Developing Large Woody Debris Budgets for Texas Rivers

by

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INTRODUCTION

Large woody debris (LWD) has been shown to be an extremely important structural and functional component for aquatic ecosystems in the lower coastal plain of the Southeast (Wallace et al., 1993). Benke et al. (1984) found that while LWD habitat may only be a small part of the total habitat surface in these types of rivers (~4%), it may support over 60% of the total invertebrate biomass for a river stretch. In addition, these researchers found that fish species obtained at least 60% of their prey biomass from snag habitat. Consequently, management practices that alter LWD dynamics may have dramatic effects on aquatic ecosystem productivity.

While the importance of LWD to ecosystem structure and function in the Southeast is widely accepted, very little empirical information exists on actually quantifying LWD biomass and dynamics in the Southeast (including Texas). A great deal of work has been done in the Pacific Northwest, particularly as related to endangered and threatened salmonids. Lacking such statutory motivation, fewer resources have been allocated to the Southeast. However, rapid population growth in recent years coupled with greater demands on limited water resources has generated concern about the health and viability of Southeastern river systems. This necessitates developing a LWD budget for Southeastern rivers to quantify possible management effects on LWD dynamics. Furthermore, little work has been conducted on developing woody debris budgets where inputs, outputs, and transformations are quantified over various instream flow regimes.

Owing to the critical nature of woody debris for aquatic ecosystems, it is imperative that woody debris budgets be evaluated in order to ensure that healthy populations of aquatic life are maintained in Texas rivers.

This report summarizes results from Texas Water Development Board Contract 0604830632. For a complete description of proposed project methodology, see the Scope of Work (SOW) for this contract. This report is organized according the 10 tasks outlined in that SOW.

TASK 1 – LITERATURE REVIEW

Task Description – Examine the scope of scientific literature that exists on LWD measurement, analysis, modeling, and decay. This first task will be important for determining specific areas where gaps currently exist in the state of the knowledge in LWD, specifically as related to Southeastern Coastal Plain streams.

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LITERATURE REVIEW

Biological Significance

Large woody debris is important to many biological factors and to overall forest health, especially within sensitive riparian zones (McClure *et al.*, 2004). Ecologically, LWD provides many important aspects for stream systems. It provides a reservoir for nutrients and energy vital to the detrital food chain, nutrient cycling, plant growth, and productivity (Harmon *et al.*, 1986; Muller and Liu, 1991; Huston, 1993; Goodburn and Lorimer, 1998). Stable debris can slow down the transport of fine organic matter allowing greater opportunity for biological processing of fine organic detritus (Swanson *et al.*, 1976). Invertebrates and aquatic insects utilize LWD for egg deposition, a direct and indirect food source, attachment sites for feeding and retreat or concealment, material for larval cases, and a substratum for pupation and emergent sites (Wallace *et al*., 1993). In the northwest, numerous studies have documented the biological, hydraulic and structural importance of LWD in high gradient, lower order headwater streams (Marzolf, 1978; Bilby and Likens, 1980). In these high gradient streams, LWD plays a minor role in providing habitat formation in the main channel as the stream order increases (Keller and Swanson, 1979), with a reduction of LWD with increasing stream orders (Minshall *et. al*., 1983). In the low gradient (0.01 – 0.02%) streams throughout the lower Gulf Coastal Plain however, LWD appears to play a major role in habitat formation in high order streams (Cudney and Wallace, 1980; Benke *et al*., 1984). Thorp *et al*. (1985) reported rapid colonization of woody substrates introduced into tributaries of the Savannah River, with most species reaching steady states within one week. Filter feeders are drawn to LWD as a stable substrate, while gathering invertebrates are attracted to the epixylic biofilms, which develop in stream woody debris as a food source (Couch and Meyer, 1992). The colonization of filterers and gatherers becomes a food source for invertebrate predators, which in turn provide a food source for vertebrate predators. Along the Satilla River (mean Q: 87 m^3/s, gradient: <.0001) sandy substrate along the main channel, muddy substrate of backwaters and submerged LWD along the outer banks comprise the main invertebrate habitat. LWD contributed only 4% of the available habitat, but contained 60% of the total invertebrate biomass and 16% of production. LWD supported greater taxonomic diversity with 63 invertebrate taxa residing on wood, compared to only 31 taxa in sandy substrate that encompassed 85% of the available habitat and 41 taxa in muddy substrate that encompassed 9% of available habitat.

Furthermore, 78% of drifting invertebrate biomass originated from LWD and comprised at least 60% of prey consumed by four of eight major fish species sampled (Benke *et al*., 1984). Benke and Wallace (1990) found the wood biomass of 6.5 kg/m^2 in the sixth order Ogeechee River (mean Q: 67.7 m^3/s, gradient: < 0.0002), and 5.0 kg/m^2 in the fourth order Black Creek (mean Q: < 45 m^3/s, gradient: < 0.003) was similar to first and second order streams in other regions, but was consistently lower than streams in the Northwest. The in-channel debris surface of the Ogeechee River and Black Creek was 0.249-0.433 m^2/m and 0.191-0.379 m^2/m, respectively, depending on the stream stage. These areas provide sites of high invertebrate diversity with an invertebrate density of 6.6 g dry mass/m^2 of debris surface, which results in at least 1.82 g of invertebrate biomass/m^2 of channel bottom (Benke and Wallace, 1990). Similar to other southeastern studies, Benke and Wallace (1990) found that LWD is preferentially located towards the outer bank, where outer bank erosion is believed to deliver most of the woody debris to the channel (Keller and Swanson, 1979). In the Ogeechee River and Black Creek LWD provides a fairly stable habitat compared to the fine grain sandy substrate typical of streams in the lower Gulf Coastal Plain. In contrast, the sixth-order reach of the Little Tennessee River, other sources of stable substrate were available along with LWD, such as the dense growth of the aquatic macrophyte, *Podostemum ceratophyllum* covering the cobble substratum of the river. Here, invertebrate abundance and biomass were significantly greater on the *Podostemum* than on LWD (Smock *et al*., 1992).

The biological role of LWD varies in accordance to the manner in which it affects stream processes. Invertebrate communities can vary greatly depending on stream size, depth, cross-sectional area, discharge, gradient and the availability of inorganic substrate.

In smaller, high gradient low order streams, LWD more drastically changes the physical stream structure, which causes the invertebrate community to adapt to food resource availability and physical environmental factors. LWD can enhance a stream's ability to process and conserve nutrient and energy inputs by offering habitats to filtering collectors who utilize suspended organic particles provided by the current, and are the major invertebrate functioning group found inhabiting in-stream debris. For example, in high gradient Appalachian streams at Coweeta, North Carolina, channel depth and width increase and velocity decreases upstream of added LWD jams, which results in increased heterogeneity of the stream channel substrate composition as sand, silt and organic matter is deposited over cobbles and riffles. The increase sedimentation from decreased velocity at Coweeta resulted in a significant decrease in filtering and scraping invertebrates and an increase in gatherer invertebrates and trichopteran and dipteran shredders, along with an increase in predators at the LWD sites relative to cobble and riffle areas (Huryn and Wallace, 1987). In contrast, low gradient, small coastal plain headwater streams showed an increase in all functional invertebrate groups, with the exception of gatherers in response to LWD jams (Smock *et al*., 1989). The debris jams provided the only stable habitat in this sandy bottom stream. Dolloff (1993) found that when LWD was removed, the result would be a loss of pool habitat, lower number and size of fish, and a loss of biomass in both warmwater and coldwater fish.

Effects on Hydraulics

LWD, including trees, snags, and logjams, have been shown to influence stream morphology (Shields and Nunnally, 1984; Mutz, 2000; MacDonald et al. 1982).

Nunnally and Keller (1979) found that standing riparian trees play a vital role in slowing down the bank erosion process (Figure 1).

Figure 1. Tree roots supporting the bank at the Bon Wier on the lower Sabine River, Texas on July 14, 2008.

From his studies, Mutz (2000) found that wood in natural quantities results in complex patterns of different flow regimes. Keller and Swanson (1979) add that tree root wads in a hardwood forest were found to protect a length of bank five times the trunk diameter.

The hydraulics of stream river systems is in a perpetual state of dynamic fluctuation as the flow of energy is distributed through the drainage basin, shaping the channel morphology. Removing debris from streams increases current velocity next to banks and reduces the amount of materials that can provide protection to the bank. This causes an acceleration of bank erosion and a wider channel (Nunnally, 1978). Also, woody debris helps control river gradient. Abbe et al. (2003) reported that clearing wood from the Red River in Louisiana caused portions of the river to incise more than 4 m. LWD provides additional roughness and resistance (Shields and Gippel, 1995) as it redirects the flow of water, slowing velocity, increasing depth, creating backwaters, local scour and various types of pools (Robison and Beschta, 1990). The number of morphological structures such as bars are also increased because of the presence of LWD (Keller and Tally, 1979; Harmon *et al.*, 1986). Because of the additional flow resistance created by the addition of LWD in the stream system, there can be a net increase in sediment storage, changes in bed texture, and changes in sediment transport (Smith *et al.,* 1993). These combined factors have the ability to change the local and reach-average hydraulic conditions, which may affect channel bank stability (Bilby, 1984; Trimble, 1997).

This change in hydraulic conditions exerted by LWD is dependent on the local hydraulic conditions, geometry and orientation of LWD, density and spacing of LWD and its relative size to the flow depth (Shields and Gippel, 1995). Beven *et al.* (1979) found that when debris is large in relation to flow depth, the roughness coefficient is abnormally high (Gippel, 1995). The channel shear stress (T_o) is a function of the density of water (ρ), gravity (g), hydraulic radius (R) and the slope of energy gradient (s). T_o is portioned between various components that each have a particular roughness element

(Einstein and Banks, 1950), including total grain stress available for sediment transport (T_{GS}), bed form stress (T_{BF}) and stress due to LWD (T_{LWD}). As the density of debris increases, T_o increases in response to the increased water depth. T_{LWD} increases more rapidly, so there is a net decrease in T_{GS} as debris is added to the stream (Manga and Kirchner, 2000). In this study the effect of T_{BF} was ignored because of the stable and uniform nature of the channel, but in other systems that have irregular bed form, T_{BF} can provide a substantial fraction of the flow resistance (Hey, 1988).

The force (F) per unit area of a piece of LWD immersed in a uniform flow with velocity V will be:

$$\frac{F}{A} = \tfrac{1}{2}\,\rho\, C_D V^2, \tag{1}$$

where A is the cross-sectional area of LWD perpendicular to flow and C_D is the drag coefficient of LWD. This drag coefficient depends on the Reynolds number, Froude number, and the shape and orientation of LWD (Magna and Kirchner, 2000). Shields and Gippel (1995) found that C_D is also dependent on the blockage ration (β), defined as the ratio of the obstruction area to cross-sectional flow area (β = H/h ; where H = mean diameter of debris and h = mean water depth). The blockage affect from LWD will alter its drag coefficient (C_D) from that of a cylinder in a flume ($\mathrm{C_{Dc}}$) by a relationship of (Gippel *et al.*, 1992):

$$\mathrm{C_{Dc}} / (1-\beta)^2 = C_D, \tag{2}$$

Magna and Kirchner (2000), on the Cultus River in Oregon, used field measurements to calculate the relative contribution of LWD to the reach-average total stress. The hydrogeomorphic properties of the Cultus River make it behave like a large natural flume. The Cultus is spring fed with a near constant discharge (Q) with a steady uniform flow, has a stable gravel bed, rectangular channel cross section, and a large width to depth ratio which simplified the analysis because the effect of LWD on channel morphology can be neglected. Here, LWD covered less than 2% of the surface area of the stream and provided about half (47%) of the total flow resistance (Magna and

Kirchner, 2000). This value was obtained assuming a uniform flow and energy grade slope, $C_D = 1.1$, $V = 0.36$ m/s $\beta = 0.56$, H/L = 0.017 where H is the diameter of debris, L is the average spacing between debris, and the hydraulic radius was equal to the mean water depth. Manga and Kirchner's study was to relate theoretical results to actual field measurements. Overall, they found that the LWD in the channels resembled cylinders in a rectangular flume, and were therefore not surprised when the drag measurements were similar to those of cylinders in steady, uniform flow. In the end, they were able to conclude that the relationship between theory and field work provides a convenient mathematical framework for the initial assessment of LWD input and loading.

Large Woody Debris Input

Because of the significance of large woody debris, it is important to know how it enters the river system. The interaction between the stream and the surrounding area cause the vegetative condition of the riparian zone to have a great influence on the recruitment of LWD (Hedman *et al*., 1996; Bragg and Kersner, 1999; Blinn and Kilgore, 2001; Ehrman and Lamberti 1992). A substantial amount of literature has been written on research that has reported on LWD origins. The amount of LWD in a stream system reflects a balance between numerous inputs and outputs (Keller and Swanson, 1979). In some cases it can be extremely difficult to determine exactly where the debris originates from and only estimates can be made, but in other cases it can be fairly simple (i.e., seeing the snapped tree still on the bank or noticing the bank undercutting that has taken place). O'Connor and Ziemer (1989) identified 6 LWD sources while studying the Caspar Creek watershed in Mendocino County, California. These include bank erosion, windthrow, logging debris, wind fragmentation, landslide, or an unknown source. They go on to state that windthrow and bank erosion were the dominant LWD sources.

Figure 2. Wind-throw at the Southern site on the lower Sabine River, Texas on August 18, 2008.

Other lists of LWD recruitment add forest death, mass wasting, tree decay, and stream transport (Keller and Swanson, 1979; Spies *et al*., 1988; Van Sickle and Gregory, 1990). Swanson *et al*., (1988) found that differences in geomorphology around their study site made for distinct differences in debris input into the stream. Another study found that in upland streams with relatively stable channel courses, the primary sources of woody debris were dead trees falling and storm blow-downs (Figure 2). For the meandering, low-gradient systems of the Coastal Plain, most of the wood originated from large trees that fell into the streams as erosional banks were undercut (Figure 3) (Benke and Wallace, 1990; Benke, 1984).

Figure 3. Bank erosion resulting in large woody debris input at the Deweyville site on October 19, 2007 on the Lower Sabine River, Texas.

Areas with a higher slope were found to have more tree mortality, which led to more woody debris input. Swanson *et al.* (1976) state that streams in narrow, steep walled valleys tend to receive more LWD because the pieces may land directly in the creek or on the hillslopes and then slide into the stream. Land with less slope (i.e., floodplains) had lower mortality and input. They attributed the higher mortality rates of the areas with more slope to increased velocities of the river during floods (Malanson, 1993). The Southern Coastal Plain LWD that enters the streams tends to be very episodic.

Hurricanes that hit the areas tend to blow down many trees at once instead of the trees entering the stream at spread out intervals (Phillips and Park, 2009). These events do not occur at regular intervals, so studies need to be conducted over decades (Wallace *et al.*, 1993; Putz and Sharitz, 1991; Sharitz *et al.*, 1992). Another process that adds large amounts of debris to a river system is large floods. In Golladay and Battle (2005), a Gulf Coastal Plain 5th order stream had most tree recruitment occurring during years with substantial floods. Palik *et al.*, (1998) found that record flooding in southwestern Georgia killed a large number of stream-side trees which added a large amount of LWD into the stream. Without periodic large floods, woody debris would still make its way into the streams. Over long periods of time normal mortality puts more LWD into the streams than infrequent large disturbances, but large disturbances still account for a lot of debris and are vital to southern streams and rivers (Harmon and Hua, 1991).

Benda and Sias (2003) developed a quantitative framework for evaluating wood abundance within river systems. To develop the budget they accounted for the definable inputs and outputs, storage times for LWD, and material fluxes over time and space. They defined the mass balance of LWD in a unit length of the channel as a consequence of the differences in input, output, and decay. The overall change in storage (ΔS_c) is a function of the length of a reach (Δx) over the time interval (Δt). L_i is defined as lateral recruitment of LWD within the reach, while the loss of wood (L_o) is due to overbank depositions in flood events or the abandonment of jams. Q_i is the fluvial transport of wood into the reach and Q_o is the transport of wood out of the reach. The loss of wood due to decay (D) is the last variable to be defined of the overall function:

$$\Delta S_c = [L_i - L_o + Q_i / \Delta x - Q_o / \Delta x - D]\,\Delta t, \qquad (3)$$

Benda and Sias (2003), also developed more specific functions that define wood recruitment into a given study reach:

$$L_i = I_m + I_f + I_{be} + I_s + I_e, \tag{4}$$

where I_m is the forest mortality, I_f is the toppling of trees after a fire or during a windstorm, and I_{be} is the recruitment due to bank erosion. They go on to define I_s as the wood brought into the system because of landslides, debris flows, and snow avalanches, and I_e as the exhumation of buried wood. Although some of these variables do not necessarily apply directly to the lower reaches of the Sabine (i.e., landslides and snow avalanches), it is still important to note what other studies of LWD have found in different parts of the United States. Benda and Sias (2003) further developed a function that defines wood recruitment based on chronic forest mortality only:

$$I_m = [B_L M H P_m]\, N, \tag{5}$$

where I_m is the annual flux of LWD. They define B_L as the volume of standing live biomass per unit area, M as the rate of mortality, H as the average stand height, P_m as the average fraction of stem length that becomes in-channel LWD, and N as the number of banks contributing LWD.

Bank Erosion

One of the biggest contributors of LWD is bank erosion. In many regions the greatest amount of in-channel debris is found on the cutbank side of the river (Wallace and Benke, 1984), and that is why the equation developed by Benda and Sias (2003) for bank erosion is applicable to the Sabine River. Hooke (1980) found that the resistance of stream banks to erosion is based on two factors that include particle size of the bank material and reinforcement by streamside trees' roots. Bank erosion is common during periods of flooding and can cause large amounts of debris recruitment in a short time (Keller and Swanson, 1979; Murphy and Koski, 1989). Simons and Li (1982) found that the weight of trees can sometimes contribute to the failure of undercut banks. LWD jams can also be a cause of bank erosion because of the water that gets diverted around it, and that is why the importance of erosion should vary strongly with position in a channel network and with flood frequency (Benda and Sias, 2003). The undercutting of banks is one of the most effective ways to get large, stable trees with intact root wads into streams (Swanson *et al*., 1976). Hooke (1980) also found that bank erosion generally increases as the channel size increases. The function used for LWD recruitment due to bank erosion is expressed as:

$$I_{be} = [B_L E P_{be}]\, N, \qquad (6)$$

where B_L is the standing biomass, E is the mean bank erosion rate, and P_{be} is the expected stem length of the debris that falls into the channel.

Mass Wasting

Because the lower reaches of the Sabine River do not experience landslides, debris flows, or snow avalanches as recruitments of LWD, this study will not define each variable reported by Benda and Sias (2003). But it is still important to note that these three variables have been shown to recruit debris into other stream systems. The importance of wood recruitment because of mass wasting depends on several variables. The first one is the type and area of the landslide or avalanche, second is the age and size of trees recruited, third the number of landslide or avalanche sources intersecting a stream channel, fourth the frequency of mass wasting events, and last the fraction of debris that is deposited into the channels. When a few or all of these variables come together (i.e., When there is wood available for transport and a mass wasting event large enough to transport them), the transported pieces of debris have an opportunity to make it into the stream channel. At the same time though, if there is no LWD or too small of an event, then the debris would not get transported into the stream.

Transportation

In relatively wide river systems like the Sabine, large amounts of debris can result from instream transportation of wood. Most wood that is transported has a length that is shorter than the width of the river (Lienkaemper and Swanson, 1987; Nakamura and Swanson, 1993; Seo and Nakamura 2009). Transport distances can also be limited by obstructions such as debris jams (Likens and Bilby, 1982). The transport of wood may be affected by the power of a stream, diameter of the logs, piece orientation, and the presence of a root wad (Abbe and Montgomery, 1996; Braudrick and Grant, 2000; Thibodeaux and Boyle, 1987). Swanson *et al.* (1976) state that a variety of mechanisms can move LWD within a stream system, including extreme flood events and everyday decay which eventually leads to the breakup of the debris. Other studies show the same results, that larger floods cause most of the debris input into the river system, and although the floods are infrequent and unpredictable they still contribute large amounts of debris (Golladay and Battle, 2005). Benke and Wallace (1990) found that periods of moderate flooding cause a net increase in woody debris. Because there are so many variables that go with the transportation of woody debris, the formula is quite comprehensive:

$$Q_w(x, t) = [L_i(x, t) \quad ø(x) \quad \xi(x, t)], \tag{7}$$

where Q_w is the volumetric wood transport rate at a cross-section (x) in year (t). L_i is defined as the average rate of lateral recruitment, ø is the long-term proportion of all recruited LWD that have less length than the width of the channel, and ξ is the transport distance of a mobile debris piece. In order for a stream to move a piece of debris it depends on the force of the water, the size of the channel, and the size of the debris (Swanson *et al.*, 1976). Debris on relatively wide rivers such as the Sabine is more readily transported, as long as individual pieces do not get caught in a debris jam.

LWD Decay

The decay of LWD limits the amount of time that it will spend within a stream system. Previous studies show that it will lose 2 to 7% of mass per year (Spies *et al.*, 1988). The pieces of LWD that are within the stream channel will break down into moveable pieces because of the force of the stream (Benda and Sias, 2003). Bilby *et al.* (1999) found that submerged wood decayed at a 2 to 3% rate, depending on the tree species. Harmon *et al.* (1986) developed an equation for wood decay:

$$D(x,t) = k_d S_s, \tag{8}$$

where k_d is annual decay loss and S_s is the storage of living and dead wood in a landslide area. The study goes on to show that loss of mass creates loss of strength, which breaks up the LWD into smaller pieces. The smaller pieces have a harder time getting caught in jams and usually exit the stream as a floatable piece.

Surrounding Forest

An understanding of the surrounding forest is an important aspect to the LWD input within a system because LWD is a product of the surrounding forest (Andrus *et al.*, 1988; Swanson *et al.*, 1976; Maser et al., 1988; Reinhardt et al., 2009). One study on a

5th order Gulf Coastal Plain river found a correlation between debris recruitment and the land surrounding the river. It was found that the greatest rates of recruitment were observed on sand ridges, then low terraces, and lastly on floodplains. In addition, landforms with more constrained stream valleys contributed more debris than floodplains (Golladay and Battle, 2005). The steep slopes around the Cascade streams caused the most input of wood into the streams, apparently caused by wind blowdowns (Lienkaemper and Swanson, 1987). Evans *et al*. (1993) found that greater amounts of LWD were found in streams that were surrounded by old growth forests. They recognized that the old growth forests had more potential debris that could enter the stream and the size of the debris was larger. Because the larger pieces of debris decompose at slower rates, the LWD within the system have a tendency to be there for longer periods of time. The forested area surrounding the stream that Evans *et al*. (1993) studied is much like the Sabine in that the area was previously devoid of woody vegetation. Because of this they found that the streams contained ten times less wood than older native forests. A well-developed understanding of the surrounding ecology is needed for the lower Sabine River region to truly understand how LWD enters the river (Figure 4 and 5).

Figure 4. Forest surrounding the Sabine River at the Burkeville site on July 21, 2008.

Figure 5. Forest surrounding the Sabine River at the Deweyville site on December 19, 2007.

LWD Loading

Once the woody debris is within the system’s channel it has several places that it can go. It can be transported down stream, get caught in a debris jam, or be pushed back out of the channel. A lot of debris has been found to end up in jams (Figure 6), which then play an important role in stream morphology and ecosystems (Shields and Nunnally, 1984). Transient wood from upstream, broken branches, and wood from surrounding swamps are what Benke and Wallace (1990) found make up debris accumulations. LWD is generally transported downstream by large flood events and it is during this time that it is most likely to get caught in jams. Debris pieces have a greater chance of getting jam associated than coming to a stop throughout the inter-jam space. Because not all jams span an entire width of a river, especially in larger rivers, not all pieces will get caught within a debris jam. The ones that do get caught will stay associated with that jam until they decay enough to free themselves and be further transported down the river (Benda and Sias, 2003) or a large enough flood can push them out of the jam.

Figure 6. Large woody debris jam on the Southern site on the lower Sabine River, Texas on August 18, 2008.

In a study on a small British Columbia stream Fausch and Northcote (1992) found that pool volume was greater in areas of the stream where LWD was stuck in a jam as compared to areas where no jams were located. The jam-created pools may then provide the most available pool habitats for macroinvertebrates and other species (Nunnally and Keller, 1979). Local channel widening, deposition, and midchannel bars have been noted immediately downstream from a jam (Keller and Swanson, 1979). Debris jams have a tendency to occur when a single large event inputs several pieces of debris at the same time (Swanson *et al*., 1976). Although it would be next to impossible to be able to tell where each debris jam originated from on the Sabine, it is highly likely that a few occurred during Hurricane Rita in 2005 whose path led almost directly up the Sabine. Golladay and Battle (2005) found that closely monitoring tropical storms and their causes will give a good indication of when large amounts of debris will enter a river system. They found that cyclical variations in climate result in periodic pulses of wood debris entering rivers.

Although some information is known about debris jams, the manner in which they accumulate is not fully understood (Abbe and Montgomery, 1996). On a second-order woodland stream in Germany, Mutz (2000) found no debris jams in the stretch of stream that he was studying, even though larger pieces of debris was present. He attributes the lack of jams to the subdued hydrological regime of the stream. He noted that the larger wood pieces were stable and could not accumulate into a structure that would capture smaller floating pieces of wood. The presence of debris jams is most likely due to site-specific reasons and cannot be categorized by one single universal cause.

Alphanumeric Classification of LWD

Montgomery (2008) devised a way to categorize LWD into an alphanumeric code. Montgomery proposed that if all LWD had a standardized classification then comparisons between surveys and regions could be achieved. Assumptions could then be able to be made about the LWD, such as lower classified pieces (smaller LWD) would tend to float and be carried downstream, while higher classified pieces (larger LWD) would be more stable and help contribute to a log jam. He went on to say that this classification, along with information on the channel size, would allow researchers to get an idea on how the woody debris would affect channel morphology. Furthermore, researchers would be able to predict which categories would be “key pieces” or the ones that would affect a given stream the most.

The classification system is broken into seven categories for length and seven categories for diameter, totaling 49 discrete classes of LWD (Table 1). LWD length would get put into a lettered class code of A-G, and wood diameter would get a class code of 1-7.

TABLE 1. Proposed size classes and codes for the length and diameter of wood debris.

