n = 5 in 2021 and there was a slight increase in the mean depth of these undercuts (Table 54). Bank angles were on average 6° less steep during 2021. This change was not statistically significant ($p = 0.462$; Table 63). Bank vegetation cover percentage was similar between the survey years (37% in 2017 and 39% in 2021; Table 54). Bank stability scores at CHAT008 were slightly lower (more stable) in 2021 compared to 2017 (Table 54).

Detailed Transects

The detailed transects at CHAT008 were surveyed on T1 (BM1; Figure 42), T6 (BM2; Figure 43), and T11 (BM3; Figure 44). On the detailed transects, bankfull cross-sectional area was on average 133% greater and mean channel full area was on average 123% greater in 2021 (Table 55). These substantial changes to channel geometry are mainly driven by improvements in the interpretation of bankfull and channel full surfaces on detailed transects 1 (T1; Figure 42) and 2 (T6; Figure 43).

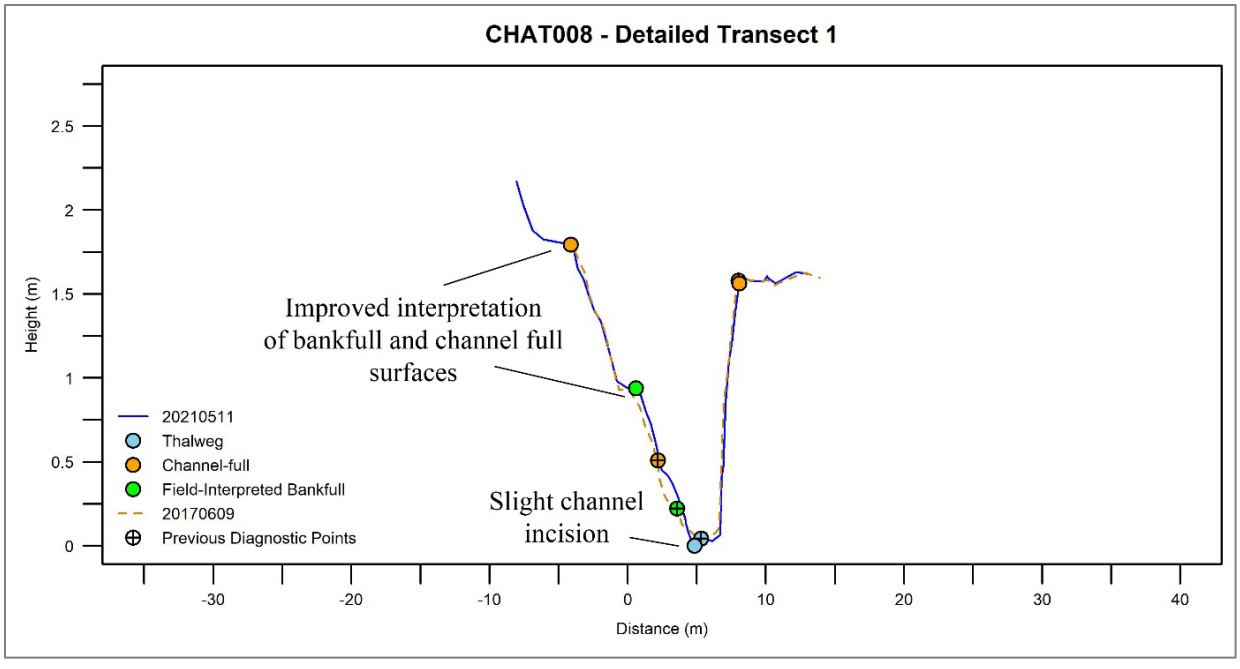


Figure 42. Differences between the 2017 and 2021 surveys of detailed transect 1 at CHAT008. View is in the downstream direction.

NPS

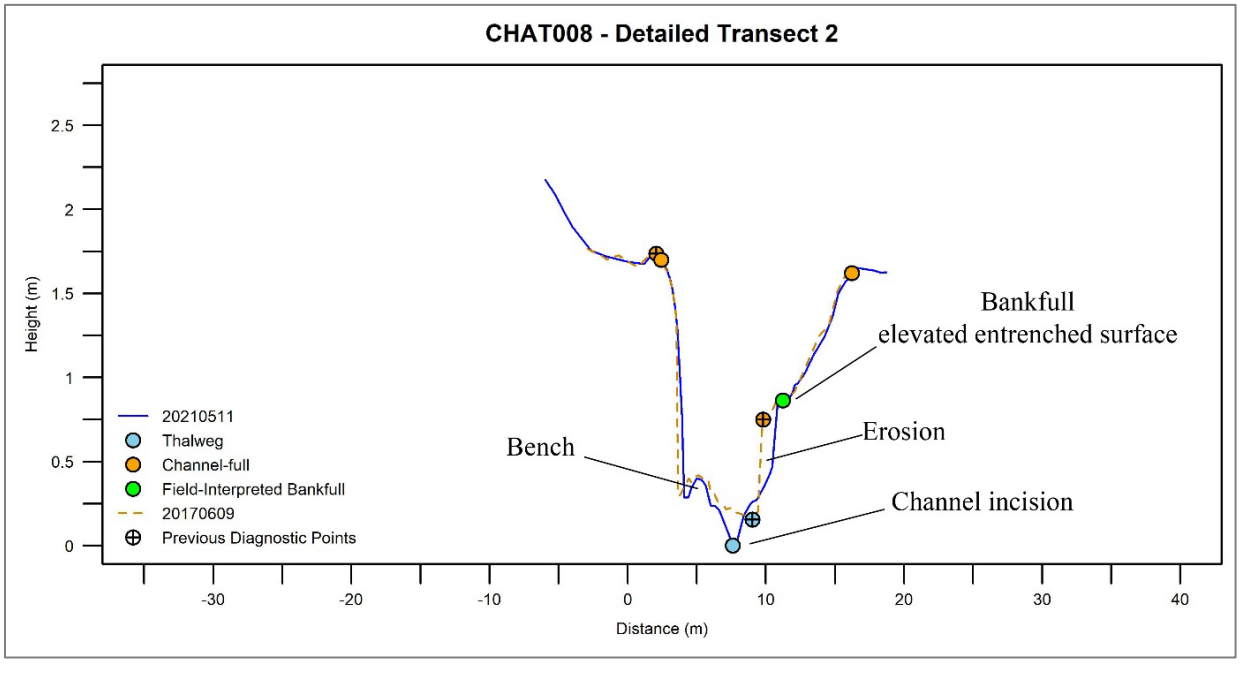


Figure 43. Differences between the 2017 and 2021 surveys of detailed transect 2 at CHAT008. View is in the downstream direction.

NPS

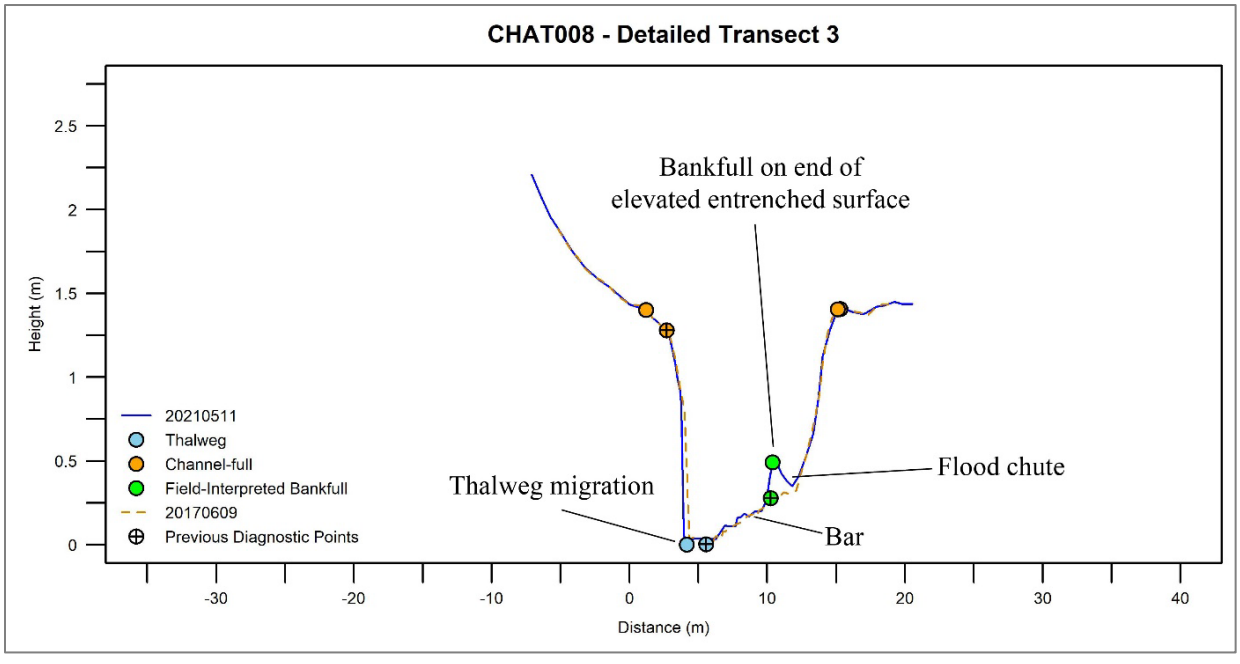


Figure 44. Differences between the 2017 and 2021 surveys of detailed transect 3 at CHAT008. View is in the downstream direction.

NPS

Water surface slope (longitudinal profile) for this section of Mulberry Creek was 0.0138 m/m in 2021 and 0.0142 m/m in 2017 (Figure 45; Table 55). This difference in slope is negligible as it falls well within the margin of error of the equipment used to conduct the survey. While the slope of the surveyed reach did not change substantially, the 2021 longitudinal profile shows some channel incision occurred downstream of the riffle at T9 and the riffle at T5 has aggraded. Sinuosity was similar between surveys (Table 55).

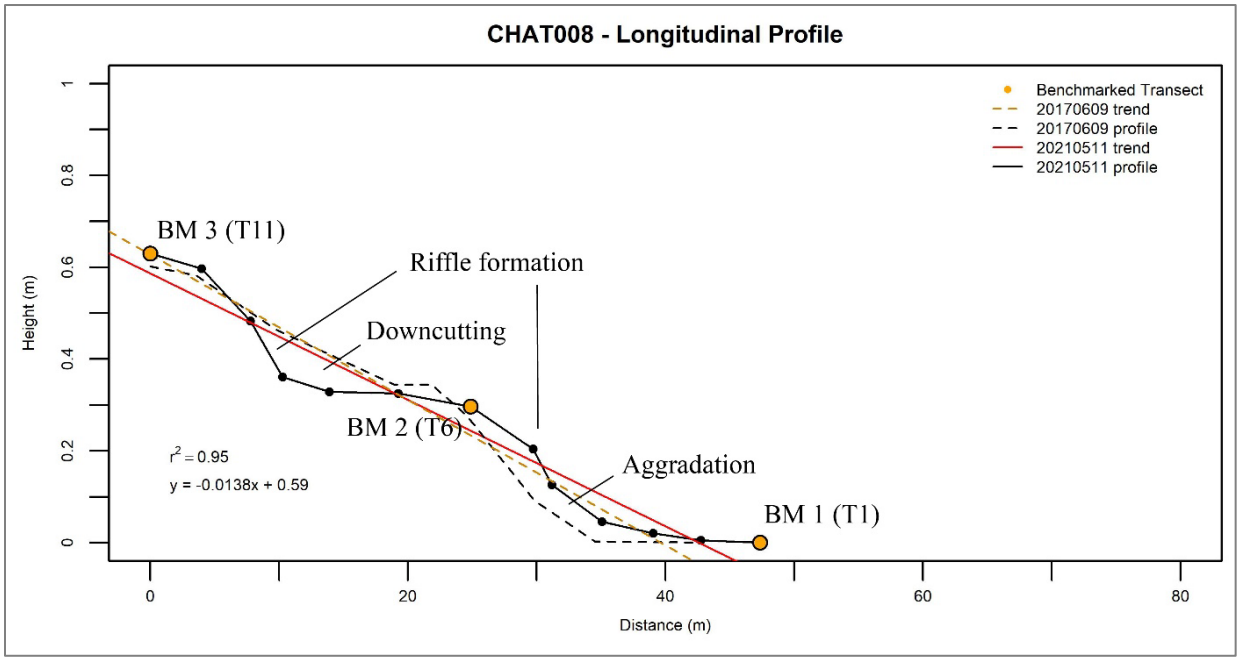


Figure 45. Longitudinal profile for CHAT008. The red line on the graph corresponds to the interpreted slope of the reach (0.0138 m/m). The r^2 value describes the strength of the 2021 trend line (interpreted slope). The "T#" in parentheses indicates the standard transect number on which the detailed transects were surveyed.
NPS

Detailed transect 1 (T1) shows slight channel incision and thalweg migration (toward the river left bank), deposition on the bar on river left, and a change in interpretation of the bankfull and channel full diagnostic points (Figure 42). The 2017 river left channel full point was reinterpreted as an elevated entrenched surface and used as the bankfull indicator during the 2021 survey. This change in interpretation placed the river left channel full surface at a more appropriate level (channel full was very low in the 2017 cross-section; Figure 42). These interpretive differences led to bankfull cross-sectional area increasing by 839% and channel full area increasing by 497% (Table 64).

Table 64. Changes to cross-sectional characteristics on detailed transect 1 at CHAT008 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	0.41	3.10	0.18
	2021	3.85	6.55	0.94
	Change 2017–2021 [A]	3.44	3.46	0.76
Channel full	2017	1.62	4.62	0.47
	2021	9.68	11.18	1.56
	Change 2017–2021 [A]	8.06	6.56	1.10

[A] Changes due to interpretive differences between survey years.

Detailed transect 2 (T6) shows channel incision, erosion of the elevated entrenched surface on river right, and another change in interpretation of the bankfull and channel full surfaces (Figure 43). Bankfull was interpreted to be at the elevated entrenched surface on river right which had been identified as channel full during the 2017 survey. This reinterpretation increased bankfull cross-sectional area by 57% and channel full area by 328% (Table 65).

Table 65. Changes to cross-sectional characteristics on detailed transect 2 at CHAT003 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	2.58	6.17	0.56
	2021	4.06	7.37	0.86
	Change 2017–2021 [A]	1.48	1.20	0.30
Channel full	2017	2.80	6.21	0.60
	2021	11.97	13.32	1.62
	Change 2017–2021 [A]	9.18	7.11	1.03

[A] Changes due to interpretive differences between survey years.

Detailed transect 3 (T11) shows thalweg migration toward the river left bank and aggradation on the small floodplain surface at river right (Figure 44). Additionally, there was a flood chute behind the small bankfull surface on river right. Besides the small change in river left channel full, there were no substantial geomorphic changes in channel full or bankfull. Bankfull cross-sectional area increased by 42% (Table 66). These changes in bankfull morphology are related to the deposition that occurred on the bankfull surface since 2017. Channel full area also increased slightly (+13%) due mostly to interpretive changes on river left (Table 66).

Table 66. Changes to cross-sectional characteristics on detailed transect 3 at CHAT002 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.05	6.01	0.28
	2021	1.49	6.22	0.35
	Change 2017–2021	0.44	0.21	0.07
Channel full	2017	10.69	11.73	1.28
	2021	12.12	13.92	1.40
	Change 2017–2021 [A]	1.42	2.19	0.12

[A] Changes due to interpretive differences between survey years.

CHAT010—"Beaver Creek"

Reach Description

On May 10, 2021, stream survey data were collected at CHAT010. CHAT010 is on an unnamed second-order stream nicknamed "Beaver Creek" because of a beaver dam downstream of the

surveyed reach present upon the initial reach assessment. “Beaver Creek” can be accessed by following the right fork on the trail along Terrell Mill Creek to within approximately 100 meters (328 ft) of the stream. CHAT010 is approximately 240 meters (787 ft) upstream of its confluence with Terrell Mill Creek. The reach surveyed was 70 meters (230 ft) long with 7 meters (23 ft) between transects.

The monitored portion of “Beaver Creek” has developed a relatively extensive floodplain area on the river left side throughout most of the reach (Figure 46). Multiple riffle, run, and pool sequences were observed during the 2021 survey. A large tree fall between T4 and T6 persisted since the 2017 survey and is still influencing the stream. More large woody debris was observed within the reach during the 2021 survey (Table 49). Water surface slope (longitudinal profile) for this section of “Beaver Creek” was 0.0123 m/m (Table 20). The longitudinal profile shows the high slope riffle pool sequence between T5 and T7 and another at the upstream portion of the reach. Possible knickpoint migration was observed as the downstream riffle has shifted upstream. The detailed transects were surveyed on T1 (BM1), T8 (BM2), and T10 (BM3). A floodplain surface was observed on river left of detailed transects 2 and 3 and another floodplain (related to an intermittent tributary) is seen on river right of detailed transect 1 (T1). Survey results for CHAT010 can be viewed in the corresponding file of supplemental materials for this site.

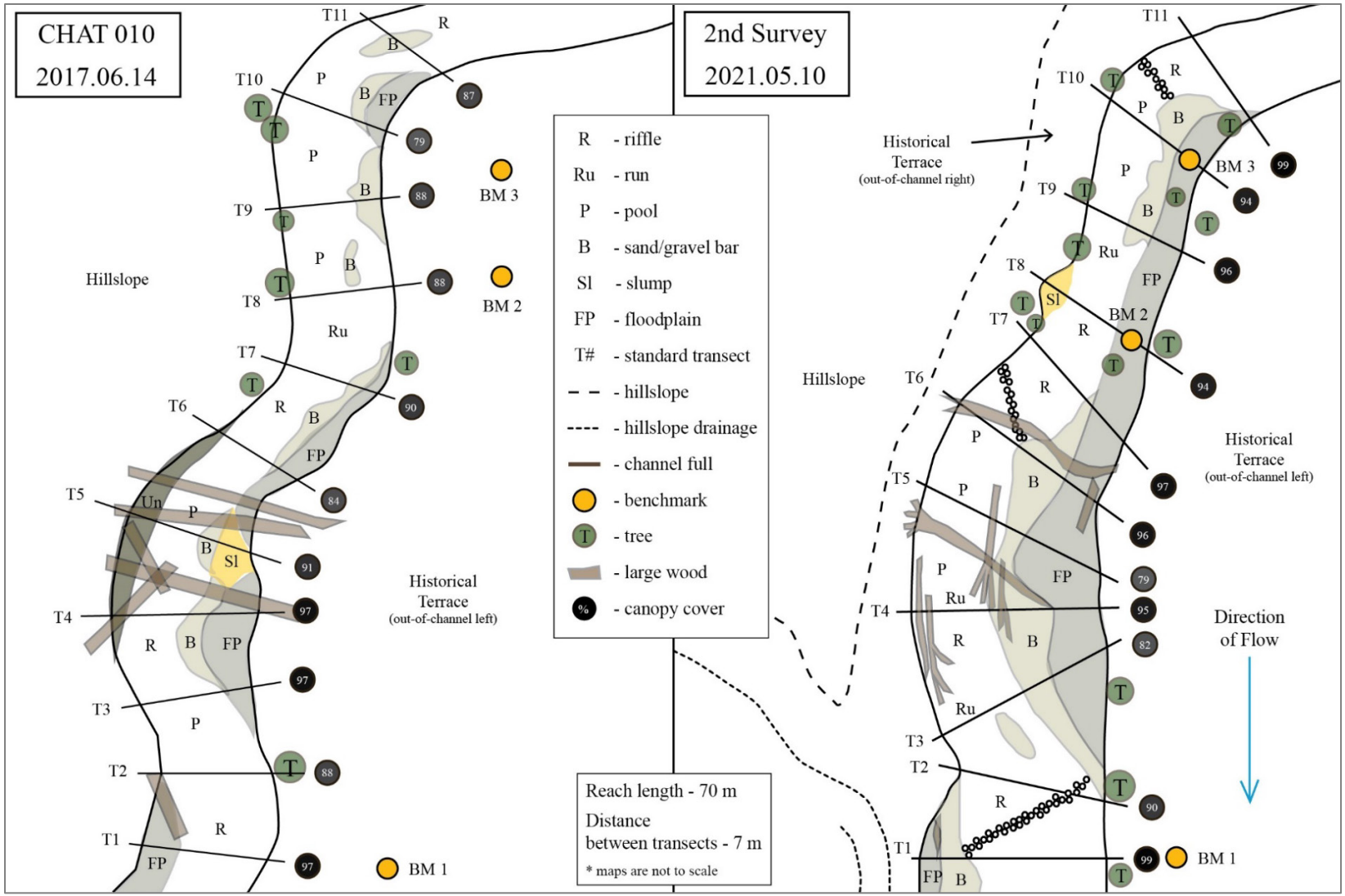


Figure 46. Reach-scale map of CHAT010. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

NPS

Habitat Characteristics

The geomorphic channel unit (GCU) types and distributions at CHAT010 changed substantially during the time between the 2017 and 2021 surveys (Table 46). Riffles, runs, and pools were present within the surveyed reach during both survey years and glides were observed during the 2021 survey. One more instance of riffle was observed during the 2021 survey (from n = 5 to n = 6) and the mean percentage of riffle increased slightly (+2%). The number of observed runs doubled from n = 4 to n = 8 and the mean percentage of run increased (+13%). The frequency of pools slightly decreased from n = 7 to n = 5 and the mean percentage of pool was greatly reduced (−31%; Table 46). No glides were observed within the reach in 2017, while two were observed in 2021. The mean percentage of glide was 17%. No steps were observed within the reach during either survey.

The pebble count data for CHAT010 showed a statistically significant coarsening of the bed sediment ($p < 0.001$; Table 67). The mean diameter of the pebbles measured at CHAT010 increased by 57% (Table 47). Every particle size percentile measure was larger in 2021, excluding the minimum observed particle size which decreased from 2 millimeters to < 0.062 millimeters (Table 47). There was an order of magnitude increase in the size of the D_5 particle (20.00 mm in 2021 and 2.00 mm in 2017).

Table 67. Difference in means t-test results comparing CHAT010 during 2017 and 2021. The significance of the difference is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [m—meters; mm—millimeters].

Measurement	n [A]	CHAT010 in 2017	CHAT010 in 2021	P-value	Significance
Pebble Count (mm)	100	41.82	65.75	< 0.001	***
Thalweg Depth (m)	11	0.28	0.30	0.819	–
Thalweg Position (%)	11	67.27	65.00	0.815	–
Wetted Width (m)	11	3.30	4.12	0.101	–
Active Channel Width (m)	11	4.13	5.50	0.007	**
Channel full Width (m) [B]	11	8.77	15.69	< 0.001	***
Minimum Bank Height (m)	22	1.33	1.40	0.548	–
Channel full Height (m) [B]	22	1.45	1.58	0.111	–
Bank Angle (°)	22	49.92	46.53	0.714	–
Vegetative Cover (%)	22	29.55	31.82	0.682	–

[A] Number of measurements taken during each survey year.

[B] Changes due to interpretive differences between survey years.

The number of pieces of large woody debris (LWD) observed at CHAT010 increased from n = 12 in 2017 to n = 16 in 2021 (Table 49). Eleven of the 16 observed pieces of LWD were contained within log jams between T3 and T5 (Figure 46). The mean length of LWD increased by 53% and the mean diameter stayed pretty much the same (Table 49). The volume of LWD per channel area at CHAT010 increased by 13%. Canopy cover did not change substantially and was dense (92%) and had very little variability (CV = 0.07; Table 50).

Mean thalweg position (relative to the left bank) was also similar between surveys, decreasing from 67% in 2017 to 65% in 2021 (Table 51). Variability in thalweg position increased between the two survey years (CV = 0.25 in 2017 to CV = 0.41 in 2021). Mean thalweg depth was slightly deeper (+7%; Table 51), but this difference was not statistically significant (p =.819; Table 67).

Channel Morphology

Mean wetted width at CHAT010 was 25% wider during the 2021 survey (Table 52), but this change was not statistically significant (p = 0.101; Table 67). Variability of wetted width measurements was similar between survey years (Table 52). Mean active channel width was 33% wider in 2021 (Table 52), and this change was statistically significant (p = 0.007; Table 67). Variability of active channel width was similar between the two surveys (Table 52).

The interpretive change in bankfull and channel full led to the number of measured bankfull widths increasing from n = 5 to n = 11 (one being measured on every transect) during the 2021 survey. On river left, all bankfull surfaces were related the developing floodplain (large longitudinal slump?) between T2 and T11. The one on river right (measure on T1) is related to an intermittent hillslope drainage running roughly parallel to the stream (Figure 46). Mean bankfull width increased by 62% and variability in bankfull width decreased by 42% (Table 52). The change in how surfaces were interpreted also caused a statistically significant increase (+79%; Table 45) in mean channel full width (p <0.001; Table 67). Variability in channel full width continued to be low and decreased by 20% (Table 52).

Mean minimum bank height at CHAT010 (lowest bank height on a transect) was similar between the survey years (Table 53). In addition to the modified interpretations increasing bankfull width, mean bankfull height increased by 72%. There was also a slight increase in mean channel full height (+9%; Table 53), but this change was not statistically significant (p = 0.111; Table 67). Variability in channel full height continued to be relatively low (Table 53).

The number of undercut banks decreased from n = 7 to n = 4 and the mean depth of the bank undercuts stayed relatively stable (Table 54). Bank angles were on average slightly less steep (−3°; Table 54). This small change in bank angle was not statistically significant (p = 0.714; Table 67). There was a slight (+3%) increase in bank vegetation cover (Table 54), but this change was not statistically significant (p = 0.682; Table 67). Bank stability scores were higher (less stable) in 2021 compared to 2017, though the classification “unstable” did not change (Table 54).

Detailed Transects

The detailed transects at CHAT10 were surveyed on T1 (BM1; Figure 47), T8 (BM2; Figure 48), and T10 (BM3; Figure 49). On the detailed transects, bankfull cross-sectional area was on average 151% larger (Table 55). The change in mean channel full area was not as large though it was still substantial (+41%; Table 55). These changes are again related to the modified interpretation of bankfull and channel full.

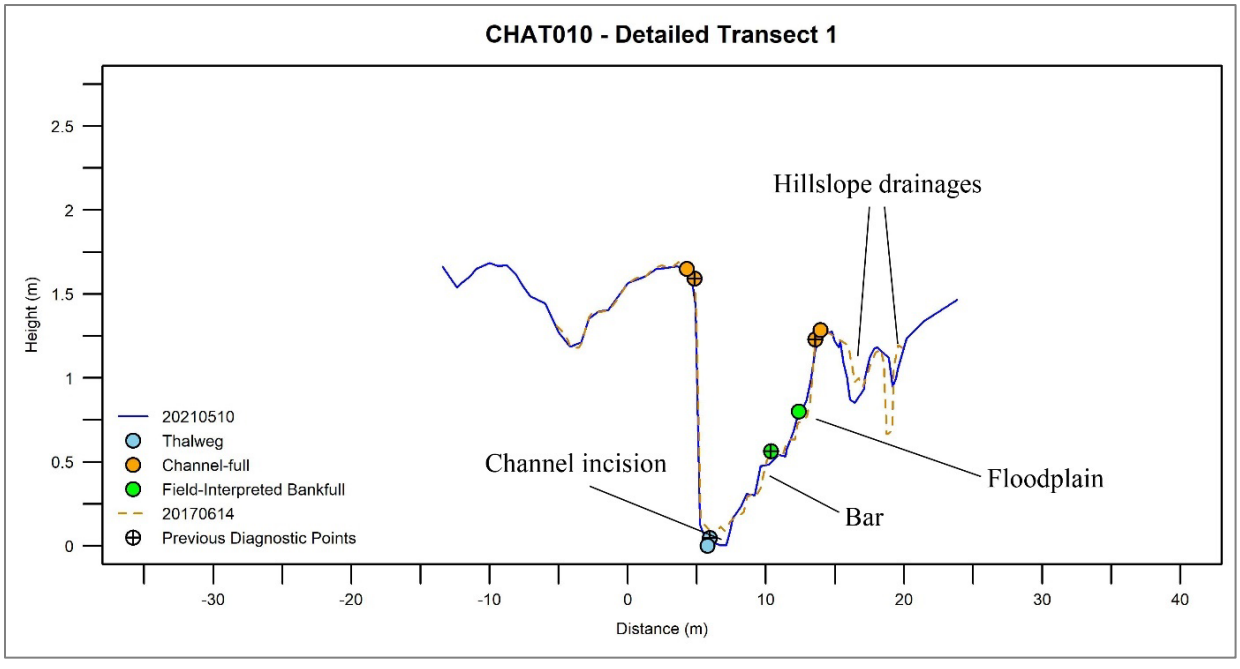


Figure 47. Differences between the 2017 and 2021 surveys of detailed transect 1 at CHAT010. View is in the downstream direction.

