Tillamook Bay Watershed Sediment and Physical Habitat Assessment

Report Prepared by Demeter Design, 2009

Report Prepared for the Tillamook Estuaries Partnership

Funding Provided by the Oregon Watershed Enhancement Board and the Tillamook Estuaries Partnership

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Preface

This document summarizes the findings of a physical habitat study conducted within the Tillamook Bay Watershed (TBW), Oregon. The results found within this document are intended to serve as a preliminary dataset for use in a monitoring program sponsored by the Tillamook Estuaries Partnership (TEP). Additionally, this document is also intended to characterize the results of pre-harvest data analysis within the upper Trask Watershed (part of the TBW) for use in the Trask Watershed Study (TWS) jointly sponsored by the Oregon Department of Forestry (ODF) and Weyerhaeuser Corporation. **No attempt was made during this study to determine whether or not land managers within the study area were in compliance with existing water quality and endangered species laws.** Thank You.

We would like to thank the following individuals and organizations for their assistance in creating this document: York Johnson of the Oregon Department of Environmental Quality (ODEQ) and TEP, Mark Trenholm formerly of TEP and Claudine Rehn of TEP, Liz Dent of ODF, Maryanne Reiter of Weyerhaeuser Corporation, Jon Wehage and Brit Madison of Stimson Lumber Company, Tom Shafer and Greg Sieglitz of the Oregon Watershed Enhancement Board (OWEB), Kim Jones of the Oregon Department of Fish and Wildlife (ODFW), Phil Kaufmann, Phil Larsen, and Tony Olsen of the Environmental Protection Agency (EPA), N. Scott Urquahart of Colorado State University, Doug Drake, Aaron Borisenko, and Robin Lefrink of ODEQ, Jesse Ford of Oregon State University, Dan Hubner, Jeremy Lees, Tim Saltzman, Eadaoin O'Drudy, Aaron Taft, John Pleasant, Bill Wessinger, and Tom Ward for their tireless energy, and the many private land owners who granted permission to survey on their property.

Glossary of Terms

303(d) List: A list of all water quality impaired systems published on a biennial basis by each state and evaluated by the EPA. The ODEQ is responsible for the list in Oregon.
Arcsine Transformation: A common transformation used to normalize proportional data for subsequent parametric analyses. Mathematically, X_i is transformed to arcsine ($\sqrt{X_i}$).
Bankfull Discharge: Corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels.
Bankfull Height: The elevation of the channel at bankfull discharge, measured from the water surface at low flow. This height is determined empirically based on vegetation and channel morphology.
Bankfull Width: The width of the channel at bankfull discharge, determined empirically based on vegetation and channel morphology.
Bankfull Width to Depth Ratio (W:D): Defined as the bankfull width divided by the bankfull depth. It is a measure of bank condition, channelization, and floodplain connectivity.
Bedded Sediments: All sediments present on the surface of the channel bed.
Competence: The ability of a fluid medium, as a stream or the wind, to move and carry particulate matter, measured by the size or weight of the largest particle that can be transported.
Critical Bankfull Diameter (D_CBF): The largest particle (diameter) which the channel can transport at bankfull discharge, estimated using channel morphology and known sediment transport equations.
Cumulative Distribution Function (CDF): A CDF describes a statistical distribution which has the value at each point of the probability of receiving that outcome or a lower one.
Environmental Monitoring and Assessment Program (EMAP): A nationwide EPA program designed to monitor water quality and provide technical resources for state and federal agencies to carry out their responsibilities under the Clean Water Act.
General Random Tessellation Stratified (GRTS): GRTS is a sampling algorithm developed by the EPA for use in EMAP. It generates random, spatially balanced samples and allows for dropped sites, frame errors, and subpopulations of unequal sizes.
Geometric Mean Particle Size (D_GM): A measure of central tendency of particle size. It is determined by a systematic pebble count and is defined as the square root of the product of the scores.
Hydraulic Diameter (DH): The mean bankfull height plus the mean thalweg depth of a reach.
Hydraulic Resistance (Cft): This is used along with the particle resistance to correct the bankfull hydraulic radius for large scale roughness due to bedform complexity and large woody debris.
Inclusion Probability: The inverse of the design weight. It represents the chance of a given site being included in the final sample.
Kinematic Viscosity of Water (v): Equal to 1.02 x 10-6 m^2/s at 20° C
Large Woody Debris (LWD): Whole logs or rootwads partially or wholly submerged in the active stream channel. LWD is a critical component of aquatic ecosystems.

Log Transformation: A common transformation used to normalize logarithmically distributed data for subsequent parametric analyses. Mathematically X_i is transformed to log (X_i).
Neighborhood Based Variance Estimator (NBV Estimator): Developed by the EPA for use in EMAP. It utilizes known spatial auto-correlation in natural resource data to provide more accurate estimates of sample and population variance.
Pebble Count: A procedure for evaluating the superficial composition of a channel bed. The general procedure is to measure and tally sediments by size at regularly spaced intervals across the channel. Under the EMAP protocol, samples are taken at 0, 25, 50, 75, and 100% of the wetted width at 21 cross sections per reach. Each sample is visually assigned to a size class. It is assumed that the sediments are log normally distributed within each size class.
Particle Resistance (Cfp): This is used along with the hydraulic resistance to correct the bankfull hydraulic radius for large scale roughness due to bedform complexity and large woody debris.
Percentage of Sands & Fines (%SAFN): The percentage of bedded sediments less than 2mm as determined by a systematic pebble count. It is reported as a proportion in this document.
Percentage of Gravels (%Gravels): The percentage of bedded sediments greater than 2mm and less than 64mm. It is reported as a proportion in this document.
Radius at Bankfull (R_BF): The hydraulic radius at bankfull discharge. Rbf ≈ 0.65*(Mean Thalweg Depth + Mean Bankfull Height)
Relative Bed Stability (RBS): A unitless ratio of the geometric mean particle size to the critical bankfull diameter. Together with %SAFN it is the prime indicator of sediment impairment. RBS = Dgm/D*cbf = Dgm/((0.604*Rbf*S*(Cfp/Cft)1/3)/ θc). Refer to Kaufmann et al 2008 for details.
Residual Pool Depth (RP100): Residual pool depth can be conceptualized as what would remain in a channel if all flow ceased. It is equal to the total longitudinal pool area per 100 meters of reach length. It is a flow invariant indicator of hydraulic roughness, bedform complexity, and pool frequency. It is calculated from a minimum of 100 systematic thalweg measurements.
Reynolds Particle Number (Rep): Rep = [(g*R_BF*S)0.5*D_GM]/v. It is used to calculate the Shield's Parameter for Critical Shear Stress.
Sample Frame: The original GIS layer which represents the population of interest. The frame is used by the GRTS algorithm to generate the sample.
Shield's Parameter for Critical Shear Stress (θc): θc = 0.04 Rep -0.24 when Rep<26 and 0.5 {0.22Rep-0.6 + 0.06(10-7.7 Rep^-0.6)} when Rep>26
Signal to Noise Ratio (S:N): An engineering term for the power ratio between a signal (meaningful information) and the background noise.
Slope (S): A unitless value equal to the change in elevation divided by the change in lateral position. It is reported as a proportion in this document.
Stable: Narrowly defined for the purpose of this document as having a larger RBS score.
Thalweg Depth: The thalweg is considered in this document to be the deepest point in the channel when measured at low flow. The mean thalweg depth is calculated from a minimum of 100-150 systematic measurements throughout the reach.

Total Maximum Daily Load (TMDL): A calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. Water quality standards are set by States, Territories, and Tribes. They identify the uses for each waterbody, for example, drinking water supply, contact recreation (swimming), and aquatic life support (fishing), and the scientific criteria to support that use. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and non-point sources. The calculation must include a margin of safety to ensure that the waterbody can be used for the purposes the State has designated. The calculation must also account for seasonal variation in water quality. The Clean Water Act, section 303, establishes the water quality standards and TMDL programs.

Welch T-Testing: A variant on standard two sample t-testing that controls for unequal variances and sample sizes. It utilizes the t distribution and statistic, calculated according to the formulas contained on pages 128-129 of Zar 2004.

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Executive Summary

1.1 Key Findings

- The Tillamook Bay Watershed (TBW) wadeable streams bedload is more stable than the ODEQ reference population. This is somewhat driven by the influence of non-mobile bedrock. The percentage of sands and fines is similar to reference, pool volume is slightly lower and the bankfull width to depth ratio in the TBW is much greater than the reference population. Excess scour and the low wood volume in mainstem channels appear to have degraded the quality of aquatic habitat to a greater degree than excess fine sediments within the TBW. The Tillamook River, lower mainstem Miami River, and Trask River have a relatively large proportion of fine sediments. This is possibly due to the significant proportion of erodible geology in these watersheds; excess levels of fine sediments can impact salmonid populations by decreasing egg to fry survival rates.

- Of the populations examined in the TBW the greatest difference was seen between small (1st order) and larger (2nd+ order) streams, which differ in all key metrics. Generally 1st order sites are less stable, smaller, steeper, and narrower with smaller substrate and more wood. 2nd+ order streams in contrast have more pool volume, more boulders, more bedrock, and less wood. Smaller streams have the potential to supply to larger channels the substrate and wood resources needed for spawning and rearing. The TBW population of streams also show a higher width to depth ratio than reference sites in 2nd+ order streams. This is of concern in that wider stream channels may lead to increased temperatures as a result of increased solar exposure.

- The results of this study show a nearly ten-fold reduction in the effective wood volume from 1st order to 2nd+ order streams in the TBW. This may reflect a natural process of ecosystem repair and this volume of large woody debris (LWD) in smaller stream reaches may eventually enter larger downstream channels. However, without large, key pieces of wood in the mainstem to hold the upstream wood, the potential benefits of improved habitat from the delivery of upstream wood to downstream reaches will be reduced. Wood placement (both active and passive) in mainstem stream channels (particularly the Miami watershed) should be considered a watershed wide restoration priority. Low wood volume in mainstem channels appears to limit the formation of complex habitat needed to support winter rearing by salmonids.

- The Trask Watershed Study (TWS) area is similar to the larger Trask River Watershed and the TBW. Where differences do exist, they are consistent with the expected effects of an increase in channel size. Specifically, the TBW has more pool volume, greater width to depth ratios, more boulders, more bank instability, and larger bankfull radii. Data and field observations suggest that the TWS has a broad range of slopes, including many low gradient reaches. Based on these results, it is hypothesized that the TWS is generally representative of the conditions within the rest of the TBW.

- Linear regression was used to evaluate the relationship between site specific stream power and mean particle size. The results of this analysis indicate a strong positive relationship with R^2 equal to 0.55 ($p=<.01$). This indicates that stream power at the reach level is the dominant factor controlling particle size within the TBW.

1.2 Background and Justification

The Tillamook Bay Watershed Sediment and Physical Habitat Assessment (the 2009 study) was initiated by the Tillamook Estuaries Partnership (the Partnership) to characterize the physical habitat condition within the TBW and to collect baseline data for use in an on-going monitoring program. The Comprehensive Conservation Management Plan (CCMP) prepared by the Partnership identified excess sedimentation as a priority issue in the Tillamook Bay Watershed.[1] The Partnership initiated an on-going monitoring program in 2006 to address the concerns raised both in the multiple sediment reports for the watershed and the CCMP. Funding for the project was provided by the Partnership and the Oregon Watershed Enhancement Board (OWEB). Finally, ODF and Weyerhaeuser Corporation are conducting the Trask Watershed Study (TWS) to evaluate the impacts of headwater management practices on stream habitat. The 2009 study was specifically designed to integrate with the TWS.

1.3 Methods

A spatially balanced, randomized sample was developed using the General Random Tesselation Stratified (GRTS) algorithm. The primary goal of the design was to accurately characterize the condition of the entire TBW and each individual 5th field. Secondary goals included the characterization of erodible versus resistant lithologies, large versus small streams, forestry versus non forestry, and public versus private. A dense sample was drawn in the TWS to understand the differences between the TWS and the larger Trask River and Tillamook Bay Watersheds and to understand the differences between headwater and larger streams.

Data was collected using the a component of the physical habitat section of the Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) protocol. Measurements and metrics included Relative Bed Stability (LRBS), substrate (%Gravels etc.), wood volume (RW), width to depth ratio (W:D), bank condition, and pool volume (RP100). Project specific data was compared externally to coastal reference data and internally to other sub-populations (e.g. Trask vs. Wilson). The DEQ has collected data from 33 minimally disturbed watersheds in the Coast Range Ecoregion. This data was compared to the TBW and sub-populations. The 5th, 25th, 75th, and 95th percentiles of the DEQ reference data were used as draft benchmarks to judge the relative condition of the TBW.

Throughout this document, descriptive terms such as scoured and sandy, or high and low are used to complement and describe the quantitative data presented in the tables, maps, and figures. In all cases, these terms describe the data relative to either reference data or other sub-populations within the TBW.

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1 Tillamook Bay CCMP 1999

1.4 Population Results

Entire TBW

The majority of the parameters measured during the 2009 study fall within ODEQ reference benchmarks. The percentage of sands and fines (%SAFN) within the TBW are near the reference benchmark at 18%. The TBW is more stable than the reference population (LRBS is -.37) and bed stability is much greater in the 2nd+ order streams of the Kilchis, Wilson, and Trask Rivers where LRBS is near or greater than 0 in most cases (LRBS values near and above 0 indicate scour). This signal is somewhat driven by bedrock in these watersheds. Excess scour can impair biotic communities. Scoured stream channels are less likely to provide quality habitat for aquatic biota including salmonids, macroinvertebrates, and amphibians. Woody debris is critical for aquatic biota. Wood volumes within the 2nd + order streams of the TBW are well below ODEQ reference averages. Channel scour indicates that peak winter flows generate high stream power which flushes wood and gravels, degrades riparian condition, and can cause direct mortality of the aquatic biota. Additionally, wood has been actively removed from the TBW and this historic wood removal has also degraded the quality of salmonid habitat within the TBW. It is possible that wood removal has occurred in ODEQ reference watersheds as well. Therefore, the 95th percentile of the reference data was used as a draft benchmark to assess the condition of the TBW and sub-populations with regards to woody debris. Using this benchmark all 2nd + order streams within the TBW could benefit from wood placement. Finally, RP100 (i.e. pool volume) in the TBW is 9.84 and is within reference draft benchmark ranges.

Miami River

The Miami River Watershed is the only 5th field where the 2nd+ order streams are more unstable than 1st order streams. W:D is high (driven by the mainstem) at 17 suggesting potential temperature issues. Pool volume is similar to reference benchmarks. Wood volume is the lowest in the TBW and extremely low (nearly 0) in 2nd+ order streams indicating that wood placement in the Miami River mainstem is a priority within the TBW. Only the Miami and Tillamook Rivers contain more gravel in the 2nd+ order streams than the 1st order streams. This supports the relative importance of the mainstem for salmonid spawning in these watersheds.

Kilchis River

The Kilchis River Watershed is stable with an LRBS of -.16 (somewhat driven by bedrock), the mainstem is very stable at 0+ (very driven by bedrock) and %SAFN is low at 11%, although they are mobile at the average bankfull flow. Pool volume and % SAFN are within reference draft benchmarks. Wood volume is the second lowest in the TBW and warrants wood placement as a restorative solution, however this may be complicated by the size of the system (stream power). An alternative solution is to remove barriers to wood passage which would allow for natural wood migration. The Kilchis River coho population is highly dependent on mainstem habitat for spawning. The signal of scour and low wood volumes observed in the 2nd+ order streams of the Kilchis River suggest that the mainstem habitat may be oversimplified and lacking complexity. Lack of complex winter habitat may impact salmonid abundance. Furthermore, on average, most gravels (2-64mm) are mobile under bankfull flow (D_CBF = 68mm), and redds may be directly disturbed as a consequence.

Trask River

Bed stability within the Trask River Watershed is within reference benchmark ranges at -.42; this is somewhat driven by bedrock (LRBS no bedrock -.7). %SAFN is 17%, which is within reference draft benchmarks but is somewhat high given the strong signal of scour in the 2nd+ order streams (LRBS near 0), stable streams more commonly have low levels of fine sediments (e.g. %SAFN < 10%). W:D is high within the 2nd+ order streams at ~18. This may lead to increased temperatures as a result of increased solar exposure. The differences between 1st and 2nd + order streams are consistent with the TBW. These conclusions are confirmed by paired summer and winter snorkel surveys conducted within the Trask River Watershed (not part of this study) in the Cruiserhorn sub-watershed. Although summer juvenile coho counts were among the highest in the TBW, winter juvenile abundance was very low.[1]

Wilson River

The Wilson River Watershed is significantly more stable than other 5th fields barring the Kilchis River Watershed, with an LRBS value of -.25. %SAFN is low at 9%; this is possibly a result of high stream power (flushing sediments supplied from upper watershed) or from low wood and pool volumes (inability to trap sediments). RP100 is marginally lower than the other 5th fields at 8.5. W:D is 14 which is slightly wider than draft reference benchmarks. Historical forestry practices included log drives (the anthropogenic transport of logs through the stream channel; includes floating and splash-damming) in the Wilson River Watershed from upstream of RM 30 to the bay and have contributed significantly to the signal of scour observed in the 2009 Study. Wood removal (historic in the upper watershed and ongoing removal in the lower watershed) limits floodplain connectivity and inhibits the sorting capacity of the stream. The low pool volume, low wood volume, and high stream power limit salmonid spawning and rearing.

Tillamook River

The Tillamook River is a unique population within the TBW in regards to nearly every metric examined as well as the pattern of lithology, land-use, and ownership. In comparison to the other four watersheds, the Tillamook River as a population is less stable and has a higher proportion of fine sediments. When resistant Tillamook sites are compared to resistant sites in other watersheds, these differences largely disappear. Bed stability within the Tillamook is within reference benchmark ranges. %SAFN is very high in both 1st and 2nd + order streams and this appears to follow lithology divides (%SAFN resistant mean 11%; %SAFN erodible mean 55%). However, erodible sites within the other four 5th fields are not as sandy. Wood volume for 2nd + order streams is below reference benchmarks. Wood volume in 1st order streams is the highest in the TBW but this is primarily driven by small pieces. Like the Miami River, the Tillamook River contains more gravel in the 2nd+ order streams than the 1st order streams. Two-thirds of the well sorted spawning gravel is found in the middle mainstem, downstream of very sandy, unstable stream reaches in the western tributaries. It is recommended that particular care continues to be taken when planning future actions in these tributaries.

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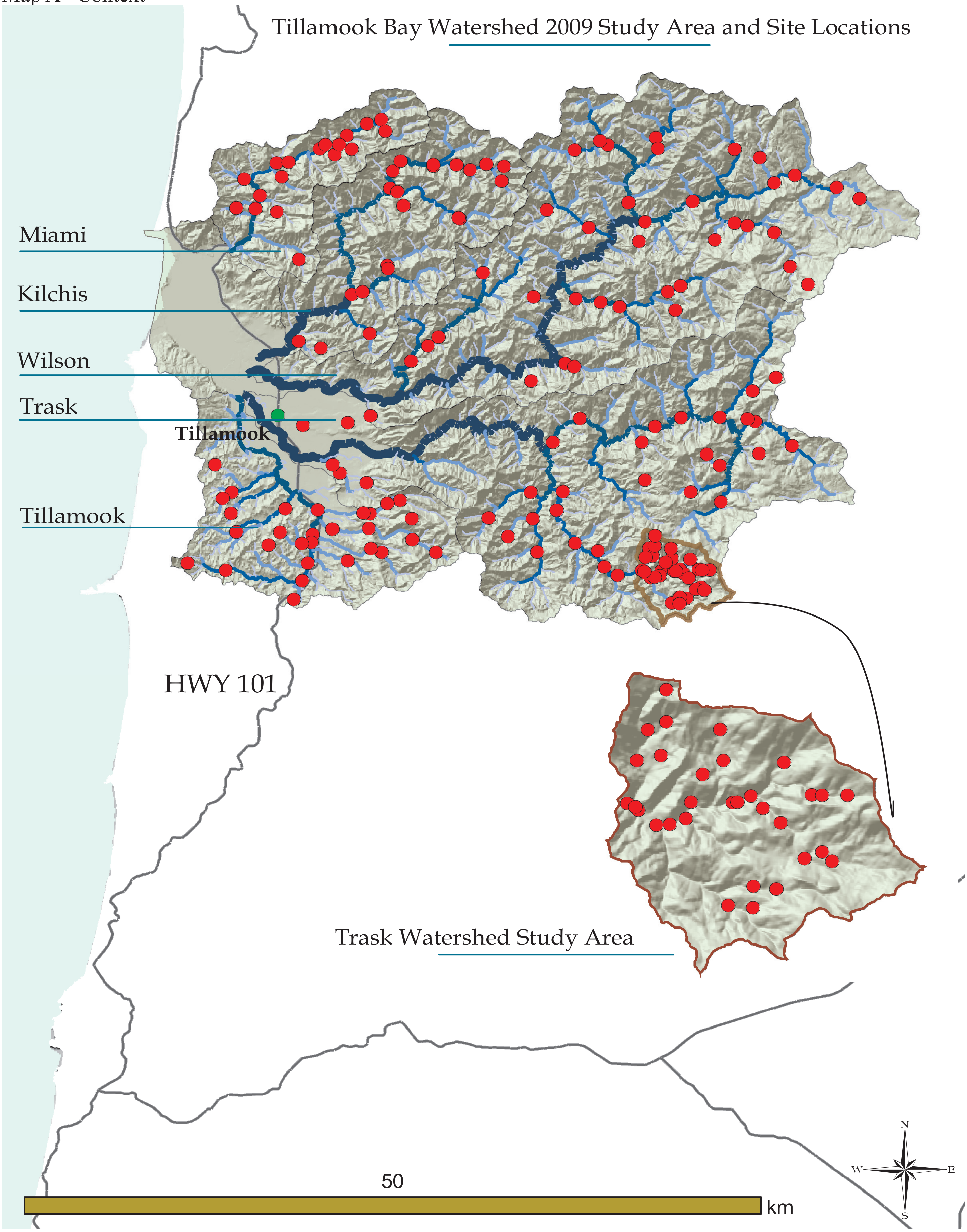
1 Personal Communication Steve Trask, Bio Surveys LLC

Map A - Context



Section 2 - Context

2.1 - Physical Setting

The Tillamook Bay Watershed (TBW) is located in the Oregon Coast Ecoregion III, ~60 miles south of the mouth of the Columbia River. The TBW encompasses six 5th field watersheds within the Nestucca-Trask-Wilson 4th field sub-basin (HUC #17100203). There are 5 main rivers that flow into the drowned river estuary (freshwater dominant). They are from north to south (clockwise around the bay) the Miami (HUC# - 1710020307; 23,390 acres), the Kilchis (HUC# - 1710020306; 41,620 acres), the Wilson (HUC# - 1710020305; 124,160 acres), the Trask (HUC# - 1710020304; 112,162 acres), and the Tillamook Rivers (HUC# - 1710020303; 36,395 acres). Refer to Map A - Context. The Bay (HUC# - 1710020308) was not included in this characterization. Elevations range from sea-level to 3691 feet in the headwaters of the Wilson River Watershed.

Stream flow in cubic feet per second (cfs) is highest in January through March, ranging from mainstem average lows of 200 cfs to record highs of 36,000 cfs during peak precipitation events, and average flows of 1000 cfs.[1] The Tillamook River is much smaller than either the Kilchis, Trask, or Wilson Rivers and slightly larger than the Miami River (drainage area). Rainfall is high throughout the TBW ranging from average lows of 80 inches near the city of Tillamook to average highs of 200 inches in the headwaters of the Wilson River Watershed. A significant area of the TBW is classified as a temperate rainforest. Temperatures are less variable with average maximum temperatures of 60° F and average low temperatures of 40° F. Vegetation within the watershed is dominated by coniferous forests managed for timber production. Prior to European settlement, forest composition within the TBW was a mixed old growth coniferous forest comprised predominantly of Douglas-fir, western hemlock, western red-cedar, and Sitka spruce (~60% old growth conifers, ~20% hardwoods[2]; low elevation areas were burned regularly by Native Americans to maintain open areas for hunting and gathering).

The lithology of the TBW is mixed. The Kilchis and Wilson River Watersheds contain the highest proportion of resistant lithology followed by the Trask, Miami, and Tillamook River Watersheds respectively. The TBW is unique among coastal Oregon watersheds. There are twenty erodible rock types and twenty resistant rock types in the TBW. The origin of the volcanic rock types are predominantly from individual island terranes which accreted to the continental plate, a process which is complete in the Blue Mountains, the only other mountain region in Oregon to have formed by this process. Additionally, although the Tyee formation is present, it is limited to a small area in the upper Trask River Watershed whereas the Tyee formation occurs as a large, somewhat uninterrupted, swath along the entire central Oregon coast until the Klamath mountains. Further, the erodible rock types of the western Tillamook River Watershed and the Trask River Watershed are mostly limited to surficial deposits from glacier melt (not common), landslides, and floodplains and sedimentary mud and silt stones. Soils range from average acidity to highly acid with small localized areas of alkalinity. Soil depths are variable to deep in floodplains and low gradient hillslopes, to shallow on higher hillslopes.

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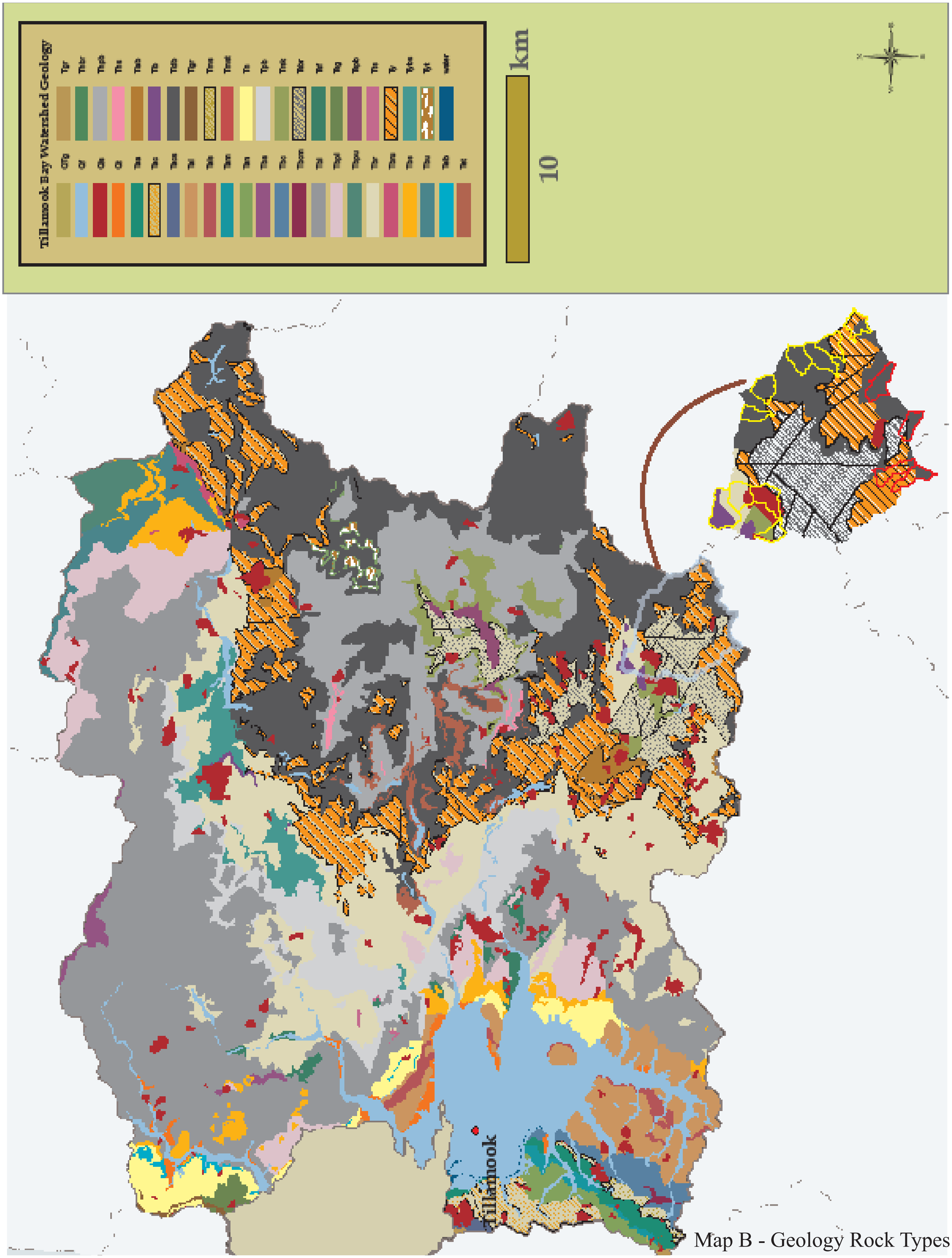
1 Trask River Watershed Analysis; Wilson River Watershed Assessment

2 Wimberly, M. Spatial simulation of historical landscape patterns in coastal forests of the Pacific Northwest. Can. J. For. Res. 32: 1316–1328 (2002)

Table 2.1 - Rock Types		
Unit	Rock Type	Erodibility
Tals	Feldspathic Sandstone	Erodible
Tsg	Sandstone of Garibaldi (Lower Miocene or Oligocene)	Erodible
Tybs	Basaltic Mudstone	Erodible
Tmst	Tuff Beds	Erodible
Tbcm	Mudstone Unit	Erodible
Tal	Alsea Formation (Lower Miocene and Oligocene)	Erodible
Tyt	Lower Tuff Unit	Erodible
Tet	Tyee Formation (Lower Middle Eocene)	Erodible
Tn	Nestucca Formation (Upper Eocene)	Erodible
Tbs	Basaltic Sandstone at Roy Creek (Upper and Middle Eocene)	Erodible
Ty	Yamhill Formation (Upper Middle Eocene)	Erodible
Qf	Fluvial and Estuarine Deposits	Erodible
Tac	Cannon Beach Member Niem&Niem (1985) (Middle and Lower Miocene)	Erodible
Tacs	Sandstone Unit	Erodible
Qls	Landslide Deposits (Holocene and Pleistocene)	Erodible
Tam	Mudstone Unit	Erodible
Taa	Angora Peak Member Niem&Niem (1985) (Middle and Lower Miocene)	Erodible
Tms	Mudstone of Sutton Creek (Lower Miocene)	Erodible
Qt	Older Fluvial and Estuarine Deposits (Pleistocene)	Erodible
Tan	Netarts Bay Member (Middle and Lower Miocene)	Erodible
Ths	Basltic Sandstone	Erodible (Borderline)
Tsbr	Basalt Lapilli Breccia Unit	Resistant
Thpb	Basalt of Hembre Ridge (Lower middle and lower Eocene)	Resistant
Tbpl	Lower Plagioclase-Porphyritic Basalt	Resistant
Tiab	Porphyritic Basalt (Late Middle Eocene)	Resistant
Tib	Basalt Dikes and Sills	Resistant
Tidb	Diabase (Middle Eocene)	Resistant
Tspb	Pillow Basalt	Resistant
Tigr	Grande Ronde Basalt (Middle Miocene)	Resistant
Teib	Basalt Sills (Late Eocene)	Resistant
Tba	Aphyric Basalt	Resistant
Tbpu	Upper Plagioclase-Porphyritic Basalt	Resistant
Tsf	Subaerial Dacite, Rhyodactie, and Rhyolite	Resistant
Tbu	Upper Porphyritic Basalt Flows	Resistant
Tbr	Submarine Basalt Tuff and Breccia	Resistant
Qtg	Basalt Boulder and Gravel Deposits (Plesitocene or Pliocene)	Resistant
Tgr	Grande Ronde Basalt	Resistant
Tbl	Lower Porphyritic Basalt Flows	Resistant
Tpb	Submarine Basalt	Resistant
Tts	Epiclastic Silicic Tuff and Tuff Breccia	Resistant (Borderline)
Tbru	Upper Submarine Basalt Lapilli Tuff and Breccia	Resistant (Borderline)



Map B - Geology Rock Types

Watershed-wide events within the past 400 years include: an earthquake in 1700 which lowered the average depth of the bay by approximately 3 feet [1]; European settlement which altered the fire regime, hydrology, and physical habitat of the region; forestry related activities which have dominated the landscape for over a century; and salmon population depletion and in the case of pink salmon, extirpation.

The fire return interval prior to European settlement ranged from ~300 years upwards to ~6000 years.[2] Although Native Americans did burn areas to maintain hunting and foraging grounds, these fires rarely impacted the larger watershed. Additionally, the burns were not as common or as frequent as burns conducted in the Willamette Valley. Food was more commonly obtained from riverine and ocean sources or through trading.[3] Extensive forest fires originating from forestry activities in the Willamette Valley burned the majority of the TBW between 1930 and 1960. It is hypothesized that these fires temporarily increased sediment accumulation rates within the bay. Several studies have evaluated both sediment sources and accumulation rates within the bay. One study concluded that roughly half of the surface sediments found within the bay were of marine origin and half were of riverine origin. Core samples indicated a substantial increase in marine sediment deposits some time between 60 and 300 years B.P. It was thought that any clays and silts were so mobile that rather than forming a depositional layer within the bay, they were flushed into the ocean.[4] Numerous reports of turbid water and silted spawning habitat led many to the idea that increased sediments in salmonid spawning habitat was a predominant driver of declining salmon populations. The reduction in salmonid populations throughout the Oregon coast has been attributed to numerous possible causes: siltation of spawning habitat; large wood removal and stream channel simplification; excessive take; poor and/or changing ocean conditions; climate change; degraded aquatic (freshwater) habitat; hatchery impacts; riparian shade reduction and increased stream temperatures; bacteria and low dissolved oxygen; toxicity; increased predation from mammals and birds; and barriers to passage. The decrease in salmonid populations throughout the coast is likely a synergistic effect of all these potential causes.[5] While the complexities of this relationship is beyond the scope of this document, there is, however, a clear relationship between degraded instream habitat and decreases in salmonid production.

Biotic use of the TBW includes large mammals (white-tail deer, Roosevelt elk, brown bear, mountain lion, bobcat, etc.), a wide variety of small common mammals (porcupine, opossum, woodrat etc.), rare mammals such as the red tree and white footed voles, Canadian lynx (may be extirpated), and beaver[6]. There are numerous bird species throughout the TBW including the marbled murrelet and spotted owl. Although many large predatory mammals were abundant historically within the TBW, most have been completely extirpated (wolf, lynx) or nearly so (mountain lion, bear) from the watershed. The removal of wolves from the watershed coupled with management practices which promote ungulate habitat may have resulted in an increase in deer and elk populations. This increase in browsers is hypothesized to have contributed to an even-aged riparian community (present throughout much of the TBW) and possibly a reduction in beaver food which subsequently reduced their populations via starvation. Additionally, these changes may have impacted the hydrology of the watershed as well.[7] Refer to section 2.2 for information regarding fish usage.

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1 CCMP Chapter 5
2 Long-Term Fire Regime Estimated from Soil Charcoal in Coastal Temperate Rainforests. Lertzman, K, et. al. 2002. ES Home. Vol. 6, No. 2. Art. 5
3 Sauter, J and Johnson, B . Tillamook Indians of the Oregon coast 1974 Binfords & Mort
4 McManus et. al. SEDIMENT SOURCES AND THE HISTORY OF ACCUMULATION IN TILLAMOOK BAY, OREGON
5 EPA - http://www.epa.gov/wed/pages/news/03June/leadarticle.htm
6 Managed as a nuisance species, their populations are in decline throughout Oregon
7 Stolzenburg, W. Where the Wild Things Were

2.2 - Fish Usage

The TBW supports an extensive and diverse fish population. Species present include coho, steelhead, chum, Chinook (spring and fall), cutthroat (resident and sea-run), lamprey (brook and Pacific), sturgeon, and numerous other species including several introduced species for sport fishing. The Partnership organized three years of summer snorkel surveys to estimate juvenile coho abundance during 2005, 2006, and 2007. This data has been reported in the Rapid Bio-Assessment Reports available through the Partnership.[1] Briefly, this data indicated that available habitat was under-utilized relative to potential abundance; the Wilson River supported the largest population followed by the Trask, the Kilchis, the Miami, and the Tillamook (correlated with watershed size); the productivity of the Wilson and the Trask River Watersheds is strongly driven by isolated areas of high quality habitat (e.g. the Little North Fork Wilson or Elkhorn in the Trask); finally abundance remained relatively steady between 2005 and 2006 but populations declined in 2007 except in the Tillamook River Watershed where they doubled. The Tillamook River appears to provide a habitat component (slow slackwater throughout with an abundance of wetland habitat and beaver ponds) that is not common among the other four 5th fields. During high water years, coho spawned in the Tillamook River may have increased survival rate as a result of this abundant rearing habitat. During lower water years the Tillamook River may be limited by high summer temperature even more than the other four 5th fields.

Coho production modeling was conducted for the Tillamook River as a component of the Tillamook River Coho Restoration Plan.[2] This analysis indicated that coho salmon production within the Tillamook River is limited by a lack of spawning substrate in the western tributaries and rearing habitat (summer followed by winter) in the eastern tributaries and mainstem. The eastern tributaries of the Tillamook River are similar to the other four 5th fields in geomorphology and it is hypothesized that these limitations may hold true throughout much of the TBW. The size of the other four 5th fields relative to the eastern tributaries of the Tillamook River Watershed may be such that habitat quality variation is greater in the larger watersheds. Additionally, the western tributaries of the Tillamook River have a unique and complex geomorphology. Although limited naturally by gravel abundance, the total volume of rearing habitat makes this region very productive for Coho, although significant habitat concerns are present. A related finding in the Tillamook River Coho Restoration Plan was that restoration of historic wetlands diked for agriculture have the potential to improve rearing conditions (primarily winter) for juvenile coho ten fold. It is possible that chum and Chinook salmon populations, which are more dependent on estuarine habitat for a portion of their life cycle, would benefit even more than coho from increased winter rearing habitat as would juvenile steelhead.

Further study is recommended to characterize fish utilization of estuarine habitat within the TBW. Lamprey, sea-run cutthroat, and sturgeon utilization of the TBW is poorly understood and warrants further study as well. It is worth noting that brook lamprey have been observed utilizing the sand/silt dominated habitat in the western portion of the Tillamook River. Although this area has limited spawning potential for coho or steelhead, it constitutes a unique habitat component of the watershed.

1 TILLAMOOK BAY RAPID BIO-ASSESSMENT 2007, 2006, and 2005. Available through the Partnership

2 Tillamook River Coho Restoration Strategy, Mico and Mico. 2009

2.3 - Land-use and Ownership

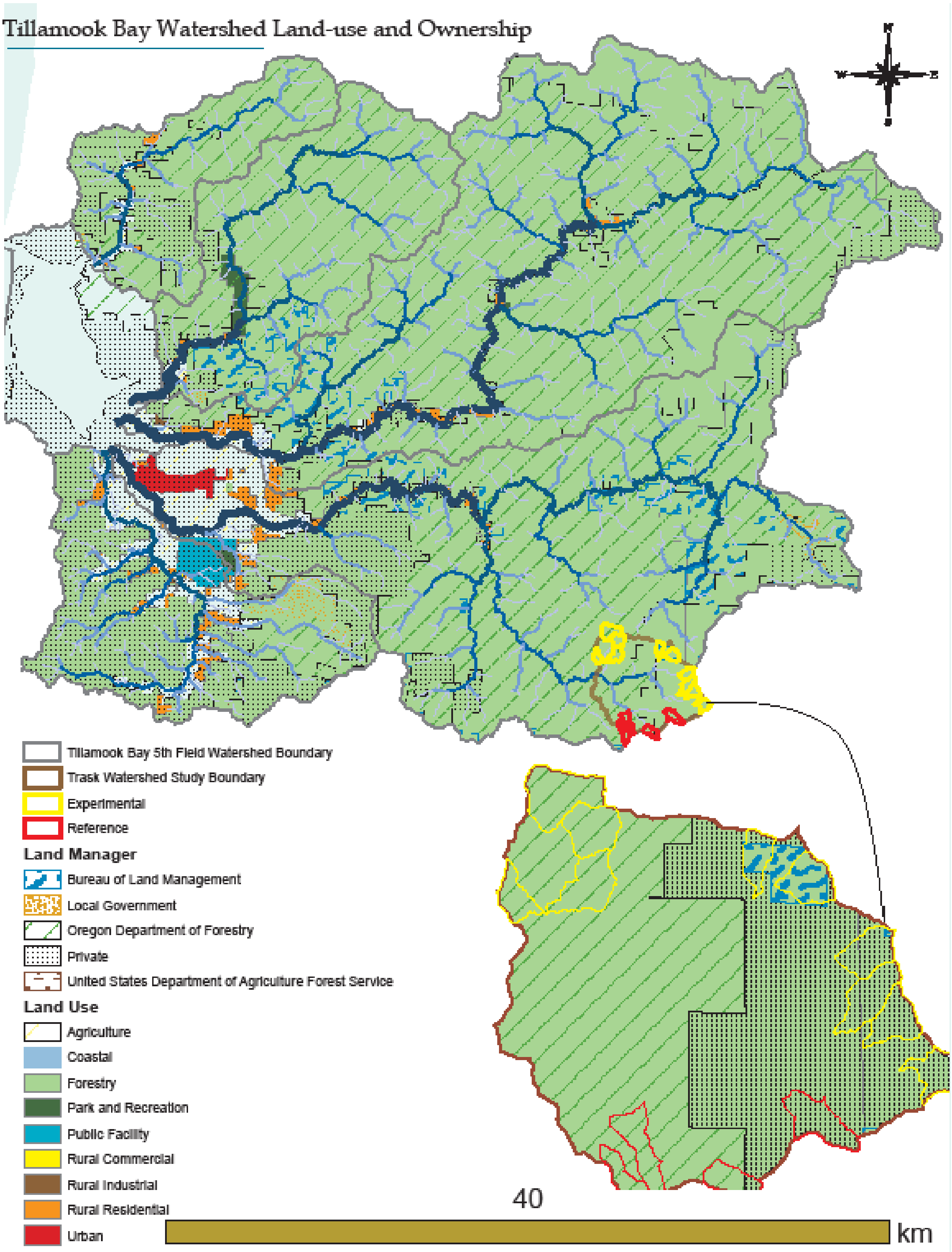
Land-use within the TBW is somewhat uniform across 5th fields and is dominated by public forestry. Land-use by watershed is moderately variable (% Forestry: Tillamook 77.1%; Trask 89.7%; Wilson 96.3%; Kilchis 95.2%; Miami 94.8%). The Oregon Department of Forestry (ODF) manages roughly 80% of all forest lands in the TBW followed by the Bureau of Land Management (BLM) in the Trask (7.1%), and finally several private forestry companies (6.8%). The Oregon Department of State Lands, local government, and the United States Forest Service are minor forest land managers within the TBW. There are several mills in the TBW one of which utilizes water from Holden Creek, a tributary of the Trask River, for machinery cooling. Agriculture (predominantly dairy) is the second major land-use in the TBW (Tillamook 15.2%, Trask 6.9%, Wilson 1.8%, Kilchis 1.9%, Miami 3.7%) and is limited to floodplains and low gradient areas near the confluence with the bay.

There is a significant urban population and numerous unincorporated neighborhoods (~8000 people within the TBW; ~5000 people within the city of Tillamook through which the Trask River runs). There is one municipal water dam (Barney Reservoir on the North Fork of the Trask) and numerous water diversions throughout the TBW although water withdraw for the city of Tillamook is limited to Killam and Fawcett creeks in the Tillamook River watershed. Rural residential land-use of the watershed is most extensive on the floodplains of the five rivers (Tillamook 4.1%, Trask 1.7%, Wilson 1.7%, Kilchis .6%, Miami 1.4%). The bay is dominated by shellfish farming and sport fishing.

The road network in the TBW is dense and extensive with 2398 miles of roads (Miami - 172 miles; Kilchis - 203 miles; Wilson - 724 miles; Trask - 737 miles; Tillamook - 407 miles) and 5611 crossings (Miami - 452 crossings; Kilchis - 558 crossings; Wilson - 2185 crossings; Trask - 1465 crossings; Tillamook - 951 crossings) in the TBW.

Fires have dominated the forestry composition post European settlement with the most significant fires occurring between 1933 and 1955 (one fire every six years) which collectively burned ~350,000 acres (some areas burned more than once). The areas most effected were the Wilson and the Trask River watersheds while the Tillamook River watershed was not burned significantly during this time.

Table 2.2 Ownership	
Bureau of Land Management	**7.1%**
Local Government	**0.6%**
Oregon Department of Forestry	**79.3%**
Oregon Department of State Lands	**6.2%**
Private	**6.8%**
Total	**100.0%**



Map C - Land-use and Ownership

2.5 - 2009 Study Justification; State-wide Monitoring Efforts and Historical Data

The 2009 study was developed with the requirement that the results integrate into existing state and nation-wide monitoring efforts. The Oregon Department of Environmental Quality (ODEQ) and the Oregon Department of Fish and Wildlife (ODFW) both monitor habitat within Oregon. The ODFW uses the Aquatic Inventories (AQI) protocol state-wide to assess and monitor habitat. AQI data was evaluated in this study to assess the mainstem channels of the Miami, Kilchis, Trask, and Tillamook rivers for instream sediments (not available for the Wilson River mainstem). EMAP was used to conduct a detailed assessment of channel morphology of the 1st through 4th order streams in the TBW. The 2009 study was conducted to characterize current instream habitat for use in an on-going monitoring study. The sampling methods are detailed in the materials and methods section of this document. All sites (excluding revisit sites) surveyed were selected from a state-wide master panel. The initial sample included 244 sites throughout the TBW. These sites were selected using the General Randomized Tessolation Stratified (GRTS) algorithm. The final sites visited are displayed in Map B - Site Locations and listed in Appendix A. The EMAP protocol is specifically designed to characterize 1st through 3rd order sites, (1st order stream in the NHD 1:100,000 stream network correspond to a 3rd or sometimes 4th order stream in a 1:24,000 hydrography coverage).

AQI data is available for the Miami (spatial overlap with EMAP data), Kilchis, Trask, and Tillamook rivers mainstems. This data indicates that the mainstem reaches of these four rivers were impacted by excess fine sediments (both by percentage sands and fines and by percentage of sands and fines in riffles) with percent sands and fines values of 30.8% in the Miami, 29.9% in the Kilchis, 38.2% in the Trask, and 65.6% in the Tillamook rivers mainstems. New data would need to be collected in these reaches, except in the Miami River mainstem where there is significant spatial overlap of the AQI and EMAP data sets, in order to determine trend. Four Watershed Assessments have been completed within the TBW study area (Kilchis, Trask, Wilson, and Miami rivers) as well as have numerous other reports (refer to the Appendix - Past Studies Summaries). These studies have identified possible reasons for the decline in the salmonid populations including the degradation of instream habitat quality and complexity through large wood removal; the fining of spawning habitat; hatcheries; fishing; increased solar radiation; and predation by wildlife.

The predominant findings within these assessments were that roughly half of the sediments found within the bay were of riverine origin and half were of ocean origin; the period of time from 1933-1955 was more unstable than between 1960 and 1994 based upon the accumulations of sediments within the bay; and the rate of sediment accumulation in the bay between 9000 years and 7000 years B.P was much greater than the period of time after 7000 years B.P. The period of time between 1933 and 1955 corresponds almost exactly with a series of forest fires of anthropogenic origin. The Bay-Ocean Spit breach also occurred during the end of this time period and likely supplied a great deal of ocean sediments to the bay. The channel which developed on the eastern edge of that breach filled in with fines (clays and silts). It is unclear as to whether or not these fine sediments are of riverine origin from the five 5th fields or are of Cape Meares origin. Finally EMAP data was collected in the Kilchis River and Tillamook River watersheds during a study conducted by Dr. Jesse Ford of Oregon State University. This data illustrated the differences between erodible and resistant morphologies and was analyzed in the 2009 study for trend.

Section 3 - Materials and Methods

TBW Sampling Methods

There have been recent efforts by the EPA and Pacific Northwest Aquatic Monitoring Partnership (PNAMP) to coordinate monitoring throughout Oregon by utilizing a single pool of sites known as the Master Sample.[1] The Master Sample is a random, spatially balanced sample that encompasses the entire state of Oregon and is built on the NHDPlus 1:100K USGS stream layer with sites seeded at ~1 km intervals. The sample frame consists of a *.shp file* which contains point features representing the location of several thousand random points within the watershed. These points represented all Master Sample sites and all previously visited EMAP sites (historical EMAP data housed in SWIM database; the majority of these sites were collected in 1998 and 1999 by Dr. Ford). A field visit was conducted to determine where wadeability began. All sites estimated in the field as over 2.5 meters in depth were dropped from the sample frame. The General Random Tesselation Stratified (GRTS) algorithm allows for the removal of sites without the interruption of the spatial balance or random design. The GRTS algorithm was used to select a random sample of sites within the TBW from the master sample and historical data sites. [2] A random GRTS sample was drawn to produce a preliminary site location map. The inclusion probabilities of each subpopulation were manipulated to produce a sampling design which maximized the spatial balance at a population level and included enough sites within each subpopulation of interest to generate accurate estimates of condition. Sampling was conducted using the *spsurvey* package for the R statistical program[3]. The sub-populations evaluated in the 2009 study are: land-use (forestry or non-forestry; determined using the Tillamook County zoning GIS layer); lithology (erodible or resistant; determined using USGS data[4]; classification of sites as erodible or resistant is found in Table 2.1 - Rock Types, this classification was verified by a BLM soils/hydrology specialist[5]); stream order (1st and 2nd +; determined using the NHD+ 1:100.000 stream layer, hand delineations of the SWIM data which did not include stream order, and a 1:24,000 stream layer in the Trask Watershed Study); revisit data (SWIM or Master Sample); ODF classification (anchor or non-anchor); and by 5th field watershed (HUC 5th field data).

The initial goal, as outlined in the sampling and analysis plan, was to seed 20-25 non-forestry sites in the first 75 site initial characterization.[6] There were not enough 1st order non-forestry sites to maintain spatial balance at a population level (20-30 sites are commonly needed to accurately characterize a given subpopulation). The final sample strata are found in Table 3.1 - Sample Strata. Sites which were inaccessible were dropped and the next site in numerical order was added.

The monitoring panel assumes 30 sites will be visited every two years following the 2009 study. There are three rotating panels, a 2, 8, and 16 year return panel. If monitoring cannot be conducted in a given year, it is possible to skip that year's monitoring and continue with the original monitoring design. The panel is designed to allow for changes in landowner permissions and other access issues.

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1 Larsen, P. Columbia Basin - Master Sample Design. EPA WED Technical Report. 2005
2 Stevens and Olsen (2004) *Spatially-balanced sampling of natural resources.* Journal of American Statistical Association 99(465): 262-278.
3 (available from the EPA website, http://www.epa.gov/nheerl/arm/)
4 USGS Geologic Map of the Tillamook Highlands, Northwest Oregon Coast Range: A digital database. Open File Report 95-670
5 Dennis Worrel, Tillamook Resource Area Field Office. Hydrologist and Soils Specialist.
6 Mico, L. and Mico, C. Tillamook Bay Watershed Sediment and Physical Habitat Assessment and Monitoring Program QAPP Version 2.1. 2008.

Table 3.1 - **TBW Final Sample Strata - The sites collected in each strata**							
(2007-2008 Data)							
Lithology		Land-use		Stream Order		Data Source	
Erodible	**Resistant**	**Forestry**	**Non-Forestry**	**1ST**	**2ND+**	**SWIM**	**MS**
51	89	124	16	60	80	28	112
Miami	**Kilchis**	**Wilson**	**Trask**	**Tillamook**		**ODF**	**ODF Anchor**
18	**21**	**38**	**64**	**30**		**96**	**44**

Trask Watershed Study (TWS) Sampling Methods

The primary goal of the TWS is to evaluate the effects of forest harvest practices on small catchments. 16 management areas are situated at the headwaters of small mountain streams. Many of these streams are not represented at the 1:100K resolution of the NHD+. A separate sample was drawn for the TWS using a 1:24K hydrography layer provided by the BLM. Data from the TWS was integrated into the greater TBW population by weighting based on the linear extent of the NHD+ coverage within the TWS area. In other words, although the sample frame for the TWS was of higher resolution, it was specifically designed to enable comparisons to the greater population. A sample of thirty sites (with an oversample of 60) was drawn for the TWS using the BLM hydro coverage. The sample was stratified by lithology to provide 12 erodible and 18 resistant sites. The density of sampling resulted in the possibility of minor overlap (dependent on wetted width at the time of sampling).

It is anticipated that all TWS sites visited in 2008 will be revisited prior to harvest, immediately after harvest, and continuing throughout the course of the study. In addition to the randomly selected sites, it is recommended that additional habitat surveys be conducted at the base of each treatment watershed. Field work at these additional sites would be consistent with the general framework of the EMAP protocol, but may be modified to increase the precision of the measurements. For example a transit or hydrostatic level may be used to measure slope, detailed measurements of wood size and placement may be made, and sieving may be used to quantify the substrate composition. These sites would be visited with the same timing and frequency of the random sites. The precise location of these sites would be determined in the field, marked on detailed topographic maps of the area, and digitized for subsequent GIS analysis.

Field Protocol

The 2009 study utilized section 7 - Physical Habitat of the EPA's EMAP protocol to collect 186 sites during the summers of 2007 and 2008. Please refer to Appendix E - EMAP Section 7. The full EMAP protocol includes protocols for the measurement of biological, chemical, and hydraulic function in addition to the physical habitat data used for sediment assessment. Site length was determined by the wetted width during summer low flow periods (40 X wetted width).

The following measurements were made at each site;

• Slope
• Modified Pebble Count
• Bankfull Height
• Thalweg Depth
• Large Woody Debris Tally
• Bankfull Width
• Habitat Unit
• Anthropogenic Disturbance
• Bank Condition

Reference Conditions

The ODEQ identifies minimally disturbed watersheds using road density, land-use practices, and forest fragmentation data supplemented with professional and local knowledge. EMAP data is collected at or near the outflow of the least disturbed watersheds to determine reach condition. Land-use, fragmentation, road density, and reach condition data are used to develop a habitat disturbance index score. Sites meeting ODEQ habitat criteria are considered candidate reference sites. The field specialists who collected the survey data are consulted to determine if the habitat disturbance index score is valid (i.e. was the road density GIS layer accurate or was there a recent clear cut?). The ODEQ evaluates the habitat disturbance index scores for all of the EMAP sites within Oregon, including the candidate reference sites, and identifies those sites within the 80th percentile (least disturbed). All candidate reference sites above the 80th percentile are used as reference sites. Any candidate reference site not above the 80th percentile are no longer considered reference. Reference sites are added to this pool as time and resources allow. The ODEQ reference sites represent the most likely condition of minimally disturbed sites within Oregon. While some sites within this reference pool may, by chance, represent pre-disturbance conditions, most do not. This is a significant issue when considering the impacts of wood and predator removal on instream and riparian conditions.

Table 3.2 - Coastal Reference Data

Metric	Mean	N	SD	SE	Lower 95 % CI	Upper 95% CI
Log Relative Bed Stability	-0.78	33	0.75	0.12	-1.01	-0.54
Percent Sands and Fines	0.17	33	0.13	0.02	0.13	0.2
Residual Pool Depth	12.64	33	13.04	1.8	9.12	16.16
Wood Radius	0.05	33	0.07	0.01	0.03	0.07
Width to Depth Ratio	9.88	33	3.47	0.57	8.76	11.01

Data Analysis Methods

EMAP data collected as part of the 2009 study and in historical studies was analyzed to determine means, confidence intervals, and population distributions. Multiple metrics were used to evaluate the condition of the watershed and sub-populations; the two primary sediment indicators used are Log Relative Bed Stability (LRBS) and the percent of sands and fines (%SAFN). Other metrics used to evaluate aquatic habitat include width to depth ratios (W:D), residual pool depth (RP100), wood volume (RW), bank condition, slope, and geology. In addition to the data collected specifically as part of the EMAP protocol, historical data sets were also evaluated including Rapid Bio-Assessment (RBA) summer snorkel data (coho and steelhead), AQI data, and Watershed Assessments/other reports. RBA data was used to determine salmonid usage and areas where salmonid use of the watershed may be impaired for spawning or rearing. AQI data was evaluated to determine historical conditions of the mainstem and, where possible, trends in %SAFN. Other reports were evaluated for potential sources of sands as well as to provide background information for this report.

The means and standard deviations of the 2009 study data were directly compared to the reference population; the distributions of the populations were evaluated for geographical clustering; and single site data was evaluated for outliers. Each of the metrics were compared to draft benchmarks at the TBW and the sub-population scale (watershed, lithology, land-use, etc.). The mean values of the 5th field sub-populations were compared to the 5th, 25th, 75th, and 95th percentiles of the reference data. Values were highlighted in orange and red in the following tables if the mean value of the metric of interest exceeded the appropriate percentile (depending on direction of potential impairment). It is assumed that values exceeding the 5th or 95th percentile may reflect greater impacts than the 25th or 75th percentile. The specific interpretation of this finding depends on the metric (e.g. %SAFN or LRBS).

The reference data was weighted by lithology, for instance the Tillamook River has the highest proportion of erodible material therefore the erodible reference sites were weighted higher than they were for the Kilchis River which is primarily resistant. The primary impact of this weighting is on the size of the distribution; the mean is relatively unaffected. As a consequence, the reference draft benchmarks are different for each subpopulation. This weighting was only conducted at the 5th field scale.

Significance Testing

Significance testing is a descriptive tool commonly used to determine the influence of sample size and population variance on a data-set. A weakness of this method is the arbitrarily chosen p value of .05. Smaller p values indicate that the deviation between two population means is large in comparison to the pooled variance but this emphasizes the probability of error over the effect size, which is often more important in living systems. In other words, it does not matter that the relationship is "not significant" as a result of a small population or a population with great variance, it matters that the effect and the relationship is present. Any difference can be made significant with a large enough sample. Numerous authors have elaborated on the shortcomings of significance testing. "The Insignificance of Statistical Significance Testing" by Douglas Johnson provides an excellent discussion of the topic. The data in this study was analyzed using a modified t test (Welch t test; controls for unequal sample sizes and variances) to determine if the sub-populations varied from each other and from the larger TBW but was not used in the reference comparison.

Estimates of Mean and Variability

Data was analyzed using custom built analytical software for data entry and metric calculation. All subsequent data analysis was carried out using the R statistical program. All data analyzed in this way was weighted according to the fraction of the stream network which it represented. Weighted averages were calculated for the TBW. Variances were calculated using the Neighborhood Based Variance (NBV) estimator developed by the EPA. NBV is a more precise estimate of variance when there is a spatial pattern to data, thus capitalizing on the spatial balance of the GRTS sample. The practical effect of utilizing the NBV is to decrease the variance. Modeling conducted by the EPA has shown that standard statistical procedures may result in substantial over-estimates of variance when there is a spatial pattern to the data.

Sediment Indicators

The Relative Bed Stability (RBS) metric was developed specifically to address the effects of bedded sediments on wadeable stream channels. RBS is defined as the ratio of the observed mean substrate diameter to the predicted competence of the channel at bankfull. Channel competence is calculated from field measurements of slope, hydraulic radius, and channel roughness. RBS is a unitless ratio of values, and is commonly expressed as log RBS or LRBS to compress the values and to normalize the variance. When the observed mean particle diameter is equal to the predicted diameter of the largest particle the system can move at bankfull (D_CBF), the RBS ratio is equal to 1 and LRBS is equal to 0. The observed mean particle diameter and the D_CBF are primarily dependent on disturbance regimes, channel morphology, geology, and climate. For example, small channels with low gradients are expected to have a small mean particle diameter and are not expected to have enough stream power to move larger particles during a bankfull event. The expected RBS score in these circumstances would be similar to a channel with large sediments and steep gradients. In other words, RBS controls for stream power at a coarse level. By logging the RBS value, the data is normalized so that parametric statistical methods can be applied. Previous studies have shown that increases in sediment input result in a fining of the streambed by overwhelming the capacity of the water column to move sediments. Decreases in the RBS score are often correlated with an increased sediment supply. Therefore RBS is a useful measure of current sediment input as well as instream conditions. Extremely low values indicate over-sedimentation (an example would be -2) whereas large values indicate armoring of the stream bed (an extreme example would be +2). However, this is not always the case. For instance some systems have naturally high RBS scores. Within the Mid-Atlantic highlands, RBS scores are commonly greater than 0. In the coastal reference data, a few sites had LRBS scores between -1 and -3. Evaluation of the system as a whole, including past disturbances, is necessary in order to understand the significance of the LRBS score. An additional strength of RBS is that it is a composite metric calculated from numerous independent observations. This significantly increases the signal to noise ratio and reduces inter-observer bias. One caveat to using the RBS metric is that streams can adjust to elevated sediment inputs over long periods of time (e.g. decades) resulting in stable beds that nonetheless contain unnaturally large quantities of fine sediments. Finally, a variant of RBS (LRBS no bedrock) was calculated with bedrock excluded from the particle size calculation. This metric focuses on the stability of the mobile bed substrate. This is useful when analyzing scoured streams such as the mainstem Kilchis River.

Habitat Complexity Indicators

Quantitative indicators of habitat complexity are generated as part of the RBS calculation. Three indicators were used in this study to assess habitat complexity; residual pool depth (RP100), width to depth ratio (W:D), and wood radius (RW). The aquatic habitat of many streams is degraded due to a lack of large woody debris (LWD) and channelized as a result of historic logging practices or active stream cleaning. These modifications serve to decrease the hydraulic roughness of the channel. Roughness elements can trap fine sediments and decrease the competence of the channel to move sediments. It is theoretically possible to mask an increase in sediment input with an increased competence due to a lack of hydraulic roughness. In this scenario fine sediment would not be considered a primary stressor, but elements critical to maintaining healthy aquatic ecosystems would be lacking. If those elements were restored, fine sediment could become a local stressor if the elevated sediment input was not corrected first. It is critical that hydraulic roughness be evaluated when interpreting data on sediment impairment.

W:D – The width to depth ratio changes as a function of disturbance. In some instances it will increase with disturbance due to sustained bank erosion and elevated sediment inputs. Generally, this is related to decreased bedform complexity and degraded riparian vegetation. As a consequence, streams with a width to depth ratio greater than reference conditions could result in increased peak temperatures. In other instances, the width to depth ratio will decrease substantially as the channel down-cuts due to channel confinement. Geology is a controlling factor on channel responses to disturbance. A decreased width to depth ratio could potentially indicate loss of over-wintering fish habitat, increased downstream flood potential, and loss of floodplain connectivity. The metric used in this study was the bankfull width divided by the bankfull height.

RW – The benefits and importance of LWD are well established in the field of restoration biology. Under the protocol used in this study, all wood inside the bankfull channel with a diameter greater than 10 centimeters and a length greater than 1.5 meters was tallied and assigned to a size class. These measurements were then converted to a statistic representing the total volume of wood inside the channel at bankfull height. This volume was divided by the surface area of the stream reach to give an estimate of wood volume per square meter. This controls for the absolute difference in wood volume between large and small channels. It is important to note that the wood volume within reference sites is also low as a result of past and current land-use practices and should not be considered the standard. For this study, the 95th percentile of the reference data was also used as the project specific draft benchmark. Where specific data on wood volume is referred to in this document, RW is always the metric of interest.

RP100 – Residual pool depth can be conceptualized as what would be left over in a stream reach if all flow stopped. It is a measure of reach-scale bedform complexity and is directly proportional to pool frequency. Qualitative classifications of reaches into habitat units such as riffle, glide, or pool are flow and observer dependent. In contrast, residual pool depth is a flow-invariant metric and is a quantitative measure. It is therefore more suitable for use in sediment transport and regression analyses.

Section 4 - Results

Section 4.1 - Population Results

The results of the 2009 study were compared to reference data collected in minimally disturbed watersheds throughout the Oregon coast (refer to Table 3.1 - Oregon Coast Reference Data). The approach used to analyze this dataset was based on previous work completed in the Nestucca and Siuslaw Rivers, and input from multiple ODEQ and EPA staff. The process through which the ODEQ determines impairment (as in not meeting state water quality or habitat standards) is currently being developed. The current narrative standard defining sediment impairment is the formation of appreciable sludge on the stream bed. Reference percentiles were used as benchmarks to judge condition in the 2009 study. The mean values of the 5th field sub-populations were compared to the 5th, 25th, 75th, and 95th percentiles of the reference data. Values were highlighted in orange and red in the following tables if the mean value of the metric of interest exceeded the appropriate percentile (depending on direction of potential impairment).

The data collected for the 2009 study was evaluated for differences among the various sub-populations (i.e. is the Miami different from the Trask and if so how). These t-test results are reported in tabular format along with summaries of key findings. Both the p values and the magnitude of difference were evaluated. For instance, the bank condition metric in the Trask River Watershed is significantly greater than in the Miami River Watershed but the magnitude of this difference is small whereas the W:D of the Miami River Watershed is not significantly greater than in the Trask River Watershed even though the magnitude of difference is large. Due to concerns over erroneous significance values due to multiple comparisons, the results of this analysis should be considered descriptive only. The original sampling design assumed that the sub-populations identified are intrinsically different. Under this assumption, the problem of multiple comparisons becomes less significant. Although there are statistical procedures for multiple comparisons (e.g. multi-factor analysis of variance), none lend themselves to the stratified samples with unequal variances and population sizes. Additionally, aquatic inventories data was reported for the mainstems of the Miami, Kilchis, Trask, and Tillamook rivers. Finally, revisit data was evaluated for trend and is reported in section 4.3.

The data is presented as a combination of figures, tables, and maps. The data tables presented for project specific data contain the mean, sample size (N), standard deviation (SD), standard error (SE), and the 95% confidence intervals (Upper 95% and Lower 95%) This information is also presented for the reference estimates in addition to percentile values.

Synopsis of Key Findings by 5th Field

Throughout this document, descriptive terms such as scoured and sandy, or high and low are used to complement and describe the quantitative data presented in the tables, maps, and figures. In all cases, these terms describe the data relative to either reference data or other sub-populations within the TBW. The interested reader should consult the relevant data tables directly for numeric values.

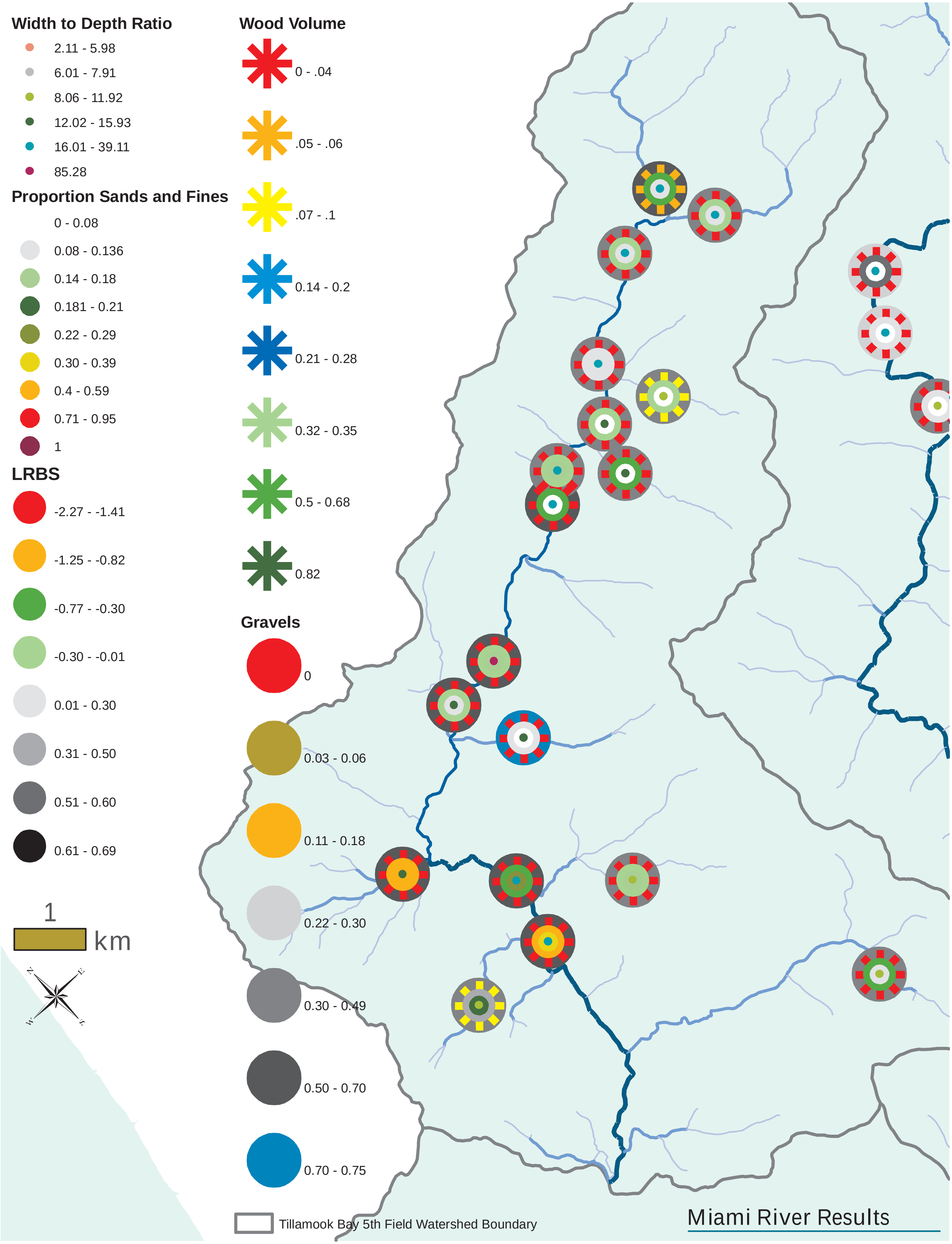
Miami - The results indicate LRBS and RP100 and are within reference benchmark ranges, wood volume is low (refer to discussion), and that the W:D is high. LRBS increases outside of 1st order channels but this is predominantly driven by the presence of bedrock in the first order streams. Pool volume is greater in the 2nd+ order streams as is expected from an increase in stream size. Wood volume is drastically less in larger streams of the Miami River. W:D is much greater in 2nd+ order streams. %SAFN is not greatly different between 1st and 2nd+ order streams.

Kilchis - The results indicate that the Kilchis is very stable compared to reference (primarily driven by bedrock), RP100 and %SAFN are within benchmark ranges, wood volume is low, and W:D is extremely high. LRBS in 1st order streams are within benchmark ranges while 2nd+ order streams within the Kilchis River watershed are very stable, this is predominantly driven by bedrock. Wood volume is low both in the 1st and 2nd+ order streams. W:D is high for both the 1st and 2nd+ order streams. %SAFN is much lower in the 2nd+ order streams.

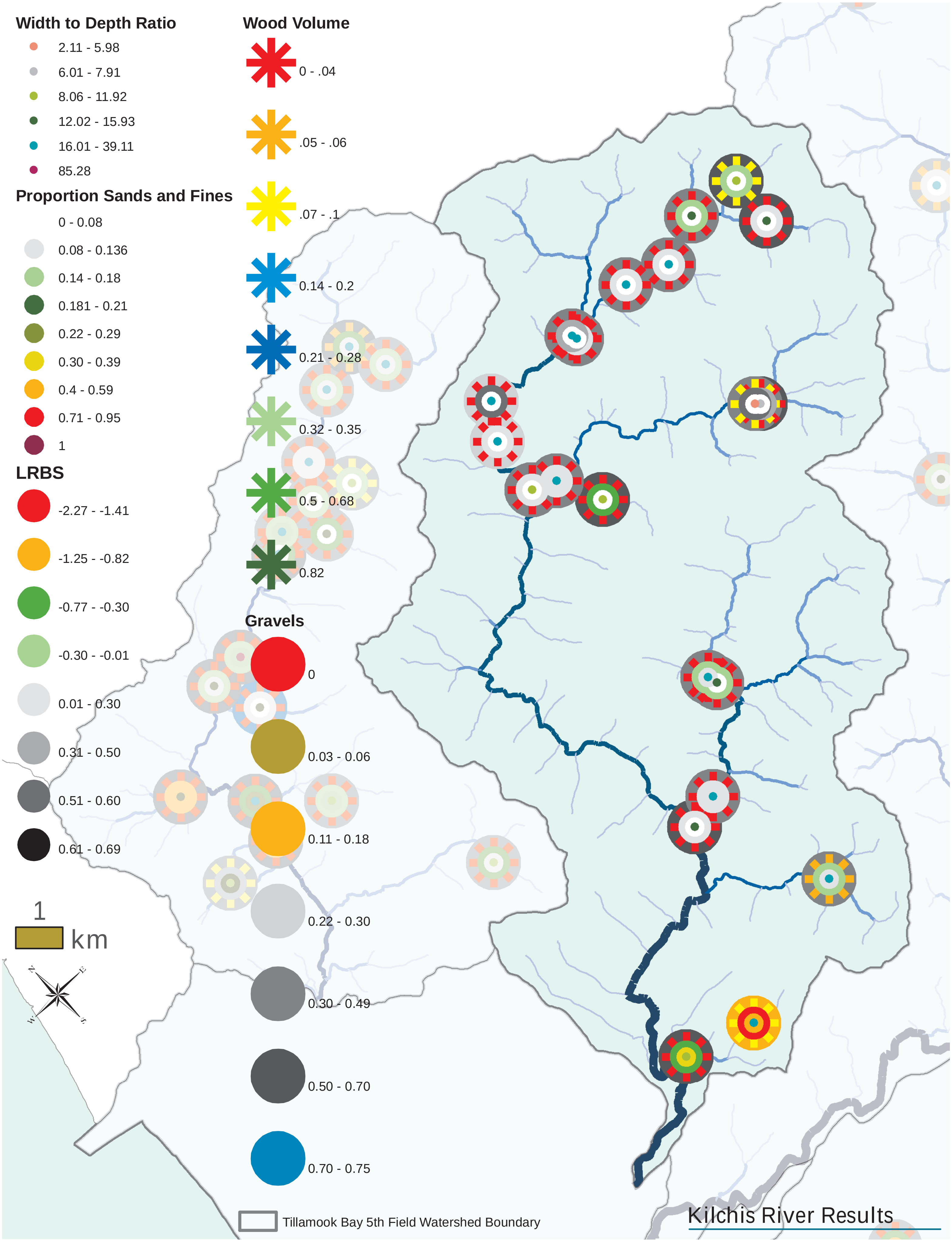
Wilson - The results indicate that bed stability is marginally higher than reference but within benchmark ranges, wood volumes are higher than in the remainder of the TBW excepting the Tillamook River, W:D is high compared to reference, and %SAFN is low when compared to the TBW but within reference ranges. First order streams are within benchmark ranges for LRBS while 2nd+ order streams of the Wilson are more stable; this is somewhat driven by bedrock. Wood volume is low both in the 1st and 2nd+ order streams. W:D is high for both the 1st and 2nd+ order streams. Wood volume is very high compared to the other four 5th fields (barring 1st order Tillamook River watershed) but this result is driven by 1st order streams. %SAFN is low for both 1st and 2nd+ order streams in the Wilson.