Wood length letter code and classes (m)	Wood diameter numeric code and classes (m)
(A) 0 to 1	(1) 0 to 0.1
(B) 1 to 2	(2) 0.1 to 0.2
(C) 2 to 4	(3) 0.2 to 0.4
(D) 4 to 8	(4) 0.4 to 0.8
(E) 8 to 16	(5) 0.8 to 1.6
(F) 16 to 32	(6) 1.6 to 3.2
(G) > 32	(7) > 3.2

(Montgomery, 2008)

Summary

A great amount of research has been performed on the importance of large woody debris to stream ecology. The importance of LWD is now more realized and understood and practices detrimental to LWD such as clearing and snagging must take this importance into account. What is now needed is a better understanding of the LWD's role in larger Coastal Plain rivers, because it is probable that LWD plays a vital role in larger river systems as well.

TASK 2 – CONCEPTUAL MODEL OF LWD DYNAMICS

Task Description - Develop a conceptual diagram of estimated pathways of large organic woody debris through a watershed. Use field work and literature sources to refine the conceptual model.

Figure 7 gives a basic visual diagram of LWD dynamics in riverine systems.

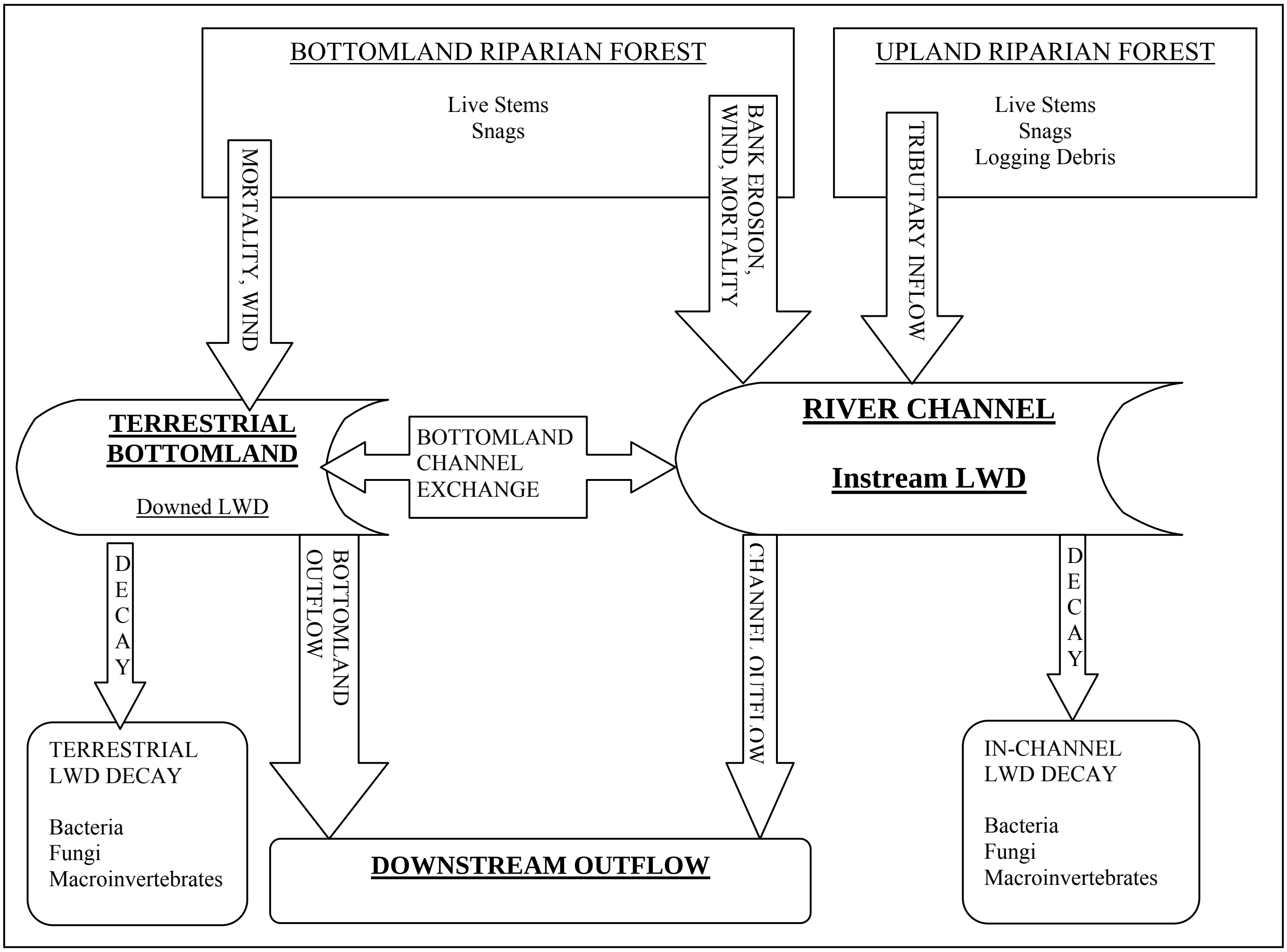

Figure 7. Basic visual model of large woody debris in Southeastern rivers.

This basic visualization can be further expounded conceptually with a quantitative framework described by Benda and Sias (2003). This was included in the Literature Review section under the sub-heading "Large Woody Debris Inputs". The basic relationship as summarized by Benda and Sias (2003) is as follows:

$$\Delta S_c = [L_i - L_o + Q_i / \Delta x - Q_o / \Delta x - D]\ \Delta t \qquad (9)$$

Where:
ΔS_c = change in woody debris storage
Δx = reach length
Δt = time interval
L_i = lateral recruitment of LWD within the reach
(L_o) wood loss due to overbank depositions in flood events or the abandonment of jams
Q_i = fluvial transport of wood into the reach
Q_o = transport of wood out of the reach
D = loss of wood due to decay

See Task 1, Literature Review for further details on each of these variables. See Observed Data and Conceptual Model section in Task 10 Report of Research Findings, for Sabine River budget calculations.

TASKS 3 AND 4 – LWD MEASURING TECHNIQUES

Task 3 Description - Test sampling, measuring, and tracking techniques at three mainstem test sites described above. In addition to LWD tagging, other measurements that will be recorded include estimates of the number, volume, tree type, and volume of logs in each study unit. A photographic record will be kept to show changes over time.

Task 4 Description - Investigate criteria for test plot selection in bottomland, tributary, and mainstem areas. Set up mainstem sites and use them to evaluate techniques as described in Step 2. As time permits, set up bottomland and tributary test plots and evaluate data collection methods for these areas.

From: Ringer, M.S., Characterizing large woody debris dynamics in the lower Sabine River, Texas. M.S. Thesis, Stephen F. Austin State University, May 2009 149 pp.

METHODS OF STUDY

Study Site

This study utilized four different sites along the Sabine River (Figure 8). Three sites were originally proposed, with remeasurements of these sites following large discharges. However, due to the study time constraints and the difficulty in coordinating pre- and post flow measurements with large discharges (with low flows following for accurate measurement), a better methodology was employed to answer the questions about woody debris recruitment rates. Following Hurricane Rita in 2005, the Sabine River Authority removed all bankside woody debris for a few river miles above the southeast Texas intake canal. This site, denoted the Southern site, was used to measure the amount of time required for woody debris to return to pre-snagging densities. Field work on the amount of LWD began in Fall 2006 and continued throughout the Summer of 2008.

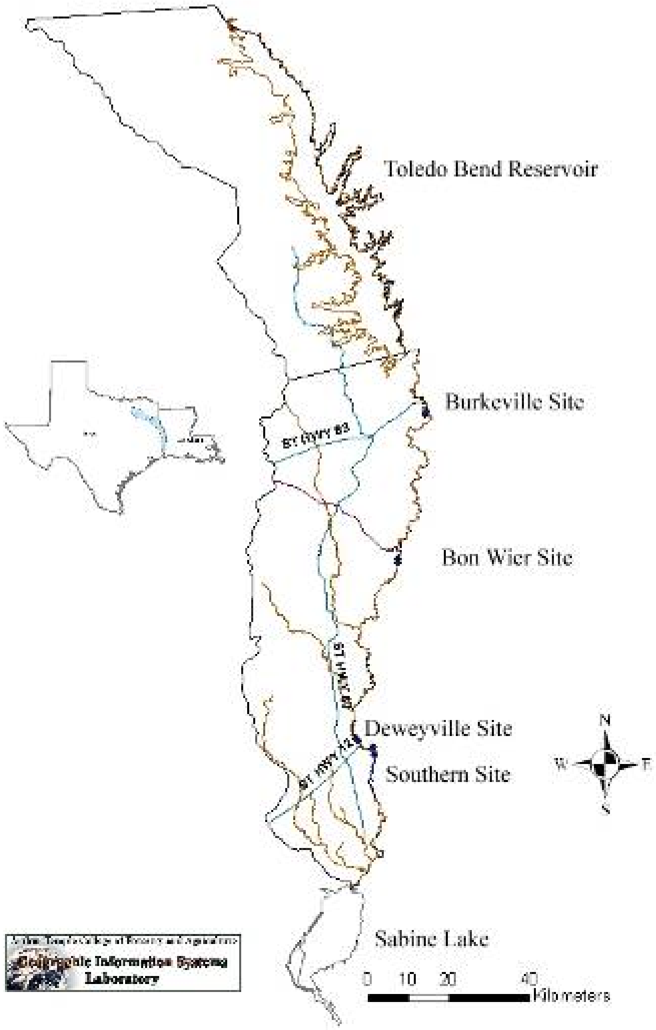

Figure 8. Four sampling sites located on the lower Sabine River in Texas.

The lower Sabine River, below Toledo Bend Reservoir, establishes the boundary between Texas and Louisiana. The total drainage area of the Sabine River is 25,267 km^2 and the area has a humid subtropical climate lying in the Gulf Coastal Plain physiographic province (Phillips, 2003). The soils surrounding the river were mostly light-colored, fine, sandy loams with subsoils that contain loamy sand to plastic clay in texture and yellow to red in color (Figure 9).

Figure 9. Sand bar on the lower Sabine River, Texas.

The vegetation was mostly composed of pines with a hardwood understory. Much of the surrounding land had previously been cultivated and is now used for pasture or has been reforested, either naturally or by planting (Phillips, 2003). All four study sections were located on the lower Sabine River (Figure 8), south of Toledo Bend.

Previous studies conducted on the lower Sabine River found that due to the almost regular daily discharge of water from the reservoir, the lower Sabine had been affected little by the impounding of the upper portion of the river. At the portion of the river near Burkeville, Texas there was evidence of bank erosion, input of large woody debris, and sandbar migration. Evidence in the area also showed that the floodplain was continuing to accrete, which indicated a normal river balance. Further downstream at the

Bon Wier site, the area had abundant amounts of woody debris, eroding banks, and tilted trees that could be potential future woody debris. Evidence was also found of a downstream migration of a large sandy point bar. At a third site near Deweyville, sandbars were found that were actively prograding, tilted trees, large amounts of LWD at the bank base and in the channel, and undercut live trees on the bank (Phillips, 2003).

The three un-snagged sites were chosen based on the low human disturbances in each section. Homes were spread along the entire length of the Sabine, and it was essential to pick three sites that did not have a house situated within the study section. The most southern of the three un-snagged sites was located near Deweyville, Texas (30°18’94”N, 93°44’68”), 2.24 kilometers north of the Highway 12 bridge (Figure 11). This site was characterized by low banks usually ranging from 0-10 feet, with active cutbanks and migrating sand bars (Figure 10).

The middle site was located near Bon Wier, Texas (30°42’57”N, 93°37’10”W), 5.21 kilometers south of the Highway 190 bridge (Figure 13). The Bon Wier site had slightly higher banks than the Deweyville site, and it also contained active cutbanks and migrating sand bars (Figure 12).

Figure 10. Characteristic Deweyville site on the lower Sabine River, Texas.

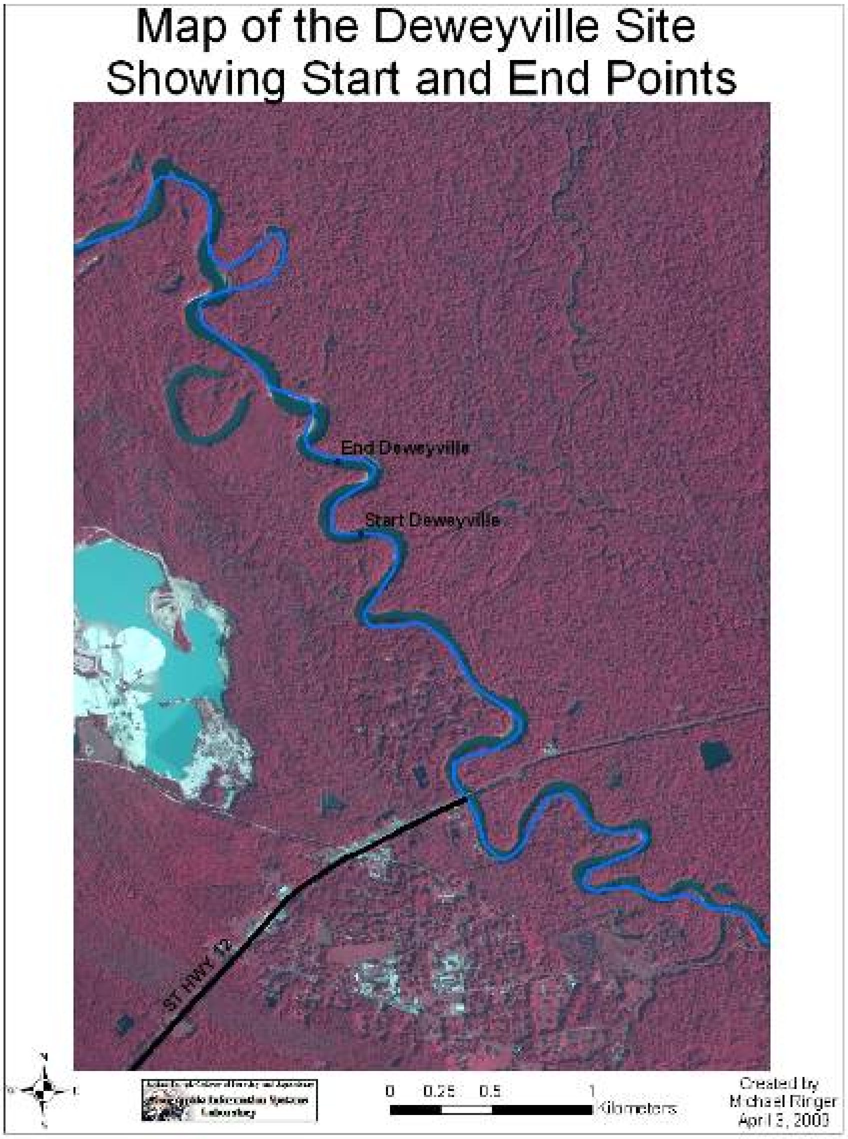

Figure 11. The Deweyville woody debris sampling site on the lower Sabine River, Texas

Figure 12. Characteristic Bon Wier site on the lower Sabine River, Texas.

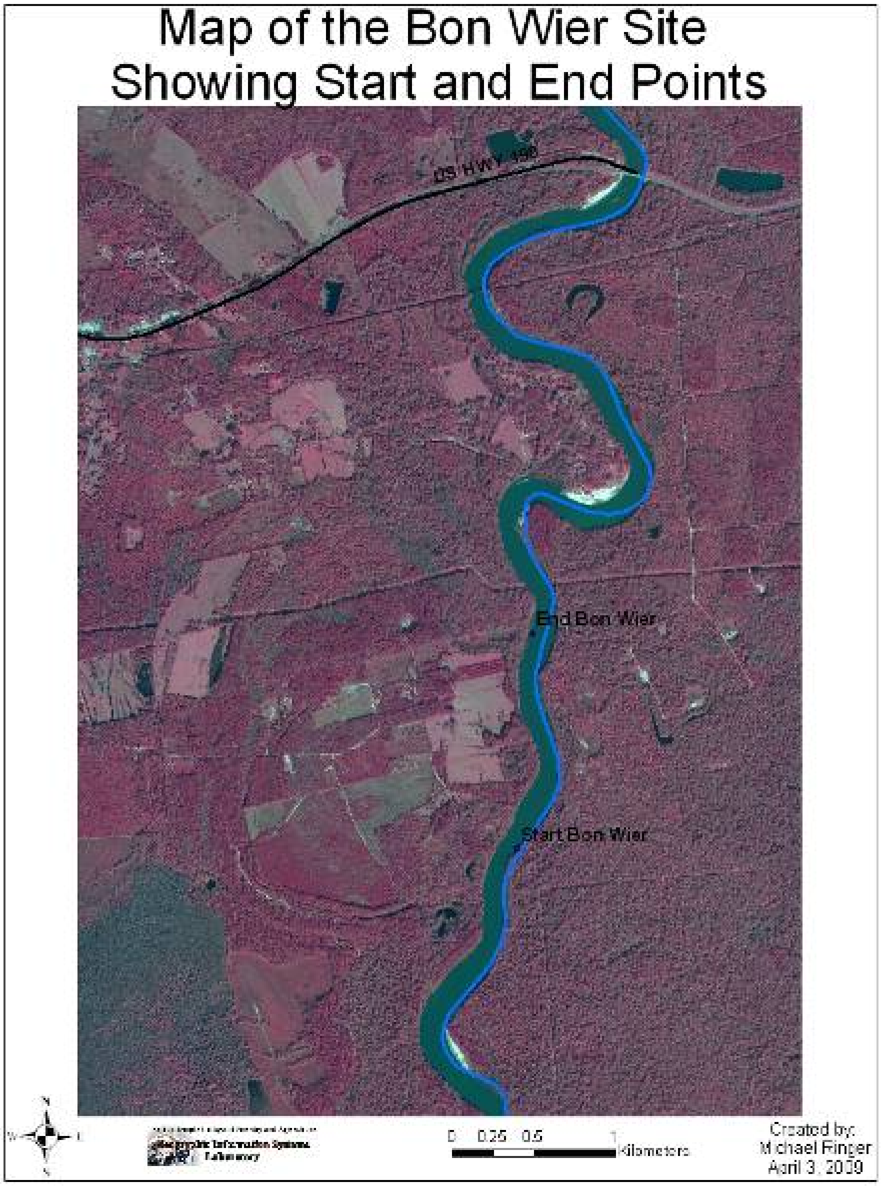

Figure 13. Map of the Bon Wier site on the lower Sabine River, Texas.

The most northern site was located near Burkeville, Texas (31°2’67”N, 93°31’21”W), 3.68 kilometers south of the Highway 63 bridge (Figure 15). The Burkeville site was most unique in that its cut banks could be as high as 30 feet tall. As with the other two sites it contained active migrating sand bars and also had cutbanks, which leads to LWD input (Figure 14). The lower Sabine had LWD in large amounts of its stretches so there was not much concern about choosing a specific site based on its amount of LWD.

Figure 14. Characteristic Burkeville site on the lower Sabine River, Texas.

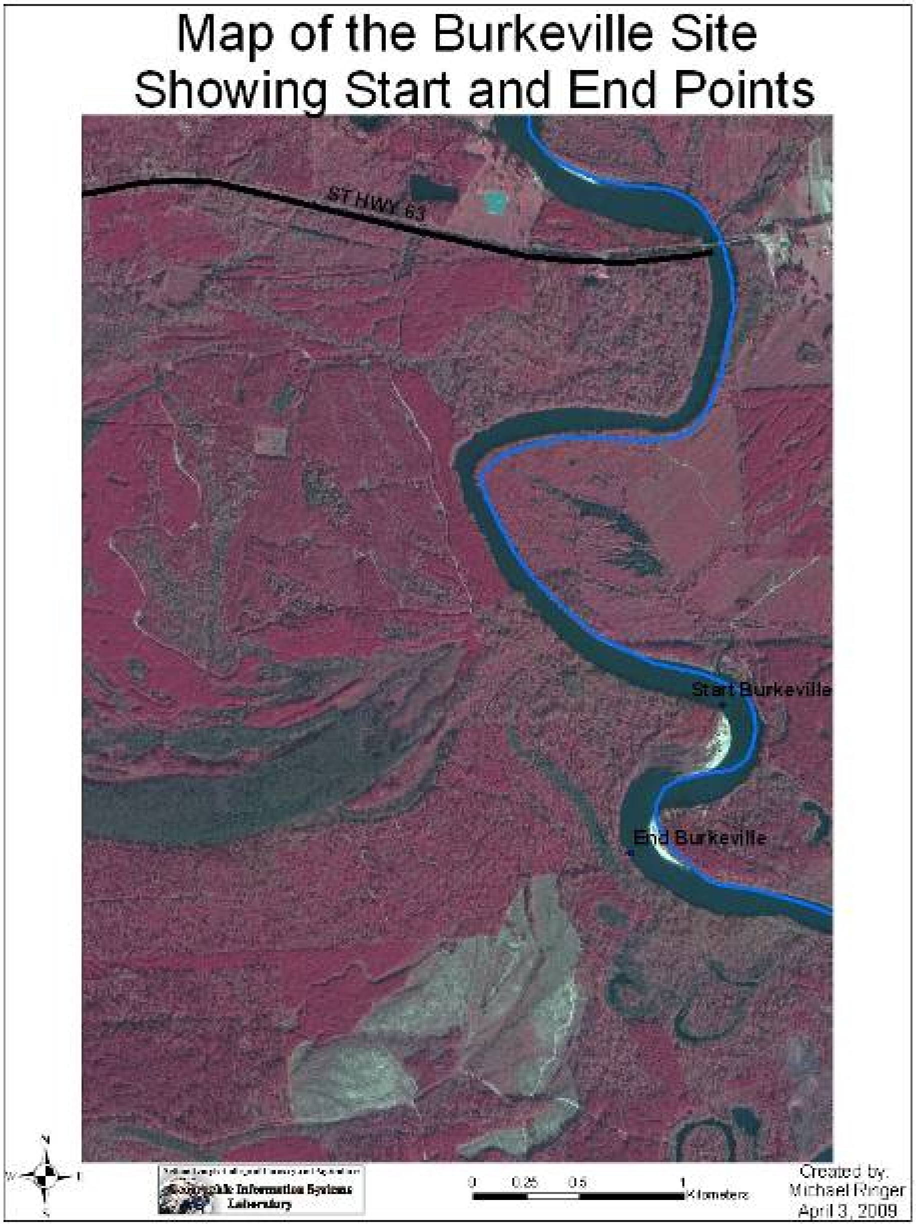

Figure 15. Map of the Burkeville site on the lower Sabine River, Texas.

An additional site, the Southern site (30°16’87”N, 93°42’37”W), was located 8.86 kilometers south of the Highway 12 bridge and 2.29 kilometers north of the river split (Figure 17). Different from the other three sites, the Southern site was snagged following Hurricane Rita in 2005 (Figure 15). This site provided a good indication of how long it took for LWD to be replenished in the Sabine.

Figure 16. Characteristic Southern site on the lower Sabine River, Texas.

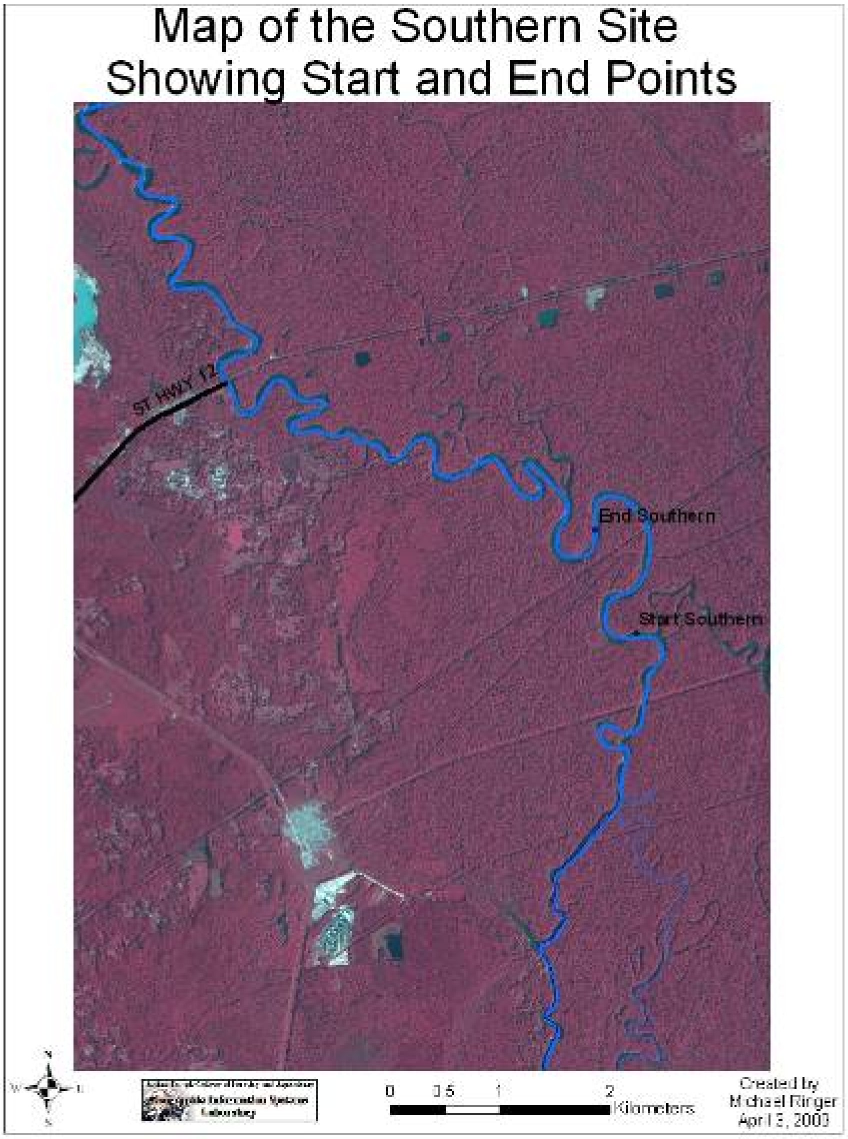

Figure 17. Map of the Southern site on the lower Sabine River, Texas.