NPS

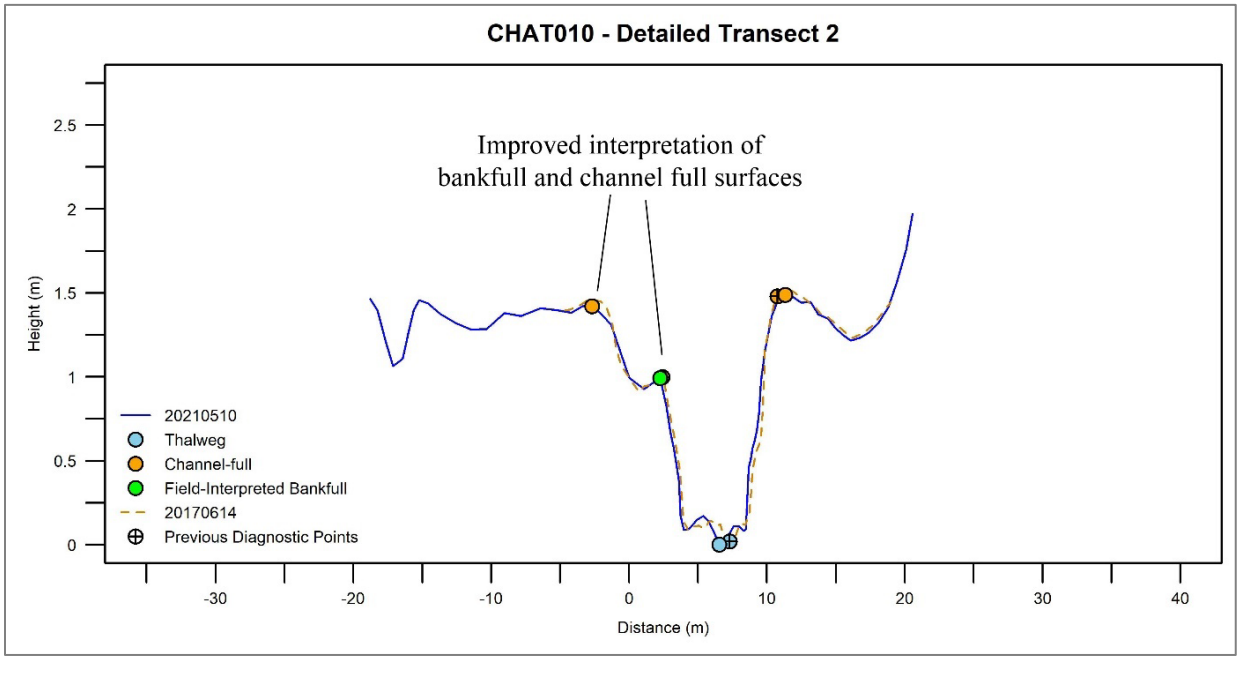


Figure 48. Differences between the 2017 and 2021 surveys of detailed transect 2 at CHAT010. View is in the downstream direction.

NPS

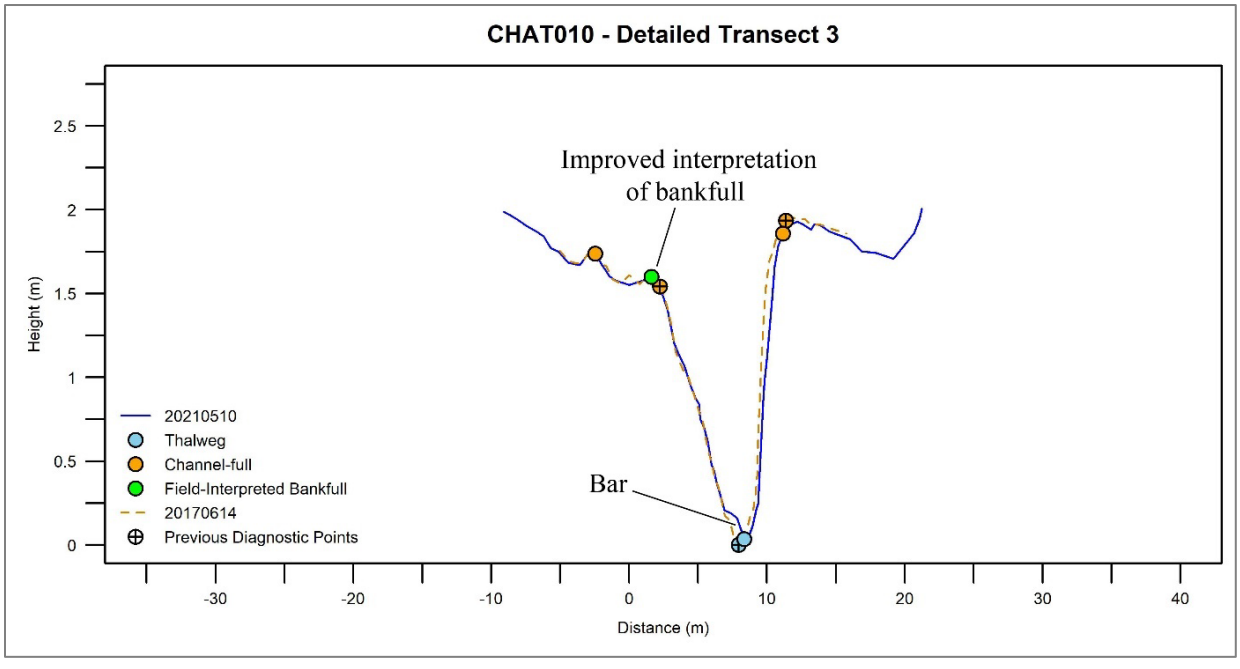


Figure 49. Differences between the 2017 and 2021 surveys of detailed transect 3 at CHAT010. View is in the downstream direction.

NPS

Water surface slope (longitudinal profile) for this section of "Beaver Creek" was slightly steeper measuring 0.0123 m/m in 2021 compared to 0.0106 m/m in 2017 (Figure 50; Table 55). The longitudinal profile of the surveyed reach was similar in 2021 when compared to the 2017 profile, with the most substantial change being the apparent upstream migration of a riffle towards and into T2. Sinuosity was similar within the surveyed reach between surveys (Table 55).

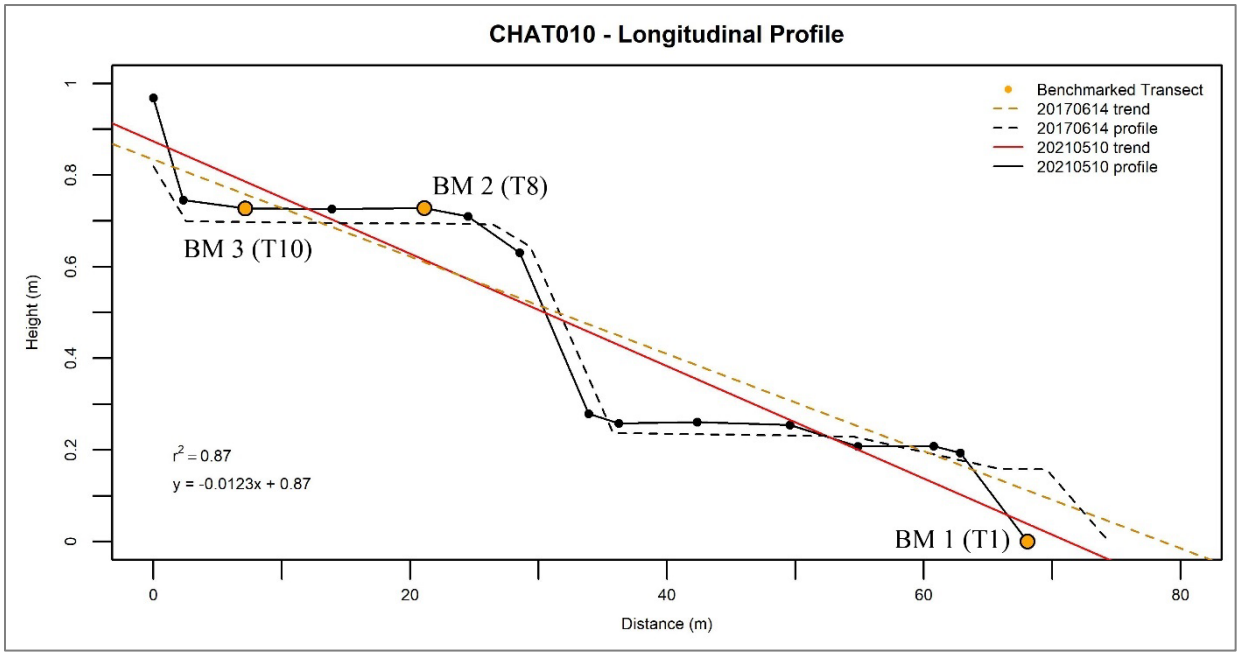


Figure 50. Longitudinal profile for CHAT010. The red line on the graph corresponds to the interpreted slope of the reach (0.0123 m/m). The r^2 value describes the strength of the 2021 trend line (interpreted slope). The "T#" in parentheses indicates the standard transect number on which the detailed transects were surveyed.
NPS

Comparison of the 2017 and 2021 cross-sections at detailed transect 1 (T1) show very little morphologic change in the channel or along the banks. The largest changes along the transect included some channel incision and some reworking of sediment in the out-of-channel area on river right (related to a hillslope drainage). The bankfull indicator was modified to be the top of a longitudinally continuous elevated entrenched surface on river right (previous interpretation had been the top of the bar surface). Bankfull cross-sectional area on detailed transect 1 (T1) increased by 123% due to the change in interpretation. There was a slight increase in channel full area (+8%) that was likely related to small differences in the line of survey (Table 68).

Table 68. Changes to cross-sectional characteristics on detailed transect 1 at CHAT010 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.60	4.98	0.48
	2021	3.55	7.32	0.80
	Change 2017–2021 [A]	1.95	2.34	0.32
Channel full	2017	7.03	8.57	1.18
	2021	7.60	9.01	1.28
	Change 2017–2021	0.57	0.44	0.10

[A] Changes due to interpretive differences between survey years.

The only geomorphic change observed at detailed transect 2 (T8) was a small amount of incision and some development of the mid-channel bar near river left (Figure 48). The modified interpretation of bankfull moved channel full up onto the valley flat and bankfull to the elevated entrenched surface on river left (which had been interpreted as channel full in 2017; Figure 48). These modified interpretations led to bankfull cross-sectional area increasing by 58% and channel full area increasing by 88% (Table 69).

Table 69. Changes to cross-sectional characteristics on detailed transect 2 at CHAT010 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	2.97	6.34	0.64
	2021	4.70	7.11	0.93
	Change 2017–2021 [A]	1.73	0.77	0.29
Channel full	2017	5.29	7.38	0.98
	2021	9.94	13.31	1.42
	Change 2017–2021 [A]	4.65	5.92	0.44

[A] Changes due to interpretive differences between survey years.

Like detailed transect 2, there was little geomorphic change observed on detailed transect 3 but the modified interpretation of diagnostic surfaces makes it look like substantial change occurred (T10; Figure 49). The elevated entrenched surface on river left was reinterpreted as bankfull because it was longitudinally connected to the bankfull surface on detailed transect 2 and the "floodplain" surface that runs along river right down toward T2. The geomorphic change observed was related to a small amount of bed aggradation and formation of an in-channel bar on river left. Bankfull cross-sectional area increased by 360% while channel full area increased by 40% (Table 70).

Table 70. Changes to cross-sectional characteristics on detailed transect 3 at CHAT002 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.55	3.83	0.64
	2021	7.13	8.38	1.51
	Change 2017–2021 [A]	5.58	4.55	0.87
Channel full	2017	6.72	7.70	1.54
	2021	9.39	13.18	1.70
	Change 2017–2021 [A]	2.67	5.48	0.16

[A] Changes due to interpretive differences between survey years.

CHAT011—Gunby Creek

Reach Description

On May 10, 2021, stream survey data were collected at CHAT011. CHAT011 is on Gunby Creek (a second-order stream along a sewage right-of-way in the Cochran Shoals unit). Gunby Creek is accessed by crossing the bridge over Terrell Mill Creek, following the road to the wetland, and then taking the trail that runs alongside the wetland to the site. CHAT011 is approximately 350 meters (1,148 ft) upstream of a wetland. The surveyed reach was 40 meters (131 ft) long with 4 meters (13.1 ft) between transects.

The monitored portion of Gunby Creek has elevated entrenched surfaces on river left and river right downstream of T8 (Figure 51). Upstream of T8, the reach, on river right, is influenced by bedrock and a steep hillslope. The river left bank is undercut in the downstream (T1–T4) and upstream (T9–T11) positions of the reach. During the 2021 survey, a LWD dam, which developed from a tree fall, was observed at T2. Riffle is the dominant habitat type within the surveyed reach and some pools converted to glide between the two survey years. Water surface slope (longitudinal profile) for this section of "Beaver Creek" was 0.0088 m/m (Table 20). The longitudinal profile appears to show bed aggradation between T2 and T7 (likely related to the tree fall at T2; Figure 51). The detailed transects were surveyed on T1 (BM1), T4 (BM2), and T6 (BM3). A detailed transect was not placed upstream of T6 because the encroaching hillslope on river right made that portion of the reach unsuitable for the total station surveys (too steep to safely navigate). Survey results for CHAT011 can be viewed in the corresponding file of supplemental materials for this site.

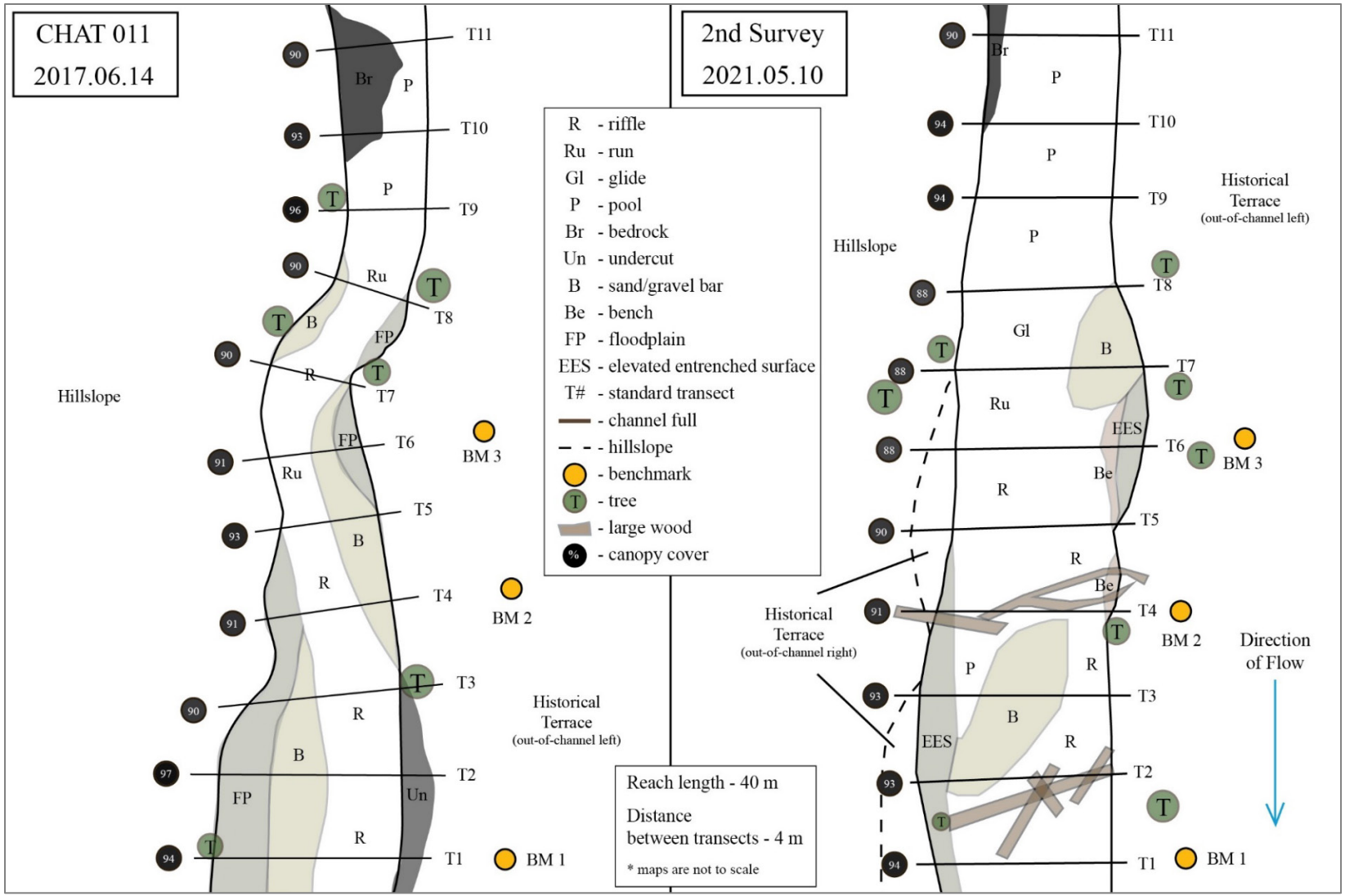


Figure 51. Reach-scale map of CHAT011. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

NPS

Habitat Characteristics

The geomorphic channel unit (GCU) types and distributions at CHAT011 changed from a mixture of riffles, runs, and pools to a reach dominated by riffles and glides with some runs and pools between (Table 46). Glides were the second most dominant habitat type during the 2021 survey and were not present in 2017. No steps were observed within the monitored reach during either survey period. The frequency of riffles increased from n = 5 to n = 6 and there was a slight increase in the mean percentage of riffle (+5%; Table 46). The mean percentage of run decreased 16% and while the frequency of pools doubled from n = 3 to n = 6, the mean percentage of pools decreased 17%. Four glides were observed, and the mean percentage of glide was 28%.

The pebble count data for CHAT011 shows a statistically significant coarsening of the mean size of the bed sediment ($p < 0.001$; Table 71). Mean sediment size increased by 66% (Table 47). While most of the particle size classes were coarser, both the minimum and D_5 size classes were finer in 2021.

Table 71. Difference in means t-test results comparing CHAT011 during 2017 and 2021. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [m—meters; mm—millimeters].

Measurement	n [A]	CHAT011 in 2017	CHAT011 in 2021	P-value	Significance
Pebble Count (mm)	100	34.23	56.99	< 0.001	***
Thalweg Depth (m)	11	0.16	0.30	0.093	–
Thalweg Position (%)	11	46.82	49.09	0.851	–
Wetted Width (m)	11	2.96	4.03	0.005	**
Active Channel Width (m)	11	4.04	4.56	0.029	*
Channel full Width (m)	11	7.30	7.94	0.233	–
Minimum Bank Height (m) [B]	22	2.77	1.20	0.060	–
Channel full Height (m)	22	3.13	3.02	0.921	–
Bank Angle (°)	22	58.95	45.62	0.117	–
Vegetative Cover (%)	22	41.36	48.18	0.298	–

[A] Number of measurements taken during each survey year.

[B] Changes due to interpretive differences between survey years.

During the first survey, no large woody debris was observed within the monitored reach while nine pieces of LWD were measured in 2021 (Table 49). Nearly all the LWD were contained within jams upstream of T1 and T4 (Figure 51). The volume of LWD per channel area within the monitored reach increased from having no LWD in 2017 to 0.0054 m^2/m^3 in 2021 (Table 49). Canopy cover at CHAT011 during the 2021 survey was like 2017 and continued to be dense (91%) and have very little variability (Table 50).

Mean thalweg position (relative to the left bank) was similar between the two surveys (Table 51). Variability in thalweg position was greater during the 2021 survey (CV = 0.66 in 2021 and CV = 0.48 in 2017). Mean thalweg depth increased by 87% (Table 51), but this change was not statistically significant ($p = 0.093$; Table 71).

Channel Morphology

There was a statistically significant increase (+36%) in mean wetted width ($p = 0.005$; Table 71). There was also a statistically significant increase (+13%) in mean active channel width ($p = 0.029$). Variability in both wetted and active channel width decreased during the 2021 survey (Table 52). Variability in wetted width decreased by 48% and variability in active channel width decreased by 75%. Like the other surveyed reaches, the bankfull interpretations were modified to incorporate the elevated entrenched surfaces contained within the reach. This change in interpretation led to the number of bankfull width measurements to increase from $n = 5$ to $n = 7$ and mean bankfull width to increase by 33% (Table 52). Mean channel full width increased by 9% (Table 52), but this change was not statistically significant ($p = 0.233$; Table 71). The inclusion of elevated entrenched surfaces did not change channel full width appreciably because it did not change the interpretation of channel full, it added extra bankfull surfaces inset within the channel full channel.

The inclusion of additional bankfull surfaces led to a reduction (−58%) in mean minimum bank height (lowest bank height on a transect) during the 2021 survey (Table 53), but this change was not statistically significant ($p = 0.060$; Table 71). Mean bankfull height increased by 90% (Table 53). Mean channel full height decreased by 56%. This large decrease in mean channel full height was caused by a change in the number of channel full height measurements taken during the two surveys. During the 2021 survey, 18 channel full heights were measured ($n = 22$ in 2017; Table 53). The reason for this discrepancy, is the hillslope on river right between T8 and T11 (which constrains channel full) was not measured in 2021 because it was high to measure channel full heights without special equipment (Figure 51). In 2017, these heights were estimated using a high-resolution TruPulse 200x laser range finder. For 2021, it was decided these estimated heights were not representative of the reach and measurements were not taken. Taking out the estimated heights reduced the variability in channel full heights by 85% (from CV = 1.15 to CV = 0.17; Table 52). For statistical analyses, the four unrecorded channel full heights at CHAT011 were set equal to the values observed at that location in 2017. With these substitution values included, the mean channel full height only decreased by 4% (Table 71), and that difference was not statistically significant ($p = 0.921$; Table 71).

Two additional undercuts were measured in 2021 and the mean depth of undercuts increased by 120% (Table 54). Bank angles were on average 13° less steep during 2021 (Table 54), but this change was not statistically significant ($p = 0.117$; Table 70). Bank vegetation cover increased slightly from 41% to 48% (Table 54), and this change was also not statistically significant ($p = 0.298$; Table 71). Mean bank stability score decreased (more stable) from 12.52 (unstable) to 11.05 (unstable; Table 54).

Detailed Transects

The detailed transects at CHAT011 were surveyed on T1 (BM1; Figure 52), T4 (BM2; Figure 53), and T6 (BM3; Figure 54). On the detailed transects, bankfull cross-sectional area increased by 200% and mean channel full area increased by 48% (Table 55). As mentioned previously, modifications to the interpretation of the bankfull and channel full diagnostic points are driving these “changes.” The geomorphic changes observed were related to bar formation and channel bed aggradation or incision not channel widening and or bank failures. There was a slight +0.0001 m/m difference in water surface slope (longitudinal profile) between the surveys (Figure 55; Table 55). This difference in

slope is negligible as it falls within the margin of error of the equipment used to conduct the survey. While channel slope did not change, the longitudinal profile shows a substantial amount of aggradation within the reach between T2 and T7. There was very little change in sinuosity between the surveys (Table 55).

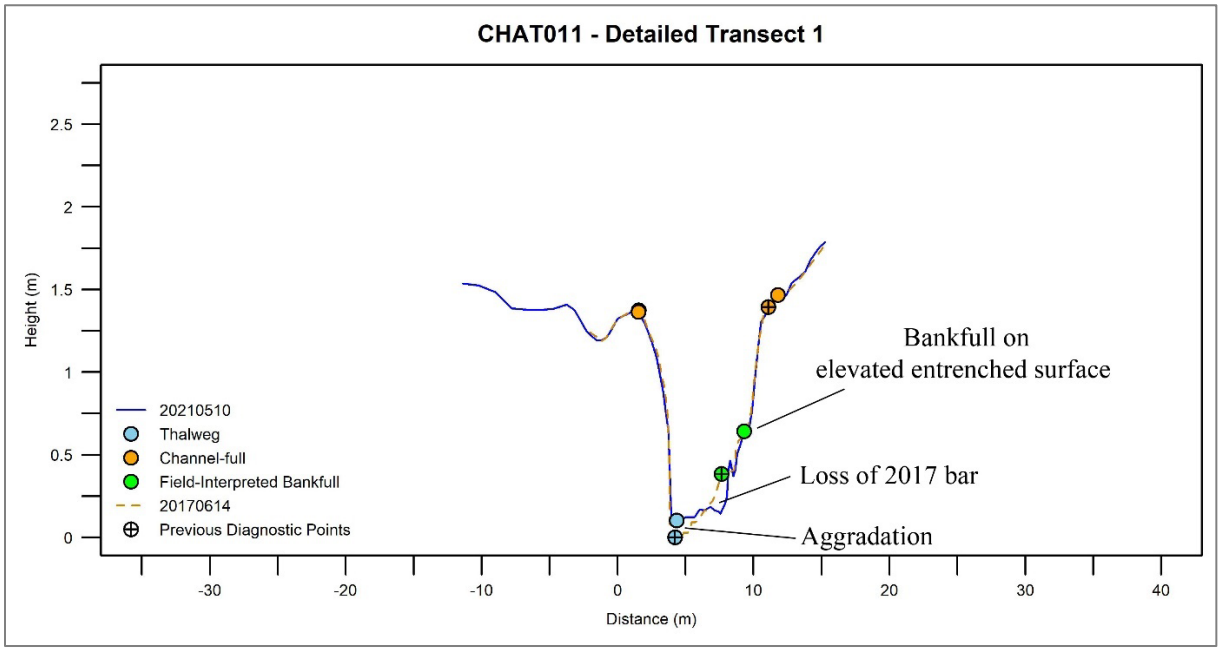


Figure 52. Differences between the 2017 and 2021 surveys of detailed transect 1 at CHAT011. View is in the downstream direction.

NPS

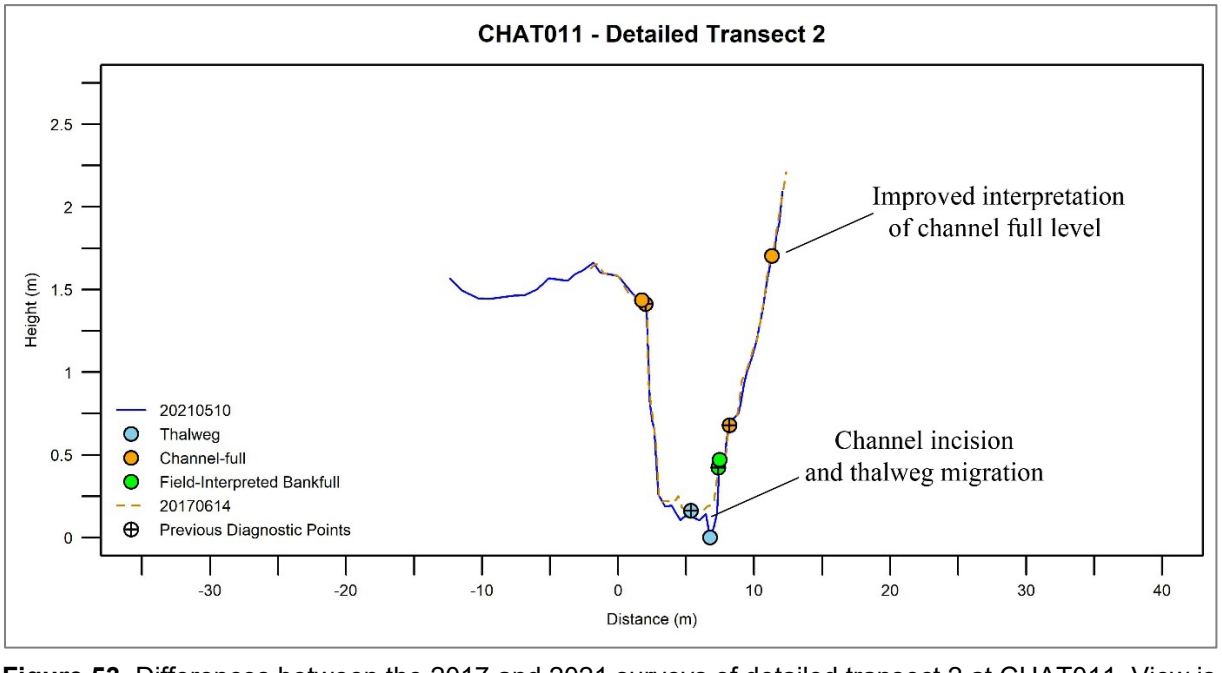


Figure 53. Differences between the 2017 and 2021 surveys of detailed transect 2 at CHAT011. View is in the downstream direction.

NPS

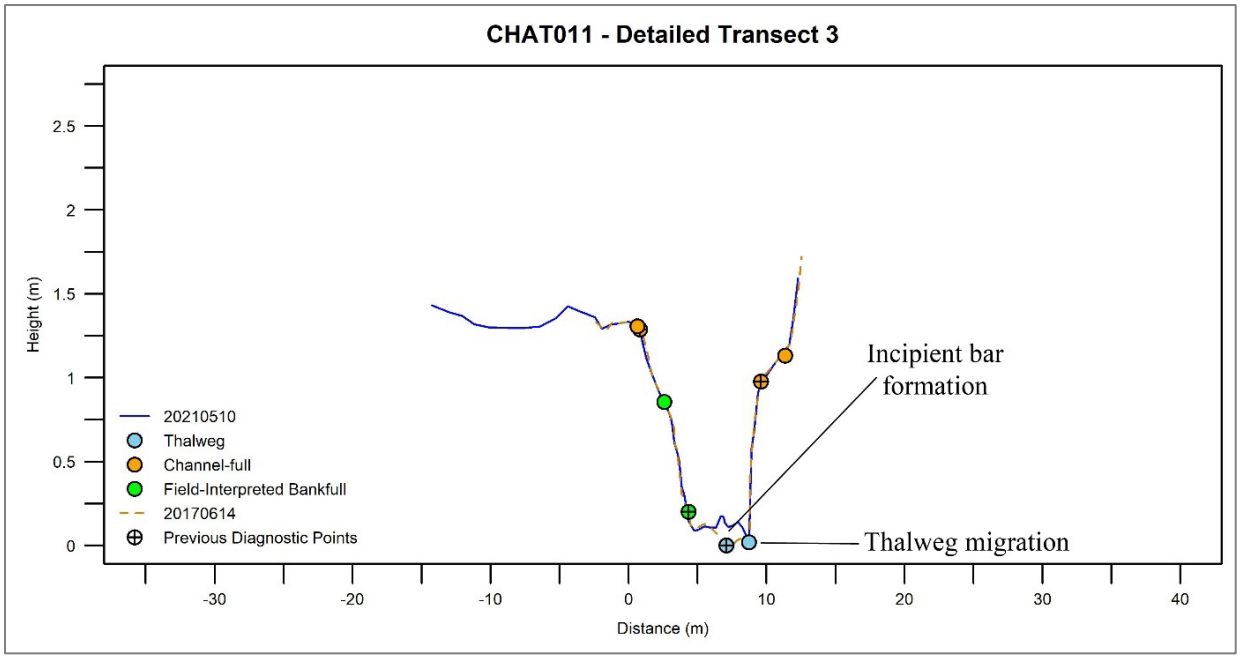


Figure 54. Differences between the 2017 and 2021 surveys of detailed transect 3 at CHAT011. View is in the downstream direction.