Trask - The results indicate that LRBS, pool volume, wood volume, %SAFN, and W:D are within reference benchmark ranges. First order streams are within benchmark ranges but when bedrock is removed are trending towards instability. Second + order streams within the Trask River watershed are very stable (driven by bedrock) and are more stable than 1st order streams. Wood volume is low in 2nd+ order streams but high in 1st order streams. W:D is high for 2nd+ order streams and low for 1st order streams. %SAFN is much lower in the 1st order streams than in 2nd+ order streams, which are within benchmark ranges. Wood volume is very high (compared to the other four 5th fields) within 1st order streams and low in 2nd + order streams.

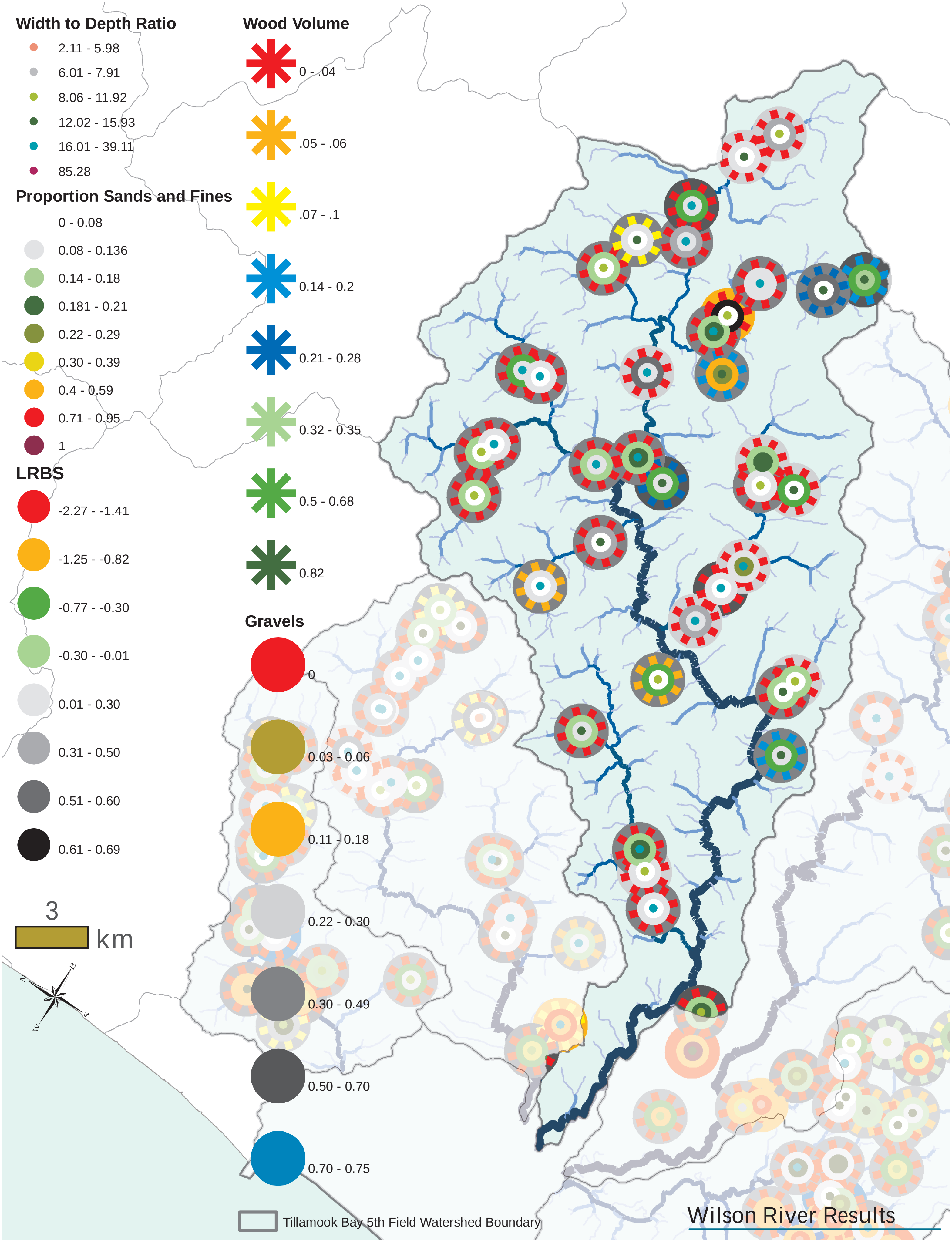
Tillamook - The results indicate that LRBS is within benchmark ranges but the Tillamook River watershed is the most unstable 5th field. RP100, wood volume, and W:D are within benchmark ranges. %SAFN is drastically above the 95th percentile. Both 1st and 2nd+ order streams are within benchmark ranges. Wood volume is low both in 2nd+ order streams but high in 1st order streams (highest in watershed). W:D is within benchmark ranges for both 1st and 2nd+ order streams. %SAFN is very high in both 1st and 2nd+ order streams but is strongly driven by lithology (%SAFN resistant mean 11%, erodible mean 55%).

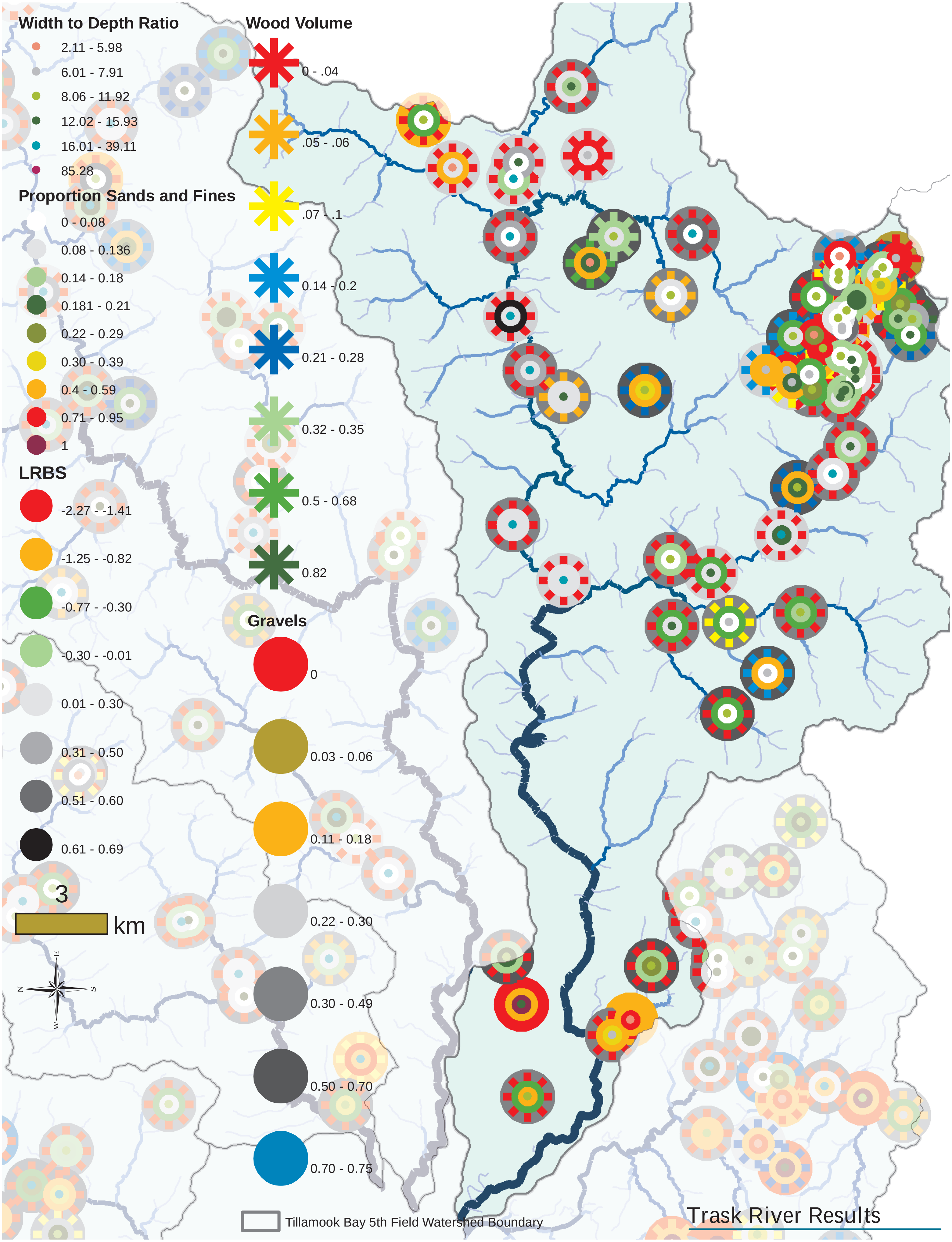


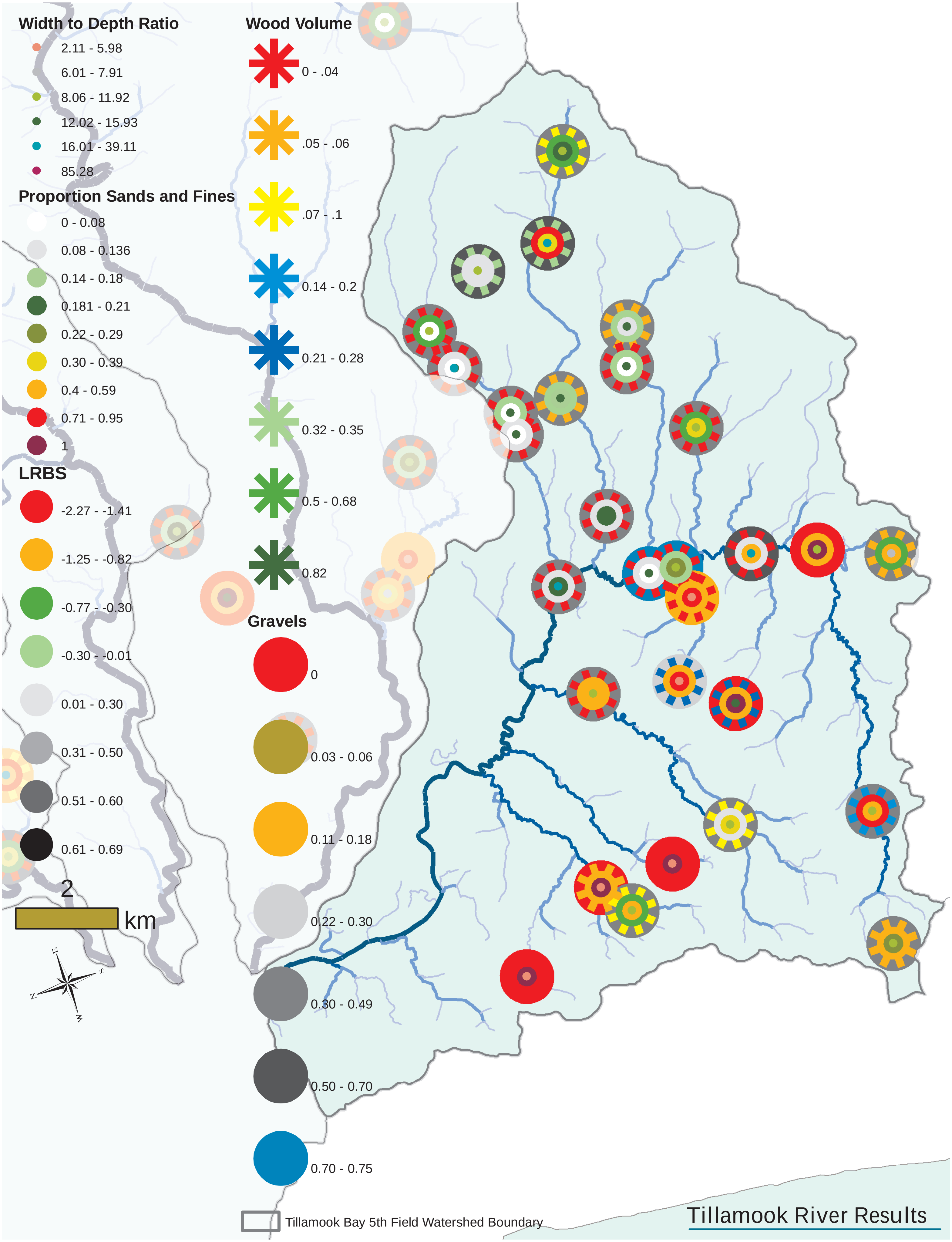
Width to Depth Ratio
2.11 - 5.98
6.01 - 7.91
8.06 - 11.92
12.02 - 15.93
16.01 - 39.11
85.28
Proportion Sands and Fines
0 - 0.08
0.08 - 0.136
0.14 - 0.18
0.181 - 0.21
0.22 - 0.29
0.30 - 0.39
0.4 - 0.59
0.71 - 0.95
1
LRBS
-2.27 - -1.41
-1.25 - -0.82
-0.77 - -0.30
-0.30 - -0.01
0.01 - 0.30
0.31 - 0.50
0.51 - 0.60
0.61 - 0.69
Wood Volume
0 - .04
.05 - .06
.07 - .1
0.14 - 0.2
0.21 - 0.28
0.32 - 0.35
0.5 - 0.68
0.82
Gravels
0
0.03 - 0.06
0.11 - 0.18
0.22 - 0.30
0.30 - 0.49
0.50 - 0.70
0.70 - 0.75
1
km
Tillamook Bay 5th Field Watershed Boundary
Miami River Results

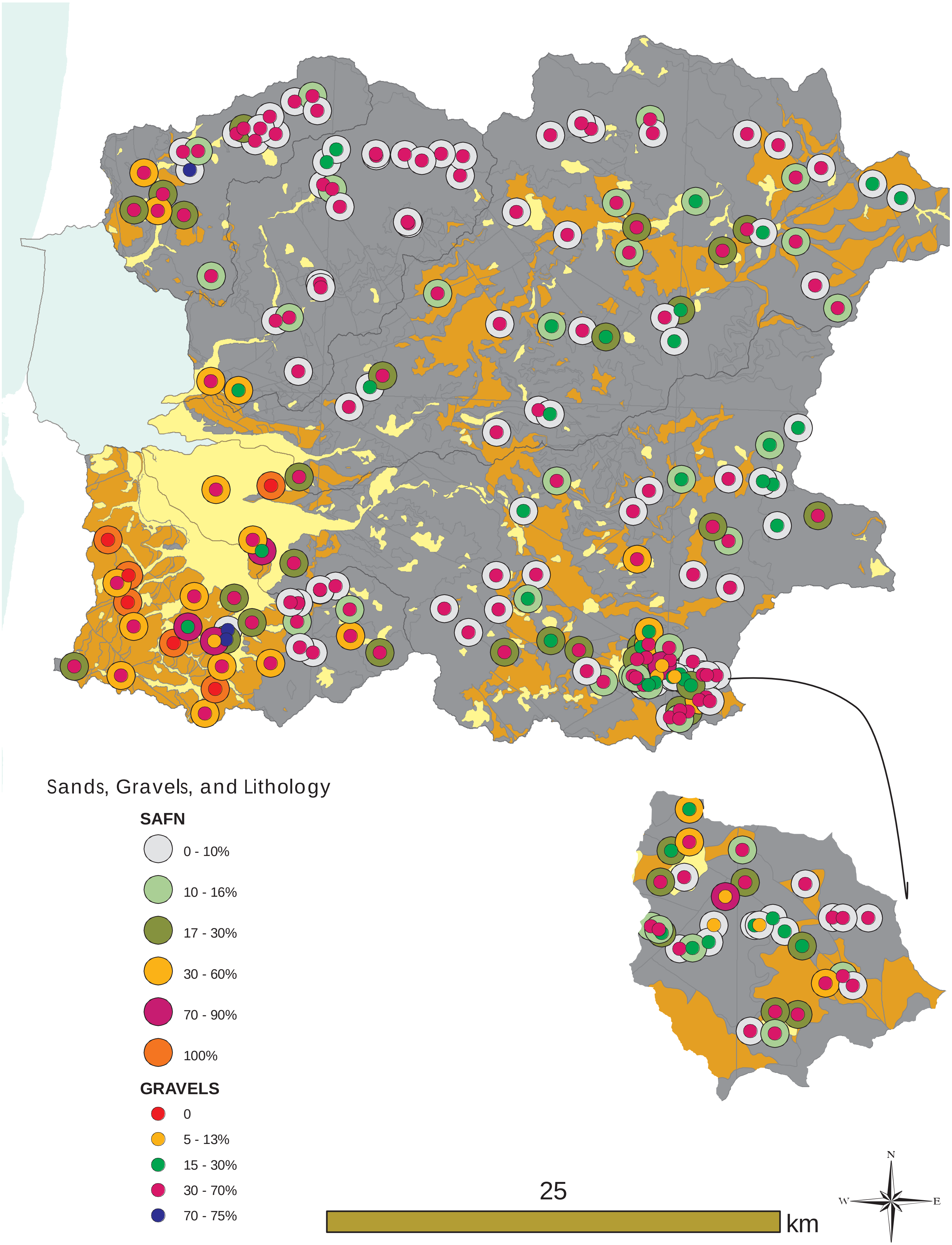


Kilchis River Results


Width to Depth Ratio
2.11 - 5.98
6.01 - 7.91
8.06 - 11.92
12.02 - 15.93
16.01 - 39.11
85.28
Proportion Sands and Fines
0 - 0.08
0.08 - 0.136
0.14 - 0.18
0.181 - 0.21
0.22 - 0.29
0.30 - 0.39
0.4 - 0.59
0.71 - 0.95
1
LRBS
-2.27 - -1.41
-1.25 - -0.82
-0.77 - -0.30
-0.30 - -0.01
0.01 - 0.30
0.31 - 0.50
0.51 - 0.60
0.61 - 0.69
Wood Volume
0 - .04
.05 - .06
.07 - .1
0.14 - 0.2
0.21 - 0.28
0.32 - 0.35
0.5 - 0.68
0.82
Gravels
0
0.03 - 0.06
0.11 - 0.18
0.22 - 0.30
0.30 - 0.49
0.50 - 0.70
0.70 - 0.75
3
km
Tillamook Bay 5th Field Watershed Boundary
Wilson River Results


Width to Depth Ratio
2.11 - 5.98
6.01 - 7.91
8.06 - 11.92
12.02 - 15.93
16.01 - 39.11
85.28
Proportion Sands and Fines
0 - 0.08
0.08 - 0.136
0.14 - 0.18
0.181 - 0.21
0.22 - 0.29
0.30 - 0.39
0.4 - 0.59
0.71 - 0.95
1
LRBS
-2.27 - -1.41
-1.25 - -0.82
-0.77 - -0.30
-0.30 - -0.01
0.01 - 0.30
0.31 - 0.50
0.51 - 0.60
0.61 - 0.69
Wood Volume
0 - .04
.05 - .06
.07 - .1
0.14 - 0.2
0.21 - 0.28
0.32 - 0.35
0.5 - 0.68
0.82
Gravels
0
0.03 - 0.06
0.11 - 0.18
0.22 - 0.30
0.30 - 0.49
0.50 - 0.70
0.70 - 0.75
3
km
Tillamook Bay 5th Field Watershed Boundary
Trask River Results


Width to Depth Ratio
2.11 - 5.98
6.01 - 7.91
8.06 - 11.92
12.02 - 15.93
16.01 - 39.11
85.28
Proportion Sands and Fines
0 - 0.08
0.08 - 0.136
0.14 - 0.18
0.181 - 0.21
0.22 - 0.29
0.30 - 0.39
0.4 - 0.59
0.71 - 0.95
1
LRBS
-2.27 - -1.41
-1.25 - -0.82
-0.77 - -0.30
-0.30 - -0.01
0.01 - 0.30
0.31 - 0.50
0.51 - 0.60
0.61 - 0.69
Wood Volume
0 - .04
.05 - .06
.07 - .1
0.14 - 0.2
0.21 - 0.28
0.32 - 0.35
0.5 - 0.68
0.82
Gravels
0
0.03 - 0.06
0.11 - 0.18
0.22 - 0.30
0.30 - 0.49
0.50 - 0.70
0.70 - 0.75
2
km
Tillamook Bay 5th Field Watershed Boundary
Tillamook River Results


Sands, Gravels, and Lithology
SAFN
0 - 10%
10 - 16%
17 - 30%
30 - 60%
70 - 90%
100%
GRAVELS
0
5 - 13%
15 - 30%
30 - 70%
70 - 75%
25
km
N
W
E
S

Site 17

Section 4.1 - Population Results

Results at the 5th or 95th percentile of reference are highlighted in red, 25th or 75th percentiles are highlighted in orange. The 95th percentile of the reference data was used for the benchmark for Wood Radius (see discussion). Slope (in percent) and substrate metrics are listed as proportions.

Section 4.1a - Tillamook Bay Watershed

The TBW population is more stable (scoured) than the reference population but this is largely driven by bedrock. When bedrock is removed from the calculation the TBW population is much closer to the reference mean. The percentage of sands and fines is similar, pool volume is slightly lower, and wood radius is marginally higher than reference. Wood volume is driven by 1st order streams. Wood volume in 2nd+ order streams is below reference. W:D is much greater than the 75th percentile of reference.

Table 3.2 Coastal Reference Data - This data is found in the materials and methods section

Metric	Mean	N	SD	SE	Lower 95 %	Upper 95%
Log Relative Bed Stability	-0.78	33	0.75	0.12	-1.01	-0.54
Percent Sands and Fines	0.17	33	0.13	0.02	0.13	0.2
Residual Pool Depth	12.64	33	13.04	1.8	9.12	16.16
Wood Radius	0.05	33	0.07	0.01	0.03	0.07
Width to Depth Ratio	9.88	33	3.47	0.57	8.76	11.01

Table 4.1a1 - Tillamook Bay Watershed Metrics

Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.3690	171	0.5385	0.0424	-0.4522	-0.2859
LRBS No Bedrock	-0.5364	171	0.5423	0.0442	-0.6230	-0.4498
Residual Pool Depth cm	9.8419	171	8.4611	0.6273	8.6124	11.0714
Wood Radius	0.0740	171	0.1062	0.0102	0.0541	0.0940
Width to Depth Ratio	12.9351	171	6.0850	0.4043	12.1428	13.7274
Percent Sands and Fines	0.1822	171	0.2378	0.0159	0.1510	0.2134
Percent Gravels	0.4069	171	0.1640	0.0147	0.3781	0.4356
Percent Cobbles	0.2010	171	0.1055	0.0087	0.1840	0.2180
Percent Small Boulders	0.1089	171	0.0889	0.0077	0.0938	0.1240
Percent Large Boulders	0.0250	171	0.0360	0.0032	0.0187	0.0312
Percent Bedrock	0.0760	171	0.1131	0.0093	0.0578	0.0943
Bank Condition	1.9972	171	0.7781	0.0684	1.8631	2.1313
Slope	0.0544	171	0.0681	0.0064	0.0419	0.0668
Station Length	217.1507	171	124.0975	9.1168	199.2822	235.0193

Table 4.1a2 - Tillamook Bay Watershed Reference Draft Benchmarks

Metric	5th Percentile	25th Percentile	75th Percentile	95th Percentile
Log Relative Bed Stability	-1.79	-1.4	-0.19	0.16
Residual Pool Depth	1.24	4.94	15.56	19.65
Wood Radius	0	0.01	0.05	0.21
Width to Depth Ratio	4.25	6.88	12.39	14.6
Percent Sands and Fines	0	0.05	0.23	0.35
Percent Bedrock	0	0.02	0.15	0.4

Section 4.1b - Miami River 5th Field Watershed

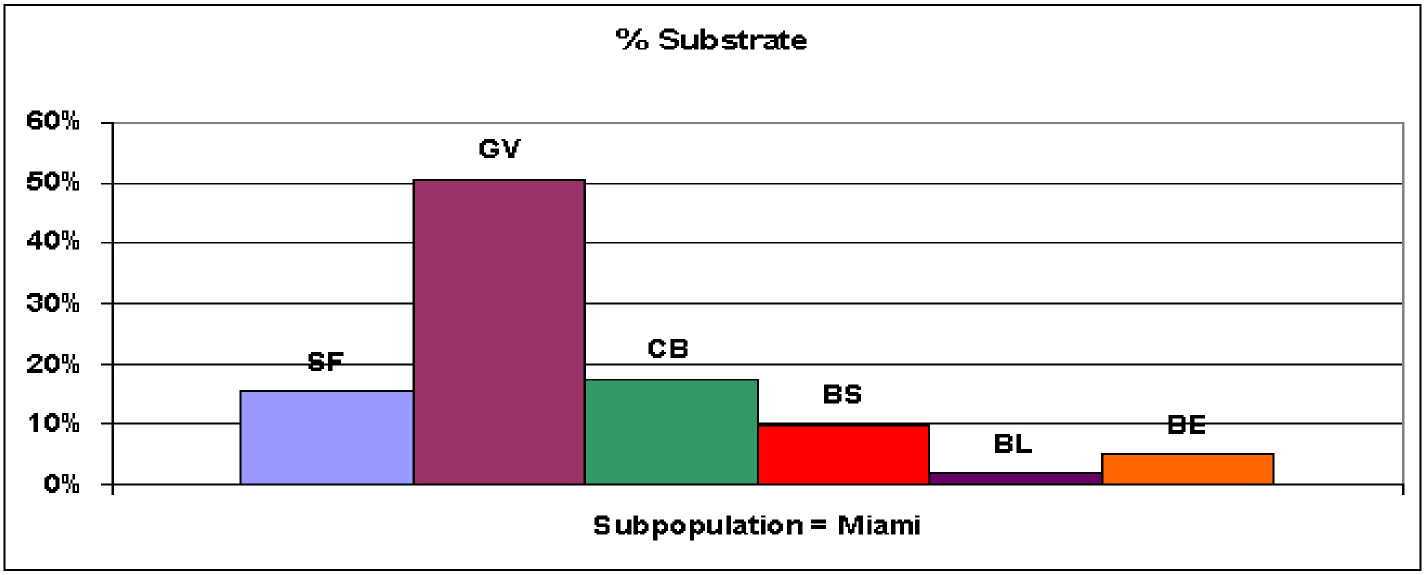
The results of the 2009 study indicate that sands and fines are within benchmark ranges at 15%. Additionally, the lowest site sampled on the Miami River mainstem had a %SAFN value greater than 30%, this is consistent with mainstem AQI data (%SAFN in 1993-1997 ~31%). This suggests a potential impact to mainstem salmonid spawning habitat in the Miami River watershed on private non-industrial ownership. Bed stability and residual pool depth are within reference benchmark ranges. Bed stability decreases in the mainstem channel. Width to depth ratios are above the 95th percentile (driven by mainstem). This indicates a potential solar radiation concern. High temperatures may limit biotic usage in the Miami River mainstem. Site 227 depicted in the photograph below is typical of the agricultural areas within the Miami River Watershed. Multiple plantings have been completed along the lowest reaches of the mainstem (downstream of final survey). Where grazing is present, cattle often utilize the riparian area and stream channel for feeding and watering, although fencing along many properties is present. Wood volume is the lowest of all 5th fields within the TBW. Wood is often removed from the mainstem channel for navigation, firewood, and to prevent channel migration.

Table 4.1b1 - Miami River Metrics						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.3249	17	0.3580	0.0919	-0.5049	-0.1448
LRBS No Bedrock	-0.4259	17	0.3107	0.0705	-0.5642	-0.2877
Residual Pool Depth cm	11.1446	17	6.6231	1.5126	8.1800	14.1092
Wood Radius	0.0300	17	0.0334	0.0078	0.0146	0.0454
Width to Depth Ratio	17.2437	17	12.0840	1.9042	13.5116	20.9758
Percent Sands and Fines	0.1548	17	0.1088	0.0196	0.1164	0.1931
Percent Gravels	0.5040	17	0.1328	0.0301	0.4451	0.5630
Percent Cobbles	0.1750	17	0.0942	0.0157	0.1443	0.2058
Percent Small Boulders	0.0987	17	0.0908	0.0211	0.0574	0.1401
Percent Large Boulders	0.0177	17	0.0265	0.0057	0.0066	0.0287
Percent Bedrock	0.0497	17	0.0693	0.0173	0.0157	0.0837
Bank Condition	1.7504	17	0.4814	0.1070	1.5406	1.9601
Slope	0.0303	17	0.0244	0.0052	0.0200	0.0405
Station Length	257.2833	17	171.8807	43.3797	172.2606	342.3060

Table 4.1b2 - Miami River Reference Draft Benchmarks				
Metric	5th Percentile	25th Percentile	75th Percentile	95th Percentile
Log Relative Bed Stability	-1.7868	-1.4161	-0.2113	0.0271
Residual Pool Depth	2.2063	8.7829	15.7591	19.5771
Wood Radius	0.0002	0.0039	0.0487	0.0832
Width to Depth Ratio	4.2379	7.5739	13.7845	14.8400
Percent Sands and Fines	0.0334	0.0495	0.2259	0.3478
Percent Bedrock	0.0000	0.0161	0.1402	0.2219

Table 4.1b4 - 2nd+ Order Miami River Metrics						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.3563	9	0.3505	0.1079	-0.5679	-0.1448
LRBS No Bedrock	-0.3847	9	0.3227	0.1021	-0.5848	-0.1846
Residual Pool Depth cm	17.4179	9	4.3375	1.0844	15.2925	19.5433
Wood Radius	0.0054	9	0.0064	0.0018	0.0019	0.0088
Width to Depth Ratio	23.4363	9	17.3721	4.6804	14.2630	32.6097
Percent Sands and Fines	0.1600	9	0.0941	0.0296	0.1020	0.2179
Percent Gravels	0.5448	9	0.1204	0.0288	0.4884	0.6012
Percent Cobbles	0.2128	9	0.1143	0.0303	0.1533	0.2722
Percent Small Boulders	0.0644	9	0.0773	0.0228	0.0196	0.1092
Percent Large Boulders	0.0054	9	0.0078	0.0016	0.0023	0.0085
Percent Bedrock	0.0127	9	0.0168	0.0041	0.0047	0.0207
Bank Condition	1.9243	9	0.5206	0.1281	1.6733	2.1753
Slope	0.0114	9	0.0064	0.0017	0.0082	0.0147
Station Length	410.2288	9	193.0100	58.5054	295.5604	524.8972

Table 4.1b3 - 1st Order Miami River Metrics						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.2696	9	0.3505	0.1102	-0.4856	-0.0537
LRBS No Bedrock	-0.4035	9	0.3085	0.0959	-0.5915	-0.2155
Residual Pool Depth cm	8.4439	9	5.3026	1.6083	5.2916	11.5961
Wood Radius	0.0402	9	0.0350	0.0109	0.0188	0.0617
Width to Depth Ratio	13.3538	9	2.4814	0.7484	11.8870	14.8207
Percent Sands and Fines	0.1397	9	0.1139	0.0296	0.0818	0.1976
Percent Gravels	0.4707	9	0.1267	0.0410	0.3904	0.5511
Percent Cobbles	0.1727	9	0.0860	0.0213	0.1310	0.2144
Percent Small Boulders	0.1270	9	0.0876	0.0272	0.0737	0.1802
Percent Large Boulders	0.0235	9	0.0294	0.0083	0.0071	0.0398
Percent Bedrock	0.0665	9	0.0761	0.0247	0.0180	0.1150
Bank Condition	1.6222	9	0.3944	0.1300	1.3674	1.8771
Slope	0.0390	9	0.0241	0.0052	0.0289	0.0492
Station Length	170.0000	9	30.9121	9.7608	150.8691	189.1309



Site 204

The Miami River is shallow and wadeable nearly to the confluence with the bay but tidal influence is limited. Nearly all of the mainstem is suitable for spawning. Only the Miami and Tillamook Rivers contain more gravel in the 2nd+ order streams than the 1st order streams. This supports the relative importance of the mainstem for spawning in these watersheds. The lack of LWD and high width to depth ratios support field observations suggesting that rearing potential is below historic levels.

1st order streams in the Miami River Watershed are generally high gradient and provide limited spawning or rearing potential. It is hypothesized that their primary value to salmonids is to supply cold water, gravel, and LWD resources to the mainstem.

Field observations suggest that complex winter rearing habitat is low throughout the Miami River Watershed. Where side channels are present, low wood volume limits their ability to prevent flow dependent mortality. Minor diking has reduced available tidally influenced rearing habitat in the lower Miami River. Terraces are present throughout most of the mainstem, and implementation of instream restoration is expected to improve these conditions. Additionally, chum salmon are known to utilize the lower Miami River mainstem extensively. The high percentage of sands and fines in the lowest reach relative to other mainstems surveyed represents a potential concern for this species.

Section 4.1c - Kilchis River 5th Field Watershed

The Kilchis River watershed is very stable compared to reference (somewhat driven by bedrock). LRBS of 1st order streams within the Kilchis River watershed are within benchmark ranges while 2nd+ order streams are scoured. RP100 and %SAFN is within benchmark ranges (%SAFN is much lower in the 2nd+ order streams), and W:D is extremely high, (both 1st and 2+ order streams). The Kilchis River mainstem AQI average %SAFN from 1994-1997 is 29.9%, possibly driven by surveys outside of the 2009 study in depositional reaches. Wood volume is low both in the 1st and 2nd+ order streams. The Kilchis River watershed has the highest proportion of boulder substrate among the five 5th fields in the TBW and bedrock proportions are second only to the Trask River watershed. Additionally, the large stream power may slow future restoration as wood recruited in this stream is more likely to flush from the system than in either the Miami or Tillamook.

Site 2

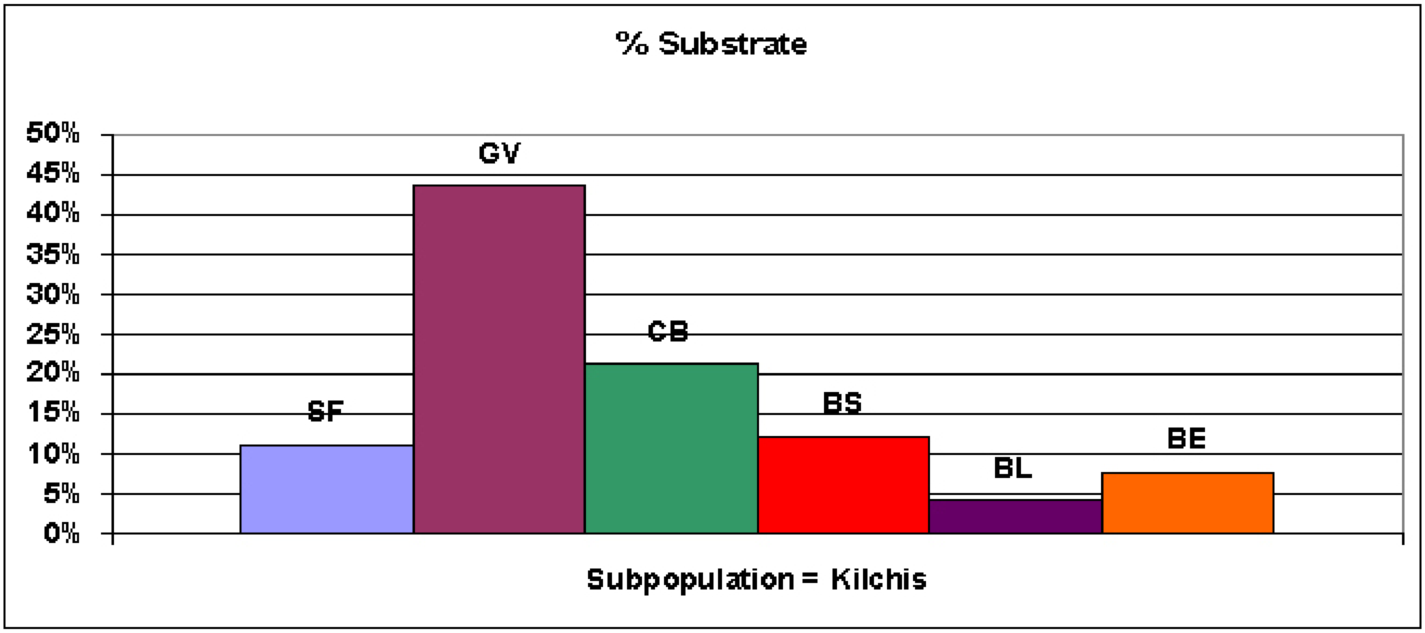
Table 4.1c1 - Kilchis River Metrics						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.1632	21	0.4770	0.0992	-0.3576	0.0311
LRBS No Bedrock	-0.3478	21	0.5387	0.1172	-0.5775	-0.1180
Residual Pool Depth cm	10.9329	21	8.8025	1.3480	8.2908	13.5749
Wood Radius	0.0293	21	0.0383	0.0091	0.0114	0.0473
Width to Depth Ratio	15.3514	21	5.2851	0.8898	13.6075	17.0953
Percent Sands and Fines	0.1112	21	0.1550	0.0317	0.0490	0.1734
Percent Gravels	0.4369	21	0.1220	0.0294	0.3792	0.4945
Percent Cobbles	0.2129	21	0.0818	0.0164	0.1807	0.2450
Percent Small Boulders	0.1210	21	0.0585	0.0104	0.1005	0.1414
Percent Large Boulders	0.0413	21	0.0348	0.0078	0.0261	0.0566
Percent Bedrock	0.0767	21	0.0750	0.0147	0.0480	0.1054
Bank Condition	1.6768	21	0.3892	0.0581	1.5629	1.7908
Slope	0.0312	21	0.0234	0.0058	0.0199	0.0425
Station Length	241.1565	21	110.7670	16.5400	208.7388	273.5742

Table 4.1c2 - Kilchis River Reference Draft Benchmarks				
Metric	5th Percentile	25th Percentile	75th Percentile	95th Percentile
Log Relative Bed Stability	-1.79	-1.42	-0.22	0.02
Residual Pool Depth	2.25	9.62	15.86	19.56
Wood Radius	0	0	0.05	0.08
Width to Depth Ratio	4.24	7.68	13.86	14.88
Percent Sands and Fines	0.03	0.05	0.22	0.35
Percent Bedrock	0	0.02	0.14	0.21

Table 4.1c3 - 1st Order Kilchis River Metrics						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.3327	8	0.4611	0.1460	-0.6187	-0.0466
LRBS No Bedrock	-0.4866	8	0.5736	0.1742	-0.8281	-0.1451
Residual Pool Depth cm	7.7564	8	2.9043	0.9990	5.7983	9.7145
Wood Radius	0.0353	8	0.0403	0.0136	0.0085	0.0620
Width to Depth Ratio	14.3316	8	3.1927	0.9789	12.4130	16.2501
Percent Sands and Fines	0.1375	8	0.1781	0.0493	0.0410	0.2341
Percent Gravels	0.4552	8	0.1346	0.0390	0.3787	0.5316
Percent Cobbles	0.2017	8	0.0836	0.0246	0.1536	0.2498
Percent Small Boulders	0.1072	8	0.0542	0.0167	0.0745	0.1399
Percent Large Boulders	0.0414	8	0.0365	0.0125	0.0169	0.0659
Percent Bedrock	0.0570	8	0.0551	0.0177	0.0222	0.0918
Bank Condition	1.6773	8	0.3252	0.0594	1.5609	1.7938
Slope	0.0363	8	0.0262	0.0088	0.0191	0.0535
Station Length	192.8362	8	39.2226	13.2875	166.7931	218.8792

Table 4.1c4- 2nd+ Order Kilchis River Metrics						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	0.2228	13	0.2165	0.0536	0.1177	0.3279
LRBS No Bedrock	-0.0316	13	0.2404	0.0598	-0.1488	0.0856
Residual Pool Depth cm	18.1693	13	12.6268	2.3397	13.5836	22.7550
Wood Radius	0.0159	13	0.0293	0.0076	0.0011	0.0307
Width to Depth Ratio	17.6748	13	7.7831	1.8766	13.9967	21.3529
Percent Sands and Fines	0.0513	13	0.0360	0.0077	0.0363	0.0663
Percent Gravels	0.3952	13	0.0704	0.0143	0.3672	0.4231
Percent Cobbles	0.2383	13	0.0712	0.0124	0.2140	0.2627
Percent Small Boulders	0.1524	13	0.0556	0.0135	0.1259	0.1789
Percent Large Boulders	0.0412	13	0.0305	0.0074	0.0267	0.0557
Percent Bedrock	0.1216	13	0.0928	0.0215	0.0794	0.1637
Bank Condition	1.6757	13	0.5055	0.1230	1.4346	1.9168
Slope	0.0197	13	0.0064	0.0015	0.0168	0.0226
Station Length	351.2371	13	138.8489	30.9016	290.6710	411.8032

The Rapid Bio Assessment conducted within the TBW for the Partnership indicate that the Kilchis River coho population is highly dependent on mainstem habitat. Although discussions of sediment impacts commonly center on an excess of fine sediments, *excess scour can also impact biotic communities.* The signal of scour and low wood volumes observed in the 2nd+ order streams of the Kilchis River suggest that the mainstem habitat may be oversimplified and lacking complexity. As is the case with the other 5th field watersheds, diking has greatly reduced available wetland habitat in the lower Kilchis River watershed. Lack of complex winter habitat may impact salmonid abundance. Furthermore, on average, most gravels (2-64mm) are mobile under bankfull flow (D_CBF = 68mm), and redds may be directly disturbed as a consequence.



Section 4.1d - Wilson River 5th Field Watershed

The results indicate that the bed stability of 1st order streams are within benchmark ranges while 2nd + order streams are more stable (driven by bedrock). Wood volumes are higher than in the remainder of the TBW (excepting the Tillamook River, refer to discussion) but lower than the 95th percentile (above in 1st order and well below in 2nd+ order), W:D is higher than reference, and %SAFN is low when compared to the TBW but within reference ranges.

Log drives in the Wilson River watershed occurred from upstream of RM 30 to the bay.[1] This had significant impacts on the instream habitat and channel morphology of the watershed. Wood removal (historic in upper watershed and ongoing removal in the lower limits floodplain connectivity and inhibits the sorting power of the stream. Additionally, Highway 6 constrains the mainstem Wilson River for much of its upper length.

1 CCMP chapter 5

Table 4.1d1 - Wilson River Metrics						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.2575	38	0.3792	0.0715	-0.3976	-0.1173
LRBS No Bedrock	-0.3628	38	0.3072	0.0595	-0.4793	-0.2463
Residual Pool Depth cm	8.5354	38	7.5137	0.9507	6.6720	10.3987
Wood Radius	0.0860	38	0.0877	0.0175	0.0517	0.1203
Width to Depth Ratio	13.9326	38	3.9517	0.6642	12.6308	15.2344
Percent Sands and Fines	0.0926	38	0.0720	0.0144	0.0644	0.1208
Percent Gravels	0.4318	38	0.1188	0.0239	0.3850	0.4786
Percent Cobbles	0.2495	38	0.0801	0.0168	0.2166	0.2824
Percent Small Boulders	0.1367	38	0.0809	0.0167	0.1041	0.1693
Percent Large Boulders	0.0322	38	0.0369	0.0073	0.0179	0.0465
Percent Bedrock	0.0573	38	0.0699	0.0100	0.0377	0.0768
Bank Condition	2.1625	38	0.7890	0.1298	1.9081	2.4169
Slope	0.0633	38	0.0492	0.0100	0.0438	0.0829
Station Length	206.9882	38	89.1675	12.5764	182.3390	231.6374

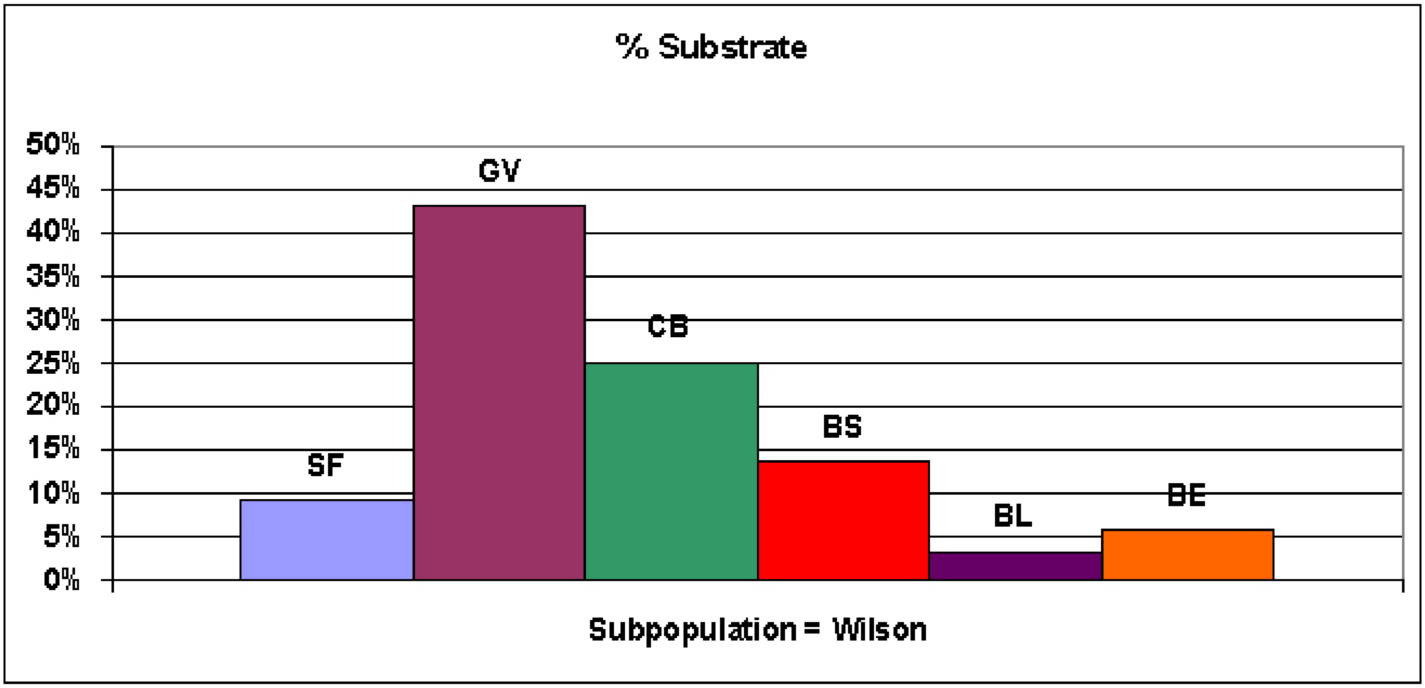
Table 4.1d2 - Wilson River Reference Draft Benchmarks				
Metric	5th Percentile	25th Percentile	75th Percentile	95th Percentile
Log Relative Bed Stability	-1.7877	-1.4096	-0.2028	0.0418
Residual Pool Depth	2.1264	7.2291	15.6023	19.5986
Wood Radius	0.0002	0.0041	0.0488	0.1093
Width to Depth Ratio	4.2414	7.3806	13.3158	14.7715
Percent Sands and Fines	0.0210	0.0496	0.2289	0.3482
Percent Bedrock	0.0000	0.0159	0.1422	0.3088

Table 4.1d3 - 1st Order Wilson River Metrics						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.4385	9	0.2819	0.0744	-0.5843	-0.2927
LRBS No Bedrock	-0.4802	9	0.2775	0.0775	-0.6320	-0.3283
Residual Pool Depth cm	5.1433	9	0.9930	0.2923	4.5703	5.7162
Wood Radius	0.1176	9	0.0838	0.0262	0.0662	0.1690
Width to Depth Ratio	12.9878	9	3.2632	1.0919	10.8478	15.1278
Percent Sands and Fines	0.0962	9	0.0762	0.0222	0.0527	0.1396
Percent Gravels	0.4683	9	0.1150	0.0384	0.3931	0.5435
Percent Cobbles	0.2516	9	0.0868	0.0271	0.1984	0.3048
Percent Small Boulders	0.1238	9	0.0863	0.0289	0.0671	0.1805
Percent Large Boulders	0.0294	9	0.0381	0.0131	0.0038	0.0550
Percent Bedrock	0.0307	9	0.0297	0.0084	0.0143	0.0472
Bank Condition	2.2144	9	0.6503	0.2132	1.7965	2.6323
Slope	0.0837	9	0.0481	0.0141	0.0559	0.1114

Table 4.1d4 - 2nd Order Wilson River Metrics						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	0.1121	29	0.2677	0.0436	0.0267	0.1975
LRBS No Bedrock	-0.1232	29	0.2105	0.0319	-0.1858	-0.0607
Residual Pool Depth cm	15.4588	29	9.9123	1.2566	12.9959	17.9217
Wood Radius	0.0215	29	0.0532	0.0086	0.0046	0.0385
Width to Depth Ratio	15.8609	29	4.4961	0.7485	14.3939	17.3279
Percent Sands and Fines	0.0853	29	0.0617	0.0097	0.0663	0.1044
Percent Gravels	0.3572	29	0.0876	0.0147	0.3285	0.3859
Percent Cobbles	0.2451	29	0.0642	0.0101	0.2253	0.2648
Percent Small Boulders	0.1631	29	0.0606	0.0099	0.1437	0.1825
Percent Large Boulders	0.0379	29	0.0335	0.0053	0.0274	0.0483
Percent Bedrock	0.1114	29	0.0932	0.0157	0.0806	0.1423
Bank Condition	2.0566	29	1.0067	0.1540	1.7548	2.3584
Slope	0.0219	29	0.0100	0.0014	0.0192	0.0246
Station Length	288.8798	29	111.1662	16.5745	256.3945	321.3652

The mainstem Wilson River exhibits very low salmonid abundance. The Little North Fork Wilson and Devil's Lake Fork are the most productive sub-watersheds within the Wilson River watershed in regards to coho production.[1] Although these sub-watersheds are below reference averages (low wood volume and somewhat scoured), these areas still represent high quality habitat relative to the remainder of the watershed.

1 Bio Surveys LLC. (2007) *Tillamook Bay Rapid Bio Assessment*



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The results indicate that LRBS, pool volume, wood volume (refer to discussion), %SAFN, and W:D are within reference benchmark ranges. First order streams are within benchmark ranges but when bedrock is removed there is a trend towards instability. Second+ order streams within the Trask River watershed are very stable (driven by bedrock) and are more stable than 1st order streams. Wood volume is low in 2nd + order streams but high in 1st order streams.

W:D is high for 2nd+ order streams and low for 1st order streams. %SAFN is much lower in the 1st order streams than in 2nd+ order streams, which are within benchmark ranges but somewhat elevated relative to the LRBS values. The Trask River mainstem AQI Average %SAFN was 38.2%   Wood volume is very high within 1st order streams (compared to the other four 5th fields; excepting the Tillamook River 1st order streams) and low in 2nd + order streams.

Table 4.1e1 - Trask River Metrics

Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.4261	64	0.5967	0.0879	-0.5983	-0.2539
LRBS No Bedrock	-0.7093	64	0.6337	0.0968	-0.8989	-0.5196
Residual Pool Depth cm	8.9191	64	8.6281	1.0853	6.7920	11.0463
Wood Radius	0.0825	64	0.1358	0.0208	0.0417	0.1233
Width to Depth Ratio	11.9017	64	6.3402	0.7959	10.3417	13.4617
Percent Sands and Fines	0.1732	64	0.2173	0.0275	0.1193	0.2272
Percent Gravels	0.3873	64	0.1722	0.0263	0.3358	0.4388
Percent Cobbles	0.1891	64	0.0991	0.0135	0.1627	0.2154
Percent Small Boulders	0.1058	64	0.0926	0.0128	0.0808	0.1308
Percent Large Boulders	0.0240	64	0.0394	0.0054	0.0135	0.0346
Percent Bedrock	0.1206	64	0.1562	0.0220	0.0775	0.1636
Bank Condition	2.1031	64	0.8615	0.1271	1.8541	2.3521
Slope	0.0682	64	0.0938	0.0135	0.0418	0.0946
Station Length	231.9213	64	154.5553	19.5593	193.5859	270.2567

Table 4.1e2 - Trask River Reference Draft Benchmarks

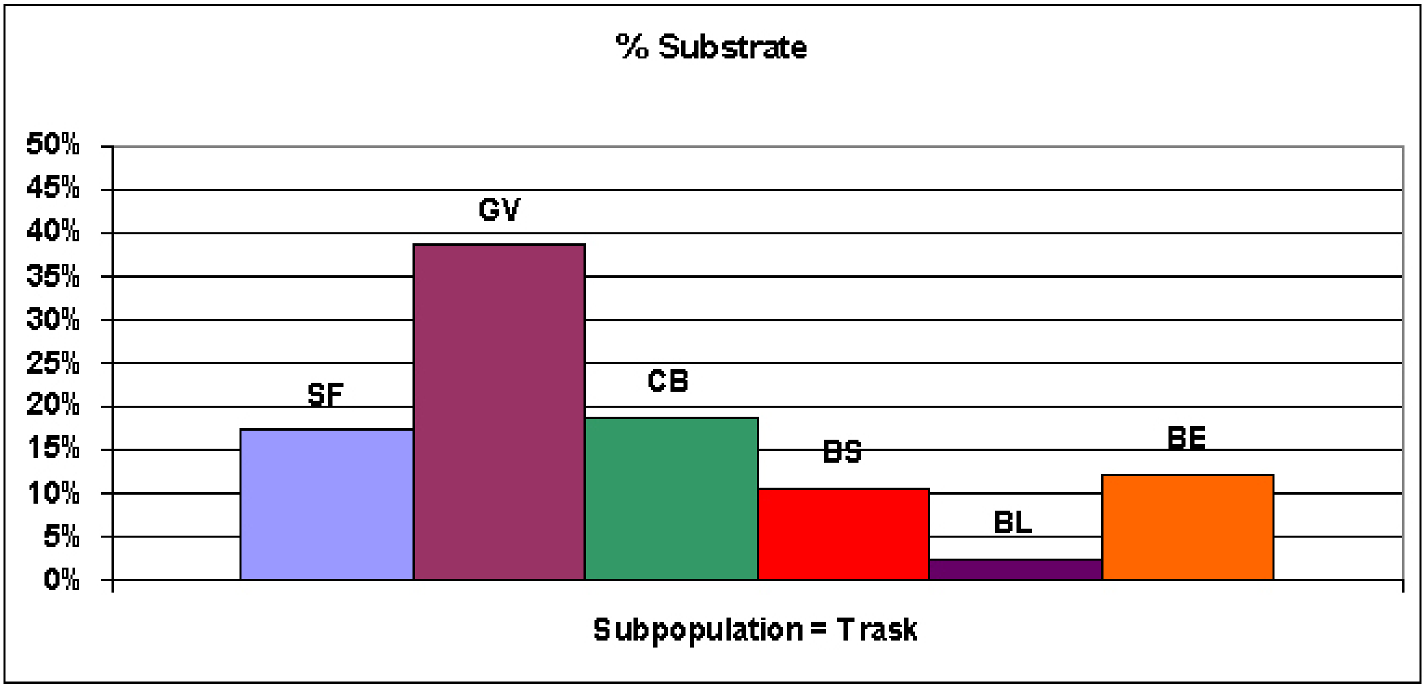
Metric	5th Percentile	25th Percentile	75th Percentile	95th Percentile
Log Relative Bed Stability	-1.79	-1.41	-0.2	0.06
Residual Pool Depth	2.09	5.79	15.59	19.61
Wood Radius	0	0	0.05	0.12
Width to Depth Ratio	4.24	7.27	13.12	14.74
Percent Sands and Fines	0.02	0.05	0.23	0.35
Percent Bedrock	0	0.02	0.14	0.33

Table 4.1e3 - 1st Order Trask River Metrics						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.6682	15	0.5325	0.1310	-0.9249	-0.4114
LRBS No Bedrock	-0.9285	15	0.6572	0.1350	-1.1931	-0.6639
Residual Pool Depth cm	4.2158	15	2.6992	0.6076	3.0249	5.4068
Wood Radius	0.1166	15	0.1501	0.0300	0.0577	0.1755
Width to Depth Ratio	8.6369	15	2.0795	0.4411	7.7723	9.5014
Percent Sands and Fines	0.2001	15	0.2522	0.0474	0.1071	0.2930
Percent Gravels	0.4296	15	0.1946	0.0413	0.3487	0.5105
Percent Cobbles	0.1784	15	0.1016	0.0200	0.1392	0.2176
Percent Small Boulders	0.0727	15	0.0790	0.0169	0.0397	0.1058
Percent Large Boulders	0.0122	15	0.0220	0.0052	0.0021	0.0224
Percent Bedrock	0.1069	15	0.1768	0.0344	0.0395	0.1743
Bank Condition	2.3565	15	0.8718	0.1911	1.9820	2.7310
Slope	0.0939	15	0.1094	0.0182	0.0581	0.1296
Station Length	150.6626	15	2.4874	0.5637	149.5577	151.7675

Table 4.1e4 - 2nd Order Trask River Metrics						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	0.0141	18	0.4161	0.0603	-0.1040	0.1323
LRBS No Bedrock	-0.3201	18	0.3442	0.0642	-0.4459	-0.1943
Residual Pool Depth cm	18.1354	18	9.1973	1.9266	14.3594	21.9114
Wood Radius	0.0134	18	0.0144	0.0031	0.0074	0.0195
Width to Depth Ratio	18.3342	18	7.1590	1.3005	15.7853	20.8832
Percent Sands and Fines	0.1250	18	0.1249	0.0161	0.0935	0.1565
Percent Gravels	0.3098	18	0.0748	0.0160	0.2784	0.3412
Percent Cobbles	0.2048	18	0.0842	0.0185	0.1685	0.2411
Percent Small Boulders	0.1630	18	0.0839	0.0165	0.1307	0.1953
Percent Large Boulders	0.0490	18	0.0540	0.0122	0.0251	0.0728
Percent Bedrock	0.1483	18	0.1040	0.0187	0.1116	0.1850
Bank Condition	1.7288	18	0.6910	0.1440	1.4465	2.0111
Slope	0.0216	18	0.0129	0.0029	0.0159	0.0272
Station Length	392.2027	18	183.9640	36.8420	319.9937	464.4117

The physical habitat within the Trask River watershed is consistent with what is found in the rest of the TBW. There are distinct differences between 1st and 2nd+ order streams: the high wood volume and abundant gravel substrate in 1st order streams suggest that these reaches have high potential to supply spawning resources; the low pool volume in these reaches limits rearing potential; the low wood volume and LRBS scores in 2nd+ order streams likely limits overwintering potential. These conclusions are confirmed by paired summer and winter snorkel surveys conducted (not part of this study) in the Cruiserhorn sub-watershed of the Trask River. Although summer juvenile coho counts were among the highest in the TBW, winter juvenile abundance was very low.[1] The high W:D in the 2nd+ order streams may exacerbate peak temperatures.

1 Bio Surveys LLC, personal communication.



Site 167

Site 30

Section 4.1f - Tillamook River 5th Field Watershed

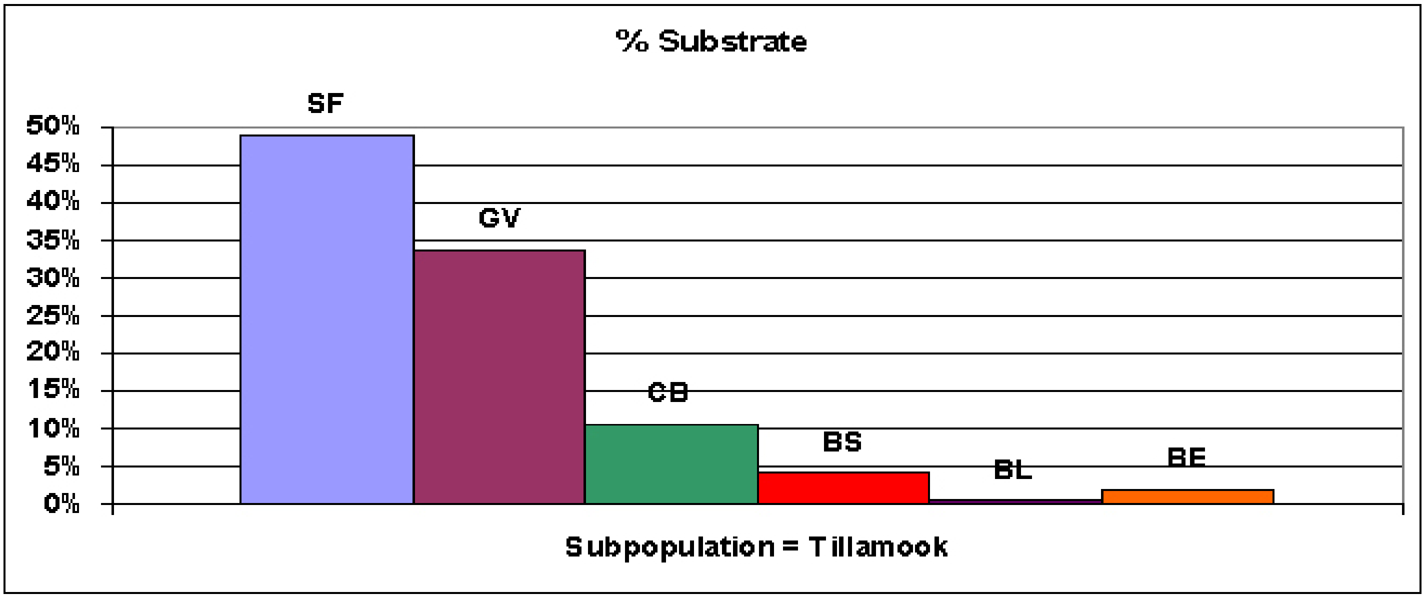
The results indicate that LRBS is within benchmark ranges although it is the most unstable of all the 5th fields in the study area. RP100 and wood volume values W:D are also within reference benchmark ranges. %SAFN is above the 95th percentile. The Tillamook River mainstem AQI Average %SAFN (1994-1997) is 65.6%.

Table 4.1f1 - Tillamook River Metrics						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.6612	28	0.6650	0.0960	-0.8494	-0.4730
LRBS No Bedrock	-0.7030	28	0.6207	0.0854	-0.8704	-0.5356
Residual Pool Depth cm	14.0438	28	9.3024	1.6193	10.8701	17.2176
Wood Radius	0.0747	28	0.0999	0.0151	0.0450	0.1043
Width to Depth Ratio	9.8114	28	4.1130	0.5849	8.6650	10.9578
Percent Sands and Fines	0.4891	28	0.3616	0.0552	0.3809	0.5972
Percent Gravels	0.3377	28	0.2293	0.0407	0.2578	0.4175
Percent Cobbles	0.1073	28	0.1165	0.0156	0.0768	0.1378
Percent Small Boulders	0.0415	28	0.0758	0.0093	0.0233	0.0597
Percent Large Boulders	0.0042	28	0.0092	0.0016	0.0010	0.0074
Percent Bedrock	0.0203	28	0.0324	0.0058	0.0089	0.0318
Bank Condition	1.6803	28	0.6238	0.1174	1.4503	1.9103
Slope	0.0241	28	0.0399	0.0062	0.0121	0.0362
Station Length	172.1600	28	68.0256	12.4121	147.8327	196.4873

Table 4.1f2 - Tillamook River Reference Draft Benchmarks				
Metric	5th Percentile	25th Percentile	75th Percentile	95th Percentile
Log Relative Bed Stability	-2.73	-1.24	-0.15	0.27
Residual Pool Depth	0.39	3.77	15.41	25.43
Wood Radius	0	0.01	0.05	0.27
Width to Depth Ratio	4.29	6.56	11.9	14.55
Percent Sands and Fines	0	0.05	0.25	0.4
Percent Bedrock	0	0.01	0.17	0.44

Table 4.1f3 - 1st Order Tillamook River Metrics						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.7472	19	0.6831	0.1225	-0.9872	-0.5072
LRBS No Bedrock	-0.7853	19	0.6386	0.1068	-0.9947	-0.5760
Residual Pool Depth cm	11.4287	19	8.4722	1.7068	8.0834	14.7740
Wood Radius	0.0947	19	0.1041	0.0201	0.0553	0.1341
Width to Depth Ratio	9.4914	19	4.1795	0.7026	8.1144	10.8684
Percent Sands and Fines	0.4970	19	0.3661	0.0612	0.3772	0.6169
Percent Gravels	0.3035	19	0.2013	0.0390	0.2271	0.3799
Percent Cobbles	0.1254	19	0.1301	0.0196	0.0870	0.1638
Percent Small Boulders	0.0513	19	0.0818	0.0130	0.0258	0.0768
Percent Large Boulders	0.0020	19	0.0049	0.0010	0.0000	0.0041
Percent Bedrock	0.0207	19	0.0298	0.0074	0.0062	0.0352
Bank Condition	1.4424	19	0.3557	0.0733	1.2987	1.5860
Slope	0.0296	19	0.0435	0.0080	0.0139	0.0454
Station Length	144.4668	19	33.3634	8.1846	128.4254	160.5082

Table 4.1f4 - 2nd Order Tillamook River Metrics						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.3229	11	0.4547	0.1657	-0.6477	0.0019
LRBS No Bedrock	-0.3791	11	0.4164	0.1494	-0.6718	-0.0864
Residual Pool Depth cm	20.4662	11	7.9758	2.1337	16.2843	24.6482
Wood Radius	0.0079	11	0.0149	0.0032	0.0017	0.0142
Width to Depth Ratio	11.3818	11	3.5089	1.1261	9.1746	13.5889
Percent Sands and Fines	0.3912	11	0.3473	0.1212	0.1536	0.6288
Percent Gravels	0.4493	11	0.2527	0.0973	0.2585	0.6400
Percent Cobbles	0.0950	11	0.1066	0.0236	0.0488	0.1411
Percent Small Boulders	0.0338	11	0.0697	0.0062	0.0217	0.0459
Percent Large Boulders	0.0098	11	0.0145	0.0056	-0.0011	0.0208
Percent Bedrock	0.0209	11	0.0368	0.0108	-0.0003	0.0422
Bank Condition	2.3256	11	0.7339	0.2064	1.9211	2.7302
Slope	0.0089	11	0.0101	0.0018	0.0052	0.0125
Station Length	254.8212	11	71.8871	23.3937	208.9704	300.6720



The Tillamook River watershed contains the highest proportion of erodible materials of the five 5th field watersheds. Additionally, the Tillamook River is distinct from the majority of coastal erodible watersheds in that the erodible material is not of Tyee origin. Watersheds dominated by Tyee lithologies are often characterized by extreme hillslopes prone to failure and broad valley floors. The western Tillamook River watershed (the eastern watershed is dominated by resistant materials) in contrast is not prone to hillslope failure or debris torrents, the slopes are not extreme, and the valley bottoms are often confined. The geology within the western watershed is prone to erosion however. The east-west watershed divide is unique within the TBW although a similar lithology divide occurs in the Miami River watershed. The Tillamook River is marginally larger than the Miami River watershed (watershed size) and much smaller than the Kilchis, Trask, and Wilson rivers (respectively smallest to largest). The eastern tributaries (east of highway 101) provide the majority of the gravels within the watershed while the western tributaries provide the majority of the sand. Although the %SAFN within the Tillamook River is high (~48%) and should be investigated further this is driven by the western drainage (%SAFN ~55% in western tributaries and ~11% in eastern tributaries). The eastern tributaries appear to provide adequate stream flow to flush excess sands and fines from the large gravel deposits in the mainstem where the two drainages meet (%SAFN in mainstem 22%). It is hypothesized that the source of the fine sediments within the western drainage is from historical beaver ponds which have largely disappeared (refer to discussion of mammalian impacts on riparian habitat). As beaver ponds age (assuming they are not actively maintained by a stable beaver population) they not only become more prone to failure but store more sediments as well. When they fail, these sediments become the new channel substrate. The Tillamook River watershed contains the most sites with 100% sand (wetlands) and two of its mainstem sites have the highest gravel percentages in the entire TBW. These gravels are located in a 2 mile stretch of known salmonid spawning habitat and are immediately downstream of very unstable, sandy sites. Beaver trapping has occurred and still does occur on an infrequent basis within the Tillamook River watershed.[1] As beaver are removed from the watershed and can no longer maintain their dams, the sediment behind those dams is more likely to travel downstream and settle in spawning habitat.

1 Private Landowners, Personal Communication

Section 4.1g - Trask River VS. Miami River

Table 4.1g - Trask VS. Miami Hypothesis Test Results

Metric	Trask VS. Miami	T Score	P Value	Significant
Log Relative Bed Stability	<	-0.88	0.38	NO
LRBS No Bedrock	<	-2.59	0.01	YES
RP100_CM	<	-1.15	0.26	NO
Wood Radius	>	2.79	0.01	YES
Width to Depth Ratio	<	-1.76	0.1	NO
ArcSin Proportion Sands and Fines	>	0.19	0.85	NO
ArcSin Proportion Gravels	<	-3.19	0	YES
ArcSin Proportion Cobbles	>	0.5	0.62	NO
ArcSin Proportion Small Boulders	>	0.16	0.87	NO
ArcSin Proportion Large Boulders	>	0.4	0.69	NO
ArcSin Proportion Bedrock	>	2.53	0.02	YES
Bank Stability	>	2.22	0.03	YES
Slope	>	2.89	0	YES
Bankfull Hydraulic Radius	<	-0.31	0.76	NO
Mean Substrate Diameter at Critical Bankfull	>	2.4	0.02	YES
Mean Substrate Size	>	2.57	0.01	YES
Mean Substrate Size No Bedrock	>	1.28	0.21	NO
Station Length	<	-0.55	0.59	NO

When bedrock is removed from the bed stability calculation, the Trask River watershed is less stable than the Miami River watershed (%Bedrock is greater in the Trask). The Miami River also provides a higher proportion of gravels, although it contains much lower wood volumes. 2nd+ order Miami River watershed sites (which provide the bulk of the spawning potential) are particularly low in LWD. Banks are less stable in the Trask River, and slopes are higher.

Table 4.1h - Kilchis VS. Trask Hypothesis Testing Results				
Metric	Kilchis VS. Trask	T Score	P Value	Significant
Log Relative Bed Stability	>	2.05	0.05	YES
LRBS No Bedrock	>	2.55	0.01	YES
RP100_CM	>	0.91	0.37	NO
Wood Radius	<	-2.81	0.01	YES
Width to Depth Ratio	>	2.47	0.02	YES
ArcSin Proportion Sands and Fines	<	-1.67	0.1	NO
ArcSin Proportion Gravels	>	1.63	0.11	NO
ArcSin Proportion Cobbles	>	1.38	0.17	NO
ArcSin Proportion Small Boulders	>	1.88	0.07	NO
ArcSin Proportion Large Boulders	>	2.51	0.02	YES
ArcSin Proportion Bedrock	<	-1.19	0.24	NO
Bank Stability	<	-3.11	0	YES
Slope	<	-2.89	0	YES
Bankfull Hydraulic Radius	<	-0.08	0.94	NO
Mean Substrate Diameter at Critical Bankfull	<	-2.4	0.02	YES
Mean Substrate Size	<	-1.64	0.11	NO
Mean Substrate Size No Bedrock	>	1.19	0.24	NO
Station Length	>	0.3	0.77	NO

The Kilchis River watershed is more stable than the Trask River watershed both with and without bedrock included in the bed stability calculations. Wood radius is lower in the Kilchis River watershed and width to depth ratios greater. Slopes are lower in the Kilchis River watershed, possibly a result of the dominant mainstem stream network (the Trask River watershed exhibits a greater proportion of tributary to mainstem habitat than the Kilchis River watershed). Banks are less stable along the Trask River, likely a result of the higher proportion of erodible lithology present within the watershed. Wood volumes are higher in the Trask River watershed although both watersheds are low in wood volume in 2nd+ order streams.

Table 4.1i - Wilson VS. Trask Hypothesis Test Results

Metric	Wilson VS. Trask	T Score	P Value	Significant
Log Relative Bed Stability	>	1.74	0.08	NO
LRBS No Bedrock	>	3.7	0	YES
RP100_CM	<	-0.24	0.81	NO
Wood Radius	>	0.16	0.87	NO
Width to Depth Ratio	>	1.99	0.05	YES
ArcSin Proportion Sands and Fines	<	-2.45	0.02	YES
ArcSin Proportion Gravels	>	1.82	0.07	NO
ArcSin Proportion Cobbles	>	3.53	0	YES
ArcSin Proportion Small Boulders	>	2.87	0.01	YES
ArcSin Proportion Large Boulders	>	1.8	0.07	NO
ArcSin Proportion Bedrock	<	-2.47	0.02	YES
Bank Stability	>	0.36	0.72	NO
Slope	<	-0.34	0.73	NO
Bankfull Hydraulic Radius	<	-0.97	0.34	NO
Mean Substrate Diameter at Critical Bankfull	<	-2.16	0.03	YES
Mean Substrate Size	<	-1.46	0.15	NO
Mean Substrate Size No Bedrock	>	2.16	0.03	YES
Station Length	<	-1.03	0.3	NO

The Trask River watershed is less stable than the Wilson River watershed when bedrock is removed from the calculation. The Trask River watershed has a greater proportion of sands and fines and is strongly trending towards a higher percentage of gravels than the Wilson River watershed. The proportion of bedrock is also greater in the Trask River watershed suggesting that the smaller sediments which dominate the bed of the Trask River are more easily flushed out to expose bedrock. The Wilson River population has a greater width to depth ratio, suggesting potentially elevated solar inputs in comparison to the Trask River. The Wilson River mainstem also is characterized as having an east-west orientation which may exacerbate temperature issues.