Field Methods

Data and samples were collected the same way at each of the four study sites. The most ideal time to study LWD was when the river was low enough to find a high percentage of LWD. Flow rates of the Sabine were regulated by the Toledo Bend Reservoir throughout the year (Table 4). Under non-flooding summer power generation schedules, water was released Monday through Friday and then shut off for the weekends when power demand was lower. Due to this baseflow regimen, the best days to sample for LWD was early in the week. As water levels rose many pieces of LWD were submerged and measurement was not possible. Prior to sampling, river stage was evaluated from United States Geological Survey (USGS) gauging stations. For Burkeville and Bon Wier, sampling would only be conducted when the gauge height was around 4.5 m (15 ft) or below. The Deweyville and Southern site would be sampled if they were around 6.1 m (20 ft) or below. Each piece of LWD was located either in the channel of the river or on the bank that had a minimum diameter of 10 cm and a minimum length of 2 m. Each piece was tagged with a specific number using a numbered metal tag, hammer, and nails. The number on the metal tag was recorded on the data sheet and was used to identify the piece during the measurement phase and for possible future measurements. The same number was then spray painted on the log using weather-proof spray paint (Figure 18).

Figure 18. Tagged and painted LWD.

Log length and top and butt diameters were then measured with a tape and recorded. The species of the LWD was identified when possible, but identification was often difficult on highly decayed specimens. When species could not be determined, unknown was recorded on the data sheet. The level of decay was selected based on five categories (Table 2). An indicator of 1 meant that no sign of decay was visible on the piece, all bark and branches were intact. An indictor of 2 meant that the piece was intact but the twigs were absent. An indictor of 3 indicated only traces of bark were left on the wood. The fourth indicator meant that the bark was absent with some holes and openings and the wood was darkened. The last category would indicate that the bark was absent and the wood was irregularly shaped and was darkened.

TABLE 2. Degree of decay classes of LWD.

Degree Class	Characteristics
I	Bark intact, twigs present
II	Bark intact, twigs absent
III	Only traces of bark, with abrasions
IV	Bark absent, some holes, wood darkened
V	Bark absent, irregular shape, wood

Next, bank orientation was determined. A bank orientation of 0° meant that the root wad was facing upstream and the LWD was parallel to the bank; a bank orientation of 90° indicated the log was perpendicular to the channel; and a bank orientation of 180° indicated the LWD was facing downstream. Then, the presence of a root wad was noted with a yes or no, as well as the presence of branches. Identification of LWD origin was attempted but was not always possible. The categories for origin were local riparian, upstream import, and non-determinable. Identification of the potential source was also attempted and classified as windthrow, windsnap, cut, and non-determinable. The origin and potential source was sometimes difficult to determine. If insufficient information was available, a non-determinable was marked on the data sheet. It was then noted if the LWD was an individual piece, jam-associated, or a fallen tree. Figure 19 shows two common ways the LWD was distributed. Often, wood was found in a jam, where one relatively large piece causes many others to get caught. Finally, each LWD was classified into a stage contact zone. A category for zone 1 indicated that the piece was sitting in a low flow contact area, zone 2 indicated that it was within the bank-full channel, zone 3 indicated that it extended over the bank full channel, and zone 4 indicated that LWD was beyond the bank-full channel.

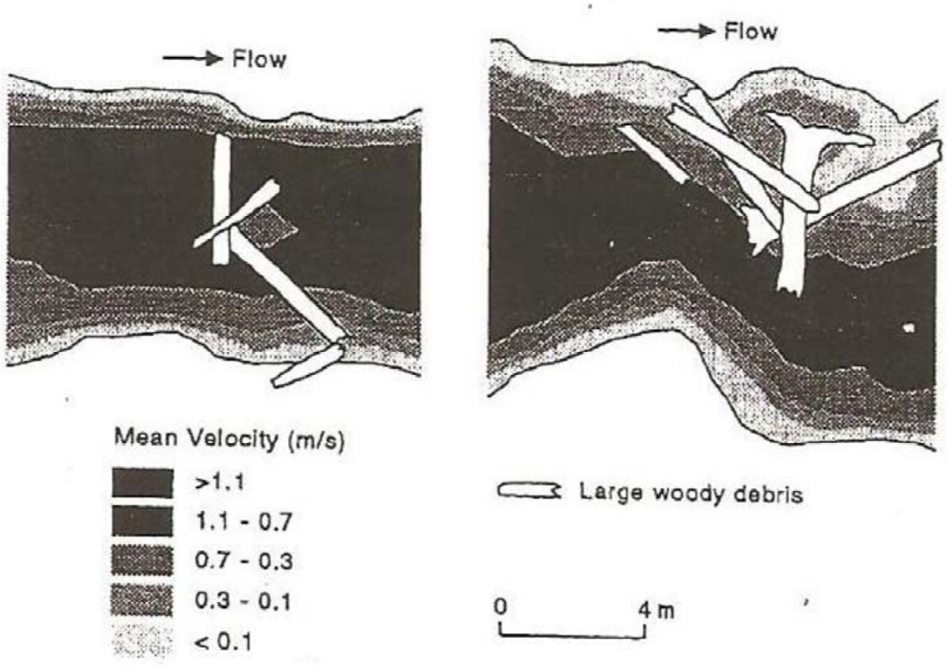

Figure 19. Common LWD distributions (Gippel, 1995).

For every piece of LWD, a sub-sample was collected and placed inside of a plastic bag marked with its identifying number. An increment borer was used to collect samples, but a handsaw, chainsaw, or hatchet was used to remove a sample when the corer failed (Figure 20). While the increment borer provided a more representative sample throughout the log, it did not work well with fully saturated wood, since the samples would swell in the borer, making it impossible to extract the sample without oven drying. All collected samples attempted to represent both inner and outer parts of the tree, to ensure different parts of the wood were collected. Most LWD locations were then marked with a Magellan GPS unit and a picture of the piece was taken. However, GPS coordinates often were not accurate enough for precise location within each jam or even reach, so these data had limited utility.

Figure 20. Using a handsaw to acquire LWD sample at the Southern site on the lower Sabine River, Texas.

Bankside Vegetation

An inventory was performed of the bankside vegetation at all four sites to determine the total volume of standing timber. Plots 0.04 ha and 0.004 ha in size were inserted one chain (about 20 m) from the bank on both the West and East banks of all three sites. In the 0.004 ha plots, all LWD top and bottom diameters, length, and the distance from the bank were measured and recorded. In the 0.04 ha plots, all trees with a minimum of 10 cm diameter at breast height (DBH) were recorded. DBH, total tree height, and distance from the bank were measured and recorded. Instruments used for both set of plots were a tape measure and a diameter tape. Stand tables were constructed using the United States Department of Agriculture Forest Service Research Paper SE-293, titled “Stem Cubic-Foot Volume Tables for Tree Species in the Deep South Area (Clark and Souter, 1996). The Girard Form Class for the pines was 81 and for the hardwoods was 79.

Sample Analysis

Each LWD sub-sample was brought to the lab and wet mass was measured. It was then oven-dried at 105° C to a constant mass. The piece was then reweighed and the dry mass was recorded. Percent moisture of each sample was then found by:

$$[(\text{wet mass} - \text{dry mass}) / \text{wet mass}] \times 100.$$

Each sample piece was then sealed in paraffin wax. The paraffin wax helped to hold together the pieces of wood that showed high amounts of decay. It also prevented volumetric changes when determining sample volume by water immersion. After the piece was dipped in wax it was reweighed to get its weight after waxing.

Due to the irregularities of each piece, a simple volume calculation (length x width x height) would not suffice. Instead, after coating each piece with wax they were immersed in water to determine displacement. The amount of water displaced was then measured resulting in volume, based on Archimedes Principle. A dish was used to catch overflow, a 1000 ml beaker for the fill container, a graduated cylinder to measure the water overflow, a metal probe for inserting the sample, and lastly a wash bottle to slowly get the water level to its maximum level in the fill container. The fill container was placed inside of the overflow dish and filled to the rim. The wash bottle was used to slowly raise the water to the very top of the container, just shy of breaking the water's surface tension. The metal probe was inserted into one sample piece and inserted slowly into the water. The water in the overflow dish was then poured into a graduated cylinder and the sample's volume was recorded in milliliters. It was possible to then find each sample's density using:

mass / volume.

Using the mass of each sample after it had been dipped in wax was important because of the changes the wax made to the mass of each piece. Because each of the four sample sites were different lengths, it was important to find the mass and volume per unit reach.

TASK 5 – DECAY ANALYSIS

Task 5 Description - Conduct decay analysis and test decay models for application in Texas. Determine degree of decay from woody debris specimens based on degree of penetration, sample specific gravity, species, and size. Terrestrial decay rates will be modified for aquatic conditions. The decay rate constant for a suitable decay function will be determined. From this, the expected time to decay in years will be calculated.

A detailed experiment involving woody debris decay rates by species and degree of stage contact was conducted a few years ago, funded by the U.S. Forest Service. This study was to form the basis for analyzing decay rates in the current study. Results from that study were not available, in spite of efforts by U.S. Forest Service, Stephen F. Austin State University (SFASU), and Texas Water Development Board (TWDB) personnel. However, it was determined that a basic understanding of decay rates, decay dynamics, and decay class would be adequate for fulfilling this task. The decay of LWD limits the amount of time that it will spend within a stream system. Previous studies show that it will lose 2 to 7% of mass per year (Spies *et al*., 1988). The pieces of LWD that are within the stream channel will break down into moveable pieces because of the force of the stream (Benda and Sias, 2003). Bilby *et al*. (1999) found that wood submerged decayed at a 2 to 3% rate, depending on the tree species. Harmon *et al*. (1986) developed an equation for wood decay:

$$D(x,t) = k_d S_s, \tag{8}$$

where k_d is annual decay loss and S_s is the storage of living and dead wood in a landslide area. The study goes on to show that loss of mass creates loss of strength, which breaks up the LWD into smaller pieces. The smaller pieces have a harder time getting caught in jams and usually exit the stream as a floatable piece.

The level of decay was selected based on five categories (Table 2). An indicator of 1 meant that no sign of decay was visible on the piece, all bark and branches were intact. An indictor of 2 meant that the piece was intact but the twigs were absent. An indictor of 3 indicated only traces of bark were left on the wood. The fourth indicator meant that the bark was absent with some holes and openings and the wood was darkened. The last category would indicate that the bark was absent and the wood was irregularly shaped and was darkened. Decay is also a function of not only LWD characteristics such as bark and limb presence, but also density.

TABLE 2. Degree of decay classes of LWD.

Degree Class	Characteristics
I	Bark intact, twigs present
II	Bark intact, twigs absent
III	Only traces of bark, with abrasions
IV	Bark absent, some holes, wood darkened
V	Bark absent, irregular shape, wood

TASK 6 – STATISTICAL ANALYSIS

Task 6 Description - Develop appropriate statistical techniques to test and verify data collected for LWD budgets.

Most of the data collected were categorical, so chi-square tests were used to determine if any category had a uniform distribution. A uniform distribution was chosen because no LWD research had been performed on the Sabine River, so there were no a-priori assumptions about expected distributions. The chi-square tests were used to examine eight categories within the individual sites. The categories tested were: degree of decay, branch presence, potential source, origin, bank orientation, root wad, position, and stage contact. SAS was used to run the chi-square tests. The following hypotheses, decision rules, and test statistics were used to test the eight categories:

Degree of decay
H_O: There is a uniform distribution of the LWD in the degree of decay of LWD.
H_A: Not H_O.
Decision Rule: reject H_O if x^2 is $\geq$ to the critical value; otherwise, do not reject.

Branch presence
H_O: There is a uniform distribution of the LWD in the branch presence of LWD.
H_A: Not H_O.
Decision Rule: reject H_O if x^2 is $\geq$ to the critical value; otherwise, do not reject.

Potential Source
H_O: There is a uniform distribution of the LWD in the potential source of LWD.
H_A: Not H_O.
Decision Rule: reject H_O if x^2 is $\geq$ to the critical value; otherwise, do not reject.

Origin
H_O: There is a uniform distribution of the LWD in the origin of LWD.
H_A: Not H_O.
Decision Rule: reject H_O if x^2 is $\geq$ to the critical value; otherwise, do not reject.

Bank orientation
H_O: There is a uniform distribution of the LWD in the degree bank orientation of LWD.
H_A: Not H_O.
Decision Rule: reject H_O if x^2 is ≥ to the critical value; otherwise, do not reject.

Root wad
H_O: There is a uniform distribution of the LWD in the root wad of LWD.
H_A: Not H_O.
Decision Rule: reject H_O if x^2 is ≥ to the critical value; otherwise, do not reject.

Position
H_O: There is a uniform distribution of the LWD in the position of LWD.
H_A: Not H_O.
Decision Rule: reject H_O if x^2 is ≥ to the critical value; otherwise, do not reject.

Stage contact
H_O: There is a uniform distribution of the LWD in the stage contact of LWD.
H_A: Not H_O.
Decision Rule: reject H_O if x^2 is ≥ to the critical value; otherwise, do not reject.

Next, contingency tables were developed to test eight categories between the sites. The categories tested were: potential source, origin, bank orientation, root wad, position, stage contact, degree of decay, and branch presence. The following hypotheses, decision rules, and test statistics were used to test the eight categories:

Position
H_O: There is no association between the position of LWD and the four study sites.
H_A: Not H_O.
Decision Rule: reject H_O if x^2 is ≥ to 12.592; otherwise, do not reject. Since $130.6693 > 12.592$ ($p<0.0001$), reject Ho and conclude that some association exists between LWD position and the four study sites.

Degree of Decay
H_O: There is no association between the degree of decay of LWD and the four study sites.
H_A: Not H_O.

Decision Rule: reject H_O if x^2 is ≥ to 21.026; otherwise, do not reject. Since 29.4311 > 21.026 (p=0.0034), reject Ho and conclude that some association exists between LWD degree of decay and the four study sites.

Branch Presence
H_O: There is no association between the presence of branches on LWD and the four study sites.
H_A: Not H_O.
Decision Rule: reject H_O if x^2 is ≥ to 7.815; otherwise, do not reject. Since 2.7287 < 7.815 (p=0.4354), do not reject Ho and conclude that no association exists between LWD branch presence and the four study sites.

Root Wad Presence
H_O: There is no association between the presence of root wads on LWD and the four study sites.
H_A: Not H_O.
Decision Rule: reject H_O if x^2 is ≥ to 7.815; otherwise, do not reject. Since 31.9060 > 7.815 (p<0.0001), reject Ho and conclude that some association exists between LWD root wad presence and the four study sites.

Stage Contact
H_O: There is no association between the stage contact of LWD and the four study sites.
H_A: Not H_O.
Decision Rule: reject H_O if x^2 is ≥ to 16.919; otherwise, do not reject. Since 38.9937 > 16.919 (p<0.0001), reject Ho and conclude that some association exists between LWD stage contact and the four study sites.

Potential Source
H_O: There is no association between the potential source of LWD and the four study sites.
H_A: Not H_O.
Decision Rule: reject H_O if x^2 is ≥ to 12.592; otherwise, do not reject. Since 87.8092 > 12.592 (p<0.0001), reject Ho and conclude that some association exists between LWD potential source and the four study sites.

Bank Orientation
H_O: There is no association between the bank orientation of LWD and the four study sites.
H_A: Not H_O.
Decision Rule: reject H_O if x^2 is ≥ to 12.592; otherwise, do not reject. Since 46.4740 > 12.592 (p<0.0001), reject Ho and conclude that some association exists between LWD bank orientation and the four study sites.

Origin
H_O: There is no association between the origin of LWD and the four study sites.
H_A: Not H_O.
Decision Rule: reject H_O if x^2 is ≥ to 7.815; otherwise, do not reject. Since 52.8256 > 7.815 ($p<0.0001$), reject Ho and conclude that some association exists between LWD origin and the four study sites.

An ANOVA test was used to compare the bankside volume and LWD volume of each site to see if the volume amounts were significantly different. Comparing the sites to one another gave an idea of how much mass per unit stream length the lower Sabine River contained. It also showed how much volume there was per unit stream length. When comparing the 3 un-snagged sites to the 1 snagged site the tests showed if snagging had affected the area at all. The following hypotheses were used to test the volumes of LWD and bankside vegetation:

LWD volume
Ho: $\mu_{\text{Burkeville}} = \mu_{\text{Bon Wier}} = \mu_{\text{Deweyville}} = \mu_{\text{Southern}}$
Ha: not Ho
Decision Rule: reject H_O if F is ≥ to 2.63; otherwise, do not reject. Since 7.03 > 2.63 (F=0.0001), reject Ho and conclude that the volumes are significantly different.

Bankside Vegetation volume
Ho: $\mu_{\text{Burkeville}} = \mu_{\text{Bon Wier}} = \mu_{\text{Deweyville}} = \mu_{\text{Southern}}$
Ha: not HoDecision Rule: reject H_O if F is ≥ to 3.01; otherwise, do not reject. Since 0.89 < 3.01 (F=0.4118), do not reject Ho and conclude that volumes are not significantly different.

TASK 7 – LWD STORAGE

Task 7 Description - Investigate methods to determine residence time for storage locations in LWD budgets. Methods that should be considered include those described by Hyatt and Naiman, 2001, and Abbe et al., 2003.

According to Hyatt and Naiman (2001), there are three general methods for determining woody debris age and thus residence time for storage locations. These included dendrochronology, radiocarbon dating, and the use of dependent vegetation. First, dendrochronology could be employed. This would involve removing increment cores from both instream LWD and from standing riparian trees to develop a master chronology for crossdating LWD cores. Ring widths vary based on annual variations in rainfall, temperature, and other climatic factors. It was assumed that patterns in ring widths from the master chronology matched up with LWD, thus not only tree age could be determined, but also when the tree died and an estimate of how long the LWD has been in the river. Hyatt and Naiman (2001) employed this technique in the Queets River in Washington. This riparian area had long-lived conifers that provided the researchers with master chronologies dating back to the 14th century A.D. Also, these conifers were found in the river channel. Hyatt and Naiman (2001) found that hardwoods were unreliable for dendrochronology due to missing or indistinct rings, rings that failed to correlate between trees or between cores from the same tree, or too short lifespans.

For the lower Sabine River, using dendrochronology as a dating technique would be a challenge. First, the most reliable trees for this work would be members of the genus *Pinus*. Loblolly pine (*Pinus taeda*) was only rarely found in the bankside inventories or as LWD specimens. About 4.2 trees per hectare pine were found in the riparian area, versus 50 trees per hectare hardwood at the Bon Wier site, with no pines found at the other three. Dominant riparian species included oaks (*Quercus*), which have some potential for developing a master chronology, though oaks are difficult for several reasons. First, they have dense wood that is difficult to bore and extract an intact core. They often have heart rot which results in missing rings. Many of the best specimens were removed in logging operations. Finally, oaks often have missing or indistinct rings. Baldcypress (*Taxodium distichum*), while a conifer, is a notoriously poor species for dendrochronology due to false and incomplete rings. Furthermore, like with the oaks, many of the oldest trees were harvested many years ago and the remaining trees were young. Other species like willow (*Salix nigra*), cottonwood (*Populus deltoids*), or tallow tree (*Sapium sebiferum*) were often short lived and also subject to rot. A final concern was the difficulty in boring saturated trees. While not mentioned by Hyatt and Naiman (2001), we found that boring saturated, higher density logs resulted in the increment core swelling in the bore bit, making core extraction impossible without first oven drying it. This is the main reason saws were used to collect specimens rather than increment borers.

While dendrochronology on the lower Sabine would be more difficult than in the Queets River, it is not impossible. Collection of multiple bores from each key tree along with cookies from selected trees would help to establish the master chronology. Cookie collection from LWD would be needed to then make the necessary matches.

The next technique discussed by Hyatt and Naiman (2001) was using radiocarbon dating. This technique worked well for older, pre 1960 specimens. However, elevated atmospheric ^{14}C concentrations after the mid-1960s from nuclear testing resulted in some challenges. Hyatt and Naiman (2001) used other techniques like dendrochronology, decay class, dependent vegetation, and age of adjacent logs to aid in calibration to determine whether the specimen was on the rising or trailing end of the bomb decay curve. This technique may be successfully employed on the lower Sabine, especially for older, more decay resistant species and merits additional exploration. For LWD recruited post-1960, additional calibration work would be necessary.

The final, and least reliable technique employed by Hyatt and Naiman (2001) was the use of dependent vegetation which has grown up on debris jams. They found this to be the least reliable indicator of residence time. Many specimens that had 1-5 year old vegetation were found to have been in the channel more than 20 years. Furthermore, several of the oldest pieces had any dependent vegetation while younger specimens did. Very little dependent vegetation was observed on the Sabine LWD jams, and due to the difficulties mentioned by Hyatt and Naiman (2001), this is not likely to be an effective method for determining residence time.

Abbe et al. (2003) reported on reintroducing wood into streams and how rehabilitation of fluvial ecosystems was best accomplished by placing wood in the appropriate hydrologic or geomorphic setting. When key members become established, jams can accumulated and lasted for many years. The most important variable for key member stability was having an attached root wad with a 2 m radius. This root wad raised the center of mass more than five times the tree’s diameter and the root mass acted like a plow, increasing resistance. Often these root wads may still be attached to the bank, further increasing key member stability. Abbe et al. (2003) concluded that log jams can be successfully reestablished for greater than 20 year floods, control bank erosion without exacerbating local flooding, and can dramatically enhance physical habitat such as pool frequency, depth, and cover.

Manners and Doyle (2008) further evaluated debris jam evolution and stability (Figure 21) and concluded that while a key member (Phase 1) is important, single log structures are frequently loaded with additional material through time. This increased drag force often resulted in failure. Therefore, additional inputs from riparian vegetation are necessary for debris jam evolution. Robison and Beschta (1990) predicted that 50% of the wood loading was from within 15.2 m (50 ft) of the edge of the channel and all in-channel wood came from within 61 m (200 ft) of the river. Ideally, these additional members coming from the riparian area form a framework of wood that buttresses the key member leading to greater jam stability and longevity (Phase 2). This allowed the jam greater stability as additional LWD pieces were recruited (Phase 3 and 4).

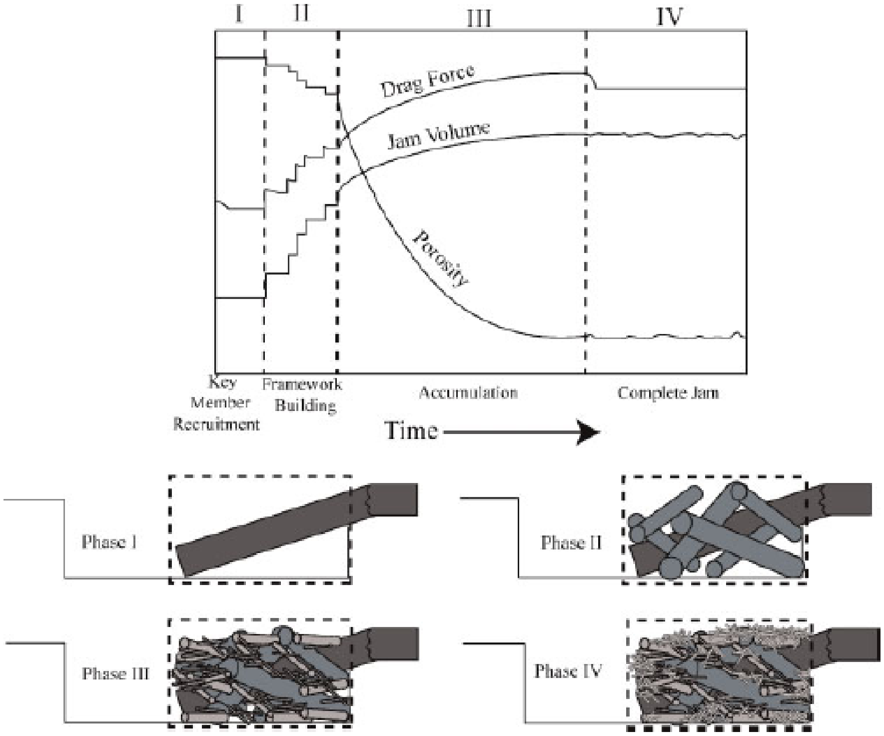

Figure 21. Theoretical debris jam evolution, from Manners and Doyle, 2008.

TASK 8 – LWD TRANSPORTATION

Task 8 Description - Investigate methods for calculating transportation rates for LWD budgets.
Evaluate the potential of theoretical calculation methods corrected with field data described by Braudrick and Grant, 2000, and Haga, et al, 2002.

Braudrick and Grant (2000) reported on a series of flume experiments designed to test simple entrainment models based on the force of moving water on logs. No consideration was given to bank or vegetative effects in their experiments. Furthermore, LWD was modeled as geometrically regular pieces smooth bores and straight without crooks or limbs. Therefore, their model provides theoretical minimum conditions required to initiate LWD transportation. In general, even in this simplified experiment, they found that movement of wood in streams was far more complex than sediment due to the cylindrical bole, irregular rootwad large size relative to channel dimension, and opportunity for various orientations relative to flow. Furthermore, unequal forces act on different parts of the log, including flotation and wood can move in different ways, including sliding, rolling, pivoting, and floating. In general, these researchers found that diameter was the most important factor determining piece stability, assuming piece length was less than channel width. Orienting parallel to flow increased stability by 39%, mostly due to the resistance offered by sediments just downstream of the LWD obstructing movement. Adding a rootwad increased piece stability by 71%. The irregular shape and open framework of rootwads increased drag forces and enhanced piece stability. These researchers did not report on varying discharge and velocity, nor did they provide estimates of how differing flow variables would affect LWD of different sizes.

In general, their flume experiment would "scale up" to a river 39.3 m wide by 0.71 m deep. These were reasonable conditions for the lower Sabine, though their model had a steeper channel slope and thus greater velocities. Furthermore, their piece sizes were the equivalent to 1-1.5 m, much larger than that found in the Sabine River of 0.32 m. By site, Burkeville had the largest mean diameter of 0.41 m and it was significantly greater than the other 3 sites. Lengths in this study were also greater, ranging from 11.8 to 23.6 m versus a mean piece length in the lower Sabine of 6.8 m. In all cases, piece length was less than channel width. In conclusion, Braudrick and Grant (2000) presented a theoretical model that could reasonably predict LWD transport conditions. However, additional model development would be required before actual field conditions could be put into the model for the Sabine River to estimate at what discharges key pieces of LWD may become mobile. Furthermore, the actual utility of such a model would be limited, since these models do not account for resting logs trapped by instream obstructions like logjams.

Due to these restrictions, Haga et al. (2002) reported on LWD transport in small mountain streams in Japan. These streams lacked the sorts of obstructions that that violate the assumptions of Braudrick and Grant's (2000) model. Furthermore, all of the LWD pieces in Haga et al.'s (2002) experiment were less than the bankfull width. In general, they found that flow depth as well as the magnitude and sequence of flows were important factors for LWD transport and retention. They found that trapping mechanisms like jams were very important, since often the potential transport distance due to flow was greater than the distance between jams. Thus, in terms of distance moved, LWD was not as much flow limited as limited by jam spacing. Therefore, jams played a crucial role in LWD entrainment. As with Braudrick and Grant (2000), Haga et al. (2002) assumed uniform piece shapes, and recognized that the shape of the piece, and presence of a rootwad and limbs would likely be most important for understanding actual LWD transport.