NPS

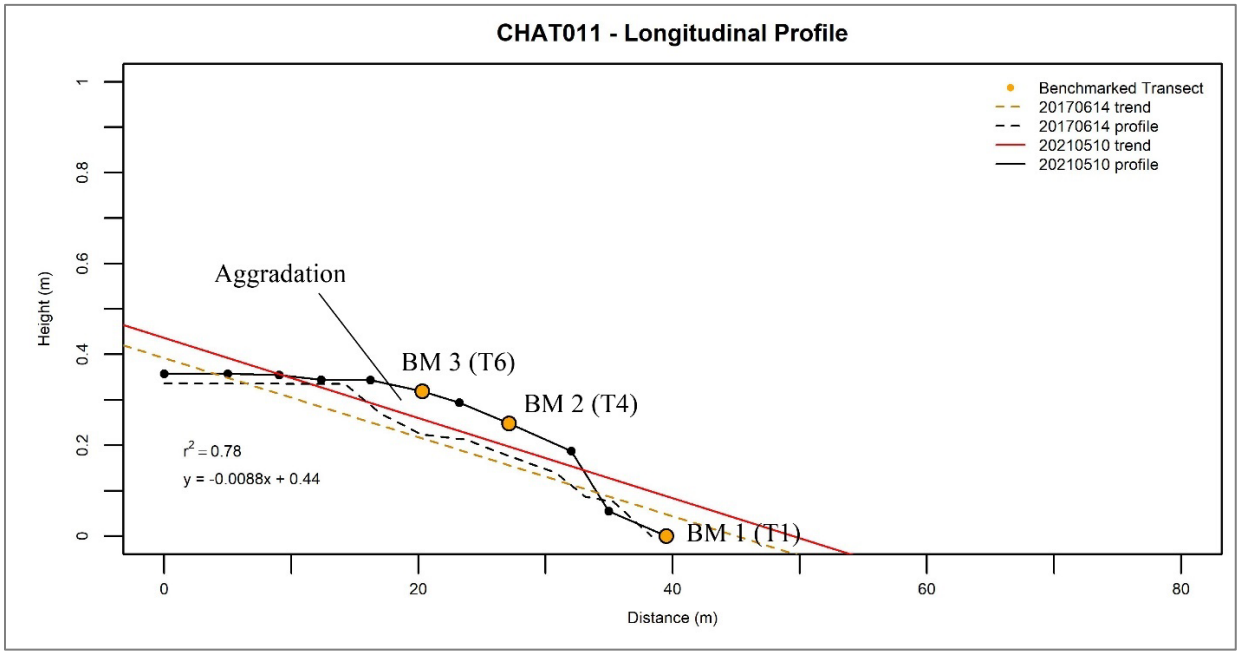


Figure 55. Longitudinal profile for CHAT011. The red line on the graph corresponds to the interpreted slope of the reach (0.0088 m/m). The r^2 value describes the strength of the 2021 trend line (interpreted slope). The "T#" in parentheses indicates the standard transect number on which the detailed transects were surveyed.

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The geomorphic changes observed on detailed transect 1 (T1) include bed aggradation on river left and erosion of an in-channel bar on river right (Figure 52). Loss of most of the bar and "floodplain"

surface on river left led to the movement of bankfull to the top of the elevated entrenched surface on river right. Moving the bankfull indicator up caused bankfull cross-sectional area to increase by 30% (Table 72). Channel full area was nearly identical between the two survey years suggesting the loss of the bar on river right was offset by the slight infilling of the channel (Table 72).

Table 72. Changes to cross-sectional characteristics on detailed transect 1 at CHAT011 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.02	3.82	0.38
	2021	2.26	5.56	0.53
	Change 2017–2021 [A]	1.25	1.74	0.15
Channel full	2017	7.55	9.38	1.37
	2021	7.53	9.44	1.26
	Change 2017–2021	−0.02	0.06	−0.11

[A] Changes due to interpretive differences and some geomorphic change between survey years.

On detailed transect 2 (T4), the thalweg migrated to river right and incised (Figure 53). Additionally, the interpretation of river right channel full was modified and moved from a high elevated entrenched surface upslope to a small flat surface on the hillslope to better match the river left channel full height. Incision of the channel led to an increase (+53%) in bankfull cross-sectional area (Table 73). The modified interpretation of channel full led to a substantial (+262%) increase in channel full area.

Table 73. Changes to cross-sectional characteristics on detailed transect 2 at CHAT011 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	0.95	4.46	0.26
	2021	1.45	4.65	0.46
	Change 2017–2021	0.51	0.19	0.20
Channel full	2017	2.27	5.57	0.52
	2021	8.24	9.00	1.44
	Change 2017–2021 [A]	5.97	3.43	0.92

[A] Changes due to interpretive differences between survey years.

The geomorphic changes observed on detailed transect 3 (T6) include thalweg migration to river right and mid-channel aggradation and incipient bar formation (Figure 54). Like the other detailed transects, bankfull was reinterpreted to include elevated entrenched surfaces and the diagnostic point on river left was moved from the top of the river left bar surface to the first flat surface on the elevated entrenched surface. Channel full on river right was also moved upslope to a flat surface more consistent with the channel full height on river left. Due mostly to these interpretive changes, bankfull cross-sectional area increased by 558% and channel full area increased 23% (Table 74). The

relatively small increase in channel full area compared to bankfull area indicates that the extra area added by the modified interpretation of channel full on river right was offset by bed aggradation and incipient bar formation.

Table 74. Changes to cross-sectional characteristics on detailed transect 3 at CHAT011 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	0.60	4.46	0.20
	2021	3.95	6.72	0.84
	Change 2017–2021 [A]	3.35	2.26	0.63
Channel full	2017	5.06	7.69	0.98
	2021	6.20	10.12	1.11
	Change 2017–2021 [A]	1.14	2.42	0.13

[A] Changes due to interpretive differences between survey years.

CHAT014—Whitewater Creek

Reach Description

On May 13, 2021, stream survey data were collected at CHAT014. CHAT014 is on Whitewater Creek (a second-order stream upstream of a utility right-of-way). Whitewater Creek is accessed by walking upstream from the Whitewater Creek parking area. The reach surveyed was 50 meters (164 ft) long with 5 meters (16.4 ft) between transects.

The monitored portion of CHAT014 is slightly entrenched in a relatively vast (compared to the other second-order streams) floodplain. Additionally, on river left, a flood chute is present on the floodplain which likely diverts flow from the main channel between T4 and T10 during overbank events. During the 2017 survey, the top of the banks at CHAT014 were identified as the channel full level, but in 2021 it was clear the stream floods onto the surrounding area and the top of the banks are the bankfull surface. Beyond the floodplain on river right, a steep hillslope is eroding and contributing sediment to the floodplain. A large point bar (persistent since the 2017 survey) is present on river left between T7 and T10 (Figure 56). Water surface slope (longitudinal profile) for this section of Whitewater Creek was 0.0025 m/m (Table 20). The longitudinal profile is relatively consistent, except for some incision upstream of T6. This portion of Whitewater Creek had lower slope than the other second-order streams in this report. The detailed transects were surveyed on T1 (BM1), T6 (BM2), and T10 (BM3). A floodplain surface was observed on each detailed transect. The river left flood chute between T4 and T10 is included on detailed transect 2 (T6). Detailed transect 2 (T6) also shows deposition (likely sediment contribution from hillslope erosion) on the river right floodplain. Survey results for CHAT014 can be viewed in the corresponding file of supplemental materials for this site.

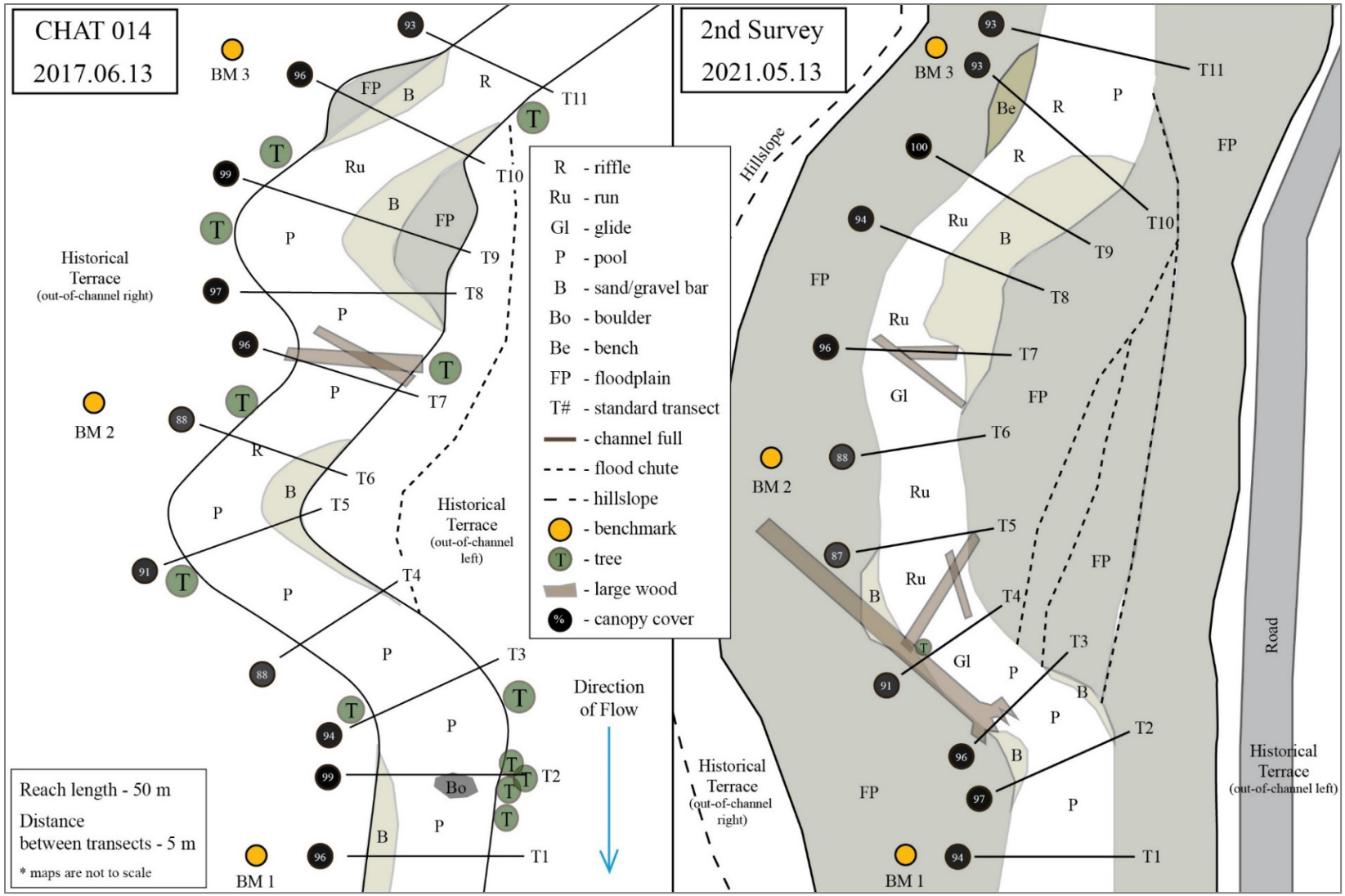


Figure 56. Reach-scale map of CHAT014. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

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Habitat Characteristics

The geomorphic channel unit (GCU) types and distributions changed substantially between the 2017 and 2021 surveys (Table 46). Riffles, runs, and pools were present within the surveyed reach during both survey years and four instances of glide were observed in 2021 (no glide was observed in 2017). The mean percentage of riffle increased 4% and the number of riffles increased by one (Table 46). The mean percentage of run increased 26% and the number of runs increased from n = 2 to n = 7. There was a large (−42%) reduction in pool habitat and the number of pools decreased from n = 8 to n = 7. No glide habitat was observed during the 2017 survey, while four were observed in 2021 and the mean percentage of glide was 12% (Table 46).

The pebble count data for CHAT014 shows a statistically significant coarsening of the bed sediment (p = 0.001; Table 75). The mean diameter of the pebbles increased by 41% (Table 47). While the mean diameter of pebbles increased, both the minimum and D_5 size classes decreased.

The number of pieces of large woody debris (LWD) increased sixfold from n = 2 to n = 12 (Table 49). While the LWD was distributed throughout the reach, half of the LWD was in a jam at T5 (Figure 56). Despite the increase in LWD, the volume of LWD per channel area decreased by 64% (Table 49). This reduction in volume of LWD is due to the change in bankfull and channel full interpretations coupled with a reduction in the mean diameter and length of LWD. Like the 2017 survey, canopy cover was very dense (93%) and had very little variability (Table 50).

Mean thalweg position (relative to the left bank) shifted toward river right increasing from 61% to 90% (Table 51). Variability in thalweg position increased between the two surveys (from CV = 0.39 to CV = 0.58). Both the minimum and maximum thalweg depths were higher in 2021 (+400% and +40%, respectively; Table 51). Mean thalweg depth was also deeper in 2021 (+32%) but this change was not statistically significant (p = 0.242; Table 75).

Table 75. Difference in means t-test results comparing CHAT014 during 2017 and 2021. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [m—meters; mm—millimeters].

Measurement	n [A]	CHAT014 in 2017	CHAT014 in 2021	P-value	Significance
Pebble Count (mm)	100	13.87	19.51	0.001	**
Thalweg Depth (m)	11	0.25	0.33	0.242	–
Thalweg Position (%)	11	61.36	60.45	0.944	–
Wetted Width (m)	11	2.66	3.17	0.275	–
Active Channel Width (m)	11	3.46	3.83	0.346	–
Channel full Width (m) [B]	11	6.37	41.36	< 0.001	***
Minimum Bank Height (m)	22	1.07	1.13	0.394	–
Channel full Height (m) [B]	22	1.13	1.45	< 0.001	***
Bank Angle (°)	22	59.19	43.84	0.059	–
Vegetative Cover (%)	22	29.32	25.00	0.466	–

[A] Number of measurements taken during each survey year.

[B] Changes due to interpretive differences between survey years.

Channel Morphology

Average wetted width was 19% wider and mean active channel width was 11% wider in 2021 (Table 52). These differences were not statistically significant ($p = 0.275$ and $p = 0.346$, respectively; Table 75). While wetted and active channel width increased, both were less variable (Table 52). Three bankfull widths were measured during the 2017 survey, while bankfull width was measured at each transect ($n = 11$) in 2021. This change was due to an improvement in the interpretation of bankfull and channel full. Mean bankfull width increased by 96% and variability in bankfull width increased from CV = 0.07 to CV = 0.23 (Table 52). Eleven channel full width measurements were taken in 2017, while only eight were able to be measured in 2021. Due to the reinterpretation of channel full, three widths were wider than the 50-meter [ft] measuring tape and could not be measured. Mean channel full width increased by 498% (Table 45). For statistical analysis, the three unrecorded channel full width measures for the 2021 survey were set equal to 50.10 meters (ft), to represent that the actual values were greater than 50 meters. With these values included the change in mean channel full width was statistically significant ($p < 0.001$; Table 75). Variability in channel full widths decreased slightly (Table 52).

Mean minimum bank height (lowest bank height on a transect) increased by 6% (Table 53). Mean bankfull height increased by 106%. Mean bankfull height in 2021 was equal to the mean channel full height from the 2017 survey as the interpretive change was essentially that the observed "channel full" level from 2017 is truly the stream's bankfull level and the out-of-channel areas on either side of the stream are floodplain. All 22 channel full height measurements were taken in 2017, while only 17 were measured in 2021 as five heights were too far from the channel to be observed by the survey team. Mean channel full height was 23% higher in 2021 (Table 53). For statistical analysis, the five unrecorded channel full heights were set equal to the channel full height value of the nearest downstream transect on the same side of the stream. With these values included, the observed changes to mean channel full height were statistically significant ($p < 0.001$; Table 75).

The number of undercut banks increased substantially from $n = 7$ to $n = 12$, while the mean depth of undercuts decreased by 24% (Table 54). Bank angles were on average statistically significantly less steep (−20%) in 2021 ($p = 0.059$; Table 75). Bank vegetation cover increased from 42% to 55% (Table 54), though this observed difference was not statistically significant (Table 75). Bank stability scores decreased (more stable) from a mean value of 13.05 in 2017 to 11.45 in 2021 (Table 54).

Detailed Transects

The detailed transects at CHAT014 were surveyed on T1 (BM1; Figure 57), T6 (BM2; Figure 58), and T10 (BM3; Figure 59). Modifications to the bankfull and channel full surfaces led to bankfull cross-sectional area being on average 109% larger in 2021 (Table 55). The mean bankfull cross-sectional area in 2021 was 18% lower than channel full cross-sectional area in 2017. Mean channel full area was also larger (+197%) in 2021 (Table 55). Water surface slope (longitudinal profile) for this section of Whitewater Creek was 0.0026 m/m in 2021 and 0.0025 m/m in 2017 (Figure 60; Table 55). This difference in slope is negligible as it falls within the margin of error of the equipment used to conduct the survey. The longitudinal profile shows evidence of channel incision downstream of T9. CHAT014 was the most sinuous of the second-order streams. Sinuosity was similar between surveys decreasing from 1.50 to 1.45 (Table 55).

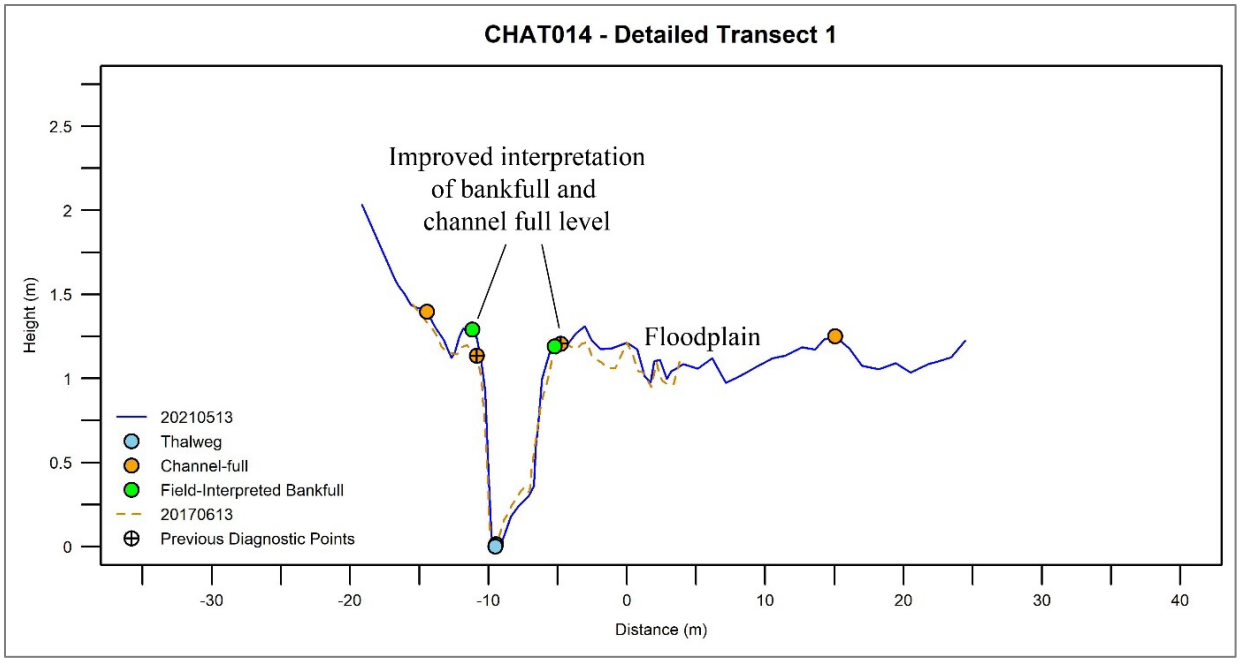


Figure 57. Differences between the 2017 and 2021 surveys of detailed transect 1 at CHAT014. View is in the downstream direction.

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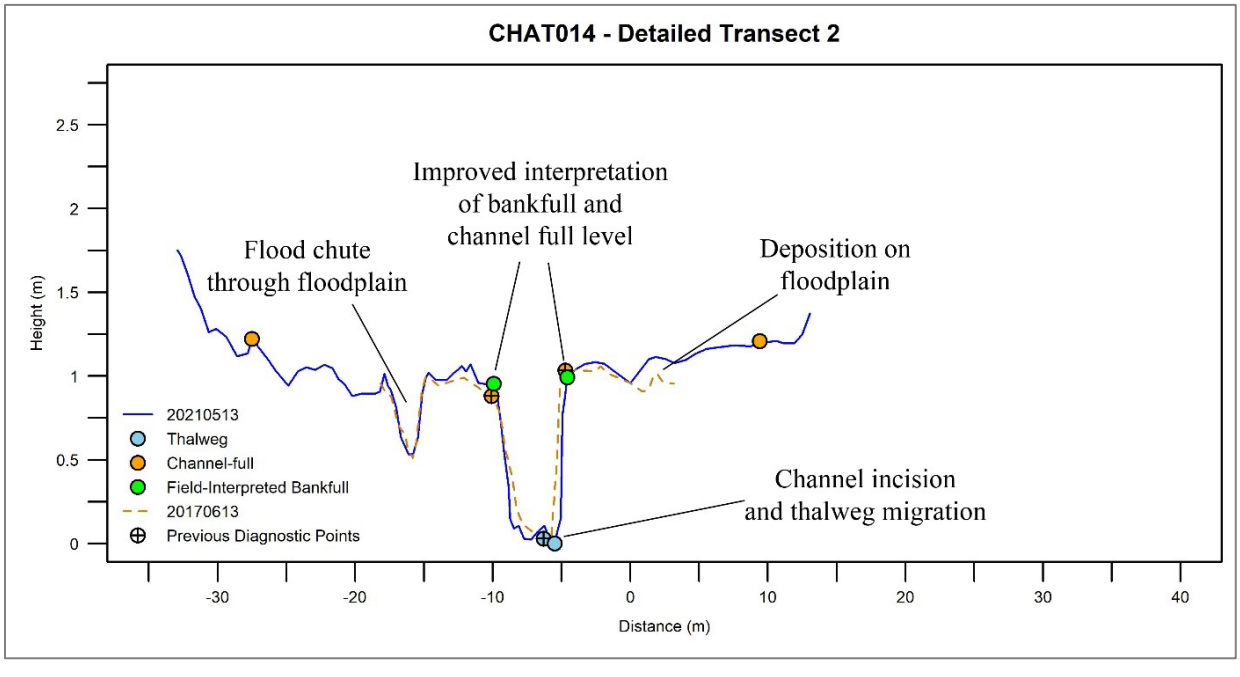


Figure 58. Differences between the 2017 and 2021 surveys of detailed transect 2 at CHAT014. View is in the downstream direction.

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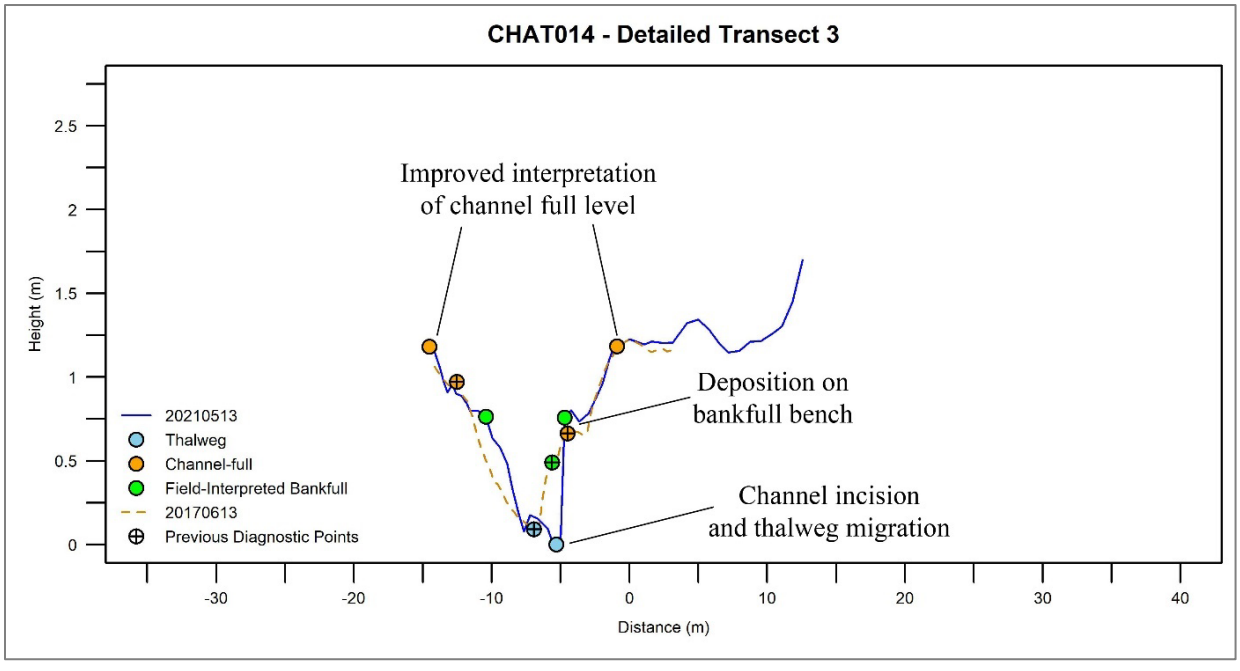


Figure 59. Differences between the 2017 and 2021 surveys of detailed transect 3 at CHAT014. View is in the downstream direction.

NPS

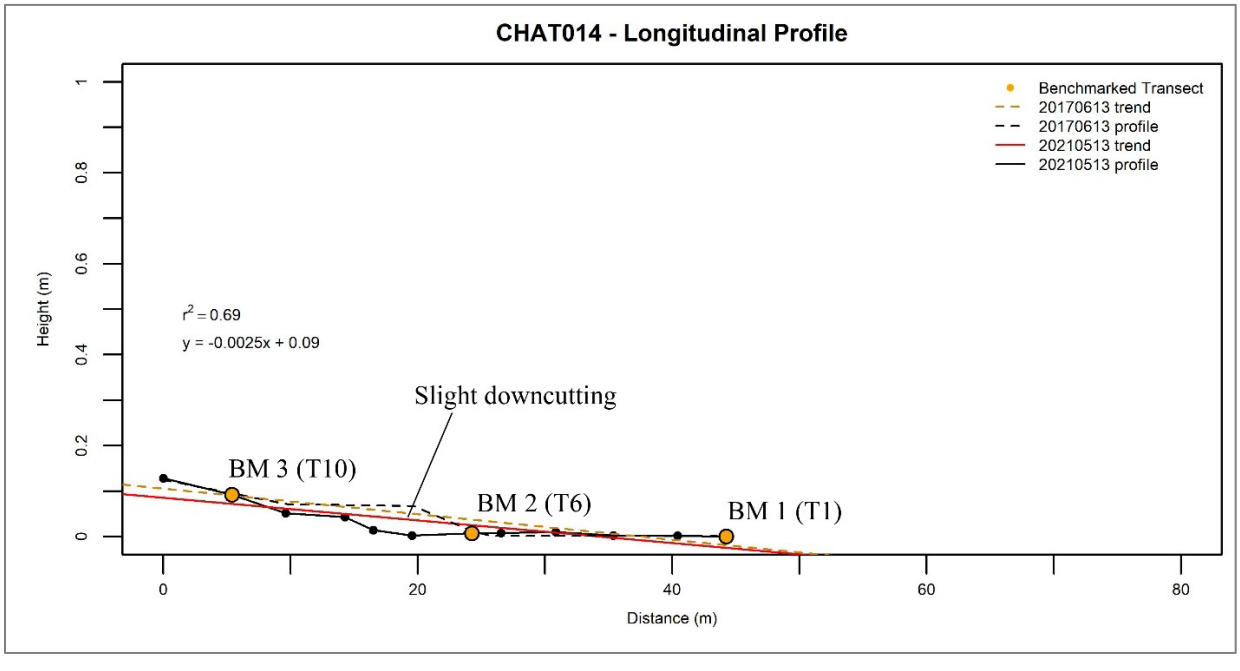


Figure 60. Longitudinal profile for CHAT014. The red line on the graph corresponds to the interpreted slope of the reach (0.0025 m/m). The r^2 value describes the strength of the 2021 trend line (interpreted slope). The "T#" in parentheses indicates the standard transect number on which the detailed transects were surveyed.

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The cross-sections at detailed transect 1 (T1) were relatively similar between the two survey years (Figure 57). While change to the channel was minimal, the bar surface on river right eroded slightly. The largest "changes" were the different interpretation of bankfull and channel full. Multiple back-channels are visible on the river right floodplain and potentially some aggradation can be seen on the river right bank top. Bankfull cross-sectional area increased by 167% and channel full area increased by 93% (Table 76). The large increase in channel full width combined with the slight increase in channel full height indicates how flat the surrounding floodplain is at CHAT014.

Table 76. Changes to cross-sectional characteristics on detailed transect 1 at CHAT014 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.07	3.39	0.53
	2021	2.86	4.16	0.97
	Change 2017–2021 [A]	1.79	0.77	0.44
Channel full	2017	3.60	5.63	1.12
	2021	6.93	28.46	1.25
	Change 2017–2021 [A]	3.33	22.82	0.13

[A] Changes due to interpretive differences between survey years.