Table 4.1j - Trask VS. Tillamook Hypothesis Test Results				
Metric	Trask VS. Tillamook	T Score	P Value	Significant
Log Relative Bed Stability	>	1.61	0.11	NO
LRBS No Bedrock	<	-0.04	0.96	NO
RP100_CM	<	-2.48	0.02	YES
Wood Radius	>	0.31	0.76	NO
Width to Depth Ratio	>	1.88	0.06	NO
ArcSin Proportion Sands and Fines	<	-4.26	0	YES
ArcSin Proportion Gravels	>	1.51	0.14	NO
ArcSin Proportion Cobbles	>	3.71	0	YES
ArcSin Proportion Small Boulders	>	3.78	0	YES
ArcSin Proportion Large Boulders	>	3.52	0	YES
ArcSin Proportion Bedrock	>	5.38	0	YES
Bank Stability	>	2.65	0.01	YES
Slope	>	3.16	0	YES
Bankfull Hydraulic Radius	>	1.39	0.17	NO
Mean Substrate Diameter at Critical Bankfull	>	2.54	0.01	YES
Mean Substrate Size	>	3.21	0	YES
Mean Substrate Size No Bedrock	>	4.69	0	YES
Station Length	>	2.58	0.01	YES

The Trask River strongly trends towards greater stability than the Tillamook River when bedrock is included; when factored out this difference is lessened significantly. The Tillamook River has a greater proportion of sands and fines and a lower proportion of gravels (mildly trending). Banks are less stable in the Trask River and slopes are steeper.

Section 4.1k - Wilson River VS. Tillamook River

Table 4.1k - Wilson VS. Tillamook Hypothesis Test Results				
Metric	Wilson VS. Tillamook	T Score	P Value	Significant
Log Relative Bed Stability	>	2.89	0.01	YES
LRBS No Bedrock	>	2.67	0.01	YES
RP100_CM	<	-2.58	0.01	YES
Wood Radius	>	0.48	0.63	NO
Width to Depth Ratio	>	4.09	0	YES
ArcSin Proportion Sands and Fines	<	-5.63	0	YES
ArcSin Proportion Gravels	>	2.45	0.02	YES
ArcSin Proportion Cobbles	>	5.68	0	YES
ArcSin Proportion Small Boulders	>	6.41	0	YES
ArcSin Proportion Large Boulders	>	5.11	0	YES
ArcSin Proportion Bedrock	>	3.03	0	YES
Bank Stability	>	2.77	0.01	YES
Slope	>	3.57	0	YES
Bankfull Hydraulic Radius	>	0.42	0.67	NO
Mean Substrate Diameter at Critical Bankfull	>	3.74	0	YES
Mean Substrate Size	>	5.78	0	YES
Mean Substrate Size No Bedrock	>	5.78	0	YES
Station Length	>	1.8	0.08	NO

The Wilson River differs from the Tillamook River in nearly all respects, with the exception of wood volume and channel size.

Section 4.1l- Wilson River VS. Kilchis River

Table 4.11 - Wilson VS. Kilchis Hypothesis Test Results				
Metric	Wilson VS. Kilchis	T Score	P Value	Significant
Log Relative Bed Stability	<	-0.78	0.44	NO
LRBS No Bedrock	<	-0.12	0.91	NO
RP100_CM	<	-1.05	0.3	NO
Wood Radius	>	3.43	0	YES
Width to Depth Ratio	<	-1.08	0.29	NO
ArcSin Proportion Sands and Fines	<	-0.19	0.85	NO
ArcSin Proportion Gravels	<	-0.09	0.93	NO
ArcSin Proportion Cobbles	>	1.61	0.12	NO
ArcSin Proportion Small Boulders	>	0.78	0.44	NO
ArcSin Proportion Large Boulders	<	-0.96	0.34	NO
ArcSin Proportion Bedrock	<	-0.92	0.37	NO
Bank Stability	>	3.16	0	YES
Slope	>	3.39	0	YES
Bankfull Hydraulic Radius	<	-0.72	0.48	NO
Mean Substrate Diameter at Critical Bankfull	>	2.52	0.02	YES
Mean Substrate Size	>	0.49	0.63	NO
Mean Substrate Size No Bedrock	>	1.05	0.3	NO
Station Length	<	-1.21	0.23	NO

The Wilson River is similar to the Kilchis River in most respects. Wood volume is higher however in the Wilson River, slopes are greater, and banks are less stable.

Table 4.1m - Wilson VS. Miami Hypothesis Test Results				
Metric	Wilson VS. Miami	T Score	P Value	Significant
Log Relative Bed Stability	>	0.63	0.53	NO
LRBS No Bedrock	>	0.7	0.49	NO
RP100_CM	<	-1.29	0.2	NO
Wood Radius	>	3.42	0	YES
Width to Depth Ratio	<	-1.1	0.29	NO
ArcSin Proportion Sands and Fines	<	-2.36	0.03	YES
ArcSin Proportion Gravels	<	-1.94	0.06	NO
ArcSin Proportion Cobbles	>	2.65	0.02	YES
ArcSin Proportion Small Boulders	>	1.98	0.06	NO
ArcSin Proportion Large Boulders	>	1.78	0.08	NO
ArcSin Proportion Bedrock	>	0.61	0.55	NO
Bank Stability	>	2.38	0.02	YES
Slope	>	3.33	0	YES
Bankfull Hydraulic Radius	<	-0.95	0.35	NO
Mean Substrate Diameter at Critical Bankfull	>	2.15	0.04	YES
Mean Substrate Size	>	3.26	0	YES
Mean Substrate Size No Bedrock	>	3.06	0	YES
Station Length	<	-1.14	0.27	NO

The Wilson River is similar to the Miami River in terms of bed stability, pool volume, and width to depth ratios. Wood volumes are lower in the Miami River, and sands, fines, and gravels are higher. This may be the result of higher slopes in the Wilson River and the erodible lithology of much of the Miami River.

Section 4.1n - Kilchis River VS. Miami River

Table 4.1n - Kilchis VS. Miami Hypothesis Test Results				
Metric	Kilchis VS. Miami	T Score	P Value	Significant
Log Relative Bed Stability	>	1.19	0.24	NO
LRBS No Bedrock	>	0.56	0.58	NO
RP100_CM	<	-0.08	0.93	NO
Wood Radius	<	-0.06	0.96	NO
Width to Depth Ratio	<	-0.6	0.55	NO
ArcSin Proportion Sands and Fines	<	-1.55	0.13	NO
ArcSin Proportion Gravels	<	-1.64	0.11	NO
ArcSin Proportion Cobbles	>	1.41	0.17	NO
ArcSin Proportion Small Boulders	>	1.42	0.17	NO
ArcSin Proportion Large Boulders	>	2.42	0.02	YES
ArcSin Proportion Bedrock	>	1.29	0.21	NO
Bank Stability	<	-0.51	0.61	NO
Slope	>	0.12	0.9	NO
Bankfull Hydraulic Radius	<	-0.34	0.74	NO
Mean Substrate Diameter at Critical Bankfull	>	0.05	0.96	NO
Mean Substrate Size	>	2.62	0.01	YES
Mean Substrate Size No Bedrock	>	2.26	0.03	YES
Station Length	<	-0.33	0.74	NO

The Kilchis River is similar to the Miami River in most respects, although sands and fines trend towards being higher in the Miami River and there is a higher proportion of boulders in the Kilchis River.

Table 4.1o - Kilchis VS.Tillamook Hypothesis Test Results				
Metric	Kilchis VS. Tillamook	T Score	P Value	Significant
Log Relative Bed Stability	>	3.05	0	YES
LRBS No Bedrock	>	2.14	0.04	YES
RP100_CM	<	-1.19	0.24	NO
Wood Radius	<	-2.19	0.03	YES
Width to Depth Ratio	>	3.98	0	YES
ArcSin Proportion Sands and Fines	<	-5.12	0	YES
ArcSin Proportion Gravels	>	2.39	0.02	YES
ArcSin Proportion Cobbles	>	4.4	0	YES
ArcSin Proportion Small Boulders	>	5.36	0	YES
ArcSin Proportion Large Boulders	>	5.15	0	YES
ArcSin Proportion Bedrock	>	3.35	0	YES
Bank Stability	<	-0.02	0.98	NO
Slope	>	0.78	0.44	NO
Bankfull Hydraulic Radius	>	1.08	0.29	NO
Mean Substrate Diameter at Critical Bankfull	>	2.33	0.02	YES
Mean Substrate Size	>	4.96	0	YES
Mean Substrate Size No Bedrock	>	5.37	0	YES
Station Length	>	2.52	0.02	YES

The Tillamook River differs from the Kilchis River in most metrics. Pool volume, slope, size, and bank stability are similar.

Section 4.1p - Miami River VS. Tillamook River

Table 4.1p - Miami VS.Tillamook Hypothesis Test Results				
Metric	Miami VS. Tillamook	T Score	P Value	Significant
Log Relative Bed Stability	>	2.2	0.03	YES
LRBS No Bedrock	>	1.99	0.05	NO
RP100_CM	<	-1.22	0.23	NO
Wood Radius	<	-2.17	0.04	YES
Width to Depth Ratio	>	2.45	0.02	YES
ArcSin Proportion Sands and Fines	<	-4.41	0	YES
ArcSin Proportion Gravels	>	3.31	0	YES
ArcSin Proportion Cobbles	>	2.69	0.01	YES
ArcSin Proportion Small Boulders	>	2.61	0.01	YES
ArcSin Proportion Large Boulders	>	1.99	0.06	NO
ArcSin Proportion Bedrock	>	1.62	0.12	NO
Bank Stability	>	0.42	0.68	NO
Slope	>	0.64	0.53	NO
Bankfull Hydraulic Radius	>	1.24	0.23	NO
Mean Substrate Diameter at Critical Bankfull	>	1.6	0.12	NO
Mean Substrate Size	>	2.8	0.01	YES
Mean Substrate Size No Bedrock	>	2.66	0.01	YES
Station Length	>	1.95	0.07	NO

The Tillamook River differs from the Miami River in many respects. Pool volume, slope, bank stability, and hydraulic radius are similar however.

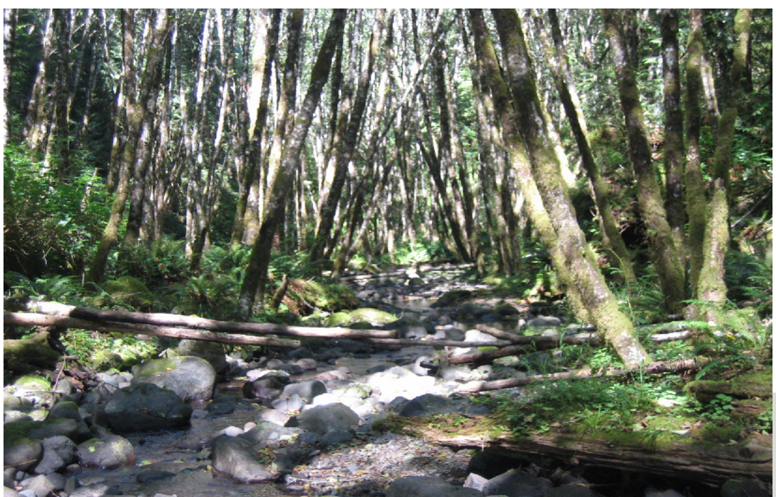
Section 4.1q - Non-forestry VS. Forestry

Bed stability is not significantly different between forestry and non-forestry sites. Wood volume is greater in forestry sites (refer to discussion). %SAFN is lower in forestry than in non-forestry sites and substrate size is significantly larger in forestry sites (even after removing bedrock). This finding may be the result of the correlation between erodibility and land use in the TBW.

Table 4.1q1 - Non-Forestry Population Results						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.5568	16	0.5192	0.1501	-0.8509	-0.2627
LRBS No Bedrock	-0.5823	16	0.4827	0.1396	-0.8559	-0.3088
Residual Pool Depth cm	14.4156	16	9.3094	2.2829	9.9412	18.8900
Wood Radius	0.0100	16	0.0197	0.0054	-0.0006	0.0207
Width to Depth Ratio	11.0436	16	4.4540	0.9252	9.2302	12.8569
Percent Sands and Fines	0.5278	16	0.3478	0.0981	0.3354	0.7201
Percent Gravels	0.3521	16	0.2618	0.0712	0.2125	0.4917
Percent Cobbles	0.0900	16	0.0963	0.0271	0.0369	0.1432
Percent Small Boulders	0.0105	16	0.0384	0.0057	-0.0006	0.0216
Percent Large Boulders	0.0064	16	0.0130	0.0026	0.0012	0.0116
Percent Bedrock	0.0132	16	0.0293	0.0082	-0.0029	0.0294
Bank Condition	2.0090	16	0.5896	0.1233	1.7674	2.2506
Slope	0.0072	16	0.0063	0.0015	0.0042	0.0102
Station Length	222.3544	16	161.9926	28.9299	165.6528	279.0559

Table 4.1q2 - Forestry Population Results						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.3439	124	0.5325	0.0476	-0.4373	-0.2506
LRBS No Bedrock	-0.5279	124	0.5484	0.0492	-0.6244	-0.4314
Residual Pool Depth cm	9.3296	124	8.2411	0.6450	8.0653	10.5939
Wood Radius	0.0815	124	0.1068	0.0115	0.0589	0.1040
Width to Depth Ratio	13.2642	124	6.2655	0.4680	12.3468	14.1815
Percent Sands and Fines	0.1371	124	0.1757	0.0108	0.1159	0.1583
Percent Gravels	0.4148	124	0.1446	0.0141	0.3871	0.4425
Percent Cobbles	0.2155	124	0.0970	0.0091	0.1976	0.2334
Percent Small Boulders	0.1214	124	0.0849	0.0086	0.1045	0.1384
Percent Large Boulders	0.0278	124	0.0376	0.0037	0.0205	0.0351
Percent Bedrock	0.0834	124	0.1161	0.0110	0.0619	0.1049
Bank Condition	2.0060	124	0.8011	0.0767	1.8556	2.1563
Slope	0.0604	124	0.0699	0.0072	0.0463	0.0744
Station Length	217.3131	124	119.3344	9.7087	198.2844	236.3418

Table 4.1q3 - Forestry VS. Non-forestry Hypothesis Test Results				
Metric	Forestry VS. Non-Forestry	T Score	P Value	Significant
Log Relative Bed Stability	>	1.54	0.14	NO
LRBS No Bedrock	>	0.42	0.68	NO
RP100_CM	<	-2.08	0.05	NO
Wood Radius	>	6.62	0	YES
Width to Depth Ratio	>	1.78	0.09	NO
ArcSin Proportion Sands and Fines	<	-4.42	0	YES
ArcSin Proportion Gravels	>	1.45	0.17	NO
ArcSin Proportion Cobbles	>	4.35	0	YES
ArcSin Proportion Small Boulders	>	9.87	0	YES
ArcSin Proportion Large Boulders	>	3.68	0	YES
ArcSin Proportion Bedrock	>	5.69	0	YES
Bank Stability	<	-0.02	0.99	NO
Slope	>	8.21	0	YES
Bankfull Hydraulic Radius	>	0.01	0.99	NO
Mean Substrate Diameter at Critical Bankfull	>	2.8	0.01	YES
Mean Substrate Size	>	4.87	0	YES
Mean Substrate Size No Bedrock	>	8.98	0	YES
Station Length	<	-0.12	0.91	NO



The results indicate that the forestry population within this study has a larger volume of wood, a lower proportion of sands & fines, a greater proportion of substrate with a diameter greater than sand, higher slopes, greater stream power, and more pool volume.

Section 4.1r - Resistant VS. Erodible Lithologies

Please refer to section five for a discussion of the results presented in the sections below.

Table 4.1r1 - Resistant Population Results						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.2822	89	0.4692	0.0525	-0.3851	-0.1792
LRBS No Bedrock	-0.4830	89	0.5145	0.0549	-0.5906	-0.3754
Residual Pool Depth cm	8.8899	89	8.2432	0.7402	7.4391	10.3407
Wood Radius	0.0661	89	0.0850	0.0117	0.0430	0.0891
Width to Depth Ratio	13.2622	89	5.4569	0.5056	12.2712	14.2531
Percent Sands and Fines	0.0906	89	0.0818	0.0085	0.0740	0.1073
Percent Gravels	0.4183	89	0.1438	0.0170	0.3849	0.4517
Percent Cobbles	0.2387	89	0.0855	0.0103	0.2185	0.2590
Percent Small Boulders	0.1310	89	0.0828	0.0107	0.1101	0.1518
Percent Large Boulders	0.0276	89	0.0363	0.0039	0.0200	0.0353
Percent Bedrock	0.0938	89	0.1265	0.0143	0.0658	0.1217
Bank Condition	1.9967	89	0.8144	0.0912	1.8179	2.1755
Slope	0.0655	89	0.0763	0.0095	0.0469	0.0840

Table 4.1r2 - Erodible Population Results						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.5320	51	0.6091	0.0810	-0.6907	-0.3733
LRBS No Bedrock	-0.6309	51	0.5765	0.0813	-0.7903	-0.4715
Residual Pool Depth cm	11.8689	51	8.7202	1.1722	9.5715	14.1664
Wood Radius	0.0864	51	0.1297	0.0208	0.0456	0.1273
Width to Depth Ratio	12.5211	51	7.1901	0.7015	11.1462	13.8960
Percent Sands and Fines	0.3560	51	0.3257	0.0414	0.2750	0.4371
Percent Gravels	0.3872	51	0.1948	0.0271	0.3340	0.4404
Percent Cobbles	0.1294	51	0.1008	0.0127	0.1046	0.1542
Percent Small Boulders	0.0661	51	0.0828	0.0098	0.0470	0.0852
Percent Large Boulders	0.0210	51	0.0359	0.0064	0.0084	0.0336
Percent Bedrock	0.0403	51	0.0637	0.0081	0.0245	0.0561
Bank Condition	2.0244	51	0.7085	0.0974	1.8334	2.2154
Slope	0.0328	51	0.0407	0.0065	0.0201	0.0455
Station Length	212.3049	51	123.6163	14.1159	184.6382	239.9715

Table 4.1r3 - Erodible VS. Resistant Hypothesis Test Results				
Metric	Erodible VS. Resistant	T Score	P Value	Significant
Log Relative Bed Stability	<	-2.53	0.01	YES
LRBS No Bedrock	<	-1.52	0.13	NO
RP100_CM	>	1.98	0.05	NO
Wood Radius	>	1	0.32	NO
Width to Depth Ratio	<	-0.64	0.53	NO
ArcSin Proportion Sands and Fines	>	5.73	0	YES
ArcSin Proportion Gravels	<	-1.65	0.1	NO
ArcSin Proportion Cobbles	<	-6.2	0	YES
ArcSin Proportion Small Boulders	<	-5.16	0	YES
ArcSin Proportion Large Boulders	<	-1.7	0.09	NO
ArcSin Proportion Bedrock	<	-3.92	0	YES
Bank Stability	>	0.21	0.83	NO
Slope	<	-3.3	0	YES
Bankfull Hydraulic Radius	<	-1.25	0.22	NO
Mean Substrate Diameter at Critical Bankfull	<	-2.4	0.02	YES
Mean Substrate Size	<	-3.31	0	YES
Mean Substrate Size No Bedrock	<	-5.02	0	YES
Station Length	<	-0.39	0.7	NO

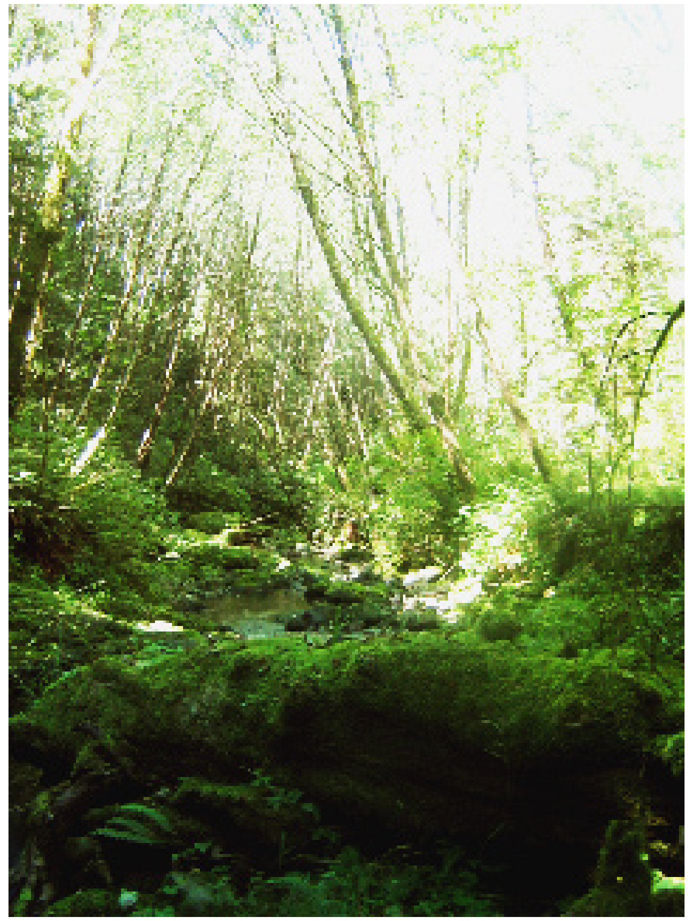


Table 4.1s1 - 1st Order Population Results						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.5460	60	0.5018	0.0554	-0.6546	-0.4374
LRBS No Bedrock	-0.6765	60	0.5656	0.0613	-0.7967	-0.5563
Residual Pool Depth cm	6.3264	60	4.8963	0.4289	5.4858	7.1670
Wood Radius	0.1009	60	0.1131	0.0139	0.0737	0.1281
Width to Depth Ratio	11.1024	60	3.7847	0.4529	10.2148	11.9900
Percent Sands and Fines	0.2040	60	0.2611	0.0215	0.1618	0.2461
Percent Gravels	0.4270	60	0.1730	0.0215	0.3849	0.4691
Percent Cobbles	0.1966	60	0.1095	0.0122	0.1728	0.2204
Percent Small Boulders	0.0933	60	0.0857	0.0116	0.0706	0.1161
Percent Large Boulders	0.0199	60	0.0315	0.0048	0.0104	0.0294
Percent Bedrock	0.0592	60	0.1133	0.0137	0.0324	0.0861
Bank Condition	2.0465	60	0.7526	0.0972	1.8560	2.2370
Slope	0.0709	60	0.0768	0.0080	0.0552	0.0866
Station Length	160.3758	60	29.8614	3.1927	154.1183	166.6333

Table 4.1s2 - 2nd Order Population Results						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	0.0007	80	0.3962	0.0373	-0.0725	0.0739
LRBS No Bedrock	-0.2377	80	0.3275	0.0339	-0.3042	-0.1712
Residual Pool Depth cm	17.4184	80	9.5564	0.9469	15.5625	19.2742
Wood Radius	0.0153	80	0.0347	0.0033	0.0087	0.0218
Width to Depth Ratio	16.9715	80	7.9076	0.7135	15.5730	18.3700
Percent Sands and Fines	0.1381	80	0.1763	0.0176	0.1037	0.1726
Percent Gravels	0.3669	80	0.1344	0.0145	0.3385	0.3954
Percent Cobbles	0.2097	80	0.0941	0.0091	0.1918	0.2275
Percent Small Boulders	0.1400	80	0.0855	0.0080	0.1243	0.1557
Percent Large Boulders	0.0367	80	0.0425	0.0051	0.0267	0.0467
Percent Bedrock	0.1085	80	0.1009	0.0095	0.0898	0.1272
Bank Condition	1.9225	80	0.8264	0.0836	1.7586	2.0864
Slope	0.0193	80	0.0117	0.0013	0.0169	0.0218
Station Length	337.8035	80	158.4756	16.8721	304.7348	370.8722

Table 4.1s3 - 1st Order VS. 2nd + Order Hypothesis Test Results				
Metric	1st VS. 2nd Order	T Score	P Value	Significant
Log Relative Bed Stability	<	-6.97	0	YES
LRBS No Bedrock	<	-5.37	0	YES
RP100_CM	<	-8.93	0	YES
Wood Radius	>	5.67	0	YES
Width to Depth Ratio	<	-5.81	0	YES
ArcSin Proportion Sands and Fines	>	1.55	0.12	NO
ArcSin Proportion Gravels	>	1.42	0.16	NO
ArcSin Proportion Cobbles	<	-1	0.32	NO
ArcSin Proportion Small Boulders	<	-3.14	0	YES
ArcSin Proportion Large Boulders	<	-3.15	0	YES
ArcSin Proportion Bedrock	<	-3.4	0	YES
Bank Stability	>	0.92	0.36	NO
Slope	>	5.15	0	YES
Bankfull Hydraulic Radius	<	-8.5	0	YES
Mean Substrate Diameter at Critical Bankfull	>	1.78	0.08	NO
Mean Substrate Size	<	-0.36	0.72	NO
Mean Substrate Size No Bedrock	<	-2.04	0.04	YES
Station Length	<	-9.78	0	YES

Table 4.1t2 - Oregon Department of Forestry Non-anchor Classification Population Results						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.4156	96	0.5327	0.0483	-0.5102	-0.3210
LRBS No Bedrock	-0.5577	96	0.5259	0.0505	-0.6567	-0.4587
Residual Pool Depth cm	9.7712	96	8.3378	0.7889	8.2250	11.3174
Wood Radius	0.0631	96	0.0808	0.0090	0.0455	0.0806
Width to Depth Ratio	12.5602	96	5.5608	0.4485	11.6812	13.4393
Percent Sands and Fines	0.2172	96	0.2751	0.0230	0.1721	0.2624
Percent Gravels	0.3914	96	0.1733	0.0189	0.3544	0.4285
Percent Cobbles	0.2007	96	0.1141	0.0112	0.1786	0.2227
Percent Small Boulders	0.1019	96	0.0905	0.0097	0.0828	0.1210
Percent Large Boulders	0.0226	96	0.0349	0.0035	0.0158	0.0295
Percent Bedrock	0.0661	96	0.1140	0.0125	0.0416	0.0907
Bank Condition	2.0380	96	0.7903	0.0836	1.8742	2.2019
Slope	0.0532	96	0.0640	0.0079	0.0377	0.0688
Station Length	202.3890	96	104.7182	9.0778	184.5969	220.1810

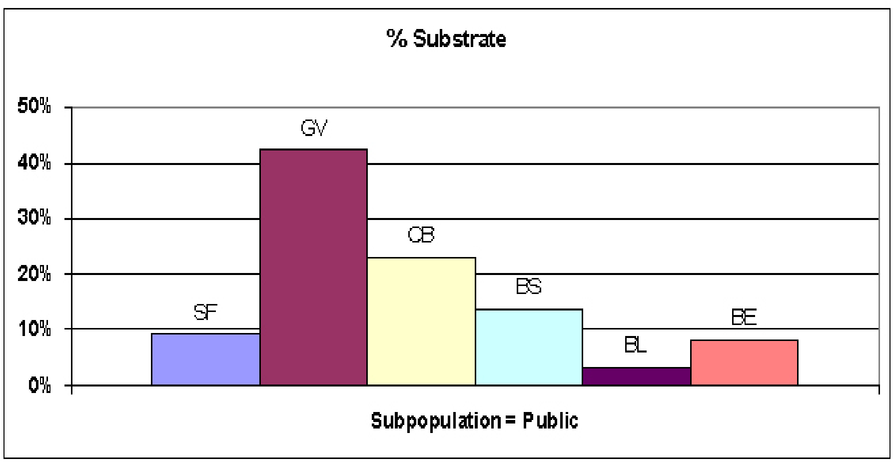
Table 4.1t1 - Oregon Department of Forestry Anchor Classification Population Results						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.26	44	0.53	0.1	-0.45	-0.07
LRBS No Bedrock	-0.48	44	0.57	0.11	-0.69	-0.27
Residual Pool Depth cm	10.27	44	8.95	1.1	8.12	12.42
Wood Radius	0.1	44	0.14	0.03	0.05	0.15
Width to Depth Ratio	14.02	44	7.15	0.83	12.4	15.65
Percent Sands and Fines	0.1	44	0.07	0.01	0.08	0.12
Percent Gravels	0.44	44	0.13	0.02	0.4	0.49
Percent Cobbles	0.2	44	0.08	0.01	0.18	0.23
Percent Small Boulders	0.12	44	0.08	0.01	0.1	0.15
Percent Large Boulders	0.03	44	0.04	0.01	0.02	0.05
Percent Bedrock	0.1	44	0.1	0.02	0.07	0.13
Bank Condition	1.93	44	0.75	0.12	1.69	2.18
Slope	0.06	44	0.08	0.01	0.03	0.08
Station Length	253.43	44	156.66	21.92	210.46	296.41

Table 4.1t3 - Anchor VS. Non Anchor Hypothesis Test Results				
Metric	Anchor VS. Non-anchor	T Score	P Value	Significant
Log Relative Bed Stability	>	1.6	0.11	NO
LRBS No Bedrock	>	0.76	0.45	NO
RP100_CM	>	0.31	0.76	NO
Wood Radius	>	1.47	0.15	NO
Width to Depth Ratio	>	1.2	0.23	NO
ArcSin Proportion Sands and Fines	<	-3.32	0	YES
ArcSin Proportion Gravels	>	2.39	0.02	YES
ArcSin Proportion Cobbles	>	0.84	0.4	NO
ArcSin Proportion Small Boulders	>	1.62	0.11	NO
ArcSin Proportion Large Boulders	>	1.19	0.24	NO
ArcSin Proportion Bedrock	>	1.94	0.06	NO
Bank Stability	<	-0.75	0.45	NO
Slope	>	0.23	0.82	NO
Bankfull Hydraulic Radius	>	1.08	0.28	NO
Mean Substrate Diameter at Critical Bankfull	>	1.14	0.26	NO
Mean Substrate Size	<	-0.57	0.57	NO
Mean Substrate Size No Bedrock	>	0.23	0.82	NO
Station Length	>	1.97	0.05	NO

Table 4.1u1 - Public Ownership Population Results						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.28	103	0.5	0.06	-0.38	-0.17
LRBS No Bedrock	-0.46	103	0.49	0.05	-0.56	-0.35
Residual Pool Depth cm	9.56	103	8.38	0.74	8.12	11.01
Wood Radius	0.08	103	0.11	0.01	0.05	0.1
Width to Depth Ratio	13.83	103	6.48	0.56	12.75	14.92
Percent Sands and Fines	0.09	103	0.07	0.01	0.08	0.11
Percent Gravels	0.42	103	0.13	0.01	0.4	0.45
Percent Cobbles	0.23	103	0.09	0.01	0.21	0.25
Percent Small Boulders	0.14	103	0.08	0.01	0.12	0.16
Percent Large Boulders	0.03	103	0.04	0	0.02	0.04
Percent Bedrock	0.08	103	0.09	0.01	0.07	0.1
Bank Condition	2.07	103	0.8	0.09	1.91	2.24
Slope	0.06	103	0.06	0.01	0.04	0.07
Station Length	228.55	103	126.06	11.88	205.27	251.84

Table 4.1u2 - Private Ownership Population Results						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.6359	37	0.5419	0.0743	-0.7814	-0.4903
LRBS No Bedrock	-0.7590	37	0.6092	0.1037	-0.9622	-0.5558
Residual Pool Depth cm	10.9505	37	8.8788	1.3147	8.3736	13.5273
Wood Radius	0.0593	37	0.0907	0.0213	0.0174	0.1011
Width to Depth Ratio	10.6298	37	4.1413	0.5076	9.6349	11.6247
Percent Sands and Fines	0.4369	37	0.3426	0.0525	0.3340	0.5399
Percent Gravels	0.3603	37	0.2330	0.0416	0.2788	0.4418
Percent Cobbles	0.1160	37	0.1065	0.0186	0.0796	0.1524
Percent Small Boulders	0.0255	37	0.0523	0.0062	0.0133	0.0377
Percent Large Boulders	0.0041	37	0.0122	0.0016	0.0010	0.0072
Percent Bedrock	0.0572	37	0.1625	0.0331	-0.0076	0.1220
Bank Condition	1.8112	37	0.6834	0.1182	1.5795	2.0428
Slope	0.0402	37	0.0795	0.0142	0.0123	0.0680
Station Length	187.3841	37	116.9263	13.8684	160.2026	214.5656

Table 4.1u3 - Public VS. Private Hypothesis Test Results				
Metric	Public VS. Private	T Score	P Value	Significant
Log Relative Bed Stability	>	3.54	0	YES
LRBS No Bedrock	>	2.72	0.01	YES
RP100_CM	<	-0.83	0.41	NO
Wood Radius	>	1.02	0.31	NO
Width to Depth Ratio	>	3.43	0	YES
ArcSin Proportion Sands and Fines	<	-5.74	0	YES
ArcSin Proportion Gravels	>	2.18	0.03	YES
ArcSin Proportion Cobbles	>	5.69	0	YES
ArcSin Proportion Small Boulders	>	10.29	0	YES
ArcSin Proportion Large Boulders	>	7.3	0	YES
ArcSin Proportion Bedrock	>	2.85	0.01	YES
Bank Stability	>	1.92	0.06	NO
Slope	>	1.31	0.2	NO
Bankfull Hydraulic Radius	>	2.86	0.01	YES
Mean Substrate Diameter at Critical Bankfull	>	0.57	0.57	NO
Mean Substrate Size	<	-0.3	0.77	NO
Mean Substrate Size No Bedrock	>	9.01	0	YES
Station Length	>	1.8	0.08	NO



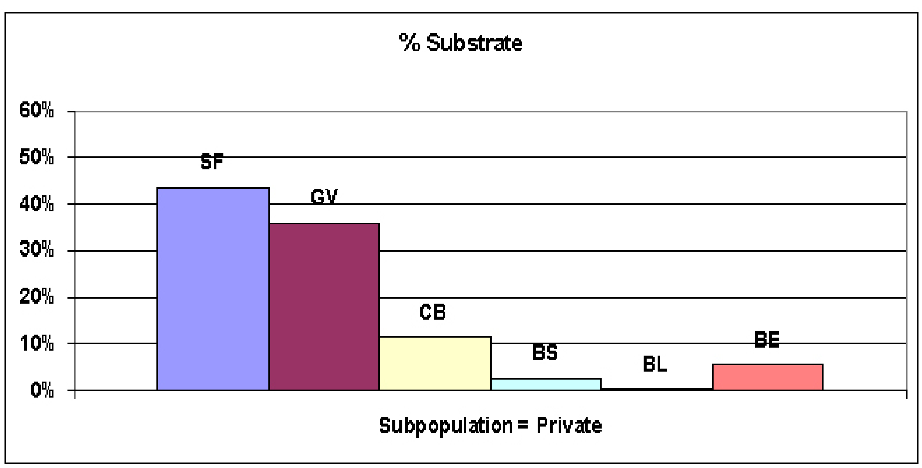


Table 4.2a - Trask Watershed Study Population Results						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.3793	31	0.6532	0.0892	-0.5542	-0.2044
LRBS No Bedrock	-0.6210	31	0.5707	0.0743	-0.7666	-0.4754
Residual Pool Depth cm	6.6322	31	3.7785	0.4394	5.7711	7.4933
Wood Radius	0.1102	31	0.1880	0.0282	0.0550	0.1654
Width to Depth Ratio	10.1447	31	3.2002	0.3611	9.4371	10.8524
Percent Sands and Fines	0.1649	31	0.1870	0.0269	0.1122	0.2177
Percent Gravels	0.3817	31	0.1647	0.0193	0.3439	0.4195
Percent Cobbles	0.2085	31	0.1267	0.0185	0.1723	0.2446
Percent Small Boulders	0.1262	31	0.1042	0.0131	0.1004	0.1519
Percent Large Boulders	0.0094	31	0.0127	0.0017	0.0061	0.0128
Percent Bedrock	0.1093	31	0.1515	0.0200	0.0701	0.1485
Bank Condition	1.6353	31	0.6226	0.0965	1.4461	1.8245
Slope	0.0634	31	0.0750	0.0110	0.0418	0.0849
Station Length	187.3217	31	69.6454	6.3537	174.8688	199.7747

Table 4.2b - Trask Watershed Study Resistant Population Results						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.2779	21	0.7051	0.1176	-0.5083	-0.0475
LRBS No Bedrock	-0.5652	21	0.5800	0.0903	-0.7422	-0.3882
Residual Pool Depth cm	7.2399	21	4.2837	0.6927	5.8823	8.5975
Wood Radius	0.1311	21	0.2151	0.0374	0.0578	0.2044
Width to Depth Ratio	10.5137	21	3.4933	0.5161	9.5021	11.5252
Percent Sands and Fines	0.1515	21	0.2021	0.0330	0.0868	0.2161
Percent Gravels	0.3226	21	0.1476	0.0263	0.2710	0.3743
Percent Cobbles	0.2223	21	0.1277	0.0221	0.1789	0.2657
Percent Small Boulders	0.1503	21	0.1091	0.0180	0.1150	0.1856
Percent Large Boulders	0.0110	21	0.0140	0.0024	0.0062	0.0157
Percent Bedrock	0.1423	21	0.1691	0.0302	0.0832	0.2015
Bank Condition	1.5195	21	0.4384	0.0936	1.3360	1.7030
Slope	0.0697	21	0.0876	0.0158	0.0387	0.1006
Station Length	202.8571	21	78.2026	7.5486	188.0622	217.6521

Table 4.2c -Trask Watershed Study Erodible Population Results						
Metric	Mean	N	SD	SE	Lower 95%	Upper 95%
Log Relative Bed Stability	-0.6166	10	0.4258	0.1124	-0.8369	-0.3963
LRBS No Bedrock	-0.7514	10	0.5257	0.1330	-1.0121	-0.4907
Residual Pool Depth cm	5.2114	10	1.3680	0.3833	4.4601	5.9627
Wood Radius	0.0613	10	0.0796	0.0235	0.0152	0.1074
Width to Depth Ratio	9.2822	10	2.1429	0.3419	8.6120	9.9523
Percent Sands and Fines	0.1965	10	0.1405	0.0411	0.1159	0.2771
Percent Gravels	0.5197	10	0.1115	0.0186	0.4833	0.5562
Percent Cobbles	0.1761	10	0.1181	0.0345	0.1086	0.2437
Percent Small Boulders	0.0697	10	0.0625	0.0185	0.0335	0.1059
Percent Large Boulders	0.0059	10	0.0078	0.0023	0.0014	0.0103
Percent Bedrock	0.0321	10	0.0355	0.0105	0.0115	0.0527
Bank Condition	1.9060	10	0.8602	0.2356	1.4443	2.3677
Slope	0.0486	10	0.0229	0.0066	0.0357	0.0615
Station Length	151.0000	10	3.0000	0.8307	149.3719	152.6281

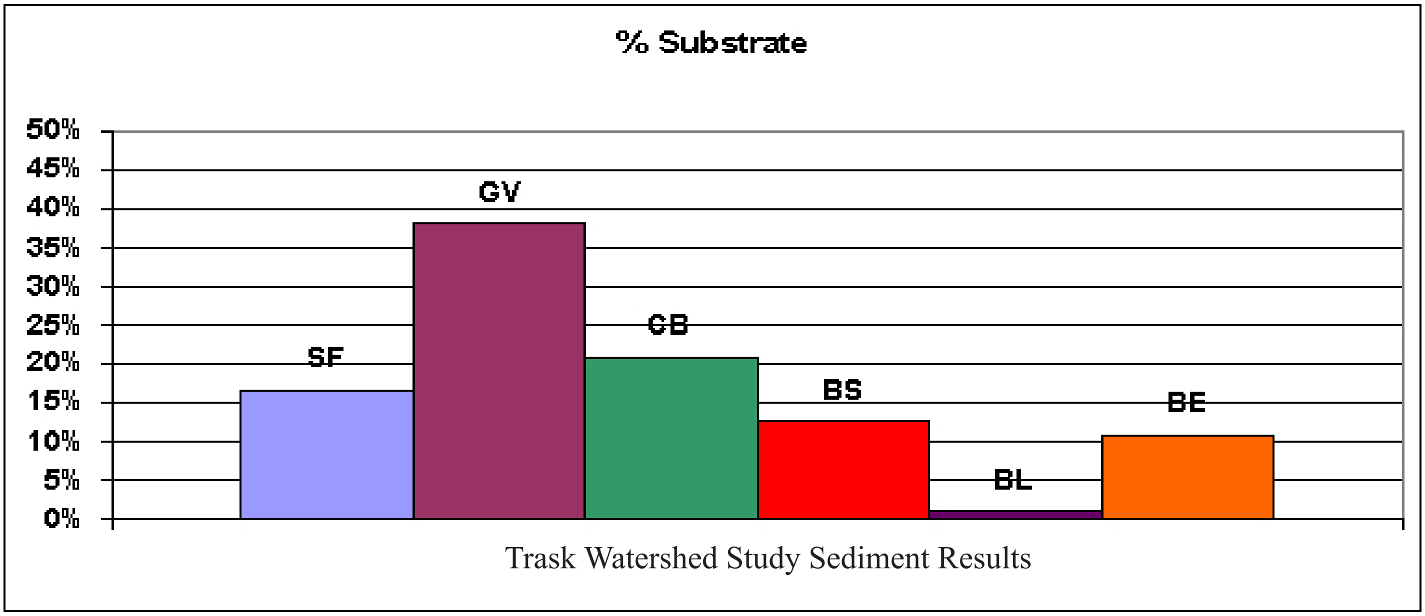


Table 4.2d - TWS Resistant VS. TWS Erodible Hypothesis Test Results				
Metric	Resistant VS. Erodible	T Score	P Value	Significant
Log Relative Bed Stability	>	1.66	0.11	NO
LRBS No Bedrock	>	0.89	0.38	NO
RP100_CM	>	1.97	0.06	NO
Wood Radius	>	1.31	0.2	NO
Width to Depth Ratio	>	1.21	0.24	NO
ArcSin Proportion Sands and Fines	<	-1.07	0.29	NO
ArcSin Proportion Gravels	<	-4.14	0	YES
ArcSin Proportion Cobbles	>	1.11	0.29	NO
ArcSin Proportion Small Boulders	>	2.33	0.03	YES
ArcSin Proportion Large Boulders	>	0.88	0.39	NO
ArcSin Proportion Bedrock	>	2.95	0.01	YES
Bank Stability	<	-1.34	0.21	NO
Slope	>	1.03	0.31	NO
Bankfull Hydraulic Radius	>	1.94	0.07	NO
Mean Substrate Diameter at Critical Bankfull	>	1.24	0.23	NO
Mean Substrate Size	>	2.55	0.02	YES
Mean Substrate Size No Bedrock	>	3.01	0.01	YES
Station Length	>	3.03	0.01	YES

Table 4.2e - TBW VS. TWS Hypothesis Test Results

Metric	TBW VS. TWS	T Score	P Value	Significant
Log Relative Bed Stability	>	0.08	0.93	NO
LRBS No Bedrock	>	0.77	0.45	NO
RP100_CM	>	3.42	0	YES
Wood Radius	<	-1.04	0.31	NO
Width to Depth Ratio	>	3.77	0	YES
ArcSin Proportion Sands and Fines	>	0.66	0.51	NO
ArcSin Proportion Gravels	>	0.5	0.62	NO
ArcSin Proportion Cobbles	<	-0.34	0.73	NO
ArcSin Proportion Small Boulders	<	-0.85	0.4	NO
ArcSin Proportion Large Boulders	>	2.75	0.01	YES
ArcSin Proportion Bedrock	<	-1.32	0.19	NO
Bank Stability	>	2.86	0.01	YES
Slope	<	-0.62	0.54	NO
Bankfull Hydraulic Radius	>	2.82	0.01	YES
Mean Substrate Diameter at Critical Bankfull	>	0.43	0.67	NO
Mean Substrate Size	<	-1.04	0.31	NO
Mean Substrate Size No Bedrock	<	-0.41	0.68	NO
Station Length	>	1.9	0.06	NO

Table 4.2f - Trask River VS. TWS-Only Hypothesis Test Results

Metric	Trask VS. TWS	T Score	P Value	Significant
Log Relative Bed Stability	<	-0.34	0.74	NO
LRBS No Bedrock	<	-0.68	0.5	NO
RP100_CM	>	1.79	0.08	NO
Wood Radius	<	-0.73	0.47	NO
Width to Depth Ratio	>	1.79	0.08	NO
ArcSin Proportion Sands and Fines	>	0.35	0.72	NO
ArcSin Proportion Gravels	<	-0.03	0.97	NO
ArcSin Proportion Cobbles	<	-0.58	0.57	NO
ArcSin Proportion Small Boulders	<	-1.11	0.27	NO
ArcSin Proportion Large Boulders	>	1.64	0.1	NO
ArcSin Proportion Bedrock	>	0.33	0.74	NO
Bank Stability	>	3.01	0	YES
Slope	>	0.27	0.79	NO
Bankfull Hydraulic Radius	>	2.77	0.01	YES
Mean Substrate Diameter at Critical Bankfull	>	1.56	0.12	NO
Mean Substrate Size	>	0	1	NO
Mean Substrate Size No Bedrock	<	-0.69	0.5	NO
Station Length	>	1.94	0.06	NO

Section 4.3 - Revisit Data

Fourteen spatially balanced sites were revisited between 2007 and 2008 in an attempt to generate a rough estimate of inter-annual variation. Data was analyzed by subtracting 2008 metric values from the 2007 values at each identical site. Estimates of mean change and deviation were calculated using standard statistical procedures (i.e. not neighborhood based variance). Two sites with inter-annual slope differences of greater than 5% were removed from the analysis under the assumption that surveys took place at different locations. Both of these sites were located on 1st order headwaters where a small difference in site location may result in a large change in slope. This resulted in a final N of 12 sites for the analysis. The primary finding of the analysis was a net decrease in LRBS, reflecting an increase in bed stability from 2007 to 2008 (Delta LRBS = -.17). This shift appears to be the result of small but cumulative changes in residual pool depth and an increase in mean particle size. The primary substrate changes were a decrease in %SAFN and an increase in %gravels. Because of the small sample size and short time elapsed between samples, it is not possible to draw definitive conclusions. A large storm event occurred in December of 2007. One hypothesis to explain the data is that this caused scouring of the bed. An alternate hypothesis is that the data reflects natural inter-annual variation. Further monitoring is expected to address this question.

An important secondary finding is that monitoring power can be increased by improving consistency in site location and station length. Although metal tags were placed at each X point during 2007, it was often impossible to locate them the next year due to growth of vegetation or treefall. GPS is limited in its usefulness given the logistical challenges of obtaining a reliable signal in the steep mountain valleys common in the study area. In the future, all sites should be monumented more visibly using rebar, flagging, and large tags.

Table 4.3a - 2007 to 2008 Revisit Results				
Metric	Mean Change	SE	Lower 95% CI	Upper 95% CI
Log Relative Bed Stability	-0.1745	0.0873	-0.3301	-0.0189
Residual Pool Depth cm	-2.9720	1.9774	-6.4957	0.5517
Wood Radius	0.0126	0.0088	-0.0032	0.0283
Width to Depth Ratio	4.7730	1.9690	1.2642	8.2818
Percent Sands and Fines	0.0461	0.0125	0.0238	0.0685
Percent Gravels	-0.1239	0.0305	-0.1783	-0.0694
Percent Cobbles	0.0449	0.0265	-0.0023	0.0922
Percent Small Boulders	0.0176	0.0158	-0.0106	0.0458
Percent Large Boulders	0.0075	0.0079	-0.0066	0.0217
Percent Bedrock	0.0077	0.0188	-0.0259	0.0413

Table 4.3b - SWIM Revisit Results				
Metric	Mean Change	SE	Lower 95% CI	Upper 95% CI
Geometic Mean Particle Size (mm)	3.1558	15.3141	-28.5290	34.8406
Percent Sands and Fines	-0.0130	0.0308	-0.0768	0.0508
Percent Boulders	-0.0229	0.0213	-0.0670	0.0212
Percent Bedrock	-0.0026	0.0178	-0.0394	0.0342

Linear regression was used to evaluate the relationship between site specific stream power (D_CBF) and mean particle size (D_GM). The data was first log transformed to normalize the variance. Linear regression was then used to determine the type and magnitude of the relationship. The results of this analysis indicate a strong positive relationship, with a p value less than .01, and R^2 equal to .5542. R^2 represents the proportion of the variance in the dependent variable (D_GM) explained by the variance of the independent variable (D_CBF). This indicates that stream power at the reach level is the dominant factor controlling particle size within the Tillamook Bay watershed. A scatterplot and least squares line is shown in Figure 4.1.

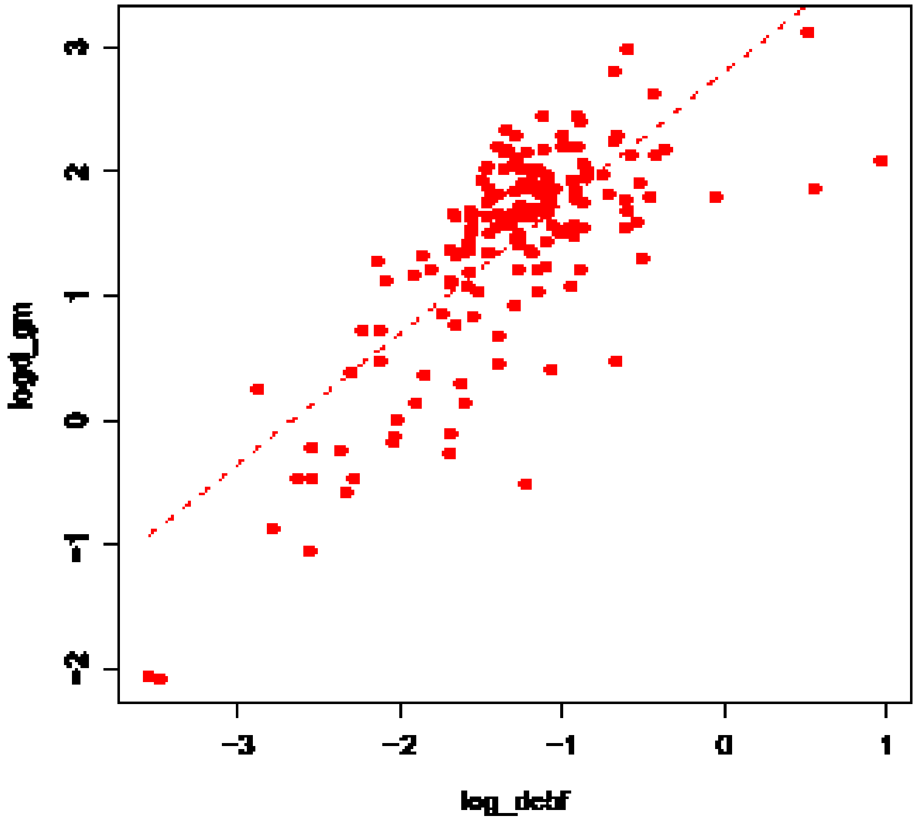


Figure 4.1 - Particle Size versus Stream Power Regression

Section 5 - Discussion

The Impact of Large Woody Debris on Habitat and Instream Sediments

Wood removal from the stream channel has occurred in nearly every major stream system in Oregon for navigation, to increase fish passage and dissolved oxygen which was reduced from slash-fill related to forestry activities, to salvage timber for milling, for firewood, and to protect homes built on stream banks. Wood removal for fish habitat improvement was generally restricted to the 1970s. Improvements to forestry equipment in the mid-twentieth century resulted in increased harvest. Stream channels were often filled with forestry debris (slash) which limited fish passage in many cases and decreased dissolved oxygen. Some streams were so filled with slash that the channel was effectively sub-surface. Additionally, riparian logging resulted in longterm decreased recruitment of LWD into the stream. These practices had largely decreased by the 1980s. Streambanks which were logged, quickly revegetated with disturbance dependent species such as red alder, salmonberry, and shrubs. Although these species play an important role in the riparian ecosystem, they do not provide long lasting roughness elements to the stream. This pattern was exacerbated in the TBW by the impacts of the Tillamook Burns and the extensive salvage logging which followed.

Fisheries scientists quickly realized the impact of log removal: increased transport capacity could lead to increased downstream flooding; downcutting of the stream channel could lead to floodplain disconnection; decreased gravel sorting and reduced sediment storage could impact spawning habitat; finally streams which experienced wood removal often experienced a reduction in pool habitat which reduced rearing potential. Wood removal often resulted in downcut, riffle-dominated systems with little or no salmon spawning or rearing habitat and high terraces. The practice of wood removal has reduced salmon productivity throughout Oregon for all lifestages. Unfortunately there are few places where this practice did not occur. Although wood removal is now limited at a federal, state, and private industrial timber level, it continues to occur legally on navigable rivers in Oregon for boat passage and on private property both for flood control and for firewood collection. Many fish bearing streams in Oregon are too remote to access, limiting wood removal to areas near human settlements and in mainstem rivers. The reference site values reflect signs of past or present disturbances. Wood volume appears to be particularly impacted.

Wood removal has altered the sediment and water transport capacity of the streams and therefore the other habitat metrics collected as part of the EMAP protocol are also altered from historical conditions. The sensitivity of a process based on minimally disturbed conditions is weakened when many streams are disturbed by wood removal, upstream logging, or even human started fires originating outside the watershed. Although LRBS indicates how stable the bed is, it cannot indicate how far the stream bed is from “natural” without a point of comparison. Finally, wood influences the sediment storage capacity and spatial distribution of a stream network. Although the overall quantity of fine sediments entering the system may stay the same, the spatial distribution of the sediments throughout the stream network may become more concentrated. For example, an increase in wood volume might lead to an increase in pools (which would trap more sands) and better sorting (which would reduce the sands found in riffle habitat). Under this scenario, although the amount of fine sediment coming into a stream would not change, the location of these sands would. This issue could be potentially mitigated by locating sites at a broad geographic scale where wood removal has never occurred (following the current criteria of minimally disturbed watershed selection).

1st VS. 2nd+ Order

No two sub-populations are more different than 1st order versus 2nd+ order streams, which differ in all the key sediment metrics and habitat metrics (LRBS, LRBS no bedrock, RP100, W:D, RW, %SAFN, %Gravels, %Boulder, %Bedrock, Slope, and Bankfull Diameter). All but %SAFN & %Gravels are significantly different (although the effect remains in these metrics and they trend towards significance). The overall pattern described is that 1st order sites are smaller, steeper, narrower, and less stable with smaller substrate and more wood. 2nd+ order streams in contrast have more pool volume, more boulders and more bedrock. Smaller streams have the potential to supply the substrate needed for spawning and LWD resources to larger mainstem channels. Inspection of the maps indicates that this pattern of bed stability is exaggerated when looking at 1st order sites near the terminus of the NHD 1:100,000 stream network. They are generally the least stable sites in the TBW (except in the TWS), driven primarily by slope. The results of this study show a ten fold decrease in the effective wood volume from small (1st order) to larger (2nd+ order) streams in the TBW. It is hypothesized that this may reflect a natural process of ecosystem repair and that over time this pulse of LWD will enter the larger stream channels. It is not clear what the magnitude of this effect will be. Much of the LWD present in the smaller streams is either hardwood (which has a short lifespan in water) or is too small to remain stable in a large stream system. As riparian vegetation has regrown, and natural processes such as landslides, debris flows, windthrow, and bank failure have continued to add wood into the system, smaller streams have been able to recover some of their pre-disturbance wood levels. Wood inputs to smaller streams in the coast range are often dominated by landslides and debris flows. Inputs to larger streams are dominated by transport from smaller streams, direct bank inputs, and windthrow. It is recommended that instream roughness elements (i.e. LWD & boulder structures) be added to the larger stream channels to help trap the wood now present in the smaller streams. Mainstem restoration has been highly limited to date, primarily due to the complexities of permitting and funding the projects.

The Five Watersheds

Where 5th field watershed differences exist, they are often consistent with either watershed size or the proportion of erodible lithology. The Tillamook River stands out as unique in the TBW in terms of sediment and habitat metrics, as well as the pattern of lithology, land use, and ownership. Any discussion of the Tillamook River is inextricably convolved with the impacts of these factors. In comparison to the other four watersheds, the Tillamook River as a population is less stable and has a higher proportion of fine sediments. This signal is largely driven by the erodible portion of the watershed substrate. When resistant Tillamook sites are compared to resistant sites in other watersheds these differences largely disappear. The Tillamook also has a relatively high abundance of LWD and pool volume. Although no determination of impairment was attempted in this analysis, the west side tributaries of the Tillamook stand out as areas of potential concern for the following reasons; they are generally both unstable and have a high %SAFN; they occupy erodible watersheds which are known to be sensitive to disturbance; they are upstream of extensive spawning beds located in the mainstem. The Tillamook River Coho Restoration Strategy developed to guide restoration efforts in the watershed by the Tillamook Bay Watershed Council included a census of all spawning gravels in the Tillamook River. It was found that over roughly 2/3 of the usable gravels were located in the middle to lower mainstem. It is recommended that additional care be given when planning and implementing management actions in these western tributaries.

Extensive past and present beaver activity strongly influences the channel morphology and %SAFN[1]. It is hypothesized that beaver play an important role in regulating the input of fine sediments to the Tillamook River mainstem. It is difficult to estimate pre-disturbance conditions for the erodible portion of the Tillamook. One hypothesis is that anthropogenic impacts such as riparian logging, stream channelization, beaver trapping, road building, splash damming, and wood removal have increased the chronic input of fine sediments and decreased the capacity of the channel to sort gravels. For example, historic instream LWD may have created local gradient breaks which provided the necessary stream hydraulics to sort gravels. Beavers active in headwater channels might have trapped fine sediment and limited their input to the mainstem. An alternate hypothesis is that the current state of the watershed reflects its maximum (or near maximum) potential to provide spawning habitat. Under this hypothesis, historically elevated LWD levels and beaver activity would have resulted in greater retention of fine sediments in spawning areas, balanced by an increase in rearing habitat. It is not possible to differentiate between these hypotheses with the data available. It is recommended that additional analyses be conducted for this area including the following: floodplain core sample analysis of a depth which would characterize historical channel substrate; sediment transport modeling to evaluate current and potential stream competence; past and present landslide assessment; and road modeling.

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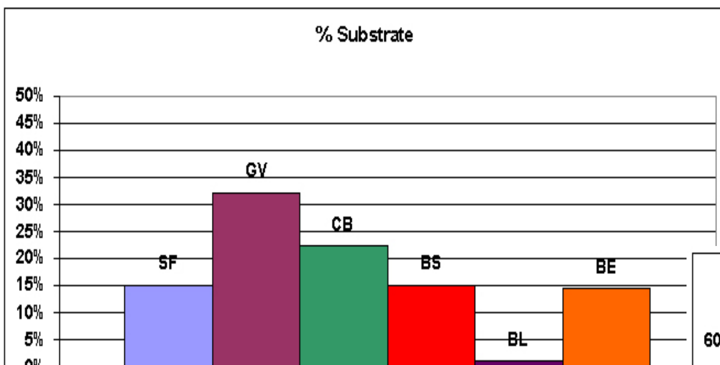
1 Mico, C. and Mico L. (2009) *Tillamook River Coho Restoration Strategy*

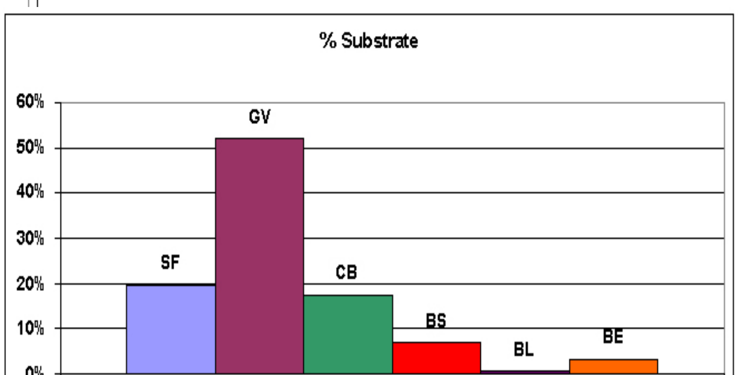
Trask Watershed Study

A portion of the TWS is inaccessible as a result of extensive bedrock and steep slopes. Collection of monitoring data will be challenging if not impossible in this reach. When sampling is based on a a 1:24k hydro layer versus a 1:100k hydro layer, more unstable sites are observed and the data becomes generally more variable. The mainstem of the TWS stream network is more stable than similar sites in the rest of the TBW. The TWS area is similar to the Trask River watershed and the larger TBW, barring the difference in bed stability found in the larger streams of the TWS. LRBS (at a population scale), %SAFN, slope, and wood volume are not significantly different. Slope, like bed stability, is more similar to the larger streams in the TBW than 1st order streams in the TBW. Field observations suggest that the TWS has a broad range of slopes, including many low gradient reaches. Where differences do exist, they are consistent with expected effects of an increase in channel size. Specifically, the TBW has more pool volume, greater width to depth ratios, more boulders, more bank instability, and larger bankfull radii. %Bedrock is similar between the populations. Based on these results, it is hypothesized that the TWS is generally representative of the conditions within the rest of the TBW. This supports (but cannot conclusively prove the validity of) the use of this watershed as a test watershed for evaluating the impacts of coast wide land management practices.

When erodible and resistant sites within the TWS are compared, the differences are less distinct than those observed at the greater TBW scale. In particular, the primary sediment indicators are similar to one another (not significantly different). It is hypothesized that this is a result of the similarity of slopes among erodible and resistant sites in the TWS, whereas slope is dramatically different in the broader TBW erodible and resistant populations. An alternate hypothesis is that the influence of geology is larger as watershed size increases (cumulative effect). This is an important hypothesis to monitor in the larger TBW in regards to the TWS. Correlating other forestry activities outside the TWS might elucidate the findings of the TWS. Finally, gravels are more abundant in the erodible TWS sites, possibly due to in-channel breakdown of larger sediment classes; bedrock is more abundant in the resistant TWS sites.



Trask Watershed Study Resistant Results



Trask Watershed Study Erodible Results

Land-use, Ownership, and Erodibility

Although the statistical design effectively allocated sites among the various strata, the overlap in many cases makes determination of causality difficult if not impossible. For example, private-erodible-non-forestry sites all overlap significantly in the lower watersheds where the conditions are favorable for agriculture and residential uses. These sites are also low gradient and in some cases very sandy and stable. Further very few wadeable stream channels are not zoned for forestry. Much of the stream network within the non-forestry zone is mainstem, non-wadeable, and often tidally influenced. Reaches of this type are generally depositional in nature; sediment inputs in these areas are limited to localized bank instabilities; much of this area is diked. Agricultural and residential land-uses can have serious impacts to water quality however. In the TBW, temperature and bacteria are major issues. Refer to the Tillamook Bay TMDL for further information on this topic. Increased prevalence of knotweed in particular is a potential concern, due to its impact on riparian vegetation and winter bank stability.

As expected, erodibility is strongly related to many sediment metrics. It is challenging to disentangle where the relationships are causal and where they are correlative. For example, %SAFN is higher and mean particle sizes are lower in erodible lithologies than in resistant. Slopes are lower however in erodible lithologies resulting in a significant confound. The lower slopes in erodible lithologies reflect a combination of two factors: the predominance of alluvial deposits (classified as erodible) in the lower depositional reaches of the stream network and the unique geomorphology of the west side of the Tillamook River Watershed characterized by gentle hillslopes and beaver impoundments. Large differences in %SAFN between the erodible and resistant sites within the Tillamook River watershed were observed. When a rough correction for stream power was applied (%SAFN multiplied by Bankfull Critical Diameter), this difference decreased drastically. Additionally, regression analysis was used to relate mean particle size to stream power (D_CBF). A significant positive relationship was found, although the R^2 value indicates that other factors influence particle size (e.g. Geology, hillslope relief). Under minimally disturbed conditions, erodibility has a reduced impact on the means of sediment indicators, although the distributions can be very different. For example, the 95th percentile for %SAFN is higher in the erodible than in the resistant reference data. When disturbance is introduced as a variable, it appears that erodible watersheds are more susceptible to disturbance than resistant sites.[1] The higher %SAFN and less stable beds in erodible stream reaches in the TBW may reflect, in part, a different response to past disturbance then that of resistant stream reaches. For this reason, it is recommended that additional care be taken when planning and implementing management actions in predominantly erodible watersheds or stream reaches.

Anchor VS. Non-anchor

Anchor sites differ from non-anchor sites in three primary metrics: %SAFN is lower in anchors; %Gravels is higher in anchors; and wood volume is higher in anchors. This generally supports their designation as salmon anchor habitat. Summer rearing may be higher in non-anchors as a result of pool volume (commonly larger). Stream shade in both anchor and non-anchor habitat should be maintained. The data collected for this study is expected to provide a valuable baseline for monitoring future trends in anchor designated watersheds.

1 Jessup, B. - Tetra Tech Corporation. Development of Bedded Sediment Benchmarks for Oregon Streams. (2009)

Trend

The majority of the historical data was collected in 1998 and 1999 by OSU researchers peripherally connected to the EPA in the Tillamook and Kilchis River watersheds. A sub-set of these sites were revisited during the 2009 study. It is hypothesized that the OSU researchers overestimated bankfull heights for nearly all of their sites: USGS gauging data indicates that bankfull heights for the mainstem Wilson River were ~3.5 meters near the confluence with the bay while the OSU researchers concluded that small tributaries of the Tillamook River had bankfull heights of ~2 meters; biologists, hydrologists, and EPA research staff believe the OSU bankfull heights are too high; and local knowledge of channel maintaining events do not support the OSU data. It is hypothesized that there were two significant drivers of this error in measurement. First, to the untrained eye, it is easy to confuse a terrace with an active floodplain. Many stream channels within the study area have been downcut and no longer access their historic floodplain. As a result, the morphologic indicators of bankfull are less obvious than they might be under pre-disturbance conditions. Second, high water events occurred in both 1996 (peak discharge) and 1998 (duration). These were well outside the boundaries of bankfull, and should be considered channel changing, not channel maintaining events. It is likely that a misunderstanding of the definition of bankfull led to the identification of the high water scour lines from these flood events as bankfull. The result is that the comparison between the historic and recent EMAP data is of limited utility. RBS, wood volume, and width to depth ratios are strongly dependent on bankfull height. Some metrics are measured based on the wetted stream channel however, and can be compared. The results of the trend analysis indicate that mean particle size is nearly identical after ~10 years. %SAFN, %Boulders, and %Bedrock are also all nearly identical. This finding is particularly interesting given the multiple greater than bankfull events which have occurred over the past decade.

These QA/QC problems have suggested a number of recommendations for future monitoring efforts in the TBW and in general for EMAP. For the TBW, it is recommended that all sites be clearly monumented. Sites visited in 2007 were marked with silver tags and flagging. In general, these were challenging to locate upon revisits in 2008. It is recommended that a more robust approach be used, for example brightly painted rebar stakes. Another recommendation is to utilize the original station length for all subsequent surveys, irrespective of the wetted width at the time of survey. This will minimize noise related to the time of the surveys and fluctuations in precipitation. All data should be reviewed for reasonableness and completeness by an analyst familiar with the watersheds in question. For EMAP as a whole, it is recommended that revisits be implemented to evaluate not just the repeatability (i.e. precision) of the metrics (which has been done extensively) but also the accuracy. For example, it is possible for a crew to be perfectly consistent with its measurements, but also entirely wrong.

A smaller sub-sample of sites was visited in 2007 and again in 2008. The results of 2007-2008 revisits show a small but measurable increase in bed stability from 2007 to 2008. A greater than bankfull event flood event occurred in December of 2007. Future monitoring will be needed to establish whether this is a indication of long-term, consistent trend or simply natural year-to-year variation. As discussed earlier, statistical significance should be interpreted with caution.

Climate Change, Stream Power, and Instream Sediments

Climate changes may impact the EMAP data collected over the longterm course of this project. There have been ~2-3 greater than bankfull events per year over the past decade. At what point do these channel changing events become reclassified as channel maintaining events (i.e. bankfull)? The regression analysis performed for this study indicates that reach specific stream power is the dominant control on mean particle size. If extreme storm events continue to increase in frequency, it is expected that instream sediments will, on average, coarsen over time to reach equilibrium with the transport capacity of the stream network.

Statistics & Metrics

A standard approach to data analysis is the use of hypothesis testing and significance values. This approach was utilized in this analysis, although it was not emphasized. As discussed in the materials and methods section, hypothesis testing has significant drawbacks. In particular, it under-emphasizes effect size and overemphasizes the difference of two populations. In a study such as this one, it is known a priori that the various sub-populations are different (e.g. The Trask River is not the Kilchis River). The primary question of interest becomes what the magnitude and direction of that difference is. This study was specifically designed to contain numerous orthogonal strata (e.g. erodibility, land-use, ownership, stream order, etc). Roughly 15 primary metrics and many secondary metrics not reported were calculated. The result is an exponentially increasing number of possible comparisons as sub-populations are further stratified (e.g. 1st order forestry VS. 2nd+ order non forestry). A variety of standard procedures exist for performing multiple comparisons such as multi-factor analysis of variance. Unfortunately, none lend themselves easily to weighted, stratified designs with unequal sample sizes and variances. Additionally, the primary goal of these tests is to establish only whether a difference exists. For these reasons, the primary methods of data presentation in this report are as follows: summary tables of means & variances for key metrics and sub-populations; CDF figures for key metrics and sub-populations; and cartographic display of key metrics for each site. Hypothesis testing was utilized as a secondary analysis, but should not be considered the primary result. The interested reader is strongly encouraged to review the subpopulation and metric results of interest directly. GIS data containing key site metrics is available for download from http://demeterdesign.net/downloads.html under the GIS data tab.

A number of useful metrics were calculated for this study outside the standard EMAP metrics. Specifically, RBS without bedrock included, %Gravels, %Cobbles, and bankfull width to depth ratios. It is recommended that these be included in standard EMAP analysis. One challenge encountered in this study was the lack of these metrics in the pool of reference sites, and the relative inaccessibility of EMAP data in general. Improving the public availability of data and development of associated open source tools for data collection and analysis would significantly improve the utility of the EMAP protocol to groups outside of the EPA. As currently instantiated, all analytical algorithms are written for the SAS software package. Although extremely powerful, SAS is also extremely expensive, making it inaccessible to smaller organizations.

Section 6 - Recommendations

• Implement mainstem instream restoration projects.
• Develop statistical procedures and software tools for comparing multiple weighted sub-populations.
• Focus the definition of bankfull height on the channel maintaining flow rather than the return interval.
• Calculate an alternate RBS metric using the previous year's high water line as an alternative to RBS.
• Calculate RBS with and without bedrock.
• Add %Gravels and %Cobbles to the standard EMAP metrics.
• Monument all monitoring sites with rebar.
• Use the original survey length rather than the time specific wetted width to conduct monitoring surveys.
• Make all EPA and ODEQ EMAP data publicly available on the internet.
• Conduct EMAP revisits for accuracy as well as precision.
• Classify hardwood and softwood separately during EMAP surveys.
• Additional care be should taken when planning and implementing management actions in predominantly erodible watersheds or stream reaches.
• Analyze EMAP data using first the disturbance index then the data to determine if any sites within the population of interest could be considered reference.
• Conduct additional sediment source and transport analysis of the erodible portion of the Tillamook River including the following: floodplain auguring to evaluate whether gravels were historically more abundant; sediment transport modeling to evaluate current and potential stream competence; past and present landslide assessment; road modeling.
• Conduct a follow-up study to address unanswered questions from McManus 1998.

Preliminary Monitoring Hypotheses

• If climate change trends continue and average winter flows increase, bed substrate will coarsen.
• Wood volumes in larger streams will increase as the pulse of LWD now in 1st order streams migrates into larger channels. This trend will be greater if wood removal is stopped and instream restoration is carried out in these larger systems.