TASK 9 – LWD DOMINANT DISCHARGE

Task 9 Description - Investigate the requirements to develop a dominant discharge for woody debris and provide example calculations. This is an untested concept with little literature support, but would follow the geomorphic concept of dominant discharge for inorganic sediment.

As noted above, Braudrick and Grant (2000) observed that the movement of wood in streams was far more complex than sediment due to the cylindrical bole, irregular rootwad large size relative to channel dimension, and opportunity for various orientations relative to flow. In that experiment, they did not account for the many other variables that affect woody debris transport, like partial burial, presence of limbs, irregular shapes, jam entrainment, variations in streambanks and channel profiles, etc. Therefore, these discharge estimates would be much lower than what would actually be encountered in a natural system. For example Haga et al (2002) assumed that movement occurred when the non-dimensional force (Ψ) > 1, that was the hydraulic force (F) was greater than log resistance (R), such that $\Psi = F/R$, or

$$\Psi = \frac{2C_d\rho C_H^2 h^* \sin\alpha\,(kh^*\sin\theta + \beta(h^*)\cos(\theta)}{gk(\pi\sigma - 4\beta(h^*)\rho)(\mu\cos\alpha - \sin\alpha)}$$

Where:

C_d = drag coefficient between log and water
ρ = water density
C_H = Chezy's coefficient
h = water depth
α = channel bed slope

k = constant depending on log
θ = angle of log relative to flow
g = acceleration due to gravity
σ = channel bed slope angle
μ = coefficient of friction between log and channel bed

The relationship is represented graphically in Figure 22.

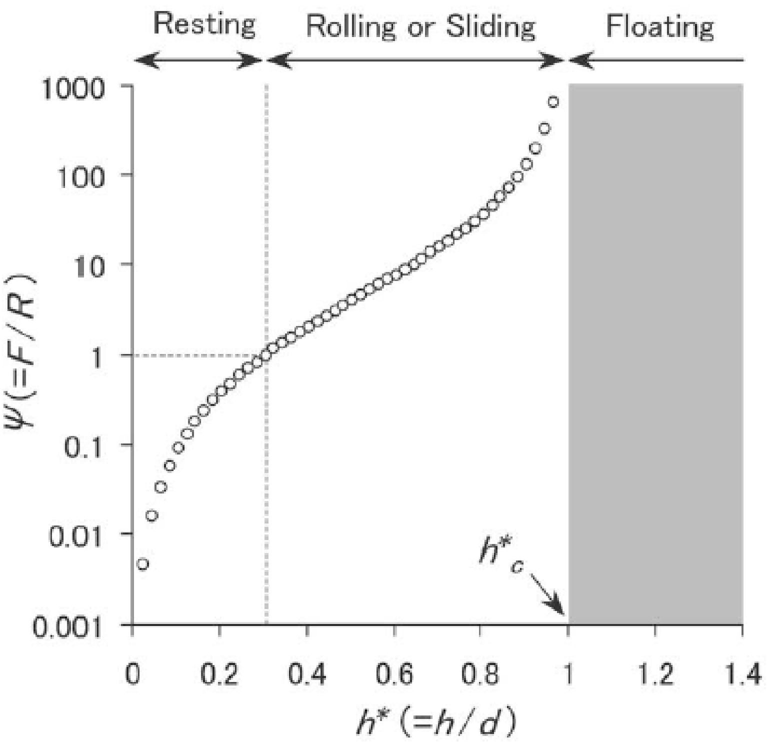

Figure 22. Relationship between flow and depth for LWD transport, from Haga et al. (2002).

This relationship assumed that the critical point for movement occurred when the water depth was about one third the diameter of the log. For simple wooden cylinders in unobstructed streams, this theoretical relationship was found by Haga et al. (2002) to be reasonable. However, in the lower Sabine with actual LWD, the observational data were found to be untenable. For example, the mean diameter was around 30 cm (12 in), and during all of the measurement periods, the depth was several times this. By this model, all of the pieces of LWD should have been mobile during low flows. However, they were not due to the irregularity of the pieces, presence of root wads, and jam associations. The utility of this model would therefore be limited for providing reasonable estimates of what stream discharge would be required to begin mobilizing key LWD elements and thus jam movement. Haga et al (2002) acknowledged this when they indicated that the limiting factor for LWD movement was not the energy of the stream, but the resistance provided by obstructions.

However, there clearly is some dominant discharge that will result in LWD mobility. For this to happen, the key LWD elements would have to be mobilized in order to destabilize the jam. The force required for this would mostly depend on the degree of entrainment of the key LWD elements. Therefore, developing a general model for jam mobility in lower Coastal Plain Rivers will require additional study.

TASK 10 – REPORT OF RESEARCH FINDINGS

Task 10 Description – Submit report and summary of findings. Assemble and present results to date from the project. Describe research needed in future years to advance the understanding of LWD in rivers of Texas.

LWD Mass and Volume

The Burkeville site contained 93 logs, Bon Wier had 95, Deweyville had 119, and the Southern site had 67 logs (Table 3). The Burkeville site had 98.94 m^3, the Bon Wier site had 29.67 m^3, Deweyville contained 49.43 m^3, and the Southern site had 30.43 m^3. The length of the Burkeville site was 1.16 kilometers, Bon Wier was 1.00 kilometers, Deweyville 1.06 kilometers, and the Southern site was 2.29 kilometers. The total length of the river from the dam to the river split was 147.58 kilometers.

The volume of LWD was significantly (p=0.0001) different between the four study sites. LWD loads did not increase further south, as was expected. Burkeville had similar counts of LWD, but its volume was much higher, indicating that the pieces found at Burkeville were much bigger than the LWD at the other sites.

TABLE 3. Total counts, volume, and ANOVA results (using Tukey's Honest Significant Difference) for LWD and bankside vegetation for each study site along the lower Sabine River.

	LWD Count	LWD Volume (m^3)	Reach Length (km)	Volume per Length (m^3/km)	Tukey Grouping for LWD	Bankside Volume (m^3ha^{-1})	Tukey Grouping for Bankside Vegetation
Burkeville	93	98.94	1.16	**85.29**	**A**	349.9	A
Bon Wier	95	29.67	1.00	29.67	B	248.1	A
Deweyville	119	49.43	1.06	49.63	B	407.1	A
Southern	67	30.43	2.29	13.29	B	476.3	A

Mean values with the same letter are not significantly different at $\alpha = 0.05$

Tables 16-19 present details for the standing vegetation at the Burkeville, Bon Wier, Deweyville, and Southern sites, respectively. From the results of the standing vegetation it was expected that Deweyville would have the highest volume of LWD because it had the highest amount of standing vegetation around it, but again that was not the case. The differences were due to Burkeville having very large amounts of volume of LWD originating from its banks or being or being recruited from upstream. Another explanation could be found by examining at Phillips' (2003) study of the lower Sabine River where he examined the effects of Toledo Bend Reservoir on the river downstream of the dam. In his study, Phillips (2003) reported significant bank erosion, sandbar migration, and LWD inputs at the Burkeville site. The banks at Burkeville were the steepest of his three study sites, and were heavily eroded, resulting in greater LWD inputs. Phillips (2003) reported that the left bank was characterized by many fallen trees and bank eroded trees. He observed that overall this section of the river was very active with many migrating sandbars and higher rates of bank erosion. On the other hand, Phillips (2003) found that near the Bon Wier section of the river there was less channel erosion. At the Deweyville site, Phillips (2003) observed that the overall river takes on a completely different form, with lower banks and fewer sandbars. He mentioned that the left bank of the site had numerous amounts of LWD and tilted trees and the right bank had former bank scarps with abundant LWD at the bank base and in the channel. The LWD loadings in this study were similar to those observed by Phillips (2003) (Table 3). Looking at local geomorphic features and understanding how the river was affecting the banks at the local sites were the best way to explain the LWD loading differences. Not only is there more active erosion at the Burkeville site, the site also was characterized by vegetation standing close to the channel, which explained why the high volumes of LWD. The Bon Wier site contained the least amount of LWD volume and was mentioned by Phillips (2003) that the banks were not very active and the riparian forest was less dense. The Deweyville site contained a LWD volume that was in the middle of the Burkeville and Bon Wier sites and the activity of its bank also lay somewhere in the middle of the other two sites but had a well-stocked riparian forest. LWD loading was best explained by the combination of bank erosion rates and riparian forest density.

Woody Debris Dynamics

Flow Rates and Stream Depth

Flow rates and river depth data were obtained for the sampling periods from USGS flow data (Table 4). The Deweyville site (USGS 08030500) was sampled on October 19, 2007, November 9, 2007, and was completed on December 19, 2007. The values shown for both flow rates and stream depth are an average of what occurred on the sampling date. For Deweyville's data the values for all three sampling dates were averaged to get one overall value. Bon Wier (USGS 08028500) was the second site sampled and it occurred on July 14, 2008. The sampling of Burkeville (USGS 08026000) occurred on July 21, 2008 and the Southern site (USGS 08030500) was completed on August 18, 2008.

TABLE 4. Averages of stream discharge and stream depth at the four study sites along the Lower Sabine River during sampling dates.

	Burkeville	Bon Wier	Deweyville	Southern
Discharge (m^3/s)	129.00	45.30	33.10	177.00
Depth (meters)	5.18	4.80	4.55	6.46
Sampling Date	July 21, 2008	July 14, 2008	October 19, November 9, and December 19, 2007	August 18, 2008

Categorical Counts

All of the sites showed similar decay class counts to one another. Burkeville, Bon Wier, and Deweyville had the most amount of LWD in the third category, and only the Southern site had the most counts in the fourth category (Table 5). Decay Class 5 contained low amounts of LWD because the material was decayed, broken, and eventually floated down river.

TABLE 5. Degree of decay LWD counts for all study sites along the lower Sabine River.

Decay Class	Burkeville	Bon Wier	Deweyville	Southern
1	7	15	17	5
2	18	14	24	9
3	48	41	46	19
4	17	19	31	30
5	3	6	1	4

Burkeville and Bon Wier had the lowest amounts of LWD in the 90 degrees category while both Deweyville and the Southern site had their higher amounts of LWD in the 90 degrees category (Table 6). Due to the more powerful force at the Burkeville and Bon Wier sites than at the Deweyville and Southern sites, the LWD turned either 0 or

180 degrees. The lower amounts of force at Deweyville and the Southern site keept more LWD facing 90 degrees, the same way it was facing when it fell in the river.

TABLE 6. Bank orientation LWD counts for all study sites along the lower Sabine River.

Bank Orientation	Burkeville	Bon Wier	Deweyville	Southern
0	56	41	35	9
90	28	31	54	45
180	9	22	26	13

All four sites showed an abundance of LWD in the first stage of contact and very few in the third and fourth stages of contact (Table 7). This was due to the fact that most trees that fell by either blow down or bank erosion were going to end up in the lowest part of the channel instead of getting caught in the middle of the bank.

TABLE 7. Stage contact LWD counts for all study sites along the lower Sabine River.

Stage Contact	Burkeville	Bon Wier	Deweyville	Southern
1	76	91	78	58
2	14	3	25	3
3	2	1	9	3
4	1	0	7	3

The Burkeville and Deweyville sites each had a fairly even distribution of LWD positions (Table 8). The Bon Wier site had the most varied distribution due to it having 0 fallen trees within its site and 83 individual LWD. The Southern site did not have as many individual pieces but had similar counts of jam associated LWD as the Burkeville and Deweyville sites.

TABLE 8. Position LWD counts for all study sites along the lower Sabine River.

Position	Burkeville	Bon Wier	Deweyville	Southern
Jam	34	12	38	33
Individual	27	83	31	9
Fallen Tree	32	0	50	23

Alphanumeric Classification

The LWD found at the four study sites on the Sabine River was classified using Montgomery's alphanumeric classification system (Montgomery, 2008). With occasional exceptions, the LWD for all study sites were grouped around only a few categories (Table 9). Categories C3, D3, D4, E3, and E4 had the largest LWD concentrations. The fact that the four sites had very similar sized LWD illustrated that the sites were similar enough for meaningful comparisons. The purpose of picking the four relatively similar sites on different sections of the Sabine was to get a good representation of the entire river. The reason why no woody debris was found before the B2 category was due to the fact that LWD requirements were too large to fall into any of the A1-B1 categories. The largest LWD found fell into the F5 category, leaving the categories F6-G7 completely empty.

TABLE 9. Montgomery’s Alphanumeric classification system of LWD on the Sabine River.

	Burkeville	Bon Wier	Deweyville	Southern
A1	0	0	0	0
A2	0	0	0	0
A3	0	0	0	0
A4	0	0	0	0
A5	0	0	0	0
A6	0	0	0	0
A7	0	0	0	0
B1	0	0	0	0
B2	0	0	0	1
B3	1	2	2	0
B4	0	0	0	0
B5	0	0	0	0
B6	0	0	0	0
B7	0	0	0	0
C1	0	0	0	0
C2	1	3	3	6
C3	**7**[1]	**16**	**9**	**10**
C4	1	2	0	2
C5	0	0	0	0
C6	0	0	0	0
C7	0	0	0	0
D1	0	0	0	0
D2	4	8	9	0
D3	**32**	**40**	**32**	**23**
D4	**16**	**6**	**4**	**5**
D5	1	0	0	0
D6	0	0	0	0
D7	0	0	0	0
E1	0	0	0	0

Table 9 (cont)

	Burkeville	Bon Wier	Deweyville	Southern
E2	1	0	3	0
E3	**6**	**11**	**16**	**7**
E4	**17**	**4**	**13**	**13**
E5	5	0	0	0
E6	0	0	0	0
E7	0	0	0	0
F1	0	0	0	0
F2	0	0	0	0
F3	0	0	2	0
F4	0	1	0	0
F5	1	0	0	0
F6	0	0	0	0
F7	0	0	0	0
G1	0	0	0	0
G2	0	0	0	0
G3	0	0	0	0
G4	0	0	0	0
G5	0	0	0	0
G6	0	0	0	0
G7	0	0	0	0

1. Indicates large amount of LWD found in that category.

Unknowns

For each of the four sample sites, with the exception of origin at Burkeville, three of the categories had a numerous amount of unknowns (Table 10). Species, potential source, and origin were all difficult to determine in the field. Out of the 119 LWD samples found at the Deweyville site, 86 were labeled as unknown with the remaining 33 being identified as a mixture of pine and hardwoods. For the potential source category, 83 were called unknowns, 15 were found to be from cutbanks, 7 from windsnaps, and 14 from windthrows. Sixty-five LWD had origins labeled as unknown while 52 were local and 2 were possibly from upstream. Out of the 95 LWD sampled at Bon Wier, 45 species were unable to be identified. Potential source had 38 unknowns, 43 cutbanks, 10 windthrows, and 4 windsnaps. The origin category had 25 unknowns, 62 locals, and 8 were found to be from upstream. Besides the origin category that only had 6 unknowns, the Burkeville site was fairly similar to others. Out of the 93 LWD sampled, 64 species were found to be unknown. Potential source had 52 unknowns, 41 cutbanks, and 0 windthrows or windsnaps. The origin category had 6 unknowns, 42 locals, and 45 pieces found from upstream. The southern site had the least amount of LWD sampled finding 67 logs. Out of those 67, 30 species were found to be unknown. For the potential source category 41 pieces of LWD were found to be unknown, windthrow had 24 logs, and windsnap and cut both had 1. The origins category had 24 unknowns, 25 locals, and 18 logs were found to come from upstream.

TABLE 10. Counts of “unknowns” in several categories that could not be determined when sampling.

Unknowns	Burkeville	Bon Wier	Deweyville	Southern
Species	64	45	86	30
Potential Source	52	38	83	41
Origin	6	25	65	24
Total Counts	93	95	119	67

Statistical Tests Results

Degree of decay was significantly (p=0.0034) different between the four locations. Excess LWD in the degree of decay class 4 at the Southern site was significantly (χ^2=9.17, p=0.1349) different than degree of decay in the other classes at the remaining three sites (Table A25). This implied that more southerly locations along the Sabine contained more decayed LWD (Table 5). Based on the Chi-Square test all four study sites were not uniformly distributed in the degree of decay category (Table 12).

Also, LWD pieces that were locked in jams were the ones that were the most decayed because of their longer residence times. Furthermore, the position of LWD was significantly ($p<0.0001$) different between sites. At the Southern site, half the LWD was located in jams, which was significantly ($\chi^2=10.77$, $p=0.0418$) greater than the other sites (Tables 8 and A28). This further supported the observation that more decayed LWD was located in jams. It would take a large, powerful flood to move some of the jams that were found on the Sabine, but after a while the LWD in a jam would begin to decay and break up into smaller pieces, thus breaking up the jam. Burkeville and Deweyville sites returned a uniformed distribution for the position category (Table 12).

Branch presence on LWD was not significantly ($p=0.4354$) different between the sites (Table A30). The presence of branches on the LWD would be expected to influence the way it interacts within the river system. The interaction between the position of the LWD and the presence of branches could be due to the branches catching a lot more debris than a log would catch without branches. The more debris that gets caught, the bigger the jam becomes and the cycle continues. Based on this conclusion it would be expected to find more LWD within a jam to have branches, but what was found was that most pieces within a jam do not have branches. This was due to the fact that when a piece of wood was decaying, the first thing to fall off was the bark and the branches; therefore, wood that was stuck in a jam for a long period of time lost its branches. Branches helped to cause the jam in the first place but eventually get broken off by the decaying process.

Another aspect of the degree of decay of LWD is the presence of branches. The lack of statistical significance was unexpected since branch presence was used to help define the degree of decay. LWD was found mostly in the third through fifth categories of degree of decay (Table 5), which represented pieces with few if any branches. Most LWD was found in the third category at the Burkeville, Bon Wier, and Deweyville sites, while the fourth category contained the most LWD at the Southern site. Had more LWD been found in the first or second categories, then branch presence may have been significantly different between sites.

The stage contact of LWD was significantly ($p<0.0001$) different (Table A27). Where the LWD was at within the bank channel had an influence on its degree of decay. Most of the LWD were found in the first category, or the low flow contact zone (Table 7). In this zone the pieces would almost always be touched, battered, and decayed by the flowing water of the Sabine. Due to the constant flow of water it was found that most pieces of the LWD would be further along in the decaying process. Like previously mentioned, at all four study sites there was more LWD in the later stages of decay.

Root wad presence on LWD was significantly ($p<0.0001$) different (Table A31). Again, the degree of decay category showed that the third category had the most pieces at the Burkeville, Bon Wier, and Deweyville sites. The Burkeville site had 53 pieces that contained a root wad while only 24 pieces did not. The Bon Wier site had 33 pieces that contained a root wad and 13 that did not, the Deweyville site had 62 pieces with a root wad and 41 without, and the Southern site had 20 pieces with a root wad and 46 without. It would be expected that as the LWD decayed, the root wad would decay with it, meaning the more pieces found that were heavily decayed then fewer root wads would be found. But at the Burkeville, Bon Wier, and Deweyville sites it was found that more root wads were still attached to the LWD. The reason that root wads do not decay as fast as branches and bark was due to the cell structure of root wads. The cells of the root wads were impregnated with wax which kept them much more water resistant than other parts of the LWD. The water resistances of the roots are what keep them from decaying at the same rate as the branches, thus keeping them attached to the LWD for longer periods of time. The presence of a root wad also confirmed that the tree entered the river by either bank erosion or windthrow because both of these ways will kept the root wad attached. If a tree enters the river via windsnap then the roots will most likely still be in the ground. All of the LWD that could be identified from the Burkeville site were found to come from a cutbank, meaning the roots were still attached. The Bon Wier site was similar to the Burkeville site in that it had most of pieces being identified as coming from a cutbank source and it also contained more root wads than not. The Deweyville site had a more uniform distribution for its source category; it had 15 pieces from a cutbank, 14 from a windthrow, and 7 from a windsnap. Although it was slightly different than either Burkeville or Bon Wier, its root wad distribution was still consistent with the other two sites. The Southern site was different in that it had a majority of its pieces coming from windthrow, but it was unusual in that it had more LWD pieces that did not contain a root wad. This could be explained by noticing that more of its pieces were in advanced stages of decay, which means that the root wad would start to decay by the fourth category of decay.

The origin of LWD was significantly ($p<0.0001$) different. Due to Burkeville's close proximity to the reservoir it would be expected that not a lot of wood would come from upstream, that most wood would be from the local area. LWD in the upstream class at the Burkeville site was significantly ($\chi^2=15.91$, $p=0.0248$) different than upstream classes at the other three sites (Table A29). Phillips (2003) found that the reservoir had the greatest impact on the Sabine River just north of the Burkeville site. The fact that a larger relative proportion of LWD from the Burkeville site came from upstream supported Phillips' (2003) conclusion. A combination of the water being released from the dam and the geomorphology upstream of the Burkeville site led to a large amount bankside erosion inputs of LWD. All four study sites had large amounts of standing vegetation and most of the overall volume was originating from bankside sources (See Observed Data and Conceptual Model of LWD Dynamics section below).

TABLE 11. Contingency Table tests for study sites along the Sabine River.

Tests	Results
Degree of Decay	**0.0034**
Branch Presence	0.4354
Potential Source	**<.0001**
Origin	**<.0001**
Bank Orientation	**<.0001**
Root Wad	**<.0001**
Position	**<.0001**
Stage Contact	**<.0001**

TABLE 12. Chi-Square tests for study sites along the Sabine River.

Tests	Sites			
	Burkeville	Bon Wier	Deweyville	Southern
Degree of Decay	**<.0001**[1]	**<.0001**	**<.0001**	**<.0001**
Branch Presence	0.2540	**0.0056**	0.0542	**0.0050**
Potential Source	0.0000	**<.0001**	0.2053	**<.0001**
Origin	0.7477	**<.0001**	**<.0001**	0.2858
Bank Orientation	**<.0001**	**0.0394**	**0.0048**	**<.0001**
Root Wad	**0.0010**	**0.0032**	**0.0385**	**0.0014**
Position	0.6575	**<.0001**	0.0975	**0.0012**
Stage Contact	**<.0001**	**<.0001**	**<.0001**	**<.0001**

1. Tests compared within sites, not across sites.

LWD Recruitment Rates

The Southern site was important to the study because all of the LWD had been removed from the site three years prior to the sampling study, following Hurricane Rita. With this knowledge, generalizations could be drawn of how long it takes LWD to be recruited into the Sabine River. Table 13 shows the LWD counts, LWD volume, and the potential source and origin categories for the Southern site. When compared to the LWD counts of the other three sites (Table 3) the Southern site had the least LWD within its reach, with 13.29 m^3/km, about half the next lowest site, Bon Wier at 29.67 m^3/km. (Table 3).

The Southern site had lower banks than the other three sites which explained why there cutbank LWD was less of a factor. There was a mixture of origin LWD, meaning that the LWD was being recruited from both local and upstream sources.

Based on the sampling done at the Southern site it was estimated that about 12 years would be required for LWD volume at the Southern site to be equal to Deweyville’s volume. Although, this figure could potential change dramatically depending on the number and size of catastrophic events (i.e. hurricanes and mass flooding) that hit the area.

TABLE 13. Southern site LWD counts and source of recruitment.

		Counts
LWD		67
LWD Volume (m^3)		30.43
Potential Source		
	Windsnap	1
	Windthrow	25
	Unknown	41
Origin		
	Local	25
	Upstream	18
	Unknown	24

Observed Data and Conceptual Models of LWD Dynamics

A conceptual model based on work conduced by Benda and Sias (2003) was presented in Task 2, Equations 4-6. This model can be applied to the lower Sabine River with data collected in the current study. For the four study reaches, the overall lateral recruitment (Li) was calculated. Volume of live standing biomass (m^3 ha^{-1}) given in Table 3 was converted to m^3 m^{-2}. Mortality rates were assumed at 1% based on relative mature forest age for the dominant species present. Average stand heights were measured. Number of contributing banks was 2 for mortality input calculations, 1 for bank erosion. The amount of stem becoming biomass was 0.13 for mortality calculations, and 0.75 for bank erosion. Fall direction for mortality was assumed to be non-preferential, and a value of 0.13 was chosen base on long term averages compiled by Van Sickle and Gregory (1990). Fall direction for bank erosion was based on values given in Benda and Sias (2003). Mean bank erosion rates were derived for Burkeville from Heitmuller and Greene (2009) at 0.1341 m yr^{-1}, and were estimated to be 0.10 m yr^{-1} at Bon Wier and 0.05 m yr^{-1} at Deweyville and the Southern site. Results are presented in Table 14.

Lateral recruitment estimates illustrate differences between the four river segments. Burkeville, which has the highest total LWD loading (85.29 m^3 km^{-1}) also had the highest recruitment rate and recruitment was dominated by bank erosion. On Deweyville and the Southern sites, the riparian forest volume was much higher with much lower bank erosion rates, and mortality recruitment dominated.

Table 14. Lateral recruitment budget estimates (m^3 km^{-1} yr^{-1}) for the four study reaches on the Lower Sabine River, Texas (Benda and Sias, 2003).

Site	Mortality Recruitment (I_m)	Bank Erosion Recruitment (I_{be})	Total Lateral Recruitment (L_i)
Burkeville	1.40	3.52	4.92
Bon Wier	0.95	1.86	2.81
Deweyville	1.80	1.53	3.33
Southern	1.92	1.79	3.71

These estimates of lateral recruitment can then be compared with the overall woody debris budget estimate presented in Task 2, Equation 9. To accomplish this, an estimate of woody debris decay is needed. As reported in Task 5, specific estimates are not available, though decay rates can be between 2 and 7% of live biomass in a forest floor environment (Spies et al., 1988). Due to warm temperatures and high humidity, southeast Texas has one of the highest wood decay rates in the continental United States, so the higher end of this range, 7%, was used for budget calculations. With a 7% decay rate, the average decay based residence time for a piece of LWD would be 14.29 years.