Detailed transect 2 (T6) shows some erosion of the left and right banks, thalweg migration toward river right, and channel incision (Figure 58). A large amount of sediment was deposited on the floodplain surface on river right (BM2 was buried when the survey team arrived to survey the reach). It appeared this sediment was from a hillslope drainage that empties directly on the floodplain. Bankfull cross-sectional area on detailed transect 2 (T6) increased by 41% (Table 77). Channel full area changed substantially, increasing by 294% (Table 77). Like the changes on detailed transect 1 (T1), bankfull and channel full width increased due to the change in interpretation of bankfull and channel full levels. The large increase in channel full width combined with the slight increase in channel full height is indicative of the flat floodplain.

Table 77. Changes to cross-sectional characteristics on detailed transect 2 at CHAT014 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.28	3.60	0.48
	2021	1.80	4.17	0.53
	Change 2017–2021 [A]	0.52	0.58	0.05
Channel full	2017	2.81	4.94	0.85
	2021	11.06	36.79	1.21
	Change 2017–2021 [A]	8.25	31.85	0.36

[A] Changes due to interpretive differences between survey years.

Detailed transect 3 (T10) shows both thalweg migration (toward river right), channel incision, improved interpretation of the channel full level, and deposition on the in-channel bench at river right (Figure 59). Due to the modifications in the interpretations of the indicator surfaces, bankfull cross-sectional area increased by 131% and channel full area increased by 231% (Table 78).

Table 78. Changes to cross-sectional characteristics on detailed transect 3 at CHAT014 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	1.11	4.76	0.40
	2021	2.56	5.60	0.73
	Change 2017–2021 [A]	1.45	0.84	0.34
Channel full	2017	2.11	6.61	0.57
	2021	7.32	13.61	1.18
	Change 2017–2021 [A]	5.21	7.00	0.61

[A] Changes due to interpretive differences between survey years.

Between Site Comparisons of Second-Order Streams

The mean bed sediment at each of the second-order streams was coarser in 2021 than 2017 (Table 79). Like 2017, CHAT014's bed sediment was statistically significantly finer than all second-order streams in 2021. Mean bed sediment at CHAT004 was statistically significantly coarser than CHAT011 in 2017 but not in 2021. Mean bed sediment particle size at CHAT010 was the coarsest of all second-order streams and became statistically significantly coarser than CHAT005 in 2021.

Table 79. Significance of the differences in means in the pebble counts of the second-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Pebble Count 2017 (mm)	Pebble Count 2021 (mm)	P-value2 2017	P-value3 2021	Significance 2017	Significance 2021
CHAT005–CHAT004	100	−13	−13	0.127	0.151	–	–
CHAT008–CHAT004	100	−10	−5	0.402	0.933	–	–
CHAT010–CHAT004	100	−9	10	0.547	0.409	–	–
CHAT011–CHAT004	100	−17	1	0.016	> 0.999	*	–
CHAT014–CHAT004	100	−37	−36	< 0.001	< 0.001	***	***
CHAT008–CHAT005	100	3	8	0.997	0.684	–	–
CHAT010–CHAT005	100	4	23	0.985	< 0.001	–	***
CHAT011–CHAT005	100	−4	14	0.991	0.083	–	–
CHAT014–CHAT005	100	−24	−23	< 0.001	< 0.001	***	***
CHAT010–CHAT008	100	1	15	> 0.999	0.053	–	–
CHAT011–CHAT008	100	−6	6	0.851	0.836	–	–
CHAT014–CHAT008	100	−27	−31	< 0.001	< 0.001	***	***
CHAT011–CHAT010	100	−8	−9	0.733	0.572	–	–
CHAT014–CHAT010	100	−28	−46	< 0.001	< 0.001	***	***
CHAT014–CHAT011	100	−20	−37	0.001	< 0.001	**	***

[A] Number of pebbles.

[B] F (6, 100) = 19.33, p < 0.001.

[C] F (5, 100) = 18.22, p < 0.001.

Except for CHAT008, mean thalweg depth increased at all second-order streams (Table 80). While mean thalweg depth at CHAT010 was significantly deeper than CHAT005 during 2017, this wasn't true in 2021 (Table 36). No statistically significant differences were found between the mean thalweg depths of any second-order streams during 2021. Also, like 2017, there were no statistically significant changes to thalweg position during 2021 (Table 81).

Table 80. Significance of the differences in mean thalweg depths of the second-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Thalweg Depth 2017 (m)	Thalweg Depth 2021 (m)	P-value2 2017	P-value3 2021	Significance 2017	Significance 2021
CHAT005–CHAT004	11	−0.06	0.04	0.949	0.994	–	–
CHAT008–CHAT004	11	0.03	−0.01	0.998	> 0.999	–	–
CHAT010–CHAT004	11	0.12	0.11	0.369	0.534	–	–
CHAT011–CHAT004	11	0.00	0.10	> 0.999	0.607	–	–
CHAT014–CHAT004	11	0.09	0.14	0.766	0.288	–	–
CHAT008–CHAT005	11	0.09	−0.04	0.702	0.988	–	–
CHAT010–CHAT005	11	0.18	0.07	0.041	0.856	*	–
CHAT011–CHAT005	11	0.06	0.07	0.956	0.902	–	–
CHAT014–CHAT005	11	0.15	0.10	0.184	0.616	–	–
CHAT010–CHAT008	11	0.09	0.12	0.721	0.481	–	–
CHAT011–CHAT008	11	−0.03	0.11	0.997	0.553	–	–
CHAT014–CHAT008	11	0.05	0.14	0.970	0.248	–	–
CHAT011–CHAT010	11	−0.13	−0.01	0.351	> 0.999	–	–
CHAT014–CHAT010	11	−0.04	0.03	0.996	0.998	–	–
CHAT014–CHAT011	11	0.09	0.03	0.748	0.994	–	–

[A] Number of measurements for thalweg depth.

[B] F (6, 11) = 2.18, p = 0.055.

[C] F (5, 11) = 1.80, p = 0.127.

Table 81. Significance of the differences in mean thalweg positions of the second-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Thalweg Position 2017 (%)	Thalweg Position 2021 (%)	P-value2 2017	P-value3 2021	Significance 2017	Significance 2021
CHAT005–CHAT004	11	26	−5	0.124	0.998	–	–
CHAT008–CHAT004	11	11	−17	0.911	0.804	–	–
CHAT010–CHAT004	11	28	12	0.081	0.948	–	–
CHAT011–CHAT004	11	8	−4	0.986	> 0.999	–	–
CHAT014–CHAT004	11	22	7	0.285	0.994	–	–
CHAT008–CHAT005	11	−15	−11	0.736	0.956	–	–
CHAT010–CHAT005	11	2	17	> 0.999	0.786	–	–
CHAT011–CHAT005	11	−19	1	0.500	> 0.999	–	–
CHAT014–CHAT005	11	−4	13	> 0.999	0.930	–	–
CHAT010–CHAT008	11	17	29	0.621	0.277	–	–
CHAT011–CHAT008	11	−4	13	> 0.999	0.930	–	–
CHAT014–CHAT008	11	11	24	0.926	0.469	–	–
CHAT011–CHAT010	11	−20	−16	0.386	0.838	–	–
CHAT014–CHAT010	11	−6	−5	0.997	0.999	–	–
CHAT014–CHAT011	11	15	11	0.763	0.956	–	–

[A] Number of measurements for thalweg position.

[B] F (6, 11) = 2.18, p = 0.055.

[C] F (5, 11) = 1.16, p = 0.341.

Except for CHAT004, mean wetted width increased at second-order streams (Table 82). In 2017, CHAT004 was statistically significantly wider than CHAT005, but the difference between the two sites was not statistically significant in 2021 (Table 82). CHAT004 and CHAT005's wetted widths were statistically significantly narrower than CHAT010 and CHAT011 in 2021. CHAT005 was significantly narrower than CHAT010 during 2017 too.

Table 82. Significance of the differences in mean wetted widths of the second-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Wetted Width 2017 (m)	Wetted Width 2021 (m)	P-value2 2017	P-value3 2021	Significance 2017	Significance 2021
CHAT005–CHAT004	11	−1.22	−0.06	0.015	> 0.999	*	–
CHAT008–CHAT004	11	−0.59	0.51	0.633	0.751	–	–
CHAT010–CHAT004	11	0.14	1.34	> 0.999	0.008	–	**
CHAT011–CHAT004	11	−0.19	1.26	0.998	0.016	–	*
CHAT014–CHAT004	11	−0.50	0.39	0.789	0.897	–	–
CHAT008–CHAT005	11	0.63	0.57	0.553	0.645	–	–
CHAT010–CHAT005	11	1.36	1.41	0.004	0.005	**	**
CHAT011–CHAT005	11	1.02	1.32	0.067	0.009	–	**
CHAT014–CHAT005	11	0.72	0.46	0.390	0.822	–	–
CHAT010–CHAT008	11	0.73	0.84	0.375	0.231	–	–
CHAT011–CHAT008	11	0.39	0.75	0.919	0.345	–	–
CHAT014–CHAT008	11	0.09	−0.11	> 0.999	> 0.999	–	–
CHAT011–CHAT010	11	−0.34	−0.09	0.961	> 0.999	–	–
CHAT014–CHAT010	11	−0.64	−0.95	0.536	0.125	–	–
CHAT014–CHAT011	11	−0.30	−0.86	0.976	0.201	–	–

[A] Number of measurements for wetted width.

[B] $F(6, 11) = 5.69$, $p < 0.001$.

[C] $F(5, 11) = 5.29$, $p < 0.001$.

Mean active channel width increased at each monitored second-order stream between the two survey years (Table 83). CHAT004 and CHAT005's active channel width became more similar, no longer being statistically significant. CHAT005 continued to be statistically significantly narrower than CHAT008, CHAT010, and CHAT011. The mean active channel width at CHAT008 and CHAT010 was significantly wider than CHAT014 during 2021 but not in 2017.

Table 83. Significance of the differences in mean active channel widths of the second-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Active Channel Width 2017 (m)	Active Channel Width 2021 (m)	P-value2 2017	P-value3 2021	Significance 2017	Significance 2021
CHAT005–CHAT004	11	−1.20	−1.27	0.043	0.075	*	–
CHAT008–CHAT004	11	0.29	0.82	0.989	0.480	–	–
CHAT010–CHAT004	11	0.20	1.08	0.998	0.185	–	–
CHAT011–CHAT004	11	0.12	0.14	> 0.999	> 0.999	–	–
CHAT014–CHAT004	11	−0.47	−0.58	0.892	0.800	–	–
CHAT008–CHAT005	11	1.49	2.09	0.005	< 0.001	**	***
CHAT010–CHAT005	11	1.40	2.35	0.010	< 0.001	**	***
CHAT011–CHAT005	11	1.32	1.41	0.018	0.034	*	*
CHAT014–CHAT005	11	0.73	0.69	0.493	0.662	–	–
CHAT010–CHAT008	11	−0.09	0.26	> 0.999	0.992	–	–
CHAT011–CHAT008	11	−0.17	−0.67	0.999	0.682	–	–
CHAT014–CHAT008	11	−0.75	−1.40	0.461	0.037	–	*
CHAT011–CHAT010	11	−0.08	−0.94	> 0.999	0.327	–	–
CHAT014–CHAT010	11	−0.67	−1.66	0.606	0.007	–	**
CHAT014–CHAT011	11	−0.58	−0.73	0.744	0.610	–	–

[A] Number of measurements for active channel width.

[B] $F(6, 11) = 4.02$, $p = 0.002$.

[C] $F(5, 11) = 7.28$, $p < 0.001$.

The mean channel full width at CHAT014 increased substantially compared to other second-order streams, as the survey team better identified the CHAT014 channel full surface in 2021. Due to this reinterpretation of channel full, CHAT014 was statistically significantly wider than the second-order streams in 2021 (Table 84). CHAT010 was statistically significantly wider than CHAT004 and CHAT005 during both survey years and CHAT011 in 2021. CHAT008 was statistically significantly wider than CHAT005 during both survey years and statistically significantly wider than CHAT011 in 2021. The mean channel full height at CHAT011 was statistically significantly higher than the other second-order streams in 2017 and was statistically significantly higher than all but CHAT004 in 2021 (Table 85).

Table 84. Significance of the differences in mean channel full widths of the second-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Channel full Width 2017 (m)	Channel full Width 2021 (m)	P-value2 2017	P-value3 2021	Significance 2017	Significance 2021
CHAT005–CHAT004	11	−0.73	−3.62	0.918	0.217	–	–
CHAT008–CHAT004	11	1.61	2.97	0.176	0.431	–	–
CHAT010–CHAT004	11	2.42	5.56	0.006	0.011	**	*
CHAT011–CHAT004	11	0.95	−2.19	0.759	0.740	–	–
CHAT014–CHAT004	11	0.02	31.23	> 0.999	< 0.001	–	***
CHAT008–CHAT005	11	2.34	6.59	0.010	0.001	**	**
CHAT010–CHAT005	11	3.15	9.19	< 0.001	< 0.001	***	***
CHAT011–CHAT005	11	1.68	1.44	0.141	0.943	–	–
CHAT014–CHAT005	11	0.75	34.85	0.907	< 0.001	–	***
CHAT010–CHAT008	11	0.81	2.60	0.866	0.577	–	–
CHAT011–CHAT008	11	−0.66	−5.15	0.946	0.022	–	–
CHAT014–CHAT008	11	−1.59	28.26	0.187	< 0.001	–	***
CHAT011–CHAT010	11	−1.47	−7.75	0.265	< 0.001	–	***
CHAT014–CHAT010	11	−2.40	25.66	0.007	< 0.001	**	***
CHAT014–CHAT011	11	−0.93	33.41	0.777	< 0.001	–	***

[A] Number of measurements for channel full width.

[B] $F(6, 11) = 6.81$, $p < 0.001$.

[C] $F(5, 11) = 133.58$, $p < 0.001$.

Table 85. Significance of the differences in mean channel full heights of the second-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Channel full Height 2017 (m)	Channel full Height 2021 (m)	P-value2 2017	P-value3 2021	Significance 2017	Significance 2021
CHAT005–CHAT004	22	−0.38	−0.66	0.975	0.671	–	–
CHAT008–CHAT004	22	−0.30	−0.38	0.993	0.954	–	–
CHAT010–CHAT004	22	−0.22	−0.47	0.999	0.896	–	–
CHAT011–CHAT004	22	1.46	0.97	0.016	0.248	*	–
CHAT014–CHAT004	22	−0.53	−0.60	0.882	0.746	–	–
CHAT008–CHAT005	22	0.08	0.28	> 0.999	0.989	–	–
CHAT010–CHAT005	22	0.17	0.19	> 0.999	0.998	–	–
CHAT011–CHAT005	22	1.84	1.62	< 0.001	0.004	***	**
CHAT014–CHAT005	22	−0.15	0.05	> 0.999	> 0.999	–	–
CHAT010–CHAT008	22	0.08	−0.09	> 0.999	> 0.999	–	–
CHAT011–CHAT008	22	1.76	1.35	0.001	0.032	**	*
CHAT014–CHAT008	22	−0.23	−0.22	0.998	0.996	–	–
CHAT011–CHAT010	22	1.68	1.44	0.003	0.018	**	*
CHAT014–CHAT010	22	−0.31	−0.14	0.991	> 0.999	–	–
CHAT014–CHAT011	22	−1.99	−1.57	< 0.001	0.007	***	**

[A] Number of measurements for channel full height.

[B] $F(6, 22) = 4.81$, $p < 0.001$.

[C] $F(5, 22) = 3.87$, $p = 0.003$.

Mean bank angle decreased slightly at each of the second-order streams except CHAT005, which changed very little between the two survey years. There was no statistically significant difference in mean bank angle between second-order stream sites in either survey year (Table 86). In 2017, there were no statistically significant differences in bank vegetative cover between the study reaches (Table 87). In 2021, however, bank vegetative cover at CHAT014 was statistically significantly lower than CHAT004, CHAT005, and CHAT011.

Table 86. Significance of the differences in mean bank angles of the second-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Bank Angle 2017 (°)	Bank Angle 2021 (°)	P-value2 2017	P-value3 2021	Significance 2017	Significance 2021
CHAT005–CHAT004	22	−18.4	−8.3	0.235	0.871	–	–
CHAT008–CHAT004	22	−11.5	−8.6	0.768	0.855	–	–
CHAT010–CHAT004	22	−17.4	−12.0	0.302	0.586	–	–
CHAT011–CHAT004	22	−8.3	−12.9	0.940	0.505	–	–
CHAT014–CHAT004	22	−8.1	−14.7	0.947	0.356	–	–
CHAT008–CHAT005	22	6.9	−0.3	0.976	> 0.999	–	–
CHAT010–CHAT005	22	1.1	−3.7	> 0.999	0.996	–	–
CHAT011–CHAT005	22	10.1	−4.6	0.861	0.989	–	–
CHAT014–CHAT005	22	10.3	−6.4	0.847	0.955	–	–
CHAT010–CHAT008	22	−5.8	−3.4	0.990	0.997	–	–
CHAT011–CHAT008	22	3.2	−4.3	> 0.999	0.992	–	–
CHAT014–CHAT008	22	3.4	−6.1	0.999	0.962	–	–
CHAT011–CHAT010	22	9.0	−0.9	0.913	> 0.999	–	–
CHAT014–CHAT010	22	9.3	−2.7	0.903	0.999	–	–
CHAT014–CHAT011	22	0.2	−1.8	> 0.999	> 0.999	–	–

[A] Number of measurements for bank angle.

[B] F (6, 22) = 1.44, p = 0.205.

[C] F (5, 22) = 1.00, p = 0.419.

Table 87. Significance of the differences in mean bank vegetative cover percentages of the second-order streams in 2017 and 2021 based on a post-hoc Tukey analysis. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001. F-value and p-value of ANOVA results are reported as footnotes [m—meters; mm—millimeters].

Pairs	n [A]	Vegetative Cover 2017 (%)	Vegetative Cover 2021 (%)	P-value2 2017	P-value3 2021	Significance 2017	Significance 2021
CHAT005–CHAT004	22	−12	−5.000	0.539	0.931	–	–
CHAT008–CHAT004	22	−3	−7.273	> 0.999	0.733	–	–
CHAT010–CHAT004	22	−10	−14.091	0.736	0.084	–	–
CHAT011–CHAT004	22	2	2.273	> 0.999	0.998	–	–
CHAT014–CHAT004	22	−10	−20.909	0.715	0.001	–	**
CHAT008–CHAT005	22	10	−2.273	0.794	0.998	–	–
CHAT010–CHAT005	22	2	−9.091	> 0.999	0.510	–	–
CHAT011–CHAT005	22	14	7.273	0.386	0.733	–	–
CHAT014–CHAT005	22	2	−15.909	> 0.999	0.033	–	*
CHAT010–CHAT008	22	−7	−6.818	0.924	0.783	–	–
CHAT011–CHAT008	22	4	9.545	0.995	0.454	–	–
CHAT014–CHAT008	22	−8	−13.636	0.913	0.103	–	–
CHAT011–CHAT010	22	12	16.364	0.584	0.026	–	*
CHAT014–CHAT010	22	0	−6.818	> 0.999	0.783	–	–
CHAT014–CHAT011	22	−12	−23.182	0.561	< 0.001	–	***

[A] Number of measurements for vegetative cover.

[B] $F(6, 22) = 3.50$, $p = 0.003$.

[C] $F(5, 22) = 5.57$, $p < 0.001$.

Larger-Sized (Third-Order) Streams

Basin Characteristics

The third-order watersheds (CHAT001 and CHAT013) drain 8.78 square kilometers (3.39 sq mi) and 16.88 square kilometers (6.52 sq mi), respectively (Table 88). Chattahoochee River National Recreation Area manages 0.4% of CHAT001's watershed and 2% of CHAT013's watershed. The drainage density and bifurcation ratios of the two watersheds are approximately the same. While the segment gradients of the two streams are nearly the same, CHAT001's entire stream gradient (0.0146 m/m) is twice that of CHAT013's (0.0065 m/m; Table 88). CHAT013 has a slightly higher average watershed slope (8.71°) than CHAT001 (7.13°). The third-order watersheds are long and narrow (basin shape is approximately equal). CHAT001 has a slightly higher basin relief ratio than CHAT013. The land use land cover (LULC) of the two third-order watersheds is similar. The main difference in LULC is CHAT013 has slightly more commercial and/or industrial land cover (medium and high-intensity development, 17% compared to 10%; Table 89). A relatively small amount of medium to high-intensity development took place within the CHAT001 watershed between 2016 and 2019 (increase in medium to high development of 3%; Table 89).

Table 88. Watershed characteristics for the third-order streams at Chattahoochee River National Recreation Area calculated using the National Elevation Dataset (NED) 10-meter digital elevation model [km—kilometers; m—meters; SD—standard deviation; CV—coefficient of variation].

Basin Characteristic	CHAT001	CHAT013
Drainage Area (km^2)	8.78	16.88
NPS Managed Area (km^2)	0.03	0.30
NPS Managed Area (%)	0.4	2
Total Stream Length (km)	13.97	27.11
Drainage Density	1.59	1.61
Strahler Order	3	3
Bifurcation Ratio	1.57	2.01
Entire Stream Gradient	0.0146	0.0065
Segment Gradient	0.0070	0.0065
Slope - Average	7.13	8.71
Slope - Std. Dev.	5.07	5.84
Slope - CV	0.71	0.67
Basin Length (km)	7.74	10.66
Basin Shape	0.15	0.15
Basin Relief (m)	125	109
Basin Relief Ratio	0.016	0.010
Elevation - Std. Dev. (m)	21.1	22.9

Table 89. Changes in land use/land cover characteristics from 2016 to 2021 for the third-order streams at Chattahoochee River NRA. The data included in this table are from the National Land Cover Dataset (Dewitz 2023). Percent change from 2016 to 2021 is shown as "%Δ."

	CHAT001			CHAT013		
NLCD Classes	**2016**	**2021**	**% Δ**	**2016**	**2021**	**% Δ**
Developed Open & Low (%)	54	52	−2	48	47	−1
Developed Med. & High (%)	7	10	3	17	18	1
Forested (%)	35	35	0	34	34	−1
Grassland (%)	1	1	−1	1	1	0
Cultivated (%)	0	0	0	0	0	0

CHAT001—Haw Creek

Reach Description

On May 11, 2021, stream survey data were collected at Haw Creek (CHAT001). The reach at Haw Creek is along a third-order segment of its stream network. CHAT001 is approximately 250 meters (820 ft) upstream of a pedestrian bridge and 340 meters (1,115 ft) upstream of its confluence with the Chattahoochee River. This reach was chosen because it did not have any evidence of backwater effects from the Chattahoochee River. A social trail, along river right, runs approximately 10–15 meters (32.8–49.2 ft) from the stream. The reach surveyed was 150 meters (492 ft) long with 15 meters (49.2 ft) between transects.

CHAT001's channel is not entirely entrenched as large areas of floodplain are present throughout the reach (Figure 61). Where floodplains are not present, the banks are relatively high. A large cobble island, which was persistent since the 2017 survey, had further developed and riffle is dominant in both threads of the stream around the island. During the 2021 survey, there was evidence of overbank flooding (sedimentation) within the reach. Deposition on the river right floodplain buried the original tie point benchmark on that surface. The survey team was unable to locate the tie point, so a new tie point was installed on the river left historical terrace, where out-of-channel deposition is far less likely (Figure 61). The river left bank experienced significant slumping and erosion in the lower half of the reach, causing the stream channel to widen substantially since 2017. On T2 (detailed transect 1), the bank eroded so far back that the original benchmark 1 (BM1; Figure 61) was in danger of being lost. For this reason, the survey crew installed a new BM1 on T2, along the same transect line but 5.82 meters (19.09 feet) farther back from the channel margin. The detailed transects were surveyed on T2 (BM1; Figure 62), T6 (BM2; Figure 63), and T8 (BM3; Figure 64). Floodplains were observed on all three detailed transects (Figure 61). Though, the floodplain surface on detailed transect 2 was much higher (though connected to) the surface on detailed transect 1. Flood chutes were present on the floodplains of detailed transects 1 (T2) and 3 (T8). The 2017 gravel island/bar between T4 and T6 now extends upstream past detailed transect 2 (T6). Water surface slope (longitudinal profile) for this section of Haw Creek was 0.0074 m/m (Figure 65). The longitudinal profile shows the riffle, run, pool sequences that characterize the reach and the aggradation near the mid-channel island downstream of T6. Survey results for CHAT001 can be viewed in the corresponding file of supplemental materials for this site.

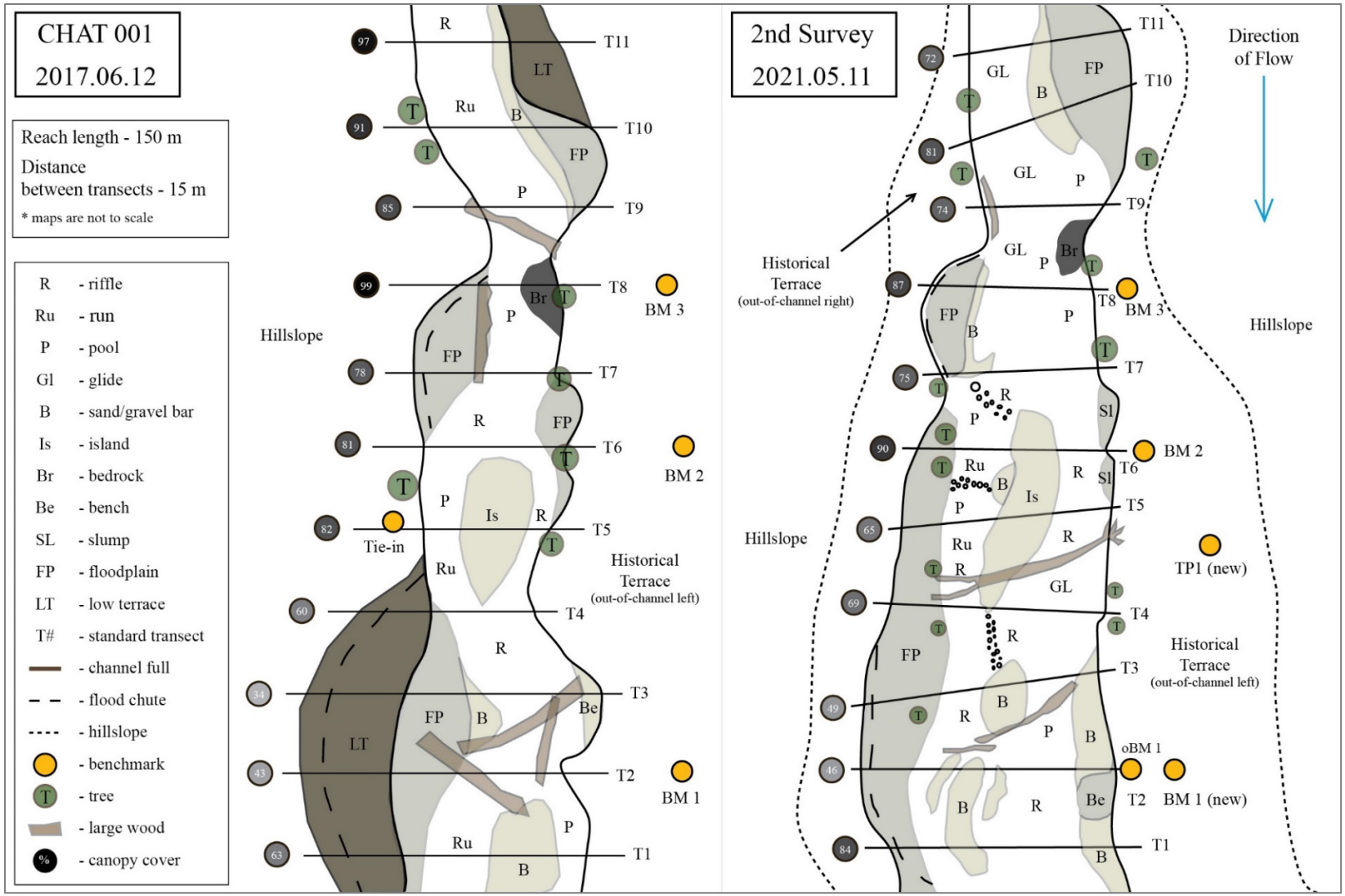


Figure 61. Reach-scale map of CHAT001. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

NPS

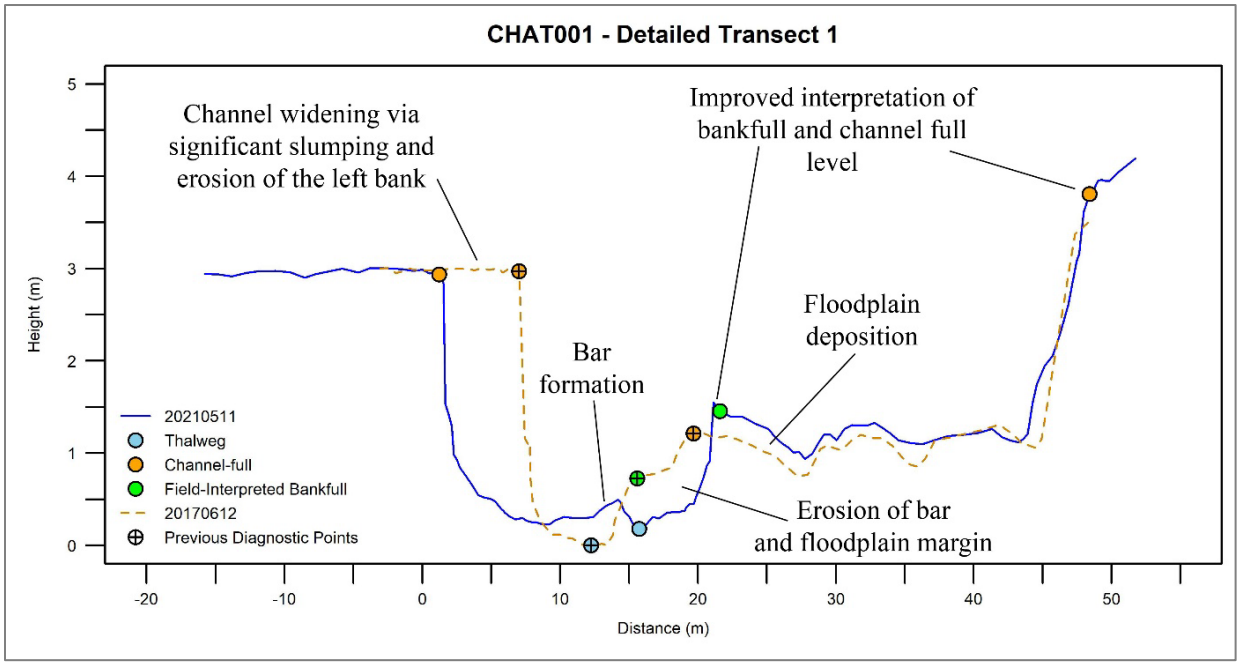


Figure 62. Differences between the 2017 and 2021 surveys of detailed transect 1 (T2) at CHAT001. View is in the downstream direction.