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Appendix A - Sites Visited

Site ID	Subpopulation	Lithology	Anchor	Ownership
TBW_9	1st_For_Tillamook_SWIM	Erodible	No	Private
TBW_25	2nd+_NonFor_Tillamook_SWIM	Erodible	No	Private
TBW_42	2nd+_For_Wilson_MS	Erodible	Yes	Public
TBW_49	2nd+_For_Wilson_MS	Erodible	Yes	Public
TBW_69	2nd+_NonFor_Tillamook_MS	Erodible	No	Private
TBW_85	2nd+_NonFor_Tillamook_MS	Erodible	No	Private
TBW_88	1st_NonFor_Trask_MS	Erodible	No	Private
TBW_108	2nd+_NonFor_Tillamook_MS	Erodible	No	Private
TBW_139	1st_For_Miami_MS	Erodible	Yes	Private
TBW_141	2nd+_For_Wilson_MS	Erodible	No	Public
TBW_143	1st_For_Trask_MS	Erodible	Yes	Public
TBW_145	1st_NonFor_Tillamook_MS	Erodible	No	Private
TBW_148	1st_NonFor_Trask_MS	Erodible	No	Private
TBW_161	1st_For_Tillamook_MS	Erodible	No	Private
TBW_168	1st_For_Tillamook_SWIM	Erodible	No	Private
TBW_170	1st_For_Tillamook_SWIM	Erodible	No	Public
TBW_177	1st_For_Tillamook_SWIM	Erodible	No	Private
TBW_179	1st_For_Tillamook_SWIM	Erodible	No	Public
TBW_180	2nd+_NonFor_Trask_MS	Erodible	No	Private
TBW_182	2nd+_For_Wilson_MS	Erodible	No	Public
TBW_206	1st_NonFor_Wilson_MS	Erodible	No	Private
TBW_227	2nd+_NonFor_Miami_MS	Erodible	Yes	Private
TBW_22	1st_For_Tillamook_MS	Erodible	No	Public
TBW_101	2nd+_For_Tillamook_MS	Erodible	No	Private
TBW_157	1st_For_Tillamook_MS	Erodible	No	Private
TBW_4	2nd+_For_Miami_MS	Erodible	Yes	Public
TBW_11	2nd+_For_Wilson_MS	Erodible	No	Public
TBW_13	1st_For_Tillamook_MS	Erodible	No	Private
TBW_16	2nd+_NonFor_Trask_MS	Erodible	No	Private
TBW_17	2nd+_For_Wilson_MS	Erodible	No	Public
TBW_23	1st_For_Wilson_MS	Erodible	No	Public
TBW_27	2nd+_For_Trask_MS	Erodible	Yes	Public
TBW_30	2nd+_For_Trask_MS	Erodible	No	Public
TBW_39	2nd+_For_Wilson_MS	Erodible	Yes	Public
TBW_55	2nd+_NonFor_Wilson_MS	Erodible	Yes	Private
TBW_44	2nd+_For_Tillamook_MS	Erodible	No	Private
TBW_53	1st_For_Tillamook_SWIM	Erodible	No	Private
TBW_64	1st_NonFor_Tillamook_MS	Erodible	No	Private
TBW_71	2nd+_For_Wilson_MS	Erodible	Yes	Public

Site ID	Subpopulation	Lithology	Anchor	Ownership
TBW_72	1st_NonFor_Kilchis_MS	Erodible	No	Private
TBW_73	1st_For_Wilson_MS	Erodible	Yes	Public
TBW_83	2nd+_For_Wilson_MS	Erodible	No	Public
TBW_100	2nd+_For_Kilchis_SWIM	Erodible	Yes	Public
TBW_113	1st_For_Tillamook_SWIM	Erodible	No	Private
TBW_117	2nd+_For_Tillamook_MS	Erodible	No	Private
TBW_124	1st_For_Tillamook_SWIM	Erodible	No	Private
TBW_188	2nd+_For_Miami_MS	Erodible	Yes	Public
TBW_204	2nd+_For_Miami_MS	Erodible	Yes	Public
TBW_X3	2nd+_For_Miami_MS	Erodible	Yes	Public
TBW_90	1st_For_Trask_MS	Erodible	Yes	Public
TBW_150	1st_For_Trask_MS	Erodible	No	Public
TBW_18	2nd+_For_Kilchis_SWIM	Resistant	Yes	Public
TBW_26	1st_For_Trask_MS	Resistant	No	Public
TBW_29	1st_For_Kilchis_MS	Resistant	No	Public
TBW_46	2nd+_For_Wilson_MS	Resistant	No	Public
TBW_61	2nd+_For_Kilchis_MS	Resistant	No	Public
TBW_81	1st_For_Wilson_MS	Resistant	No	Public
TBW_84	1st_For_Miami_MS	Resistant	Yes	Private
TBW_106	2nd+_For_Wilson_MS	Resistant	No	Public
TBW_114	2nd+_For_Wilson_MS	Resistant	Yes	Public
TBW_115	1st_For_Wilson_MS	Resistant	Yes	Private
TBW_119	1st_For_Tillamook_SWIM	Resistant	No	Private
TBW_121	2nd+_For_Kilchis_SWIM	Resistant	No	Public
TBW_122	2nd+_For_Wilson_MS	Resistant	No	Public
TBW_123	2nd+_NonFor_Miami_MS	Resistant	Yes	Private
TBW_128	1st_For_Miami_MS	Resistant	Yes	Public
TBW_129	2nd+_For_Trask_MS	Resistant	No	Public
TBW_131	2nd+_For_Wilson_MS	Resistant	No	Public
TBW_135	1st_For_Wilson_MS	Resistant	No	Public
TBW_137	1st_For_Kilchis_MS	Resistant	No	Public
TBW_138	1st_For_Trask_MS	Resistant	Yes	Public
TBW_142	2nd+_For_Kilchis_SWIM	Resistant	No	Public
TBW_151	2nd+_For_Miami_MS	Resistant	Yes	Private
TBW_169	2nd+_For_Trask_MS	Resistant	No	Public
TBW_171	2nd+_For_Wilson_MS	Resistant	No	Public
TBW_174	2nd+_For_Wilson_MS	Resistant	Yes	Public
TBW_175	2nd+_For_Wilson_MS	Resistant	No	Public
TBW_176	1st_For_Kilchis_SWIM	Resistant	No	Private

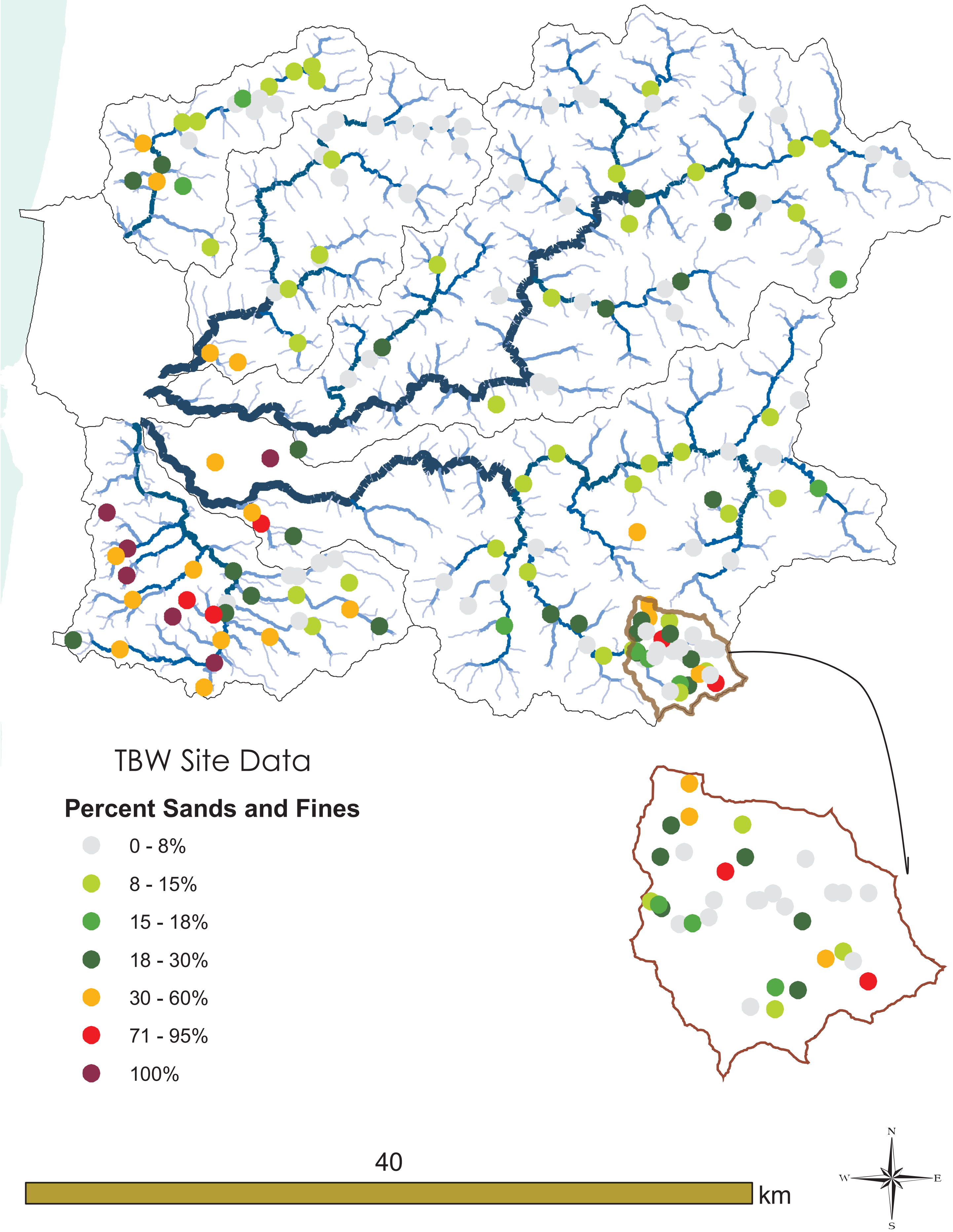
Site ID	Subpopulation	Lithology	Anchor	Ownership
TBW_178	2nd+_For_Trask_MS	Resistant	Yes	Public
TBW_208	2nd+_NonFor_Kilchis_MS	Resistant	No	Public
TBW_6	1st_For_Trask_MS	Resistant	No	Private
TBW_24	1st_For_Miami_MS	Resistant	Yes	Private
TBW_50	2nd+_For_Tillamook_MS	Resistant	No	Public
TBW_110	2nd+_For_Tillamook_SWIM	Resistant	No	Public
TBW_163	1st_For_Tillamook_SWIM	Resistant	No	Public
TBW_167	1st_For_Miami_MS	Resistant	Yes	Public
TBW_1	2nd+_For_Wilson_MS	Resistant	No	Public
TBW_2	2nd+_For_Kilchis_MS	Resistant	No	Public
TBW_3	2nd+_For_Wilson_MS	Resistant	No	Private
TBW_10	1st_For_Kilchis_SWIM	Resistant	No	Public
TBW_14	2nd+_For_Trask_MS	Resistant	No	Public
TBW_20	2nd+_For_Miami_MS	Resistant	Yes	Public
TBW_33	2nd+_For_Wilson_MS	Resistant	No	Public
TBW_34	2nd+_For_Kilchis_SWIM	Resistant	No	Public
TBW_43	2nd+_For_Trask_MS	Resistant	Yes	Public
TBW_45	1st_For_Miami_MS	Resistant	Yes	Public
TBW_51	2nd+_For_Trask_MS	Resistant	No	Public
TBW_52	1st_For_Miami_MS	Resistant	Yes	Public
TBW_54	2nd+_For_Wilson_MS	Resistant	Yes	Public
TBW_58	1st_For_Wilson_MS	Resistant	No	Public
TBW_59	1st_For_Tillamook_SWIM	Resistant	No	Public
TBW_62	2nd+_For_Wilson_MS	Resistant	No	Public
TBW_66	2nd+_For_Tillamook_MS	Resistant	No	Public
TBW_74	2nd+_For_Trask_MS	Resistant	No	Public
TBW_78	2nd+_For_Kilchis_SWIM	Resistant	No	Public
TBW_79	2nd+_For_Trask_MS	Resistant	No	Public
TBW_93	2nd+_For_Wilson_MS	Resistant	No	Public
TBW_94	2nd+_For_Kilchis_MS	Resistant	No	Public
TBW_96	1st_For_Miami_MS	Resistant	Yes	Public
TBW_98	1st_For_Kilchis_MS	Resistant	Yes	Public
TBW_99	2nd+_For_Wilson_MS	Resistant	No	Public
TBW_105	1st_For_Miami_MS	Resistant	Yes	Public
TBW_126	2nd+_For_Kilchis_SWIM	Resistant	No	Public
TBW_130	2nd+_For_Tillamook_MS	Resistant	No	Public
TBW_220	2nd+_For_Miami_MS	Resistant	Yes	Public
TBW_X1	1st_For_Tillamook_MS	Resistant	No	Public
TBW_X2	1st_For_Tillamook_MS	Resistant	No	Public

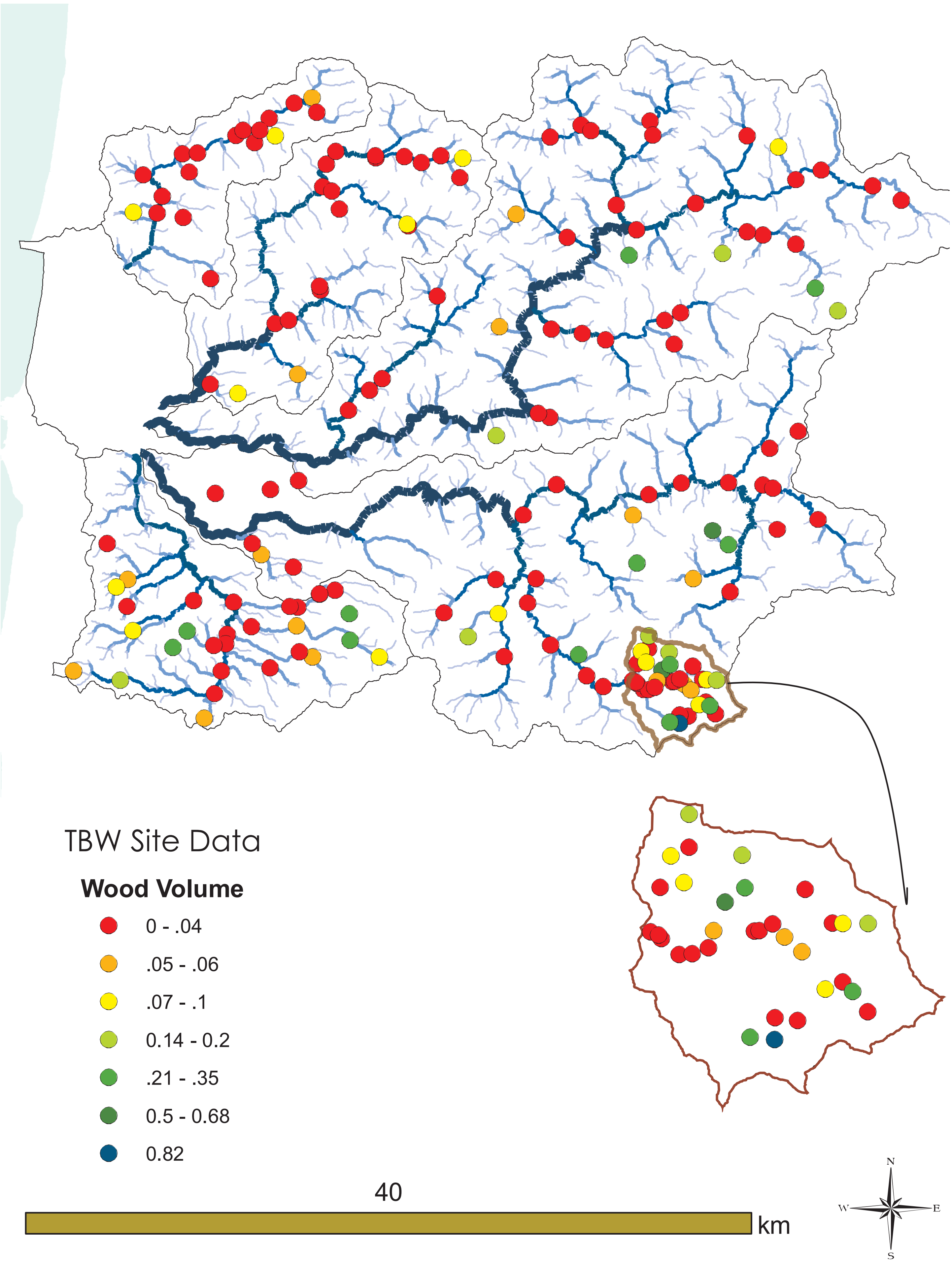
Site ID	Subpopulation	Lithology	Anchor	Ownership
TBW_5	1st_For_Trask_MS	Resistant	Yes	Public
TBW_15	2nd+_For_Trask_MS	Resistant	No	Public
TBW_37	1st_For_Trask_MS	Resistant	No	Public
TBW_65	2nd+_For_Trask_SWIM	Resistant	No	Public
TBW_75	1st_For_Trask_MS	Resistant	No	Public
TBW_86	1st_For_Trask_MS	Resistant	No	Public
TBW_87	1st_For_Trask_MS	Resistant	Yes	Public
TBW_89	2nd+_For_Kilchis_SWIM	Resistant	No	Public
TBW_95	2nd+_For_Trask_MS	Resistant	Yes	Public
TBW_97	1st_For_Trask_MS	Resistant	No	Private
TBW_111	2nd+_For_Trask_MS	Resistant	No	Public
TBW_118	1st_For_Trask_MS	Resistant	Yes	Public
TBW_125	2nd+_For_Wilson_MS	Resistant	Yes	Public
TBW_127	2nd+_For_Wilson_SWIM	Resistant	No	Public
TBW_146	2nd+_For_Trask_MS	Resistant	No	Public
TBW_147	2nd+_For_Trask_MS	Resistant	Yes	Public
TBW_149	2nd+_For_Kilchis_SWIM	Resistant	No	Public
TBW_153	2nd+_For_Wilson_MS	Resistant	No	Public
TBW_154	1st_For_Kilchis_SWIM	Resistant	No	Public
TBW_158	1st_For_Kilchis_SWIM	Resistant	Yes	Public
TBW_159	2nd+_For_Wilson_MS	Resistant	No	Public
TBW_162	1st_For_Wilson_MS	Resistant	No	Public
TBW_166	1st_For_Wilson_MS	Resistant	No	Public
IMW-05	IMW	Erodible	Yes	IMW
IMW-13	IMW	Erodible	Yes	IMW
IMW-37	IMW	Resistant	Yes	IMW
IMW-41	IMW	Resistant	Yes	IMW
IMW-43	IMW	Resistant	Yes	IMW
IMW-49	IMW	Resistant	Yes	IMW
IMW-55	IMW	Resistant	Yes	IMW
IMW-56	IMW	Resistant	Yes	IMW
IMW-02	IMW	Erodible	Yes	IMW
IMW-04	IMW	Erodible	Yes	IMW
IMW-06	IMW	Erodible	Yes	IMW
IMW-07	IMW	Erodible	Yes	IMW
IMW-08	IMW	Erodible	Yes	IMW
IMW-11	IMW	Erodible	Yes	IMW
IMW-12	IMW	Erodible	Yes	IMW
IMW-38	IMW	Resistant	Yes	IMW

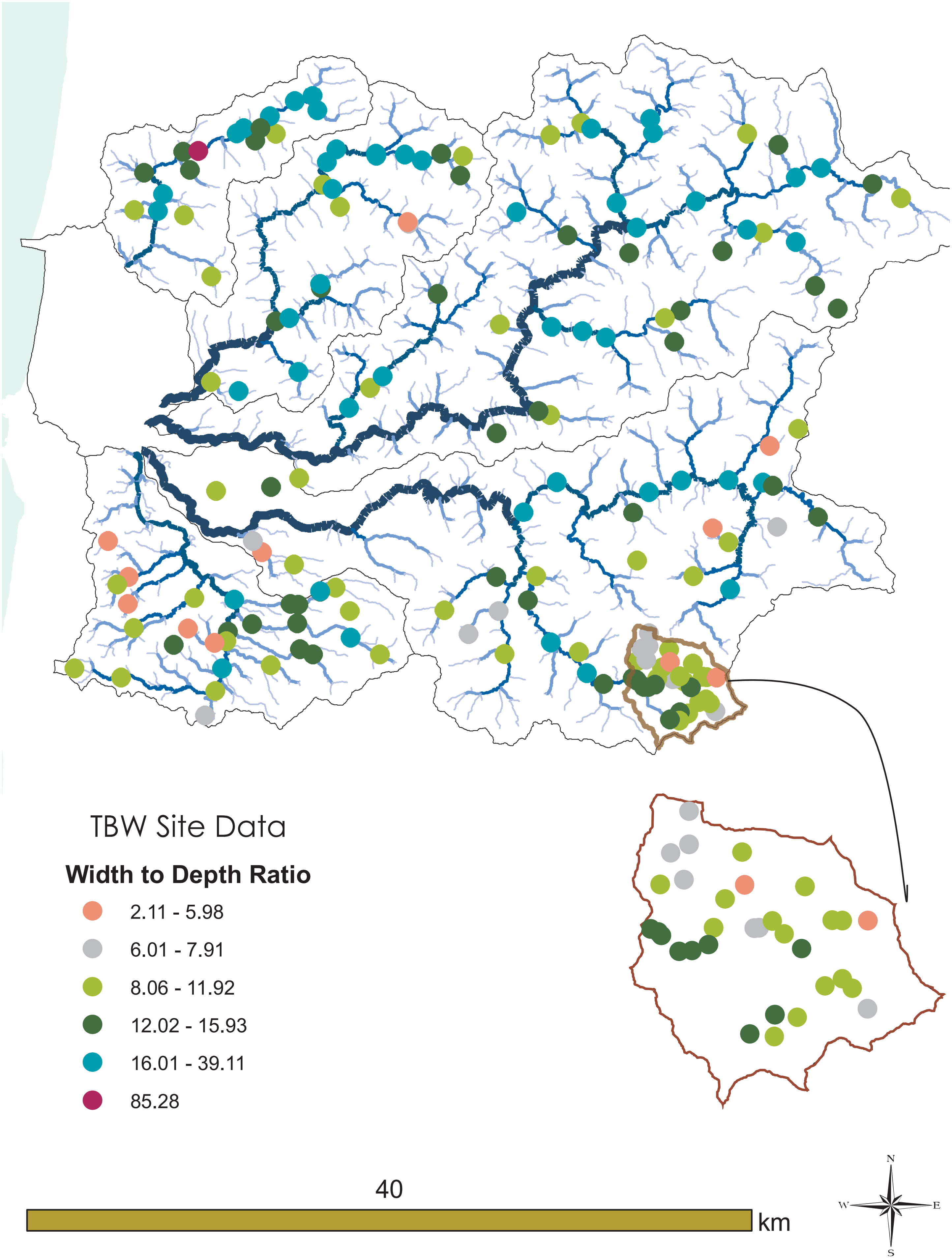
Site ID	Subpopulation	Lithology	Anchor	Ownership
IMW-39	IMW	Resistant	Yes	IMW
IMW-40	IMW	Resistant	Yes	IMW
IMW-44	IMW	Resistant	Yes	IMW
IMW-42	IMW	Resistant	Yes	IMW
IMW-45	IMW	Resistant	Yes	IMW
IMW-46	IMW	Resistant	Yes	IMW
IMW-47	IMW	Resistant	Yes	IMW
IMW-09	IMW	Erodible	Yes	IMW
IMW-51	IMW	Resistant	Yes	IMW
IMW-53	IMW	Resistant	Yes	IMW
IMW-54	IMW	Resistant	Yes	IMW
IMW-57	IMW	Resistant	Yes	IMW
IMW-58	IMW	Resistant	Yes	IMW
IMW-59	IMW	Resistant	Yes	IMW
IMW-60	IMW	Resistant	Yes	IMW

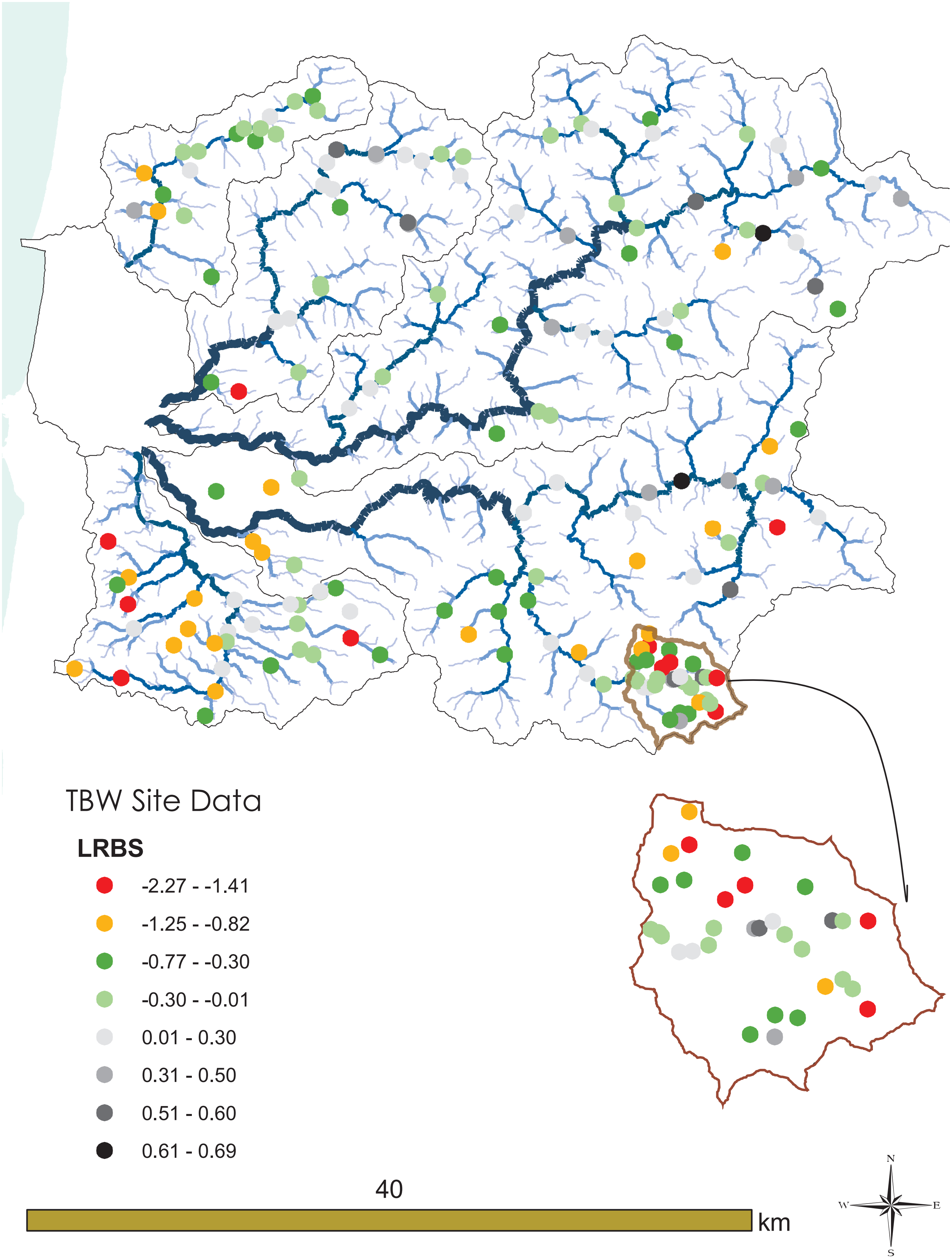
Appendix B - Past Studies Summaries

Title	Chapters Referenced; Summary	Date; Author
Miami River Watershed Assessment	6 - Sediment Sources - "Slope instability, road instability, and rural road runoff are the most significant sediment sources... Agricultural and pasture land runoff, as well as the history of fire in the Tillamook region are also contributing factors. However, agricultural and pastoral lands occupy a small portion of the watershed. Agricultural lands account for approximately 1.5 percent of this watershed, and are mostly located at the lower elevations. There is no urban runoff in this watershed."	2001; E&S Environmental Chemistry, Inc.
Kilchis Watershed Analysis	5 - Erosion - "Hill-slope steepness commonly exceeds 35 degrees (70%)... Most landslides in the Kilchis watershed originate as shallow translational (debris) slides from the steep hill-slopes... Slumps and earth-flow type landslides are less common in the Kilchis watershed, as are the infrequent but very large structural/rock failures... There were 57 shallow, road-related landslides in the Kilchis watershed during the winter of 1995–96, of which 48 involved more than 10 cubic yards [of materials]. 5 Additional landslides occurred in harvest units and timber stands. Of the 48 larger landslides, 45 were due to failure of fill material and the other three were due to failure of the cut-slope, 29 entered stream channels, while another ten may have entered channels... Less than 20% of the landslides occurred on slopes of less than 70%. Forty-five (94%) of the landslides were caused by a failure of fill materials along a road, and thirty-one of these landslides were not associated with road drainage waters. The road survey found 50 road drainage structure washouts from the 1995–96 winter; of these 22 resulted in greater than 10 cubic yards of erosion (Mills 1997). 12 of the large washouts occurred at stream crossings, while the other 10 were associated with water diverted down roads... Approximately 39% of the road [network has] no ditching... The two lowest reaches of the Kilchis that were included in the ODFW stream habitat survey had active erosion on 29% and 11% of the banks (ODFW 1995)."	1998; Bruce Follansbee, Ph.D., Senior Scientist Ann Stark, M.S., GIS Coordinator
Wilson River Watershed Assessment	6 - "Sediment in Tillamook Bay comes from marine sources, the five major rivers and numerous smaller streams which flow into Tillamook Bay, and from bayshore erosion (Glenn 1978)... Slope instability, road instability, and rural road runoff are the most significant sediment sources. Rural roads are a common feature of this watershed, and many are present on steep slopes. Washouts from rural roads contribute sediment to streams, and sometimes initiate debris flows... Agricultural and pasture land runoff, as well as the history of fire in the Tillamook region are also contributing factors... Agricultural lands account for approximately 2 percent of this watershed, and are mostly located at the lower elevations of the watershed. Urban runoff is not a major contributor of sediment in this watershed. Developed lands occupy less than 1% of the Wilson River watershed... More than 3/4 of the Wilson River watershed is in the debris flow activity zone. Nearly equal proportions of the watershed fall in the moderate and high-risk categories: 40% in moderate, and 38% in high-risk. The Little North Fork and North Fork are completely in the debris flow risk zone (97% for both subwatersheds). Devils Lake Fork of the Wilson has very little area in the debris flow zone (13%). Hall Slough is the only subwatershed completely outside of the debris flow risk zone... In ODF lands throughout the Tillamook District, there are approximately 1,143 miles of road (Harrison, pers comm.). ODF surveyed over a thousand sidecast road sites. Of these, over half were determined by ODF to pose a moderate or high risk of contributing sediment to a stream if a road-related landslide were to occur. The overall density of these highrisk sites was approximately 1 site per every 2 miles of road... [There is] an average density of 2.3 crossings per square mile in the Wilson River Watershed. The highest density was in Hall Slough, with 7.5 crossings per square mile. However, it should be noted that Hall Slough is very atypical: it is the smallest subwatershed and covers a fairly developed lowland agricultural and urban area near the bottom of the watershed. The second highest density was in the Lower Wilson subwatershed, with 4.1 crossings/sq. mi. The lowest density was 0.5 crossings/sq. mi. in the Little N. Fork of the Wilson River subwatershed... Agricultural and urban lowlands occupy approximately 8% of the Tillamook Bay watershed (USDA 1978). USDA (1978) estimated that 60,613 tons (54,976 metric tons) of sediment enter Tillamook Bay annually. Of that total, 9,010 tons (8,172 metric), or 15%, were determined to be derived from agricultural lands... Channel modification, removal of LWD, and streamside grazing have increased streambank erosion... Roads are the primary source of sediment related to human activity."	2001; E&S Environmental Chemistry, Inc.
Trask River Watershed Assessment	"Barney Reservoir was built in 1966–68 to capture 4,000 acre feet of municipal water for cities along the Tualatin River. The dam was raised in 1996–98 to increase the storage capacity to 20,000 acre feet and will be filled starting in Winter 1998... The sediment assessment uses several measures to rate whether a subwatershed is at risk for serious erosion. They include: the number of miles of unpaved road per square mile of land; the amount of land with steep slopes (moderate 60–70%, high 70+%); the percentage of the subwatershed with the potential to contribute sediment from mass wasting and soil erosion; and the miles of road contributing sediment to streams... all five of the heavily forested subwatersheds have road densities above the cutoff figure and are thus at risk for elevated erosion due to roads... For turbidity and sediment, the mainstem of the Trask is listed by DEQ as a waterbody of concernfrom the confluence of the North and Middle Forks of the North Fork all the way down to the bay. The primary reason is probably the increase in erosion due to forest roads coupled with the background level of natural erosion."	1998; Bruce Follansbee, Ph.D. GIS Analyst: Ann Stark, M.S.
Sediment Accumulation and Human Impacts in Tillamook Bay, Oregon.	"The results of these hydrology analyses suggest that the Tillamook watershed gradually recovered from a period of major disturbances (from 1933 to 1955) to more normal conditions (from 1977 to 1998)... The results of the model suggest a 1.6-factor decrease of the amount of river sediments from the Heavily Impacted Period (1933-1955) of major disturbances to the Normal Period (1977- 1998)... The spatial variations of beach and river derived sediments throughout the Bay are determined from textural and mineralogical analyses of surface sediment samples, with the beach sands dominating the area close to the inlet and the river derived sands being mainly deposited at the southeast and northeast parts of the Bay. The relative contributions of these two major sources of sediment were found to be 60% for the marine beach and 40% for the river sands."	2001; Michael N. Styllas
The Tillamook Bay Watershed National Estuary Partnership Sedimentation Study	"Sediment accumulated rapidly with measured rates of sedimentation having been on the order of 200 cm per century [between 9000 BP and 7000 BP and slowed] after ~7,000 years BP to 20 to 40 cm per century. These latter "pre-historic" rates are on the same order as those measured in this study from short cores that penetrated about 1 meter into the bottom of the Bay and reached back to sediment that was deposited up to 300 to 500 years BP... The average sedimentation rates [derived from bathymetric data from 1867, 1954 and 1995 and samples for this study] ranging from 7 to 138 cm per century, with the higher values found in the southeastern part of the Bay near the river mouths. The bathymetric surveys can only provide values for total-Bay sedimentation rates, but yield the surprising result that sedimentation has decreased substantially during the last 50 years (i.e., during the first half of this century sedimentation may have been as much as a factor 10 greater than during the second half of the century)..."	1998; James McManus et. al.
Comprehensive Conservation and Management Plan; Erosion and Sedimentation Action Plan	SED-01 Implement Road Erosion and Risk Reduction Projects SED-02 Implement Practices That Will Improve Sediment Storage and Routing SED-03 Reduce Risks in Landslide-Prone Areas SED-04 Ensure Sufficient Resources to Enforce Forest Practices Act SED-05 Reduce Sedimentation from Non-Forest Management Roads SED-06 Develop, Implement, and Enforce a Stormwater Management Ordinance	1999 - Tillamook National Estuary Partnership

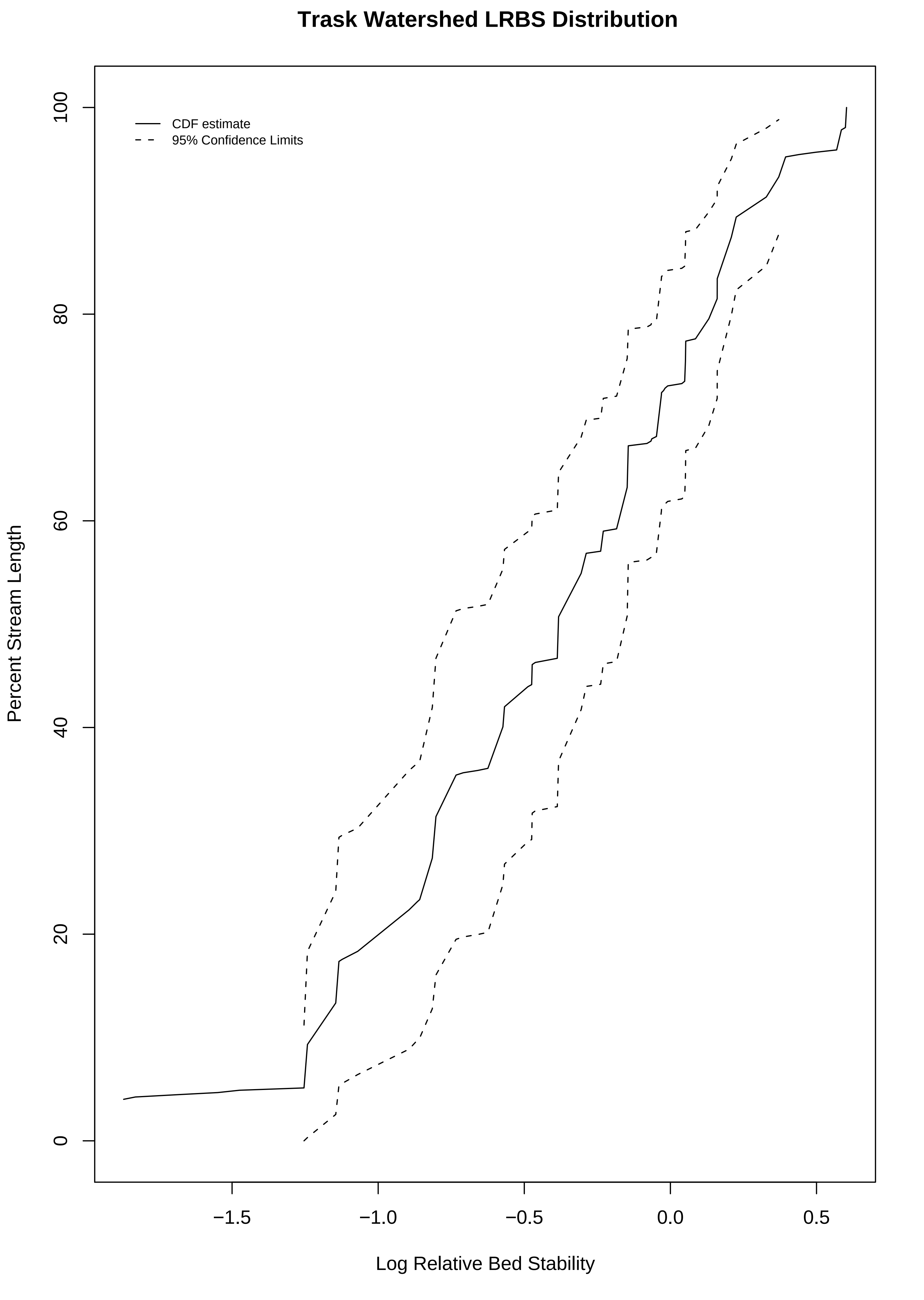

TBW Site Data
Percent Sands and Fines
0 - 8%
8 - 15%
15 - 18%
18 - 30%
30 - 60%
71 - 95%
100%
40
km
N
E
S
W

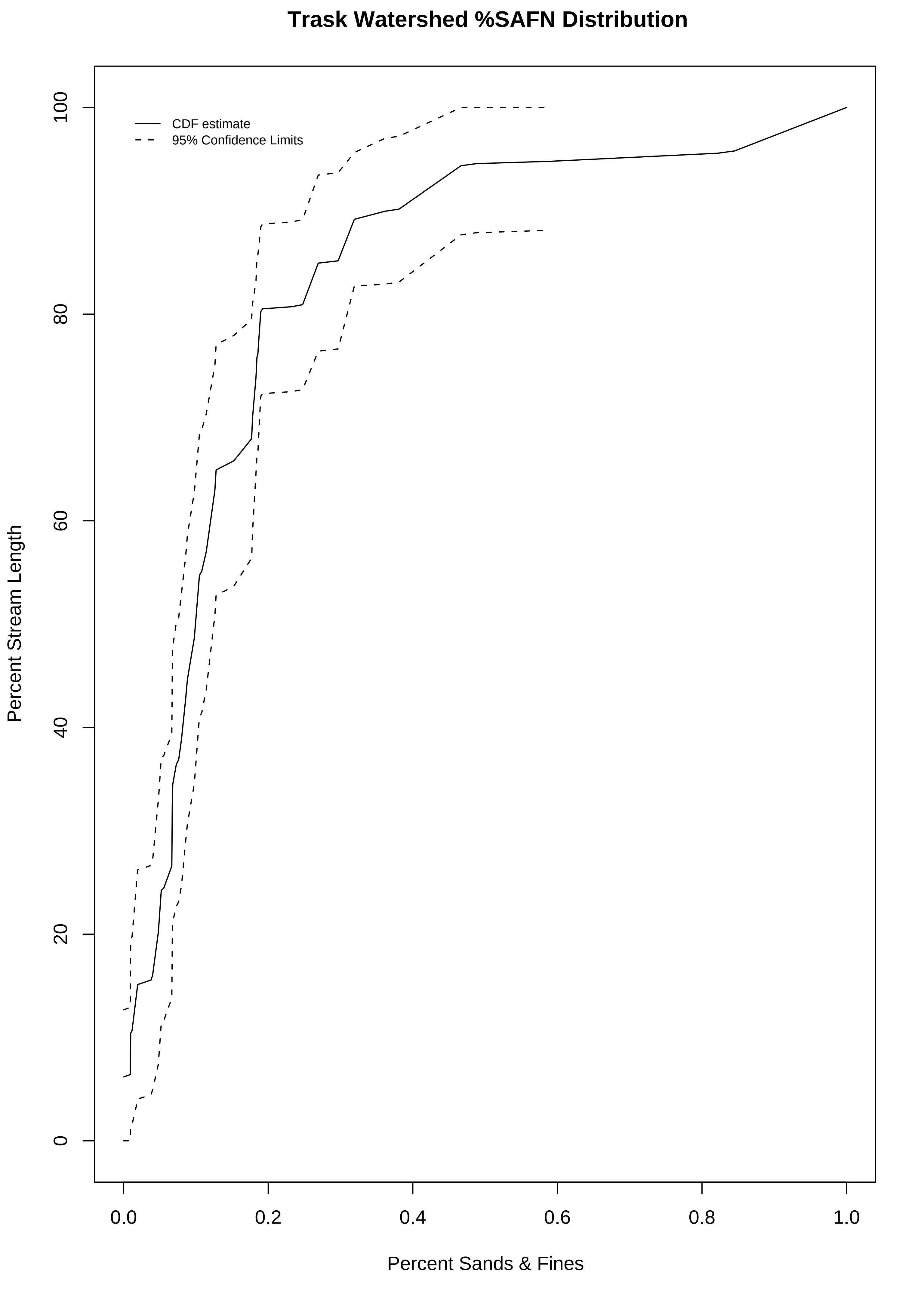

TBW Site Data
Wood Volume
0 - .04
.05 - .06
.07 - .1
0.14 - 0.2
.21 - .35
0.5 - 0.68
0.82
40
km
N
W
E
S


TBW Site Data
Width to Depth Ratio
2.11 - 5.98
6.01 - 7.91
8.06 - 11.92
12.02 - 15.93
16.01 - 39.11
85.28
40
km
N
E
S
W

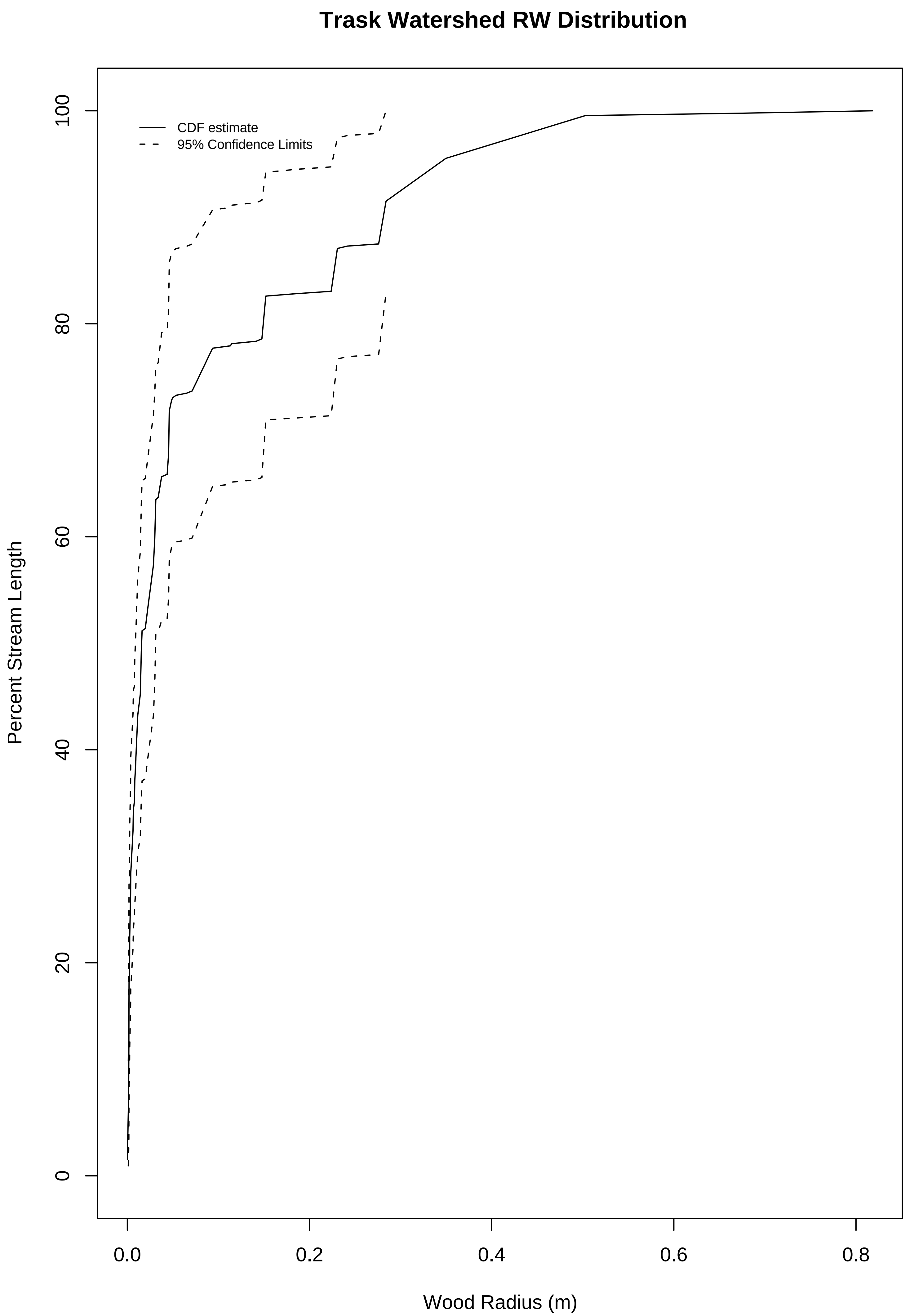

TBW Site Data
LRBS
-2.27 - -1.41
-1.25 - -0.82
-0.77 - -0.30
-0.30 - -0.01
0.01 - 0.30
0.31 - 0.50
0.51 - 0.60
0.61 - 0.69
40
km
N
W
E
S

Appendix D - Cumulative Distribution Function Graphs

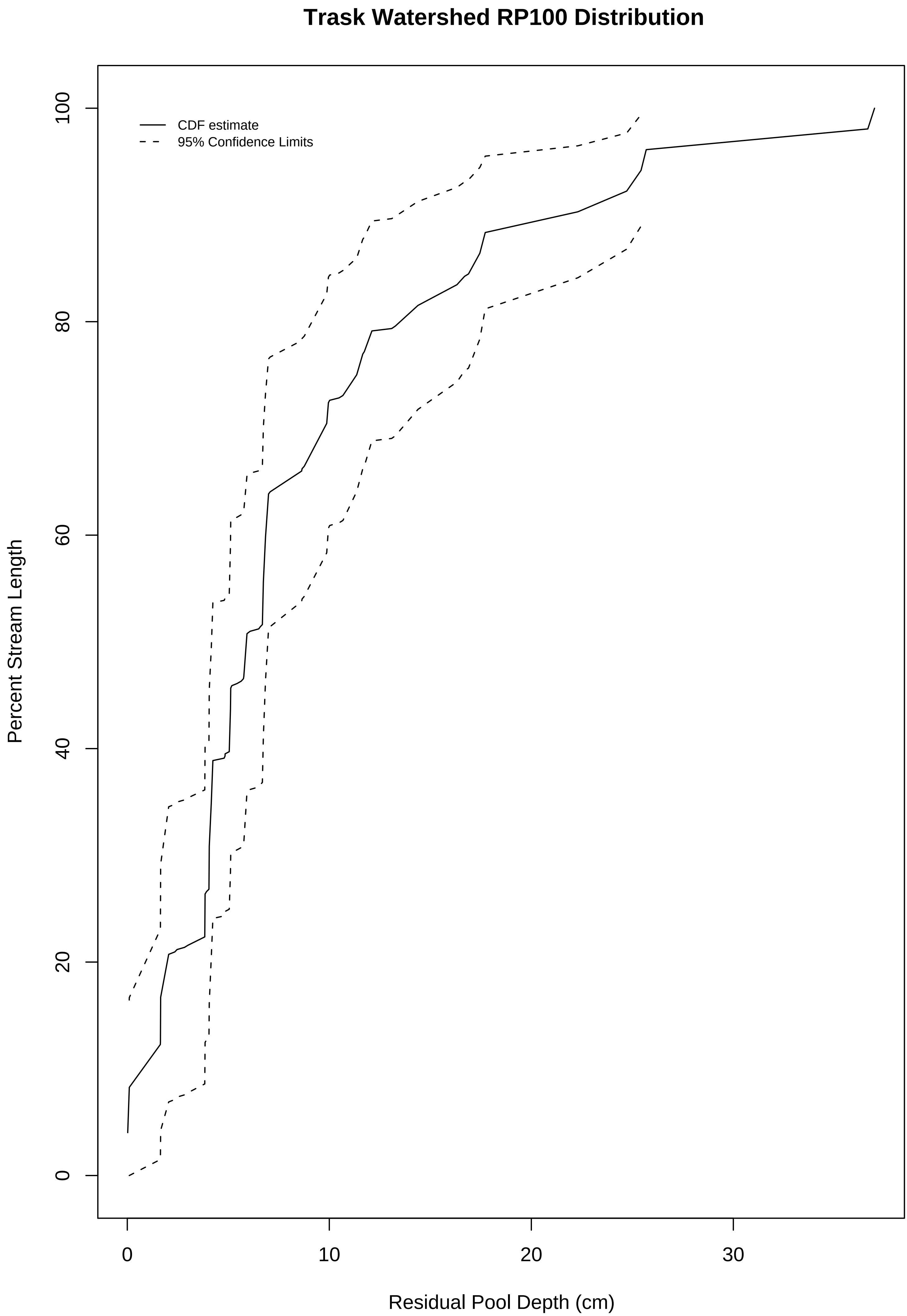

Trask Watershed LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−1.5
−1.0
−0.5
0.0
0.5
Log Relative Bed Stability



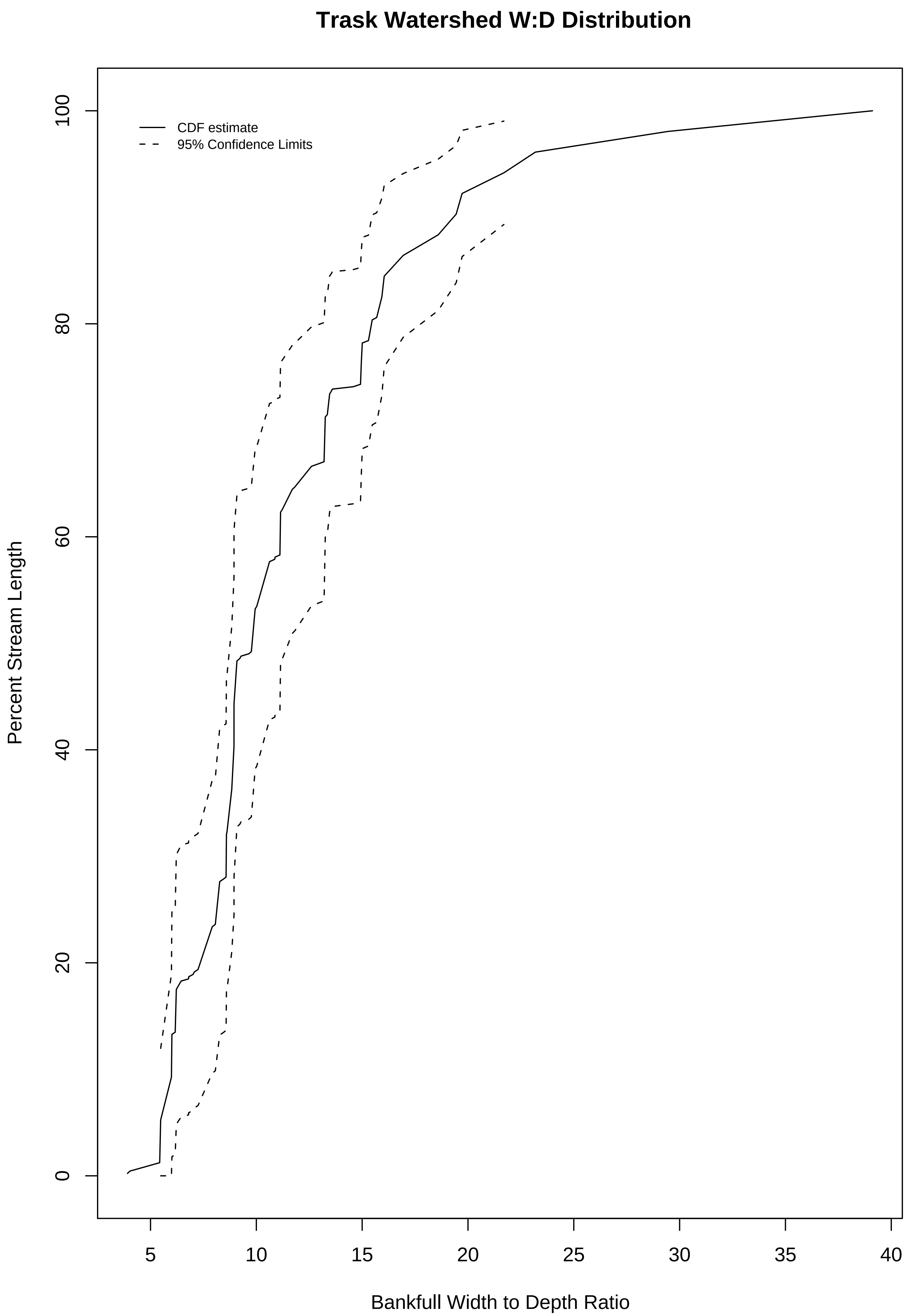
Trask Watershed %SAFN Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0
Percent Sands & Fines



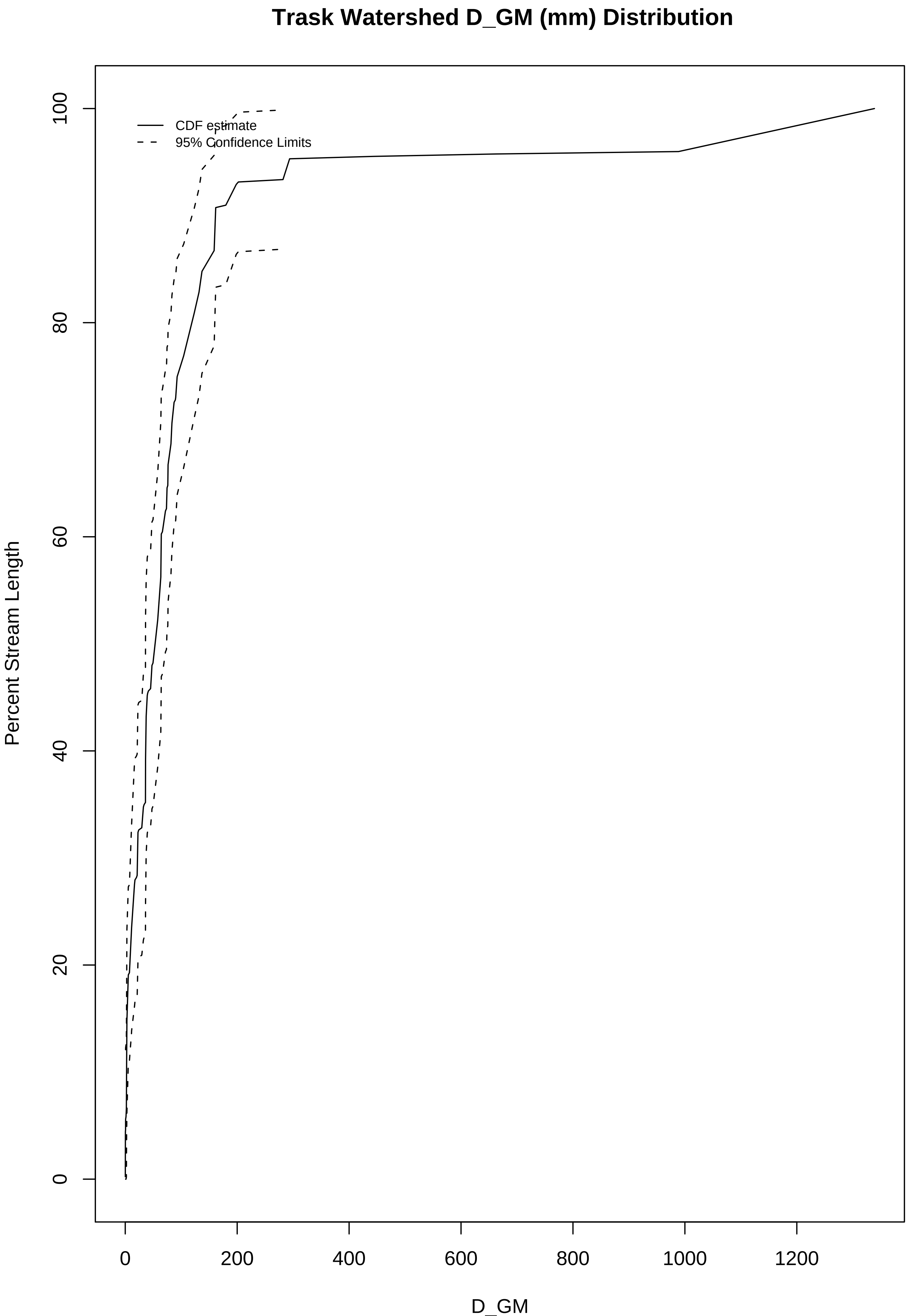
Trask Watershed RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
Wood Radius (m)

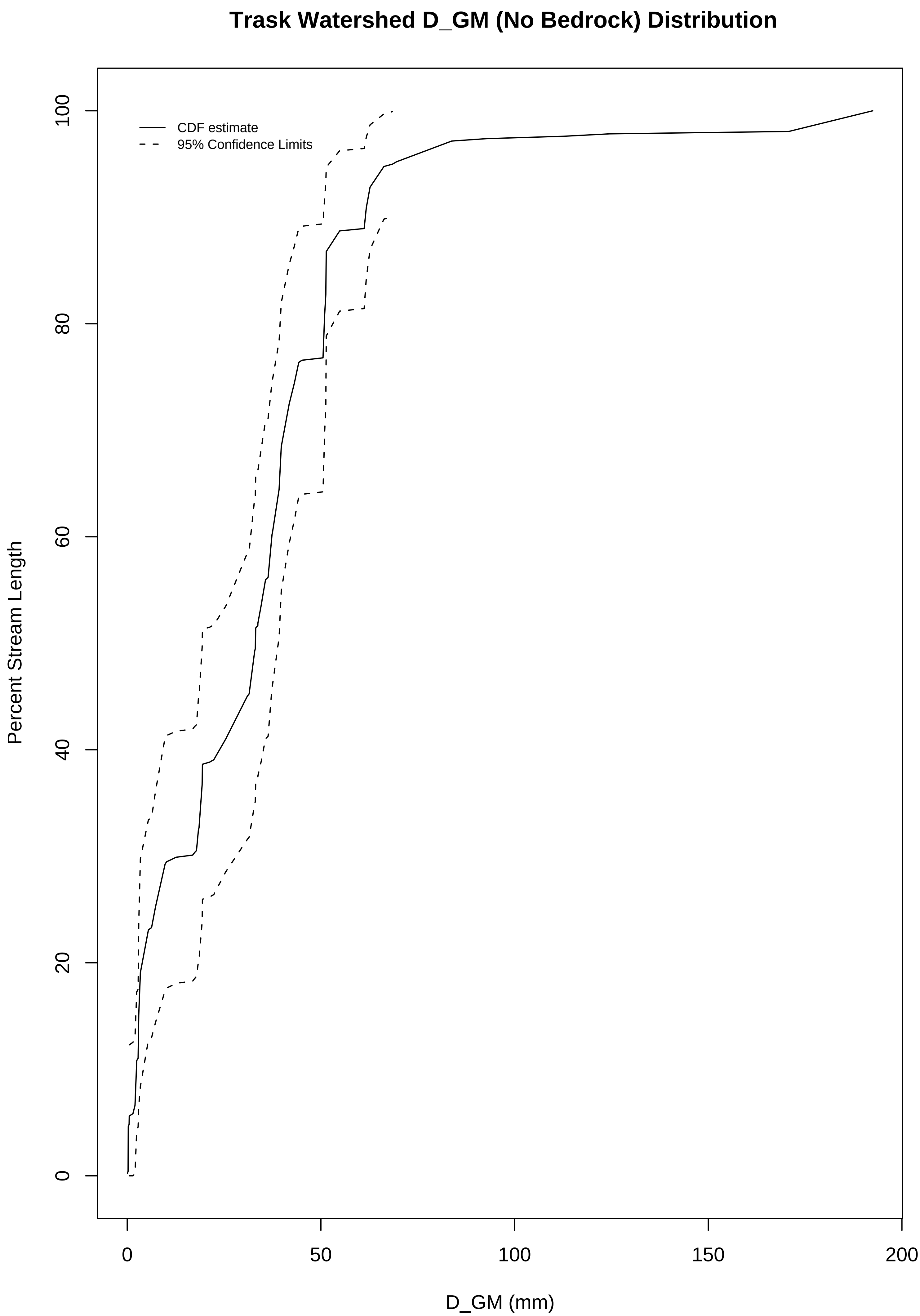


Trask Watershed RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
10
20
30
Residual Pool Depth (cm)

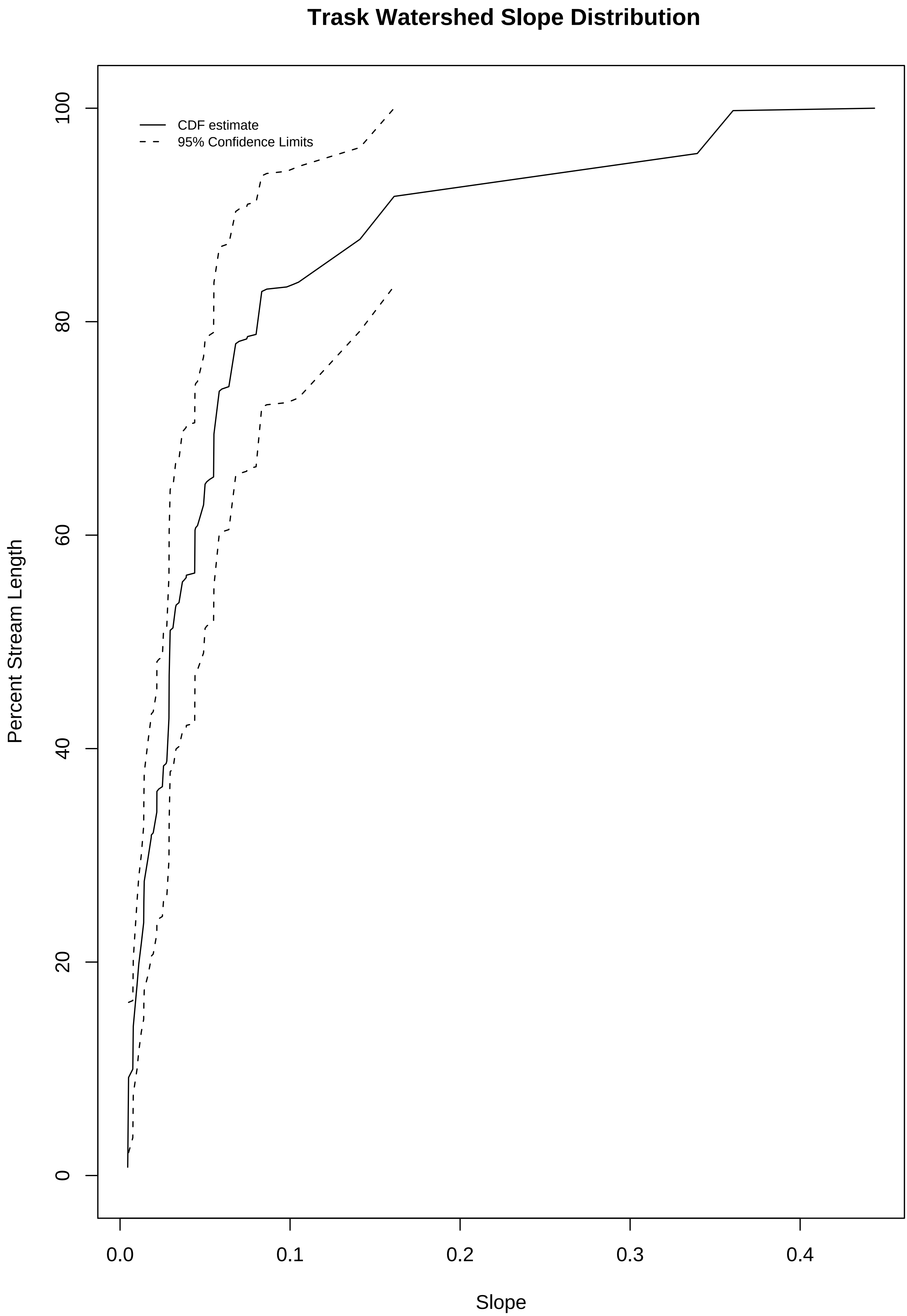


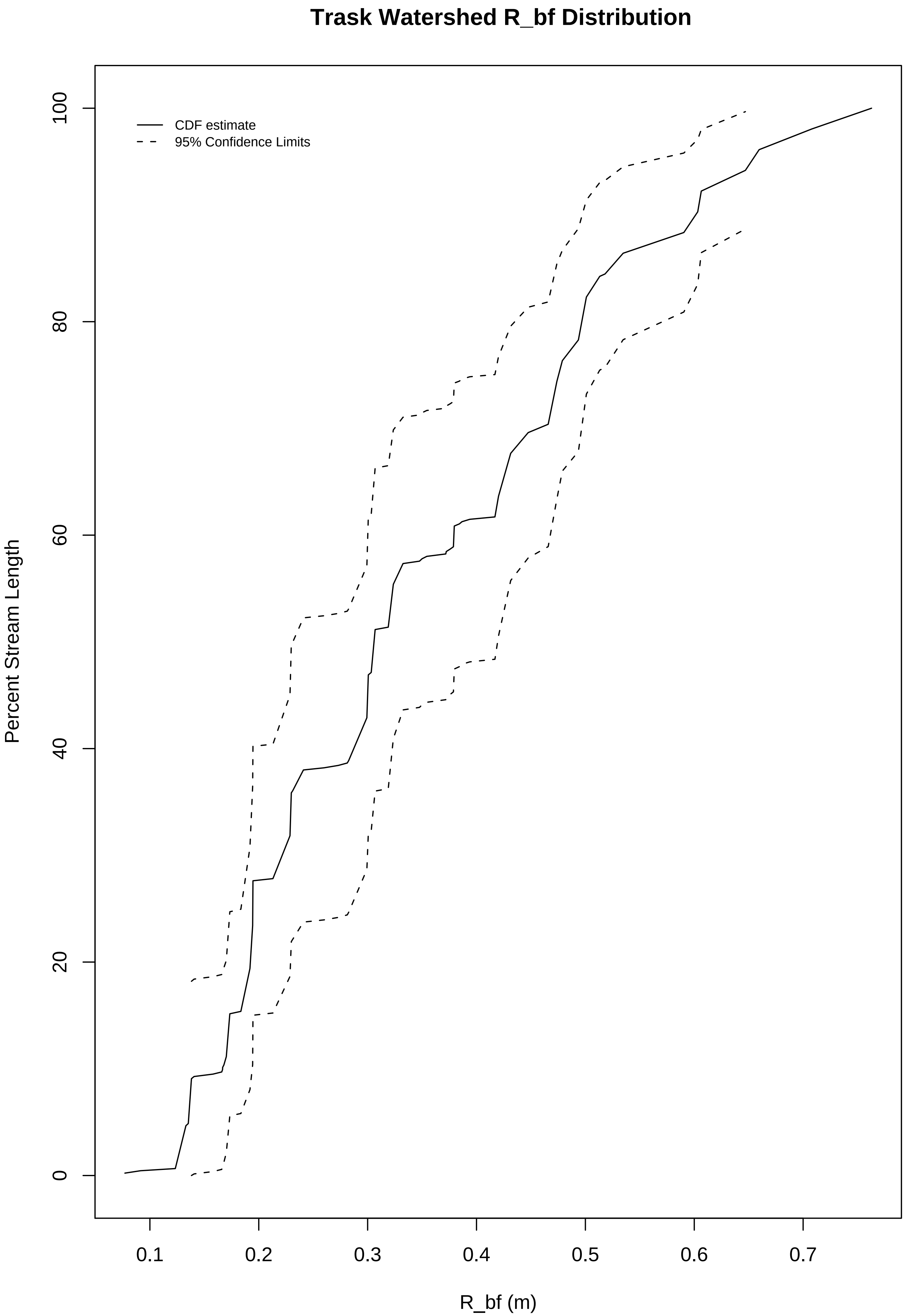
Trask Watershed W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
5
10
15
20
25
30
35
40
Bankfull Width to Depth Ratio

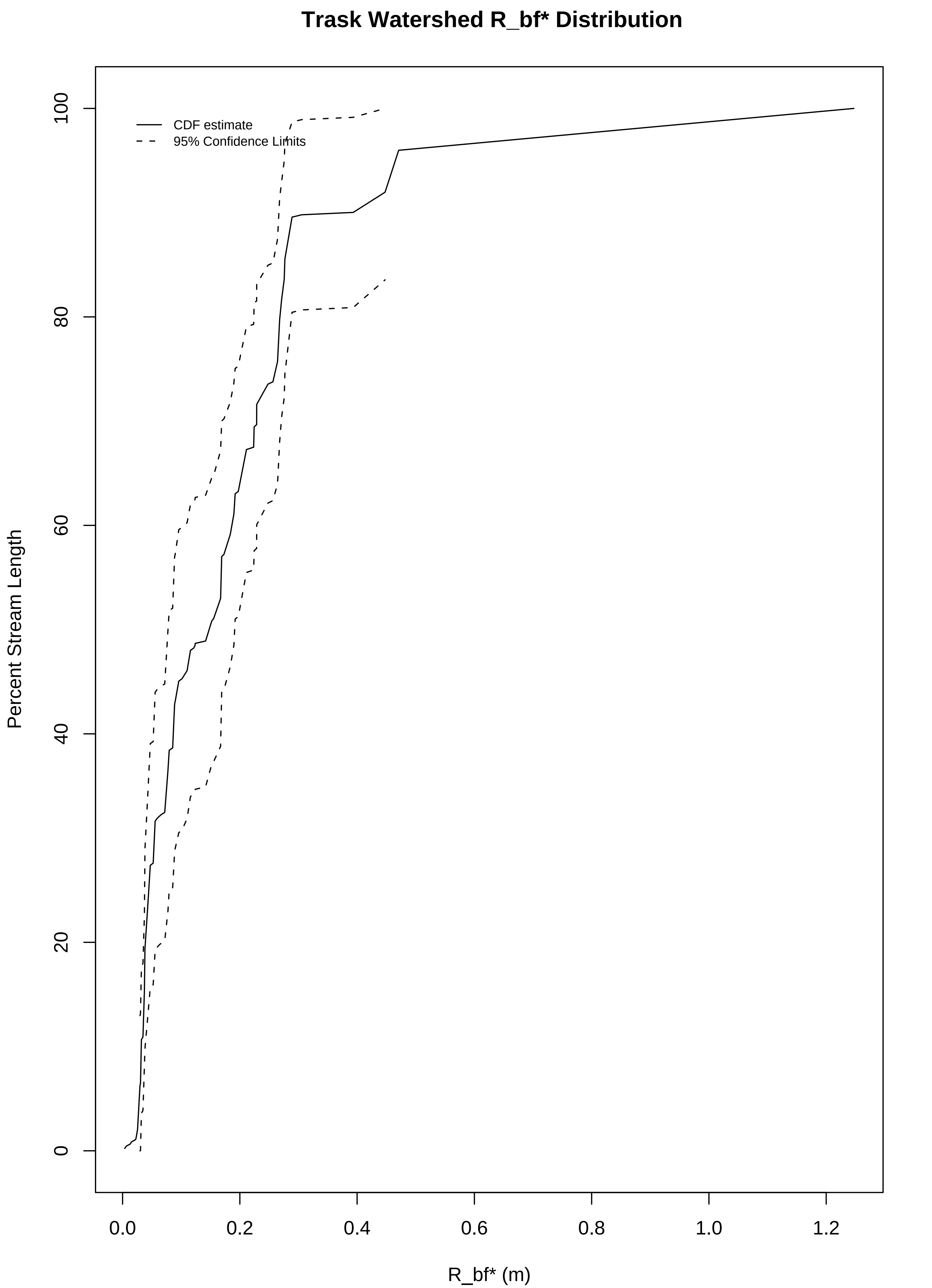

Trask Watershed D_GM (mm) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
200
400
600
800
1000
1200
D_GM



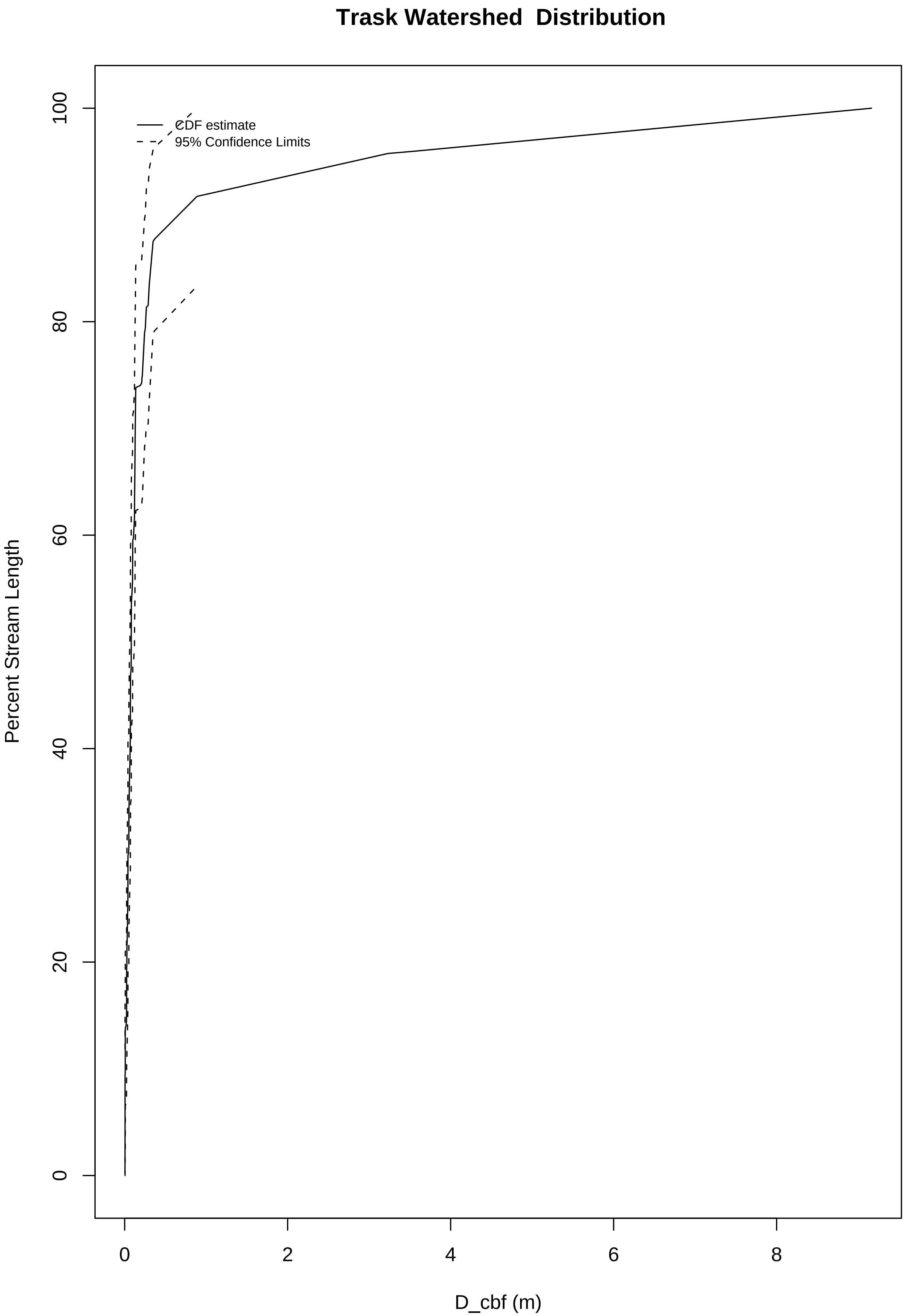
Trask Watershed D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
D_GM (mm)
0
20
40
60
80
100
0
50
100
150
200