The total woody debris budget was then calculated from Equation 9 (Table 15). The unknown variables were the volume of woody debris flowing into the reach (Qi), the volume flowing out of the reach (Qo), and the volume being deposited on the floodplain out of the reach (Lo). For the Burkeville and Deweyville sites, this volume was a net positive, meaning that fluvial transport of wood into the reach is likely occurring at a greater rate than fluvial outflow. This value was highest at Burkeville, which is to be expected given the higher rates of bank erosion immediately downstream of Toledo Bend Reservoir reported by Phillips (2003) and is also consistent with measured source data. This is also consistent with the lateral recruitment estimates for Burkeville, where recruitment due to erosion is 2.5 times higher than recruitment due to mortality (Table 14). It is unlikely that the Toledo Bend Dam had a significant impact on reducing LWD loadings due to reservoir interruptions of fluvial LWD at the Burkeville site. Additional measurements immediately below the dam in which the scour reported by Phillips (2003) was observed would be necessary to determine if these LWD reservoir storage effects extend upstream of the Burkeville site. At Deweyville, forest mortality recruitment is greater than bank erosion, due to the lower gradients at this site. Also, with lower gradients more LWD accumulations from upstream may be occurring. For Bon Wier, it is estimated that more wood is being recruited than stored in the channel, so the remainder may be transported off site (0.54 $m^3\ km^{-1}\ yr^{-1}$) as fluvial outflow or floodplain deposition. At the Southern site, LWD accumulation has only occurred for about 3 years since the post-Hurricane Rita snagging operation, with a lateral recruitment estimate of

10.47 m^3 km^{-1}, meaning that the difference of 2.82 m^3 km^{-1} may have come in as fluvial inflow from further upstream.

Table 15. Estimated woody debris storage, decay, and recruitment for the lower Sabine River Texas.

Variable	Burkeville	Bon Wier	Deweyville	Southern
Total Recruitment (L_i, m^3 km^{-1} yr^{-1})	4.92	2.81	3.33	3.71
Volume Decayed (D, m^3 km^{-1} yr^{-1})	0.34	0.20	0.23	0.22
Net Recruitment (m^3 km^{-1} yr^{-1})	4.58	2.61	3.10	3.49
Recruitment in 14.29 Yrs (m^3 km^{-1})	69.29	37.29	44.29	49.86
Volume Measured (m^3 km^{-1})	85.29	29.67	49.63	13.29
(Qi – Qo – Lo) Vol. (m^3 km^{-1} yr^{-1})[a]	1.05	-0.54	0.38	N/A

[a] Qi = LWD from fluvial inflow, Qo = LWD from fluvial outflow, Lo = floodplain deposition. Estimates are not available for the Southern site since it was snagged 3 years prior to measurement.

These budget estimates do have a high degree of uncertainty, particularly for estimated variables like bank erosion, decay, and mortality rates. Future studies will need to quantify these variables for more precise budget estimates. However, these numbers do represent a reasonable approximation of LWD dynamics in the lower Sabine River. One obvious conclusion from these data is that the riparian forest density and volume plays a significant role in LWD recruitment. Fluvial dynamics were estimated to be between 11 and 21% of total annual recruitment, with the remainder governed by lateral recruitment, which depends mostly on surrounding forest density. Therefore the most effective means of enhancing LWD recruitment for the lower Sabine would be to protect and enhance the riparian forest. There does not seem to be much evidence from this analysis that the Toledo Bend Dam had a significant impact on LWD dynamics in the lower Sabine River due to LWD storage. As noted by Phillips (2003), the lower Sabine is transport limited for sediment, and the same seems to be generally true for LWD. It is likely that the large volumes of LWD that were historically in the rivers of East Texas were due to the large, dense forests composed of relatively decay resistant species like cypress and oak and that centuries of riparian forest degradation and invasive species spread resulted in lower maximum potential LWD loadings.

Comparison to Other River Systems

Other studies that have examined LWD have found similar results to the study of LWD in the Sabine. For example, Swanson *et al.* (1976) studied LWD on Western Oregon streams and found that a stream flowing through both a 75 year old stand and a 135 year old stand contained similar counts of LWD compared to the Sabine. They found the LWD to be an important factor in the stream environment, even after a severe wildfire. The quantity of LWD they found was a direct result from the balance of debris inputs and outputs of the stream system. They reported that the input of LWD was controlled by age and condition of the surrounding forest, the stability and steepness of banks, and the ability of the stream to transport LWD downstream. The biggest contributors of LWD in their study were blowdowns, extreme discharge events, debris torrents, and stream cleanup after logging. The export of LWD was found to be caused by the ability of the stream to float debris downstream, rates of decomposition, and physical breakdown of debris in channels. Like the study of the Sabine, other researchers have found that many variables contribute to the import and export of LWD within the stream system and all variables must be considered when looking at the whole picture (Swanson *et al*., 1976; Palik *et al*., 1998; Hedman *et al*., 1996). Other studies have shown that bank erosion, windthrow, logging debris, wind fragmentation, and landslides were the major contributors to LWD input (O’Connor and Ziemer, 1989). A study by Murphy and Koski (1989) found that most LWD was recruited by bank erosion and windthrow. Of the LWD that had identifiable sources, the researchers found that 99 percent came from within 30 meters off the stream bank.

Differences among sites on the Sabine River can be attributed to variations in geomorphology, vegetation, and hydrology. Other studies performed showed that geomorphic differences among reaches resulted in different patterns of tree death and LWD input into the stream system, or that landforms controlled a variety of ecosystem patterns and processes (Swanson *et al.*, 1988). Palik *et al.* (1998) studied a stream in southwestern Georgia and found that constrained reaches, like sand ridges and terraces, had the highest tree mortality rates which recruited the most LWD into the stream, while floodplains and terraces had low tree mortality and low LWD recruitment. Other studies showed that large floods were the primary source for LWD recruitment. Researchers like Palik *et al.* (1998) found that most LWD was from constrained stream valleys (i.e. sand ridges) (Golladay and Battle, 2005). Palik *et al.* (1998) went on to suggest that unconstrained reaches, floodplains, could become LWD sinks, where LWD moved into the area but did not move any further downstream. The relationship between the sand ridges and floodplains could become what they call a “source-sink relationship” where parts of the river were more likely to input LWD and transport it downstream and other parts would more likely keep the LWD it receives.

The transport of LWD downstream was an important function of the LWD import and export from a given stream reach in several studies. The ability of a stream to move a piece of LWD downstream was more of a characteristic of higher order streams, like the Sabine (Keller and Swanson, 1979; Lienkaemper and Swanson, 1987).

Like the study on the Sabine, O'Connor and Ziemer (1989) found many pieces that had to be classified as unknown, and they attributed this to the amount of time since the trees had fallen and also to the fragmentation of the LWD. Although many pieces were found to be unknown, they were able to find that 60 percent of the LWD from outside of the bank channel came from windthrow. LWD that occurred from within the channel were mostly from bank erosion. The researchers also noted that 27 percent of the LWD volume was found to be in a jam.

Benke and Wallace (1990) found on the sixth order Ogeechee River 66 pieces of LWD in 9 transects that were placed along the river. If 9 transects in Benke and Wallace (1990) are equal to 1 meander scar in the current study, then LWD loads in the lower Sabine were greater.

Bankside Vegetation Inventory

The Burkeville site had the least amount of standing trees with a total trees ha^{-1} of 210 and a total volume of 349.9 m^3 ha^{-1} (Table 16). The 15 centimeter diameter class had the greatest number of stems, with 52.5 17 trees ha^{-1}. The basal area was rather low, at 14.4 m^2 ha^{-1}, indicating that the stand is not fully stocked.

While the Bon Wier site had slightly more stems per hectare (220), the overall volume and basal area were lower. (Table 17). This is due to the fact that this site had more smaller trees, accounting for less overall volume per stem. Once again most stems were in the 15 cm diameter class. A basal area of 11.5 m^2 ha^{-1} indicates rather poor stocking for a bottomland hardwood forest.

The Deweyville site had more stems, volume, and basal area than the previous two sites (Table 18). The basal area of 18.8 m^2 ha^{-1} indicates rather good stocking, and there was more volume distributed into the larger diameter classes, though once again most stems (107.5) were in the 15 cm diameter class.

TABLE 16. Stand and stock table from the standing vegetation at the Burkeville site on the lower Sabine River, Texas.

	Diameter Class (cm)	Trees ha^{-1}	Basal Area ha^{-1}	Volume (m^3 ha^{-1})	Dominant Species
Hardwood	10	40.2	0.3	1.1	sweetgum
	15	52.5	1.0	8.5	water oak
	20	37.1	1.2	14.0	sugarberry
	25	27.8	1.4	18.3	river birch
	30	9.3	0.7	8.6	river birch
	35	9.3	0.9	26.6	hickory
	45	12.4	2.0	38.5	hickory
	55	6.2	1.5	41.7	bald cypress
	60	6.2	1.8	57.9	bald cypress
	65	6.2	2.1	75.1	bald cypress
	75	3.1	1.4	59.6	bald cypress
Grand Total		210.0	14.4	349.9	

TABLE 17. Stand and stock table from the standing vegetation at the Bon Wier site on the lower Sabine River, Texas.

	Diameter Class (cm)	Trees ha^{-1}	Basal Area ha^{-1}	Volume (m^3 ha^{-1})	Dominant Species
	10	32.9	0.3	0.9	river birch
	15	68.0	1.2	12.1	hornbeam
	20	39.1	1.3	16.5	sweetgum
	25	14.4	0.7	10.7	sweetgum
	30	20.6	1.5	25.7	sweetgum
	35	16.5	1.6	38.7	sweetgum
	40	14.4	1.9	52.8	sweetgum
	45	6.2	1.0	30.8	sweetgum
	50	2.1	0.4	13.0	swamp chestnut oak
	55	6.2	1.5	47.0	sweetgum
Grand Total		220.3	11.5	248.1	

TABLE 18. Stand and stock table from the standing vegetation at the Deweyville site on the lower Sabine River, Texas.

	Diameter Class (cm)	Trees ha^{-1}	Basal Area ha^{-1}	Volume (m^3 ha^{-1})	Dominant Species
	10	43.2	0.3	1.1	Chinese Tallow
	15	107.5	1.9	21.5	Chinese Tallow
	20	40.8	1.3	20.9	Chinese Tallow
	25	46.9	2.3	36.1	hickory
	30	38.3	2.7	53.8	hickory
	35	29.7	2.9	56.2	Chinese Tallow
	40	13.6	1.7	43.9	black willow
	45	12.4	2.0	58.0	sweet gum
	50	4.9	1.0	21.6	water oak
	55	6.2	1.5	44.9	water oak
	60	1.2	0.3	14.9	green ash
	65	1.2	0.4	13.6	sweet gum
	75	1.2	0.5	20.6	water oak
Grand Total		347.2	18.8	407.1	

TABLE 19. Stand and stock table from the standing vegetation at the Southern site on the lower Sabine River, Texas.

	Diameter Class (cm)	Trees ha^{-1}	Basal Area ha^{-1}	Volume (m^3 ha^{-1})	Dominant Species
	10	57.7	0.5	1.6	Chinese Tallow
	15	45.3	0.8	8.8	Chinese Tallow
	20	37.1	1.2	15.6	Chinese Tallow
	25	41.2	2.1	30.9	hickory
	30	30.9	2.3	28.7	hickory
	35	14.4	1.4	38.0	Chinese Tallow
	40	8.2	1.1	28.4	black willow
	45	4.1	0.7	18.5	sweet gum
	50	4.1	0.8	22.1	water oak
	55	10.3	2.5	69.5	water oak
	60	2.1	0.6	15.8	green ash
	65	2.1	0.7	19.1	sweet gum
	75	8.2	3.3	93.0	water oak
Grand Total		6.2	2.8	86.3	

The Southern site had best stocked forest, with an overall basal area of 20.8 m^2 ha^{-1}. It also had the most volume and stems per hectare (Table 19). An ANOVA was conducted on total volume and no significant differences between sites was observed (p=0.4118). This lack of statistical significance can in part be attributed to the large amount of variation observed among individual plots in each stand. Riverside volumes tend to be rather heterogeneous overall. One conclusion that can be reached is that recent hurricanes have not resulted in significant forest losses in the sites closer to the coast when compared to the sites further upriver, though Hurricane Rita in particular did result in significant LWD contributions to the river (Phillips and Park, 2009). Another important observation is the dominance of Chinese tallow tree in the two southernmost sites, particularly in the smaller diameter classes. This may indicate that regeneration of native species is being inhibited, and that this exotic invasive tree will dominate the future forest at these sites. In general, wood of Chinese tallow is less durable than species like oak and cypress, and this may alter future average residence times of LWD due to decay.

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APPENDIX A – DATA AND STATISTICAL ANALYSIS

TABLE A1. Burkeville bankside standing volume.

Species	DBH (cm)	Height (m)	Volume (m3)
American holly	10	6.10	0.020
American hornbeam	10	4.57	0.020
American hornbeam	10	6.10	0.020
Sugarberry	10	6.10	0.020
Sugarberry	10	6.10	0.020
Sweetgum	10	4.57	0.020
Sweetgum	10	9.14	0.020
Sweetgum	10	8.53	0.020
Sweetgum	10	7.62	0.020
Unknown	10	2.44	0.020
Water oak	10	10.67	0.020
Water oak	10	9.14	0.020
Willow oak	10	7.62	0.020
Elm	15	4.57	0.020
Hickory	15	9.14	0.020
Oak	15	4.57	0.020
River birch	15	4.57	0.020
Sugarberry	15	7.62	0.020
Sugarberry	15	7.62	0.020
Water oak	15	10.67	0.025
Water oak	15	12.19	0.028
American hornbeam	15	10.67	0.065
American hornbeam	15	3.05	0.051
American hornbeam	15	6.10	0.051
Blackgum	15	9.14	0.051
Blackwillow	15	9.14	0.051
Hickory	15	6.10	0.051
River birch	15	7.62	0.051
Water oak	15	10.67	0.065
Water oak	15	6.10	0.051
American hornbeam	20	4.57	0.076
Bald cypress	20	13.72	0.113
Hickory	20	9.14	0.076
Sugarberry	20	7.62	0.076
Unknown	20	4.88	0.076
Hickory	20	10.67	0.125
River birch	20	3.05	0.105
Sugarberry	20	13.72	0.153
Sugarberry	20	7.62	0.105
Sugarberry	20	12.19	0.139
Sweetgum	20	10.67	0.125
Water oak	20	7.62	0.105
Sycamore	25	13.72	0.198
Water oak	25	6.10	0.133

TABLE A1. (Continued).

Species	DBH (cm)	Height (m)	Volume (m3)
Elm	25	13.72	0.246
River birch	25	12.19	0.224
River birch	25	7.62	0.167
River birch	25	7.62	0.167
Unknown	25	8.84	0.167
Water oak	25	4.57	0.167
Water oak	25	10.67	0.204
Water oak	30	10.67	0.275
Bald cypress	30	4.57	0.328
River birch	30	12.19	0.328
Sweetgum	35	21.34	0.654
Hickory	35	21.34	0.762
Water oak	35	16.76	0.603
Water hickory	45	16.76	1.045
Snag	45	4.57	0.915
Water hickory	45	18.29	1.314
Water oak	45	13.72	0.915
Bald cypress	55	22.86	2.217
Hickory	55	15.24	1.659
Bald cypress	60	24.38	2.483
Hickory	60	19.81	1.968
Bald cypress	65	24.38	2.945
Bald cypress	65	24.38	2.945
Bald cypress	75	28.96	3.811

TABLE A2. Bon Wier bankside standing volume.

Species	DBH (cm)	Height (m)	Volume (m^3)
American holly	10	7.62	0.020
American hornbeam	10	9.14	0.020
American hornbeam	10	7.62	0.020
American hornbeam	10	6.10	0.020
American hornbeam	10	4.57	0.020
Oak	10	6.10	0.020
Oak	10	6.10	0.020
River birch	10	7.62	0.020
River birch	10	7.62	0.020
River birch	10	6.10	0.020
River birch	10	6.10	0.020
Sweetgum	10	4.57	0.020
Sycamore	10	9.14	0.020
Water oak	10	7.01	0.020
Water oak	10	4.57	0.020
Water oak	10	6.10	0.020
American holly	15	7.62	0.020
American holly	15	6.10	0.020
American hornbeam	15	6.10	0.020
American hornbeam	15	8.53	0.020
American hornbeam	15	7.62	0.020
American hornbeam	15	7.62	0.020
American hornbeam	15	9.14	0.020
American hornbeam	15	7.62	0.020
American hornbeam	15	6.10	0.020
Oak	15	6.10	0.020
River birch	15	10.67	0.025
River birch	15	9.14	0.020
River birch	15	6.10	0.020
River birch	15	6.10	0.020
Sweetgum	15	7.62	0.020
Sycamore	15	13.72	0.042
Sycamore	15	10.67	0.025
Water oak	15	7.62	0.020
Water oak	15	6.10	0.020
Water oak	15	9.14	0.020
American hornbeam	15	9.14	0.051
American hornbeam	15	13.72	0.076
American hornbeam	15	7.62	0.051
American hornbeam	15	4.57	0.051
River birch	15	9.14	0.051
River birch	15	10.67	0.065
River birch	15	7.62	0.051
River birch	15	9.14	0.051
Sycamore	15	15.24	0.085

TABLE A2 (Continued).

Species	DBH (cm)	Height (m)	Volume (m^3)
Unknown snag	15	3.66	0.051
Water oak	15	9.14	0.051
Water oak	15	6.10	0.051
Water oak	15	11.58	0.071
American holly	20	1.52	0.076
American hornbeam	20	7.62	0.076
American hornbeam	20	4.57	0.076
Elm	20	9.14	0.076
River birch	20	9.14	0.076
River birch	20	7.62	0.076
Sugarberry	20	9.14	0.076
Sweetgum	20	7.62	0.076
Sweetgum	20	12.19	0.102
Sycamore	20	15.24	0.122
Sycamore	20	14.63	0.122
Water oak	20	10.67	0.093
American hornbeam	20	6.10	0.105
Blackgum	20	6.10	0.105
Sugarberry	20	13.72	0.153
Swamp chestnut oak	20	7.62	0.105
Sweetgum	20	12.19	0.139
Sweetgum	20	15.24	0.167
Sweetgum	20	15.24	0.167
Sweetgum	25	13.72	0.198
Sweetgum	25	2.13	0.133
American hornbeam	25	9.14	0.167
American hornbeam	25	7.62	0.167
River birch	25	15.24	0.269
Sweetgum	25	7.62	0.167
Sycamore	25	18.29	0.326
Sugarberry	30	9.14	0.275
Sweetgum	30	18.29	0.399
Sweetgum	30	16.76	0.365
Snag	30	9.14	0.328
Sweetgum	30	10.67	0.311
Sweetgum	30	10.67	0.311
Sweetgum	30	15.24	0.513
Sweetgum	30	15.24	0.513
Sweetgum	30	3.66	0.311
Sweetgum	30	12.19	0.416
Snag	35	13.72	0.561
Sweetgum	35	16.76	0.688
Sweetgum	35	13.72	0.561
Sycamore	35	13.72	0.561
Sweetgum	35	18.29	0.810
Sweetgum	35	19.81	0.810
Sweetgum	35	16.76	0.688

TABLE A2 (Continued).

Species	DBH (cm)	Height (m)	Volume (m^3)
Sycamore	35	18.29	0.810
Ash	40	21.34	1.195
Sweetgum	40	16.76	0.892
Sweetgum	40	15.24	0.892
Swamp chestnut oak	40	19.81	1.045
Sweetgum	40	21.34	1.195
Sweetgum	40	19.81	1.195
Water oak	40	21.34	1.195
Sweetgum	45	19.81	1.045
Sweetgum	45	21.34	1.195
Willow oak	45	21.34	1.501
Swamp chestnut oak	50	21.34	1.841
Sweetgum	55	19.81	1.943
Water oak	55	19.81	1.943
Sweetgum	55	24.38	2.483
Loblolly pine	10	6.10	0.020
Loblolly pine	10	2.44	0.020
Loblolly pine	15	2.13	0.020
Loblolly pine	20	6.10	0.074
Loblolly pine	20	7.32	0.099
Loblolly pine	30	22.86	0.671
Loblolly pine	30	10.67	0.334
Loblolly pine	35	21.34	0.736
Loblolly pine	45	25.91	1.606

TABLE A3. Deweyville bankside standing volume.

Species	DBH (cm)	Height (m)	Volume (m^3)
American holly	10	7.62	0.020
American hornbeam	10	6.10	0.020
Black willow	10	2.44	0.020
Chinese tallow	10	10.67	0.025
Chinese tallow	10	13.11	0.042
Chinese tallow	10	10.67	0.025
Chinese tallow	10	12.19	0.028
Chinese tallow	10	7.01	0.020
Chinese tallow	10	6.10	0.020
Chinese tallow	10	6.10	0.020
Chinese tallow	10	7.62	0.020
Chinese tallow	10	4.57	0.020
Chinese tallow	10	9.14	0.020
Chinese tallow	10	3.05	0.020
Chinese tallow	10	3.66	0.020
Chinese tallow	10	6.10	0.020
Oak	10	6.10	0.020
Possumhaw	10	10.67	0.025
Red maple	10	9.14	0.020
Red maple	10	6.10	0.020
Red maple	10	1.83	0.020
River birch	10	6.10	0.020
River birch	10	3.05	0.020
Sweet gum	10	9.14	0.020
Unknown snag	10	1.58	0.020
Water hickory	10	7.62	0.020
Water hickory	10	6.10	0.020
Water hickory	10	7.62	0.020
Water oak	10	6.10	0.020
White oak	10	9.14	0.020
River birch snag	10	3.66	0.020
Sweet gum	10	12.19	0.028
American hornbeam	10	6.10	0.020
Red maple	10	7.62	0.020
Water oak	10	9.14	0.020
Blackgum	15	12.19	0.028
Chinese tallow	15	11.58	0.028
Chinese tallow	15	14.63	0.045
Chinese tallow	15	14.02	0.042
Chinese tallow	15	3.66	0.020
Chinese tallow	15	9.75	0.020
Chinese tallow	15	7.62	0.020
Chinese tallow	15	4.57	0.020
Chinese tallow	15	9.14	0.020
Chinese tallow	15	15.24	0.045
Elm	15	9.14	0.020

TABLE A3 (Continued).

Species	DBH (cm)	Height (m)	Volume (m^3)
Green ash	15	12.19	0.028
Red maple	15	10.67	0.025
Red maple	15	9.14	0.020
Red maple	15	6.71	0.020
Red maple	15	3.66	0.020
Red maple	15	4.57	0.020
Red maple	15	6.71	0.020
Red maple	15	12.19	0.028
Red maple	15	7.62	0.020
River birch	15	2.44	0.020
River birch	15	6.10	0.020
River birch	15	15.24	0.045
Tree sparkleberry	15	4.57	0.020
Tree sparkleberry	15	10.67	0.025
Tree sparkleberry	15	7.62	0.020
Water hickory	15	15.24	0.045
Water hickory	15	9.14	0.020
Water hickory	15	10.67	0.025
Water hickory	15	7.32	0.020
Water hickory	15	7.62	0.020
Water oak	15	6.10	0.020
Water oak	15	9.14	0.020
Winged elm	15	10.67	0.025
Sweetgum	15	9.75	0.020
Elm	15	7.62	0.051
Water hickory	15	9.14	0.051
Sweetgum	15	12.19	0.071
American hornbeam	15	7.62	0.051
American hornbeam	15	9.14	0.051
American hornbeam	15	9.14	0.051
ash	15	7.01	0.051
Chinese tallow	15	9.14	0.051
Chinese tallow	15	6.10	0.051
Chinese tallow	15	3.05	0.051
Chinese tallow	15	15.24	0.085
Chinese tallow	15	12.19	0.071
Chinese tallow	15	13.72	0.076
Chinese tallow snag	15	15.24	0.085
Elm	15	9.14	0.051
Elm	15	6.10	0.051
Elm	15	16.76	0.093
Green ash	15	13.72	0.076
Overcup oak	15	16.76	0.093
Possumhaw	15	6.10	0.051
Red maple	15	9.14	0.051
Red maple	15	13.72	0.076
Red maple	15	9.14	0.051

TABLE A3 (Continued).

Species	DBH (cm)	Height (m)	Volume (m^3)
Red maple	15	9.14	0.051
Red maple	15	3.05	0.051
River birch	15	10.67	0.065
River birch	15	4.57	0.051
River birch	15	6.10	0.051
River birch	15	9.14	0.051
River birch	15	16.46	0.093
River birch	15	15.24	0.085
River birch	15	14.63	0.085
Sweet gum	15	9.14	0.051
Sweet gum	15	9.14	0.051
Sycamore	15	14.63	0.085
Sycamore	15	6.10	0.051
Sycamore	15	13.72	0.076
unknown	15	3.05	0.051
Unknown snag	15	3.05	0.051
Unknown snag	15	10.67	0.065
Water hickory	15	18.29	0.102
Water hickory	15	15.85	0.085
Water hickory	15	13.72	0.076
Water oak	15	7.62	0.051
Water oak	15	7.62	0.051
Water oak	15	13.72	0.076
Water oak	15	13.11	0.071
Winged elm	15	9.14	0.051
American hornbeam	15	9.14	0.051
Elm	15	12.19	0.071
Black gum	15	13.72	0.113
American hornbeam	15	7.62	0.076
Blackgum	20	12.19	0.102
Chinese tallow	20	9.14	0.076
Chinese tallow	20	16.76	0.136
Chinese tallow	20	4.88	0.076
Chinese tallow	20	13.72	0.113
Chinese tallow	20	3.66	0.076
Chinese tallow	20	10.67	0.093
Chinese tallow	20	10.67	0.093
Overcup oak	20	7.62	0.076
Red maple	20	13.72	0.113
River birch	20	18.29	0.147
Sweet gum	20	12.19	0.102
Sweetgum	20	10.67	0.093
Sycamore	20	13.72	0.113
Sycamore	20	7.01	0.076
unknown	20	1.68	0.076
Water oak	20	11.58	0.093
Winged elm	20	12.19	0.102

TABLE A3 (Continued).