NPS

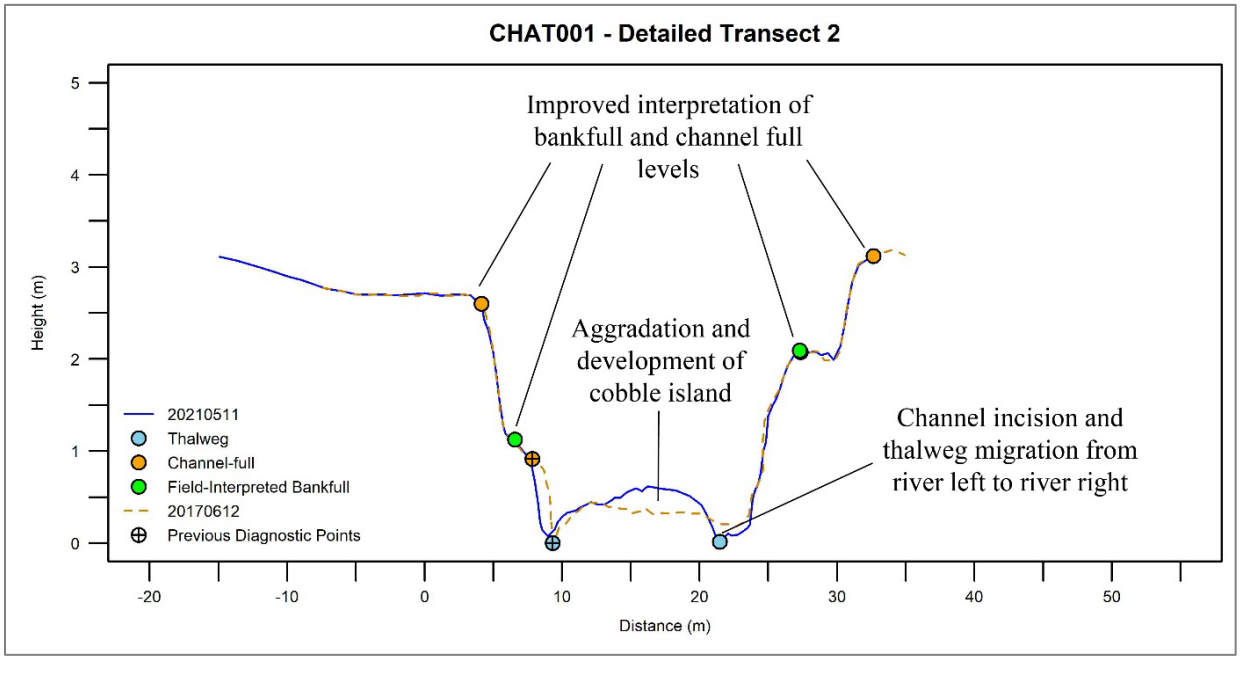


Figure 63. Differences between the 2017 and 2021 surveys of detailed transect 2 (T6) at CHAT001. View is in the downstream direction.

NPS

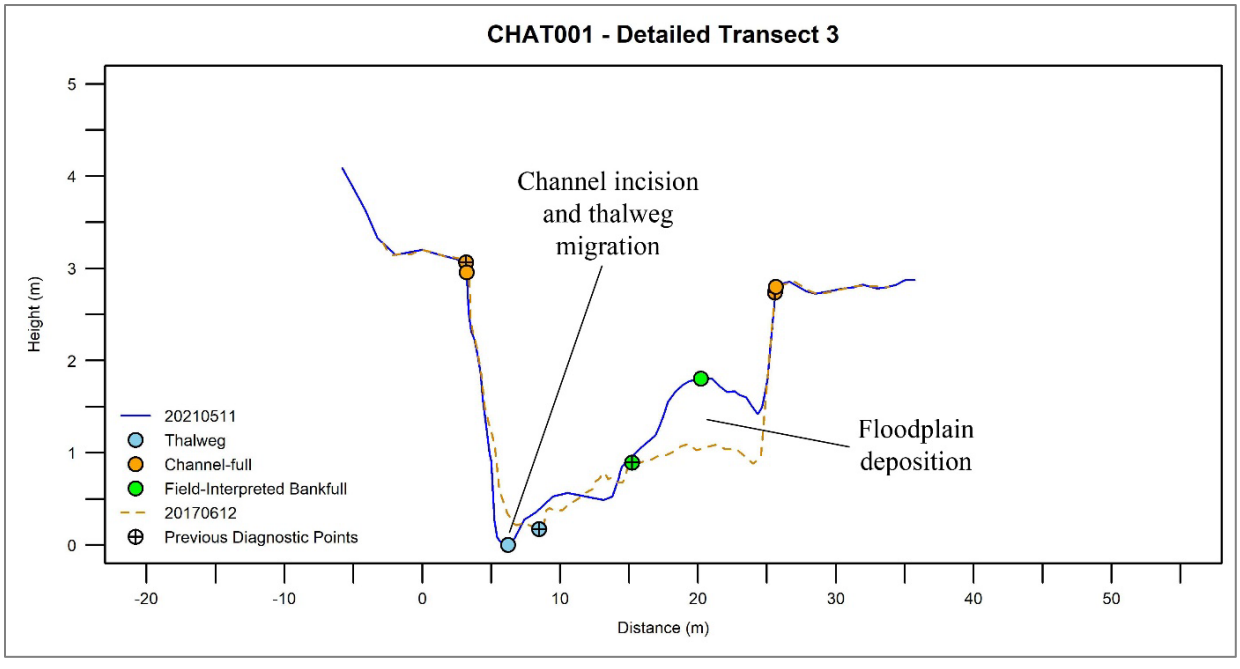


Figure 64. Differences between the 2017 and 2021 surveys of detailed transect 3 (T10) at CHAT001. View is in the downstream direction.

NPS

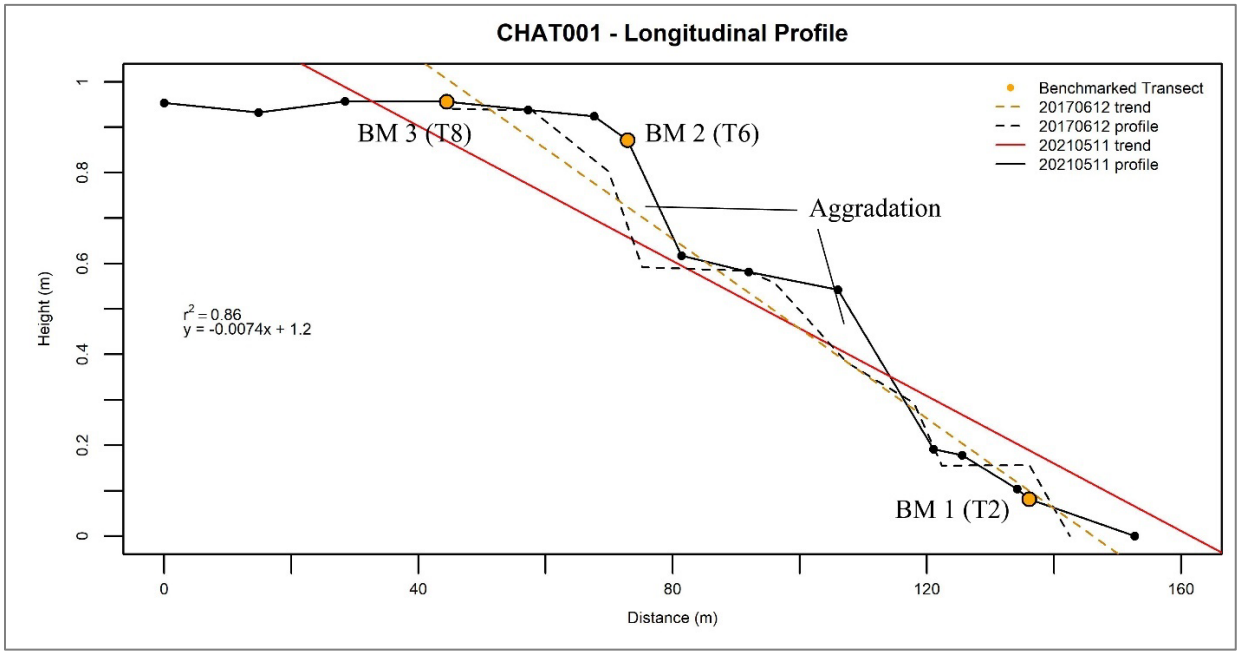


Figure 65. Longitudinal profile for CHAT001. The red line on the graph corresponds to the interpreted slope of the reach (0.0074 m/m). The r^2 value describes the strength of the 2021 trend line (interpreted slope). The "T#" in parentheses indicates the standard transect number on which the detailed transects were surveyed.

NPS

Habitat Characteristics

The geomorphic channel unit (GCU) types and distributions changed during the time between the 2017 and 2021 surveys (Table 90). Riffles, runs, glides, and pools were present during both survey years and again no steps were observed within the surveyed reach. The frequency of riffles increased from n = 6 to n = 7 and the mean percentage of riffle increased 9%. The mean percentage of run also increased (7%), while the mean percentage of pool greatly decreased (−31%). One instance of glide was observed within the reach in 2017, while six were observed in 2021. Mean percentage of glide increased 13%.

Table 90. Geomorphic channel units (GCUs) observed in the area between transects during the 2017 and 2021 surveys for the third-order streams at Chattahoochee River NRA.

GCU Type	Site	Year	n [A]	Max (%)	Mean (%)	SD (%)
Riffle	CHAT001	2017	6	100	24	32
	CHAT001	2021	7	80	33	31
	CHAT013	2017	10	85	46	24
	CHAT013	2021	6	80	23	27
Run	CHAT001	2017	5	70	17	23
	CHAT001	2021	8	60	24	19
	CHAT013	2017	3	15	4	6
	CHAT013	2021	10	100	48	37
Glide	CHAT001	2017	1	75	8	24
	CHAT001	2021	6	60	21	24
	CHAT013	2017	1	60	6	19
	CHAT013	2021	6	70	17	22
Pool	CHAT001	2017	8	100	53	39
	CHAT001	2021	7	80	22	27
	CHAT013	2017	10	95	39	27
	CHAT013	2021	4	60	12	20
Step	CHAT001	2017	0	0	0	0
	CHAT001	2021	0	0	0	0
	CHAT013	2017	1	60	6	19
	CHAT013	2021	0	0	0	0

[A] Number of transects on which the GCU type was observed.

The pebble count data shows a slight coarsening of the D_{16} and larger portions of bed sediment and a fining of the minimum and D_5 portions. The mean diameter of the pebbles increased by 11% (Table 91), but this increase was not statistically significant ($p = 0.298$; Table 92). The smallest size fractions (minimum and D_5) decreased in size down to the smallest size fraction (< 0.06 mm).

Table 91. Particle size distributions of bed sediment (in millimeters [mm]) from the pebble counts conducted in 2017 and in 2021 at the third-order stream sites. The subscripts indicate the percent of the sample that is smaller than the reported diameter [Min—Minimum; Max—Maximum; n—Number of measurements taken].

	CHAT001 (n = 100)		CHAT013 (n = 100)	
Statistic	**2017**	**2021**	**2017**	**2021**
Min	2.00	> 0.06	> 0.06	> 0.06
D_5	4.90	0.06	2.00	0.06
D_{16}	15.00	17.16	9.00	11.16
D_{50}	44.00	43.00	25.00	26.50
Mean	46.10	51.32	24.76	30.31
D_{84}	74.16	85.68	41.16	46.00
D_{95}	100.35	132.40	50.00	75.85
Max	187	197	65	155

Table 92. Difference in means t-test results comparing CHAT001 during 2017 and 2021. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [m—meters; mm—millimeters].

Measurement	**n [A]**	**CHAT001 in 2017**	**CHAT001 in 2021**	**P-value**	**Significance**
Pebble Count (mm)	100	46.10	51.32	0.298	–
Thalweg Depth (m)	11	0.40	0.42	0.825	–
Thalweg Position (%)	11	56.36	38.64	0.212	–
Wetted Width (m)	11	6.59	9.07	0.035	*
Active Channel Width (m)	11	8.01	12.63	< 0.001	***
Channel full Width (m)	11	14.14	29.87	< 0.001	***
Minimum Bank Height (m)	22	1.82	2.29	0.058	–
Channel full Height (m)	22	2.09	2.84	< 0.001	***
Bank Angle (°)	22	47.55	45.88	0.820	–
Vegetative Cover (%)	22	53.41	28.64	0.005	**

[A] Number of measurements taken.

The amount of large woody debris (LWD) was relatively similar between the two survey years (n = 16 to n = 17; Table 93) and was well distributed throughout the reach. Despite the increase in the number of pieces of LWD, the volume of LWD per channel area decreased substantially from 0.0015 m^3/m^2 to 0.0005 m^3/m^2 (Table 93). This decrease in volume was due to changes in the interpreted channel full diagnostic points which increased overall channel area between the two survey years. Canopy cover at CHAT001 during the 2021 survey was slightly less dense than 2017 (−2%; Table 94).

Table 93. Summary statistics for the large woody debris measured in 2017 and 2021 at the third-order monitoring sites at Chattahoochee River NRA (m—meters; SD—Standard deviation].

Statistic	Site	Year	n [A]	Length (m)	Diameter (m)	Volume (m3)
Min	CHAT001	2017	16	2.51	0.12	0.04
	CHAT001	2021	17	1.03	0.10	0.02
	CHAT013	2017	30	1.06	0.10	0.01
	CHAT013	2021	21	1.50	0.10	0.02
Mean	CHAT001	2017	16	6.60	0.18	0.20
	CHAT001	2021	17	4.05	0.36	0.34
	CHAT013	2017	30	2.94	0.21	0.15
	CHAT013	2021	21	4.42	0.22	0.23
Max	CHAT001	2017	16	13.17	0.43	0.74
	CHAT001	2021	17	7.86	1.42	1.63
	CHAT013	2017	30	7.17	0.46	0.82
	CHAT013	2021	21	12.15	0.53	1.40
SD	CHAT001	2017	16	3.20	0.08	0.20
	CHAT001	2021	17	2.62	0.52	0.64
	CHAT013	2017	30	1.54	0.10	0.19
	CHAT013	2021	21	3.04	0.10	0.33
Sum	CHAT001	2017	16	–	–	3.23
	CHAT001	2021	17	–	–	2.04
	CHAT013	2017	30	–	–	4.51
	CHAT013	2021	21	–	–	4.87
Per Channel Area (m^3/m^2)	CHAT001	2017	–	–	–	0.0015
	CHAT001	2021	–	–	–	0.0005
	CHAT013	2017	–	–	–	0.0019
	CHAT013	2021	–	–	–	0.0020

[A] Number of pieces of LWD.

Table 94. Comparison of the variability in canopy cover in 2017 and 2021 at the third-order stream sites at Chattahoochee River NRA [SD—Standard deviation; CV—Coefficient of variation].

Site	Year	n [A]	Min (%)	Mean (%)	Max (%)	SD (%)	CV
CHAT001	2017	11	34	74	99	21	0.29
	2021	11	46	72	90	14	0.20
CHAT013	2017	11	75	85	93	6	0.07
	2021	11	60	85	93	11	0.13

[A] Number of transects.

Mean thalweg position (relative to the left bank) shifted slightly toward river left, decreasing from 56% to 39% (Table 95). Variability in thalweg position increased from CV = 0.58 to CV = 0.82.

Mean thalweg depth was slightly deeper (+5%; Table 95), but this increase was not statistically significant (p = 0.825; Table 92).

Table 95. Comparison of reach-scale averaged thalweg conditions in 2017 and 2021 at the third-order stream sites at Chattahoochee River NRA. Water depth measurements are in meters and position is the percent distance from the left bank1 [SD—Standard deviation, CV—Coefficient of variation].

Thalweg	Site	Year	n2	Min	Mean	Max	SD	CV
Depth (m)	CHAT001	2017	11	0.13	0.40	0.71	0.22	0.56
	CHAT001	2021	11	0.17	0.42	0.79	0.22	0.52
	CHAT013	2017	11	0.14	0.27	0.77	0.19	0.70
	CHAT013	2021	10	0.21	0.36	0.45	0.07	0.20
Position [A] (%)	CHAT001	2017	11	5	56	90	33	0.58
	CHAT001	2021	11	5	39	80	32	0.82
	CHAT013	2017	11	30	77	95	20	0.26
	CHAT013	2021	10	15	67	95	29	0.43

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

[B] Number of measurements.

Channel Morphology

Average wetted width at CHAT001 was wider during the 2021 survey (+38%; Table 95) and this change was statistically significant (p = 0.035; Table 92). Mean active channel width was 58% wider in 2021 (Table 96), and this increase was also statistically significant (p < 0.001; Table 92). Variability of both wetted and active channel widths was lower during the 2021 survey (Table 96). The number of bankfull width measurements increased from n = 6 to n = 10. This change was due to modified interpretation of bankfull and channel full described throughout this report. During 2021, deposition on the 2017 river right channel full surface between T1 and T4 led the survey crew to reinterpret that surface as a bankfull surface leading to this increase in the number of measured bankfull widths. Mean bankfull width increased by 72% and variability (CV) decreased (Table 96). The modified interpretation also led to mean channel full width increasing by a statistically significant 111% (p < 0.001; Table 92). Both the minimum and maximum channel full width values were wider in 2021 than in 2017 and variability stayed fairly consistent (Table 96).

Table 96. Comparison of reach-scale averaged width characteristics in 2017 and 2021 at the third-order stream sites at Chattahoochee River NRA [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Widths	Site	Year	N [C]	Min (m)	Mean (m)	Max (m)	SD (m)	CV
Wetted	CHAT001	2017	11	4.34	6.59	12.26	2.30	0.35
	CHAT001	2021	11	6.07	9.07	15.34	2.80	0.31
	CHAT013	2017	11	3.27	6.68	9.30	2.27	0.34
	CHAT013	2021	10	5.60	7.53	9.75	1.33	0.18
Active Channel	CHAT001	2017	11	5.70	8.01	14.55	2.45	0.31
	CHAT001	2021	11	7.04	12.63	15.85	2.89	0.23
	CHAT013	2017	11	6.35	8.95	14.00	2.27	0.25
	CHAT013	2021	10	7.40	9.54	14.39	2.01	0.21
Bankfull [A,B]	CHAT001	2017	6	7.16	9.44	12.76	2.14	0.23
	CHAT001	2021	10	14.17	16.27	20.60	1.86	0.11
	CHAT013	2017	3	10.55	11.09	11.75	0.61	0.05
	CHAT013	2021	2	12.27	12.84	13.40	0.80	0.06
Channel full [A,B]	CHAT001	2017	11	8.97	14.14	20.95	3.72	0.26
	CHAT001	2021	11	19.52	29.87	41.91	6.64	0.22
	CHAT013	2017	11	10.46	14.77	26.65	4.44	0.30
	CHAT013	2021	10	12.70	14.97	19.85	2.27	0.15

[A] Statistics are based on the transects where feature is present and measurable.

[B] Changes due to interpretive differences between survey years.

[C] Number of measurements.

Mean minimum bank height (lowest bank height on a transect) was 26% higher in 2021 (Table 97), but this increase was not statistically significant ($p = 0.058$; Table 91). Mean bankfull height increased by 52% (Table 97). The change in mean bankfull height is again influenced by the reinterpretation of bankfull in the lower portion of the reach. There was a statistically significant (+36%) increase in mean channel full height ($p < 0.001$; Table 92). This change in channel full height was also driven by the change in interpretation of the floodplain surface in the downstream portion of the reach.

Table 97. Comparison of reach-scale averaged bank heights in 2017 and 2021 at the third-order stream sites at Chattahoochee River NRA [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Heights	Site	Year	N [E]	Min	Mean	Max	SD	CV
Minimum Bank Height (m) [A,B]	CHAT001	2017	22	0.57	1.82	3.15	0.82	0.45
	CHAT001	2021	22	0.72	2.29	3.18	0.78	0.34
	CHAT013	2017	22	0.47	2.15	2.99	0.65	0.30
	CHAT013	2021	20	0.94	2.51	3.00	0.46	0.18
Bankfull Height (m) [A,C,D]	CHAT001	2017	6	0.57	0.94	1.34	0.26	0.28
	CHAT001	2021	9	0.72	1.43	1.79	0.36	0.25
	CHAT013	2017	3	0.47	0.74	1.19	0.39	0.54
	CHAT013	2021	2	0.94	1.67	2.40	1.03	0.62
Channel full Height (m) [A,D]	CHAT001	2017	22	0.74	2.09	3.15	0.75	0.36
	CHAT001	2021	22	2.32	2.84	3.22	0.23	0.08
	CHAT013	2017	22	1.96	2.37	2.99	0.29	0.12
	CHAT013	2021	20	1.91	2.60	3.00	0.25	0.10

[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 feature is present and measurable (# in parentheses).

[D] Changes due to interpretive differences between survey years.

[E] Number of measurements.

The same number of bank undercuts were measured during both survey years (n = 5), while the mean depth of bank undercuts decreased (−39%; Table 98). Bank angles were on average slightly less steep during 2021 compared to 2017, but this change was not statistically significant (p = 0.820; Table 92). There was a statistically significant reduction (−24%) in mean bank vegetation cover percentage between the survey years (p = 0.005; Table 92). These changes led to a higher (less stable) bank stability score in 2021 (Table 98).

Table 98. Comparison of reach-scale averaged bank characteristics in 2017 and 2021 at the third-order stream sites at Chattahoochee River NRA [m—meters; SD—Standard deviation; CV—Coefficient of variation].

Bank Characteristics	Site	Year	n [A]	Min	Mean	Max	SD	CV
Bank Undercut (m)	CHAT001	2017	5	0.20	0.59	1.62	0.60	1.02
	CHAT001	2021	5	0.25	0.36	0.62	0.15	0.41
	CHAT013	2017	7	0.09	0.21	0.54	0.15	0.71
	CHAT013	2021	7	0.20	0.35	0.45	0.10	0.27
Bank Angle (°)	CHAT001	2017	22	13.70	47.55	118.30	27.28	0.57
	CHAT001	2021	22	10.80	45.88	74.40	20.68	0.45
	CHAT013	2017	22	6.40	59.52	88.40	27.38	0.46
	CHAT013	2021	20	25.00	50.42	74.40	14.29	0.28
Vegetation Cover (%)	CHAT001	2017	22	5.00	53.41	100.00	31.14	0.58
	CHAT001	2021	22	0.00	28.64	80.00	22.74	0.79
	CHAT013	2017	22	0.00	34.32	60.00	18.60	0.54
	CHAT013	2021	20	10.00	36.84	70.00	18.87	0.51
Bank Stability [B]	CHAT001	2017	22	7.00	12.73	17.00	2.25	0.18
	CHAT001	2021	22	11.50	14.14	16.00	1.05	0.07
	CHAT013	2017	22	9.00	13.70	18.00	2.51	0.18
	CHAT013	2021	20	8.00	13.00	16.00	1.65	0.13

[A] Number of measurements.

[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 at CHAT001 were surveyed on T2 (BM1; Figure 62), T6 (BM2; Figure 63), and T8 (BM3; Figure 64). On the detailed transects, bankfull cross-sectional area was on average 88% larger in 2021 (Table 99). On average, channel full area was also much larger in 2021 (+190%). These increases are driven by the major improvement in the interpretation of geomorphic surfaces at detailed transect 1 (T1; Figure 62). Water surface slope (longitudinal profile) for this section of Haw Creek did not change between the two survey years, measuring 0.0074 m/m (Figure 65; Table 99). While overall water surface slope did not change, aggradation and island and bar can be seen on T3 and T6. Sinuosity continued to be relatively low (Table 99).

Table 99. Comparison of 2017 and 2021 reach scale and average detailed transect characteristics for the third-order streams at Chattahoochee River NRA [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)
CHAT001	2017	14	−0.0074	1.07	3	5.87	11.50	0.79	19.95	17.06	1.57
	2021	15	−0.0074	1.05	3	11.04	16.56	1.10	57.92	31.64	2.71
	Difference 2017–2021 [C]	1	0.0000	−0.02	–	5.18	5.05	0.31	37.97	14.58	1.14
CHAT013	2017	17	−0.0044	1.14	2	3.24	9.07	0.55	18.24	12.24	2.02
	2021	12	−0.0013	1.09	2	15.25	11.87	1.65	22.06	13.37	2.28
	Difference 2017–2021 [C]	−5	0.00312	−0.05	–	12.02	2.80	1.10	3.83	1.14	0.27

[A] Number of measurements for slope.

[B] Number of measurements for bankfull and channel full area, width, and depth.

[C] Changes due to interpretive differences between survey years.

The cross-sections at detailed transect 1 (T2) were quite different between the survey years (Figure 62). The most notable change was the channel widening which had occurred via erosion and slumping of the river left bank. Also, a major improvement in the interpretation of bankfull and channel full surfaces on river right occurred during the 2021 survey. The survey team was able to identify deposition on the river right elevated entrenched surface and appropriately modified the interpretation to a bankfull surface. This reinterpretation coupled with substantial widening of the channel caused bankfull cross-sectional area to increase by 149% (Table 100). An incipient bar had formed mid-channel and slight aggradation, and thalweg migration were also observed (Figure 62). There was also a substantial (884%) increase in channel full area (Table 100). This increase was driven by channel widening (via slumping) and the improvement of the interpretation of channel full diagnostic point.

Table 100. Changes to cross-sectional characteristics on detailed transect 1 (T2) at CHAT001 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	4.03	7.74	0.72
	2021	10.02	18.39	0.76
	Change 2017–2021 [A]	5.99	10.65	0.03
Channel full	2017	9.15	12.23	1.21
	2021	90.08	45.88	2.74
	Change 2017–2021 [A]	80.93	33.65	1.52

[A] Changes due to interpretive differences between survey years.

Detailed transect 2 (T6) shows another improvement in the interpretation of the bankfull and channel full surfaces. The 2017 river right low terrace (channel full) surface was reinterpreted as floodplain due to sediment deposition on this surface since 2017. Channel full was shifted to the higher "historical" terrace surface (matching river left) during the 2021 survey (Figure 63). There were also substantial changes in the channel bed, as the thalweg had migrated from extreme river left to extreme river right in 2021 (Figure 63). Aggradation leading to the development of a mid-channel cobble island had created a two-thread stream at detailed transect 2 (T6). These changes led to bankfull cross-sectional area to increase by 103% and channel full area to increase by 388% (Table 101).

Table 101. Changes to cross-sectional characteristics on detailed transect 2 (T6) at CHAT001 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	6.10	15.71	0.72
	2021	12.39	18.28	1.11
	Change 2017–2021 [A]	6.29	2.57	0.39
Channel full	2017	9.29	16.81	0.92
	2021	45.31	26.65	2.59
	Change 2017–2021 [A]	36.02	9.84	1.67

[A] Changes due to interpretive differences between survey years.

Detailed transect 3 (T8) shows slight channel incision and thalweg migration toward river left (Figure 64). The cross-section also showed the floodplain area on river right had experienced a substantial amount of deposition since 2017. Increases in bankfull height and width drove a 170% increase in bankfull area (Table 102). There was a slight (−7%) decrease in channel full area due to the large amount of sedimentation on the river right bankfull surface. Channel full width and height were both similar to 2017's values (Table 102).

Table 102. Changes to cross-sectional characteristics on detailed transect 3 (T10) at CHAT001 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	3.97	9.74	0.71
	2021	10.72	13.00	1.42
	Change 2017–2021	6.75	3.26	0.71
Channel full	2017	41.40	22.13	2.57
	2021	38.37	22.38	2.80
	Change 2017–2021	−3.03	0.25	0.23

CHAT013—Long Island Creek

Reach Description

On May 7, 2021, stream survey data were collected at CHAT013. CHAT013 is along Long Island Creek (a third-order stream in the Palisades unit). CHAT013 is accessed by taking the hiking trail from the Whitewater Creek parking lot upstream to the site. Like CHAT001, this reach was chosen because it did not have any evidence of backwater effects from the Chattahoochee River. The monitored reach on Long Island Creek was 160 meters (525 ft) in length with 16 meters (52.5 ft) between transects. The hiking trail from the Whitewater Creek parking lot runs along the reach on river right (Figure 66). The trail is still threatened by bank erosion between T8 and T9.