Trask Watershed Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
Slope
0.0
0.1
0.2
0.3
0.4

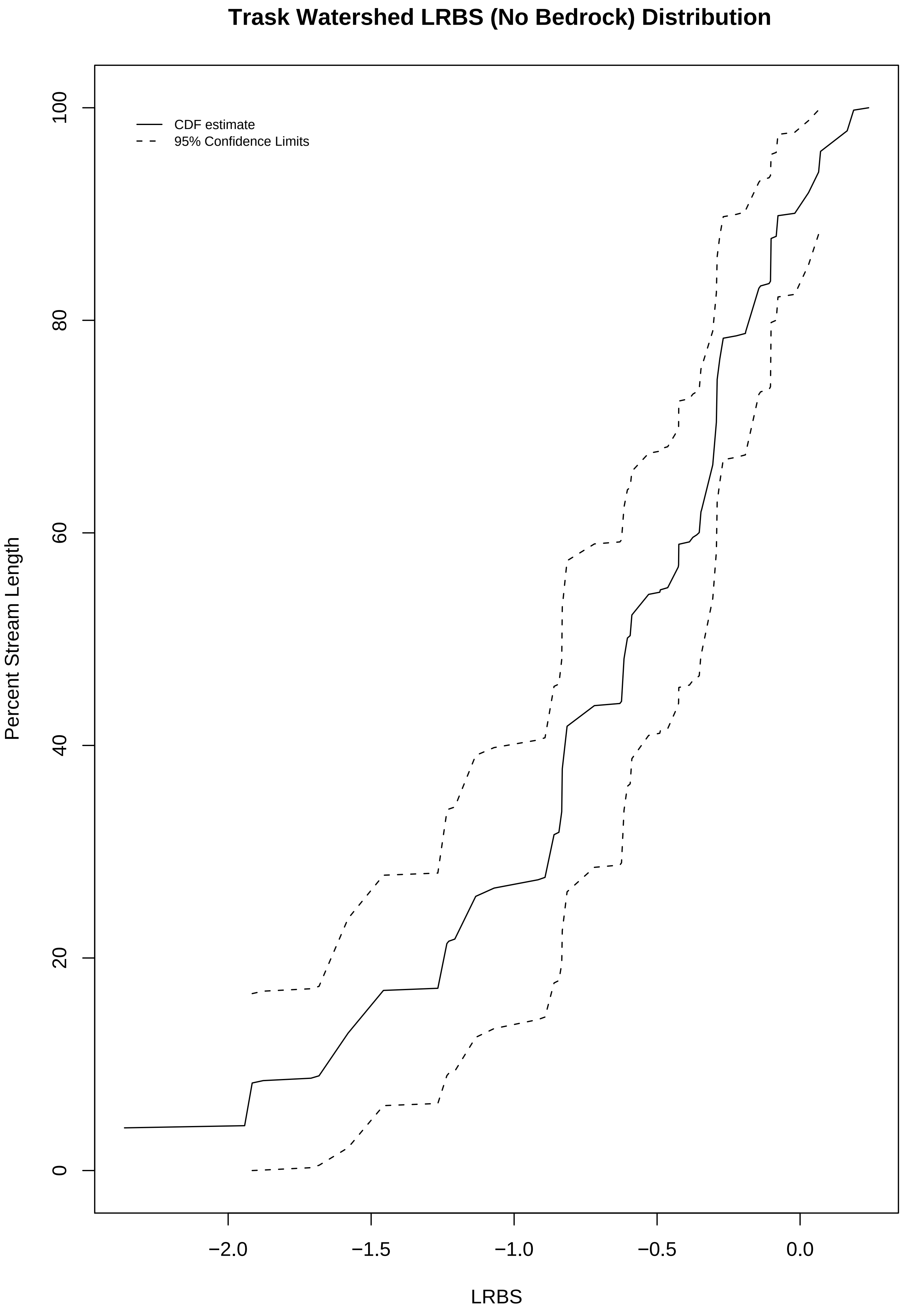

Trask Watershed R_bf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
0.5
0.6
0.7
R_bf (m)

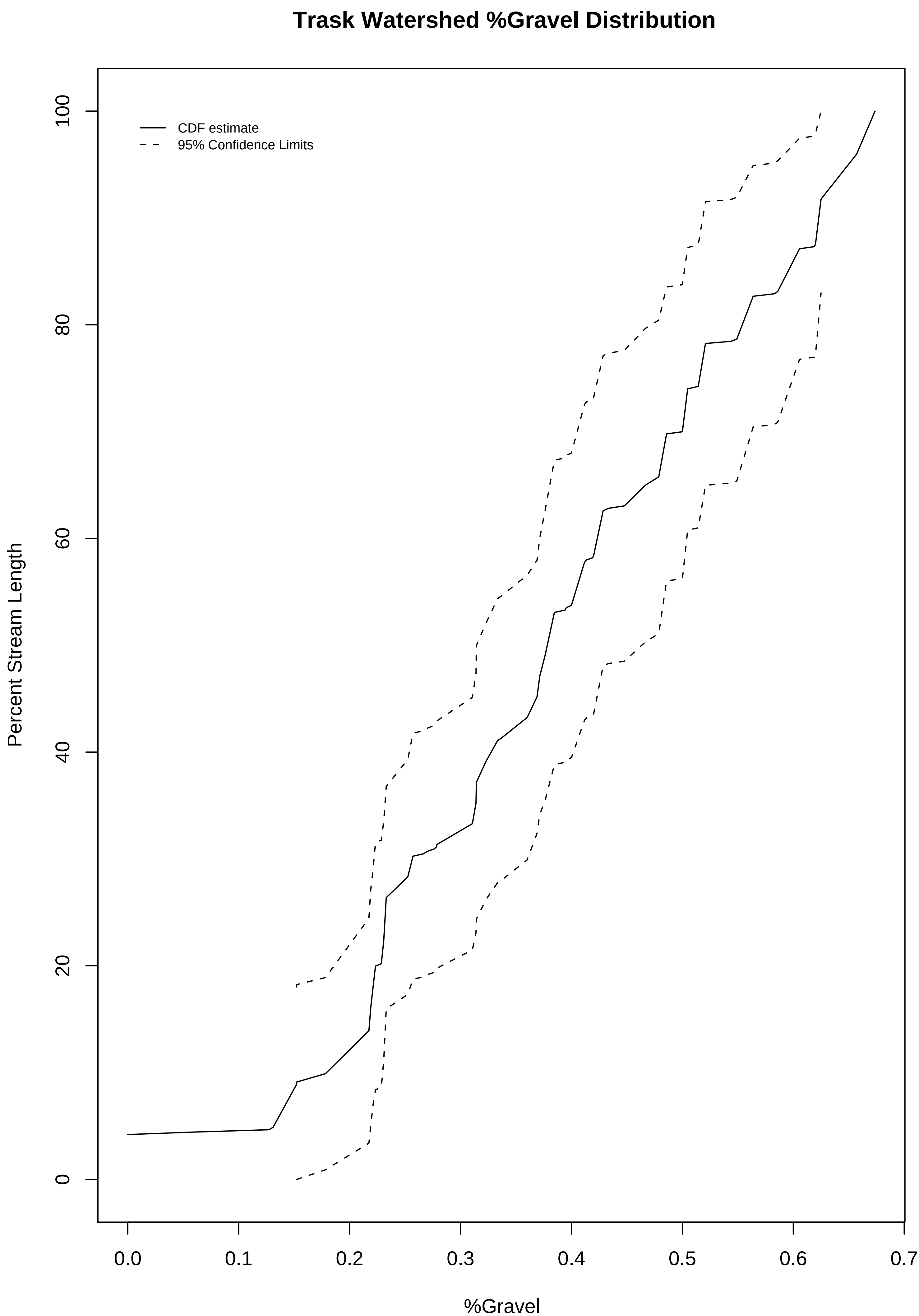


Trask Watershed R_bf* Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0
1.2
R_bf* (m)

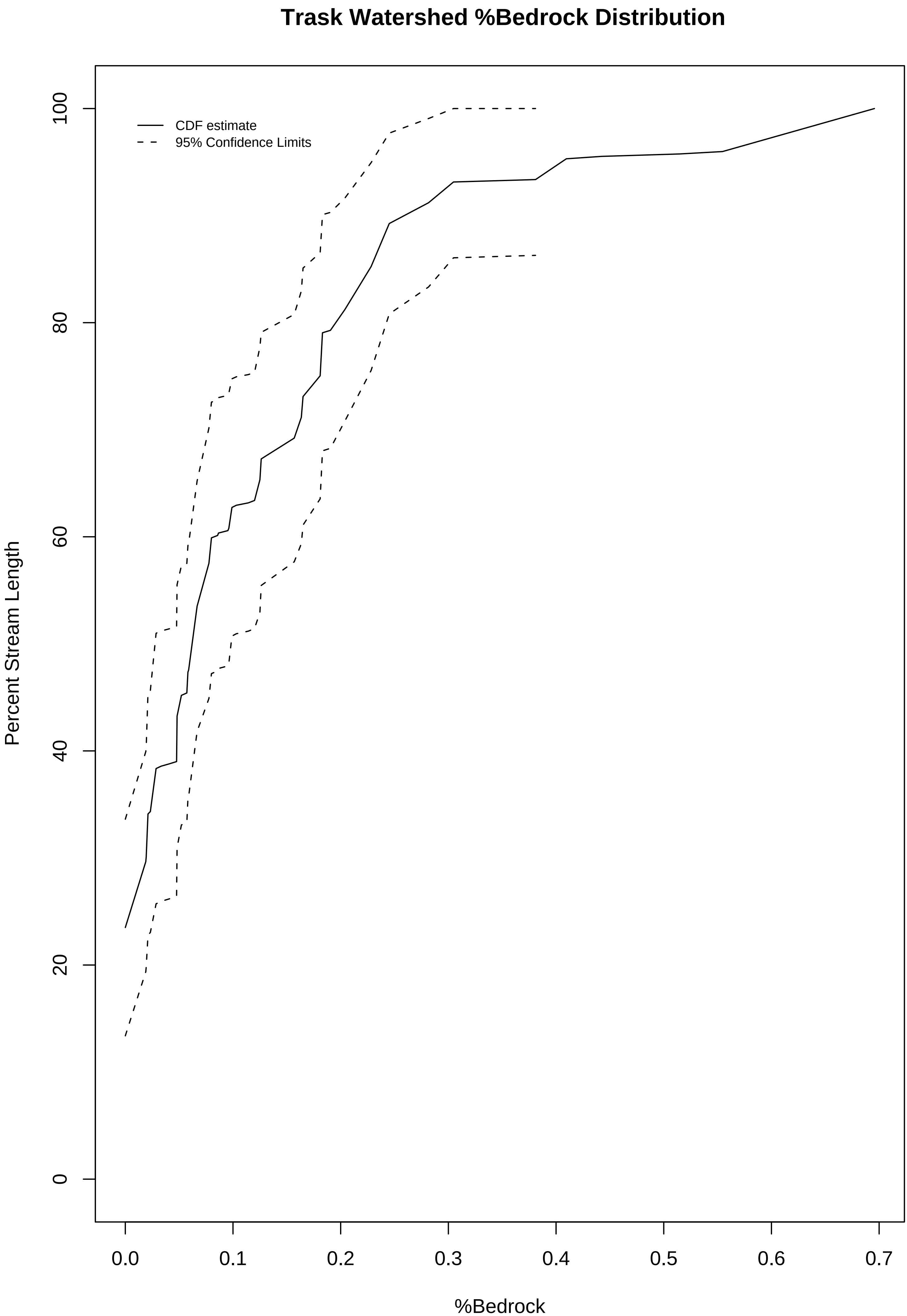


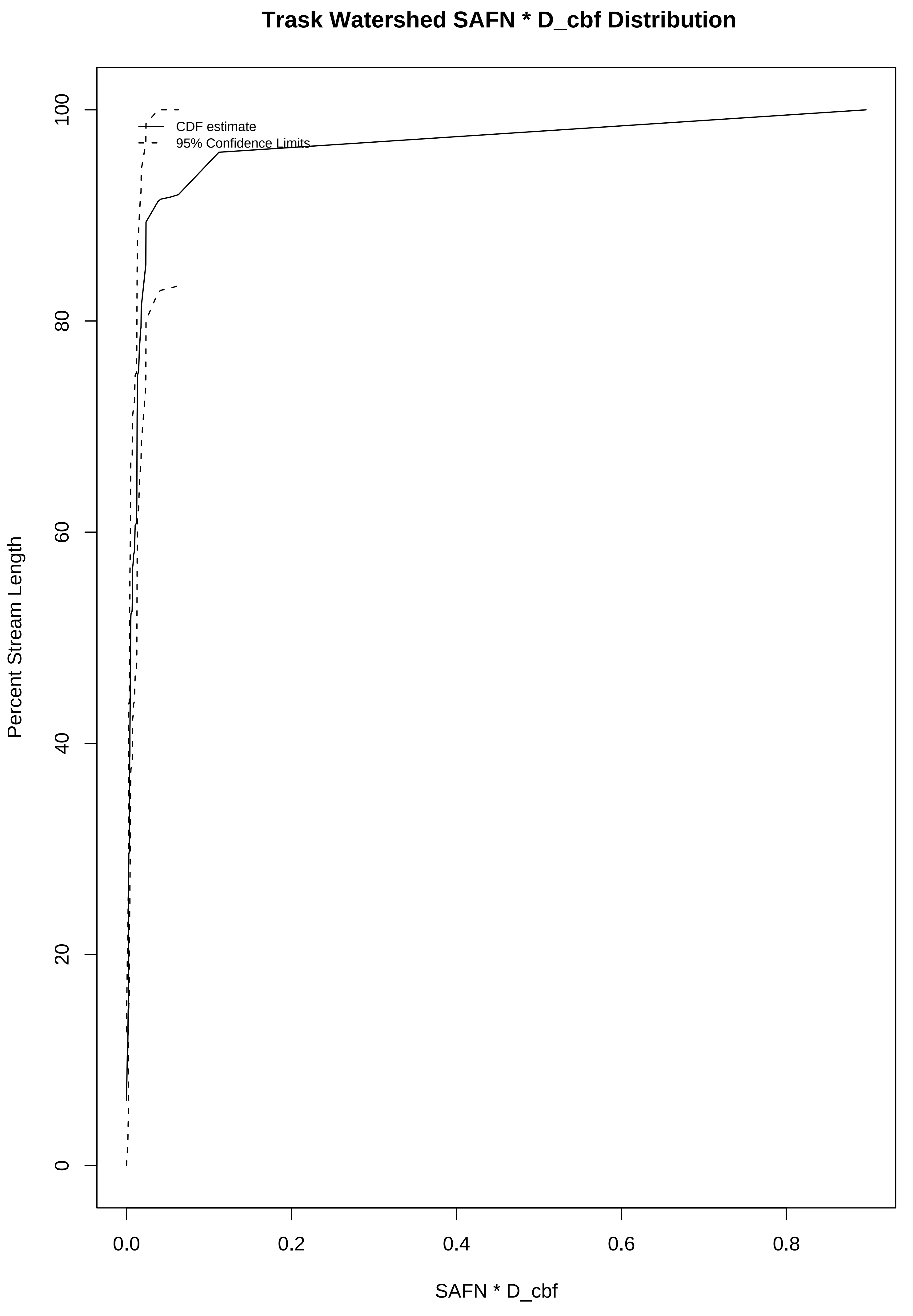
Trask Watershed Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
2
4
6
8
D_cbf (m)

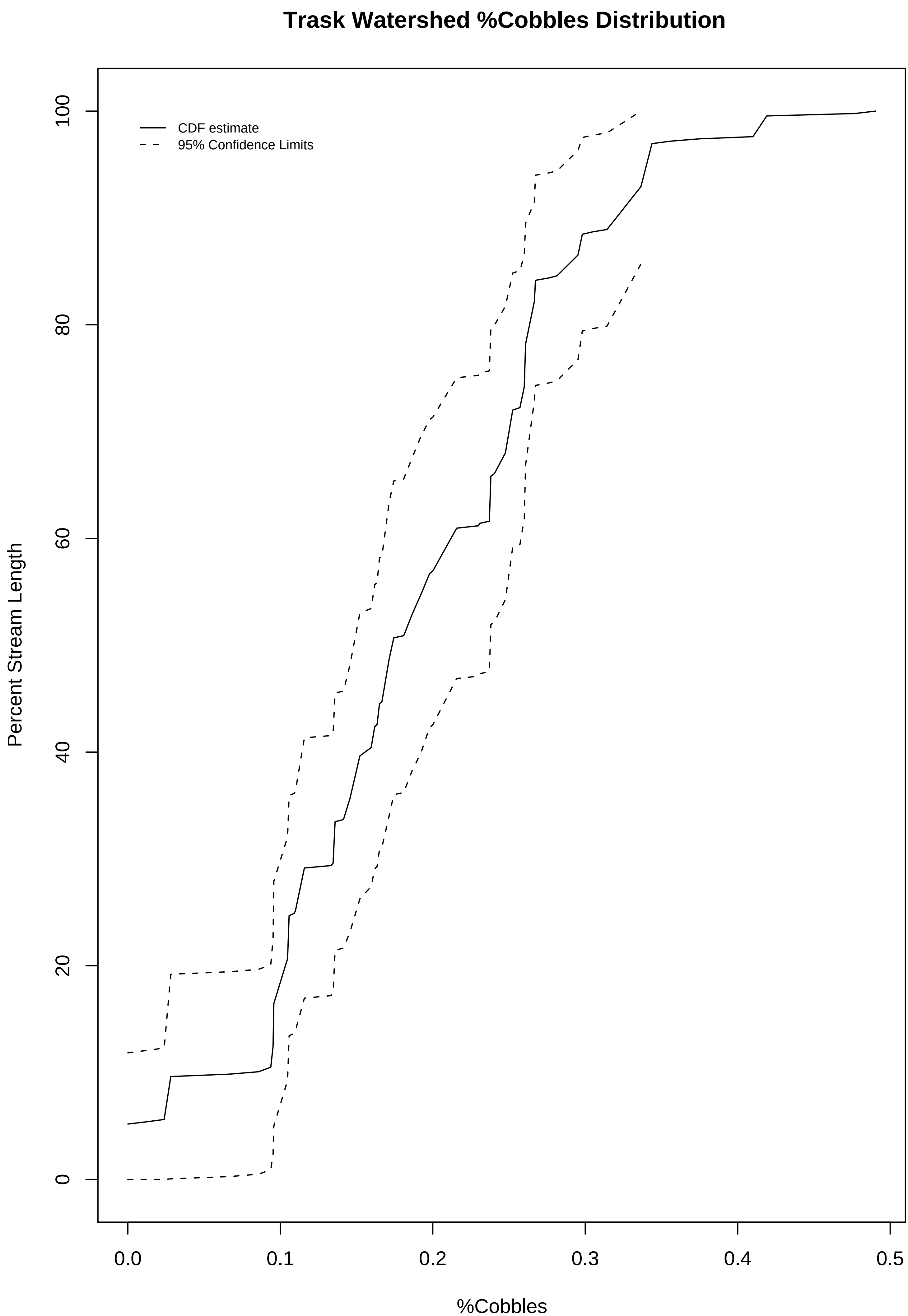

Trask Watershed LRBS (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−2.0
−1.5
−1.0
−0.5
0.0
LRBS

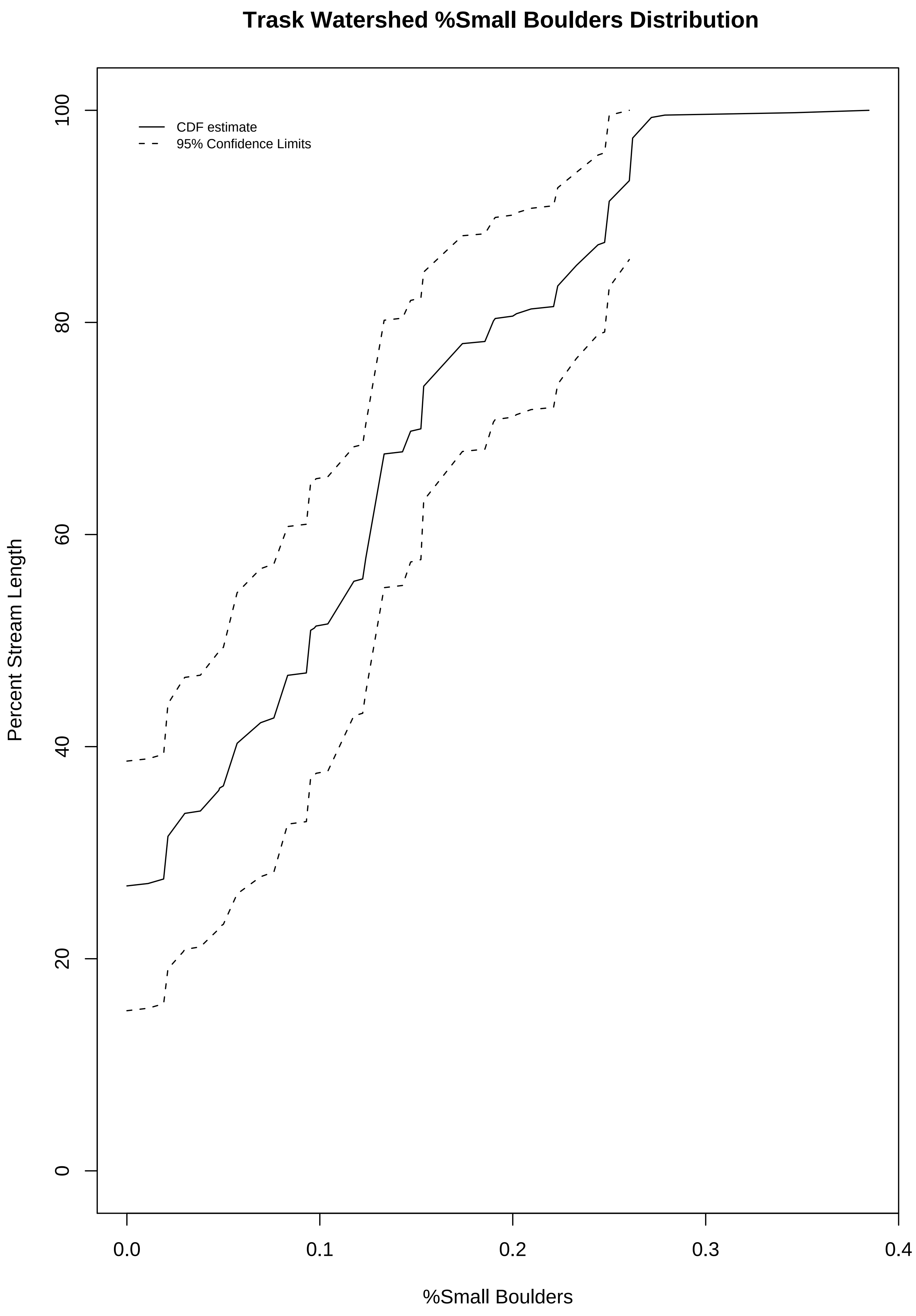


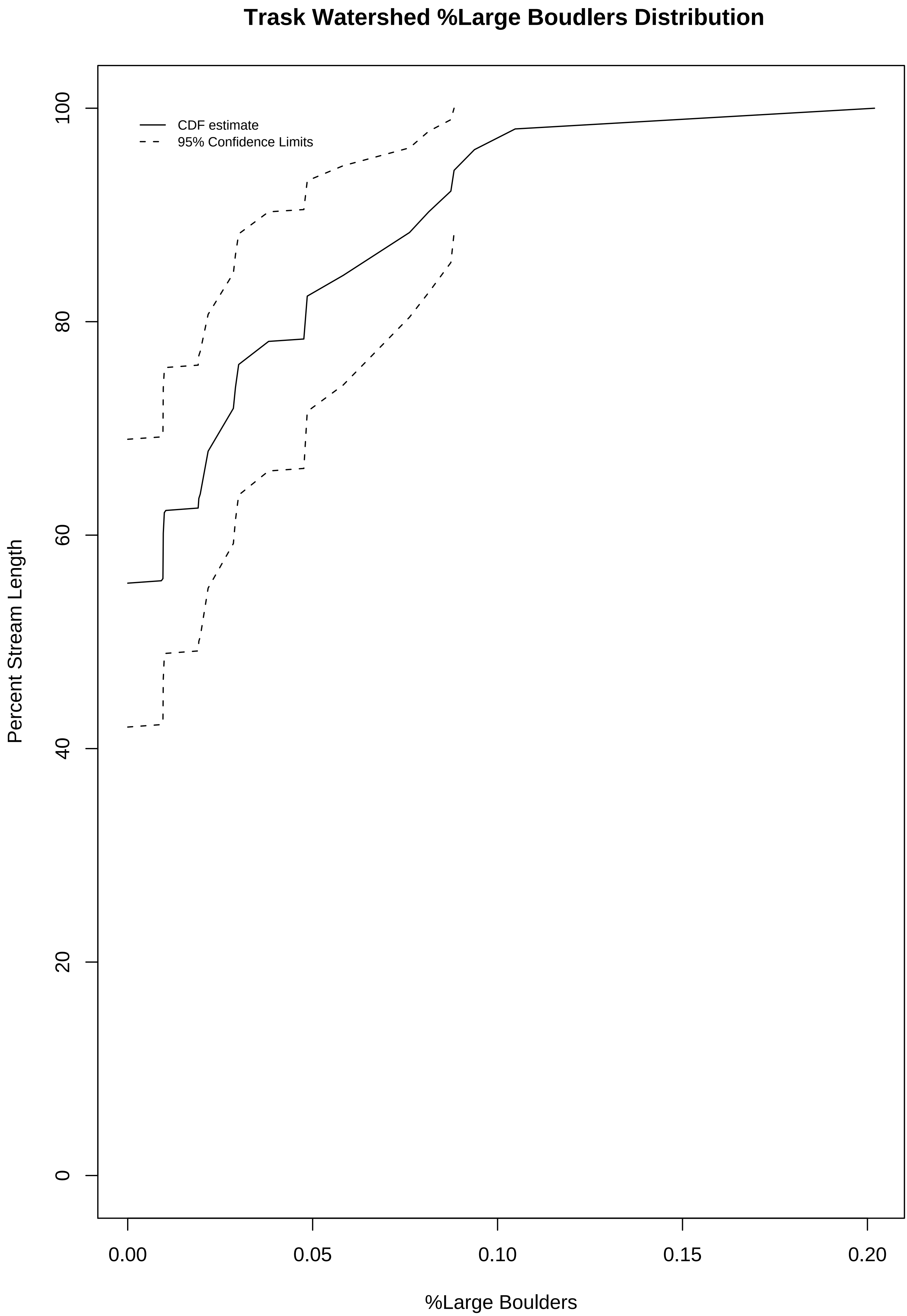
Trask Watershed %Gravel Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
%Gravel


Trask Watershed %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
%Bedrock

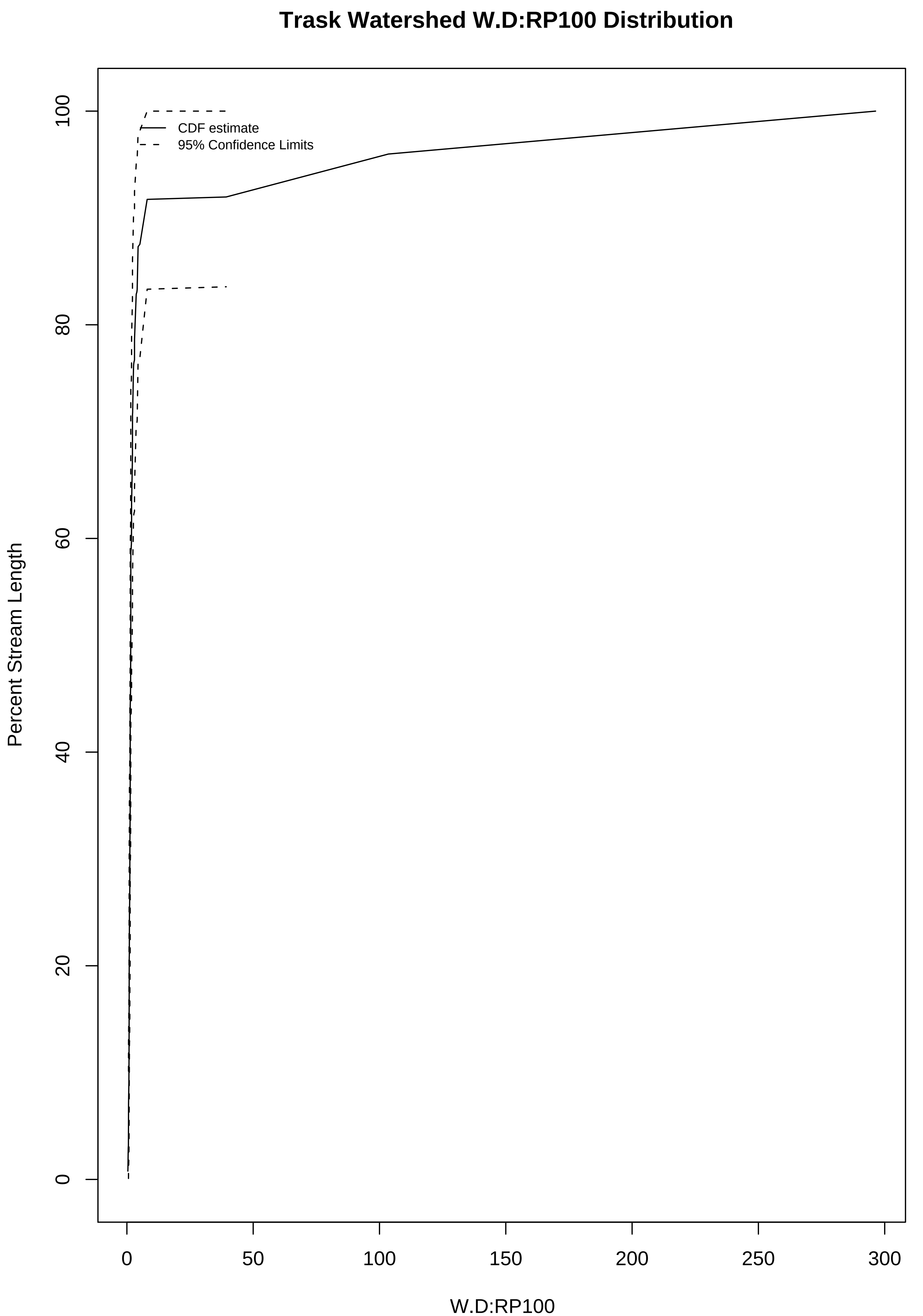

Trask Watershed SAFN * D_cbf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
SAFN * D_cbf

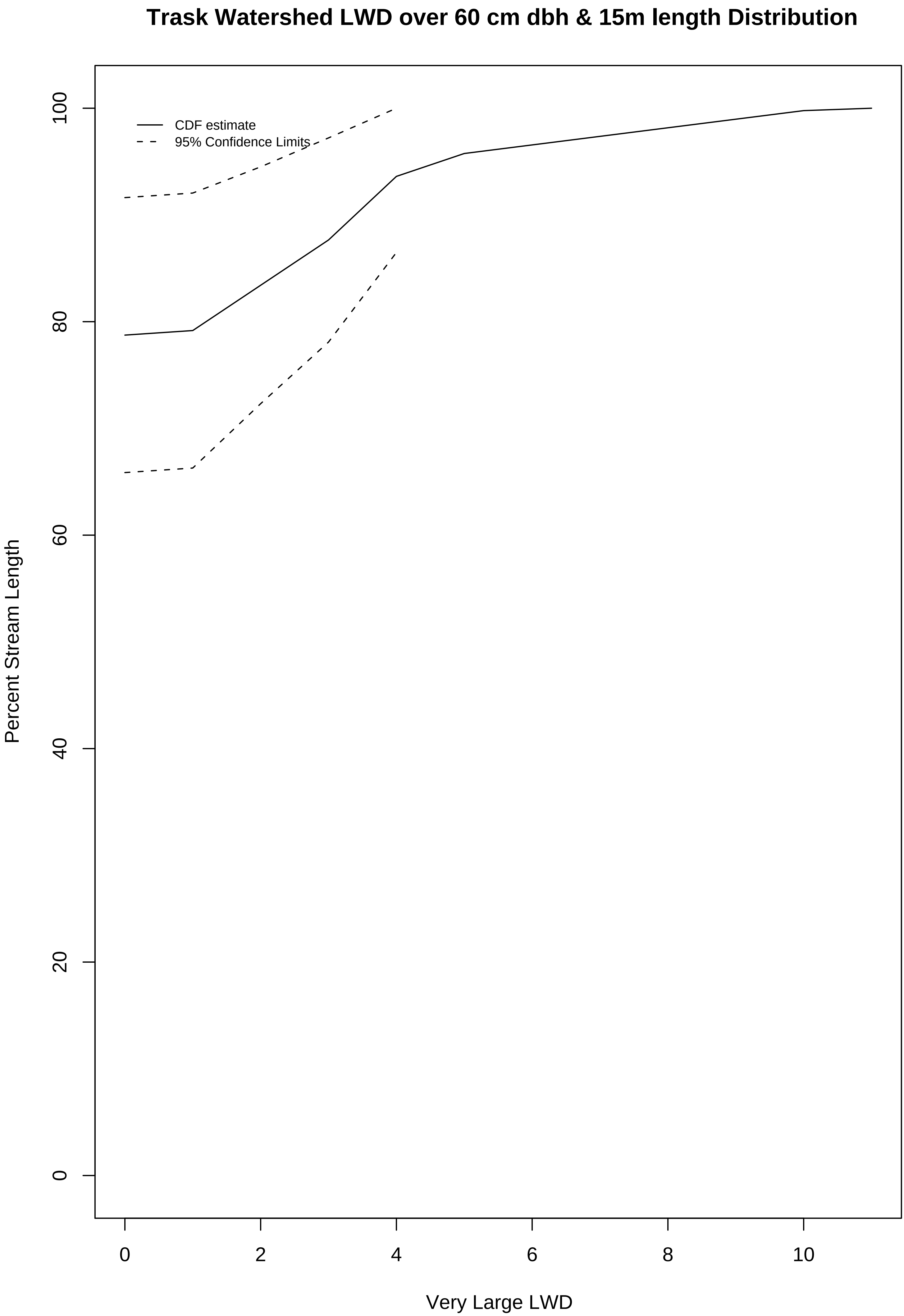

Trask Watershed %Cobbles Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
%Cobbles

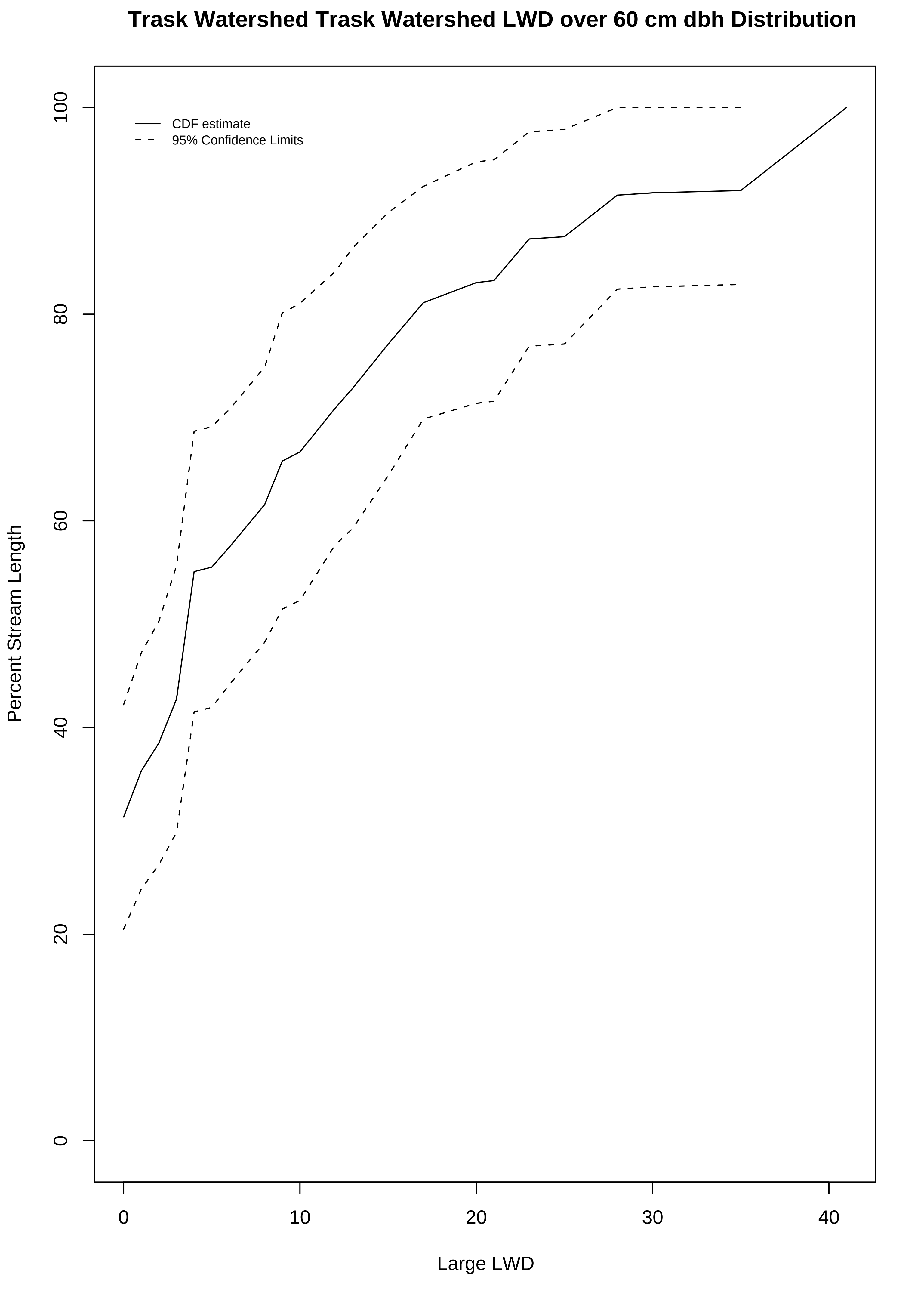

Trask Watershed %Small Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
%Small Boulders



Trask Watershed %Large Boudlers Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
%Large Boulders

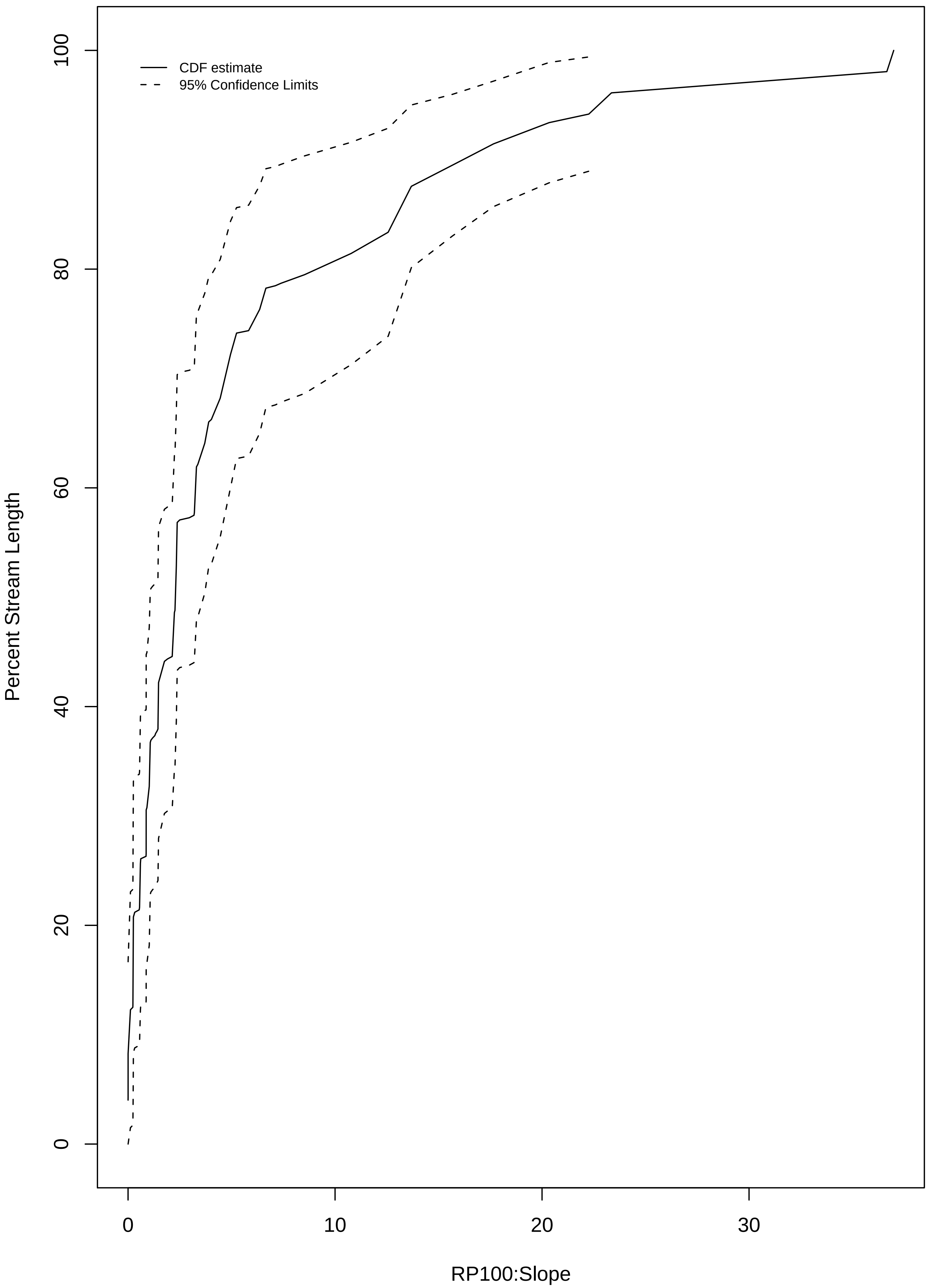

Trask Watershed W.D:RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
50
100
150
200
250
300
W.D:RP100

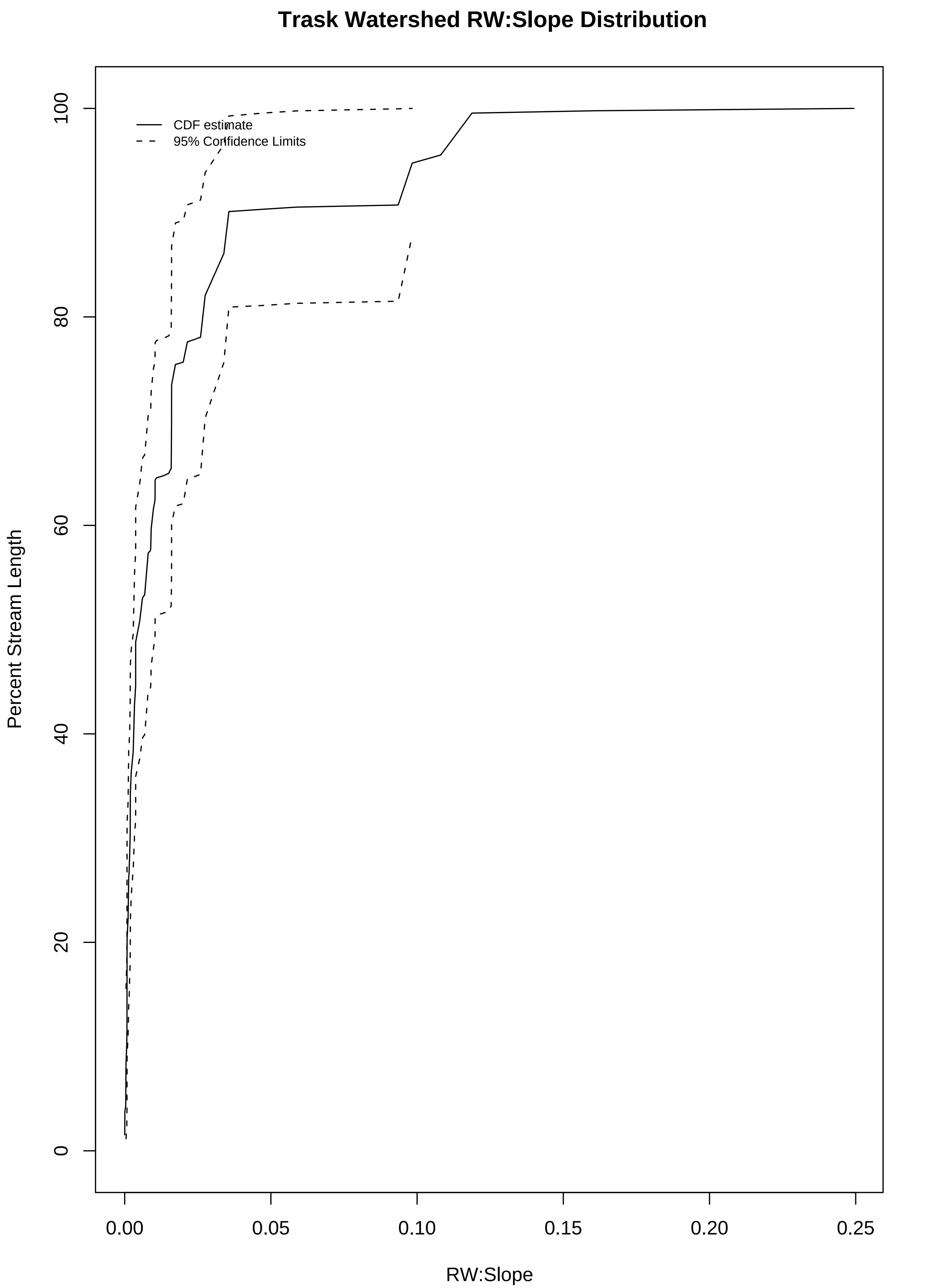

Trask Watershed LWD over 60 cm dbh & 15m length Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
2
4
6
8
10
Very Large LWD



Trask Watershed Trask Watershed LWD over 60 cm dbh Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
Large LWD
0
20
40
60
80
100
0
10
20
30
40

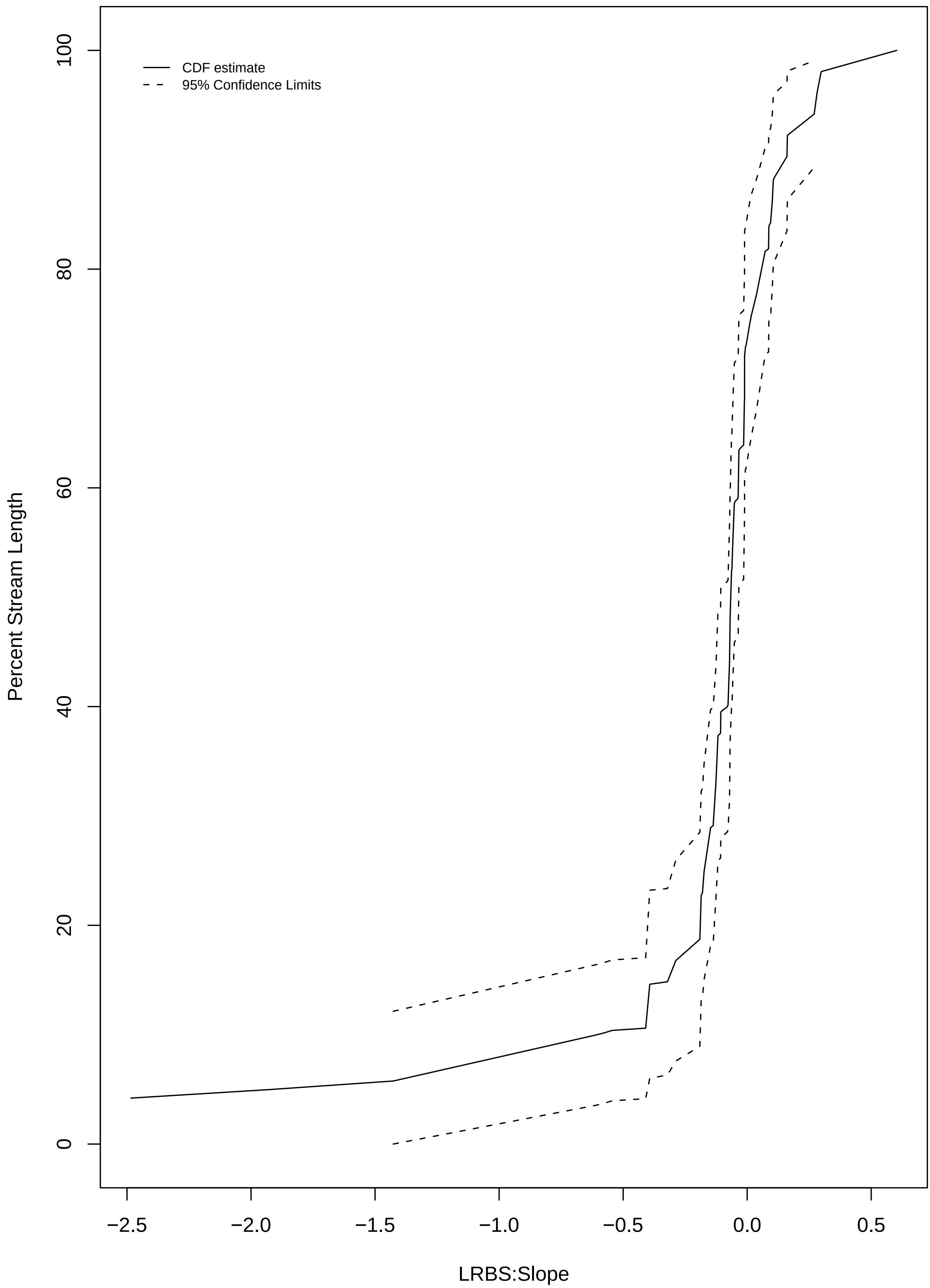
Trask Watershed RP100:Slope Distribution

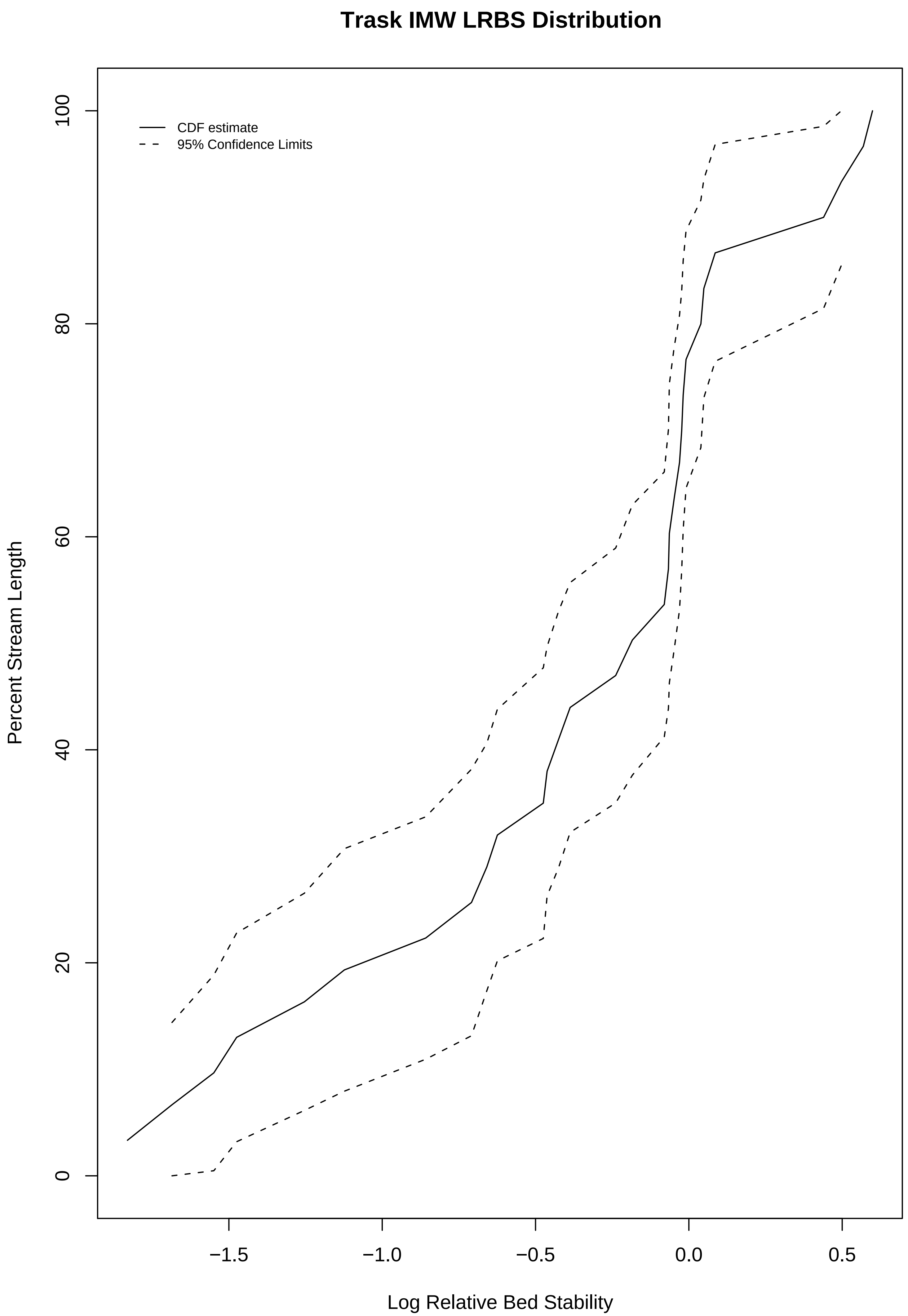


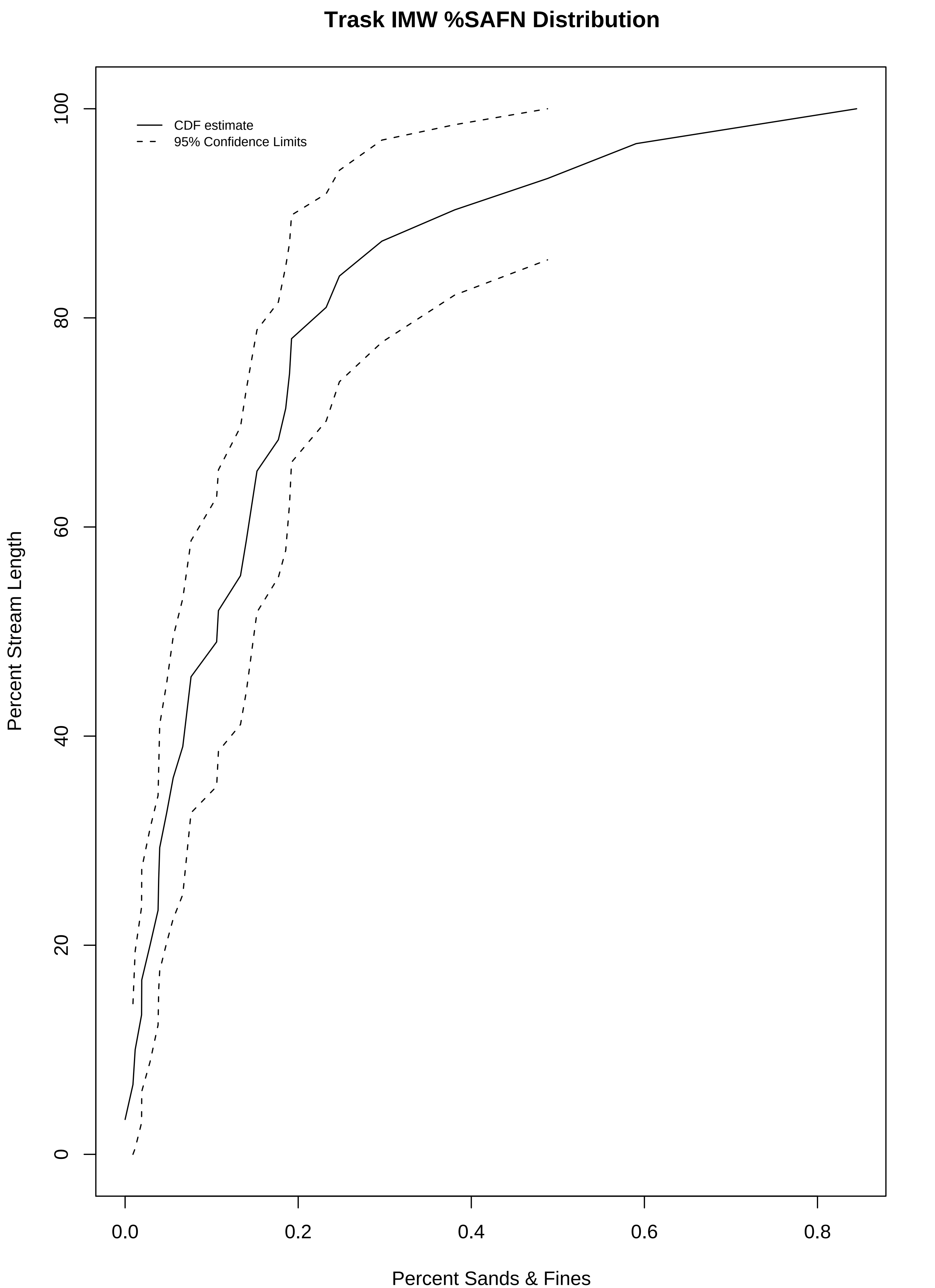


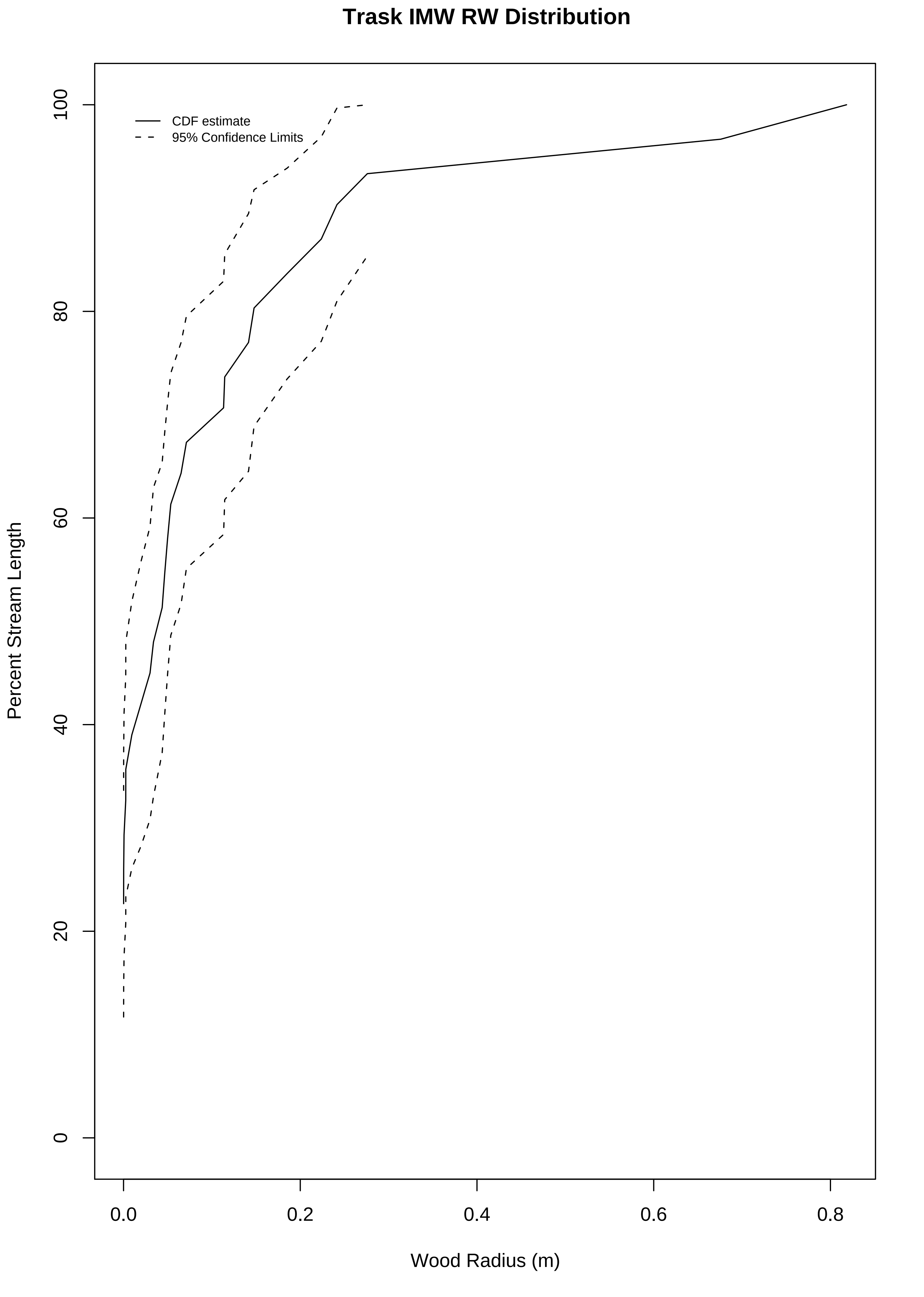
Trask Watershed RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
RW:Slope

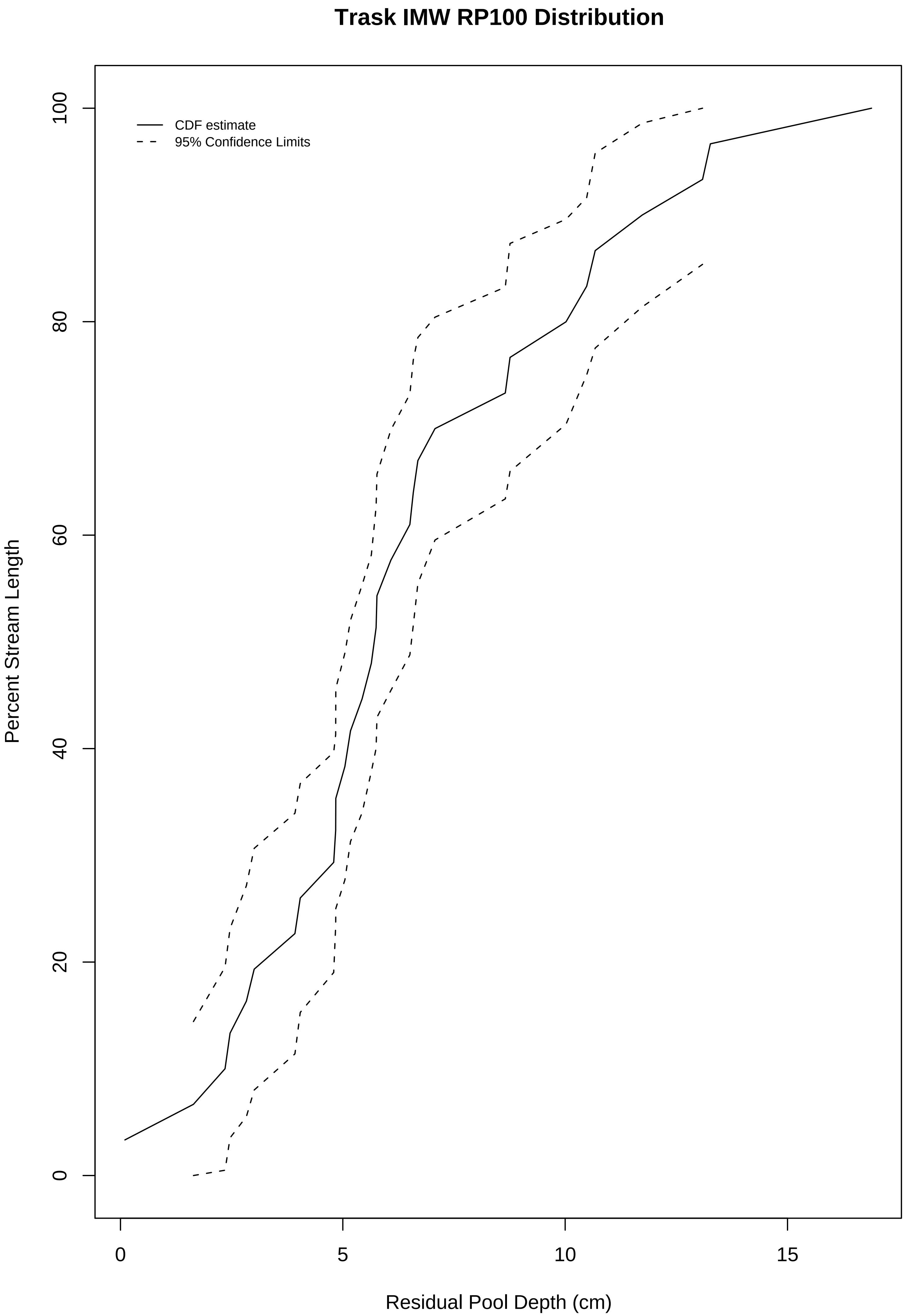
Trask Watershed LRBS:Slope Distribution



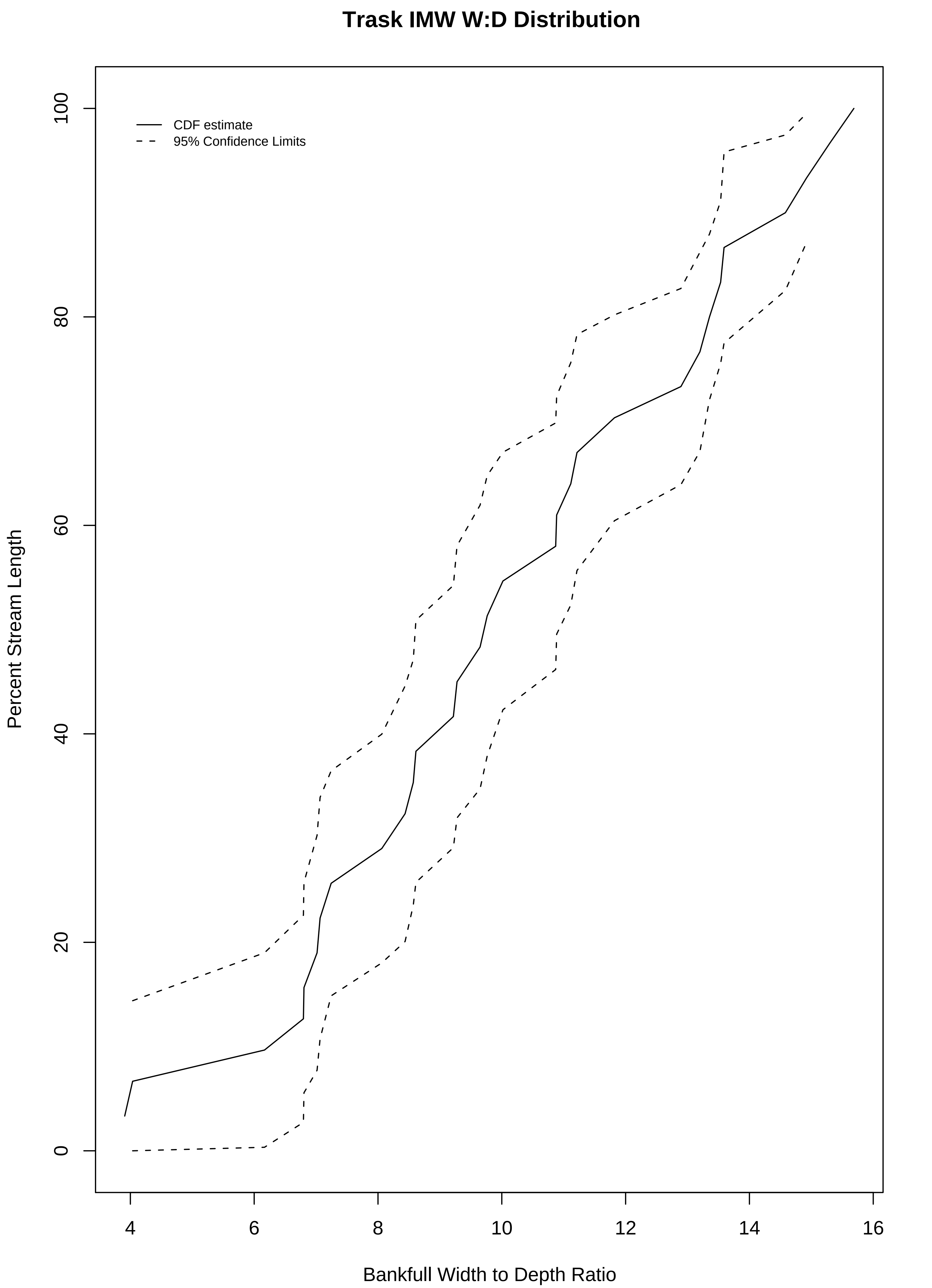

Trask IMW LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−1.5
−1.0
−0.5
0.0
0.5
Log Relative Bed Stability


Trask IMW %SAFN Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
Percent Sands & Fines
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8

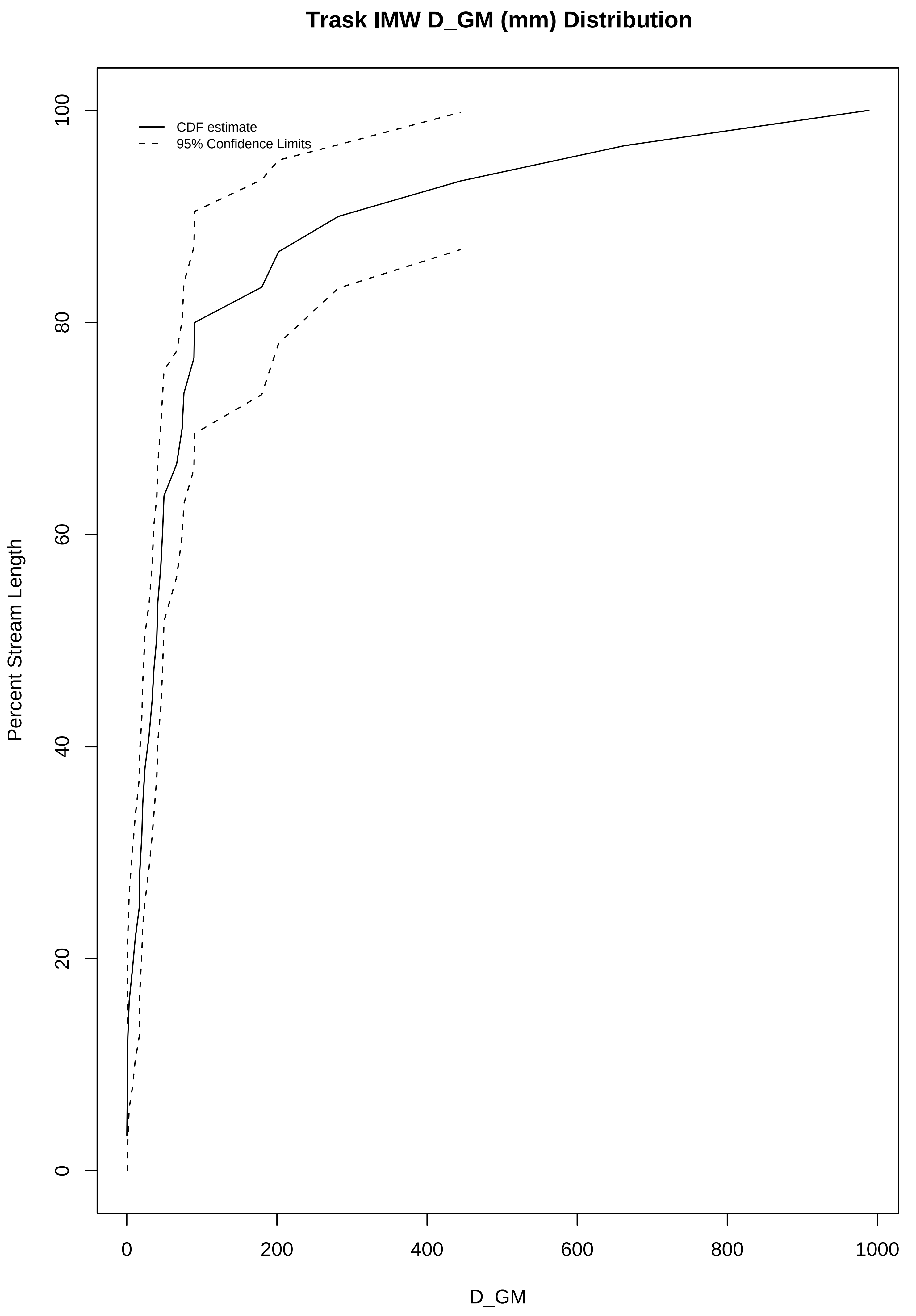

Trask IMW RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
Wood Radius (m)
0.0
0.2
0.4
0.6
0.8