Species	DBH (cm)	Height (m)	Volume (m^3)
American hornbeam	20	9.14	0.076
Sweetgum	20	14.33	0.167
Black gum	20	12.19	0.139
Black willow snag	20	13.72	0.153
Chinese tallow	20	7.32	0.105
Hickory	20	12.19	0.139
Red maple	20	9.14	0.105
Sweet gum	20	12.19	0.139
Sweetgum	20	18.29	0.201
Sweetgum	20	12.19	0.139
Water hickory	20	15.24	0.167
Water hickory	20	19.81	0.218
Water hickory	20	17.37	0.201
Water hickory	20	21.34	0.232
Oak	20	18.29	0.201
Blackgum	25	13.72	0.198
Chinese tallow	25	15.24	0.215
Elm	25	9.14	0.133
Elm	25	9.14	0.133
Elm	25	15.24	0.215
Oak	25	13.72	0.198
Red maple	25	15.24	0.215
River birch	25	17.68	0.261
Sweetgum	25	9.14	0.133
Sweetgum	25	16.76	0.238
Sycamore	25	18.29	0.261
Unknown snag	25	3.66	0.133
Water hickory	25	21.34	0.300
Water hickory snag	25	13.72	0.198
Water hickory snag	25	2.74	0.167
American hornbeam	25	10.67	0.204
Black willow	25	2.74	0.167
Black willow	25	15.24	0.269
Black willow	25	3.05	0.167
Chinese tallow	25	1.83	0.167
Chinese tallow	25	18.29	0.326
Hickory	25	15.24	0.269
Hickory	25	21.34	0.377
Oak	25	15.24	0.269
Red maple	25	4.57	0.167
River birch	25	7.62	0.167
River birch	25	10.67	0.204
Sweetgum	25	18.29	0.326
Sycamore	25	4.57	0.167
Sycamore	25	12.19	0.224
Sycamore	25	15.24	0.269
unknown snag	25	3.05	0.167

TABLE A3 (Continued).

Species	DBH (cm)	Height (m)	Volume (m^3)
Unknown snag	25	2.13	0.167
Water hickory	25	18.29	0.326
Water hickory	25	3.05	0.167
Water hickory	25	15.24	0.269
Water hickory snag	25	3.66	0.167
Water oak snag	25	12.19	0.275
American hornbeam	30	6.10	0.275
Black willow	30	19.81	0.430
Black willow	30	15.24	0.331
Chinese tallow	30	18.29	0.399
Elm	30	19.81	0.430
River birch	30	9.14	0.275
River birch	30	18.29	0.399
River birch	30	12.19	0.275
Water hickory	30	21.34	0.462
Water hickory	30	12.19	0.275
Water hickory	30	19.81	0.430
Water hickory	30	3.05	0.275
Sweetgum	30	18.29	0.399
Oak	30	12.19	0.275
Water hickory	30	18.29	0.399
Red maple	30	15.24	0.396
Snag	30	12.19	0.328
American hornbeam	30	12.19	0.328
Black willow	30	8.53	0.328
Elm	30	12.19	0.328
Oak	30	16.76	0.439
Overcup oak	30	21.34	0.552
River birch	30	6.10	0.328
Sweetgum	30	19.81	0.515
Water hickory	30	3.66	0.328
Water hickory	30	13.72	0.362
Water hickory	30	18.29	0.479
Water oak	30	9.14	0.328
Red maple	30	16.76	0.518
American hornbeam	30	10.67	0.388
Willow oak	30	12.19	0.388
Black willow	35	6.10	0.388
Black willow	35	6.10	0.388
Chinese tallow	35	16.15	0.467
Chinese tallow	35	18.29	0.564
River birch	35	12.19	0.388
River birch	35	18.29	0.564
Sweet gum	35	13.72	0.428
Sweet gum	35	19.81	0.609
Bald cypress	35	16.76	0.518
Water hickory	35	21.34	0.654

TABLE A3 (Continued).

Species	DBH (cm)	Height (m)	Volume (m^3)
Water oak	35	3.93	0.388
Water oak snag	35	6.10	0.388
Black willow	35	9.14	0.388
Chinese tallow	35	3.05	0.544
Chinese tallow	35	7.92	0.544
Sycamore	35	18.29	0.657
Sycamore	35	16.76	0.603
Water hickory	35	24.38	0.858
Water hickory	35	18.29	0.657
Water hickory	35	18.29	0.657
Water oak	35	21.34	0.762
Water oak	35	21.34	0.762
Water oak snag	35	6.10	0.544
Sweet gum	35	7.38	0.629
Black willow	40	21.34	0.875
Black willow	40	19.81	0.818
Green ash	40	6.10	0.629
Overcup oak	40	13.11	0.629
Water hickory	40	22.86	1.065
Ash	40	12.19	0.716
Black willow	40	24.38	1.342
River birch	40	15.24	0.892
Water hickory	40	18.90	1.045
Water oak snag	40	18.29	1.045
Water hickory	40	22.86	1.342
Black willow	45	15.24	0.892
Sweet gum	45	18.29	1.045
Oak	45	25.91	1.863
Water hickory	45	24.38	1.682
Ash	45	24.38	1.682
Red oak	45	21.34	1.501
Sweetgum	45	19.81	1.501
Water hickory	45	17.98	1.314
Water oak snag	45	15.24	1.119
River birch	45	19.81	1.501
Water oak	50	22.25	1.501
Black willow	50	15.24	1.119
Water hickory	50	4.88	0.915
Oak	50	19.81	1.611
Ash	55	24.38	2.064
Black willow	55	13.72	1.376
Water hickory	55	25.91	2.282
Water oak	55	16.76	1.659
Water oak	55	24.38	2.483
Green ash	60	28.96	3.259
Sweet gum	65	22.86	3.078
Water oak	75	25.91	4.174

TABLE A4. Bon Wier Woody Debris Analysis

		Diameter				
Log Number	Length (ft)	Butt	Top	Species	Degree of Decay	Branch Presence
152	18.29	50.80	5.08	Water oak	1	Yes
153	3.66	30.48	10.16	unknown	3	Yes
154	6.10	20.32	5.08	unknown	3	Yes
155	3.05	30.48	5.08	unknown	3	No
156	6.10	38.10	5.08	unknown	3	No
157	14.63	30.48	17.78	Ash	2	Yes
158	7.62	17.78	5.08	unknown	3	Yes
159	4.57	15.24	5.08	American hornbeam	1	Yes
160	7.62	15.24	7.62	unknown	4	No
161	6.10	38.10	5.08	Water oak	2	Yes
162	2.13	25.40	5.08	Sweet gum	2	Yes
163	4.57	20.32	10.16	unknown	3	No
164	9.14	27.94	7.62	Elm	1	Yes
165	7.62	30.48	5.08	Sweet gum	1	Yes
166	5.49	38.10	15.24	Loblolly pine	3	No
167	3.66	10.16	30.48	unknown	3	No
168	9.14	20.32	76.20	Water oak	1	Yes
169	6.10	15.24	50.80	Maple	2	Yes
201	4.57	25.40	5.08	unknown	3	No
202	9.14	30.48	10.16	unknown	3	No
203	3.05	20.32	20.32	unknown	5	No
204	3.05	15.24	15.24	Loblolly pine	4	No
205	3.05	20.32	17.78	Loblolly pine	5	No
206	4.57	30.48	10.16	Loblolly pine	3	No
207	6.10	50.80	20.32	Loblolly pine	3	No
208	4.57	50.80	10.16	Loblolly pine	5	No
209	10.67	22.86	7.62	Sweet gum	1	No
210	12.19	35.56	7.62	Sycamore	1	Yes
211	4.57	20.32	5.08	American hornbeam	3	Yes
213	6.10	20.32	7.62	unknown	3	No
214	3.66	30.48	35.56	Loblolly pine	4	No
215	7.62	40.64	10.16	Sweet gum	1	No
216	6.10	40.64	10.16	unknown	5	No
217	3.66	30.48	35.56	Loblolly pine	4	No
218	3.05	30.48	35.56	Loblolly pine	4	No
219	3.66	25.40	25.40	Loblolly pine	4	No
220	3.66	25.40	35.56	Loblolly pine	3	No
221	3.05	22.86	5.08	unknown	4	No
222	4.57	20.32	5.08	unknown	4	No
223	7.62	20.32	5.08	unknown	4	No
224	4.57	10.16	5.08	unknown	4	No
225	9.14	50.80	10.16	unknown	3	No
226	5.49	30.48	7.62	American hornbeam	2	Yes
227	2.44	53.34	30.48	unknown	3	No

TABLE A4. (Continued).

Log Number	Potential Source	Origin	Bank Orientation	Root Wad	Position	Stage Contact
152	Cut	Local	0	Yes	Individual	1
153	Cut	Local	0	Yes	Individual	1
154	Cut	Local	0	No	Individual	1
155	unknown	unknown	0	Unknown	Individual	1
156	unknown	unknown	0	Unknown	Individual	1
157	Cut	Local	0	Yes	Individual	1
158	Cut	Local	0	Yes	Individual	1
159	Cut	Local	0	Yes	Individual	1
160	Cut	unknown	0	Unknown	Individual	1
161	Cut	Local	0	Unknown	Individual	1
162	Cut	Local	0	Unknown	Individual	1
163	Cut	Local	0	Yes	Individual	1
164	Cut	Local	90	Yes	Individual	1
165	Cut	Local	90	Yes	Individual	1
166	Windsnap	Local	90	No	Individual	1
167	unknown	unknown	90	No	Individual	1
168	Cut	Local	90	Yes	Jam	1
169	Cut	Local	90	Yes	Jam	1
201	Cut	Local	90	Yes	Individual	1
202	unknown	Local	0	No	Individual	1
203	unknown	Local	0	Yes	Individual	1
204	unknown	Local	0	No	Individual	1
205	unknown	Local	90	No	Individual	1
206	Windthrow	Local	0	Yes	Individual	1
207	Cut	Local	0	Yes	Individual	1
208	Cut	unknown	0	Unknown	Individual	1
209	unknown	Local	0	Yes	Individual	1
210	Cut	Local	0	Yes	Jam	1
211	Windthrow	Local	180	Yes	Jam	1
212	Cut	Local	90	Yes	Individual	1
213	Windthrow	Local	0	No	Individual	1
214	Cut	Upstream	180	Unknown	Individual	1
215	unknown	Local	90	Yes	Individual	1
216	Cut	unknown	180	Yes	Individual	1
217	unknown	Upstream	180	Unknown	Individual	1
218	unknown	Upstream	180	Unknown	Individual	1
219	unknown	Upstream	180	Unknown	Individual	1
220	unknown	Local	90	Unknown	Individual	1
221	unknown	unknown	0	Unknown	Individual	1
222	unknown	unknown	0	Unknown	Individual	1
223	unknown	unknown	0	Unknown	Individual	1
224	unknown	unknown	0	Unknown	Individual	1
225	Cut	Local	90	Unknown	Individual	1
226	Cut	Local	90	Yes	Jam	1
227	Windthrow	Local	0	Yes	Jam	1

TABLE A4. (Continued).

Log Number	Length (ft)	Diameter Butt	Diameter Top	Species	Degree of Decay	Branch Presence
228	4.57	15.24	38.10	American hornbeam	1	Yes
229	1.83	20.32	15.24	Loblolly pine	4	No
230	4.57	10.16	38.10	Maple	2	Yes
400	7.62	30.48	20.32	unknown	3	No
401	4.57	30.48	20.32	Loblolly pine	4	No
402	9.14	20.32	5.08	unknown	3	Yes
403	4.57	25.40	5.08	unknown	4	Yes
404	6.10	30.48	10.16	River birch	4	No
405	11.58	33.02	10.16	unknown	3	No
406	1.83	20.32	20.32	Black willow	3	No
407	7.62	20.32	10.16	Black willow	3	No
408	4.57	20.32	7.62	Sycamore	2	Yes
409	6.10	25.40	7.62	unknown	4	No
410	6.10	30.48	10.16	Black willow	2	Yes
411	6.10	15.24	5.08	River birch	1	Yes
412	6.10	20.32	7.62	River birch	1	Yes
413	3.05	25.40	20.32	Loblolly pine	4	No
414	9.14	40.64	7.62	Black willow	2	Yes
415	10.67	30.48	5.08	Black willow	2	No
416	4.57	35.56	25.40	unknown	3	No
417	3.05	15.24	7.62	unknown	3	No
418	12.19	30.48	5.08	River birch	1	Yes
419	7.62	20.32	10.16	unknown	3	No
420	3.05	30.48	10.16	unknown	4	No
421	4.57	25.40	15.24	unknown	3	No
422	3.05	20.32	5.08	unknown	3	No
423	6.10	35.56	15.24	unknown	3	No
424	9.14	45.72	15.24	Bald cypress	3	No
425	3.05	20.32	5.08	unknown	4	No
426	4.57	30.48	20.32	unknown	3	No

TABLE A4. (Continued).

Log Number	Potential Source	Origin	Bank Orientation	Root Wad	Position	Stage Contact
228	Windsnap	Local	0	No	Jam	1
229	unknown	Upstream	unknown	No	Jam	1
230	Cut	Local	0	Yes	Jam	1
400	Cut	Local	90	No	Individual	1
401	Cut	Local	90	Yes	Individual	1
402	unknown	Local	0	Unknown	Individual	1
403	unknown	unknown	0	Unknown	Individual	1
404	unknown	unknown	0	Unknown	Individual	1
405	Cut	Local	0	Yes	Individual	1
406	Cut	Local	90	Yes	Individual	1
407	Cut	Local	90	Unknown	Individual	1
408	Cut	Local	90	Yes	Individual	1
409	Cut	Local	90	Yes	Individual	1
410	Cut	Local	90	Yes	Individual	1
411	Windsnap	Local	0	No	Individual	3
412	Windsnap	Local	90	Yes	Individual	2
413	unknown	unknown	90	Unknown	Individual	1
414	Windthrow	Local	90	Yes	Individual	1
415	Windthrow	Local	0	Unknown	Individual	1
416	Windthrow	Local	90	Unknown	Individual	1
417	Cut	Local	90	Yes	Individual	1
418	Windthrow	Local	0	Unknown	Individual	2
419	Windthrow	Local	90	No	Individual	2
420	Cut	Local	90	Unknown	Individual	1
421	Cut	Local	180	Unknown	Individual	1
422	Cut	Local	180	Yes	Individual	1
423	Cut	Local	180	Yes	Individual	1
424	unknown	Upstream	180	Yes	Individual	1
425	unknown	Upstream	90	Unknown	Individual	1
426	unknown	Upstream	0	Unknown	Individual	1

TABLE A4. (Continued).

Log Number	Length (ft)	Diameter		Species	Degree of Decay	Branch Presence
		Butt	Top			
427	7.62	30.48	5.08	unknown	3	No
428	6.10	40.64	10.16	unknown	3	No
429	4.57	30.48	15.24	unknown	3	No
430	7.62	30.48	15.24	unknown	3	No
431	10.67	40.64	5.08	River birch	1	Yes
432	6.10	35.56	5.08	unknown	1	Yes
433	3.66	45.72	25.40	Loblolly pine	3	No
434	10.67	35.56	5.08	Loblolly pine	2	Yes
435	6.10	30.48	15.24	oak	2	Yes
436	4.57	20.32	5.08	Sweet gum	2	No
437	6.10	38.10	5.08	unknown	3	Yes
438	3.05	30.48	15.24	unknown	4	No
439	6.10	25.40	10.16	unknown	3	No
440	4.57	30.48	20.32	Loblolly pine	3	No
441	7.62	30.48	5.08	River birch	1	Yes
442	4.57	50.80	50.80	Loblolly pine	5	No
443	7.62	30.48	5.08	unknown	3	No
444	7.62	38.10	5.08	unknown	3	Yes
445	6.10	25.40	15.24	Water oak	2	Yes
446	6.10	30.48	20.32	unknown	3	No

TABLE A4. (Continued).

Log Number	Potential Source	Origin	Bank Orientation	Root Wad	Position	Stage Contact
427	unknown	unknown	0	Unknown	Individual	1
428	unknown	unknown	0	Yes	Jam	1
429	unknown	unknown	90	Unknown	Jam	1
430	unknown	unknown	180	Unknown	Individual	1
431	Cut	Local	0	Yes	Jam	1
432	Cut	Local	180	Yes	Individual	1
433	Cut	Local	90	Yes	Individual	1
434	Cut	Local	0	Yes	Individual	1
435	Cut	Local	180	Yes	Individual	1
436	Cut	Local	180	Yes	Individual	1
437	unknown	unknown	0	Unknown	Individual	1
438	unknown	unknown	180	Unknown	Individual	1
439	unknown	unknown	180	Yes	Individual	1
440	unknown	unknown	180	Unknown	Individual	1
441	unknown	Local	180	Unknown	Individual	1
442	Windthrow	Local	90	Unknown	Individual	1
443	unknown	unknown	180	Unknown	Individual	1
444	unknown	unknown	180	Unknown	Individual	1
445	unknown	unknown	180	No	Individual	1
446	unknown	unknown	180	No	Individual	1

TABLE A5. Burkeville Woody Debris Analysis

Log Number	Length (ft)	Diameter Butt	Diameter Top	Species	Degree of Decay	Branch Presence
501	7.62	45.72	30.48	unknown	3	No
502	1.83	35.56	10.16	unknown	5	No
503	6.10	50.80	38.10	unknown	5	No
504	7.62	27.94	17.78	unknown	4	No
505	15.24	121.92	63.50	unknown	4	No
506	12.19	111.76	63.50	unknown	4	No
507	9.14	50.80	5.08	water oak	2	Yes
508	6.10	38.10	20.32	unknown	4	No
509	7.62	50.80	25.40	unknown	4	No
510	9.14	15.24	5.08	unknown	3	No
511	6.10	25.40	10.16	American hornbeam	3	No
512	6.10	106.68	35.56	unknown	3	No
513	4.57	25.40	15.24	unknown	3	No
514	4.57	30.48	10.16	unknown	4	No
515	4.57	15.24	15.24	unknown	3	No
516	3.05	20.32	27.94	unknown	3	No
517	12.19	40.64	10.16	Loblolly pine	2	Yes
518	4.57	50.80	35.56	unknown	3	No
519	8.53	22.86	7.62	unknown	2	No
520	12.19	63.50	5.08	unknown	3	Yes
521	6.10	20.32	15.24	Loblolly pine	3	No
522	4.57	25.40	15.24	Loblolly pine	4	No
523	6.10	30.48	20.32	unknown	3	No
524	4.57	35.56	20.32	Loblolly pine	3	No
525	6.10	30.48	5.08	Loblolly pine	1	Yes
526	4.57	40.64	25.40	Loblolly pine	1	Yes
527	9.14	50.80	25.40	Loblolly pine	1	Yes
528	7.62	17.78	5.08	unknown	3	Yes
529	6.10	25.40	10.16	unknown	3	No
530	9.14	45.72	10.16	unknown	3	No
531	6.10	50.80	20.32	unknown	3	No
532	3.05	20.32	20.32	unknown	4	No
533	9.14	38.10	15.24	unknown	3	No
534	6.71	50.80	25.40	unknown	3	No
535	3.05	20.32	15.24	unknown	3	No
536	6.10	20.32	12.70	unknown	3	No

TABLE A5. (Continued).

Log Number	Potential Source	Origin	Bank Orientation	Root Wad	Position	Stage Contact
501	Cut	Local	0	Yes	Fallen tree	1
502	Cut	Local	180	Yes	Fallen tree	1
503	Cut	Local	90	Yes	Fallen tree	1
504	Cut	Local	0	No	Fallen tree	1
505	Cut	Local	0	Yes	Fallen tree	1
506	Unknown	Upstream	0	Yes	Individual	1
507	Cut	Local	0	Yes	Fallen tree	1
508	Cut	Local	0	Yes	Fallen tree	1
509	Cut	Local	90	Yes	Fallen tree	1
510	Unknown	Upstream	0	Unknown	Individual	1
511	Unknown	Upstream	0	Unknown	Individual	1
512	Unknown	Upstream	90	Yes	Individual	1
513	Unknown	Upstream	90	No	Jam	1
514	Unknown	Upstream	180	No	Individual	1
515	Unknown	Upstream	0	Yes	Jam	1
516	Unknown	Upstream	90	No	Jam	1
517	Unknown	Upstream	90	Yes	Individual	1
518	Unknown	Upstream	0	No	Jam	1
519	Unknown	Upstream	0	No	Jam	1
520	Unknown	Upstream	90	Unknown	Jam	1
521	Unknown	Upstream	0	No	Jam	1
522	Unknown	Upstream	0	No	Jam	1
523	Unknown	Upstream	0	No	Jam	1
524	Cut	Local	90	Yes	Fallen tree	3
525	Cut	Local	0	Yes	Fallen tree	2
526	Cut	Local	90	Yes	Fallen tree	4
527	Cut	Local	180	Yes	Fallen tree	3
528	Unknown	Upstream	0	Unknown	individual	1
529	Unknown	Upstream	0	No	individual	1
530	Unknown	Upstream	0	No	individual	1
531	Unknown	Upstream	0	Yes	individual	1
532	Unknown	Upstream	180	Unknown	individual	1
533	Unknown	Upstream	0	Yes	Jam	1
534	Unknown	Upstream	90	No	Jam	1
535	Unknown	Upstream	0	No	Jam	1
536	Unknown	Upstream	0	No	Jam	1

TABLE A5. (Continued).

Log Number	Length (ft)	Diameter Butt	Diameter Top	Species	Degree of Decay	Branch Presence
537	3.66	20.32	10.16	unknown	3	No
538	4.27	63.50	40.64	Loblolly pine	2	No
539	15.24	114.30	25.40	Sweet gum	2	Yes
540	9.14	38.10	5.08	water oak	1	Yes
541	9.14	25.40	7.62	Loblolly pine	1	Yes
542	5.49	50.80	15.24	unknown	3	Yes
543	7.62	40.64	7.62	unknown	3	No
544	5.49	25.40	5.08	unknown	3	Yes
545	5.49	20.32	5.08	unknown	3	Yes
546	4.27	25.40	20.32	unknown	3	No
547	10.67	45.72	10.16	unknown	2	Yes
548	9.14	45.72	10.16	Sweet gum	2	Yes
549	6.10	20.32	5.08	Loblolly pine	2	Yes
550	10.67	40.64	5.08	Loblolly pine	2	Yes
551	9.14	40.64	5.08	Sweet gum	1	Yes
552	2.44	20.32	10.16	unknown	3	No
553	4.88	20.32	7.62	unknown	3	No
554	6.71	25.40	15.24	unknown	4	No
555	7.62	40.64	7.62	unknown	3	No
556	7.32	30.48	5.08	hickory	3	Yes
557	12.80	149.86	76.20	unknown	3	No
558	7.62	35.56	15.24	Black tupelo	1	Yes
559	2.44	55.88	30.48	unknown	2	No
560	5.18	30.48	15.24	unknown	3	No
561	7.62	30.48	30.48	unknown	3	No
562	9.75	50.80	10.16	unknown	4	No
563	6.10	25.40	10.16	unknown	4	No
564	4.57	50.80	25.40	unknown	3	No
565	4.57	20.32	5.08	unknown	2	Yes
566	7.62	33.02	5.08	unknown	3	Yes
567	10.67	50.80	10.16	water oak	2	Yes
568	7.62	40.64	10.16	unknown	3	Yes
569	9.14	45.72	20.32	unknown	2	Yes
570	6.71	20.32	10.16	Loblolly pine	4	No
571	8.23	53.34	15.24	Sweet gum	3	Yes
572	6.10	35.56	15.24	unknown	3	No
573	2.13	30.48	22.86	unknown	3	Yes

TABLE A5. (Continued).

Log Number	Potential Source	Origin	Bank Orientation	Root Wad	Position	Stage Contact
537	Unknown	Upstream	90	No	Jam	1
538	Cut	Local	180	Yes	Jam	1
539	Cut	Local	0	Yes	Fallen tree	2
540	Cut	Local	0	Yes	Fallen tree	2
541	Cut	Local	0	Yes	Fallen tree	2
542	Cut	Local	180	Yes	Fallen tree	2
543	Cut	Local	0	Yes	Jam	2
544	Cut	Local	180	Yes	Jam	2
545	Cut	Local	180	Yes	Jam	2
546	Unknown	Local	90	No	Jam	1
547	Cut	Local	0	Yes	Fallen tree	2
548	Cut	Local	0	Yes	Fallen tree	2
549	Cut	Local	90	Yes	Fallen tree	2
550	Cut	Local	180	Yes	Fallen tree	2
551	Cut	Local	90	Yes	Fallen tree	2
552	Unknown	Unknown	90	No	Jam	1
553	Unknown	Unknown	0	No	Jam	1
554	Unknown	Unknown	0	No	Jam	1
555	Unknown	Unknown	0	No	Jam	1
556	Unknown	Unknown	0	Yes	individual	1
557	Cut	Local	0	No	Fallen tree	1
558	Cut	Local	0	No	Fallen tree	2
559	Cut	Local	90	Yes	Fallen tree	1
560	Unknown	Unknown	0	Yes	Jam	1
561	Unknown	Upstream	0	No	individual	1
562	Unknown	Upstream	0	No	individual	1
563	Unknown	Upstream	90	Yes	individual	1
564	Unknown	Upstream	0	Unknown	individual	1
565	Cut	Local	0	Yes	Fallen tree	1
566	Unknown	Upstream	0	Unknown	individual	1
567	Cut	Local	0	Yes	Fallen tree	1
568	Cut	Local	0	Yes	Fallen tree	1
569	Cut	Local	0	Yes	Fallen tree	1
570	Cut	Local	90	Yes	Fallen tree	1
571	Cut	Local	90	Yes	Fallen tree	1
572	Unknown	Upstream	0	Yes	Jam	1
573	Unknown	Upstream	0	Yes	Jam	1

TABLE A5. (Continued).

Log Number	Length (ft)	Diameter		Species	Degree of Decay	Branch Presence
		Butt	Top			
574	6.10	22.86	20.32	water oak	2	Yes
575	12.19	25.40	10.16	Bald cypress	4	Yes
576	4.88	20.32	10.16	unknown	4	No
577	6.10	25.40	5.08	unknown	4	No
578	6.10	63.50	25.40	unknown	4	No
579	4.57	45.72	45.72	water oak	3	No
580	6.10	50.80	15.24	Sweet gum	3	Yes
581	15.24	50.80	5.08	Loblolly pine	2	Yes
582	19.81	101.60	5.08	Ash	2	Yes
583	6.10	25.40	5.08	unknown	3	Yes
584	2.44	15.24	5.08	unknown	3	No
585	9.14	50.80	5.08	unknown	3	Yes
586	6.10	15.24	10.16	unknown	3	Yes
587	9.14	45.72	10.16	unknown	3	Yes
588	6.10	25.40	10.16	unknown	4	Yes
589	6.10	15.24	7.62	unknown	3	Yes
590	12.19	45.72	20.32	unknown	3	Yes
591	9.14	30.48	12.70	Sweet gum	2	Yes
592	12.19	114.30	12.70	unknown	2	Yes
593	2.13	30.48	10.16	unknown	5	No

TABLE A5. (Continued).