Major changes were observed upstream of T10, as bank erosion on the outside of a meander (just upstream of the monitored reach) caused a large bank collapse and tree fall event to occur prior to the 2021 survey. The original benchmark for detailed transect 3 (T11) was lost in this erosive event, so the survey crew installed another benchmark farther back on the low terrace. The bank collapse and tree fall caused a diversion of flow, forcing it toward river left and exacerbating erosion of the river left bank near T11. Due to these conditions, the SECN survey team was unable to survey T11. The streambank on river left was not navigable and the fallen trees prevented navigation of the cross-section at T11. Measures that could be safely collected were taken.

The monitored portion of Long Island Creek was highly entrenched with only one area of floodplain present within the reach (at T11 river right; Figure 66). Not surveyed in 2021 due to the tree fall, this floodplain area was present during the 2021 survey. The stream is entrenched within the historical terrace. Reinterpretation of the out-of-channel area subdivided the river left channel full area into a lower terrace level inset within a higher historical terrace level where a sewer line is buried. Large woody debris between T9 and T10 were persistent between the survey years but had infilled and were no longer step habitat. Small bedrock outcrops were still influencing the stream around T1, T4, and T8. Bar surfaces were generally smaller during the 2021 survey and a major section of the stream (T4 to T8) was one long continuous run. Bank slumping occurred within the monitored reach and an elevated entrenched surface was identified on river left between T1 and T2. The detailed transects are on T3 (BM1; Figure 67), T6 (BM2; Figure 68), and T11 (BM3). Erosion and downcutting was observed on detailed transects 1 (T3) and 2 (T6), respectively. Detailed transect 3 (T11) could not be surveyed due to dangerous conditions caused by the tree fall event (Figure 69). The SECN survey crew installed a new benchmark on the low terrace and surveyed the position of the left bank margin (Figure 70). Water surface slope (longitudinal profile) for this section of Long Island Creek was 0.0013 m/m (Table 99; Figure 71). The longitudinal profile shows a substantial amount of aggradation at the bottom of the reach and that stream slope is very consistent upstream of the riffle at T4. Survey results for CHAT013 can be viewed in the corresponding file of supplemental materials for this site.

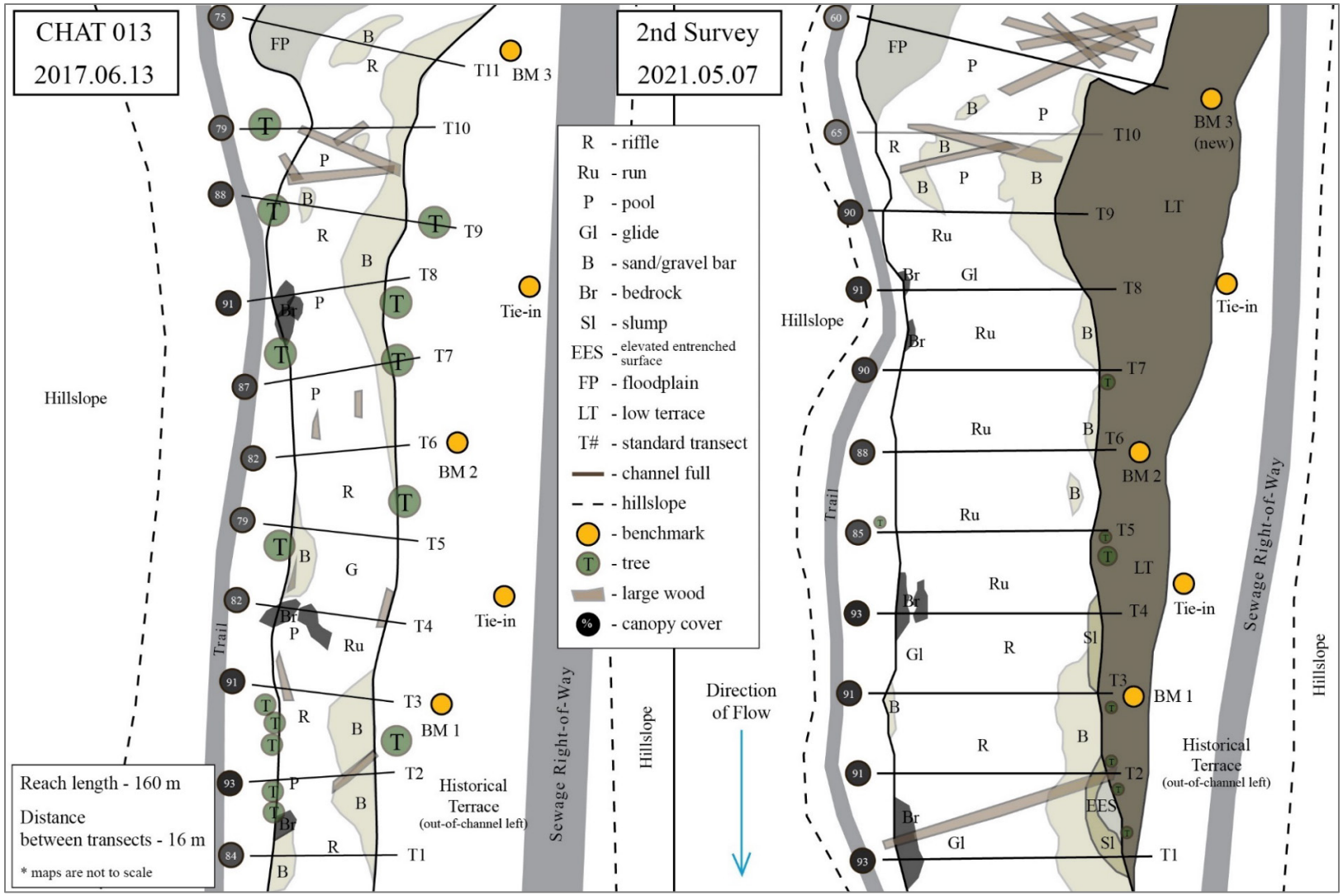


Figure 66. Reach-scale map of CHAT013. Important geomorphic surfaces and in-channel features are labeled to provide a context for the standard and detailed transect information provided in this report. The canopy cover circles are varying shades of grey which indicate the amount of canopy cover at each transect (high and low coverages are labeled).

NPS

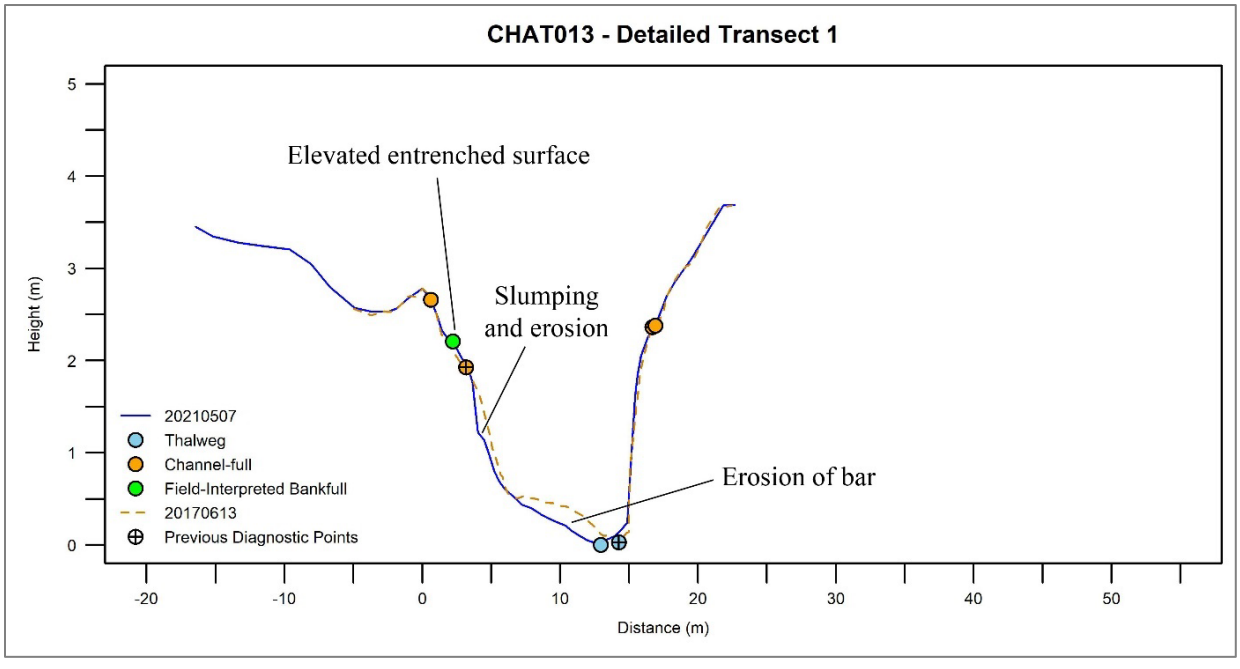


Figure 67. Differences between the 2017 and 2021 surveys of detailed transect 1 at CHAT013. View is in the downstream direction.

NPS

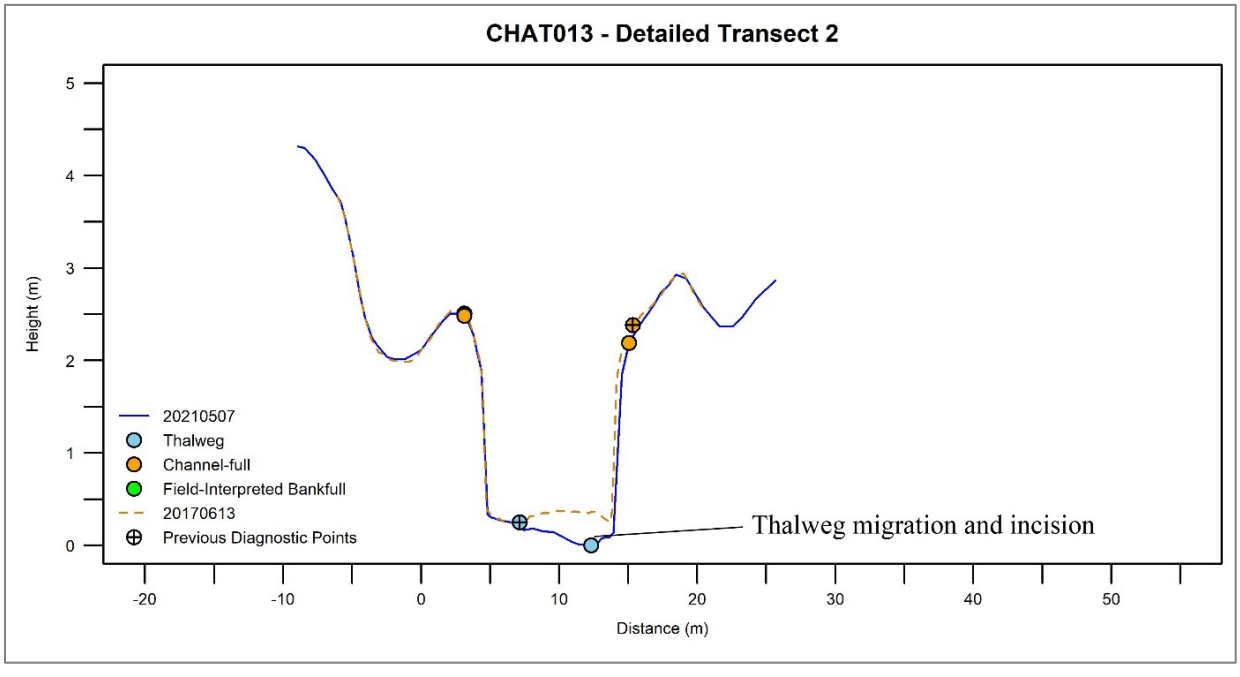


Figure 68. Differences between the 2017 and 2021 surveys of detailed transect 2 at CHAT013. View is in the downstream direction.

NPS



Figure 69. Photo of tree fall at CHAT013 detailed transect 3 (T11) that prevented the cross-sectional survey on May 7, 2021. View is in the upstream direction as Dr. Jacob M. Bateman McDonald stands on a bar at river right (left of photo) and SECN Hydrologic Technician Daniel McCay is standing at the top of the river left bank (right of photo).

NPS

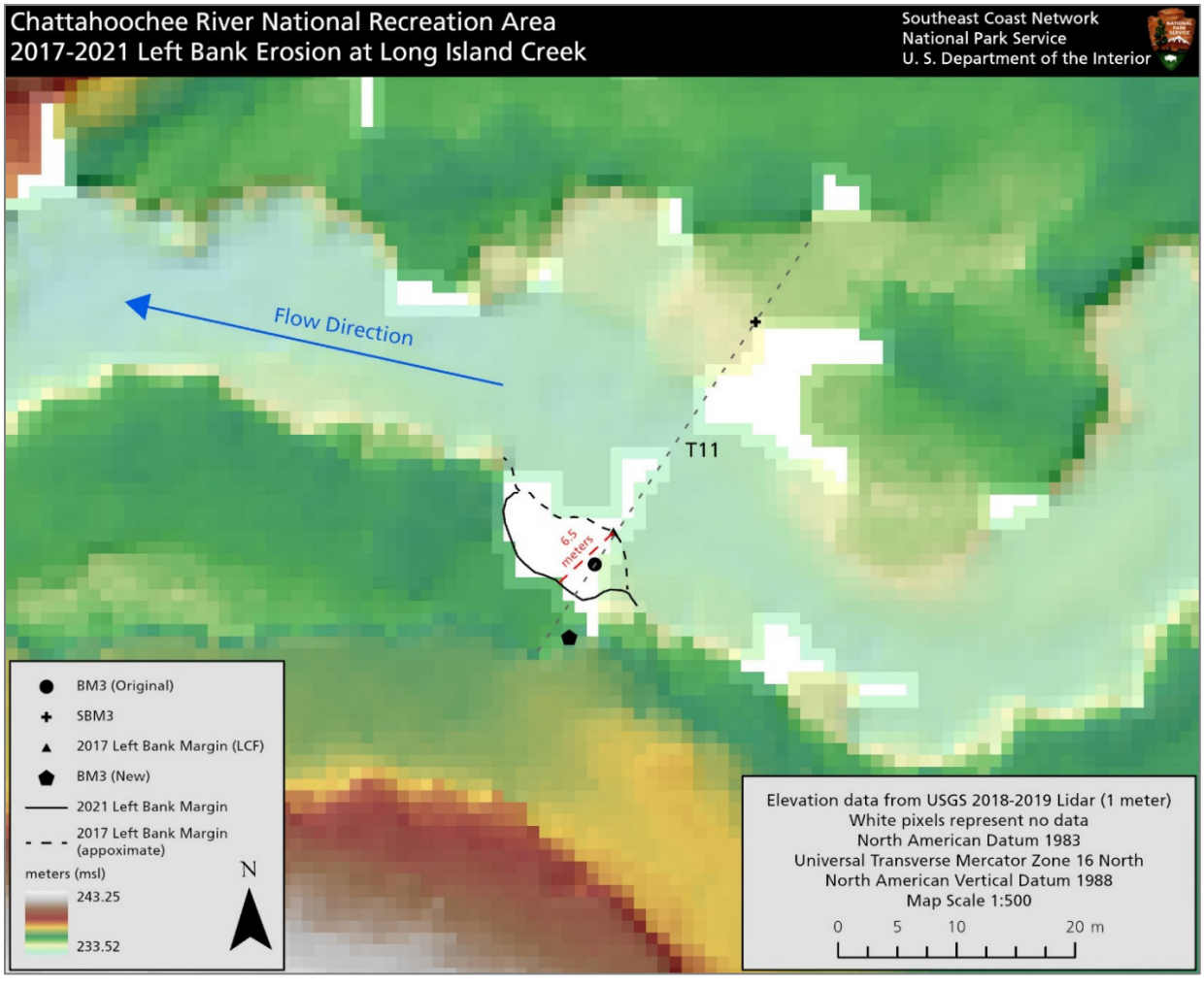


Figure 70. Map showing the stream channel and area of bank erosion at T11 of CHAT013. Flow direction is left to right. Note that the 2021 left channel margin had receded 6.5 meters from the 2017 location and that the original BM3 (circle) was lost.

NPS

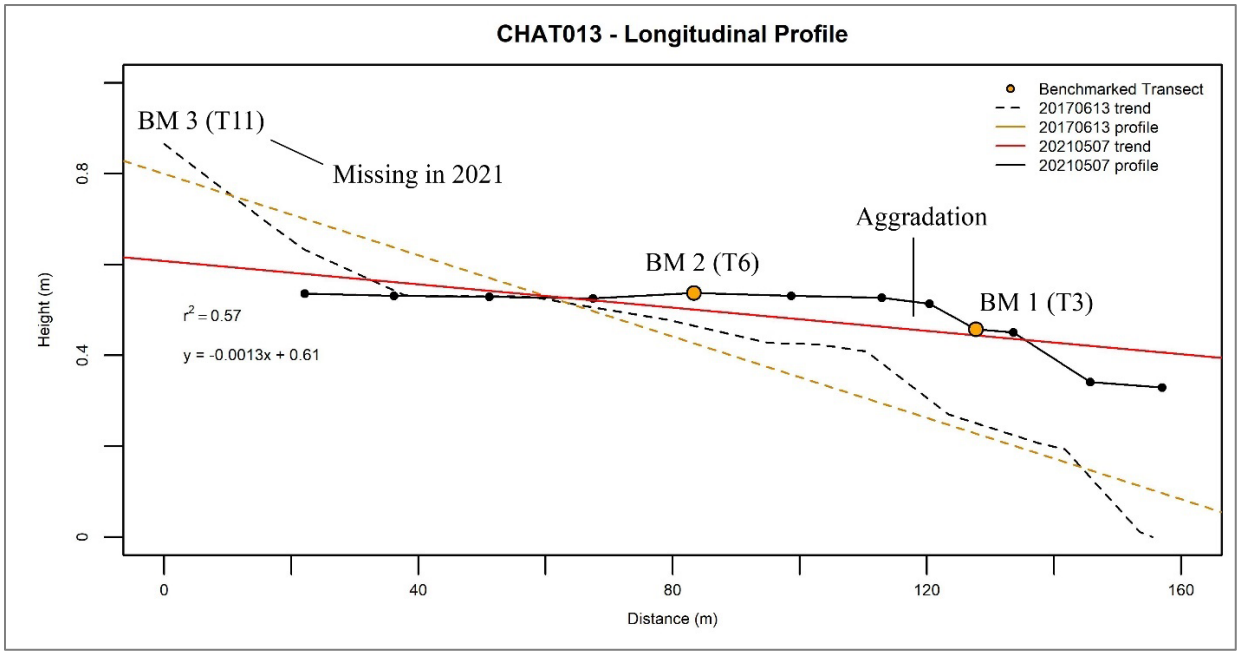


Figure 71. Longitudinal profile for CHAT013. The red line on the graph corresponds to the interpreted slope of the reach (0.0013 m/m). The r^2 value describes the strength of the 2021 trend line (interpreted slope). The "T#" in parentheses indicates the standard transect number on which the detailed transects were surveyed.
NPS

Habitat Characteristics

The geomorphic channel unit (GCU) types and distributions at CHAT013 changed during the time between the 2017 and 2021 surveys (Table 90). Riffles, pools, runs, and glides were present within the surveyed reach during both survey years and the one step observed in the 2017 survey was not observed during 2021. The frequency of riffles within the reach decreased from n = 10 to n = 6 and the mean percentage of riffle decreased substantially (−23%). The frequency of pools also decreased from n = 10 to n = 4 and the mean percentage of pool fell 27%. Instances of run more than tripled from n = 3 to n = 10 and the mean percentage of run increased 44%. Only one glide was observed within the reach in 2017, while six were observed in 2021. The mean percentage of glide increased 11%. Though the LWD was still there, the one log step observed between T9 and T10 during the 2017 survey was no longer a step as sediments had filled in the river left side of the former step and flow was diverting around it on river right.

The pebble count data for CHAT013 shows a slight coarsening of the bed sediment, though the smallest size fractions are getting finer. The mean diameter of the pebbles increased by 22% (Table 91), but this increase was not statistically significant (p = 0.055; Table 103). While the mean diameter of pebbles increased, the D_5 pebble diameter decreased from sand-sized (2.00 mm) to fine (0.06 mm; Table 91).

Table 103. Difference in means t-test results comparing CHAT013 during 2017 and 2021. The significance of the differences is indicated by: "–" not significant; "*" p-value < 0.05, "**" p-value < 0.001. Note that individual measurements at T11 were removed from the 2017 dataset.

Measurement	n [A]	CHAT013 in 2017	CHAT013 in 2021	P-value	Significance
Pebble Count (mm)	100	24.76	30.31	0.055	–
Thalweg Depth (m)	10	0.28	0.36	0.239	–
Thalweg Position (%)	10	75.00	67.00	0.483	–
Wetted Width (m)	10	6.52	7.53	0.254	–
Active Channel Width (m)	10	8.45	9.54	0.196	–
Channel full Width (m)	10	13.58	14.97	0.176	–
Minimum Bank Height (m)	20	1.95	2.51	0.068	–
Channel full Height (m) [B]	20	2.33	2.60	0.041	*
Bank Angle (°)	20	58.05	50.42	0.404	–
Vegetative Cover (%)	20	23.00	36.00	0.090	–

[A] Number of measurements taken.

[B] Changes due to interpretive differences between survey years.

The number of pieces of large woody debris (LWD) decreased from n = 30 to n = 21 (Table 93). More pieces of LWD were present within the reach during 2021 but could not be reached due to the tree fall upstream of T10. The pieces measured were distributed relatively evenly throughout the reach, but one-third of the counted pieces were upstream of T10 near the tree fall. Despite the decrease in pieces of LWD, the volume of LWD per channel area stayed approximately the same (Table 93). Though mean canopy cover did not change, variability in canopy cover increased slightly (Table 94).

Mean thalweg position (relative to the left bank) shifted toward the middle of the channel between surveys, decreasing from 77% to 67% (Table 95). Variability in thalweg position increased between the two survey years (CV = 0.26 to CV = 0.43). Mean thalweg depth increased by 33% (Table 95), but this change was not statistically significant (p = 0.239; Table 103). Variability in thalweg depth changed substantially, decreasing from CV = 0.70 to CV = 0.20 (Table 95).

Channel Morphology

Average wetted width at CHAT013 was slightly wider (+13%) during the 2021 survey (Table 96), though this change was not statistically significant (p = 0.254; Table 103). To test the statistical significance of changes in channel morphology, the 2017 values for T11 were removed from analysis. Removing the 2017 T11 measurements allowed a direct comparison of T1 through T10, as T11 was inaccessible in 2021. Mean active channel width was slightly wider (+7%) in 2021 (Table 96), though this change was again not statistically significant (p = 0.196; Table 103). The number of bankfull widths decreased from n = 3 to n = 2 because the bankfull measurement at T11 could not be measured (Table 96). Mean bankfull width increased by 58% and variability was low (CV = 0.06). Mean channel full width stayed approximately the same (Table 96), and the small change that occurred was not statistically significant (p = 0.176; Table 103). Variability in channel

full width decreased from CV = 0.30 to CV = 0.15 and this is likely influenced by the loss of the width measurement at T11 (Table 96).

Mean minimum bank height (lowest bank height on a transect) in 2021 was 17% higher than in 2017 (Table 97), though this change was not statistically significant (p = 0.068; Table 103). Mean bankfull height increased by 52% and variability of bankfull height remained relatively high (Table 97). Mean channel full height increased by 10% and this change was statistically significant (p = 0.041; Table 103). Channel full heights were equally variable between the two survey years (CV = 0.12; Table 97).

The same number of undercut banks (n = 7) were measured during both survey years (Table 98). The mean depth of the undercuts increased by 67%. Bank angles were on average less steep during 2021 (Table 98) though this change was not statistically significant (p = 0.404; Table 103). Bank vegetation cover remained relatively low (Table 98) and the small difference between the two survey years was not statistically significant (p = 0.090; Table 103). Bank stability scores were slightly lower (more stable) in 2021 (Table 98).

Detailed Transects

The detailed transects on CHAT013 were surveyed on T3 (BM1; Figure 67) and T6 (BM2; Figure 68) The cross-section at detailed transect 3 (T11) could not be surveyed due to bank collapse and the presence of the large tree fall that occurred at the transect prior to the 2021 survey (Figure 69). Because detailed transect 3 was impassable, the crew instead surveyed the left bank margin at T11 (BM3; Figure 70). Since detailed transect 3 was not surveyed in the same way during both years, the 2017 detailed transect 3 data were not used to calculate the 2017 mean channel geometry measures included in Table 99. Comparing the mean of the lower two detailed transects between survey years, bankfull cross-sectional area was on average 371% larger in 2021 (Table 99). This substantial increase in bankfull area was caused by the reinterpretation of bankfull and channel full on detailed transect 1 (Figure 67). Channel full was moved up to the higher elevated entrenched surface and 2017 channel full surface was designated as bankfull. These changes also contributed to mean channel full area of the two lower detailed transects to increase by 21% (Table 99). Changes in these average measures of channel geometry would have been greater if the third detailed transect could have been included. The channel was larger at T11 during the 2021 survey due to the tree fall and left bank collapse. Water surface slope (longitudinal profile) for this section of Long Island Creek decreased from 0.0044 m/m to 0.0013 m/m (Figure 71; Table 99). This decrease was due to substantial aggradation of the reach downstream from detailed transect 2 (T6). Sinuosity did not change appreciably between the survey years (Table 99).

Detailed transect 1 (T3) showed bank slumping on the river left bank, reinterpretation of the elevated entrenched surface (bankfull) on river left, and erosion of the bar on river left (Figure 67). The modification to the interpretation of bankfull and channel full led to a 918% increase in bankfull cross-sectional area (Table 104). Channel full area also increased, though not as substantially (+46%; Table 104).

Table 104. Changes to cross-sectional characteristics on detailed transect 1 at CHAT013 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	2.11	8.87	0.55
	2021	21.49	14.05	2.21
	Change 2017–2021 [A]	19.38	5.18	1.66
Channel full	2017	16.43	12.71	1.90
	2021	24.05	15.61	2.38
	Change 2017–2021	7.62	2.90	0.48

[A] Changes due to interpretive differences between survey years.

Detailed transect 2 (T6) showed channel incision and thalweg migration toward river right (Figure 68). Besides the changes in the streambed, the two cross-sections are relatively similar. Bankfull cross-sectional area increased by 107% (Table 105). This "change" in bankfull cross-sectional area was due to an increase in reach-scale bankfull height used to calculate the bankfull dimensions of this detailed transect as there were no bankfull surfaces identified in the field along this cross-section. Channel full area was very similar (<1% difference) between the two survey years (Table 105).

Table 105. Changes to cross-sectional characteristics on detailed transect 2 at CHAT013 [m-meters].

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	4.36	9.27	0.55
	2021	9.01	9.69	1.10
	Change 2017–2021 [A]	4.66	0.42	0.55
Channel full	2017	20.04	11.77	2.13
	2021	20.08	11.14	2.19
	Change 2017–2021 [A]	0.04	−0.63	0.06

[A] Changes due to interpretive differences between survey years.

The cross-section at detailed transect 3 (T11) could not be surveyed in 2021 due to the large bank collapse and tree fall event along river left (Figure 69). When the tree fall event occurred, a large portion of the bank fell into the stream, taking the original SECN-installed BM3 with it. The survey crew installed a new BM3 approximately 3.5 meters (11.5 feet) back from the new streambank margin and conducted a survey of the river left channel margin at T11 (Figure 70). Comparison of the left bank margins in 2017 and 2021 shows that the river left bank receded approximately 6.50 meters (ft) during that time span. Cross-sectional measures for 2017 are provided in Table 106.

Table 106. Changes to cross-sectional characteristics on detailed transect 3 at CHAT013 [m-meters]. Cross-sectional characteristics data were not collected in 2021 due to a large tree fall along the transect.

Type	Year	Area (m^2)	Width (m)	Height (m)
Bankfull	2017	8.76	16.05	0.80
	2021	–	–	–
	Change 2017–2021	–	–	–
Channel full	2017	42.32	25.68	2.22
	2021	–	–	–
	Change 2017–2021	–	–	–

Between Site Comparison of Third-Order Streams

In 2017, the only variable that was statistically significantly different between the two streams was bed sediment. In 2021, bed sediment continued to be statistically significantly different (CHAT001 coarser than CHAT013) but due to a combination of interpretive and geomorphic changes at CHAT001, active channel width, channel full width, and channel full height are also statistically significantly different (Table 107). The statistical significance of these differences may not be as strong because the widest transect at CHAT013 (T11) could not be measured due to the tree fall that occurred in this portion of the reach. The third set of surveys (planned for 2024) will help determine if the statistically significant differences between the two reaches remains stable or is more ephemeral and the stream measures converge back to what was seen in 2017.

Table 107. Difference in means t-test results comparing CHAT001 and CHAT013 during each survey period. The significance of the differences is indicated by: "–" not significant; "*" p-value <0.05, "**" p-value <0.01, and "***" p-value <0.001 [m—meters; mm—millimeters].

Measurement	n [A]	Difference in means 2017	Difference in means 2021	P-value 2017	P-value 2021	Significance 2017	Significance 2021
Pebble Count (mm)	100	21.34	21.01	< 0.001	< 0.001	***	***
Thalweg Depth (m)	10	0.12	0.05	0.173	0.513	–	–
Wetted Width (m)	10	−0.09	1.80	0.927	0.089	–	–
Active Channel Width (m)	10	−0.95	3.65	0.358	0.002	–	**
Channel full Width (m)	10	−0.63	14.98	0.721	< 0.001	–	***
Channel full Height (m)	20	−0.28	2.73	0.113	0.008	–	**
Bank Angle (°)	20	−11.98	47.44	0.154	0.612	–	–

[A] Number of measurements taken.

Implications and Synthesis of Results

This section describes the in-stream habitat and geomorphic characteristics of each reach during the 2021 surveys, changes that occurred since the 2017 surveys, potential changes that may occur in the future, and the implications of any changes observed. Like the results section, the Implications and Synthesis of Results section is divided by Strahler stream order and further subdivided by reach.