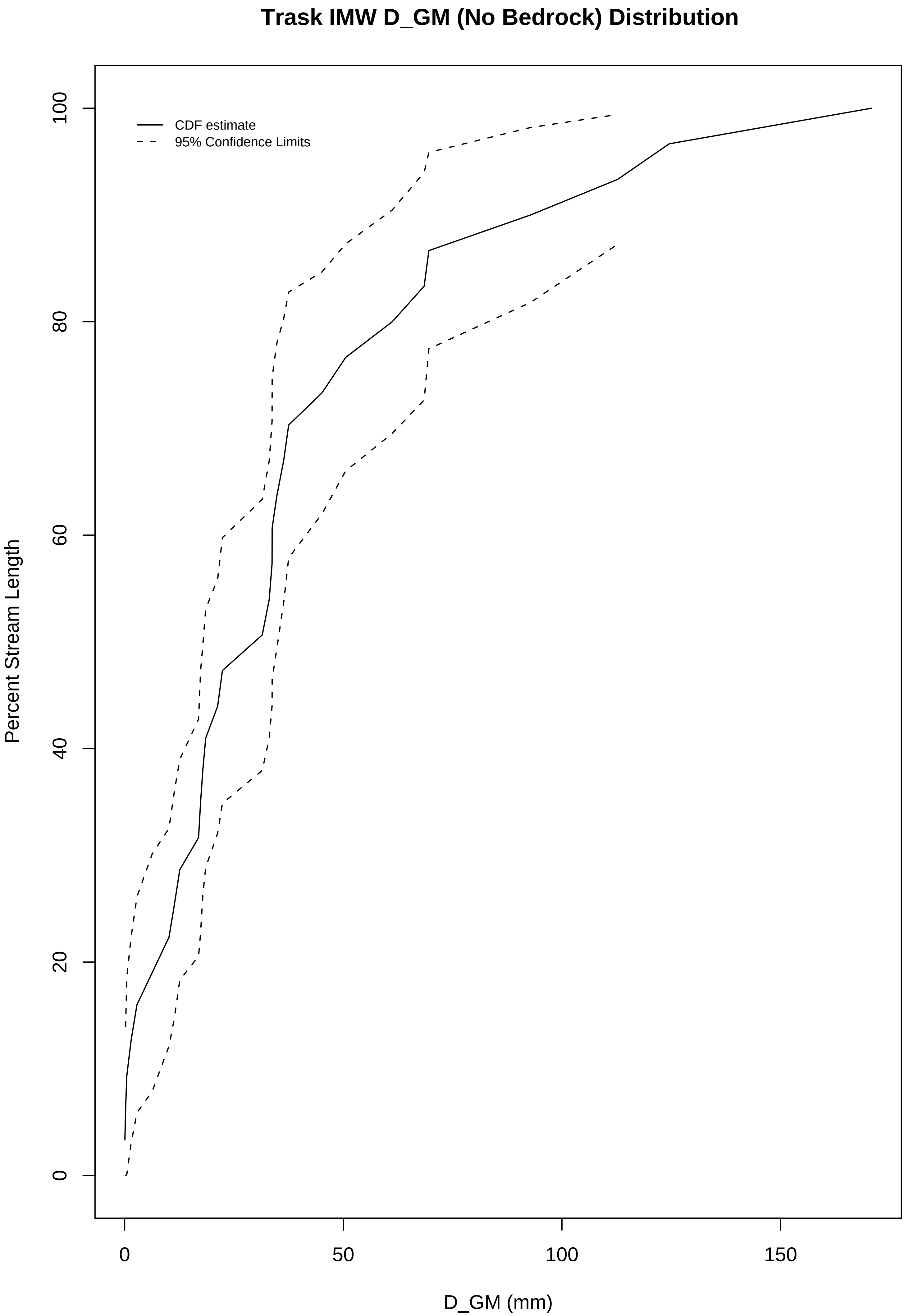


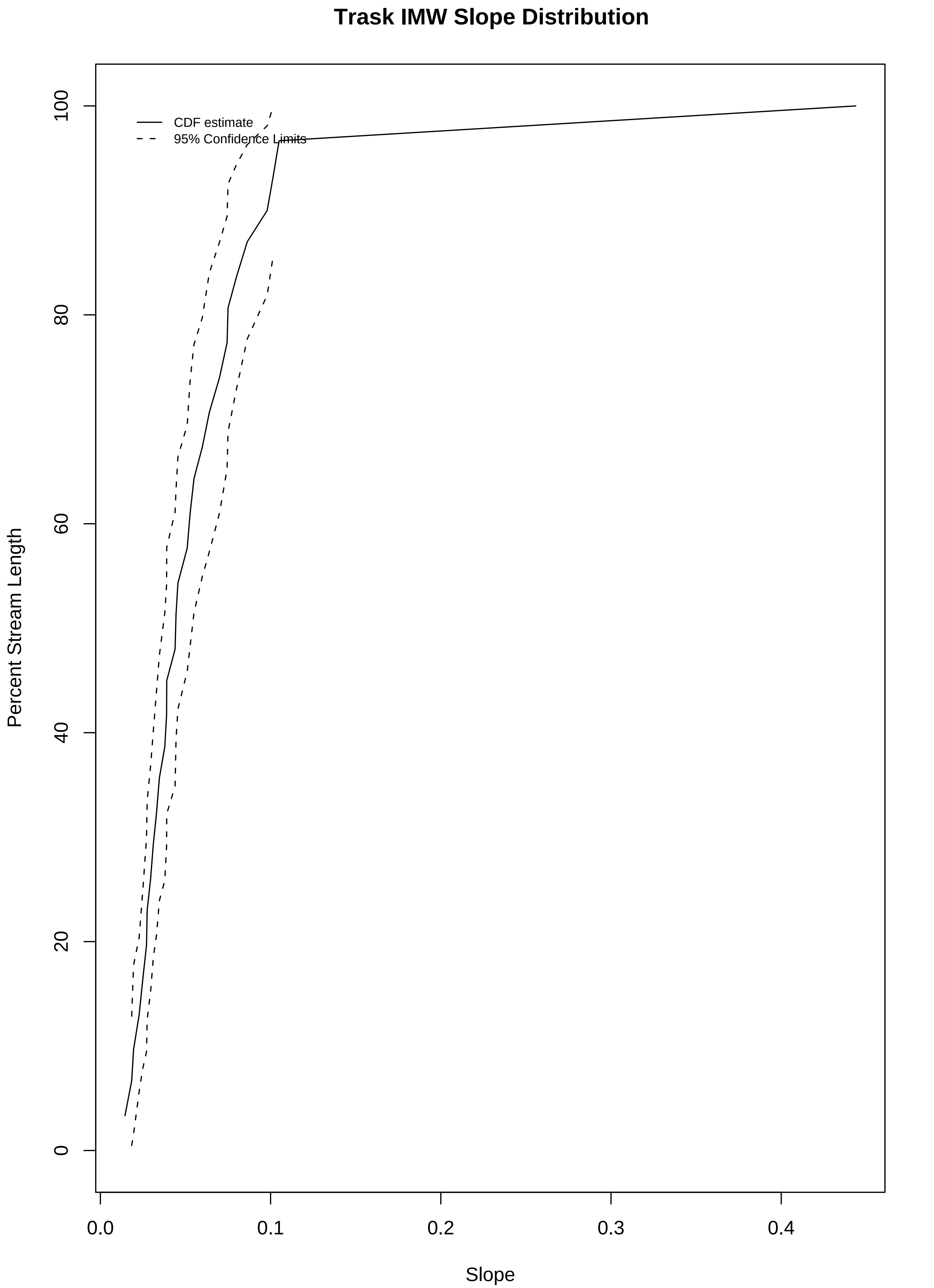
Trask IMW RP100 Distribution
CDF estimate
95% Confidence Limits
100
80
60
40
20
0
Percent Stream Length
0
5
10
15
Residual Pool Depth (cm)



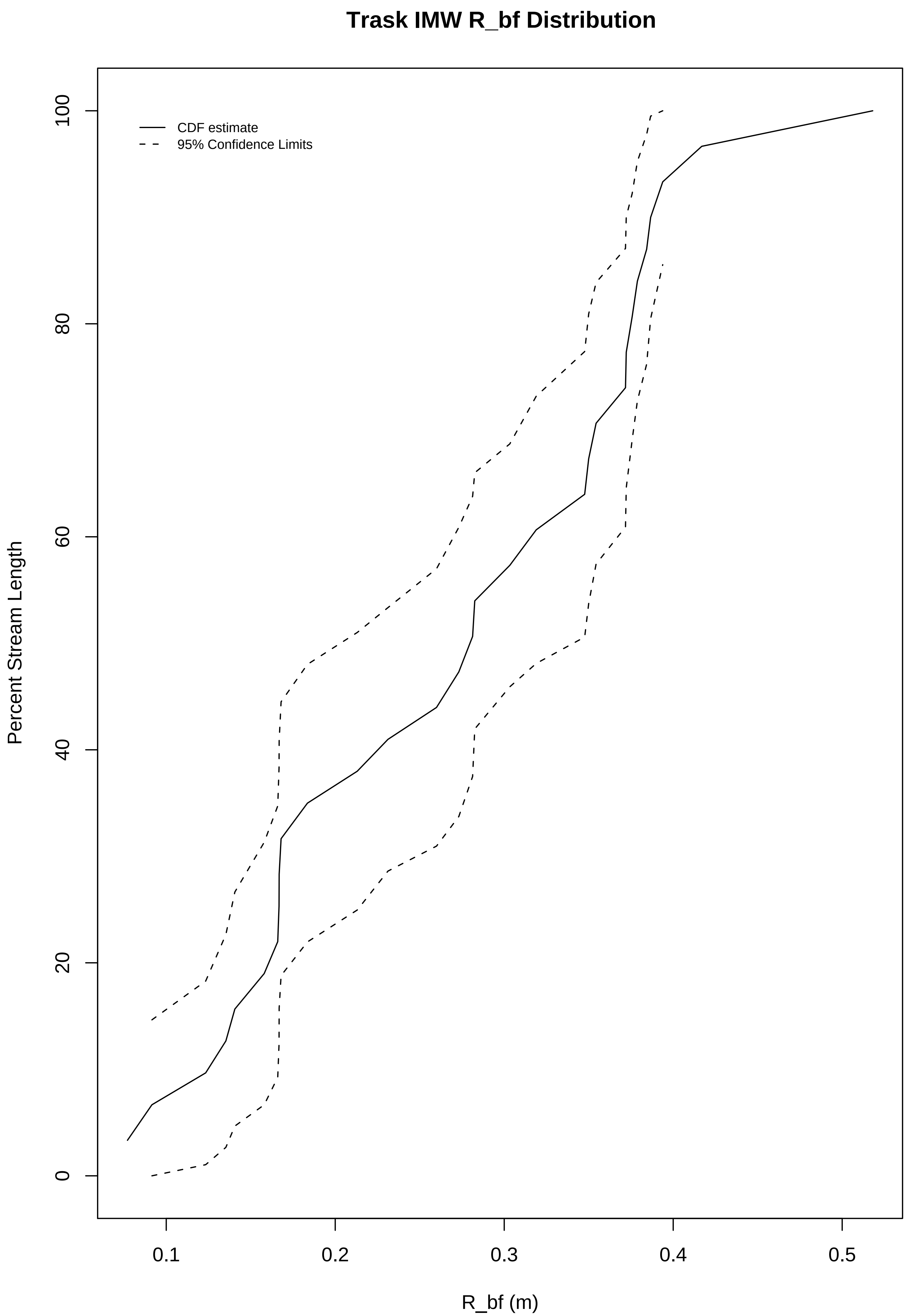
Trask IMW W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
4
6
8
10
12
14
16
Bankfull Width to Depth Ratio

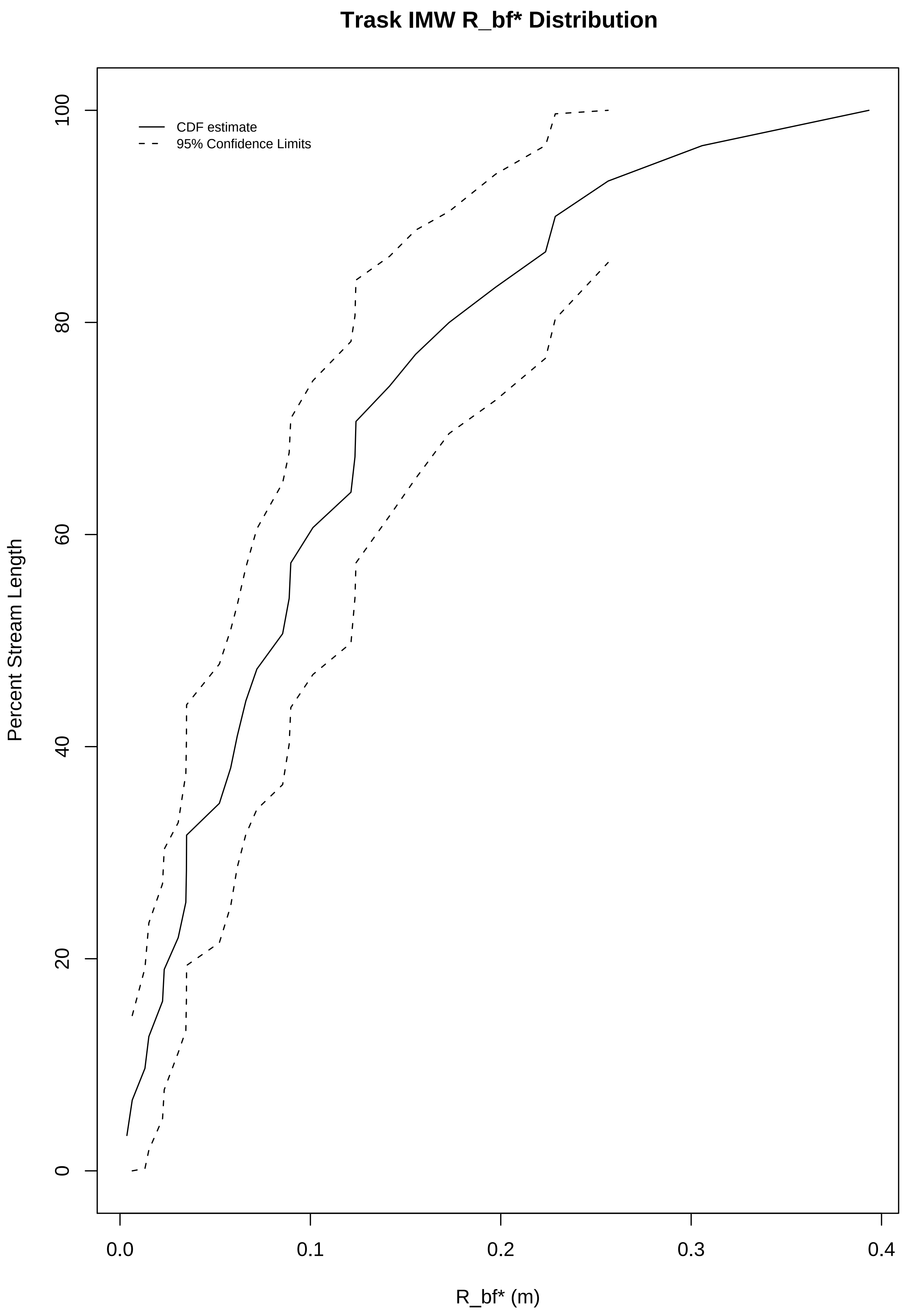

Trask IMW D_GM (mm) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
200
400
600
800
1000
D_GM


Trask IMW D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
50
100
150
D_GM (mm)

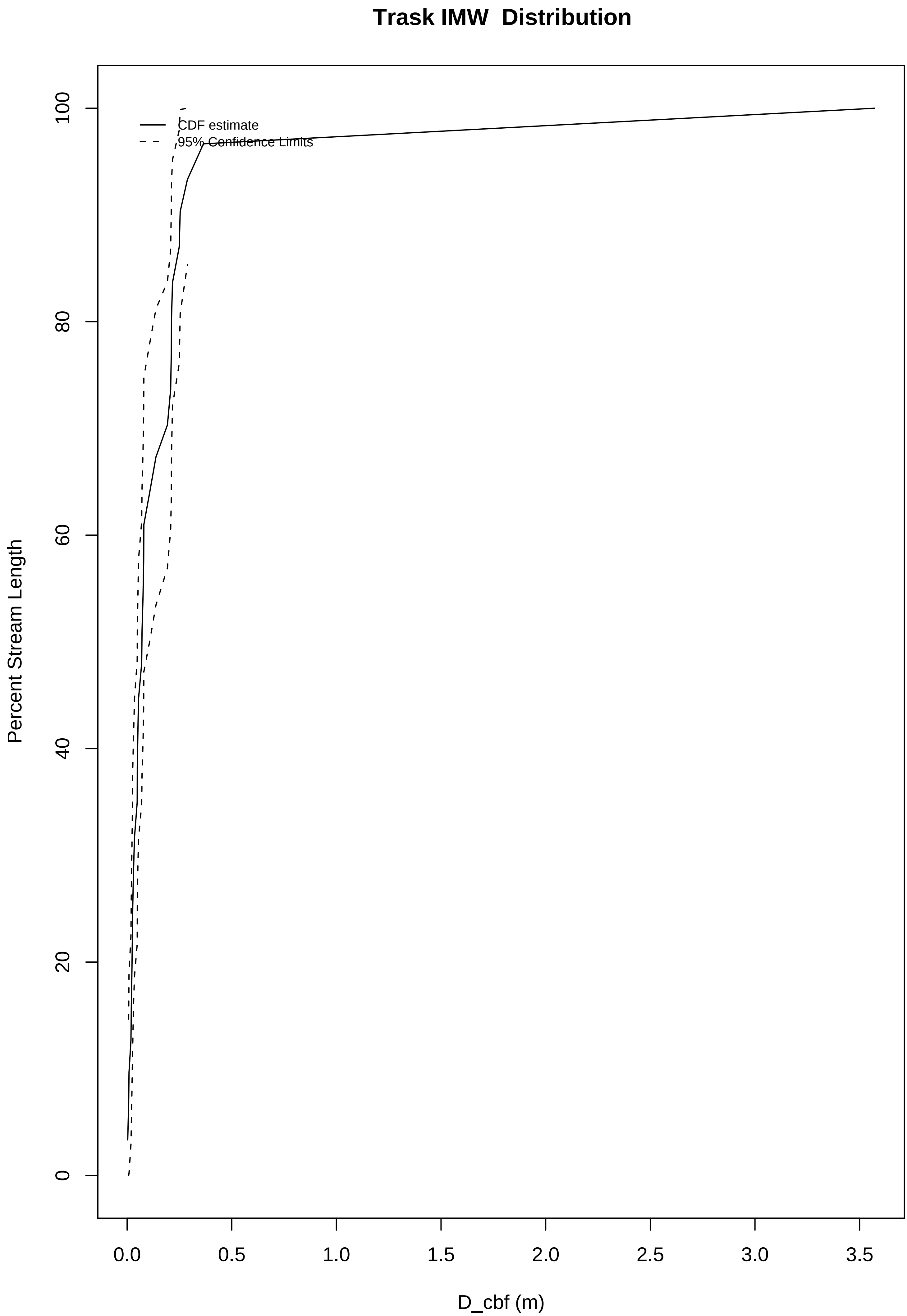


Trask IMW Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
Slope

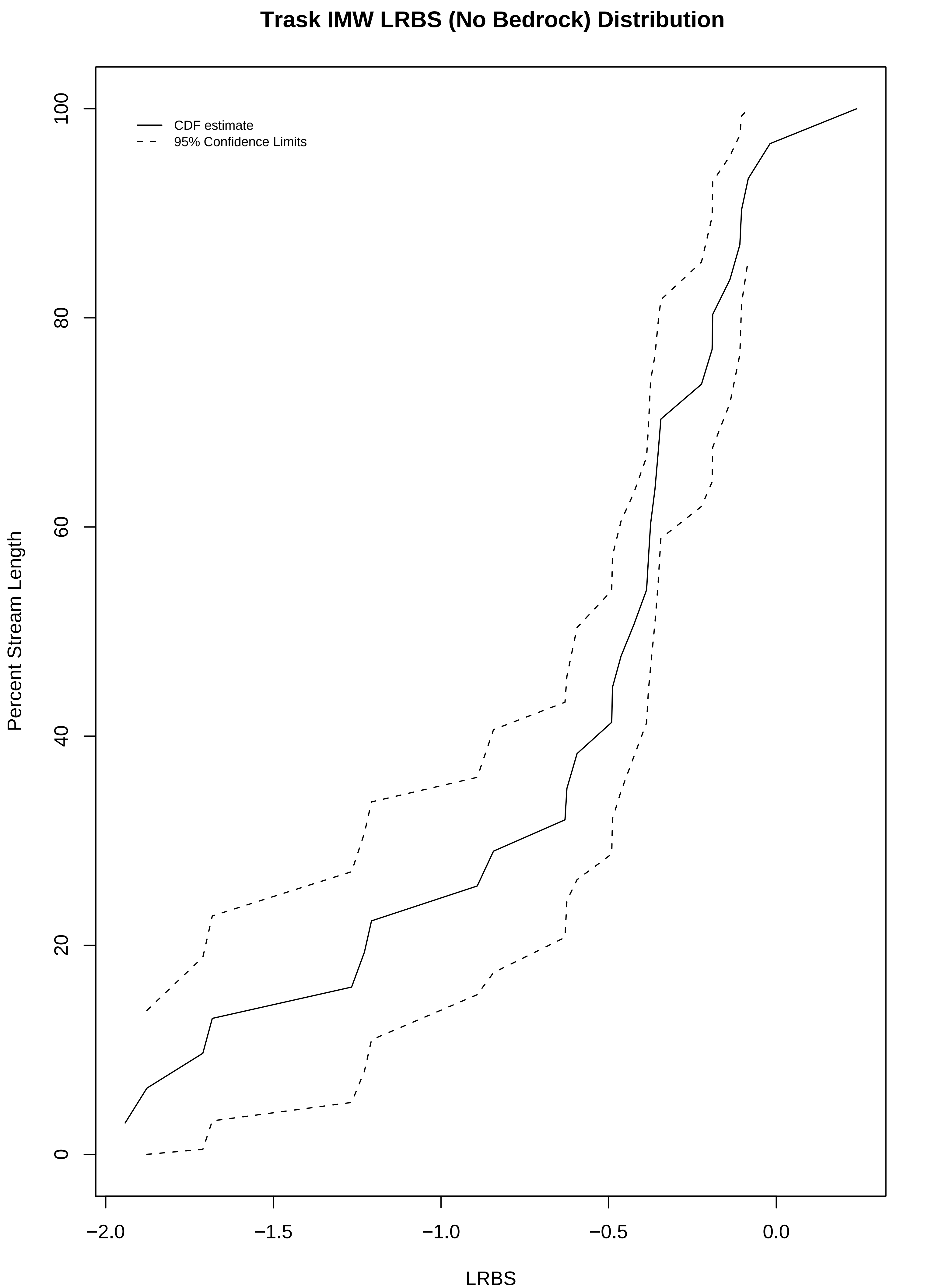

Trask IMW R_bf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
0.5
R_bf (m)



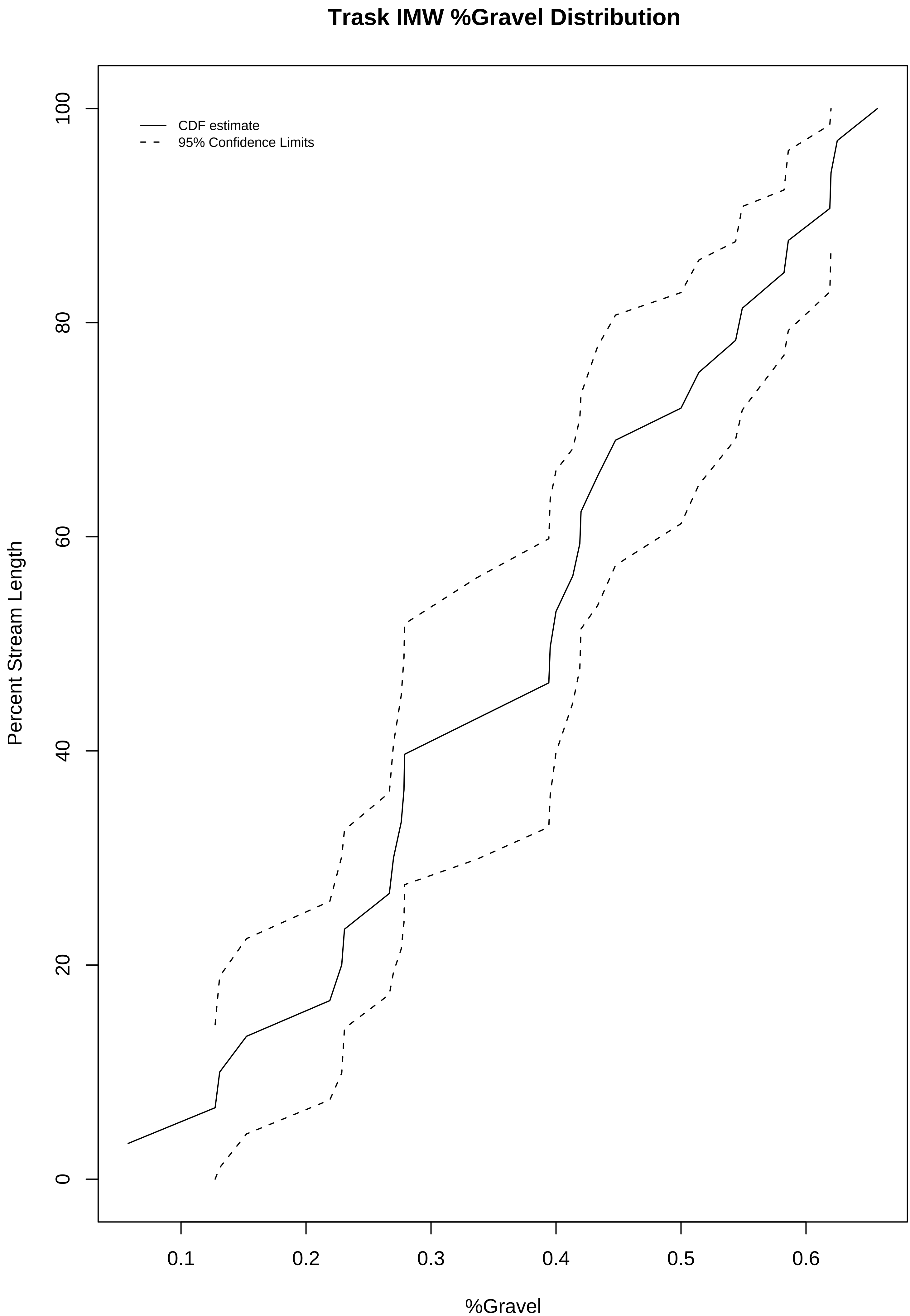
Trask IMW R_bf* Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
R_bf* (m)



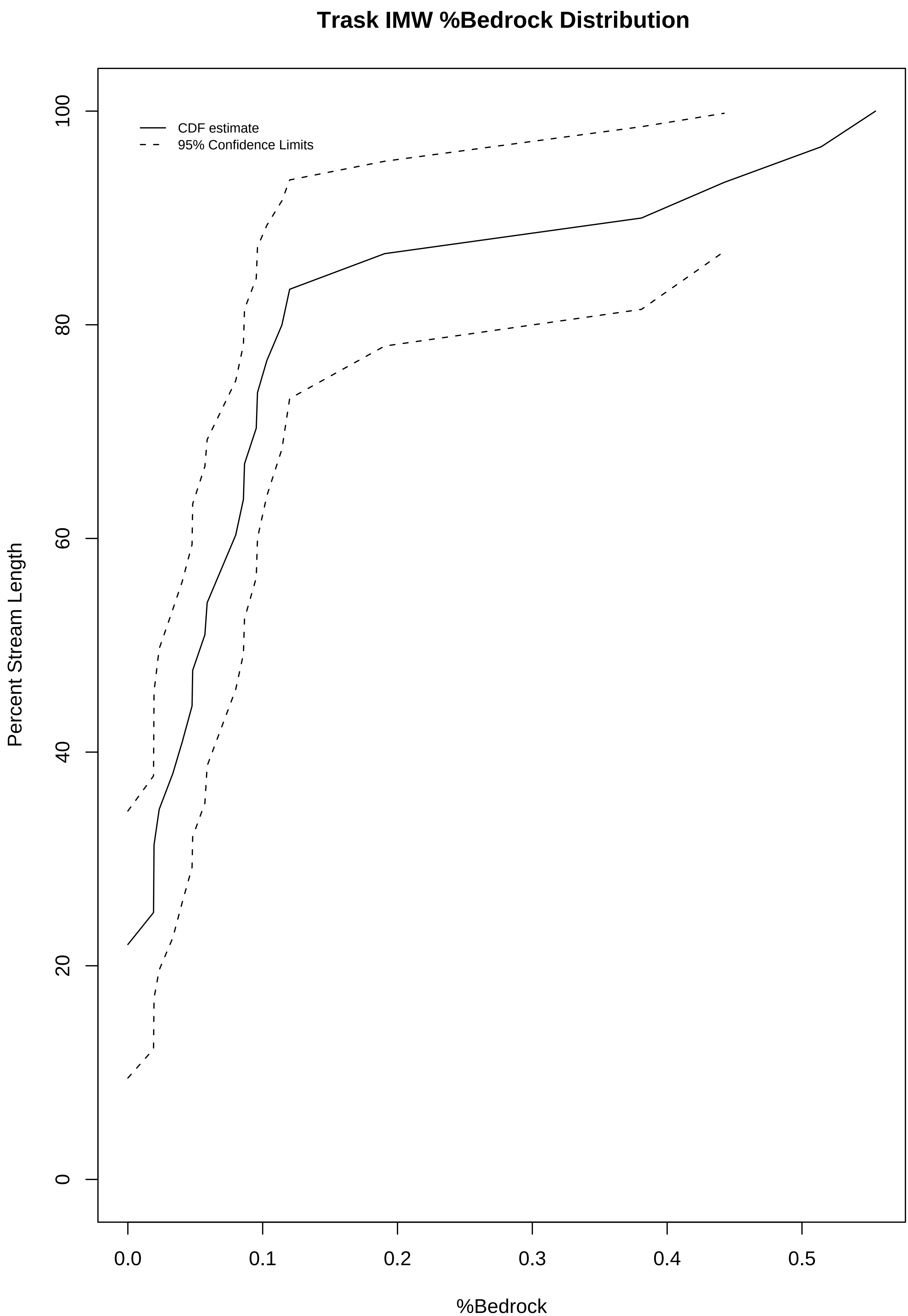
Trask IMW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
D_cbf (m)



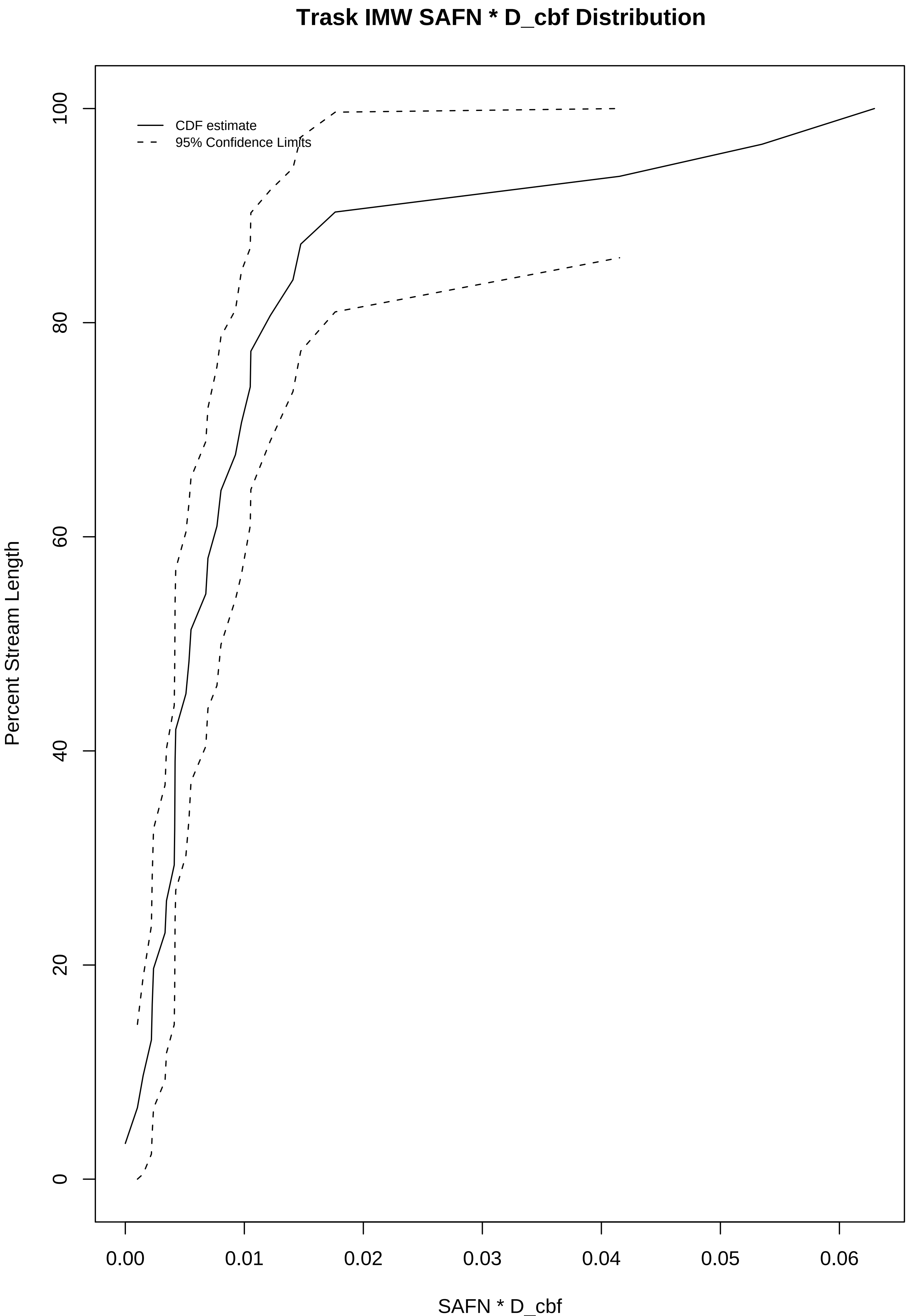
Trask IMW LRBS (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
LRBS
−2.0
−1.5
−1.0
−0.5
0.0



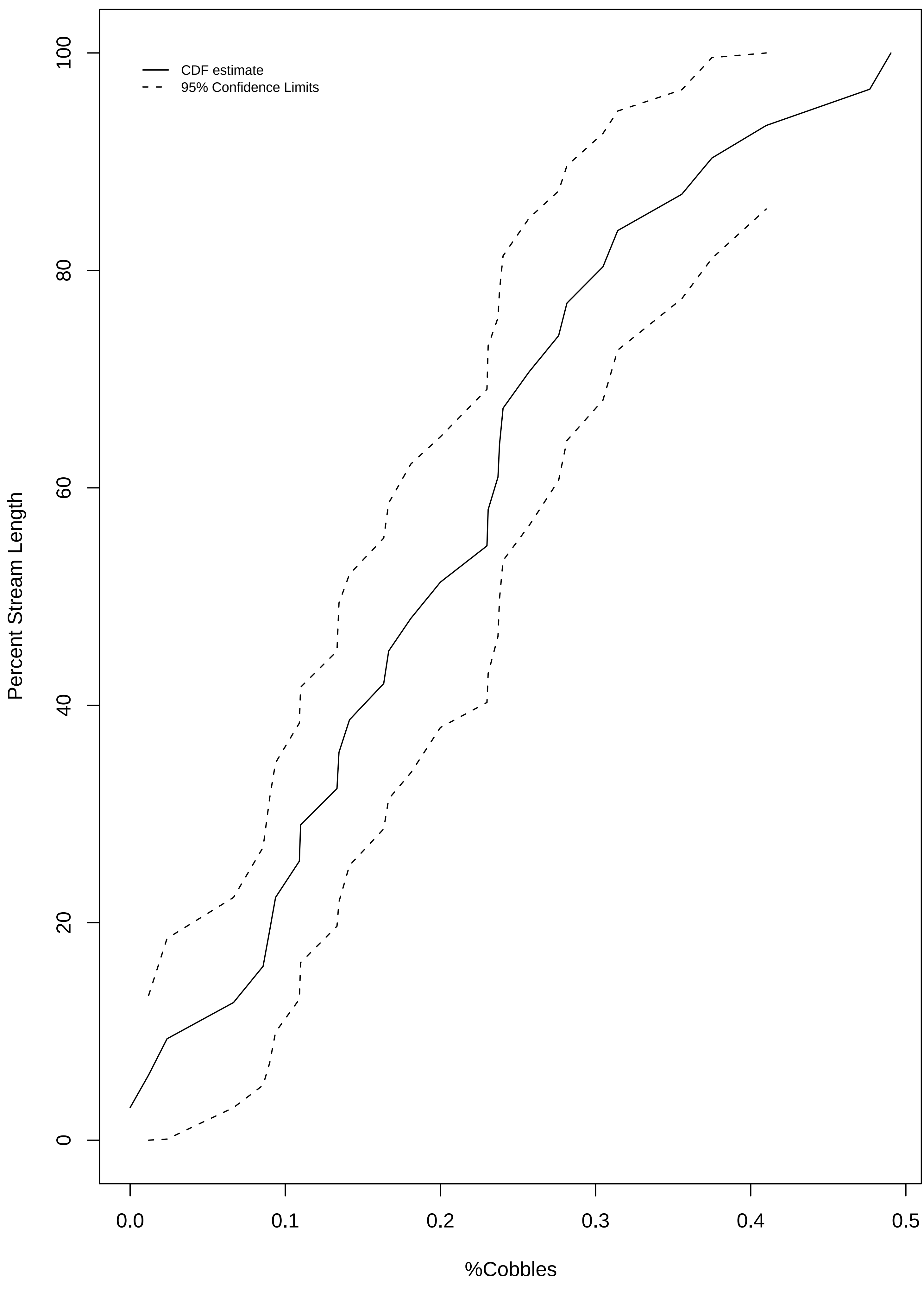
Trask IMW %Gravel Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
0.5
0.6
%Gravel

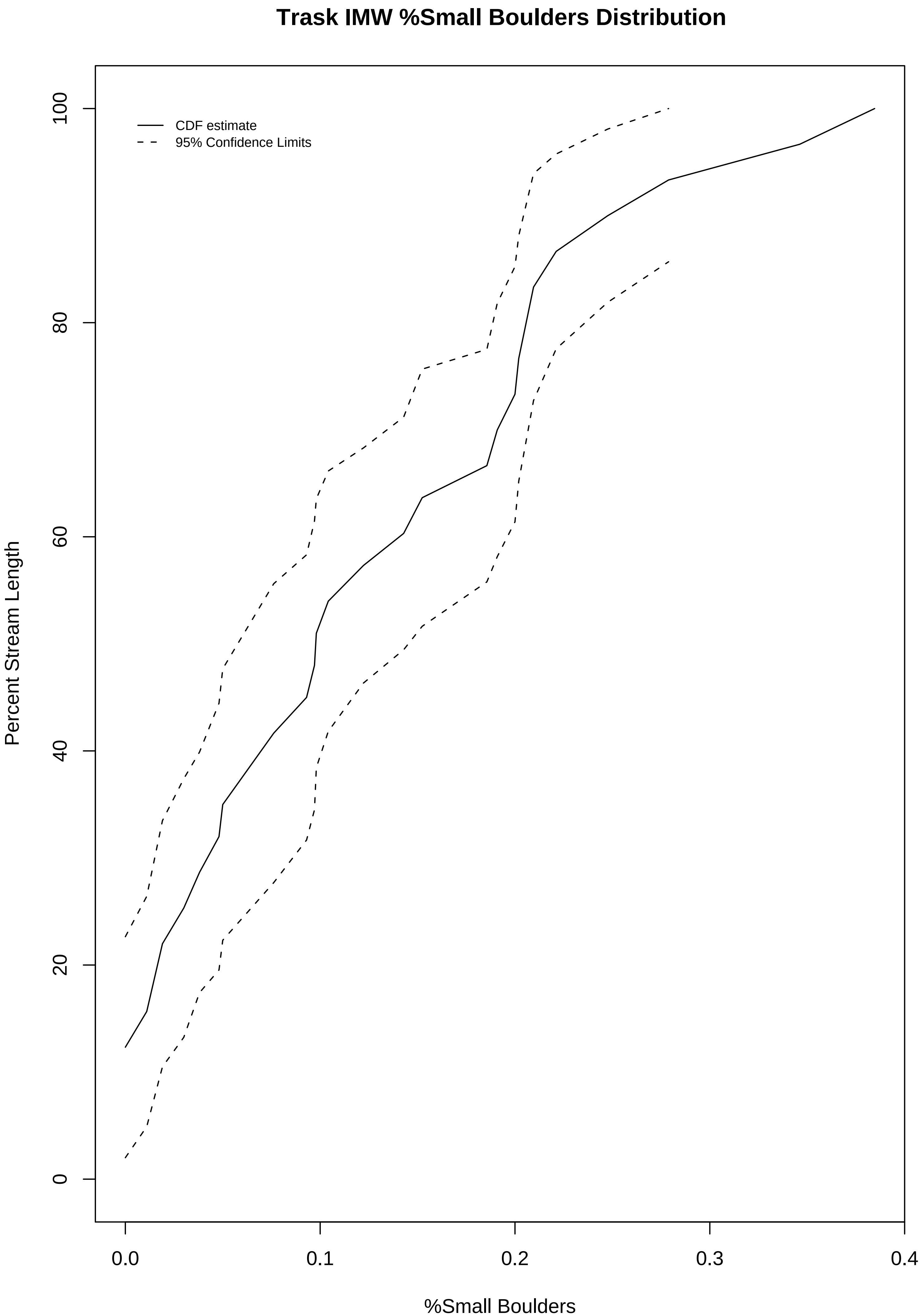


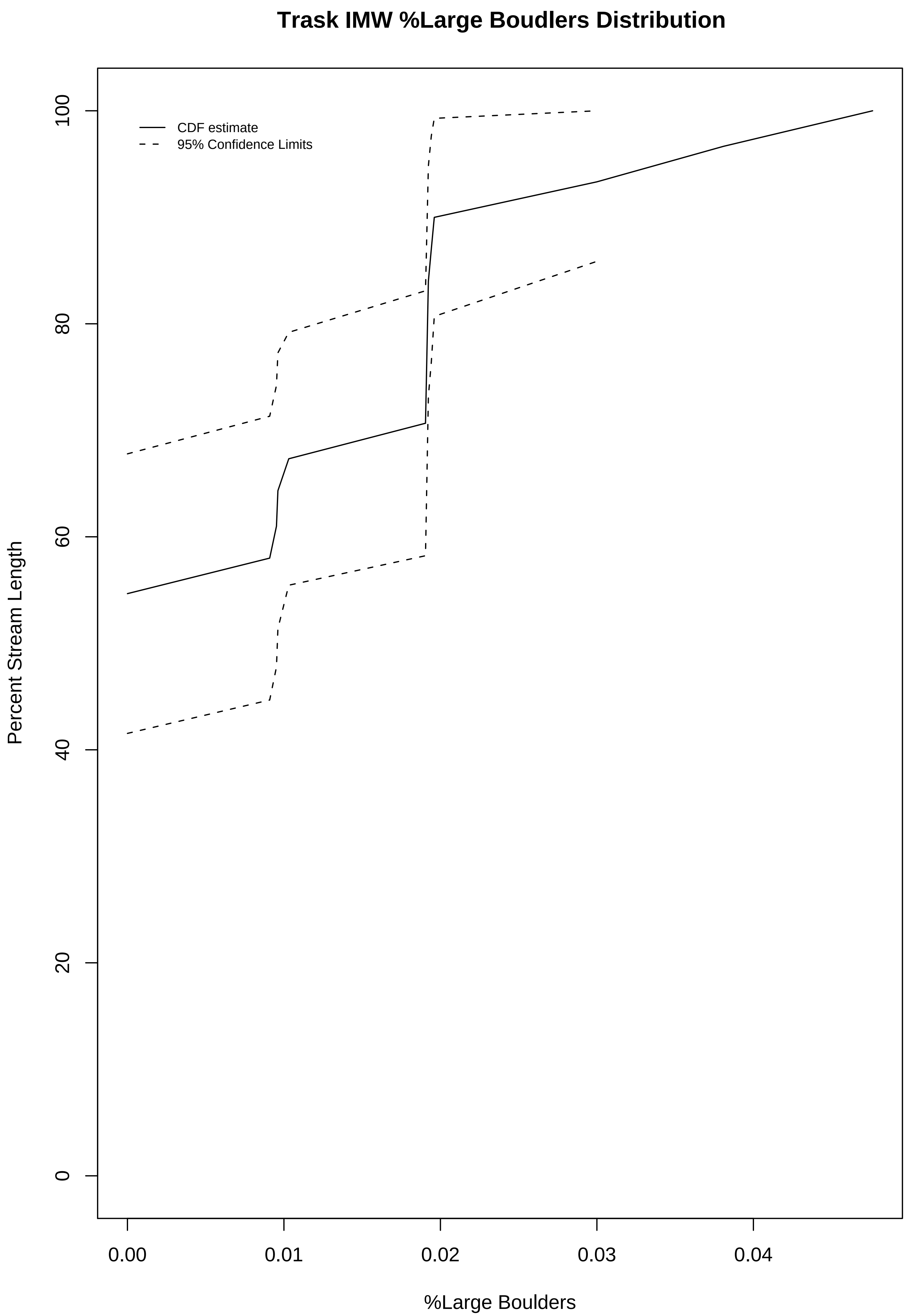
Trask IMW %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
%Bedrock


Trask IMW SAFN * D_cbf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.01
0.02
0.03
0.04
0.05
0.06
SAFN * D_cbf

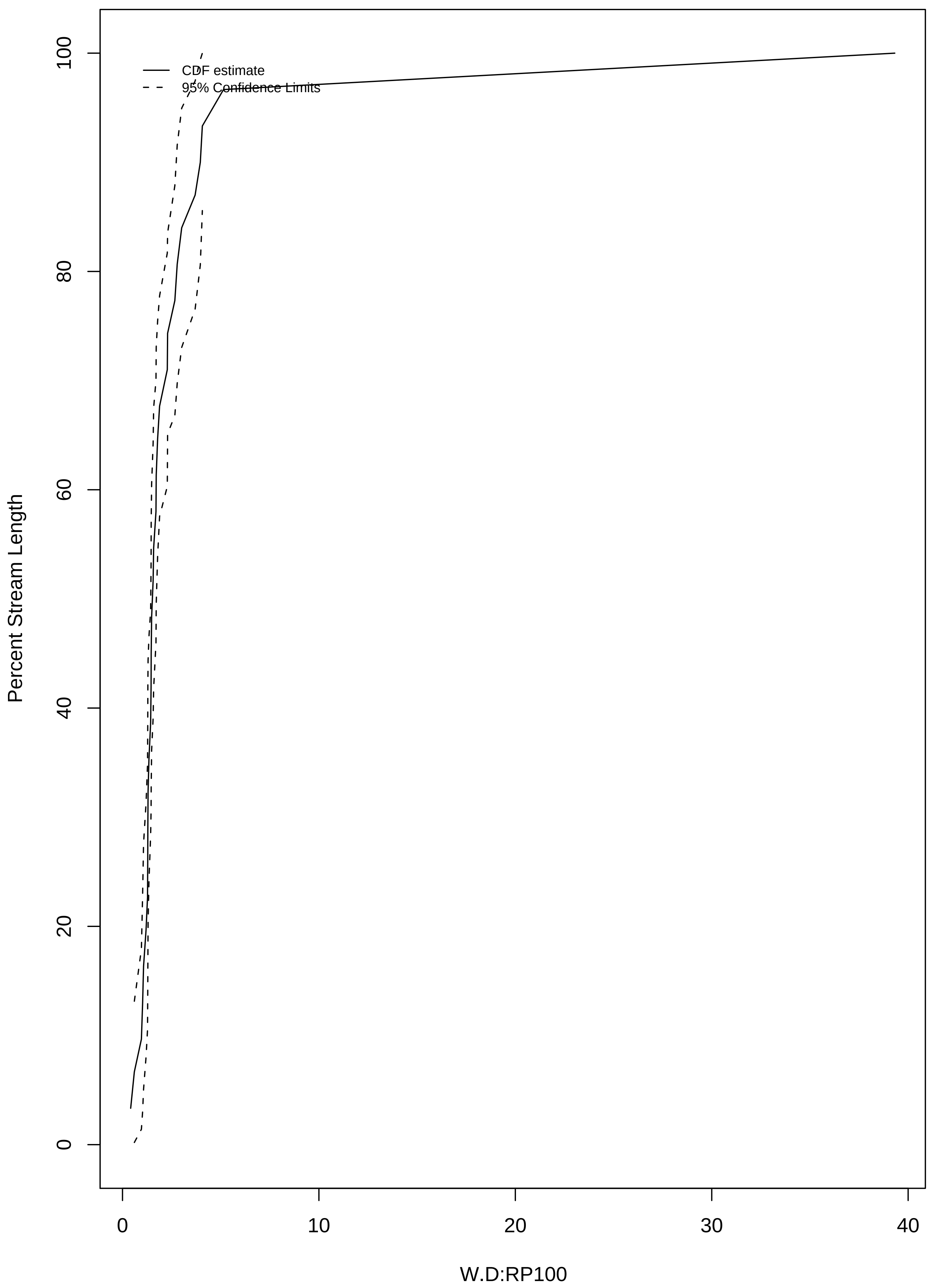
Trask IMW %Cobbles Distribution

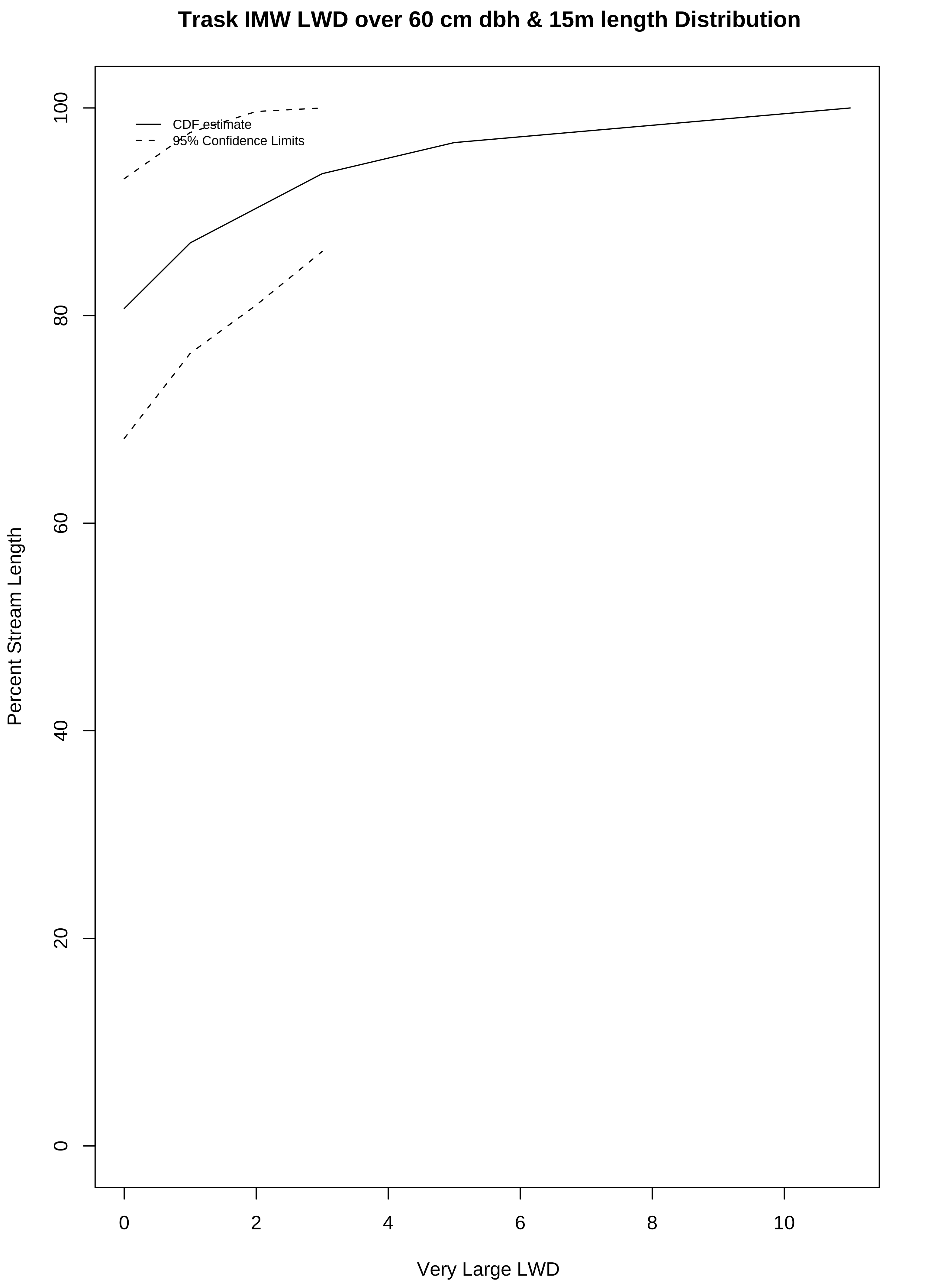



Trask IMW %Small Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
%Small Boulders

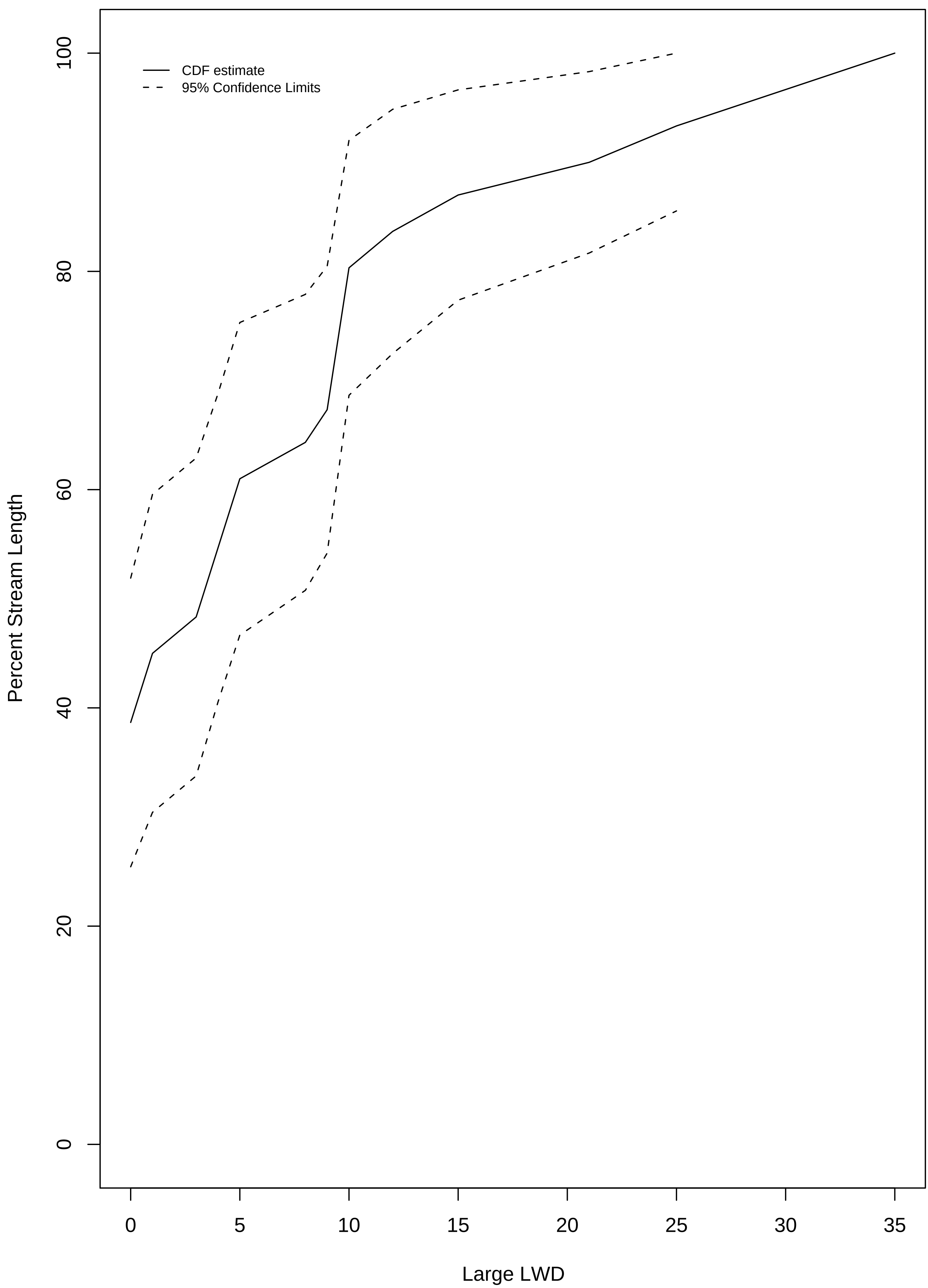

Trask IMW %Large Boudlers Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.01
0.02
0.03
0.04
%Large Boulders

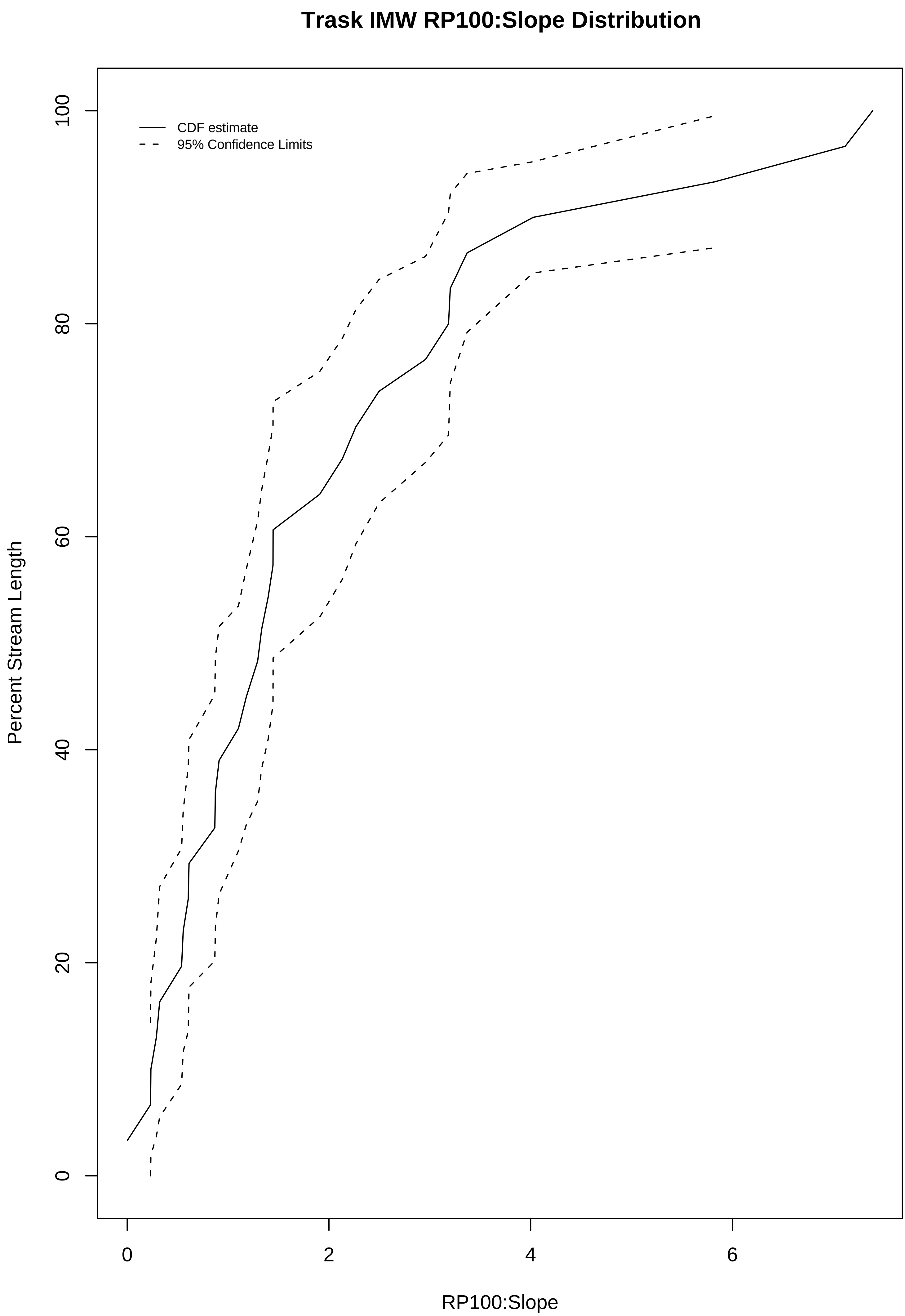
Trask IMW W.D:RP100 Distribution

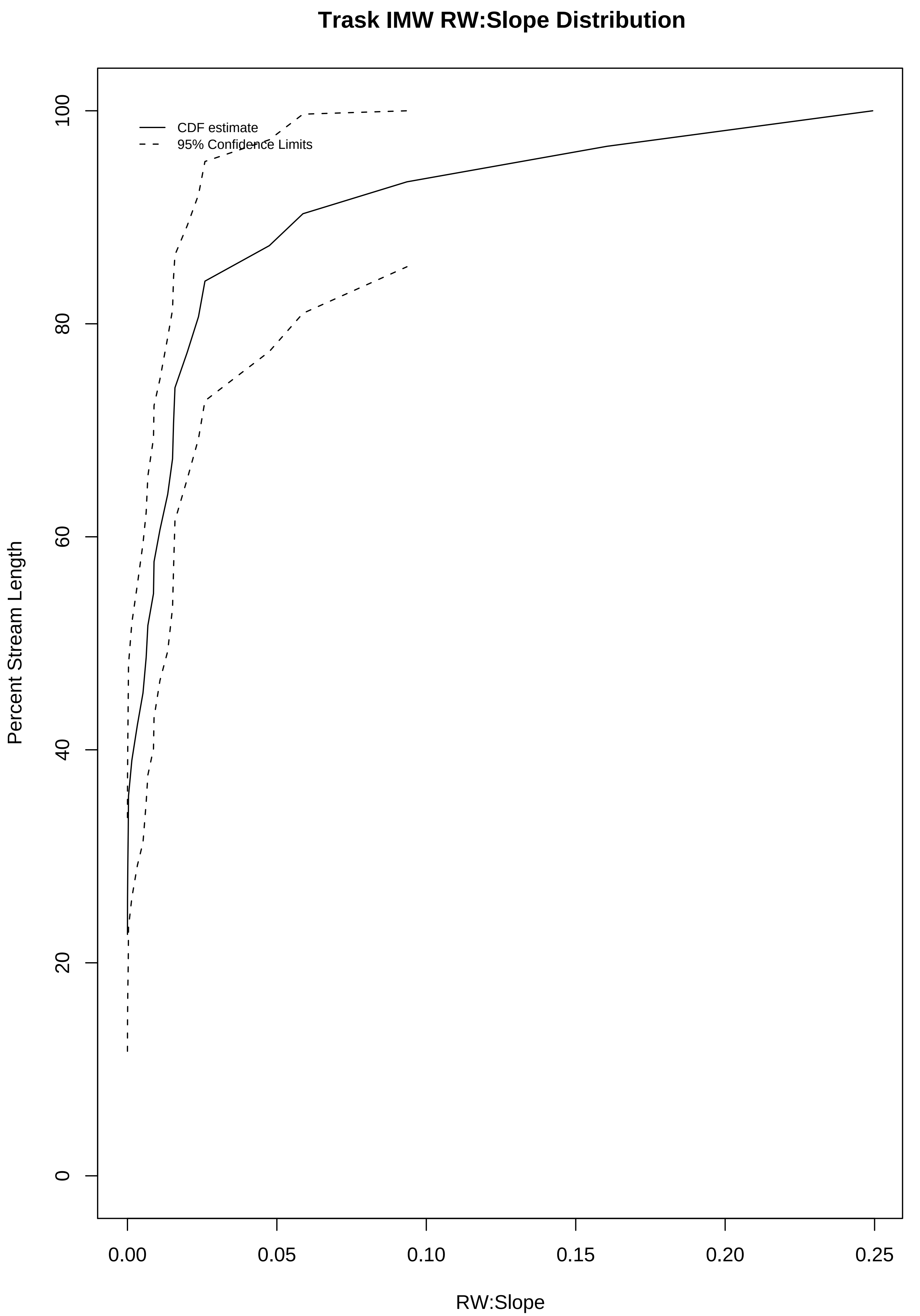


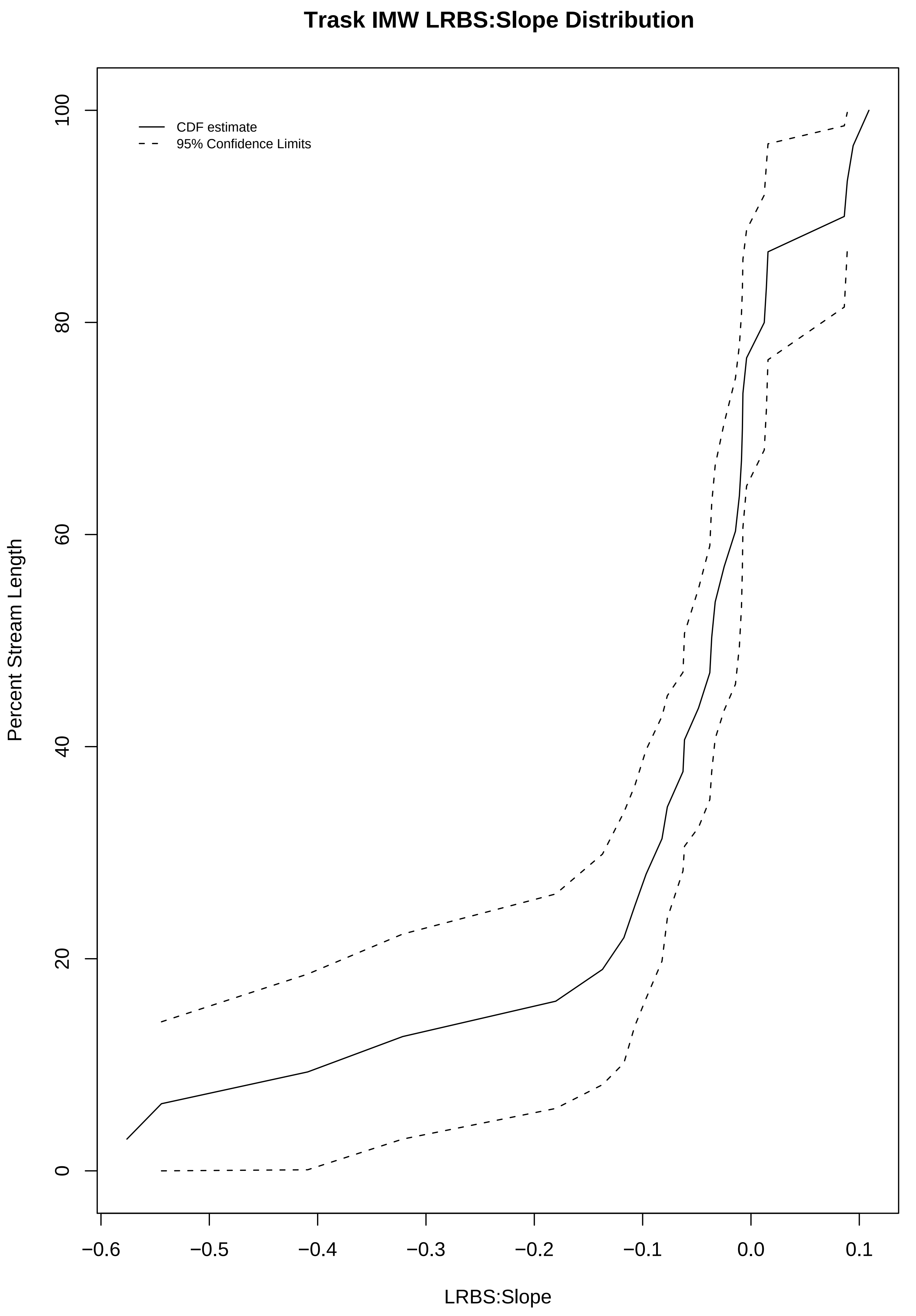

Trask IMW LWD over 60 cm dbh & 15m length Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
2
4
6
8
10
Very Large LWD

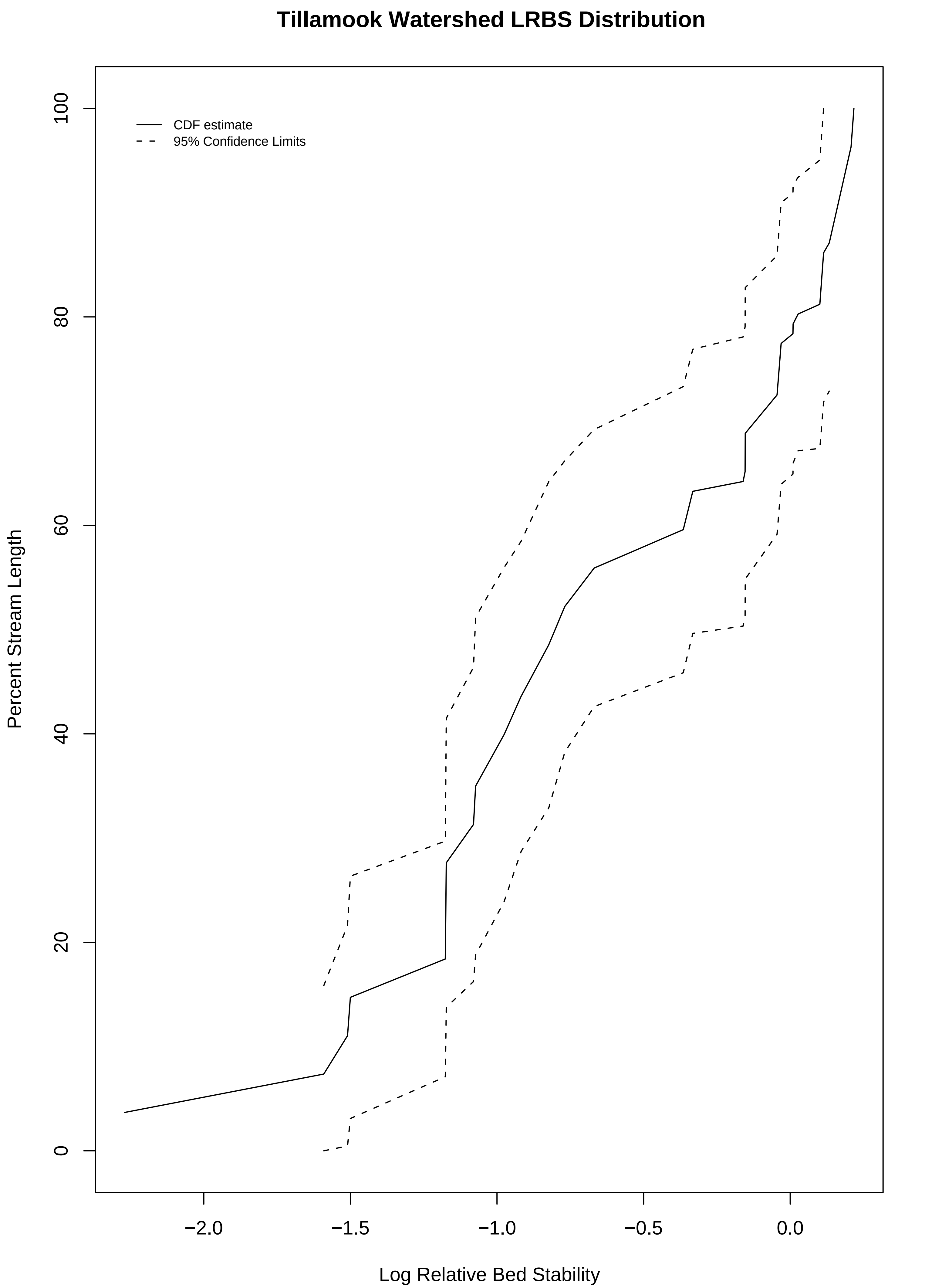
Trask IMW Trask IMW LWD over 60 cm dbh Distribution