Log Number	Potential Source	Origin	Bank Orientation	Root Wad	Position	Stage Contact
574	Unknown	Upstream	0	Yes	Jam	1
575	Unknown	Upstream	0	Yes	individual	1
576	Unknown	Upstream	90	Unknown	Jam	1
577	Unknown	Upstream	90	Unknown	Jam	1
578	Unknown	Upstream	90	Unknown	Jam	1
579	Cut	Local	90	Yes	Jam	1
580	Cut	Local	0	Yes	Fallen tree	1
581	Cut	Local	0	Yes	Fallen tree	1
582	Unknown	Upstream	0	Unknown	individual	1
583	Unknown	Upstream	0	Unknown	individual	1
584	Unknown	Upstream	0	Unknown	individual	1
585	Unknown	Upstream	90	Unknown	individual	1
586	Unknown	Upstream	90	Yes	individual	1
587	Unknown	Upstream	0	Yes	individual	1
588	Unknown	Upstream	90	Yes	individual	1
589	Unknown	Upstream	0	Unknown	individual	1
590	Cut	Local	0	Yes	Jam	1
591	Cut	Local	90	Yes	Jam	1
592	Cut	Local	90	Yes	Jam	1
593	Cut	Local	0	Unknown	individual	1

TABLE A6. Deweyville Woody Debris Analysis

Log Number	Length (ft)	Diameter Butt	Diameter Top	Species	Degree of Decay	Branch Presence
101	9.14	30.48	34.29	Unknown	3	No
102	4.57	35.81	28.70	Unknown	3	No
103	3.05	30.48	22.86	Unknown	3	No
104	3.35	25.40	15.24	Unknown	3	No
105	9.14	20.32	7.62	Chinese tallow	1	Yes
106	12.19	25.40	12.70	River birch	1	Yes
107	2.44	12.70	12.70	Unknown	4	No
108	4.57	35.56	30.48	Unknown	5	No
109	4.57	35.56	30.48	Unknown	3	No
110	6.10	38.10	20.32	Elm	3	No
111	7.62	15.24	5.08	Unknown	1	Yes
112	6.10	15.24	5.08	Unknown	1	Yes
113	12.19	17.78	5.08	Black willow	3	Yes
114	7.62	22.86	10.16	Unknown	2	No
115	15.24	69.09	45.72	Oak	4	No
116	9.14	22.86	7.62	Sweet gum	3	Yes
117	6.10	43.18	38.10	Unknown	4	No
118	2.13	25.40	20.32	Unknown	4	No
119	6.10	15.24	7.62	River birch	1	Yes
120	3.66	36.58	25.40	Unknown	3	No
121	6.10	17.78	10.16	Unknown	4	No
122	7.62	26.92	12.70	Chinese tallow	3	Yes
123	2.44	25.40	25.40	Unknown	4	No
124	3.35	22.86	10.16	Unknown	4	No
125	4.57	20.32	5.08	Unknown	3	Yes
126	6.10	25.40	25.40	Unknown	2	Yes
127	6.10	35.56	25.40	Unknown	3	No
128	15.24	43.18	25.40	Black willow	1	Yes
129	4.57	12.70	10.16	Unknown	3	Yes
130	6.10	33.78	5.08	Elm	2	Yes
131	6.10	38.10	25.40	Chinese tallow	3	No
132	12.19	45.72	17.78	River birch	2	Yes
133	6.10	30.48	12.70	River birch	2	Yes
134	16.76	38.10	15.24	River birch	2	Yes
135	12.19	22.86	5.08	Unknown	2	Yes
136	12.19	30.48	12.70	Unknown	3	Yes

TABLE A6. (Continued).

Log Number	Potential Source	Origin	Bank Orientation	Root Wad	Position	Stage Contact
101	Unknown	Unknown	90	No	Ind piece	2
102	Unknown	Unknown	90	No	Ind piece	2
103	Unknown	Unknown	90	No	Ind piece	1
104	Unknown	Unknown	180	Yes	Ind piece	3
105	Cut	Local	90	Yes	Ind piece	2
106	Cut	Local	90	Yes	Ind piece	2
107	Unknown	Unknown	Unknown	No	Ind piece	4
108	Unknown	Unknown	Unknown	No	Jam	4
109	Unknown	Unknown	Unknown	No	Jam	4
110	Unknown	Unknown	Unknown	No	Jam	4
111	Windthrow	Local	0	Yes	Fallen tree	1
112	Windthrow	Local	90	Yes	Fallen tree	1
113	Unknown	Unknown	180	Unknown	Fallen tree	1
114	Unknown	Unknown	90	Yes	Fallen tree	1
115	Unknown	Unknown	90	Yes	Fallen tree	1
116	Unknown	Unknown	90	Yes	Fallen tree	1
117	Unknown	Unknown	0	No	Ind piece	1
118	Unknown	Unknown	90	No	Ind piece	1
119	Unknown	Unknown	90	Unknown	Fallen tree	1
120	Unknown	Unknown	180	Yes	Fallen tree	1
121	Unknown	Unknown	90	No	Ind piece	1
122	Unknown	Unknown	0	Yes	Fallen tree	1
123	Unknown	Unknown	180	No	Ind piece	2
124	Unknown	Unknown	180	No	Ind piece	3
125	Unknown	Unknown	90	No	Ind piece	2
126	Unknown	Unknown	90	Unknown	Fallen tree	1
127	Unknown	Unknown	90	Yes	Ind piece	1
128	Windsnap	Local	90	Yes	Fallen tree	2
129	Unknown	Unknown	180	No	Ind piece	2
130	Unknown	Unknown	90	Yes	Fallen tree	1
131	Unknown	Local	90	Yes	Fallen tree	1
132	Unknown	Local	90	Yes	Fallen tree	3
133	Unknown	Local	180	Yes	Fallen tree	3
134	Unknown	Local	0	Yes	Fallen tree	1
135	Unknown	Local	180	Yes	Fallen tree	3
136	Unknown	Local	0	Unknown	Fallen tree	1

TABLE A6. (Continued).

Log Number	Length (ft)	Diameter		Species	Degree of Decay	Branch Presence
		Butt	Top			
137	3.66	20.32	10.16	Unknown	4	No
138	9.14	30.48	27.94	Unknown	2	Yes
139	12.19	52.32	20.32	Unknown	2	Yes
140	1.98	31.24	30.48	Unknown	3	No
141	7.62	38.10	26.42	Unknown	3	No
142	6.10	35.56	7.62	Unknown	2	No
143	4.57	30.48	15.24	Unknown	2	Yes
144	9.14	10.16	20.32	Unknown	2	No
145	7.62	17.78	10.16	Unknown	2	Yes
146	10.67	25.40	5.08	Unknown	2	Yes
147	4.57	10.16	20.32	Chinese tallow	2	Yes
148	3.05	10.16	20.32	Unknown	2	Yes
149	6.10	27.94	5.08	Unknown	3	Yes
151	3.05	12.70	12.70	Unknown	4	No
232	2.44	20.32	15.24	Unknown	4	No
233	13.72	30.48	10.16	Unknown	3	No
234	15.24	30.48	10.16	Chinese tallow	2	No
235	6.10	25.40	15.24	Unknown	4	No
236	6.10	20.32	15.24	Unknown	3	No
237	4.57	15.24	10.16	Unknown	3	No
238	13.72	17.78	5.08	Unknown	3	Yes
239	4.57	15.24	5.08	Unknown	3	No
240	4.57	15.24	10.16	Unknown	3	No
241	3.66	33.02	33.02	Unknown	4	No
242	3.66	25.40	10.16	Unknown	4	No
243	4.57	25.40	20.32	Unknown	3	No
244	6.10	15.24	10.16	Unknown	3	No
245	6.10	33.02	20.32	Unknown	4	No
246	12.19	40.64	30.48	Black willow	3	Yes
247	6.10	15.24	15.24	Unknown	3	No
248	6.10	30.48	5.08	Black willow	2	Yes
249	4.57	25.40	12.70	Unknown	4	No
250	7.62	25.40	5.08	American hornbeam	1	Yes
251	4.57	35.56	15.24	Unknown	3	No
252	7.62	20.32	15.24	Unknown	3	Yes
253	2.44	30.48	20.32	Unknown	3	No
254	6.10	20.32	12.70	Unknown	2	Yes
255	15.24	30.48	5.08	Black willow	2	Yes
256	4.57	25.40	15.24	Sweet gum	2	No
257	7.62	20.32	10.16	Unknown	3	Yes
258	7.62	20.32	5.08	Unknown	3	Yes
259	13.72	40.64	5.08	Unknown	1	Yes
260	6.10	20.32	10.16	Unknown	3	No
261	6.10	20.32	7.62	Unknown	3	No

TABLE A6. (Continued).

Log Number	Potential Source	Origin	Bank Orientation	Root Wad	Position	Stage Contact
137	Unknown	Local	90	No	Ind piece	4
138	Unknown	Local	180	Yes	Fallen tree	1
139	Unknown	Local	180	Yes	Fallen tree	1
140	Unknown	Local	90	No	Ind piece	2
141	Unknown	Unknown	180	No	Ind piece	1
142	Unknown	Unknown	0	No	Ind piece	1
143	Unknown	Unknown	0	Yes	Fallen tree	1
144	Unknown	Unknown	0	Unknown	Fallen tree	1
145	Unknown	Unknown	0	Yes	Fallen tree	1
146	Unknown	Local	0	Yes	Fallen tree	2
147	Unknown	Local	0	Yes	Fallen tree	2
148	Unknown	Unknown	0	Unknown	Ind piece	1
149	Windthrow	Unknown	90	Yes	Ind piece	1
151	Unknown	Unknown	90	No	Ind piece	1
232	Cut	Local	90	Yes	Jam	1
233	Cut	Local	0	Yes	Jam	1
234	Cut	Local	0	Yes	Jam	1
235	Unknown	Local	90	Yes	Ind piece	1
236	Windsnap	Local	90	No	Ind piece	2
237	Windsnap	Local	90	No	Ind piece	2
238	Windsnap	Local	90	No	Fallen tree	3
239	Unknown	Unknown	90	No	Jam	2
240	Unknown	Unknown	90	No	Jam	2
241	Unknown	unknown	90	Yes	Jam	2
242	Unknown	Unknown	90	No	Jam	2
243	Unknown	Unknown	90	No	Jam	2
244	Unknown	Unknown	90	Yes	Jam	2
245	Unknown	Unknown	0	Yes	Jam	2
246	Windsnap	Local	90	No	Fallen tree	3
247	Cut	Local	90	Yes	Fallen tree	3
248	Cut	Local	90	Yes	Fallen tree	3
249	Unknown	Unknown	90	No	Ind piece	1
250	Cut	Local	90	Yes	Fallen tree	2
251	Cut	Local	90	Yes	Fallen tree	1
252	Unknown	Unknown	180	Unknown	Ind piece	1
253	Unknown	Unknown	180	No	Ind piece	1
254	Cut	Local	90	Yes	Fallen tree	1
255	Cut	Local	0	Yes	Fallen tree	1
256	Unknown	Unknown	0	Yes	Jam	1
257	Unknown	Local	0	Yes	Fallen tree	1
258	Unknown	Unknown	0	Unknown	Jam	1
259	Cut	Local	0	Yes	Jam	1
260	Unknown	Unknown	180	Yes	Ind piece	1
261	Unknown	Unknown	180	No	Jam	1

TABLE A6. (Continued).

Log Number	Length (ft)	Diameter Butt	Diameter Top	Species	Degree of Decay	Branch Presence
262	7.62	30.48	10.16	Unknown	4	No
263	7.62	33.02	7.62	Unknown	2	No
264	15.24	40.64	5.08	Sycamore	1	Yes
265	4.57	50.80	25.40	Unknown	4	No
266	9.14	33.02	30.48	Unknown	3	No
267	12.19	20.32	5.08	Unknown	2	Yes
268	4.57	50.80	45.72	Unknown	4	No
269	4.57	25.40	20.32	Unknown	4	No
270	7.62	30.48	20.32	Unknown	4	No
271	9.14	50.80	5.08	Unknown	3	Yes
272	4.57	45.72	15.24	Unknown	4	No
273	9.14	30.48	30.48	Unknown	3	No
274	12.19	35.56	20.32	Bald cypress	3	No
275	12.19	55.88	20.32	Unknown	3	No
276	7.62	25.40	5.08	Ash	3	Yes
277	7.62	33.02	25.40	Pine	4	No
278	4.57	15.24	15.24	Unknown	4	No
279	6.10	27.94	22.86	Unknown	4	No
280	7.62	35.56	20.32	Pine	3	No
281	10.67	40.64	20.32	Pine	3	No
282	9.14	40.64	5.08	Unknown	1	Yes
283	9.14	40.64	20.32	Unknown	4	No
284	9.75	17.78	10.16	Unknown	4	No
285	9.14	25.40	5.08	American elm	1	Yes
286	9.14	25.40	5.08	Slippery elm	1	Yes
287	1.52	30.48	25.40	Unknown	4	No
288	10.67	30.48	7.62	Water oak	1	Yes
289	15.24	30.48	7.62	Sweet gum	1	Yes
290	21.34	30.48	5.08	Unknown	1	Yes
291	10.67	66.04	25.40	Unknown	4	No
292	7.62	35.56	22.86	Unknown	3	No
293	10.67	48.26	25.40	Unknown	4	No
294	6.10	38.10	27.94	Unknown	2	No
295	6.10	15.24	5.08	Oak	1	Yes
296	5.49	38.10	15.24	Unknown	3	No
297	2.13	27.94	27.94	Unknown	4	No
298	3.05	22.86	22.86	Unknown	4	No
299	6.10	20.32	5.08	Unknown	3	Yes
300	7.62	20.32	5.08	River birch	1	Yes

TABLE A6. (Continued).

Log Number	Potential Source	Origin	Bank Orientation	Root Wad	Position	Stage Contact
262	Unknown	Unknown	180	No	Jam	1
263	Unknown	Unknown	180	Yes	Jam	1
264	Windthrow	Local	0	Yes	Fallen tree	4
265	Unknown	Unknown	90	No	Jam	1
266	Windsnap	Local	0	No	Fallen tree	1
267	Windsnap	Local	90	Yes	Fallen tree	1
268	Unknown	Unknown	0	Unknown	Jam	1
269	Unknown	Unknown	0	Yes	Jam	1
270	Unknown	Unknown	0	Unknown	Jam	1
271	Cut	Local	90	Unknown	Jam	1
272	Unknown	Unknown	0	Yes	Jam	1
273	Unknown	Unknown	90	Unknown	Jam	1
274	Unknown	Unknown	0	Unknown	Jam	1
275	Unknown	Local	180	Yes	Jam	1
276	Windthrow	Local	90	Yes	Fallen tree	1
277	Unknown	Unknown	90	No	Jam	1
278	Unknown	Upstream	180	No	Jam	1
279	Unknown	Upstream	180	No	Jam	1
280	Unknown	Unknown	0	No	Jam	1
281	Unknown	Unknown	180	No	Jam	1
282	Windthrow	Local	0	Yes	Fallen tree	2
283	Unknown	Unknown	0	No	Jam	1
284	Unknown	Unknown	180	No	Jam	1
285	Windthrow	Local	0	Yes	Fallen tree	4
286	Windthrow	Local	0	Yes	Fallen tree	2
287	Unknown	Unknown	0	Yes	Jam	2
288	Windthrow	Local	180	Yes	Fallen tree	1
289	Windthrow	Local	180	Yes	Fallen tree	1
290	Windthrow	Local	0	Yes	Fallen tree	1
291	Cut	Local	0	No	Jam	1
292	Windthrow	Unknown	180	Yes	Jam	1
293	Windthrow	Local	90	Yes	Fallen tree	1
294	Windthrow	Local	90	Yes	Fallen tree	1
295	Cut	Local	180	Yes	Fallen tree	1
296	Unknown	Unknown	90	Yes	Ind piece	1
297	Unknown	Local	90	Unknown	Fallen tree	1
298	Unknown	Local	90	Unknown	Fallen tree	1
299	Unknown	Unknown	90	Unknown	Ind piece	1
300	Unknown	Local	90	Yes	Fallen tree	2

TABLE A7. Southern Site Woody Debris Analysis

Log Number	Length (ft)	Diameter Butt	Diameter Top	Species	Degree of Decay	Branch Presence
594	6.10	30.48	5.08	unknown	3	No
595	4.27	20.32	7.62	unknown	4	No
596	4.57	40.64	20.32	unknown	4	No
597	3.66	30.48	20.32	unknown	4	No
598	7.62	20.32	7.62	unknown	3	No
599	6.10	25.40	5.08	unknown	3	No
600	6.10	25.40	12.70	loblolly pine	4	No
601	10.67	30.48	20.32	oak	4	No
602	9.14	30.48	15.24	cedar	4	No
603	3.05	17.78	10.16	unknown	4	No
604	2.44	12.70	10.16	unknown	3	No
605	2.44	12.70	12.70	loblolly pine	2	No
606	2.44	20.32	15.24	unknown	4	No
607	10.67	20.32	10.16	Chinese tallow	2	Yes
608	6.10	30.48	15.24	loblolly pine	4	No
609	3.05	45.72	40.64	River birch	5	No
611	12.19	60.96	30.48	unknown	3	No
612	15.24	20.32	55.88	Black willow	2	Yes
613	7.62	35.56	15.24	Black willow	3	Yes
614	4.57	30.48	15.24	unknown	4	No
615	3.05	15.24	10.16	unknown	4	No
616	3.05	15.24	10.16	loblolly pine	3	No
617	3.05	25.40	30.48	unknown	4	No
618	12.19	45.72	20.32	Black willow	2	Yes
619	12.19	50.80	10.16	Black willow	2	Yes
620	9.14	40.64	10.16	Black willow	1	Yes
621	3.05	20.32	25.40	oak	3	No
622	6.10	40.64	25.40	unknown	4	No
623	2.44	40.64	30.48	Black willow	3	No
624	6.10	27.94	20.32	unknown	3	No
625	9.14	40.64	30.48	unknown	3	No
626	10.67	50.80	10.16	Black willow	3	No
627	3.05	30.48	25.40	unknown	4	No
628	7.62	30.48	15.24	Black willow	2	Yes
629	12.19	45.72	15.24	Black willow	1	Yes
630	3.35	30.48	10.16	loblolly pine	3	No
631	3.05	30.48	15.24	unknown	4	No
632	6.10	30.48	10.16	Black willow	1	Yes

TABLE A7. (Continued).

Log Number	Potential Source	Origin	Bank Orientation	Root Wad	Position	Stage Contact
594	Unknown	Unknown	0	No	Individual	4
595	Unknown	Unknown	180	No	Jam	3
596	Unknown	Unknown	90	No	Jam	1
597	Unknown	Upstream	90	No	Jam	1
598	Unknown	Upstream	0	No	Jam	1
599	Unknown	Upstream	0	No	Jam	1
600	Unknown	Upstream	0	No	Jam	1
601	Unknown	Unknown	90	No	Jam	1
602	Unknown	Unknown	90	No	Jam	1
603	Unknown	Upstream	90	No	Jam	1
604	Unknown	Upstream	90	No	Jam	1
605	Unknown	Upstream	90	No	Jam	1
606	Unknown	Upstream	90	No	Jam	1
607	Windthrow	Local	180	Yes	Fallen tree	1
608	Unknown	Unknown	180	No	Individual	1
609	Unknown	Unknown	90	No	Individual	1
611	Windthrow	Unknown	90	No	Jam	1
612	Windthrow	Local	90	Yes	Jam	1
613	Unknown	Unknown	180	No	Jam	1
614	Unknown	Unknown	180	No	Jam	2
615	Unknown	Unknown	90	No	Jam	1
616	Unknown	Unknown	180	Yes	Jam	1
617	Unknown	Unknown	180	No	Jam	1
618	Windthrow	Local	90	Yes	Fallen tree	1
619	Windthrow	Local	90	Yes	Fallen tree	1
620	Windthrow	Local	180	Yes	Fallen tree	1
621	Unknown	Unknown	90	No	unknown	1
622	Unknown	Unknown	90	No	unknown	1
623	Cut	Local	90	No	Fallen tree	1
624	Windthrow	Local	90	No	Fallen tree	1
625	Unknown	Upstream	0	No	Jam	1
626	Windthrow	Local	90	No	Fallen tree	1
627	Windthrow	Upstream	90	No	Jam	1
628	windsnap	Local	90	No	Fallen tree	2
629	Windthrow	Local	90	Yes	Fallen tree	2
630	Unknown	Upstream	90	No	Fallen tree	1
631	Unknown	Unknown	90	No	Individual	1
632	Windthrow	Local	90	No	Individual	3

TABLE A7. (Continued).

Log Number	Length (ft)	Diameter		Species	Degree of Decay	Branch Presence
		Butt	Top			
701	5.49	25.40	20.32	loblolly pine	4	No
702	6.10	25.40	15.24	unknown	5	No
703	3.05	15.24	20.32	unknown	4	No
704	7.62	38.10	5.08	American holly	1	Yes
705	6.10	33.02	20.32	unknown	3	No
706	7.62	33.02	7.62	unknown	4	No
707	3.66	30.48	15.24	River birch	1	Yes
708	4.57	43.18	20.32	unknown	4	No
709	1.83	10.16	10.16	unknown	4	No
710	5.49	40.64	10.16	oak	5	No
712	10.67	40.64	5.08	oak	3	Yes
713	5.49	25.40	10.16	loblolly pine	4	No
715	4.57	30.48	15.24	unknown	4	No
717	9.14	55.88	30.48	loblolly pine	4	Yes
718	3.05	25.40	25.40	loblolly pine	5	No
719	9.14	40.64	5.08	River birch	2	Yes
720	6.10	30.48	20.32	unknown	4	No
721	9.14	30.48	5.08	loblolly pine	4	No
722	3.66	20.32	7.62	unknown	4	No
723	6.10	20.32	5.08	River birch	2	Yes
724	9.14	30.48	15.24	unknown	3	No
725	6.10	30.48	5.08	unknown	4	Yes
726	12.19	50.80	20.32	River birch	3	Yes
727	13.72	55.88	10.16	oak	4	Yes
728	10.67	50.80	5.08	water oak	3	Yes
729	7.62	30.48	5.08	unknown	4	No
730	9.14	30.48	5.08	hickory	4	Yes
731	4.57	30.48	20.32	Black willow	3	Yes
732	6.10	50.80	10.16	Black willow	2	Yes

TABLE A7. (Continued).

Log Number	Potential Source	Origin	Bank Orientation	Root Wad	Position	Stage Contact
701	Unknown	Upstream	0	No	Jam	1
702	Unknown	Upstream	90	No	Jam	1
703	Unknown	Unknown	90	No	Individual	4
704	Windthrow	Local	0	Yes	Fallen tree	1
705	Unknown	Unknown	180	No	Individual	1
706	Unknown	Unknown	180	No	Individual	4
707	Windthrow	Local	90	Yes	Fallen tree	3
708	Unknown	Unknown	0	No	Jam	1
709	Unknown	Unknown	90	No	Jam	1
710	Windthrow	Local	90	Yes	Individual	1
712	Windthrow	Local	90	Yes	Fallen tree	1
713	Unknown	Unknown	0	No	Jam	1
715	Unknown	Unknown	90	No	Jam	1
717	Windthrow	Local	90	Yes	Fallen tree	1
718	Windthrow	Local	90	Yes	Fallen tree	1
719	Windthrow	Local	90	No	Fallen tree	1
720	Unknown	Upstream	180	No	Jam	1
721	Unknown	Upstream	180	No	Jam	1
722	Unknown	Upstream	90	No	Jam	1
723	Unknown	Local	90	Yes	Fallen tree	1
724	Unknown	Upstream	90	No	Jam	1
725	Unknown	Upstream	90	unknown	Jam	1
726	Windthrow	Local	90	Yes	Fallen tree	1
727	Windthrow	Local	180	Yes	Fallen tree	1
728	Windthrow	Local	90	Yes	Fallen tree	1
729	Unknown	Unknown	90	No	Jam	1
730	Windthrow	Local	90	Yes	Fallen tree	1
731	Windthrow	Local	90	Yes	Fallen tree	1
732	Windthrow	Local	90	Yes	Fallen tree	1

TABLE A8. Burkeville Smalian's Formula for finding log volume

Log Number	Butt	Butt Area	Top	Top Area	Length (ft)	(1/2)(Area+Area)(L)	Total (m^3)
501	18	1.77	12	0.79	25	31.91	0.90
502	14	1.07	4	0.09	6	3.47	0.10
503	20	2.18	15	1.23	20	34.09	0.97
504	11	0.66	7	0.27	25	11.59	0.33
505	48	12.57	25	3.41	50	399.37	11.31
506	44	10.56	25	3.41	40	279.35	7.91
507	20	2.18	2	0.02	30	33.05	0.94
508	15	1.23	8	0.35	20	15.76	0.45
509	20	2.18	10	0.55	25	34.09	0.97
510	6	0.20	2	0.02	30	3.27	0.09
511	10	0.55	4	0.09	20	6.33	0.18
512	42	9.62	14	1.07	20	106.90	3.03
513	10	0.55	6	0.20	15	5.56	0.16
514	12	0.79	4	0.09	15	6.54	0.19
515	6	0.20	6	0.20	15	2.95	0.08
516	8	0.35	11	0.66	10	5.04	0.14
517	16	1.40	4	0.09	40	29.67	0.84
518	20	2.18	14	1.07	15	24.38	0.69
519	9	0.44	3	0.05	28	6.87	0.19
520	25	3.41	2	0.02	40	68.61	1.94
521	8	0.35	6	0.20	20	5.45	0.15
522	10	0.55	6	0.20	15	5.56	0.16
523	12	0.79	8	0.35	20	11.34	0.32
524	14	1.07	8	0.35	15	10.64	0.30
525	12	0.79	2	0.02	20	8.07	0.23
526	16	1.40	10	0.55	15	14.56	0.41
527	20	2.18	10	0.55	30	40.91	1.16
528	7	0.27	2	0.02	25	3.61	0.10
529	10	0.55	4	0.09	20	6.33	0.18
530	18	1.77	4	0.09	30	27.82	0.79
531	20	2.18	8	0.35	20	25.31	0.72
532	8	0.35	8	0.35	10	3.49	0.10
533	15	1.23	6	0.20	30	21.35	0.60
534	20	2.18	10	0.55	22	30.00	0.85
535	8	0.35	6	0.20	10	2.73	0.08
536	8	0.35	5	0.14	20	4.85	0.14
537	8	0.35	4	0.09	12	2.62	0.07
538	25	3.41	16	1.40	14	33.63	0.95

TABLE A8. (Continued).