Headwater Streams (First-Order)

CHAT002—"Undercut Creek"

CHAT002's watershed is steep and forested. Approximately 77% of the watershed is forested while the remainder is covered by residential or suburban development (Table 5). The watershed area draining to "Undercut Creek" is approximately the same size as CHAT012's watershed, is larger than CHAT006's, and smaller than CHAT003 and CHAT009's watersheds (Table 4). CHAT002's watershed has the highest entire stream gradient (0.0616 m/m; Table 4), the highest segment gradient (0.840 m/m; Table 4), and the steepest reach gradient (0.0392 m/m; Table 15 and Figure 10). The reach gradient at CHAT002 had become slightly steeper than what was observed in 2017 (0.0341 m/m in 2017, 0.0392 m/m in 2021; Table 15). CHAT002's watershed has the third highest basin relief ratio and the elevation within the watershed is more variable than all other first-order stream watersheds (highest standard deviation of elevation; Table 4). While high slope and relief can contribute to flashier flows, CHAT002's watershed is also the most elongated (lowest basin shape; Table 4). Elongated basins often have less flashy flood regimes than more circular (high basin shape) basins (Gregory and Walling 1973). Given the high slope and relief of the watershed and the high reach gradient, the authors infer the stream has a flashy flood regime although gage data are needed to determine the flashiness of the flow at CHAT002.

The reach surveyed on "Undercut Creek" (CHAT002) is not frequently accessed by the public. While there is a social trail leading to the stream, off the main trail along the Chattahoochee River, it is seemingly not used with frequency (no litter). CHAT002's in-stream habitat shifted to higher energy geomorphic channel units since the initial survey (more riffle [+7%] and run [+19%] than pool [−22%]; Table 6). This substantial reduction in pool habitat, and the large increase in run habitat, could be attributed to the introduction of fine sediments to the reach which infilled the pool habitat. The mean pebble size at CHAT002 significantly increased ($p = 0.004$; Table 8) between the survey years (29.93 mm in 2017 to 42.82 mm in 2021; Tables 7, 8), but the smaller size classes (both minimum and D_5) were smaller than observed in 2017, indicating that fine sediments were more prominent during the 2021 survey. The increase in glide habitat could be related to an increase in flow due to the precipitation within the watershed in the days prior to the survey. An increase in flow velocity could cause an area of pool to be flowing faster, and therefore classified as glide (if relatively deep). To determine the long-term ramifications of the changes in habitat, a better understanding of bed sediment mobility is needed to determine residence time of stormflow-derived sediments.

This reach had the second highest volume of LWD per channel area (0.0097 m^3/m^2; Table 9). Though, the volume decreased since the 2017 survey (0.0105 m^3/m^2). The high volume of LWD likely has a positive effect on the benthic macroinvertebrate assemblage (Allan and Castillo 2007).

Though a stream may look negatively impacted immediately after a significant tree fall, LWD is usually beneficial to stream biota by increasing the complexity of in-stream habitat (Allan and Castillo 2007; Benke et. al. 1984; Smock et. al. 1989; Lemly and Hilderbrand 2000). The distribution of GCU within the reach indicate a high-energy system with small pools and more run, which could be detrimental to in-stream biota. Though the bed material coarsened overall, there was evidence of an increase in fine sediments that possibly contributed to the loss of pool habitat. Following the 2017 survey, CHAT002's in-stream habitat was classified as "good" (McDonald et al. 2019a). Based on the changes in GCU diversity, introduction of fines to the bed sediment, and the influence of LWD, CHAT002's in-stream habitat classification was downgraded to "fair to good." This classification is a generalized interpretation of in-stream habitat and more 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 CHAT002. Habitat at CHAT002 may return to "good" if the fine sediment is not stored long-term in the reach, if LWD increases, or if habitat (GCU) diversity increases (Allan and Castillo 2007). One way habitat diversity may continue to decrease is if the downstream knickpoint migrates upstream into the reach, further increasing the reach gradient and eliminating lower energy habitat types. Additionally, if there is a substantial upstream disturbance, additional fine sediment may be introduced leading to additional loss and degradation of CHAT002's habitat.

The defining morphological characteristics of the surveyed reach were the same during both survey years (heavy undercutting on the outside of the bend between T5 and T6 and the presence of the flood chute on river left; Figure 6). In addition to undercuts and the flood chute, a better interpretation of the reach has identified two additional processes influencing the reach. These additional processes are related to LWD and slumping. As the stream continues to erode and undercut its banks, more LWD will be introduced to the stream via tree fall. These pieces of LWD are important for both habitat creation and bank protection but they can also divert flow and cause localized areas of increased bank erosion. An example of this is between T8 and T9, where LWD has diverted flow into the natural levee, eroding it, and further developing the flood chute on the river left out-of-channel area (Figure 6). The increased prominence of the flood chute is affecting the main channel by diverting flow during higher flow events (reducing stream power in the main channel). Immediately downstream of where the flood chute rejoins the channel, the channel is incising (Figure 10). This diversion of flow could also be contributing to the loss of pool habitat as the reduction in main channel flow would increase the likelihood of in-channel deposition.

In 2017, the benches between T6 and T10 and the "floodplains" on T3 and river left T6 were likely the result of bank slumping. A better term for these "floodplain" surfaces, is elevated entrenched surface after the surfaces observed at KEMO in 2019 (Bateman McDonald 2020). On river left T3, this elevated entrenched surface eroded, and an undercut has developed just downstream of where this surface used to be. This loss of surface and undercutting of the bank is hypothesized to be related to the return flow of water from the flood chute that enters the stream in this section of the stream. Based on the development of the benches and elevated entrenched areas in the reach, it appears these surfaces are not stable and are not serving as areas of long-term sediment storage. In addition to the in-stream processes, a potential disturbance that will affect CHAT002 is the upstream migration of a knickpoint approximately 20–30 meters (65.6–98.4 ft) downstream. Upstream migration of the

knickpoint will cause the reach to incise as the stream equilibrates to this lower base level (current level of the Chattahoochee River), thereby further increasing the reach gradient and increasing the rate at which elevated entrenched surfaces develop.

There are no management concerns related to this reach. The changes observed are not creating conditions that are unsafe to visitors. More work related to understanding the flow regime, water quality, and in-stream biota is needed to determine how upstream conditions are influencing the water moving through this reach.

CHAT003—"Steep Draw Creek"

CHAT003's watershed is steep and forested and shares its northern ridgeline with CHAT002's watershed. Analysis of the new NLCD datasets indicate that watershed landcover has not changed (Dewitt et al. 2023). Approximately 77% of the watershed is forested while the rest is covered by residential (suburban) and commercial development (Table 5). The watershed draining to "Steep Draw Creek"' is the same size as CHAT009's watershed and is larger than the other three first-order stream watersheds (Table 4). CHAT003's watershed has the third highest entire stream gradient, the second highest segment gradient, and the second steepest reach gradient (Table 15 and Figure 15). Reach gradient at CHAT003 was slightly steeper during the 2021 survey (0.0313 m/m up to 0.0319 m/m; Table 15 and Figure 15) though this change is within the expected instrument/survey uncertainty. Additionally, CHAT003's watershed has the second highest basin relief ratio, the second highest average watershed slope, the second highest standard deviation of elevation, and the highest basin shape (Table 4). These characteristics suggest CHAT003's flow regime is likely flashy, though gage data are needed to confirm this interpretation. Additional urban or suburban development in the watershed will likely make this watershed flashier.

The reach surveyed on "Steep Draw Creek" (CHAT003) has a well-worn social trail running along river left. Multiple visitors (and their pets) have been seen using this trail while conducting the surveys. The mean diameter of bed sediment was the third coarsest of the first-order streams (Tables 6 and 7) behind CHAT012 and CHAT002. Like CHAT002, the mean diameter of bed sediment slightly increased from 2017 (+2.65 millimeters [0.1 in]), but the smaller classes were finer indicating fine sediments have been introduced to the reach. CHAT003's in-stream habitat changed substantially with riffle and pool being replaced by run habitat (−28% riffle, +28% run, and −8% pool; Table 6). While abundant riffle habitat can indicate a healthy stream, the lack of habitat heterogeneity (loss of pool) likely means there is poor biodiversity (Allan and Castillo 2007; Palmer et al. 2010).

This reach had a lower volume of LWD per channel area (−0.0026 m^3/m^2, Table 9) and there were fewer pieces of LWD within the reach (−3 pieces). Though in-stream habitat continues to lack diversity, the reach had relatively coarse bed sediment and the third highest volume of LWD per channel area, therefore CHAT003's in-stream habitat remained classified as "fair." This classification is a generalized interpretation of in-stream habitat and more 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 CHAT003. If additional fine bed material is introduced to the reach, and if the GCUs within the reach become more homogenous, the habitat classification may degrade to "poor to fair." Alternatively, stable (non-mobile) LWD may

increase habitat diversity and provide more stability to the reach that could upgrade the classification to “fair to good.”

The defining characteristic of the stream was its high degree of entrenchment and the presence of multiple elevated entrenched surfaces within the reach. The stream is widening (at channel full) and the slumping of banks and presence of benches and elevated entrenches surfaces indicate the stream is in the widening stage (Stage 3) of channel evolution (Schumm et al. 1984). The benches and elevated entrenched surfaces indicate the stream is beginning to create semi-stable surfaces within the channel through undercutting and slumping. The laterally migrating and depositionally-developing “floodplain” interpretation of the surface on T1’s river right in 2017 was determined to be incorrect. This surface is now believed to be an elevated entrenched surface (likely slump cored) which is slowly sinking into the channel as the toe is eroded and the slump block slides on its failure plane.

As the channel has widened, it has also exposed two clay “shelves” in the bed of the channel on river left on T1 and river right between T3 and T4 (Figure 11). It is hypothesized by the authors that this clay-rich shelf is a prehistoric surface (because of its location under the historical overburden), though its pedogenic context is unclear. In addition to the bank slumping and channel widening observed in the reach, the main disturbance that will affect CHAT003 in the future is the upstream migration of a knickpoint (approximately 5–10 meters [16.4–32.8 ft] downstream during the 2021 survey) that will cause the reach to incise, increase in slope, and further destabilize the banks as the stream equilibrates to this lower base level (current level of the Chattahoochee River).

There is no immediate management concern for this reach but the trail in the out-of-channel area on river left is frequently used by visitors. Erosion along the cutbank on T1 and downstream from T1 may eventually influence this trail. The trail’s condition will be monitored during subsequent surveys. More work related to understanding the flow regime, water quality, and in-stream biota is needed to determine how upstream conditions are influencing the water moving through this reach.

CHAT006—“Three Mind Creek”

CHAT006’s watershed has low slope and relief and is mostly covered by residential, suburban, and commercial development (59%) with much of the rest being forested (Table 5). Land use within the CHAT006 watershed did not change between the two surveys. The watershed draining to “Three Mind Creek” is the smallest (0.20 square kilometers [0.08 sq mi]) of all other first-order watersheds (Table 4). CHAT006’s watershed has the second highest entire stream gradient, the lowest segment gradient, and the lowest reach gradient (0.0042 m/m; Table 4). During 2017, the reach gradient at CHAT006 was much steeper (0.0236 m/m) due to a large increase in slope at a log step between T3 and T4 (Figure 16). This area of the reach (downstream of T4) infilled since 2017 behind a large wood jam that developed just downstream of T1. CHAT006’s watershed has the second lowest basin relief ratio, the lowest average watershed slope, the lowest standard deviation of elevation, and the second lowest basin shape (Table 3). Though gage data are needed to determine the flashiness of the flow regime at CHAT006, the geomorphic characteristics of the watershed suggest the flow regime is not flashy. Alternatively, the high level of development in the watershed may counteract the dampening effects of the geomorphic characteristics.

The reach surveyed on “Three Mind Creek” (CHAT006) is not frequently visited by the public (i.e., no trash was seen, and no well-worn trails were observed). While there is a trail within 40 meters (131.2 ft) of the creek (path on hillslope on river left) there are no defined trails to or near the stream. CHAT006’s in-stream habitat changed substantially becoming dominantly run habitat converted from pool and riffle (+51% run, −35% pool, and −15% riffle). While there was a statistically significant increase in the mean diameter of the bed sediment at CHAT006 (+4 mm), there was a reduction in the smallest size fractions of the pebble count which indicate an influx of fine sediment into the reach. The addition of fines, conversion of the reach to run habitat, and the reduction in channel slope are likely related. Alternatively, the large rainstorms that influenced the area prior to the surveys may have introduced the fine sediment and the habitat may return to 2017 conditions if this sediment is not stored within the reach over the long term.

CHAT006’s reach had the third highest volume of LWD per channel area of the first-order streams during 2017 (Table 9) and the amount of LWD increased substantially between the two surveys (+0.0093 m^3/m^2 [+381%])). The observed increase in LWD is attributed to a very large (channel-spanning) tree fall that occurred just downstream of T5 (Figure 16). However, most of the LWD introduced by the tree fall event bridges the stream channel and was not influencing habitat conditions within the reach. Though there was a very large volume of woody debris within the reach, based on the lack of GCU diversity (mostly run) and bed sediment (very fine), CHAT006’s in-stream habitat remained classified as “poor.” This classification is a generalized interpretation of in-stream habitat and more 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 CHAT006.

The habitat classification at CHAT006 may be upgraded to “fair” if stable (non-mobile) in-channel (non-bridging) LWD increases the diversity of habitat, upstream conditions reduce the amount of fine sediment delivered to the reach, and if the fine sediment stored in the reach is remobilized and more heterogeneous habitat is established. A process that will help remobilize the fine sediment deposited within the reach is when the log jam downstream from T1 fails. Failure of the log jam will lead to a steepening of the channel slope as the temporary knickpoint head cuts back to the organic jam observed in 2017 between T3 and T4.

The major changes observed at CHAT006 were the infilling of the channel downstream of T4 and lateral erosion (meander migration) along T11 (detailed transect 3). During the 2017 survey, downstream of T4, the channel was entrenched below a log step and the survey team interpreted the channel full extent of this portion of the reach as the tops of the banks that surrounded the entrenched channel (even though this surface was the upstream bankfull surface). The development of another large wood jam downstream of the reach caused the channel to completely infill along those transects. The interpretation of channel full within this section of the reach had to be modified to account for this rise in bed elevation and reconnection of the channel to the out-of-channel area (Figure 16). In addition to the cross-sectional changes, in-filling of the channel led to a substantial reduction (−600%) in channel slope (Table 15).

On the upstream side of the reach, substantial change was observed on T11. The stream is eroding into the river left bank and depositing sediment on the river right side forming a point bar. Further

downstream, flood chutes were observed on river left downstream of T7 that flanked the left bank leading downstream past T1. Overall, the monitored reach at CHAT006 displayed the most change of the first-order streams between the two survey years. Considering the differences in the stream up- and downstream of the reach, it is hypothesized by the authors this reach will change considerably by the time the next survey is completed (scheduled for 2024).

There are no management concerns related to this reach. The changes observed are not creating conditions unsafe to visitors. Additional work related to understanding the flow regime, water quality, and in-stream biota is needed to determine how upstream conditions are influencing the water moving through this reach.

CHAT009—Fox Creek

CHAT009's watershed has low slope and relief and is mostly forested. Approximately 81% of the watershed is forested and 19% is developed (Table 5). The watershed draining to Fox Creek is the same size as CHAT003's watershed (0.51 square kilometers [0.20 sq mi]) and larger than the other three first-order watersheds (Table 4). CHAT009's watershed has the lowest entire stream gradient, the second lowest segment gradient, and the surveyed reach had the second gentlest channel gradient (0.0148 m/m; Table 15 and Figure 25). The reach slope at CHAT009 was virtually unchanged from 2017. CHAT009's watershed has the lowest basin relief ratio, the second lowest average watershed slope, and the third highest basin shape (Table 4). The geomorphic attributes (low slope and relief) coupled with the LULC characteristics of the watershed (high forest cover) suggest the stream does not have a flashy flow regime. But, the more circular basin (relatively high basin shape) may cause the flow regime of the watershed to be flashier than the low slope and relief would suggest. Gage data are needed to determine the actual discharge characteristics of the reach.

The reach surveyed on Fox Creek (CHAT009) is not likely to be visited by the public. While there is a trail within 40 meters (131.2 ft) of the creek (path on hillslope on river left) there are no defined trails near the stream reach. The GCUs observed within the reach during 2021 were substantially different than during the 2017 survey (+8% riffle, +20% run, and −28% pool; Table 6). Like the previously described first-order streams, there was a general shift to more homogenous in-stream habitat with pools being infilled and replaced with run habitat. There was a statistically significant coarsening (> 250% increase) of the mean diameter of bed material between the two survey years (Table 27). Like the other first-order streams, while there was a statistically significant increase in the mean diameter of bed sediment, the smallest size classes were finer.

The number of pieces of large woody debris increased from 3 to 9 pieces. Though the number of pieces of LWD increased, the reach still had a low volume of LWD per channel area (Table 9). This low volume per channel area is partially due to changes in the interpretation of channel full. As mentioned previously in this report, channel full interpretations were standardized along the reach to always measure to the highest ("historical terrace") surface. Increasing the channel full area (within which LWD are measured) greatly reduced the volume of LWD per channel area.

Based on the loss of GCU diversity, coarsening of bed sediment, and slight increase in LWD within the reach; CHAT009's in-stream habitat remained classified as "fair." This classification is a generalized interpretation of in-stream habitat and more 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 CHAT009. If the bed material at CHAT009 becomes finer and the GCUs within the reach become more homogenous, the habitat classification may degrade to "poor to fair." Alternatively, addition of more stable LWD to the reach may increase habitat diversity by developing step and pool sequences and provide more bed stability that could upgrade the classification to "fair to good" (Allan and Castillo 2007).

The defining characteristic of the reach is that it is in the process of widening via undercutting and slumping of the banks and is currently in stage three of channel evolution (Schumm et al. 1984). Like CHAT002 and CHAT003, multiple elevated entrenched surfaces were observed within the reach. During the 2017 survey, the tops of these elevated surfaces were interpreted as the channel full level. During the 2021 survey, it was clear these surfaces were in-channel and changed the survey crew's interpretation of diagnostic points. The inconsistency of the heights of these elevated entrenched surfaces was interpreted as evidence these surfaces are not stable. It is hypothesized that erosion along the toe of these EES causes continued slumping which increases the potential for vegetation to be stripped off the top of block; further exacerbating bank sediment loss.

The undercut at T6 was present during both surveys and will eventually fail. The two large trees being undercut may topple into the stream which would cause substantial changes. Undercut heights were approximately at the same height as the tops of the in-reach benches. While the reach had low sinuosity (Table 15), the coefficient of variation of thalweg position was relatively high (Table 11). The high CV of thalweg position indicates the stream is beginning to develop a meandering planform within the entrenched channel (Simon and Darby 1999).

There are no management concerns for this reach. The changes observed are not creating conditions unsafe to visitors. Additional work related to understanding the flow regime, water quality, and in-stream biota are needed to determine how upstream conditions are influencing the water moving through this reach.

CHAT012—Cabin Creek

CHAT012's watershed is steep and forested. Approximately 73% of the watershed is forested and 24% is developed (Table 5). The amount of development within CHAT012's watershed increased by 6% from 2016 to 2019 (Dewitz 2023). The watershed draining to Cabin Creek is approximately the same size as CHAT002's watershed (0.30 square kilometers [0.12 sq mi]), is smaller than CHAT003 and CHAT009's watersheds, and larger than CHAT006's watershed (Table 4). CHAT012 has the second lowest entire stream gradient, the third highest segment gradient, and the third highest reach gradient (0.0237 m/m; Table 15 and Figure 30). The reach gradient was virtually unchanged from the 2017 survey. CHAT012's watershed has the highest basin relief ratio, the highest average watershed slope, and the second highest basin shape (Table 4). Though CHAT012's watershed has high slope and relief, the low network entire stream gradient, average segment gradient, and relatively low reach slope indicate CHAT012 is in a relatively low energy portion of the network. Stormflow is likely to have less erosive potential in this portion of the stream than in steeper portions of the stream network, though gage data are needed to confirm this interpretation.

The GCUs at CHAT012 were more heterogeneous during the 2017 survey (50% riffle, 15% run, and 30% pool) than in 2021 (70% riffle, 28% run, and 2% pool; Table 6). This change in GCU follows the pattern observed at the other first-order streams (i.e., loss of pool habitats and an increase in run habitats). The mean diameter of bed sediment was also statistically significantly coarser in 2021 than in 2017 and the smallest sediment classes also got finer. These changes again could be related to the large storm event that influenced these streams immediately prior to the survey and the next scheduled survey (Summer 2024) will help provide an understanding of the long-term nature of this change.

The volume of LWD within the channel at CHAT012 nearly doubled, but the reach still had the lowest volume of LWD per channel area (Table 9) of all the first-order streams. Low levels of LWD, the introduction of fine bed sediment, and loss of pool habitat may indicate sub-optimal habitat conditions for benthic macroinvertebrates (Allan and Castillo 2007). The reach had fairly homogenous high energy GCUs and an influx of fine sediment, but the coarsening of the bed sediment and increased amount of LWD since 2017 led the authors to continue to classify CHAT012's in-stream habitat as "fair." This classification is a generalized interpretation of in-stream habitat and more 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 CHAT012. Habitat within the reach may degrade to a "fair to poor" rating if more fine sediment is added to the reach (potentially from a disturbance upstream or from the eroding adjacent trail) which further homogenizes the in-channel habitat. Conversely, if the diversity of habitat improves (possibly through the introduction of more stable LWD) and upstream conditions reduce the amount of fine sediment introduced to the reach, habitat may increase to "fair to good."

The defining geomorphic characteristics of CHAT012 were channel incision and the identification of multiple elevated entrenched surfaces. During the 2017 survey, an organic jam had created a step between T3 and T4. Between surveys, this jam broke and the sediment stored behind this temporary baselevel has migrated downstream, potentially between T1 and T3 (Figure 30). Just upstream of the area of channel incision, the stream continues to cut into the trail along the river left side of the reach (between T6 and T8). Since 2017, a small drainage has developed from the trail into the stream at T7 (Figure 26). It is hypothesized this small drainage has contributed to the creation of an elevated entrenched surface on T7 river left as the (drainage) saturated bank slumped into the channel. Drainage from the trail will continue to exacerbate erosion and further destabilize the trail at that location.

Erosion of the hiking trail is a management concern. Continued erosion along river left cutbank between T5 and T8 and disturbance of the out-of-channel area on river left by visitor use of the trail coupled with hillslope drainage across the trail and into the stream will eventually cause the stream to migrate into the hiking trail. While this issue could negatively impact visitors, any bank or trail management should be done sparingly as redirection of flow within the channel or from the hillslope could have unintended consequences that further exacerbate the situation.

Medium-Sized (Second-Order) Streams

CHAT004—"Crayfish Creek"

CHAT004's watershed has medium to high slope and relief and a high amount of development. Approximately 61% of the watershed is developed and 35% is forested (Table 45). Developed area within the watershed increased 4% between 2016 and 2019, while forested area decreased by 2% (Dewitz 2023). The watershed draining to "Crayfish Creek"' (1.39 square kilometers [0.54 sq mi]) is the second smallest of the second-order watersheds, behind only CHAT011 (Table 44). Compared to the other second-order watersheds, CHAT004's watershed has an intermediate entire stream gradient, the lowest segment gradient, and an average reach gradient (Tables 44 and 55). CHAT004's watershed has the lowest drainage density, the second highest basin relief ratio, the second highest average watershed slope, and a relatively low standard deviation of elevation (Table 44). Though CHAT004's watershed has the lowest drainage density, the other geomorphic characteristics (i.e., relatively high slope and relief), coupled with the high percent of development, suggest the stream likely has a flashy flow regime. Gage data are needed to determine the actual discharge characteristics of the reach.

The reach surveyed on "Crayfish Creek" (CHAT004) is likely not frequented by the public, but the park conducted a stream restoration effort just downstream of the monitored reach during early summer 2021. There is a trail within 10 meters (32.8 ft) of the creek (path on river left) and the area is readily accessible from the parking lot off the eastbound lanes of GA Highway 20. Since the 2017 survey, GCU diversity decreased as low energy pools had converted to higher energy habitat such as glides and runs. Riffle declined by 6%, run increased 20%, pools decreased 30%, and glide increased from being absent in 2017 to 11% in 2021 (Table 46). The mean diameter of bed material was the third most coarse of the second-order streams and was slightly (though not statistically significantly) coarser than 2017 (Table 47). While the coarse bed material is another indication the stream has a flashy flow regime, the smallest sediment classes were finer in 2021 indicating fine sediments are being introduced to and accumulating within the stream.

The monitored reach at "Crayfish Creek" had the lowest volume of LWD per channel area of the second-order streams during the 2021 surveys. A strong contributor to this low volume per channel area was a change in the interpretation of channel full in the lower portions of the reach, as channel full area increased. Despite the change, there were few pieces of LWD and most of the pieces were bridging the stream and not actively influencing in-stream habitat, like in 2017. Based on the loss of pool habitats, the introduction of finer sediments, and the low volume of LWD per channel area, CHAT004's in-stream habitat was downgraded from "good" to "fair to good." This classification is a generalized interpretation of in-stream habitat and more 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 CHAT004. Habitat at CHAT004 will return to "good" if the fine bed material moves out of the reach, LWD increases due to downstream transport, and/or habitat (GCU) diversity increases (Allan and Castillo 2007). Alternatively, habitat could downgrade to "fair" if GCU continue to homogenize, additional fine sediment is added to the reach, and LWD continues not to positively influence habitat creation.

The defining characteristics of "Crayfish Creek"' were the entrenched nature of much of the stream, the presence of multiple elevated entrenched surfaces, and the development of a massive cobble bar in the downstream portion of the reach (Figure 31). The cobble bar has grown on the river left side of the channel from T4 downstream to the bottom of the reach, extended outward past the middle of the stream channel. Deposition on this bar built it so high in the middle portions of the channel that a secondary flow path had developed against the river left bank behind the bar. As flow is diverted to this secondary channel, increased erosion of the river left bank could be a result. Throughout the reach, widespread bank slumping (and creation of elevated entrenched surfaces) and potential tree failure is likely due to the high, steep banks and the high occurrence of undercutting. The channel at CHAT004 has low sinuosity but also a consistently high CV of thalweg position which indicates the thalweg continues to try to establish a meandering pattern within the entrenched channel (Simon and Darby 1999). The incipient meandering has contributed to the construction of alternating (side) bars and elevated entrenched surfaces throughout the reach. The stream is widening via undercutting and slumping, evident by the presence of these elevated entrenched surfaces. As the stream continues to reestablish a meandering planform, lateral migration will become an important contributor to the amount of sediment produced by the reach.

There are no management concerns for this reach. The changes observed are not creating conditions that are unsafe to visitors. More work related to understanding the flow regime, water quality, and in-stream biota is needed to determine how upstream conditions are influencing the water moving through this reach.

CHAT005—"Egg Creek"

CHAT005's watershed is steep and forested. Approximately 84% of the watershed is forested and 13% is developed (Table 45). The watershed draining to "Egg Creek" is the smallest of the second-order streams (Table 44). Compared to the other second-order watersheds, CHAT005's watershed has the highest entire stream gradient, an intermediate segment gradient, and the second steepest reach gradient (Tables 44 and 55). CHAT005's watershed has the highest average slope, highest basin relief ratio, highest basin shape, and the lowest CV of slope (Table 44). The high watershed slope and relief coupled with the relatively round watershed (high basin shape) suggests the stream has a flashy flow regime. Conversely, potentially high infiltration rates (high percent forest cover) and lower landscape to stream network connectivity (low drainage density) likely reduces the flashiness of the stream. Gage data are needed to determine the flow characteristics of the reach.

The reach surveyed on "Egg Creek" is between two trails (on either side of the stream; Figure 36) and visitors have crossed the stream between T4 and T5 (Cooper 2021, personal observation). During the 2017 survey, the reach had a variety of GCUs with alternating riffle and pool sequences (representing 44% and 41% respectively; Table 46), but pool habitats were greatly reduced (−35%) during the 2021 survey. Higher energy GCUs (riffles, runs, and glides) were more prominent during 2021 (Table 46). The mean diameter of the bed material was slightly (though not statistically significantly) coarser than in 2017 and was finer than all the other second-order streams, excluding CHAT014 (Table 47).

The volume of LWD per channel area increased in 2021 (Table 49). Although pool habitat had converted to higher energy runs and glides, GCUs were still rather heterogenous. Based on the GCU,

bed sediment, and LWD within the reach, CHAT005's in-stream habitat remained classified as "fair." This classification is a generalized interpretation of in-stream habitat and more 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 CHAT005. If the bed material at CHAT005 becomes finer and/or the GCUs within the reach become more homogenous, the habitat classification may degrade to "poor to fair." Alternatively, addition of more stable LWD to the reach may further increase habitat diversity by developing more pool habitat and provide more stability to the reach that could upgrade the classification to "fair to good" (Allan and Castillo 2007).

The defining characteristics of the stream were the upstream migration of a knickpoint within the reach and the presence of alternating bars and elevated entrenched surfaces. McDonald et al. (2019) hypothesized that if the LWD step observed above T2 in 2017 were to break or be bypassed, a knickpoint would likely migrate upstream. This hypothesis was confirmed during the 2021 survey, as the LWD step at T2 had failed, leading to channel incision and headcutting up to another LWD step just downstream of T4. To add to this hypothesis, if the log step downstream of T4 fails, this knickpoint will continue to headcut and influence the reach. The presence of alternating bars and elevated entrenched surfaces are evidence the stream is establishing a meandering planform within the channel and is widening though bank slumping. Given the influence of headcutting and bank slumping within the reach, it's likely that this and similar streams are contributing a potentially large amount of sediment to the Chattahoochee River.