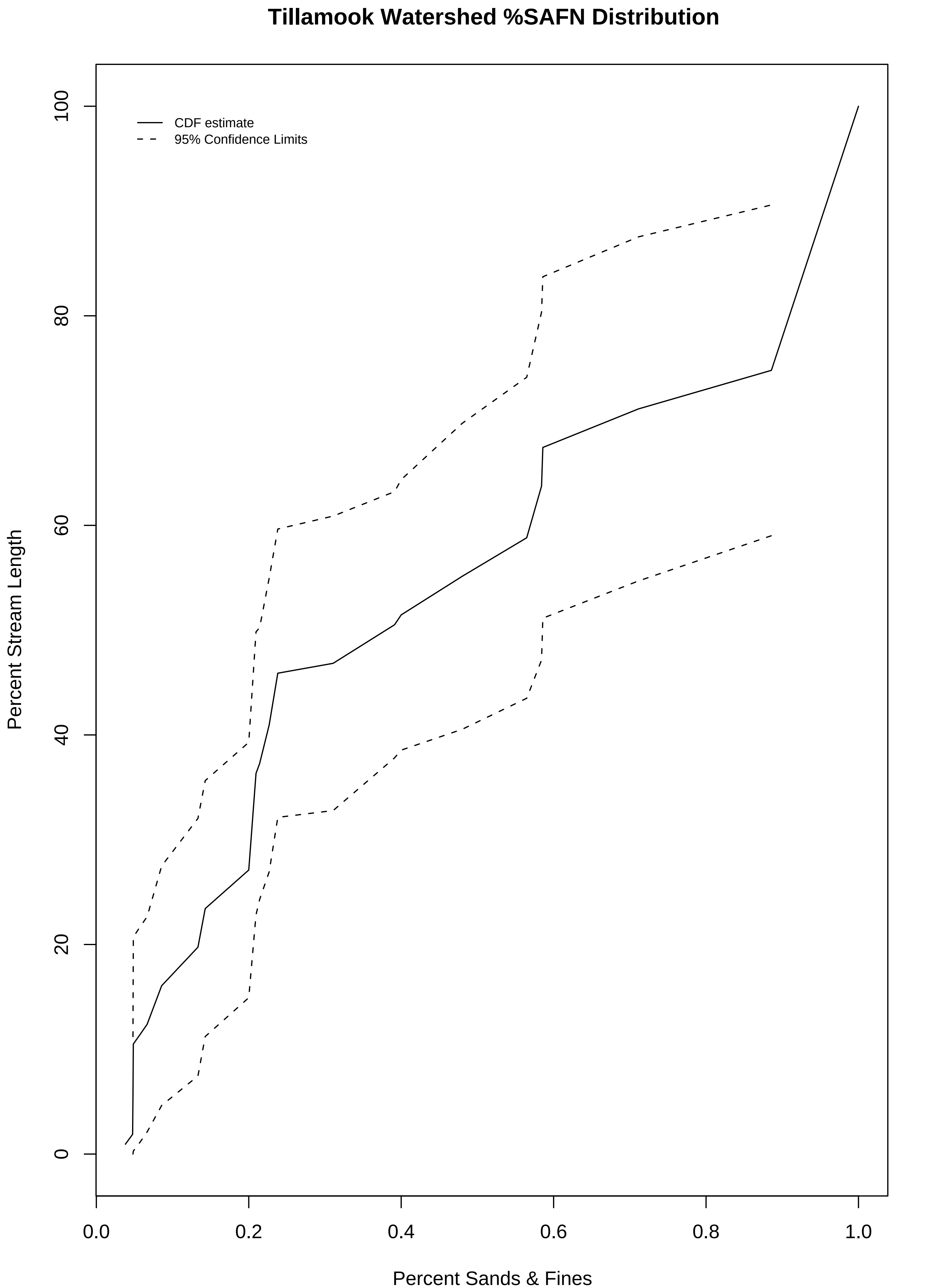



Trask IMW RP100:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
RP100:Slope
0
20
40
60
80
100
0
2
4
6

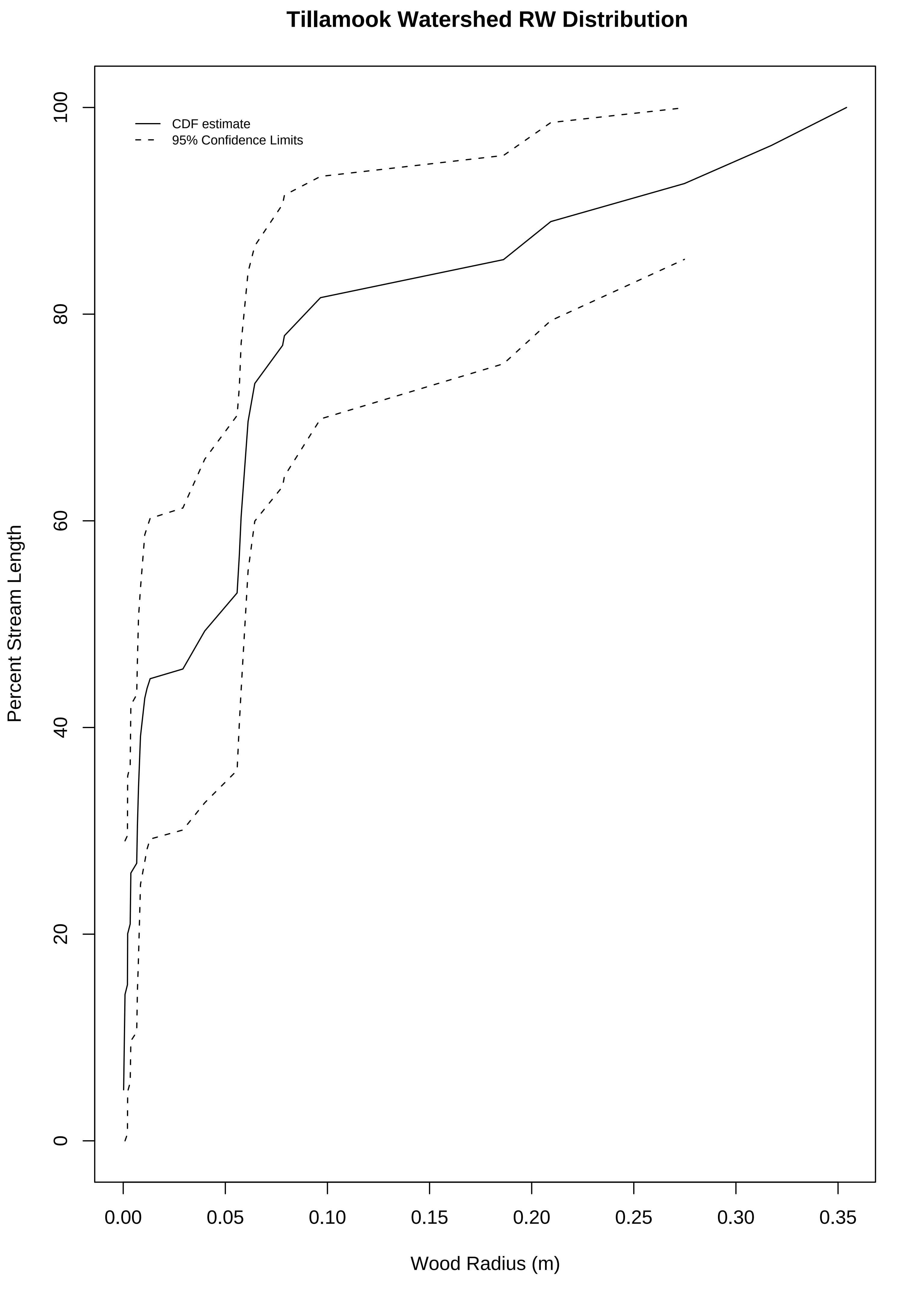

Trask IMW RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
RW:Slope


Trask IMW LRBS:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−0.6
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
0.1
LRBS:Slope

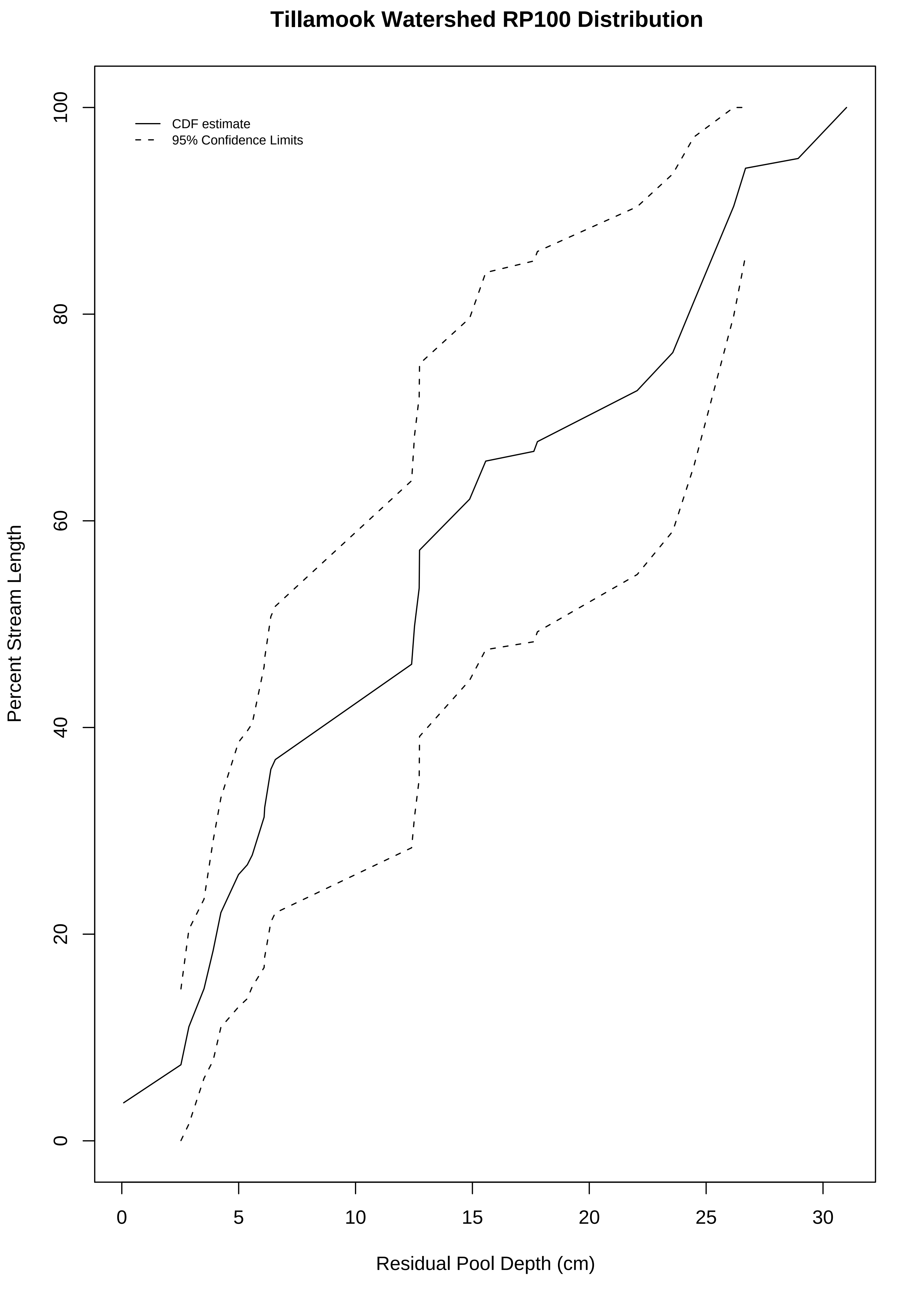

Tillamook Watershed LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−2.0
−1.5
−1.0
−0.5
0.0
Log Relative Bed Stability



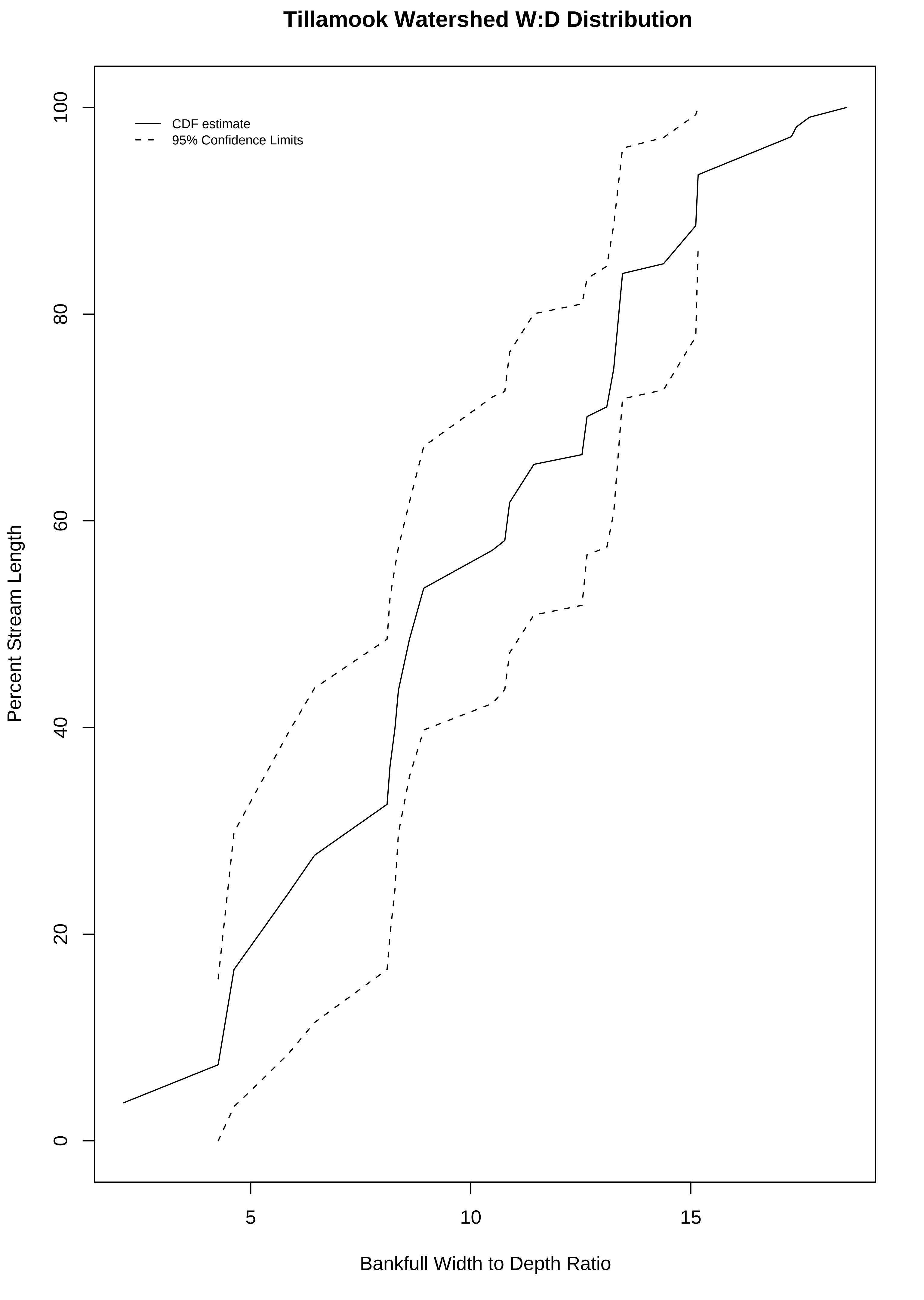
Tillamook Watershed %SAFN Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0
Percent Sands & Fines



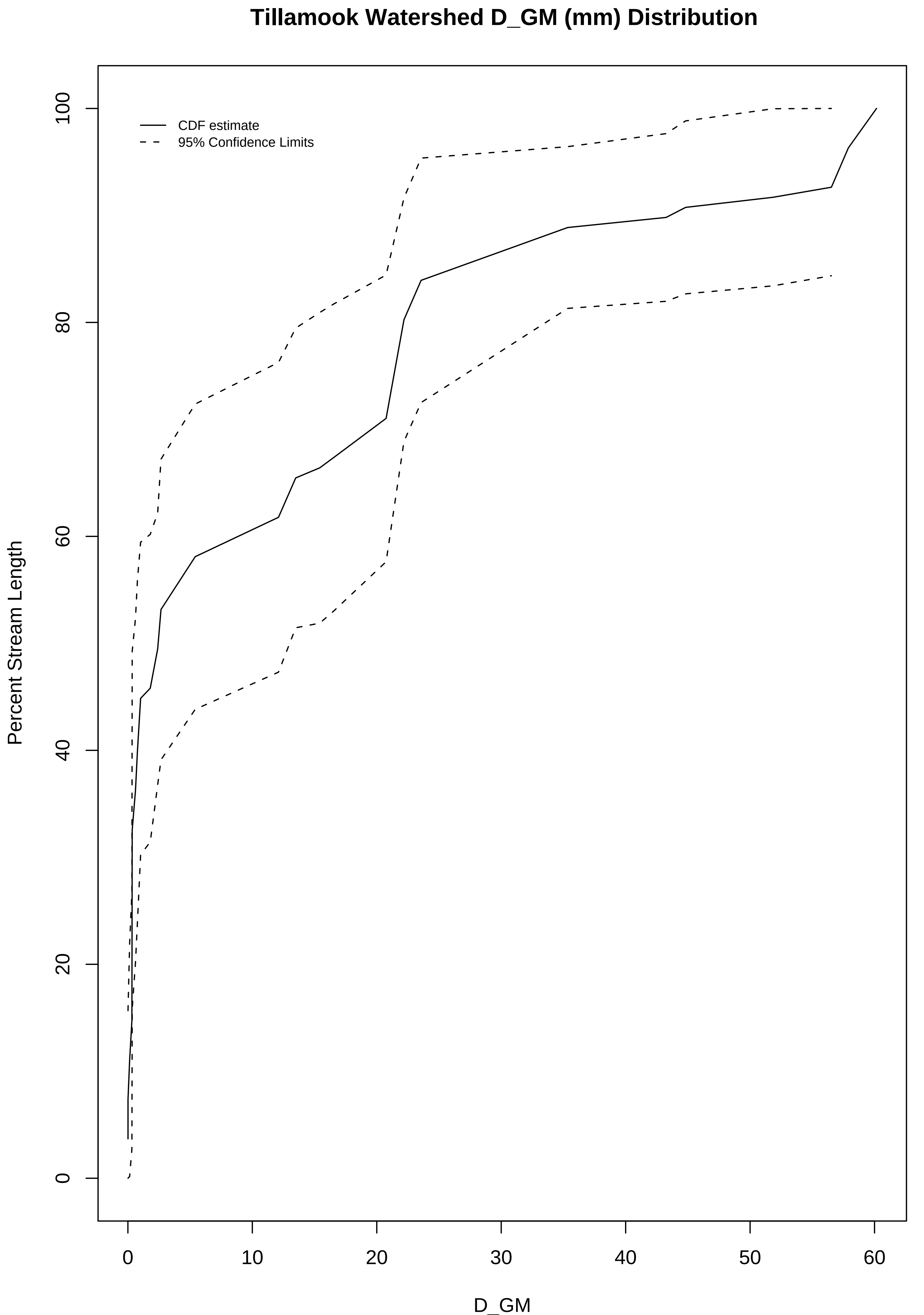
Tillamook Watershed RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Wood Radius (m)



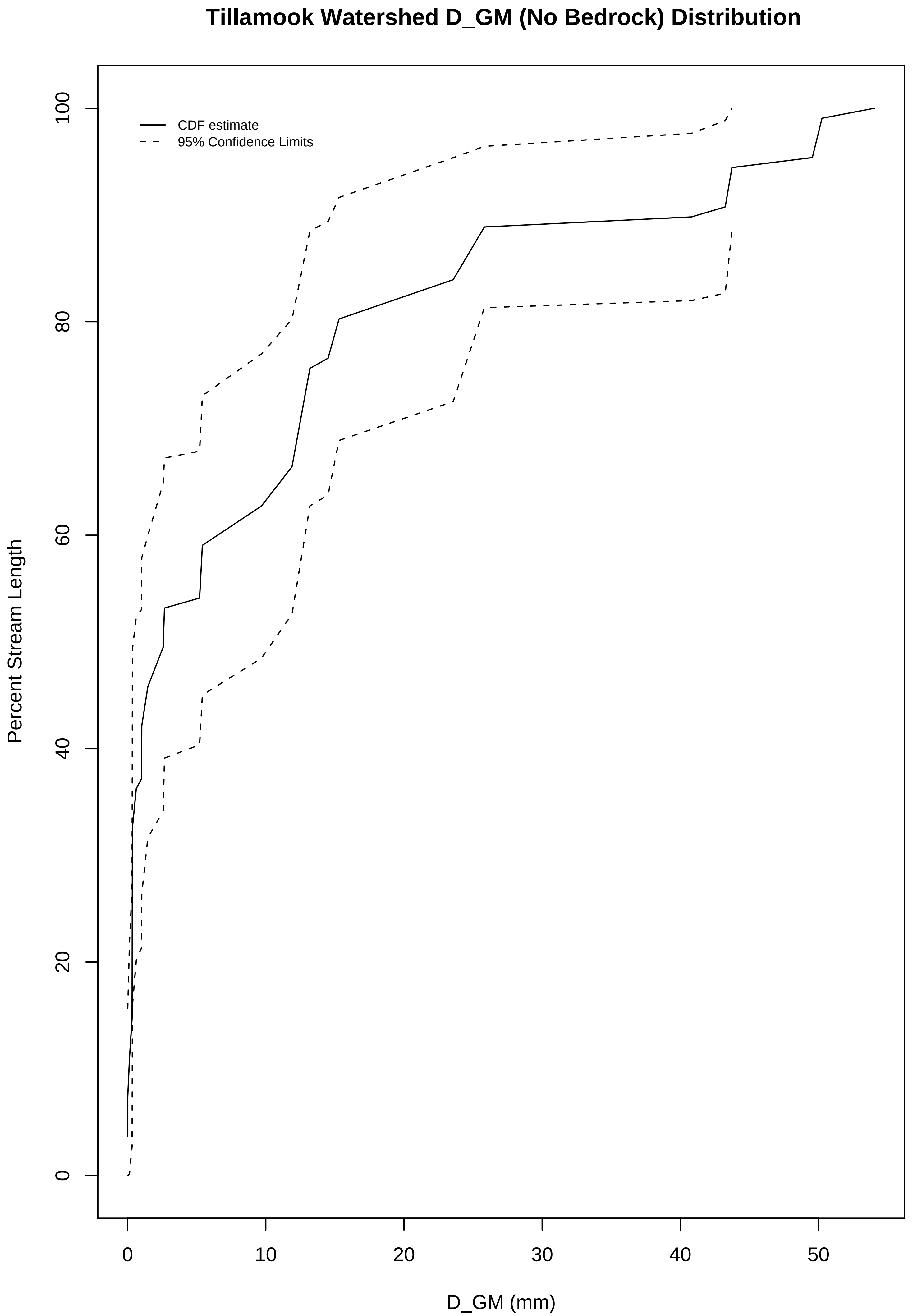
Tillamook Watershed RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
5
10
15
20
25
30
Residual Pool Depth (cm)



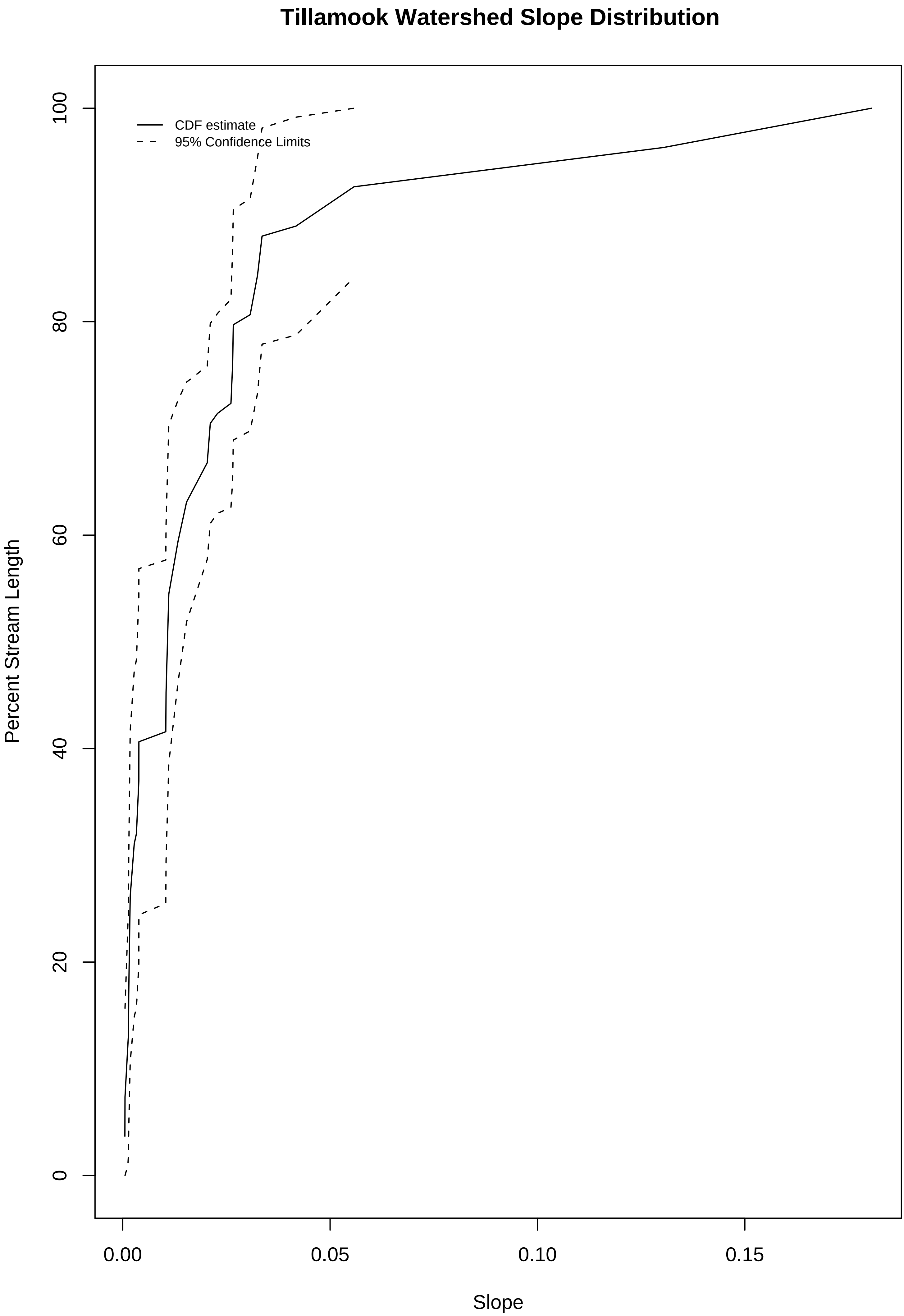
Tillamook Watershed W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
5
10
15
Bankfull Width to Depth Ratio



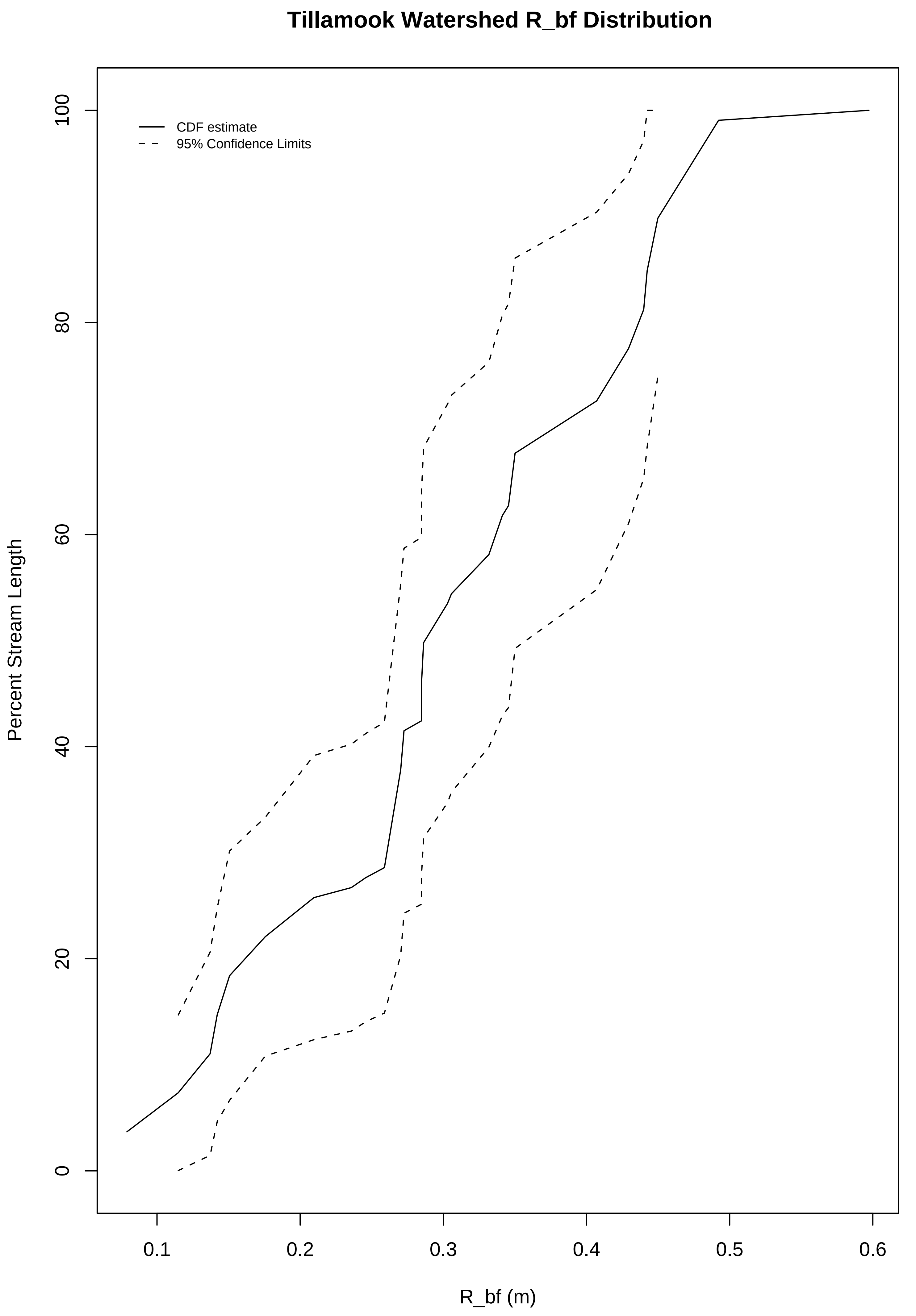
Tillamook Watershed D_GM (mm) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
10
20
30
40
50
60
D_GM



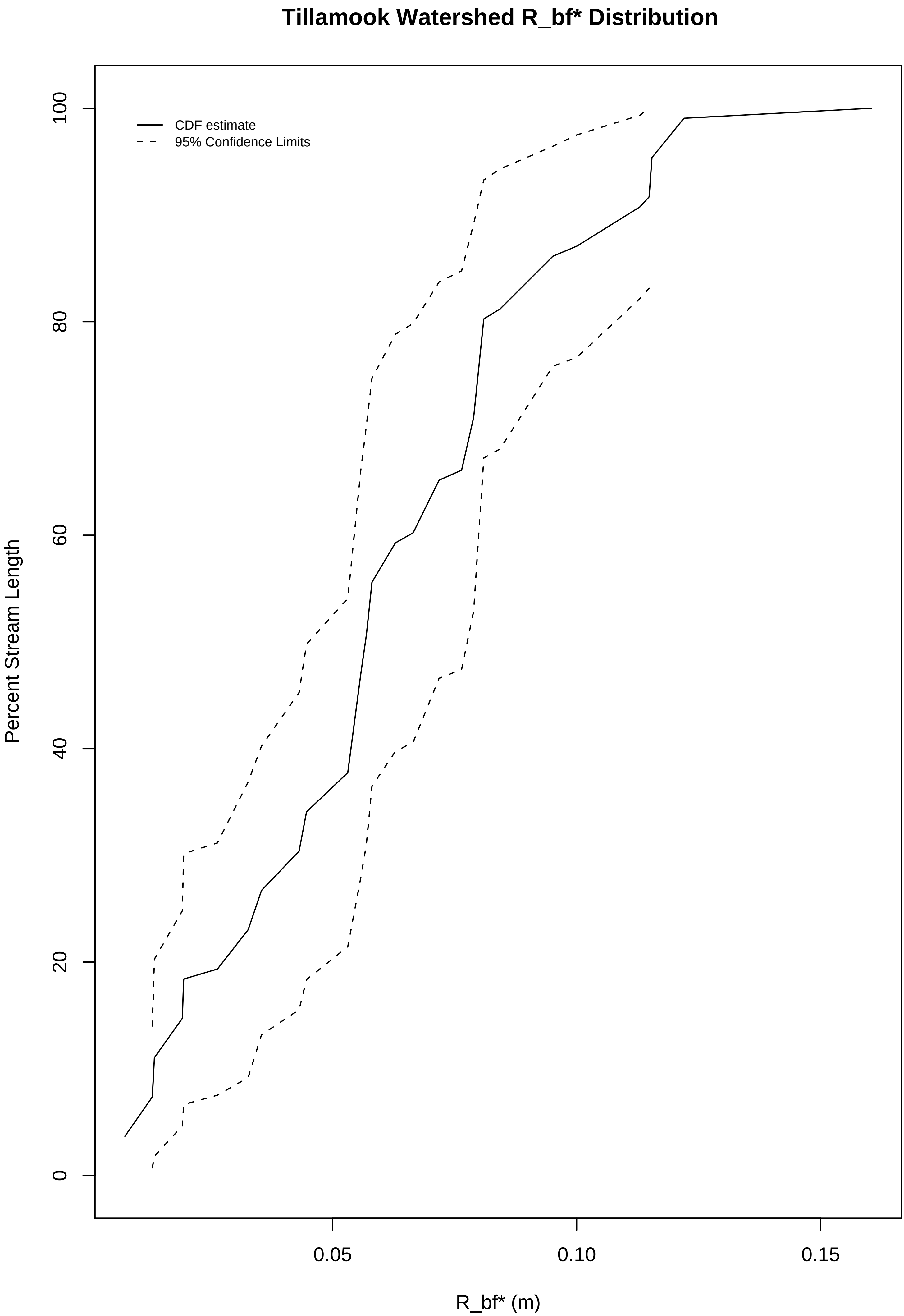
Tillamook Watershed D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
10
20
30
40
50
D_GM (mm)

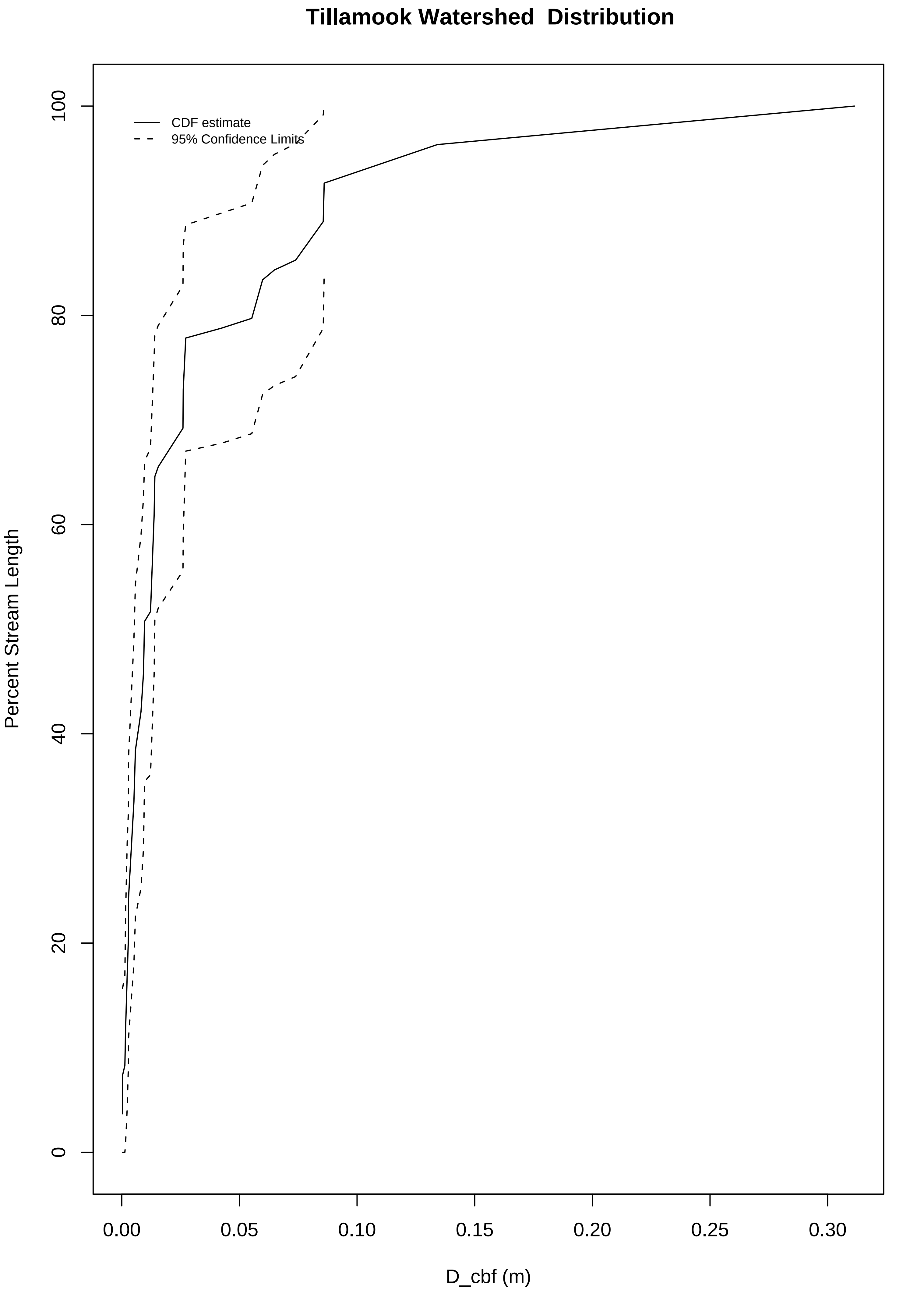


Tillamook Watershed Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
Slope

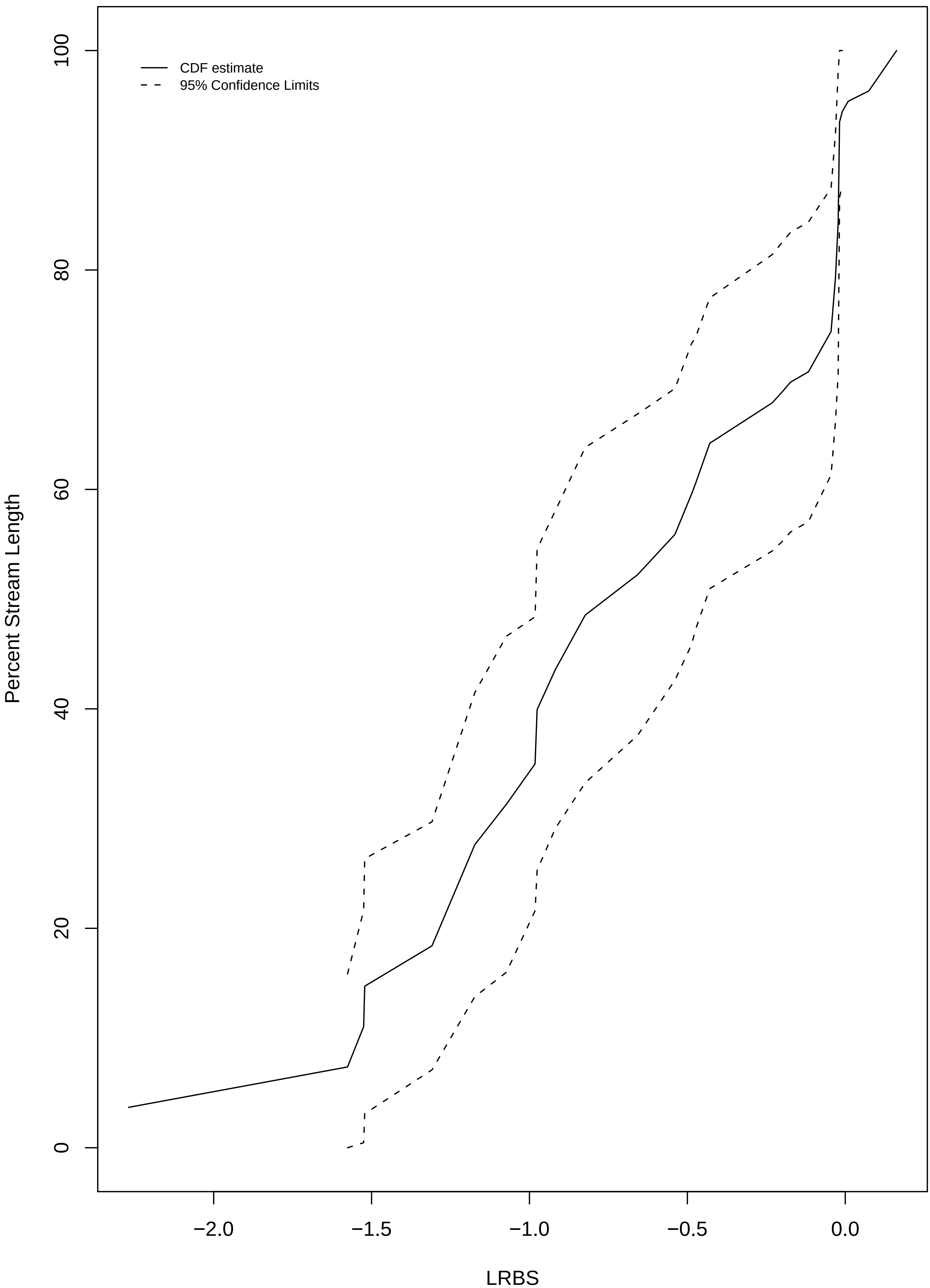


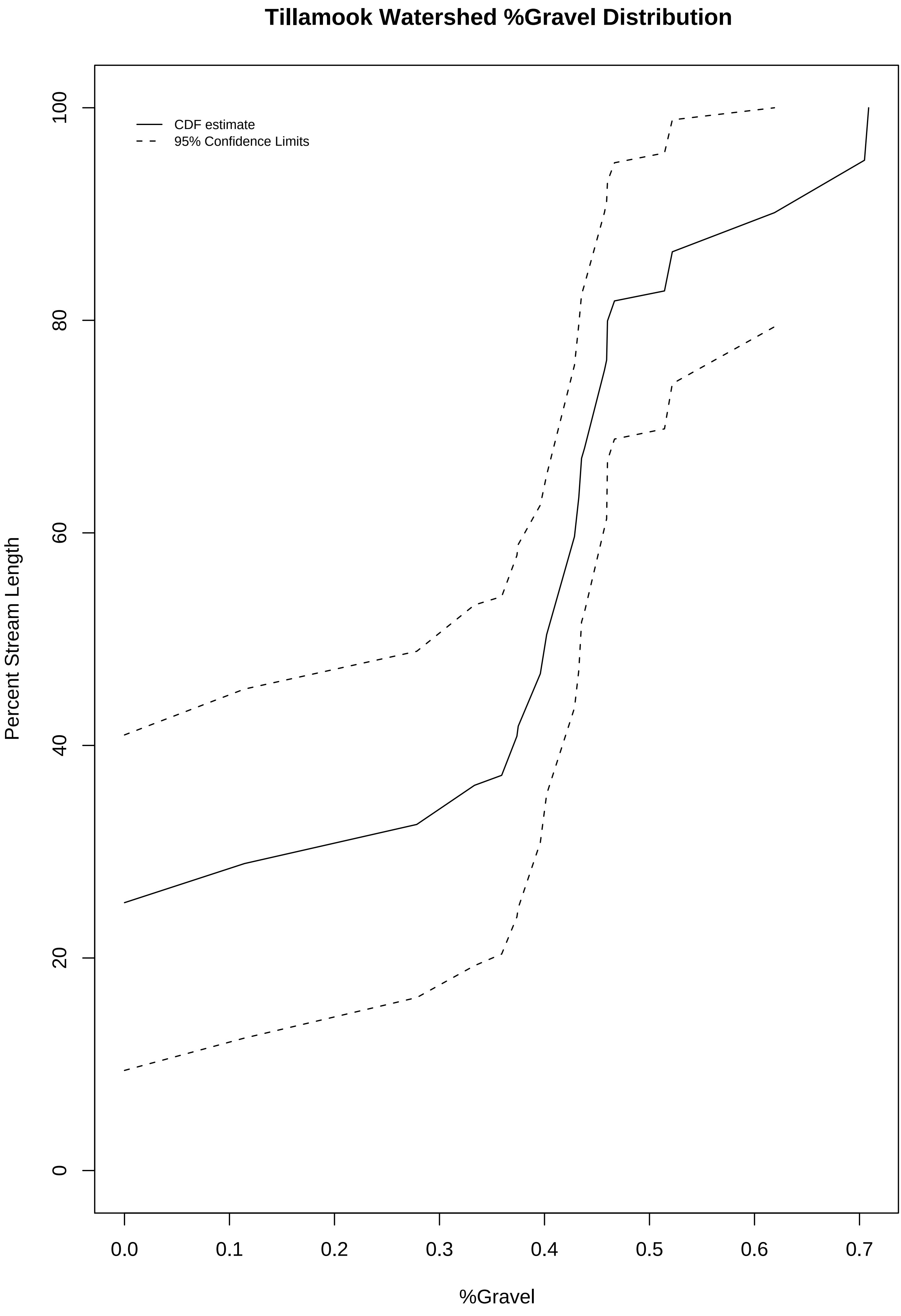
Tillamook Watershed R_bf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
0.5
0.6
R_bf (m)


Tillamook Watershed R_bf* Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.05
0.10
0.15
R_bf* (m)

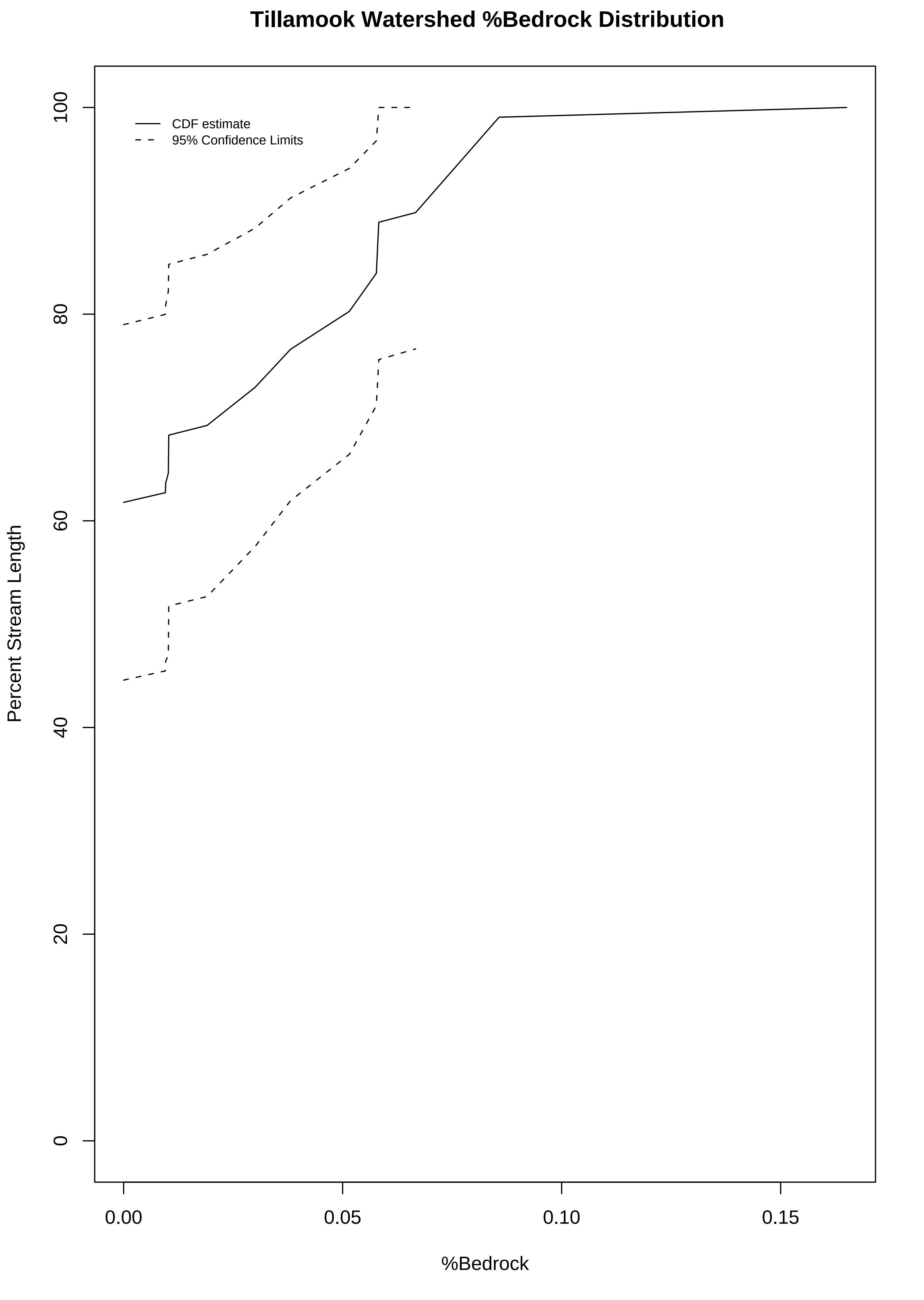

Tillamook Watershed Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
D_cbf (m)

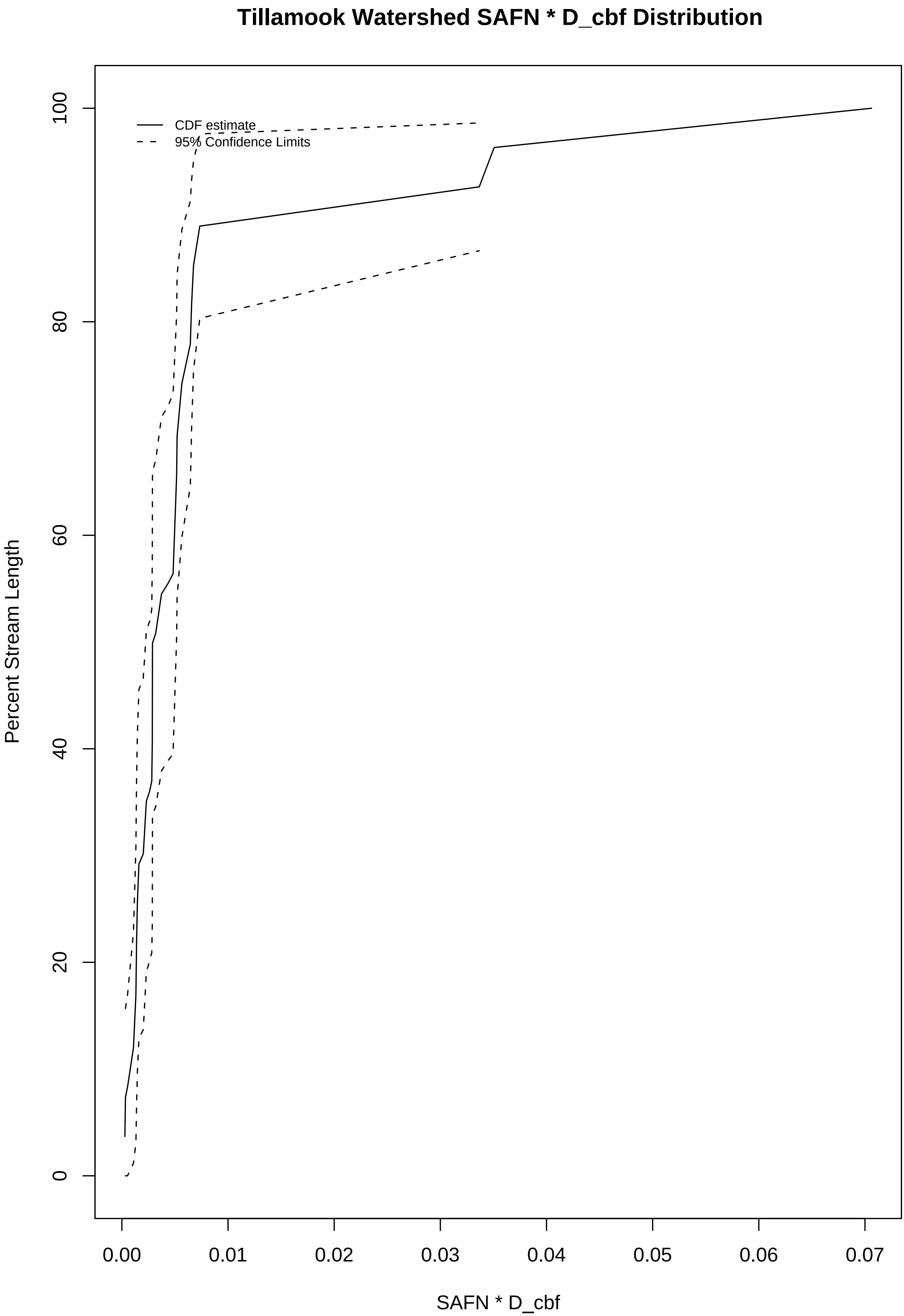
Tillamook Watershed LRBS (No Bedrock) Distribution



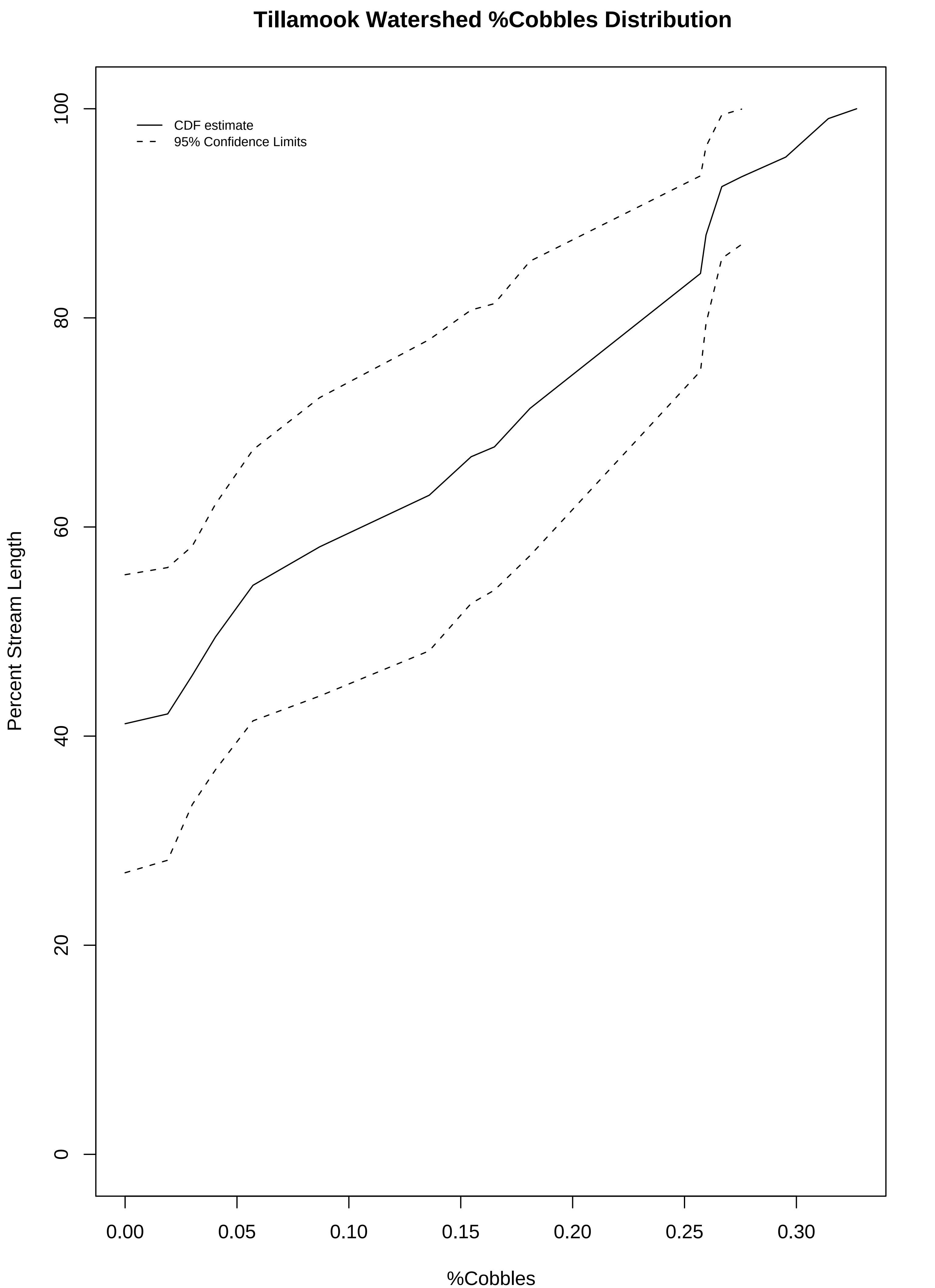


Tillamook Watershed %Gravel Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
%Gravel

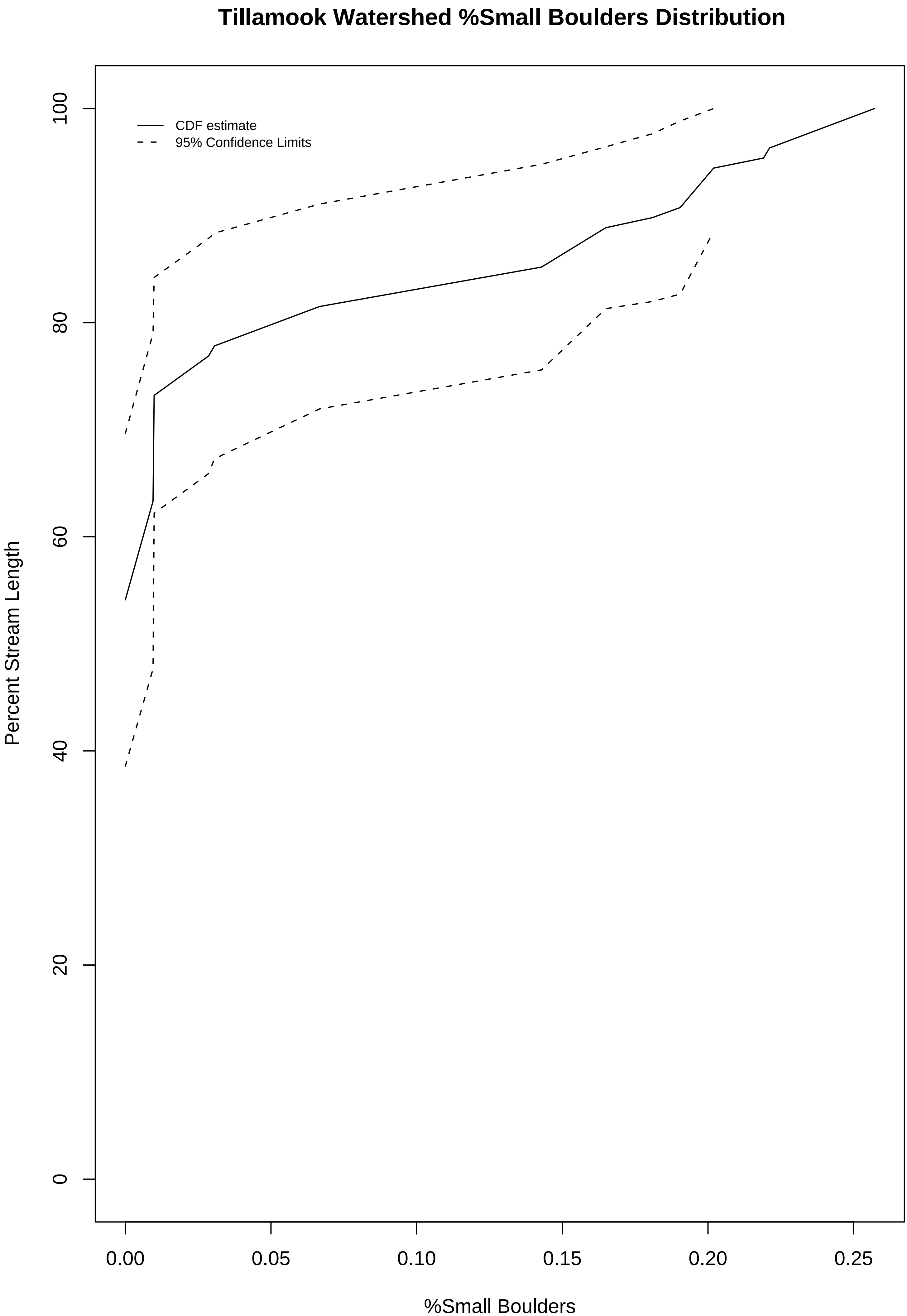

Tillamook Watershed %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
%Bedrock

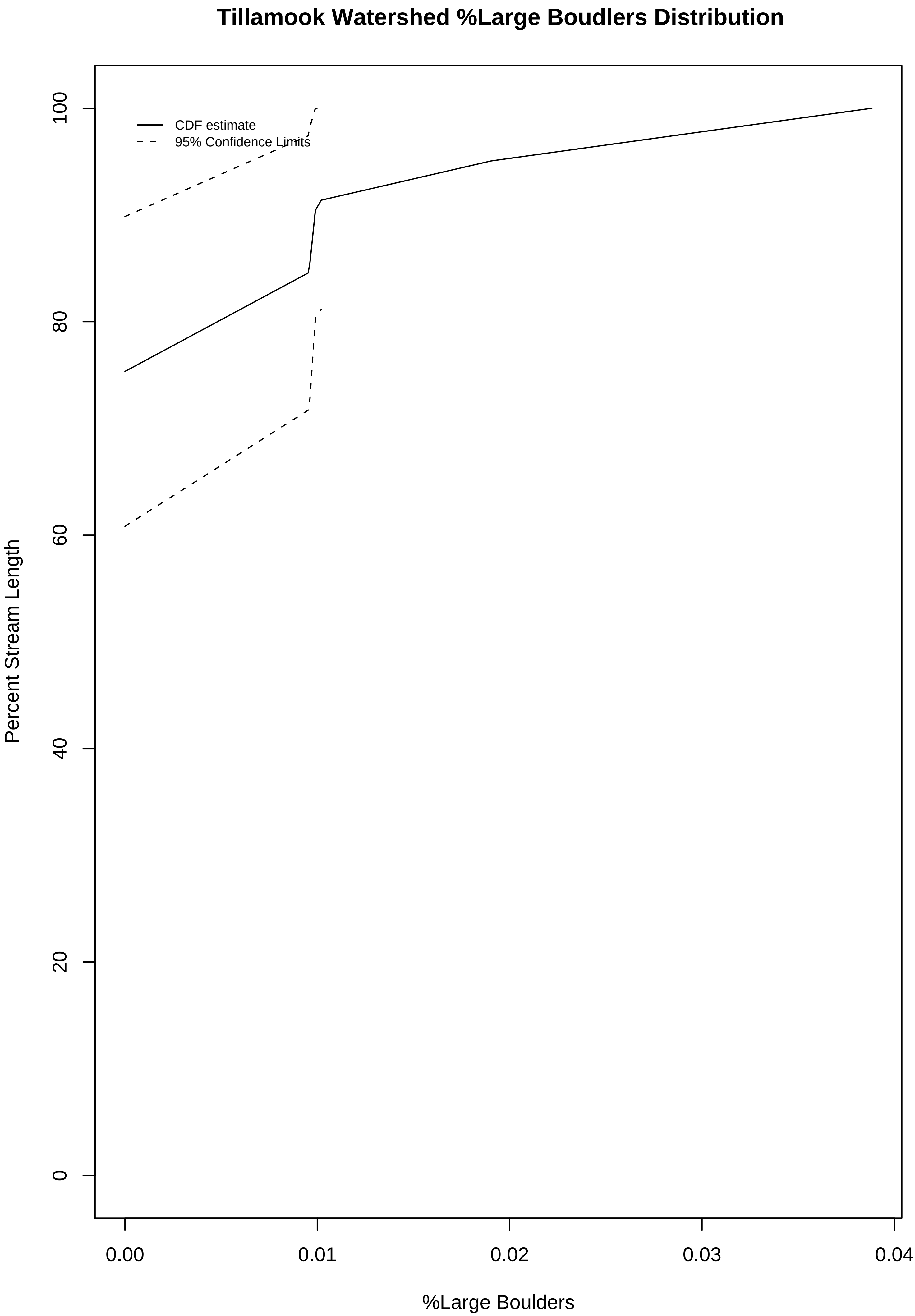


Tillamook Watershed SAFN * D_cbf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
SAFN * D_cbf

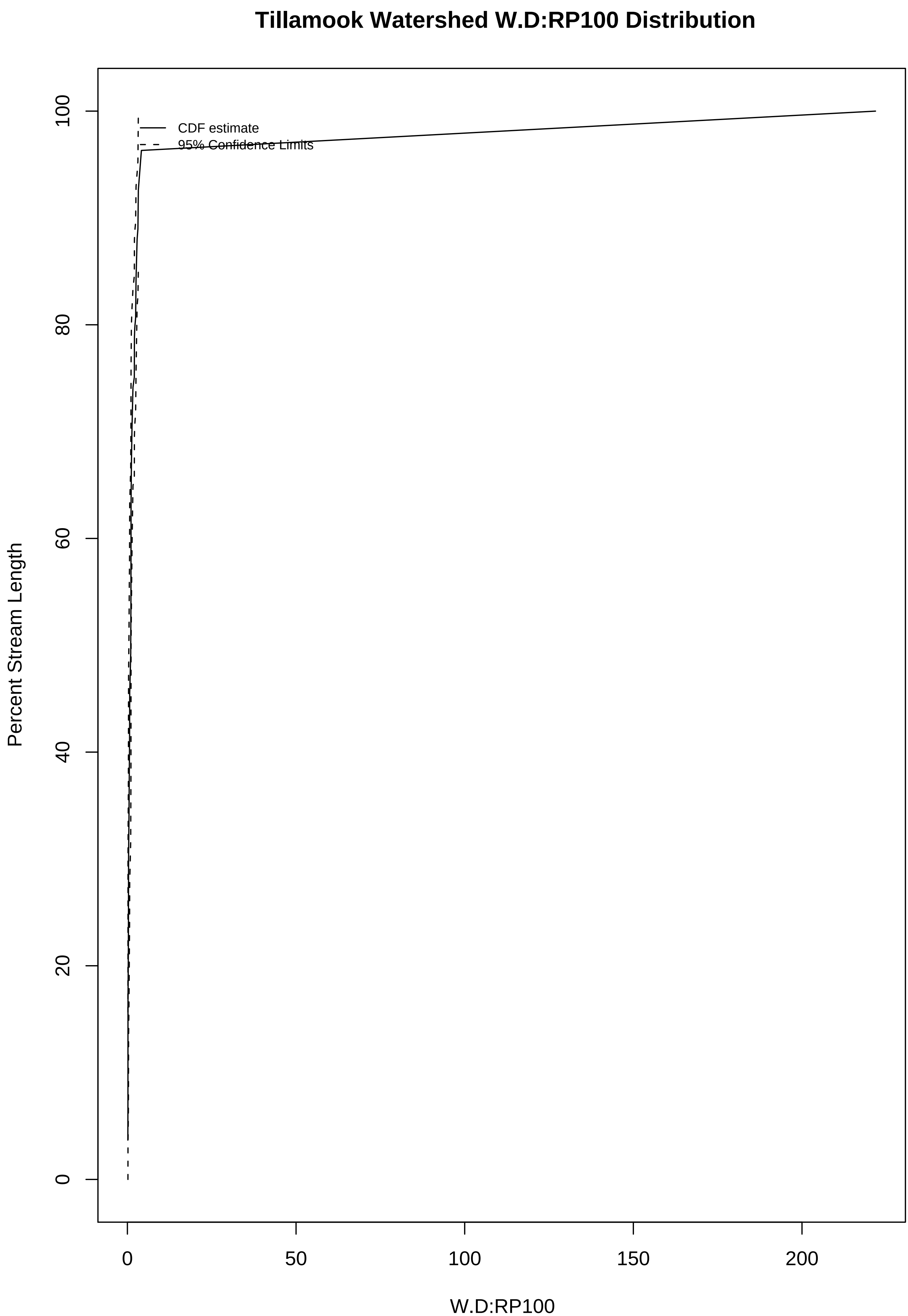


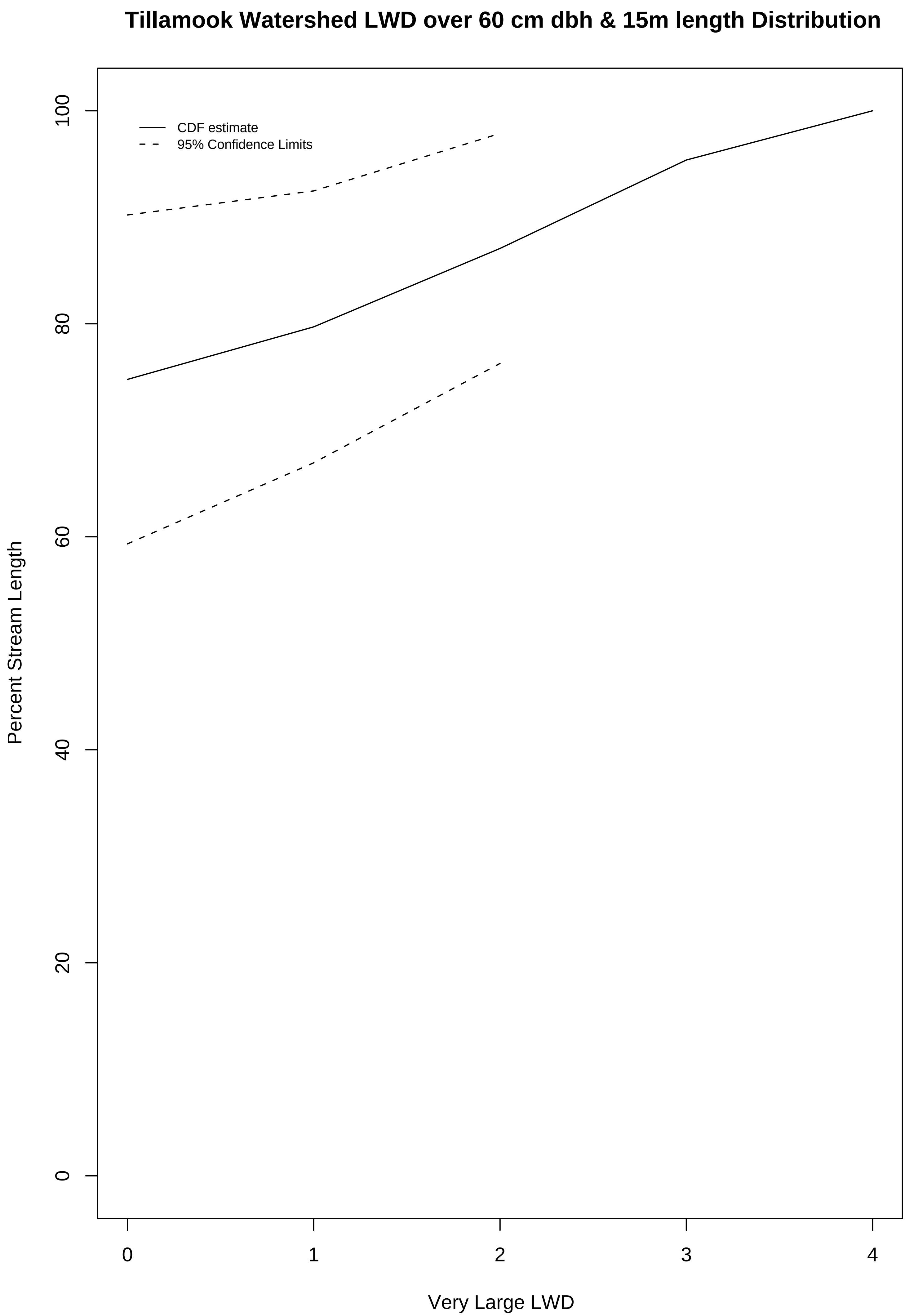
Tillamook Watershed %Cobbles Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
%Cobbles


Tillamook Watershed %Small Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
%Small Boulders