Log Number	Butt	Butt Area	Top	Top Area	Length (ft)	(1/2)(Area+Area)(L)	Total (m^3)
539	45	11.04	10	0.55	50	289.74	8.20
540	15	1.23	2	0.02	30	18.73	0.53
541	10	0.55	3	0.05	30	8.92	0.25
542	20	2.18	6	0.20	18	21.40	0.61
543	16	1.40	3	0.05	25	18.07	0.51
544	10	0.55	2	0.02	18	5.10	0.14
545	8	0.35	2	0.02	18	3.34	0.09
546	10	0.55	8	0.35	14	6.26	0.18
547	18	1.77	4	0.09	35	32.45	0.92
548	18	1.77	4	0.09	30	27.82	0.79
549	8	0.35	2	0.02	20	3.71	0.11
550	16	1.40	2	0.02	35	24.82	0.70
551	16	1.40	2	0.02	30	21.27	0.60
552	8	0.35	4	0.09	8	1.75	0.05
553	8	0.35	3	0.05	16	3.19	0.09
554	10	0.55	6	0.20	22	8.16	0.23
555	16	1.40	3	0.05	25	18.07	0.51
556	12	0.79	2	0.02	24	9.69	0.27
557	59	18.99	30	4.91	42	501.77	14.21
558	14	1.07	6	0.20	25	15.82	0.45
559	22	2.64	12	0.79	8	13.70	0.39
560	12	0.79	6	0.20	17	8.34	0.24
561	12	0.79	12	0.79	25	19.63	0.56
562	20	2.18	4	0.09	32	36.30	1.03
563	10	0.55	4	0.09	20	6.33	0.18
564	20	2.18	10	0.55	15	20.45	0.58
565	8	0.35	2	0.02	15	2.78	0.08
566	13	0.92	2	0.02	25	11.79	0.33
567	20	2.18	4	0.09	35	39.71	1.12
568	16	1.40	4	0.09	25	18.54	0.53
569	18	1.77	8	0.35	30	31.74	0.90
570	8	0.35	4	0.09	22	4.80	0.14
571	21	2.41	6	0.20	27	35.12	0.99

TABLE A8. (Continued).

Log Number	Butt	Butt Area	Top	Top Area	Length (ft)	(1/2)(Area+Area)(L)	Total (m^3)
572	14	1.07	6	0.20	20	12.65	0.36
573	12	0.79	9	0.44	7	4.30	0.12
574	9	0.44	8	0.35	20	7.91	0.22
575	10	0.55	4	0.09	40	12.65	0.36
576	8	0.35	4	0.09	16	3.49	0.10
577	10	0.55	2	0.02	20	5.67	0.16
578	25	3.41	10	0.55	20	39.54	1.12
579	18	1.77	18	1.77	15	26.51	0.75
580	20	2.18	6	0.20	20	23.78	0.67
581	20	2.18	2	0.02	50	55.09	1.56
582	40	8.73	2	0.02	65	284.32	8.05
583	10	0.55	2	0.02	20	5.67	0.16
584	6	0.20	2	0.02	8	0.87	0.02
585	20	2.18	2	0.02	30	33.05	0.94
586	6	0.20	4	0.09	20	2.84	0.08
587	18	1.77	4	0.09	30	27.82	0.79
588	10	0.55	4	0.09	20	6.33	0.18
589	6	0.20	3	0.05	20	2.45	0.07
590	18	1.77	8	0.35	40	42.32	1.20
591	12	0.79	5	0.14	30	13.83	0.39
592	45	11.04	5	0.14	40	223.61	6.33
593	12	0.79	4	0.09	7	3.05	0.09

TABLE A9. Bon Wier Smalian's Formula for finding log volume

Log Number	Butt	Butt Area	Top	Top Area	Length (ft)	(1/2)(Area+Area)(L)	Total (m^3)
152	20	2.18	2	0.02	60	66.10	1.87
153	12	0.79	4	0.09	12	5.24	0.15
154	8	0.35	2	0.02	20	3.71	0.11
155	12	0.79	2	0.02	10	4.04	0.11
156	15	1.23	2	0.02	20	12.49	0.35
157	12	0.79	7	0.27	48	25.26	0.72
158	7	0.27	2	0.02	25	3.61	0.10
159	6	0.20	2	0.02	15	1.64	0.05
160	6	0.20	3	0.05	25	3.07	0.09
161	15	1.23	2	0.02	20	12.49	0.35
162	10	0.55	2	0.02	7	1.99	0.06
163	8	0.35	4	0.09	15	3.27	0.09
164	11	0.66	3	0.05	30	10.64	0.30
165	12	0.79	2	0.02	25	10.09	0.29
166	15	1.23	6	0.20	18	12.81	0.36
167	4	0.09	12	0.79	12	5.24	0.15
168	8	0.35	30	4.91	30	78.86	2.23
169	6	0.20	20	2.18	20	23.78	0.67
201	10	0.55	2	0.02	15	4.25	0.12
202	12	0.79	4	0.09	30	13.09	0.37
203	8	0.35	8	0.35	10	3.49	0.10
204	6	0.20	6	0.20	10	1.96	0.06
205	8	0.35	7	0.27	10	3.08	0.09
206	12	0.79	4	0.09	15	6.54	0.19
207	20	2.18	8	0.35	20	25.31	0.72
208	20	2.18	4	0.09	15	17.02	0.48
209	9	0.44	3	0.05	35	8.59	0.24
210	14	1.07	3	0.05	40	22.36	0.63
211	8	0.35	2	0.02	15	2.78	0.08
212	10	0.55	4	0.09	20	6.33	0.18
213	8	0.35	3	0.05	20	3.98	0.11
214	12	0.79	14	1.07	12	11.13	0.32
215	16	1.40	4	0.09	25	18.54	0.53
216	16	1.40	4	0.09	20	14.83	0.42
217	12	0.79	14	1.07	12	11.13	0.32
218	12	0.79	14	1.07	10	9.27	0.26
219	10	0.55	10	0.55	12	6.54	0.19
220	10	0.55	14	1.07	12	9.69	0.27

TABLE A9. (Continued).

Log Number	Butt	Butt Area	Top	Top Area	Length (ft)	(1/2)(Area+Area)(L)	Total (m^3)
221	9	0.44	2	0.02	10	2.32	0.07
222	8	0.35	2	0.02	15	2.78	0.08
223	8	0.35	2	0.02	25	4.64	0.13
224	4	0.09	2	0.02	15	0.82	0.02
225	20	2.18	4	0.09	30	34.03	0.96
226	12	0.79	3	0.05	18	7.51	0.21
227	21	2.41	12	0.79	8	12.76	0.36
228	6	0.20	15	1.23	15	10.68	0.30
229	8	0.35	6	0.20	6	1.64	0.05
230	4	0.09	15	1.23	15	9.86	0.28
400	12	0.79	8	0.35	25	14.18	0.40
401	12	0.79	8	0.35	15	8.51	0.24
402	8	0.35	2	0.02	30	5.56	0.16
403	10	0.55	2	0.02	15	4.25	0.12
404	12	0.79	4	0.09	20	8.73	0.25
405	13	0.92	4	0.09	38	19.17	0.54
406	8	0.35	8	0.35	6	2.09	0.06
407	8	0.35	4	0.09	25	5.45	0.15
408	8	0.35	3	0.05	15	2.99	0.08
409	10	0.55	3	0.05	20	5.94	0.17
410	12	0.79	4	0.09	20	8.73	0.25
411	6	0.20	2	0.02	20	2.18	0.06
412	8	0.35	3	0.05	20	3.98	0.11
413	10	0.55	8	0.35	10	4.47	0.13
414	16	1.40	3	0.05	30	21.68	0.61
415	12	0.79	2	0.02	35	14.13	0.40
416	14	1.07	10	0.55	15	12.11	0.34
417	6	0.20	3	0.05	10	1.23	0.03
418	12	0.79	2	0.02	40	16.14	0.46

TABLE A9. (Continued).

Log Number	Butt	Butt Area	Top	Top Area	Length (ft)	(1/2)(Area+Area)(L)	Total (m^3)
419	8	0.35	4	0.09	25	5.45	0.15
420	12	0.79	4	0.09	10	4.36	0.12
421	10	0.55	6	0.20	15	5.56	0.16
422	8	0.35	2	0.02	10	1.85	0.05
423	14	1.07	6	0.20	20	12.65	0.36
424	18	1.77	6	0.20	30	29.45	0.83
425	8	0.35	2	0.02	10	1.85	0.05
426	12	0.79	8	0.35	15	8.51	0.24
427	12	0.79	2	0.02	25	10.09	0.29
428	16	1.40	4	0.09	20	14.83	0.42
429	12	0.79	6	0.20	15	7.36	0.21
430	12	0.79	6	0.20	25	12.27	0.35
431	16	1.40	2	0.02	35	24.82	0.70
432	14	1.07	2	0.02	20	10.91	0.31
433	18	1.77	10	0.55	12	13.87	0.39
434	14	1.07	2	0.02	35	19.09	0.54
435	12	0.79	6	0.20	20	9.82	0.28
436	8	0.35	2	0.02	15	2.78	0.08
437	15	1.23	2	0.02	20	12.49	0.35
438	12	0.79	6	0.20	10	4.91	0.14
439	10	0.55	4	0.09	20	6.33	0.18
440	12	0.79	8	0.35	15	8.51	0.24
441	12	0.79	2	0.02	25	10.09	0.29
442	20	2.18	20	2.18	15	32.72	0.93
443	12	0.79	2	0.02	25	10.09	0.29
444	15	1.23	2	0.02	25	15.61	0.44
445	10	0.55	6	0.20	20	7.42	0.21
446	12	0.79	8	0.35	20	11.34	0.32

TABLE A10. Deweyville Smalian's Formula for finding log volume

Log Number	Butt	Butt Area	Top	Top Area	Length (ft)	(1/2)(Area+Area)(L)	Total (m^3)
101	12	0.79	13.5	0.99	30	26.69	0.76
102	14.1	1.08	11.3	0.70	15	13.36	0.38
103	12	0.79	9	0.44	10	6.14	0.17
104	10	0.55	6	0.20	11	4.08	0.12
105	8.2	0.37	3	0.05	30	6.24	0.18
106	8.9	0.43	5	0.14	40	11.37	0.32
107	5	0.14	5	0.14	8	1.09	0.03
108	14	1.07	12	0.79	15	13.91	0.39
109	14	1.07	12	0.79	15	13.91	0.39
110	15	1.23	8	0.35	20	15.76	0.45
111	6	0.20	2	0.02	25	2.73	0.08
112	6	0.20	2	0.02	20	2.18	0.06
113	7	0.27	2	0.02	40	5.78	0.16
114	9	0.44	4	0.09	25	6.61	0.19
115	27.2	4.04	18	1.77	50	145.05	4.11
116	9	0.44	3	0.05	30	7.36	0.21
117	17	1.58	15	1.23	20	28.03	0.79
118	10	0.55	8	0.35	7	3.13	0.09
119	6	0.20	3	0.05	20	2.45	0.07
120	14.4	1.13	10	0.55	12	10.06	0.28
121	7.3	0.29	4	0.09	20	3.78	0.11
122	10.6	0.61	5	0.14	25	9.36	0.27
123	10	0.55	10	0.55	8	4.36	0.12
124	9.4	0.48	4	0.09	11	3.13	0.09
125	8	0.35	2	0.02	15	2.78	0.08
126	10	0.55	10	0.55	20	10.91	0.31
127	14	1.07	10	0.55	20	16.14	0.46
128	17	1.58	10	0.55	50	53.04	1.50
129	5.4	0.16	4	0.09	15	1.85	0.05
130	13.3	0.96	2	0.02	20	9.87	0.28
131	15	1.23	10	0.55	20	17.73	0.50
132	18	1.77	7	0.27	40	40.69	1.15
133	12	0.79	5	0.14	20	9.22	0.26
134	15	1.23	6	0.20	55	39.15	1.11
135	9	0.44	2	0.02	40	9.27	0.26
136	12	0.79	5.5	0.16	40	19.01	0.54
137	8	0.35	4	0.09	12	2.62	0.07
138	12	0.79	11	0.66	30	21.68	0.61

TABLE A10. (Continued).

Log Number	Butt	Butt Area	Top	Top Area	Length (ft)	(1/2)(Area+Area)(L)	Total (m^3)
139	20.6	2.31	8	0.35	40	53.27	1.51
140	12.3	0.83	12	0.79	6.5	5.23	0.15
141	15	1.23	10.4	0.59	25	22.71	0.64
142	14	1.07	3	0.05	20	11.18	0.32
143	12	0.79	6	0.20	15	7.36	0.21
144	4	0.09	8	0.35	30	6.54	0.19
145	7	0.27	4.2	0.10	25	4.54	0.13
146	10	0.55	2	0.02	35	9.93	0.28
147	4	0.09	8	0.35	15	3.27	0.09
148	4	0.09	8	0.35	10	2.18	0.06
149	11	0.66	2	0.02	20	6.82	0.19
151	5	0.14	5	0.14	10	1.36	0.04
232	8	0.35	6	0.20	8	2.18	0.06
233	12	0.79	4	0.09	45	19.63	0.56
234	12	0.79	4	0.09	50	21.82	0.62
235	10	0.55	6	0.20	20	7.42	0.21
236	8	0.35	6	0.20	20	5.45	0.15
237	6	0.20	4	0.09	15	2.13	0.06
238	7	0.27	2	0.02	45	6.50	0.18
239	6	0.20	2	0.02	15	1.64	0.05
240	6	0.20	4	0.09	15	2.13	0.06
241	13	0.92	13	0.92	12	11.06	0.31
242	10	0.55	4	0.09	12	3.80	0.11
243	10	0.55	8	0.35	15	6.71	0.19
244	6	0.20	4	0.09	20	2.84	0.08
245	13	0.92	8	0.35	20	12.71	0.36
246	16	1.40	12	0.79	40	43.63	1.24
247	6	0.20	6	0.20	20	3.93	0.11
248	12	0.79	2	0.02	20	8.07	0.23
249	10	0.55	5	0.14	15	5.11	0.14
250	10	0.55	2	0.02	25	7.09	0.20
251	14	1.07	6	0.20	15	9.49	0.27
252	8	0.35	6	0.20	25	6.82	0.19
253	12	0.79	8	0.35	8	4.54	0.13
254	8	0.35	5	0.14	20	4.85	0.14
255	12	0.79	2	0.02	50	20.18	0.57
256	10	0.55	6	0.20	15	5.56	0.16
257	8	0.35	4	0.09	25	5.45	0.15
258	8	0.35	2	0.02	25	4.64	0.13

TABLE A10. (Continued).

Log Number	Butt	Butt Area	Top	Top Area	Length (ft)	(1/2)(Area+Area)(L)	Total (m^3)
259	16	1.40	2	0.02	45	31.91	0.90
260	8	0.35	4	0.09	20	4.36	0.12
261	8	0.35	3	0.05	20	3.98	0.11
262	12	0.79	4	0.09	25	10.91	0.31
263	13	0.92	3	0.05	25	12.14	0.34
264	16	1.40	2	0.02	50	35.45	1.00
265	20	2.18	10	0.55	15	20.45	0.58
266	13	0.92	12	0.79	30	25.61	0.73
267	8	0.35	2	0.02	40	7.42	0.21
268	20	2.18	18	1.77	15	29.62	0.84
269	10	0.55	8	0.35	15	6.71	0.19
270	12	0.79	8	0.35	25	14.18	0.40
271	20	2.18	2	0.02	30	33.05	0.94
272	18	1.77	6	0.20	15	14.73	0.42
273	12	0.79	12	0.79	30	23.56	0.67
274	14	1.07	8	0.35	40	28.36	0.80
275	22	2.64	8	0.35	40	59.78	1.69
276	10	0.55	2	0.02	25	7.09	0.20
277	13	0.92	10	0.55	25	18.34	0.52
278	6	0.20	6	0.20	15	2.95	0.08
279	11	0.66	9	0.44	20	11.02	0.31
280	14	1.07	8	0.35	25	17.73	0.50
281	16	1.40	8	0.35	35	30.54	0.86
282	16	1.40	2	0.02	30	21.27	0.60
283	16	1.40	8	0.35	30	26.18	0.74
284	7	0.27	4	0.09	32	5.67	0.16
285	10	0.55	2	0.02	30	8.51	0.24
286	10	0.55	2	0.02	30	8.51	0.24
287	12	0.79	10	0.55	5	3.33	0.09
288	12	0.79	3	0.05	35	14.60	0.41
289	12	0.79	3	0.05	50	20.86	0.59
290	12	0.79	2	0.02	70	28.25	0.80
291	26	3.69	10	0.55	35	74.07	2.10
292	14	1.07	9	0.44	25	18.88	0.53
293	19	1.97	10	0.55	35	44.00	1.25
294	15	1.23	11	0.66	20	18.87	0.53
295	6	0.20	2	0.02	20	2.18	0.06
296	15	1.23	6	0.20	18	12.81	0.36
297	11	0.66	11	0.66	7	4.62	0.13
298	9	0.44	9	0.44	10	4.42	0.13
299	8	0.35	2	0.02	20	3.71	0.11
300	8	0.35	2	0.02	25	4.64	0.13

TABLE A11. Frequency counts for Contingency Tests for branch presence vs. position categories.

Categories	Burkeville	Bon Wier	Deweyville	Southern
Yes, Fallen Tree	21	0	38	18
No, Fallen Tree	11	0	12	5
Yes, Jam	8	8	3	3
No, Jam	26	4	35	30
Yes, Individual	12	26	8	1
No, Individual	15	57	23	8

TABLE A12. Frequency counts for Contingency Tests for degree of decay vs. position categories.

Categories	Burkeville	Bon Wier	Deweyville	Southern
1, Fallen Tree	7	0	14	4
1, Jam	0	4	1	0
1, Individual	0	11	2	1
2, Fallen Tree	11	0	19	7
2, Jam	5	3	3	2
2, Individual	2	11	2	0
3, Fallen Tree	7	0	13	8
3, Jam	24	4	16	8
3, Individual	17	37	17	2
4, Fallen Tree	5	0	4	3
4, Jam	5	1	17	22
4, Individual	7	18	10	14
5, Fallen Tree	2	0	0	1
5, Jam	0	0	1	1
5, Individual	1	6	0	2

TABLE A13. Frequency counts for Contingency Tests for bank orientation vs. position categories.

Categories	Burkeville	Bon Wier	Deweyville	Southern
90, Fallen Tree	9	0	24	19
90, Individual	6	27	19	5
90, Jam	13	4	11	19
0, Fallen Tree	19	0	17	1
0, Individual	19	35	3	1
0, Jam	18	6	15	7
180, Fallen Tree	4	0	9	3
180, Individual	2	21	8	3
180, Jam	3	1	9	7

TABLE A14. Frequency counts for Contingency Tests for bank orientation vs. stage contact categories.

Categories	Burkeville	Bon Wier	Deweyville	Southern
90, 1	24	29	31	40
90, 2	2	2	17	2
90, 3	1	0	5	2
90, 4	1	0	1	1
0, 1	48	39	27	8
0, 2	8	1	6	0
0, 3	0	1	0	0
0, 4	0	0	2	1
180, 1	4	22	20	10
180, 2	4	0	2	1
180, 3	1	0	4	1
180, 4	0	0	0	1

TABLE A15. Frequency counts for Contingency Tests for bank orientation vs. stage contact categories.

Categories	Burkeville	Bon Wier	Deweyville	Southern
Fallen Tree, 1	18	0	34	20
Fallen Tree, 2	11	0	7	2
Fallen Tree, 3	2	0	7	1
Fallen Tree, 4	1	0	2	0
Individual, 1	27	79	1	5
Individual, 2	0	3	1	0
Individual, 3	0	1	2	1
Individual, 4	0	0	2	3
Jam, 1	31	12	27	31
Jam, 2	3	0	8	1
Jam, 3	0	0	0	1
Jam, 4	0	0	3	0

TABLE A16. Frequency counts for Contingency Tests for root wad vs. position categories.

Categories	Burkeville	Bon Wier	Deweyville	Southern
Yes, Fallen Tree	17	0	40	29
No, Fallen Tree	6	0	3	3
Yes, Individual	1	34	8	10
No, Individual	8	12	20	5
Yes, Jam	2	9	14	14
No, Jam	30	2	18	16

TABLE A17. Frequency counts for Contingency Tests for root wad vs. stage contact categories.

Categories	Burkeville	Bon Wier	Deweyville	Southern
Yes, 1	37	42	41	18
No, 1	23	12	21	39
Yes, 2	13	1	13	1
No, 2	1	1	12	2
Yes, 3	2	0	6	1
No, 3	0	1	3	2
Yes, 4	1	0	2	0
No, 4	0	0	5	1

TABLE A18. Frequency counts for Contingency Tests for branch presence vs. root wad categories.

Categories	Burkeville	Bon Wier	Deweyville	Southern
Yes, Yes	33	22	36	17
Yes, No	1	4	4	4
No, Yes	20	21	26	3
No, No	23	10	37	42

TABLE A19. Frequency counts for Contingency Tests for branch presence vs. bank orientation categories.

Categories	Burkeville	Bon Wier	Deweyville	Southern
Yes, 0	25	18	18	1
Yes, 90	11	10	21	17
Yes, 180	5	6	10	4
No, 0	31	23	17	8
No, 90	17	21	33	28
No, 180	4	16	16	9

TABLE A20. Frequency counts for Contingency Tests for branch presence vs. stage contact categories.

Categories	Burkeville	Bon Wier	Deweyville	Southern
Yes, 1	26	21	30	18
Yes, 2	13	2	11	2
Yes, 3	1	1	6	2
Yes, 4	1	0	2	0
No, 1	50	60	48	40
No, 2	1	1	14	1
No, 3	1	0	0	1
No, 4	0	0	0	3

TABLE A21. Frequency counts for Contingency Tests for degree of decay vs. branch presence categories.

Categories	Burkeville	Bon Wier	Deweyville	Southern
1, Yes	7	13	17	5
2, Yes	15	12	17	8
3, Yes	17	7	15	5
4, Yes	2	1	0	4
5, Yes	0	1	0	0
1, No	0	2	0	0
2, No	3	2	7	1
3, No	31	34	31	14
4, No	15	18	31	26
5, No	3	5	1	4

TABLE A22. Frequency counts for Contingency Tests for degree of decay vs. stage contact categories.

Categories	Burkeville	Bon Wier	Deweyville	Southern
1, 1	0	12	8	2
1, 2	5	2	7	1
1, 3	1	1	0	2
1, 4	1	0	2	0
2, 1	13	14	18	8
2, 2	5	0	2	1
2, 3	0	0	4	0
2, 4	0	0	0	0
3, 1	43	40	29	18
3, 2	4	1	11	0
3, 3	1	0	4	0
3, 4	0	0	2	1
4, 1	17	19	23	26
4, 2	0	0	5	1
4, 3	0	0	1	1
4, 4	0	0	2	2
5, 1	3	6	0	4
5, 2	0	0	0	0
5, 3	0	0	0	0
5, 4	0	0	1	0

TABLE A23. Frequency counts for Contingency Tests for degree of decay vs. root wad categories.

Categories	Burkeville	Bon Wier	Deweyville	Southern
1, Yes	6	11	16	4
1, No	1	2	0	1
2, Yes	16	10	20	6
2, No	1	1	1	3
3, Yes	21	17	17	5
3, No	17	8	21	14
4, Yes	8	2	9	3
4, No	5	2	18	26
5, Yes	2	3	0	2
5, No	0	1	1	2

TABLE A24. Frequency counts for Contingency Tests for orientation vs. root wad categories.

Categories	Burkeville	Bon Wier	Deweyville	Southern
90, No	6	5	20	29
90, Yes	17	17	27	15
180, No	1	2	11	9
180, Yes	7	9	13	4
0, No	17	6	6	8
0, Yes	29	17	22	1

TABLE A25. Chi-Square values from the Two-Way Contingency Table analysis of the Degree of Decay category.

Degree of Decay	Sites			
	Burkeville	Deweyville	Southern	Bon Wier
1	1.42	0.64	1.05	1.31
2	0.21	0.53	0.60	0.38
3	2.46	0.18	2.67	0.09
4	2.10	0.00	9.17	1.29
5	0.07	2.68	0.89	1.68

TABLE A26. Chi-Square values from the Two-Way Contingency Table analysis of the Bank Orientation category.

Bank Orientation	Sites			
	Burkeville	Deweyville	Southern	Bon Wier
0	11.78	1.82	10.77	0.72
90	3.51	0.46	9.27	2.13
180	4.23	0.80	0.00	0.97

TABLE A27. Chi-Square values from the Two-Way Contingency Table analysis of the Stage Contact category.

Stage Contact	Sites			
	Burkeville	Deweyville	Southern	Bon Wier
1	0.01	3.52	0.25	2.56
2	0.71	7.97	3.18	6.22
3	0.80	3.74	0.04	2.07
4	1.10	3.50	0.54	2.79

TABLE A28. Chi-Square values from the Two-Way Contingency Table analysis of the Position category.

Position	Sites			
	Burkeville	Deweyville	Southern	Bon Wier
Fallen Tree	1.23	7.91	1.32	26.89
Individual	2.87	5.90	12.19	52.71
Jam	0.74	0.01	8.14	10.77

TABLE A29. Chi-Square values from the Two-Way Contingency Table analysis of the Origin category.

Origin	Sites			
	Burkeville	Deweyville	Southern	Bon Wier
Local	6.45	4.75	1.04	2.94
Upstream	15.99	11.78	2.58	7.30

TABLE A30. Chi-Square values from the Two-Way Contingency Table analysis of the Branch Presence category.

Branch Presence	Sites			
	Burkeville	Deweyville	Southern	Bon Wier
Yes	0.61	0.14	0.66	0.26
No	0.39	0.09	0.42	0.16

TABLE A31. Chi-Square values from the Two-Way Contingency Table analysis of the Root Wad Presence category.

Root Wad Presence	Sites			
	Burkeville	Deweyville	Southern	Bon Wier
Yes	1.33	0.04	9.09	2.70
No	1.90	0.05	12.94	3.85

TABLE A32. Chi-Square values from the Two-Way Contingency Table analysis of the Potential Source category.

Potential Source	Sites			
	Burkeville	Deweyville	Southern	Bon Wier
Bank cut	9.23	2.50	14.31	1.53
Windsnap	3.08	6.85	0.46	0.02
Windthrow	12.30	0.95	33.65	2.95