The hiking trail along river right passes near the stream between T4 and T7. Continued erosion, undercutting, and slumping of the river right bank will eventually lead to the trail becoming undermined. This is not an immediate concern but the integrity of this trail will be monitored during subsequent surveys. More work related to understanding the flow regime, water quality, and in-stream biota is needed to determine how upstream conditions are influencing the water moving through this reach.

CHAT008—Mulberry Creek

CHAT008's watershed has average slope and relief and is mostly covered by residential and suburban development. Approximately 64% of the watershed is developed and 34% is forested (Table 45), and the amount of developed land within the watershed did not change significantly between the survey years. The watershed draining to Mulberry Creek is smaller than CHAT010's and CHAT014's watersheds and larger than the other three second-order stream watersheds (Table 44). Mulberry Creek's watershed has the third highest drainage density. Compared to the other second-order watersheds, CHAT008's watershed has the third highest entire stream gradient, the fourth highest segment gradient, and the second steepest reach gradient (Tables 44 and 55). CHAT008's watershed has the third lowest basin relief ratio, the third lowest average watershed slope, and the third lowest basin shape (Table 44). The slope and relief of the watershed are average to below average which suggests the stream does not have a flashy flow regime. Alternatively, the high amount of development in the watershed and the high drainage density may contribute to a flashier flow regime than expected based on the other watershed characteristics. Gage data are needed to determine the actual flow characteristics of CHAT008.

Although there is a trail running nearly parallel to the stream about 40 meters outside of the river right bank, no visible evidence of visitors near the stream reach were observed. The pattern of change in GCU distribution was very similar to what was observed at the other sites, in that they had shifted to higher energy habitats. Riffle increased by 10%, run increased by 15%, and two instances of glide were observed during 2021 while none were observed in 2017 (Table 46). While the instances of pool habitat within the reach only declined by one, the mean percentage of pool dropped 37%. There was a statistically significant (+24%) increase in the mean diameter of bed material (Table 47). Every size class of bed sediment (D_5, D_{16}, D_{50}, D_{84}, and D_{95}) was coarser in 2021, though the minimum observed size was smaller (> 0.062, fine sediment).

The number of pieces of LWD within the reach increased and the volume of LWD per channel area increased (Table 49). The volume of LWD per channel area was the second highest of the second-order streams during 2021. While pool habitat was lost to higher energy habitats, there was still good heterogeneity in GCU distributions within the reach. Based on the increase in LWD, the relatively coarse bed material, and diversity of GCUs, in-stream habitat was again classified as "good." This classification is a generalized interpretation of in-stream habitat and more 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 CHAT008. Habitat at CHAT008 will continue to be "good" unless fine bed material is deposited within the reach, LWD is lost to downstream transport, and/or the loss of pool habitat persists and GCUs become more homogeneous.

During the 2017 survey, McDonald et al. (2019) observed the presence of multiple out-of-channel surfaces (i.e., floodplains, low terraces, and high terraces). These surfaces were observed during the 2021 survey and with a better understanding of Appalachian Piedmont streams, were interpreted differently. The defining characteristic of the reach is the presence of these elevated entrenched surfaces observed on alternating banks throughout the reach. These surfaces were identified as "low terraces" in 2017 (Figure 41) and were thought to represent the channel full height on a given bank. Now they are believed to be developing via bank slumping and widening and are below the channel full level and closer to bankfull. For that reason, elevated entrenched surfaces were interpreted as the bankfull level indicator on detailed transects 1 (T1; Figure 42) and 2 (T6; Figure 43). While the sinuosity of the reach is relatively low (Table 55) the CV of thalweg position was the highest of any second-order stream and had increased significantly from 0.47 to 0.78 (Table 51). This fact and the presence of the alternating bars, floodplains, and elevated entrenched surfaces indicates the stream is returning to a meandering planform inset within the high historical terrace (Simon and Darby 1999), which is now interpreted as channel full.

There are no management concerns related to this reach. The changes observed are not creating unsafe conditions for visitors. More work related to understanding the flow regime, water quality, and in-stream biota is needed to determine how upstream conditions are influencing the water moving through this reach.

CHAT010—"Beaver Creek"

Compared to the other second-order watersheds, CHAT010's watershed has average geomorphic characteristics (i.e., slope and relief) and is mostly covered by residential and suburban development. Approximately 75% of the watershed is developed, with Developed-Open and Low (mostly

residential) representing 66%, and 24% is forested (Table 45; Dewitz 2023). The amount of development within the watershed increased by 4% between 2016 and 2019, at the expense of forested land. The watershed draining to "Beaver Creek" is smaller than CHAT014's watersheds and is larger than the other four second-order watersheds (Table 44). CHAT010's watershed has the third lowest entire stream gradient the highest segment gradient, and the third steepest reach gradient (Table 44). CHAT010's watershed has the third lowest basin relief ratio, the second lowest watershed slope, the third highest basin shape, the third lowest drainage density, and the lowest standard deviation of elevation (Table 44). Though the watershed has a high basin shape and substantial development, the flashiness of the stream is likely attenuated by the low drainage density and watershed slope. Alternatively, the high segment gradient likely increases the likelihood of flashy flows in this portion of the stream network. Gage data are needed to determine the actual flow characteristics of this reach.

The reach surveyed on "Beaver Creek" is not frequently visited by the public, though residential areas are nearby just outside of park grounds. One of the original installed benchmarks was missing and appeared to have been removed by a visitor. While there is a trail within 50 meters (164 ft) of the creek (bike path on hillslope on river left) there are no defined trails near the stream. The habitat within the reach changed in a similar fashion to the other second-order streams as pool was lost to higher energy habitat such as run and glide. Run increased 13% and the number of instances increased twofold (n = 4 to n = 8). No glide habitat was observed during the 2017 survey, while 4 instances (mean percentage of 17%) were observed during 2021. The number of pools fell from 7 to 5 and these pools were smaller (−31% mean percentage; Table 46). While the change in GCUs indicates high-energy flows occur within the stream, there was still heterogeneity known to produce biodiversity within the stream (Allan and Castillo 2007). The mean diameter of bed material during the 2021 survey was the coarsest of the second-order streams. This mean diameter of bed material was statistically significantly coarser (+57%) than in 2017 (Table 47). Bed sediment coarsened in every size class excluding the minimum.

During both survey years, the reach had the most pieces of LWD (n = 12 in 2017, n = 16 in 2021; Table 49). The average volume of LWD per channel area also increased. While LWD was observed mostly in the lower half of the reach during the 2021 survey, it was better distributed than in 2017 (Figure 46). Given the distribution of GCUs, the high volume of LWD, and the coarse bed sediments, habitat at CHAT010 remains classified as "good." This classification is a generalized interpretation of in-stream habitat and more 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 CHAT010. Habitat at CHAT010 will likely continue to be "good" unless fine bed material is deposited within the reach (potentially from upstream disturbance), LWD decreases due to downstream transport, and/or habitat (GCU) diversity decreases (Allan and Castillo 2007).

The defining characteristics of the reach are the well-developed riffles (and associated increases in slope) and the presence of a longitudinally extensive floodplain which spans nearly the entire river left side of the reach. This floodplain surface was not initially interpreted as floodplain during the 2017 surveys, but evidence of deposition was observed during 2021. A point bar was also observed within the channel along the river-left floodplain between T7 and T2 (Figure 46). This point bar at the base of the floodplain at the inside of a meander serves as further evidence this surface is

developing through lateral migration processes. The possible migration of a downstream knickpoint into the monitored reach was observed in the longitudinal profile of the stream, though this knickpoint is not expected to migrate further into the reach due to the presence of the cobble riffles armoring the streambed. Overall, the monitored reach at CHAT010 was relative to 2017, with the major changes being bed material coarsening and further development of the floodplain.

There are no management concerns related to this reach. The changes observed are not creating unsafe conditions for visitors. More work related to understanding the flow regime, water quality, and in-stream biota is needed to determine how upstream conditions are influencing the water moving through this reach.

CHAT011—Gunby Creek

Compared to the other second-order watersheds, CHAT011's watershed has moderate slope and relief and is the least forested. Approximately 83% of the watershed is developed and 17% is forested (Table 45). The watershed draining to Gunby Creek is smaller than the other second-order watersheds except for CHAT005 (Table 44). CHAT011's watershed has the second highest entire stream gradient, the second highest segment gradient, and the third lowest reach gradient (Tables 44 and 55). CHAT011's watershed has the third highest basin relief ratio, an intermediate watershed slope, the lowest basin shape, and the highest standard deviation of elevation (Table 44). While the shape of the watershed will attenuate flood flows, the high entire stream gradient and relatively high watershed slope and relief coupled with the high developed cover suggest the stream has a flashy flow regime, though gage data are needed to confirm this interpretation.

The reach surveyed on Gunby Creek (CHAT011) is not frequently visited by the public. There is a trail within 10 meters (32.8 ft) of the creek (along sewage right-of-way on river left), but no defined trails to the stream. The amount of riffle remained similar within the reach between the two survey years, but changes were observed in other GCUs (Table 46). No instances of glide were observed in 2017, while four were observed in 2021 (mean of 28%). Unlike most of the other streams in this report, run decreased (−16%). Though instances of pool doubled (n = 3 to n = 6), the mean percentage of pool fell 17% indicating much smaller pools in 2021.

There was a statistically significant (+66%) coarsening of the mean diameter of bed material (Table 47). Bed material was the second coarsest of the second-order streams. However, the D5 and minimum size classes were much smaller than their 2017 values (Table 47). This fining in the smallest bed sediment classes indicates fine sediments are being contributed to the reach.

CHAT011 had no LWD within the reach during 2017, but nine pieces were measured during the 2021 survey (Table 49). This addition of LWD caused CHAT011 to have the highest volume of LWD per channel area of all the second-order streams (Table 49). Though the reach did have evidence of fine sediments becoming more prevalent, it still had relatively coarse bed sediment and a mixture of GCUs. The introduction of LWD to the reach since the previous survey is optimal habitat for improving conditions for benthic macroinvertebrates (Allan and Castillo 2007). Based on the distribution of GCU, mean bed sediment, and LWD within the reach, CHAT011's in-stream habitat was upgraded from "fair to good" to "good." This classification is a generalized interpretation of in-stream habitat and more 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 CHAT011. If fine sediments continue to be contributed to the reach (due to upstream input or through bank failures within the reach), habitat (GCU) diversity decreases, and/or LWD is transported downstream, it could be downgraded to "fair to good" or even "fair."

McDonald et al. (2019) identified the defining characteristics of the stream as a "longitudinally extensive floodplain along river right (T1–T5)" and the steep hillslope at river right upstream of T6. The steep hillslope on river right is still influencing the reach though little change was observed. In 2021, the survey team reinterpreted the "longitudinally extensive floodplain" as a large elevated entrenched surface related to rotational slumping of the bank away from the hillslope. Additionally, the "floodplain" area identified by McDonald et al. (2019) on river right near T6 was reinterpreted as an elevated entrenched surface and multiple surfaces were observed in this area related to the progressive development of these hypothesized rotational slumps. McDonald et al. (2019) also hypothesized that a meander neck cutoff (approximately 30 meters [98.4 ft]) downstream is immanent and could cause an increase in slope within the monitored reach. This neck cutoff still had not occurred by the time of the 2021 survey and the longitudinal profile and cross sections show aggradation within the reach. While aggradation had occurred between the two survey years, a large bar on river right of detailed transect 1 (T1) had been lost through erosion. The loss of this bar may exacerbate slumping of the elevated entrenched surface within that portion of the reach.

There are no management concerns related to this reach. The changes observed are not creating unsafe conditions for visitors. More work related to understanding the flow regime, water quality, and in-stream biota is needed to determine how upstream conditions are influencing the water moving through this reach.

CHAT014—Whitewater Creek

CHAT014's watershed has intermediate slope and low relief and is covered by a mixture of forest and residential and suburban development. Approximately 52% of the watershed is forested and 47% is developed (Table 45). The watershed draining to Whitewater Creek is larger than all other second-order watersheds (Table 44). CHAT014's watershed has the second lowest entire stream gradient, the third lowest segment gradient, and the lowest reach gradient (Tables 44 and 55). Compared to the other second-order streams, CHAT014's watershed has the third highest average watershed slope, the second lowest coefficient of variation of slope, the third lowest basin shape, the second lowest basin relief ratio, and an intermediate standard deviation of elevation (Table 44). Based on the relatively low relief and low network, segment, and channel slope, the stream likely does not have a flashy flow regime, though gage data are needed to confirm this interpretation.

The reach surveyed on Whitewater Creek (CHAT014) is not frequently visited by the public. While there is a road within 15 meters (49.2 ft) of the creek (on river left) the reach is upstream of the Whitewater Creek parking lot, is separated from the road by thick undergrowth, and there are no defined trails near the stream. There is a steep hillslope about 35 meters (114.8 ft) to the north (river right side) of the stream with residential areas on top. In 2017, the GCUs reflected very low energy habitats (76% pool) and only three instances of riffle (8%) were observed within the reach (Table 46). In 2021, pool had reduced to 34%, having been converted to higher energy run and glide habitat. The number of pools only decreased by one indicating that though pool habitat was available,

the pools have become smaller. Run was the most dominant GCU observed during the 2021 survey, having increased from 16% to 42%.

In 2017, the reach had few pieces of LWD (n = 2) and the lowest volume of LWD per channel area (0.0011 m^3/m^2; Table 49). Much more LWD was observed during 2021 (n = 12). Though there was more LWD, channel full area greatly increased due to an improvement in the interpretation of bankfull and channel full, causing the amount of LWD per channel area to decrease from 0.0011 m^3/m^2 to 0.0004 m^3/m^2. In both survey years CHAT014 had the lowest volume of LWD per channel area of all the second-order streams.

CHAT014 had the finest bed material of all the monitored second-order streams in both survey years. The fine bed material provides additional evidence for the interpretation that the reach does not have a flashy flow regime or there is a large upstream source of sediment. While there was a statistically significant increase in the mean diameter of bed sediment, the smallest size classes (minimum and D_5) were smaller in 2021 (Table 47).

The low volume of LWD per channel area, the high proportion of higher energy GCUs (run and glide), and the fine bed sediment are all indicative of sub-optimal habitat conditions for benthic macroinvertebrates (Allan and Castillo 2007). Based on these physical characteristics, CHAT014's in-stream habitat was again classified as "poor." This classification is a generalized interpretation of in-stream habitat and more 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 CHAT011. Habitat at CHAT014 will continue to be "poor" until GCUs become more heterogeneous, in-channel LWD further increases the diversity of habitat, and upstream conditions reduce the amount of fine sediment delivered to the reach.

The monitored reach at CHAT014 is far different from the other monitored second-order streams because it lies in a relatively flat plain adjacent to a roadway and is constricted by a downstream culvert. Its reach gradient is much lower than the other second-order streams which contributes to it being the most sinuous (1.45) of those streams. The defining characteristics of the stream are its high sinuosity, relatively small bankfull area, and presence of flood chutes that divert flow from the main channel in the upper portion of the reach. Occupation of the flood chutes during higher flows will reduce the amount of stress applied to the main channel downstream of these flood chutes during a storm event. The reduction of energy caused by this flow diversion may explain why the surveyed reach had the second smallest bankfull area of the second-order streams even though it has the largest watershed. The biggest change between the survey years was the SECN survey team modified their interpretation of bankfull and channel full to accommodate their better understanding of Appalachian Piedmont streams.

The team recognized the channel was fully connected to the surrounding flat area between the road on river left and the steep hillslope on river right. This entire flat area serves as the stream's floodplain and evidence of overbank flows were observed on the floodplain on both sides of the stream. This improvement in interpretation caused the channel full area to increase by more than 5 square meters (53.8 ft^2) and CHAT014 went from having the smallest channel full area in 2017 (2.84 square meters [30.57 ft^2) to third smallest in 2021 (8.43 square meters [90.74 ft^2]). Another

observation was fine and sandy sediments are being introduced to the reach from a gully in the adjacent hillslope. These sediments were deposited along the river right floodplain burying the river right detailed transect 2 benchmark by 0.19 meters (7.48 in) of sediment.

There are no management concerns for this reach. The changes observed are not creating unsafe conditions for visitors. More work related to understanding the flow regime, water quality, and in-stream biota is needed to determine how upstream conditions are influencing the water moving through this reach.

Larger-Sized (Third-Order) Streams

CHAT001—Haw Creek

CHAT001's watershed is approximately half the size of CHAT013's watershed (Table 88). Approximately 62% of Haw Creek's watershed is developed and 35% is forested (Table 89). Compared to CHAT013, CHAT001 has a steeper stream gradient at all measured scales (Tables 88 and 99). CHAT001's watershed has lower slope, slightly lower drainage density, equal basin shape, and a higher basin relief ratio (Table 88). Though the low basin shape (elongated basin) likely attenuates flood flows, the other geomorphic characteristics (specifically the high entire stream gradient) coupled with the high level of development suggest Haw Creek (CHAT001) has a flashier flow regime than Long Island Creek (CHAT013). Gage data are needed to confirm this interpretation.

The reach surveyed on Haw Creek is not likely to be frequently visited by the public. There is a social trail from the trail head at the bridge leading to the site (on river right), but it was grown over and no evidence of recent use (i.e., no footprints) during either survey. Glide and pool habitats were dominant in the upstream portion of the reach, while the downstream portion was dominated by run. The mid-channel island observed between T4 and T6 during the 2017 survey had aggraded and was larger (and higher) during the 2021 survey (Figure 61). Multiple areas of riffle had also developed in the vicinity of the mid-channel island.

Overall, in-stream habitat was heterogeneous with nearly equal amounts of riffle, run, glide, and pool (Table 90). The mean diameter of bed material was slightly coarser in 2021 and remained statistically significantly coarser than CHAT013. Like many other reaches, most of the bed material size classes at CHAT001 were relatively coarse, but the D_5 and minimum particle size classes have become finer (Table 91). The number of pieces of large woody debris was similar between the survey years, but bank erosion and changes in the interpretation of the bankfull and channel full level in the downstream portions of the reach caused the volume of LWD per channel area to decrease by an order of magnitude (Table 93).

The presence of riffle areas is generally indicative of a healthy environment with a diversity of habitats (Allan and Castillo 2007; Palmer et al. 2010), but the shrinking of pool habitat by conversion to more run and glide, and the addition of fine bed sediments, indicates pools within the monitored reach had been infilled by fine sediment. Based on the change in GCUs, fining of the smaller classes of bed sediment, and the decrease of LWD within the reach, CHAT001's in-stream habitat was downgraded from "good" to "fair to good." This classification is a generalized interpretation of in-stream habitat and more 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 CHAT001. The habitat classification at CHAT001 may be downgraded further (to "fair" or even "poor") if fine bed material continues to be deposited within the reach, or if LWD and GCU diversity continue to decrease. Alternatively, if the addition of stable (non-mobile) in-channel LWD enhances habitat diversity through the development of step and pool sequences and fine sediments are washed through the reach, habitat could rebound to "good" (Allan and Castillo 2007).

The geomorphic changes were the occurrence of severe bank erosion on river left on and around T2 and the continued development of the mid-channel island in the middle portions of the reach. At detailed transect 1 (T2) the river left bank had receded by approximately 5 meters (16.4 ft) since 2017 (Figure 62). At the base of the bank was a dark clay "bench" surface. It is hypothesized this "bench" surface is the prehistoric A-horizon as it extends upstream and downstream and into the river left bank. Additionally, it is hypothesized this layer acts as an aquitard allowing groundwater to preferentially flow along the contact between the historical overburden and this prehistoric ground surface. This preferential groundwater flow along the prehistoric surface coupled with this bank's location on an outside bend of the reach (where water pressure is greatest during stormflow events) would create zones of oversaturation in the historical overburden allowing failure planes to form and large chunks of bank to become detached as flood flows recede. The further development of the mid-channel island between T4 and T7 caused the stream to occupy two threads through that portion of the reach with developed riffles. Vegetation had begun to grow on top of this large surface indicating it is no longer regularly inundated. If this vegetation becomes strongly rooted, the island would be more protected from erosion and continue to develop.

No immediate management issues were identified within the reach. The changes to habitat indicate a general increase in the amount of fine sediment held within the reach. This fining of bed sediment could be due to increased supply from upstream development or simply a natural "complex response" of bed sediment due to upstream geomorphic change (Schumm 1973). The large loss of bank in the lower portion of the reach highlights the importance of understanding the processes that cause potentially large areas of episodic change.

CHAT013—Long Island Creek

CHAT013's watershed is approximately twice the size of CHAT001's watershed. The majority (65%) of the watershed is developed (high percentage medium and high-intensity development) and 34% is forested (Table 89). Compared to CHAT001, CHAT013's watershed has a gentler entire stream gradient, similar segment gradient, and a much gentler reach gradient (Tables 88 and 99). CHAT013's watershed has higher slope, a lower basin relief ratio, approximately equal drainage density, and equal basin shape (Table 88). While the watershed and stream network do not have a lot of relief, high slope, or high basin shape and the reach gradient is relatively low, the large amount of development within the watershed likely increases the flashiness of the flow regime affecting CHAT013. Gage data are needed to determine the flow regime influencing CHAT013.

The reach surveyed on Long Island Creek (CHAT013) showed evidence of visitors (e.g., trail on river right and footprints on floodplain and bar surfaces near T11) and the survey crews have interacted with park visitors at this site or seen visitors playing with pets in the stream. The hiking trail on river right (between T8 and T9) continues to be actively undercut by the stream (Figure 66).

Erosion of the trail was more pronounced in 2021 and there was evidence that visitors chose to avoid this precarious portion of trail by using a recently developed social trail further from the undercut bank.

Similar to other streams, GCUs shifted from riffle (−23%) and pool (−27%) to run (+44%) and glide (+11%; Table 90). No steps were recorded during 2021 because the area of steps in 2017 was buried beneath a very large tree fall and could not be safely navigated.

The mean diameter of bed material in 2021 was slightly coarser than 2017 and continued to be statistically significantly finer than CHAT001. As with many of the streams in this report, the D_5 and minimum particle size classes were smaller, indicating an increase in fine sediment being supplied to the reach (Table 91). The large root wad and section of bank lost when the tree fell are likely contributors to the increase in fines observed in the pebble count. Another potential contributor to the fining of the bed sediment is the bank erosion observed on river right where the social trail is being compromised.

The volume of LWD per channel area increased slightly though nine fewer pieces of LWD were observed in 2021 (Table 93). Note, volume per channel area in 2021 is an underestimate as the survey team was unable to safely measure the very large pieces of LWD that were the direct result of the T11 river left tree fall or captured from upstream.

Despite the addition of LWD that may become established and benefit macroinvertebrate biodiversity, the fine sediment deposition and shift to a run-dominated habitat led the authors to downgrade the habitat classification from “fair-to-good” to “fair.” This classification is a generalized interpretation of in-stream habitat and more 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 CHAT013. The habitat classification may be downgraded further if more fine bed material is deposited within the reach and GCU diversity continues to homogenize. Alternatively, if some stability is introduced to the reach (e.g., through the addition of stable (non-mobile) in-channel LWD), the fine sediment is flushed out, and GCU diversity increases, habitat could rebound to a better classification.

McDonald et al. (2019) observed the defining geomorphic characteristics of the stream in 2017 were the LWD steps between T9 and T11 and the high frequency of sand and gravel bars throughout the reach. During 2021, the steps were no longer present or covered by a massive tree fall and the bars had been mostly lost in the middle portion of the reach. The most defining characteristic was the T11 tree fall bank collapse event that caused substantial widening and loss of bank. The river left bank at T11 receded approximately 6.5 meters (21.3 ft) due to this tree fall event (Figure 70). Additionally, the tree fall, associated root wad, and block of bank sediment were deposited in the stream approximately 10 meters (32.8 ft) from river left. This massive log jam and mass of sediment has created a significant streamflow diversion, pushing flow directly into the river left bank further eroding the bank. While detailed transect 3 could not be measured due to safety concerns, a new BM3 was installed away from the eroding bank up on the lower terrace for future surveys.

The erosion of the bank near the social trail along river right is an immediate management issue. Based on the location of these eroding areas within the reach (along the outside bend of the stream), erosion is expected to continue and further impact visitors. The large loss of bank due to the tree fall on T11 highlights the importance of identifying large trees near park infrastructure in similar geomorphic positions that may catastrophically collapse and potentially impact visitor experience and safety.

Conclusion

The watersheds draining to the surveyed stream reaches at Chattahoochee River National Recreation Area range from small, mostly forested first-order watersheds to large, mostly developed third-order watersheds. Based on the geomorphic and land cover characteristics of the watersheds, five of the watersheds (first-order: CHAT003; second-order: CHAT004 and CHAT011; third-order: CHAT001 and CHAT013) likely have a flashy flow regime and five watersheds likely have a moderately flashy flow regime (first-order: CHAT002 and CHAT009; second-order: CHAT005, CHAT008, and CHAT010). The remaining three watersheds (first-order: CHAT006 and CHAT012, second-order: CHAT014) likely have less flashy flow regimes because they have lower slope/relief and or low amounts of development. Stream gage data are needed to confirm these interpretations of each watershed's flow regime.

The surveyed streams are developing along an expected trajectory related to land use legacies of poor agricultural practices. The streams are in Stage III or early Stage IV of channel evolution (Schumm et al. 1984) and are experiencing widening via cutbank erosion, undercutting, and bank slumping (Figure 1). The rate at which bank collapse and widening through slumping is not yet fully understood and more research is necessary to determine the pace at which these streams are approaching a new equilibrium. Additionally, tree fall and related bank collapse influence the rate at which these streams are widening. Similar processes have been observed in SECN monitored streams at Kennesaw Mountain National Battlefield Park and Horseshoe Bend Military Park (Bateman McDonald 2020; McDonald 2020).

Pool habitat was replaced by run and glide habitat at many of the monitored reaches, regardless of stream order. Mean bed sediment particle sizes were higher in most streams, indicating a potential shift to higher energy flows. While mean bed sediment particle size increased in many streams, there was also a concomitant fining of the smallest bed sediment classes at nearly all the monitored reaches. This trend in fining of the smallest classes and with overall coarsening suggests that higher energy flows are influencing these reaches, but there is also an increase in fine sediments being supplied to these reaches. The presence of LWD within the monitored reaches continues to influence the shape of the streambeds and contribute to habitat diversity. In many cases, LWD served to dissipate energy and trap fine organic material or sediment that would otherwise be transported downstream creating jams and step/pool sequences (Allan and Castillo 2007).

Based on the GCUs, bed sediment particle sizes, and LWD characteristics of the surveyed stream reaches, in-stream habitat was classified as "good" for three streams (CHAT008, CHAT010, and CHAT011), "fair to good" for three streams (CHAT001, CHAT002, CHAT004), "fair" for five streams (CHAT003, CHAT005, CHAT009, CHAT012, CHAT013), and "poor" for two streams (CHAT006 and CHAT014). Only one stream classification was upgraded (CHAT011), while four were downgraded (CHAT001, CHAT002, CHAT004, and CHAT014) and classifications for the remaining eight streams did not change. These classifications are generalized interpretations of in-stream habitat and more work is needed to determine how flow regime (e.g., flashiness of flow and baseflow conditions), water quality, and in-stream physical characteristics affect the biodiversity and stream health. Overall, habitat classification for each reach may improve if: (1) there is an increase in

stable (non-mobile) in-channel (non-bridging) LWD, (2) there is a reduction in fine sediment delivered to the reach, and/or (3) habitat (GCU) diversity increases. Conversely, habitat may degrade if: (1) LWD is transported out of the reach, (2) there is an increase in fine sediment added to and stored within the bed of the stream, and/or (3) habitat diversity decreases due to the previous two mechanisms.

In addition to recovering from a legacy of poor land use practices, all the streams are influenced by varying amounts of impervious surface cover and urban/suburban development in their watersheds. Given the interpreted flashy nature of the streams' stormflow regimes and the occurrence of substantial precipitation events within the days prior to the 2021 surveys, it is possible some of the observed changes were short-term. The general shift toward run-dominated GCUs and the fining of the smallest bed sediment classes could be a temporary change directly related to increased contributions of fine sediments in-filling pool habitats and the interstitial areas of the riffles sampled for the pebble counts. More research is needed to determine the influence different sized precipitation events have on the mobilization, transportation, and storage of fine sediments in these streams.

Infrastructure (hiking trails) continues to be threatened by erosion on two of the monitored reaches (CHAT012 and CHAT013). Cabin Creek, CHAT012, is eroding into a hiking trail on river left of the monitored reach and Long Island Creek, CHAT013, is eroding into a hiking trail on the river right side of the stream. Large areas of erosion were observed at both third-order streams. The left bank in the lower portion of CHAT001 had receded nearly 6 meters (19.7 ft) since 2017 potentially due to the interaction between groundwater and the historical overburden. The left bank in the upper portion of CHAT013 had also receded nearly 6 meters due to a recent tree fall event. The data collected on these reaches will be helpful to determine the rate at which these portions of stream are eroding and will help determine the effectiveness of any management actions taken.

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Appendix A. Explanation of Variables

Table 108 contains information about the variables collected using the SECN Wadeable Stream Habitat Monitoring Protocol.

Table 108. Explanation of variables collected by the SECN Wadeable Stream Habitat Monitoring Protocol (McDonald et al. 2018) including the scale at which each is collected.

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.
Pebble Count	Reach	The size and distribution of 100 particles (pebble count) from a representative riffle (Wolman 1954).

[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 108 (continued). Explanation of variables collected by the SECN Wadeable Stream Habitat Monitoring Protocol (McDonald et al. 2018) including the scale at which each is collected.

Variable	Variable Scale	Description
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
In-channel features	Transect [A]	A description of the in-channel features (e.g., bars or islands) that are present 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 108 (continued). Explanation of variables collected by the SECN Wadeable Stream Habitat Monitoring Protocol (McDonald et al. 2018) including the scale at which each is collected.

Variable	Variable Scale	Description
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 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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