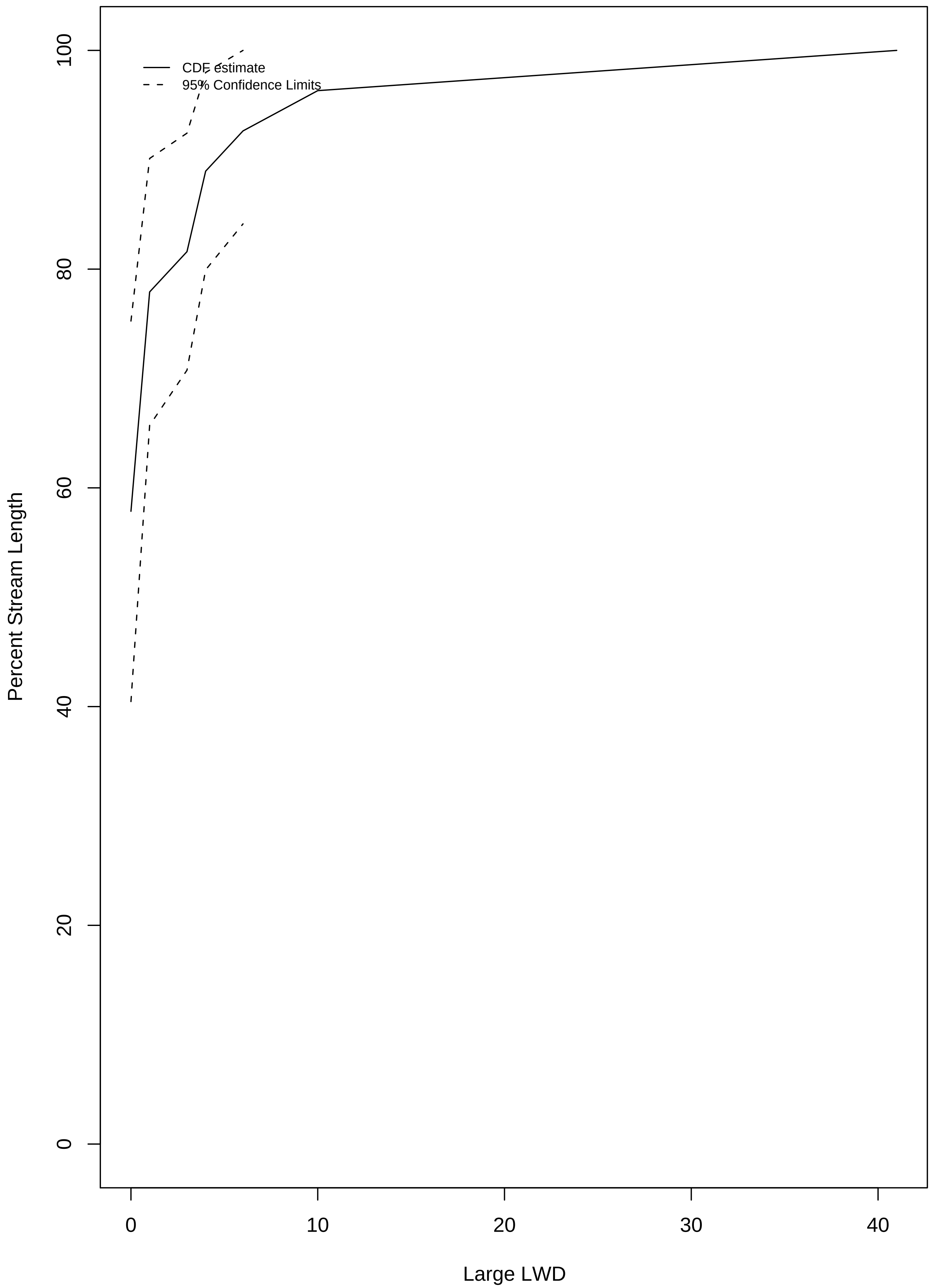


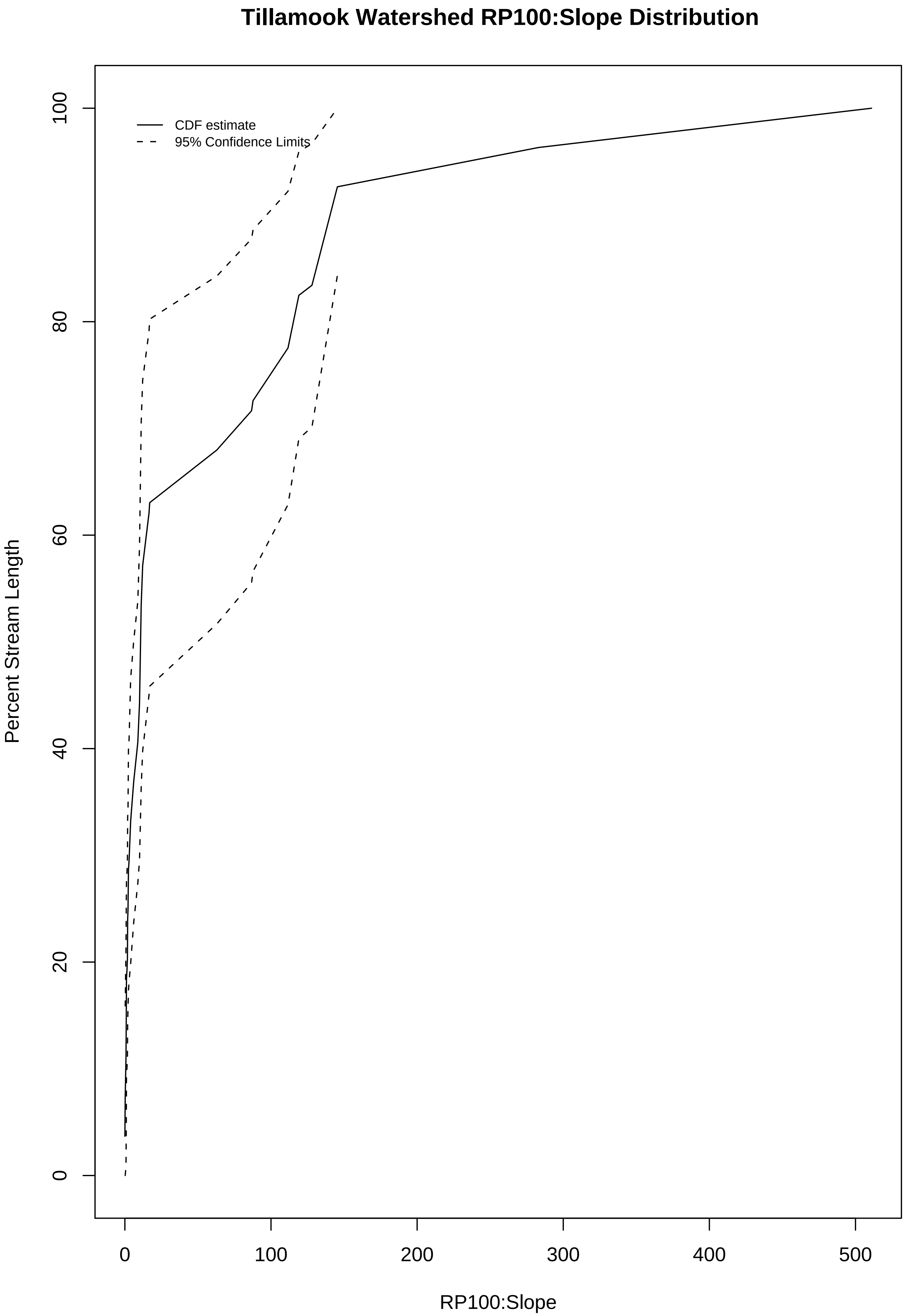
Tillamook Watershed %Large Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.01
0.02
0.03
0.04
%Large Boulders

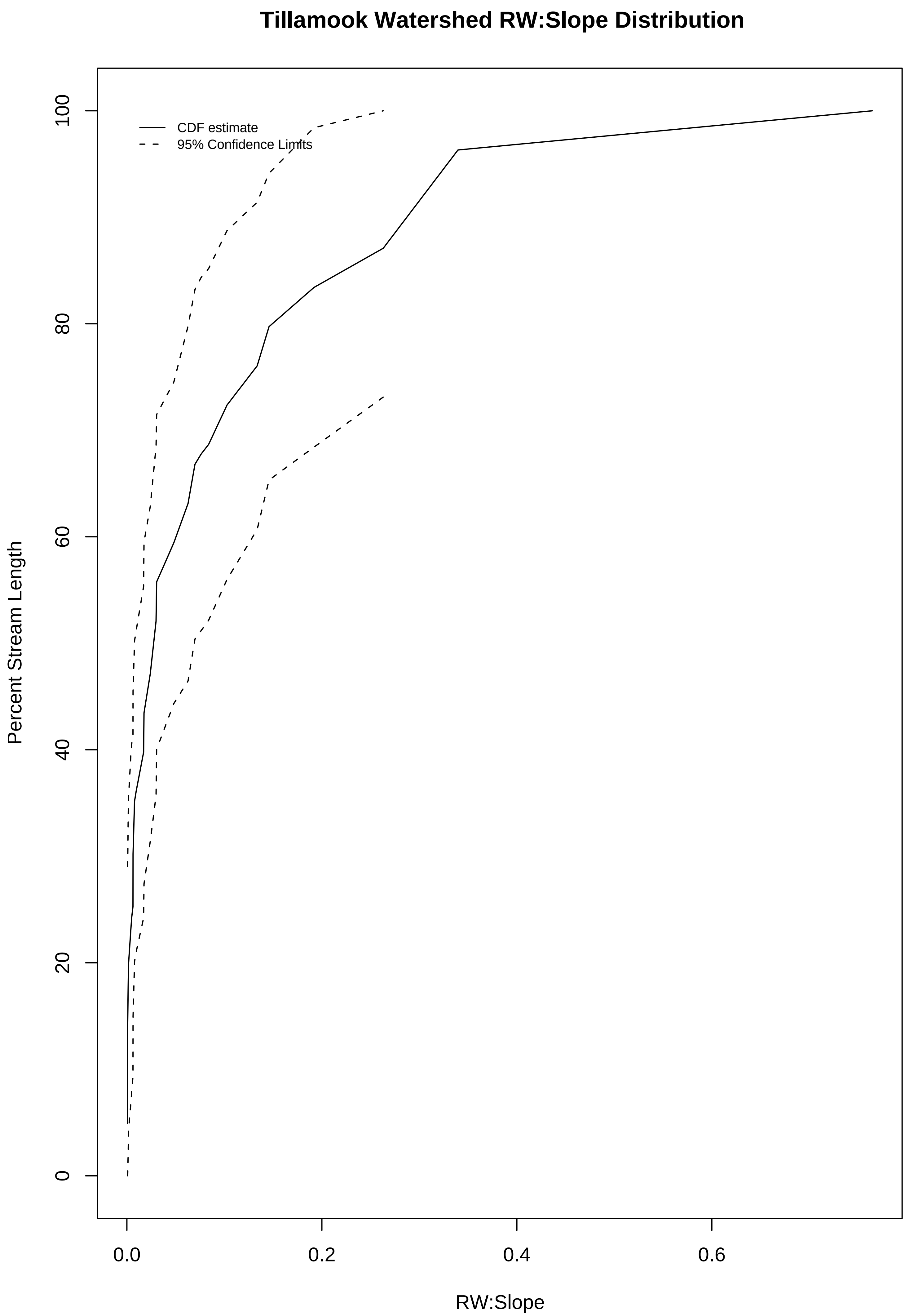

Tillamook Watershed W.D:RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
50
100
150
200
W.D:RP100


Tillamook Watershed LWD over 60 cm dbh & 15m length Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
1
2
3
4
Very Large LWD

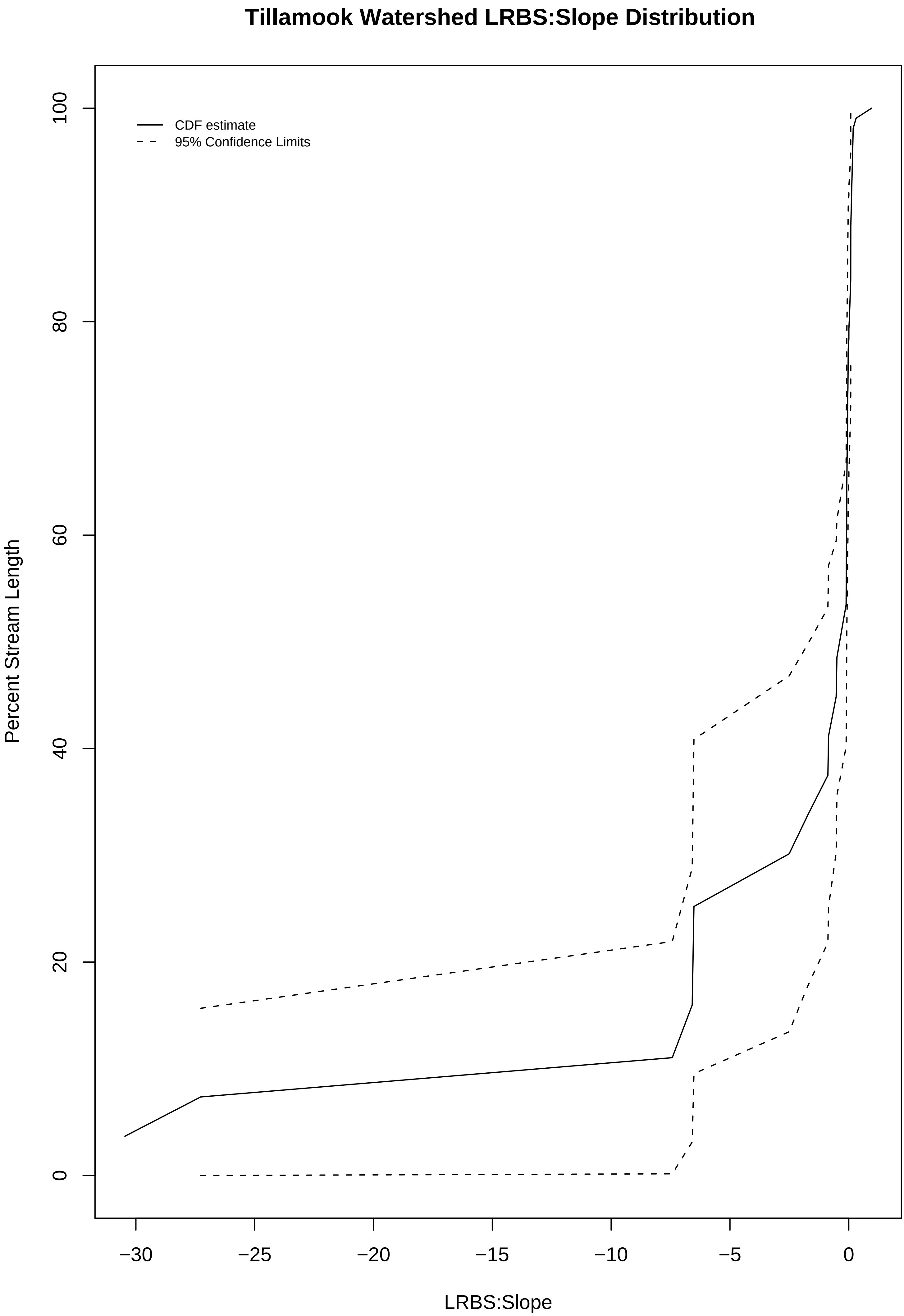
Tillamook Watershed Tillamook Watershed LWD over 60 cm dbh Distribution

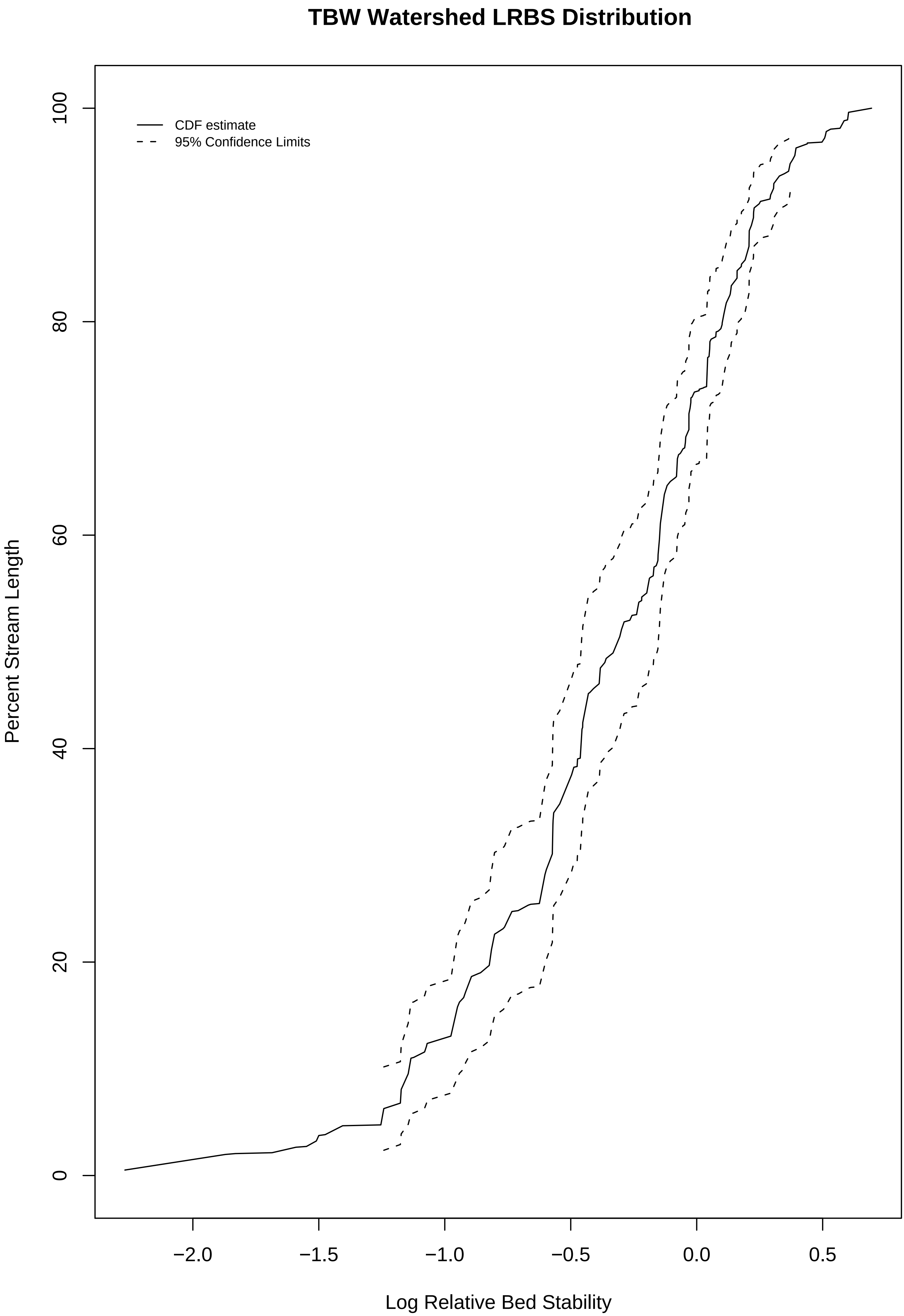


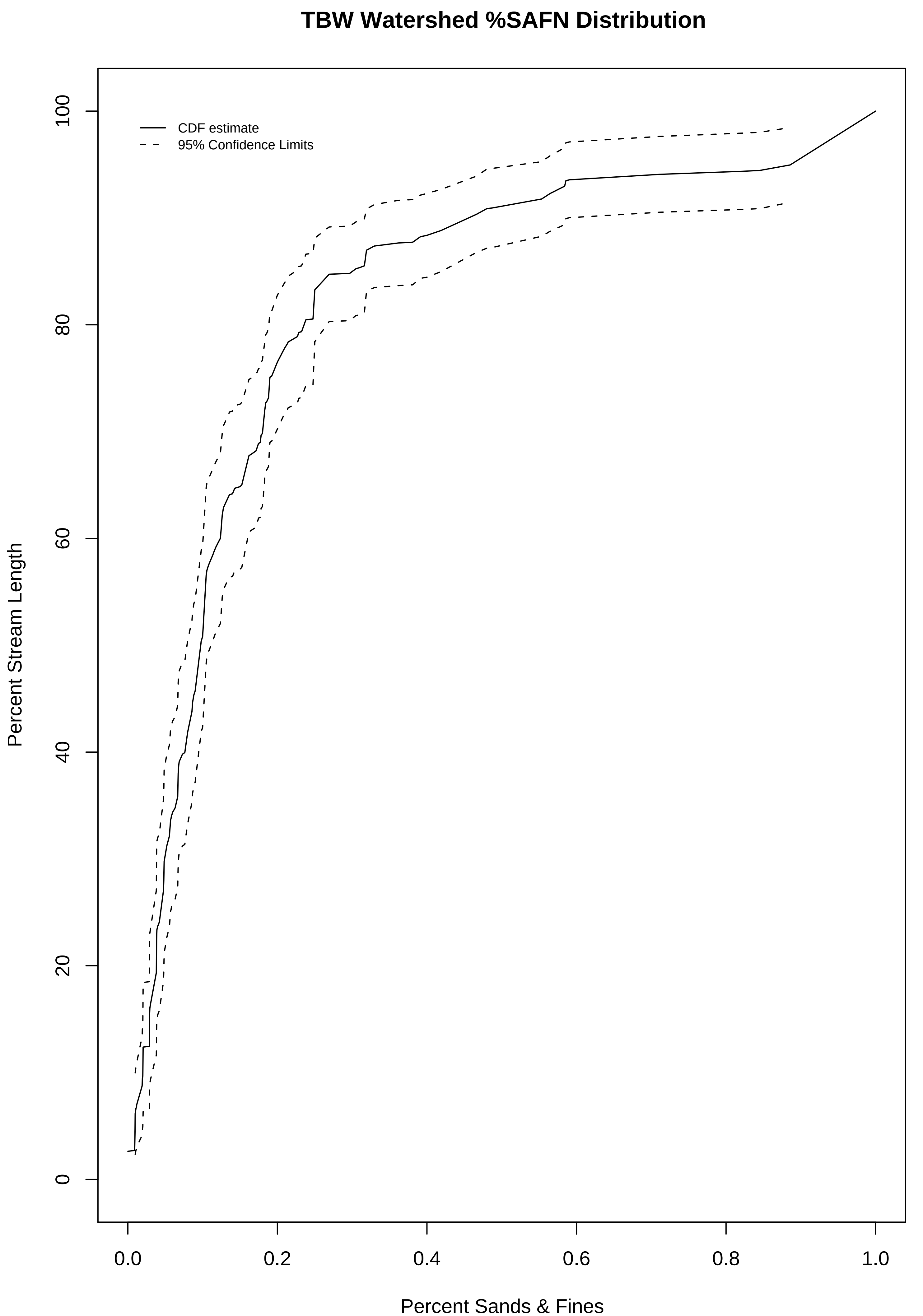

Tillamook Watershed RP100:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
100
200
300
400
500
RP100:Slope



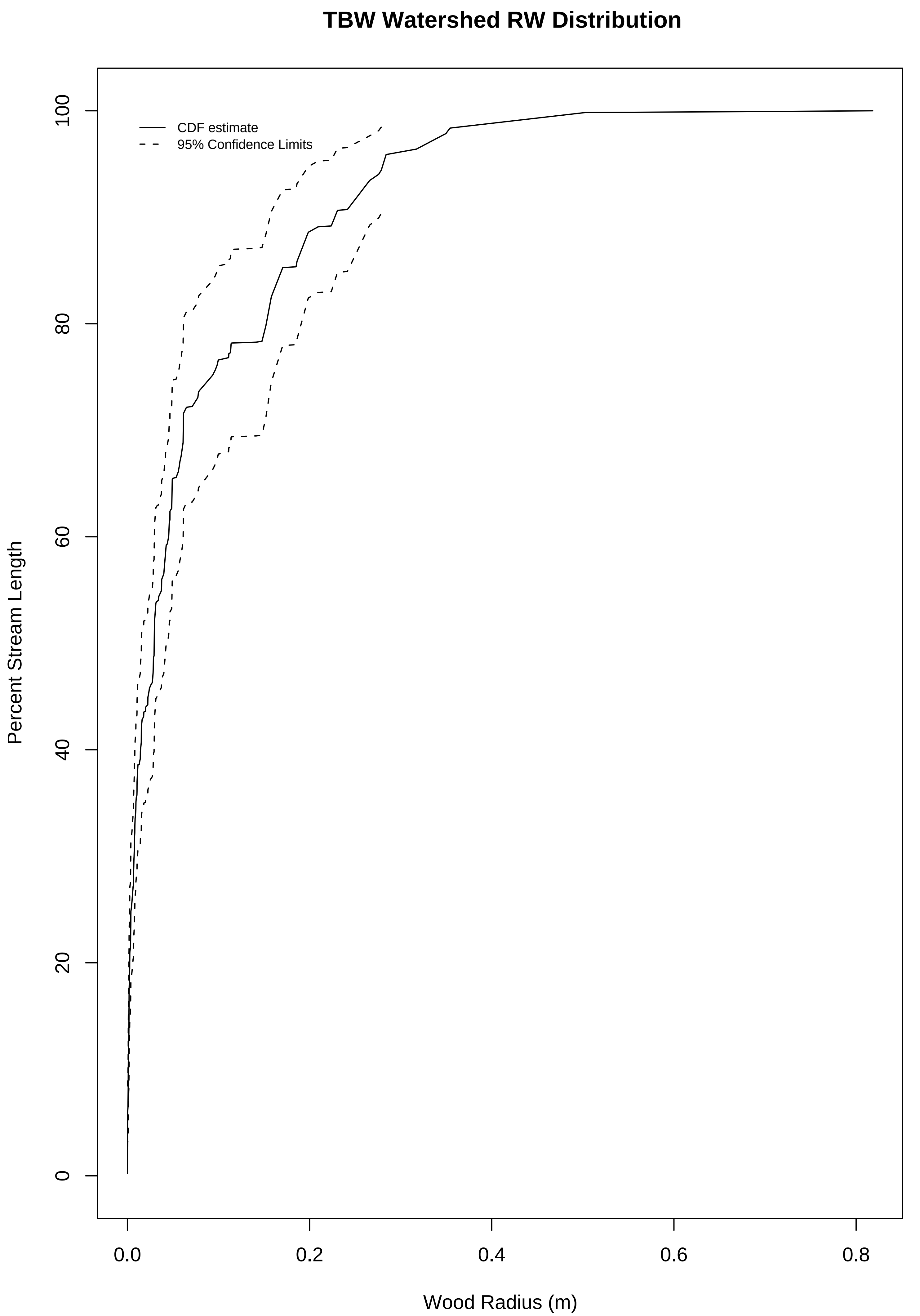
Tillamook Watershed RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
RW:Slope

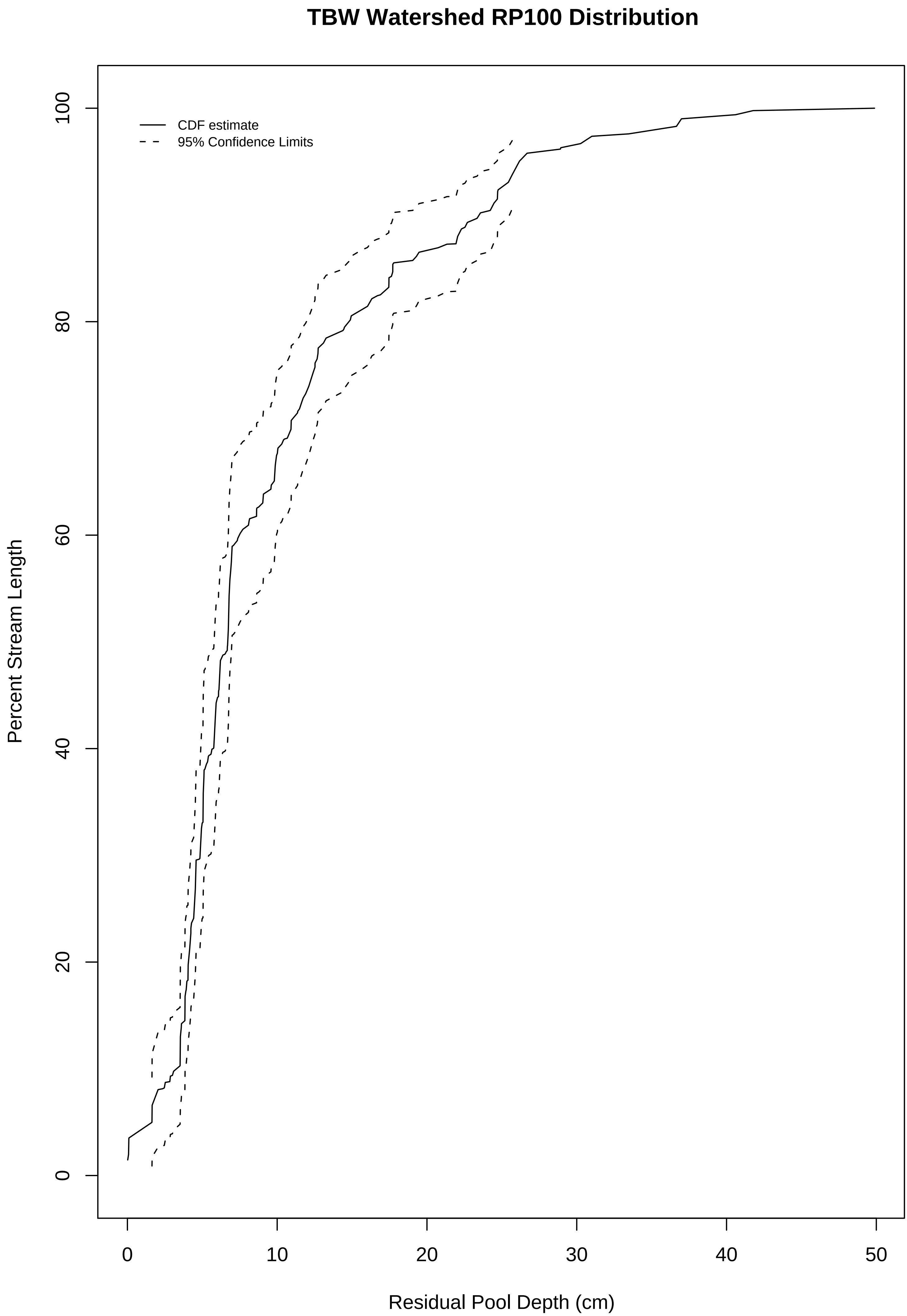

Tillamook Watershed LRBS:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−30
−25
−20
−15
−10
−5
0
LRBS:Slope

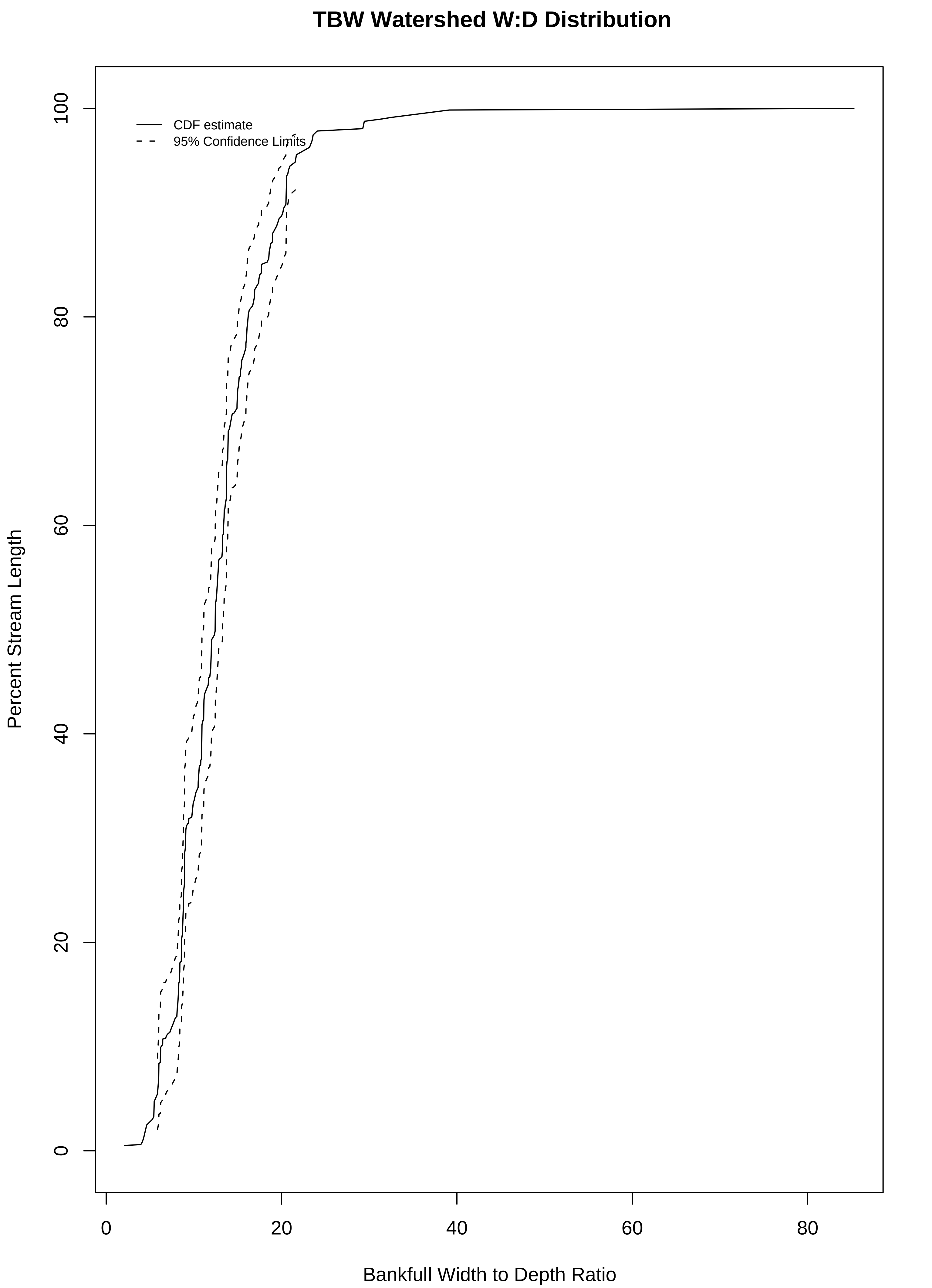

TBW Watershed LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−2.0
−1.5
−1.0
−0.5
0.0
0.5
Log Relative Bed Stability



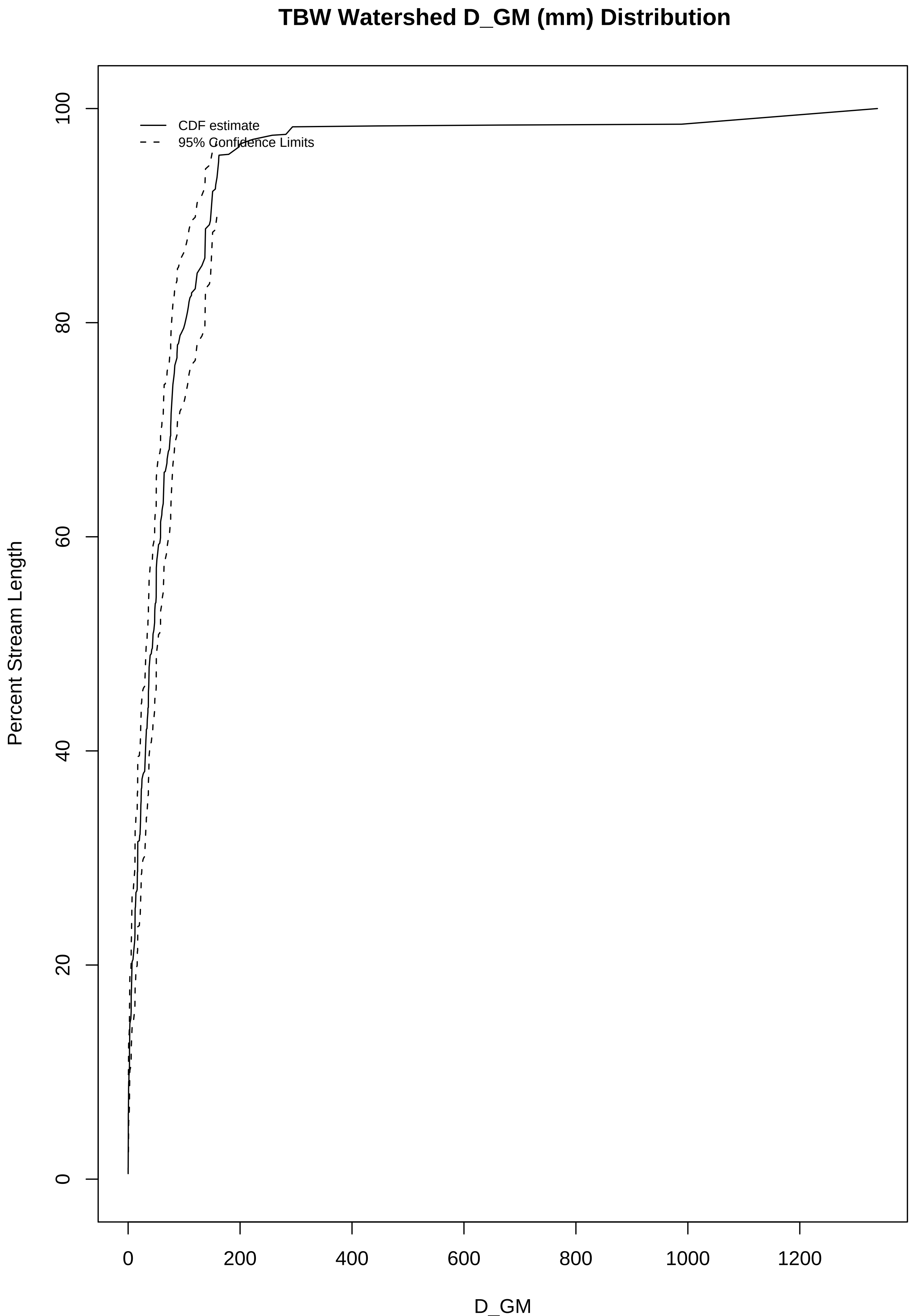
TBW Watershed %SAFN Distribution
CDF estimate
95% Confidence Limits
0
20
40
60
80
100
Percent Stream Length
0.0
0.2
0.4
0.6
0.8
1.0
Percent Sands & Fines


TBW Watershed RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
Wood Radius (m)

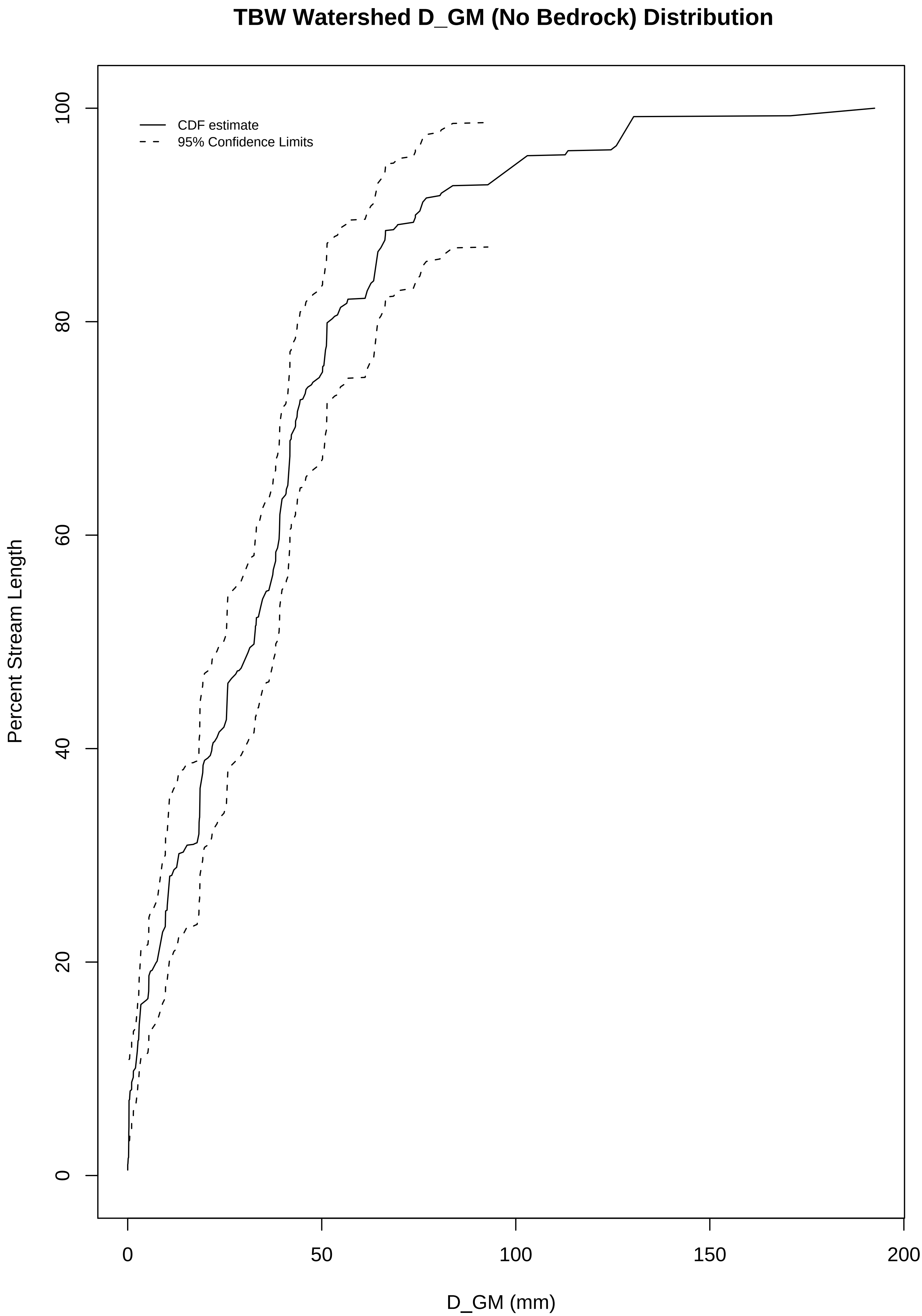

TBW Watershed RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
10
20
30
40
50
Residual Pool Depth (cm)

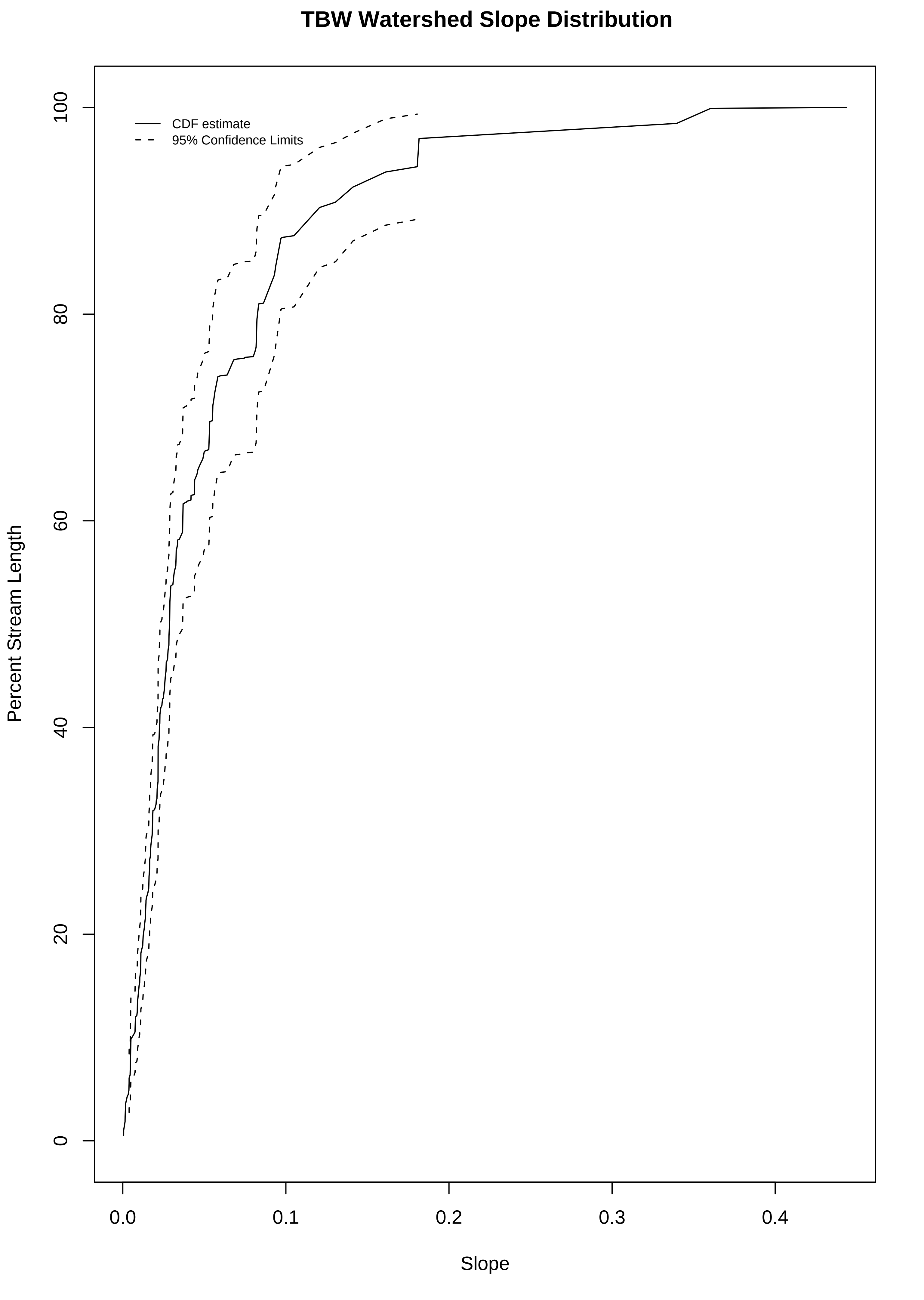


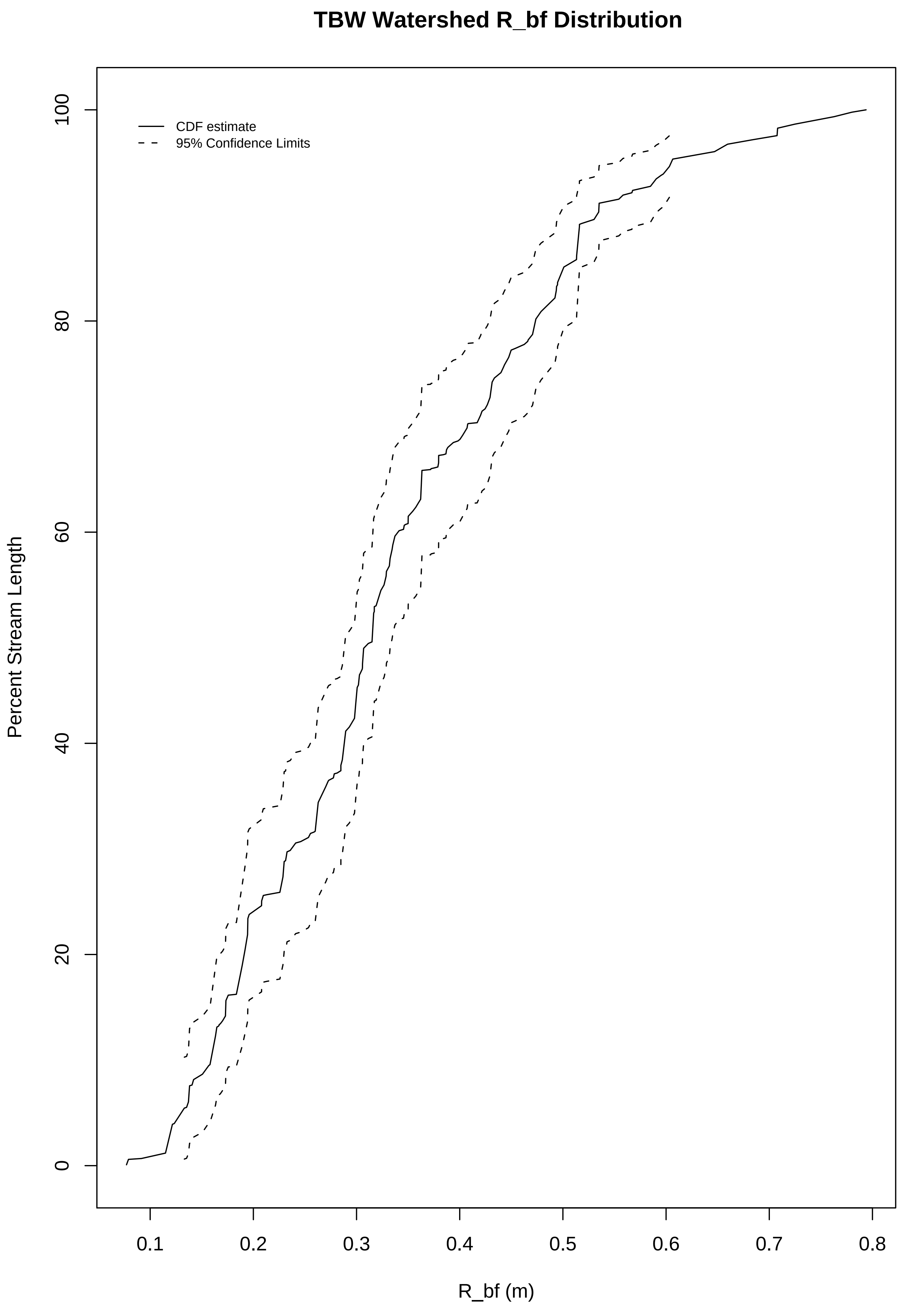
TBW Watershed W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
20
40
60
80
Bankfull Width to Depth Ratio

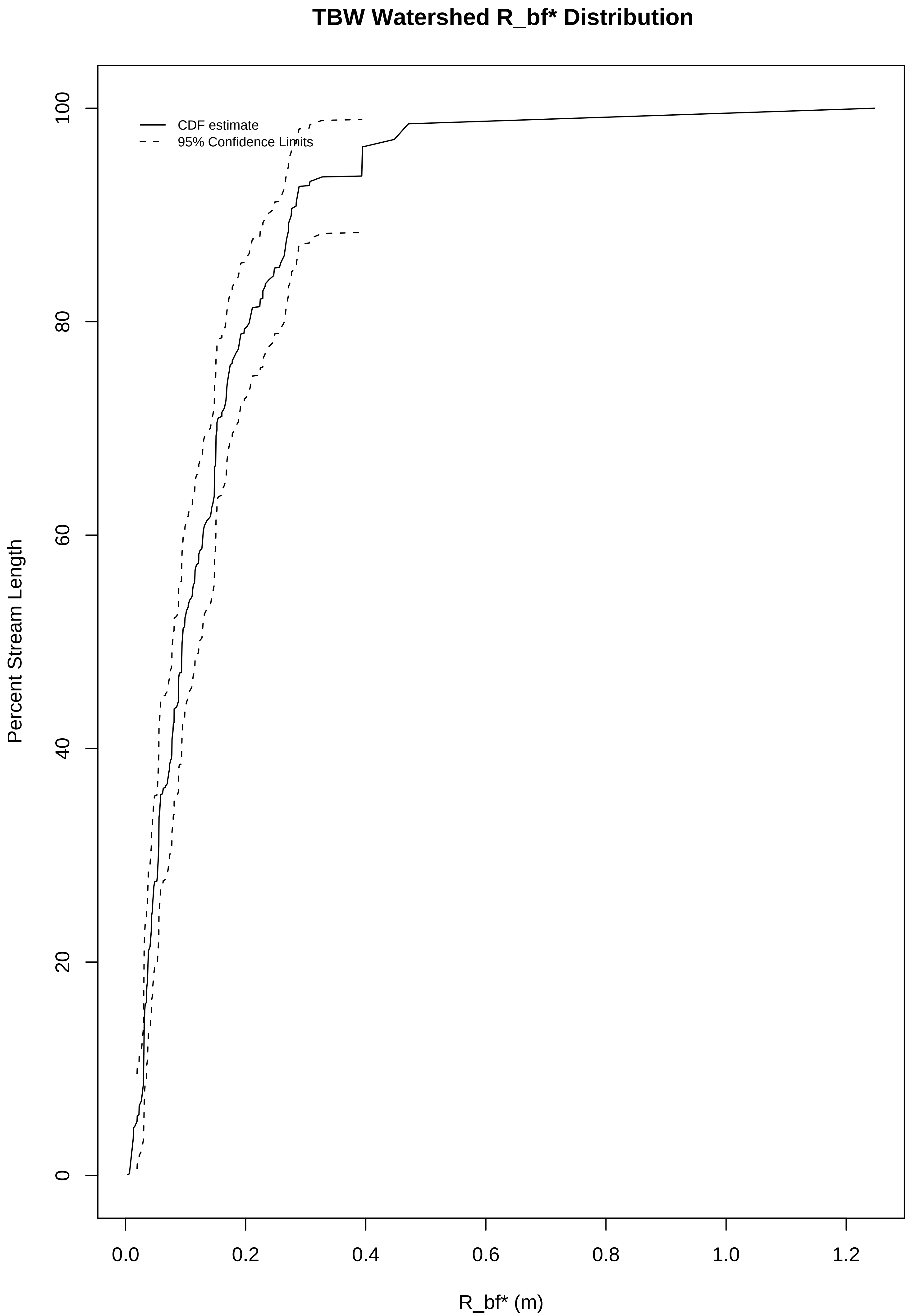


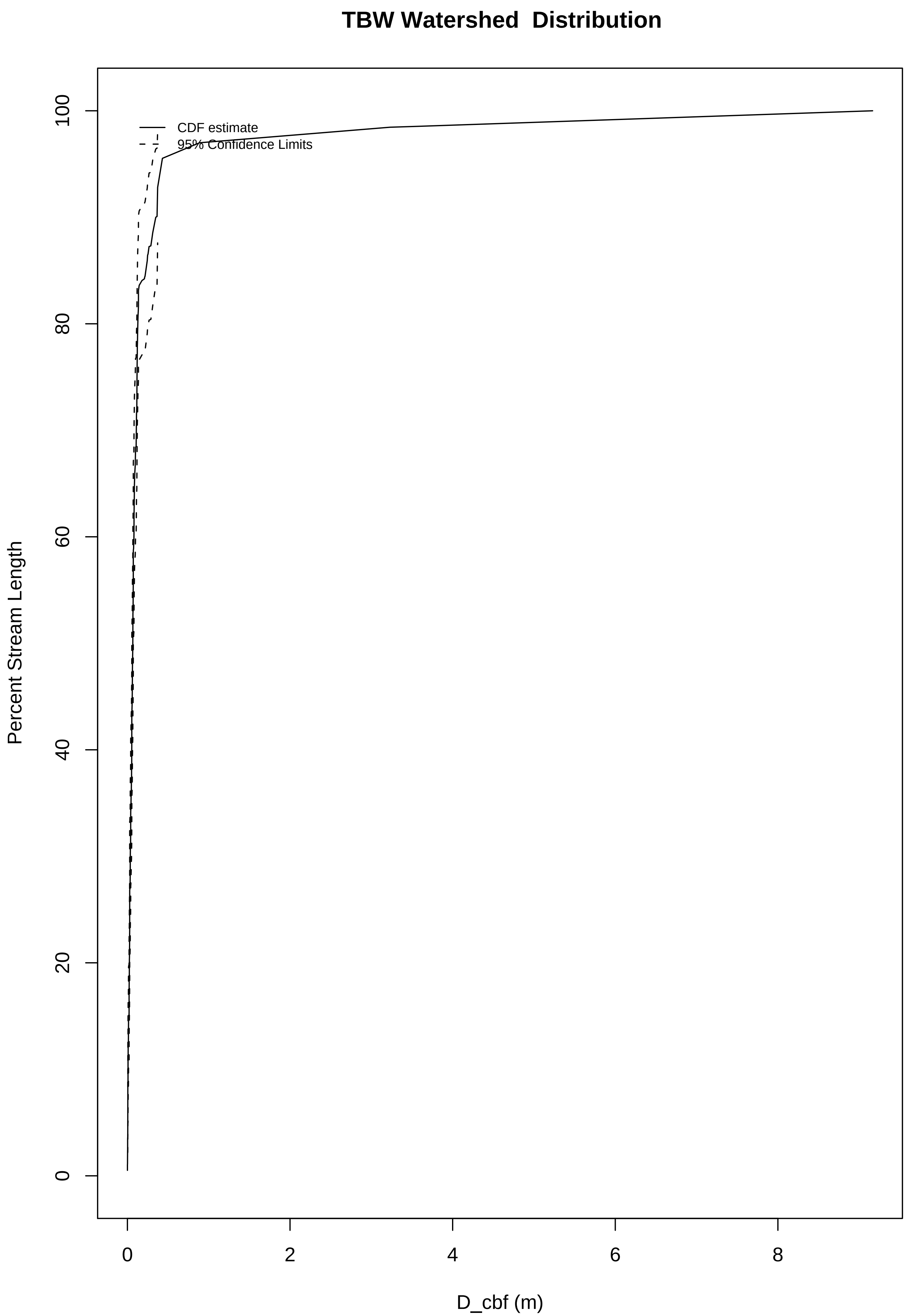
TBW Watershed D_GM (mm) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
200
400
600
800
1000
1200
D_GM

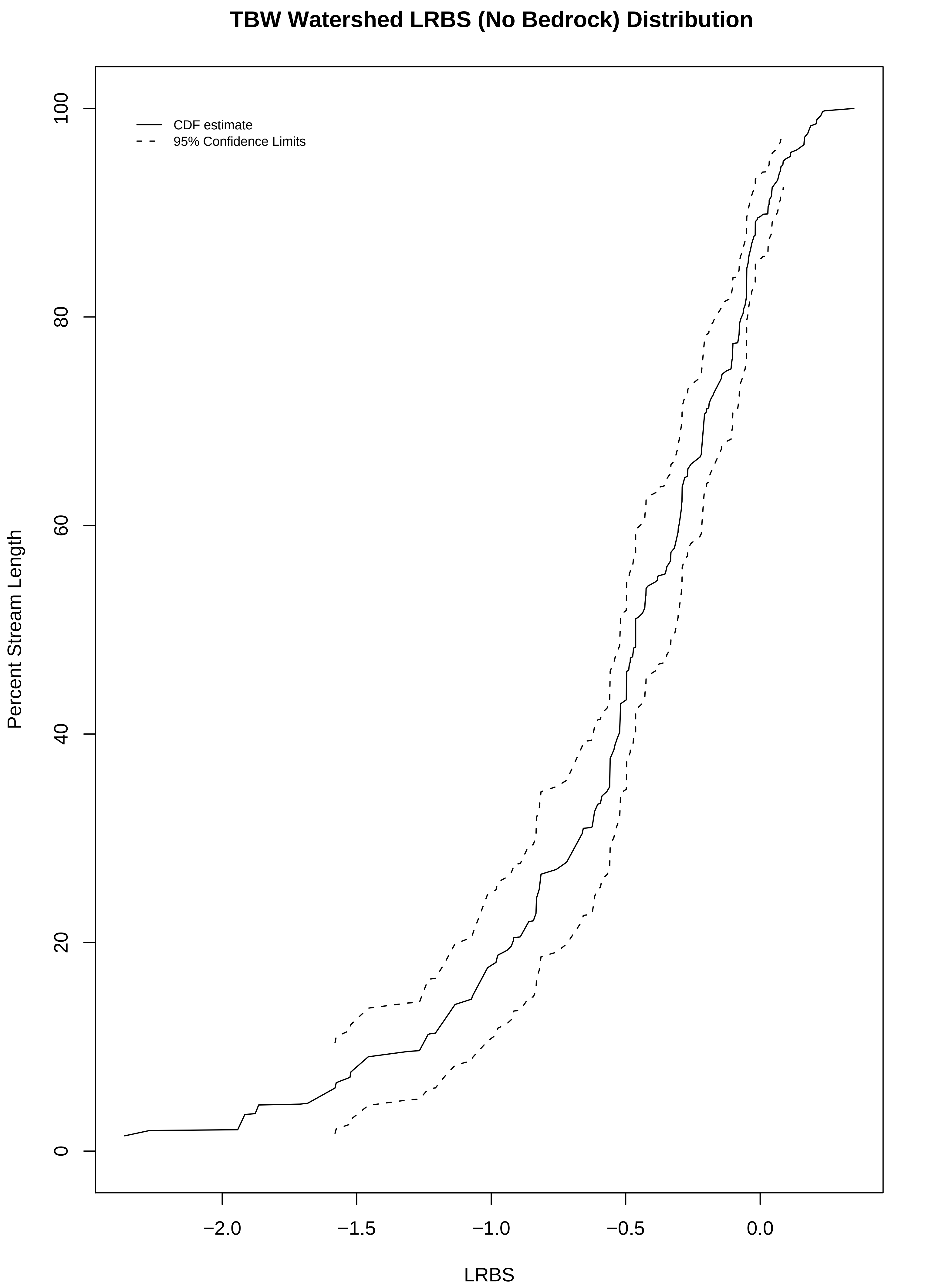

TBW Watershed D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
50
100
150
200
D_GM (mm)

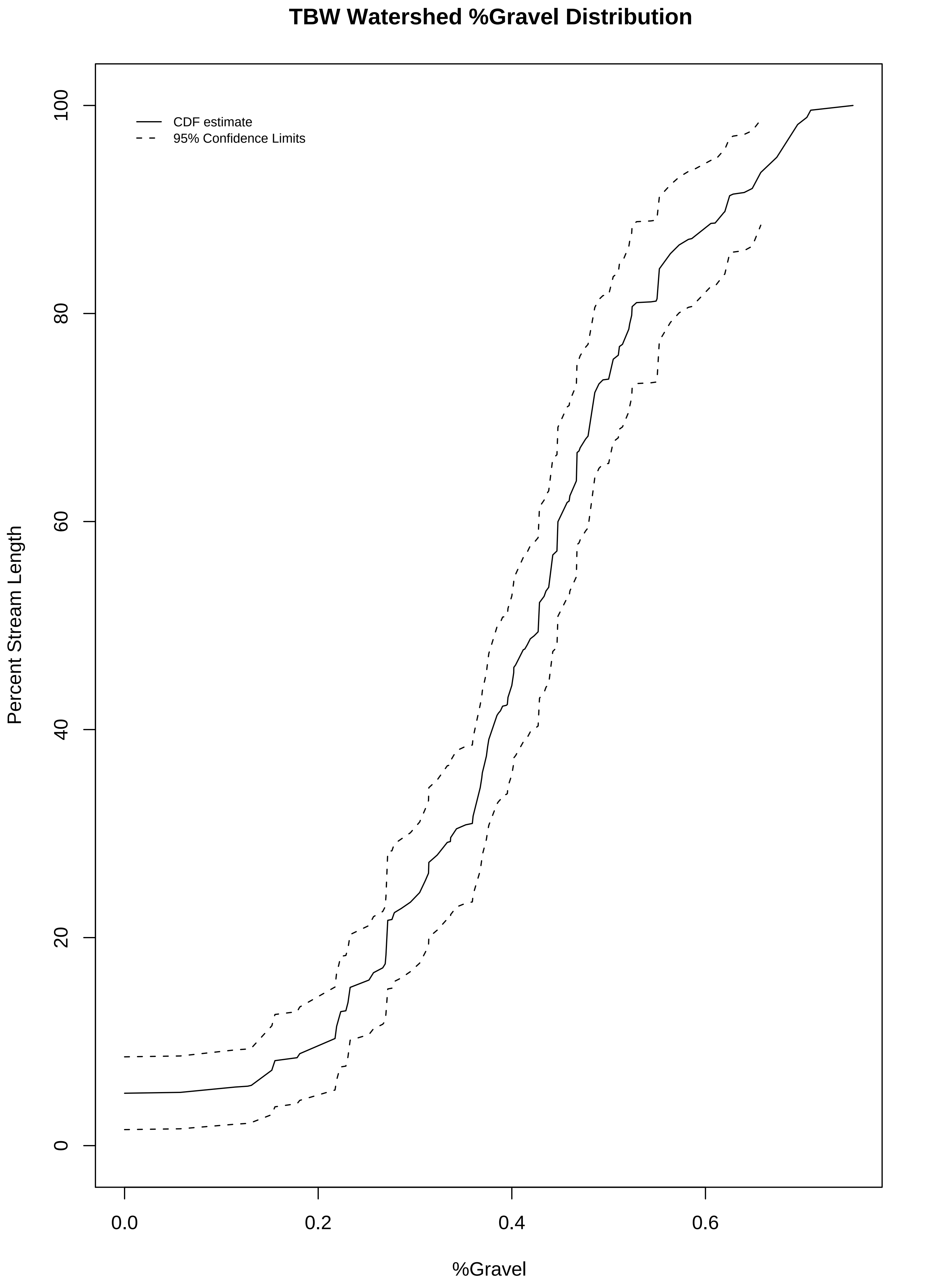

TBW Watershed Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
Slope


TBW Watershed R_bf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
R_bf (m)

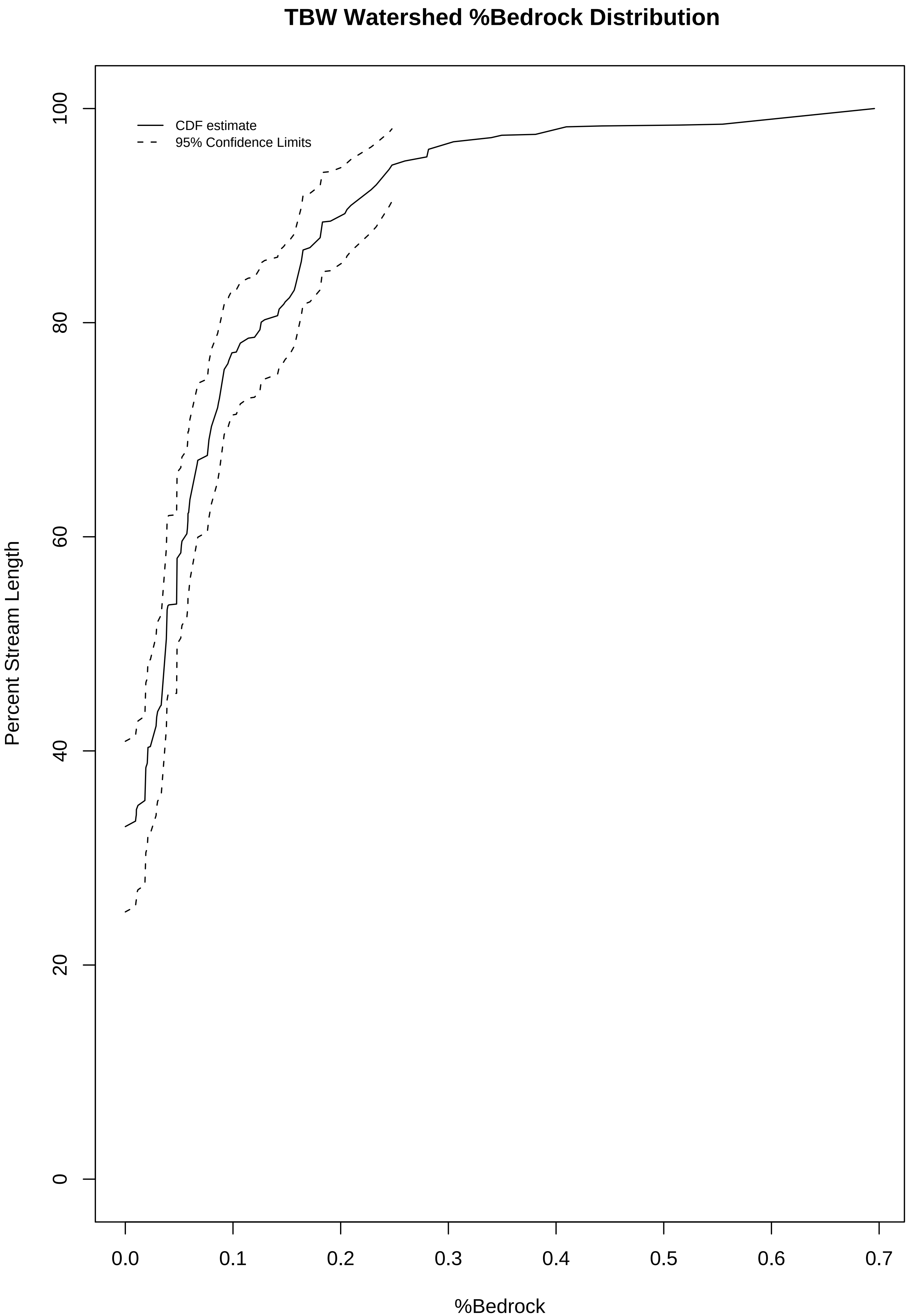

TBW Watershed R_bf* Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0
1.2
R_bf* (m)


TBW Watershed Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
2
4
6
8
D_cbf (m)

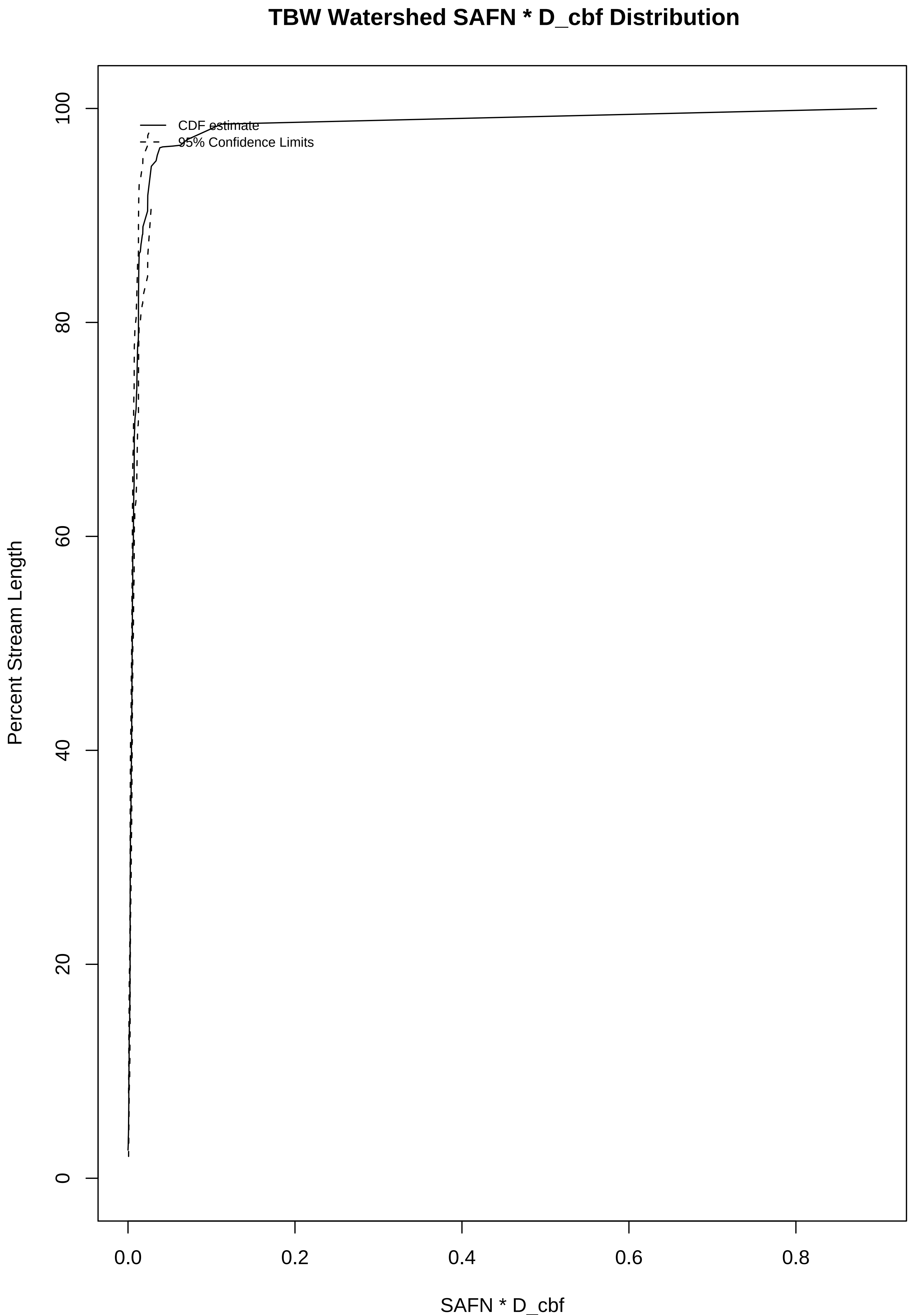

TBW Watershed LRBS (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−2.0
−1.5
−1.0
−0.5
0.0
LRBS

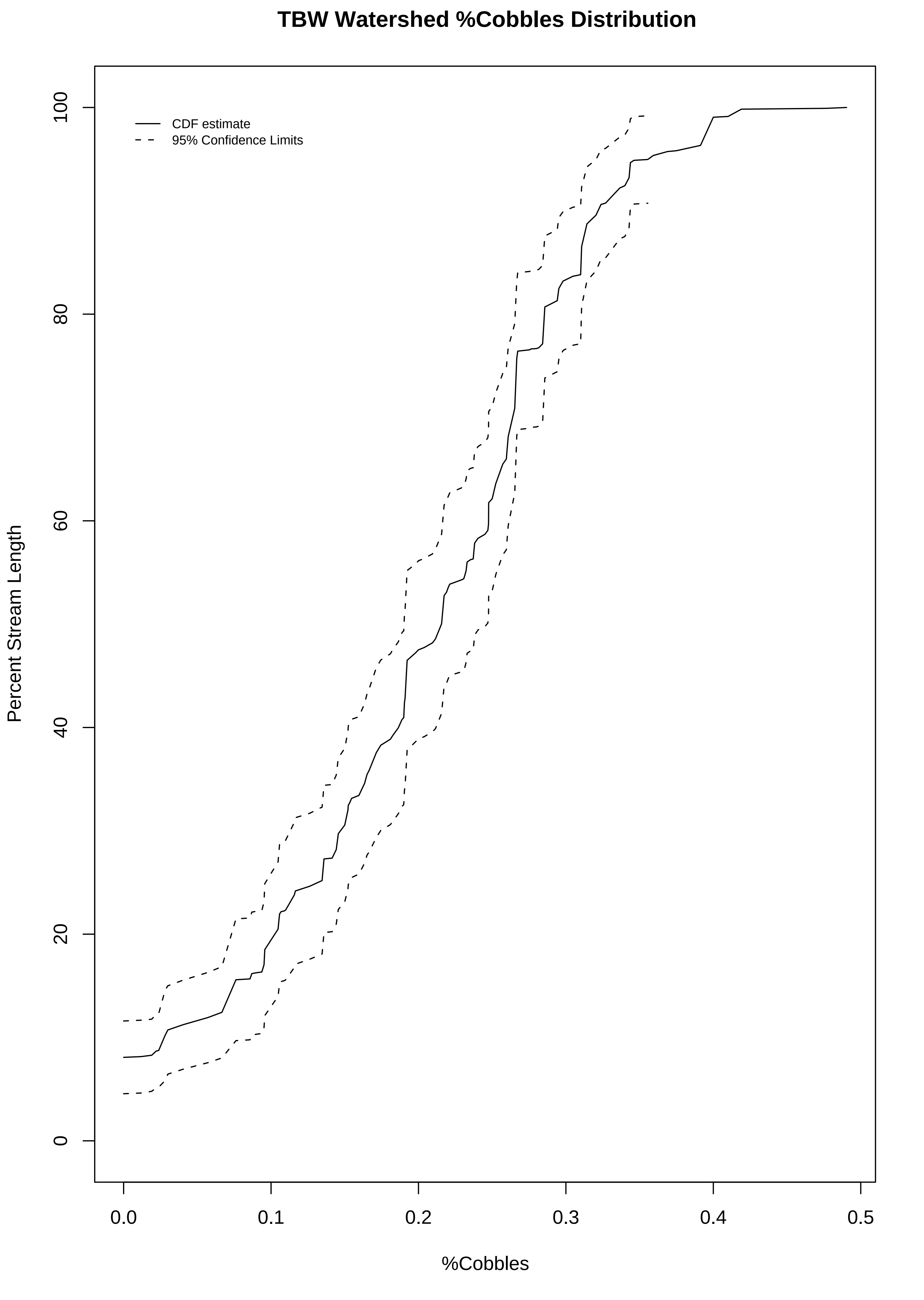


TBW Watershed %Gravel Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
%Gravel

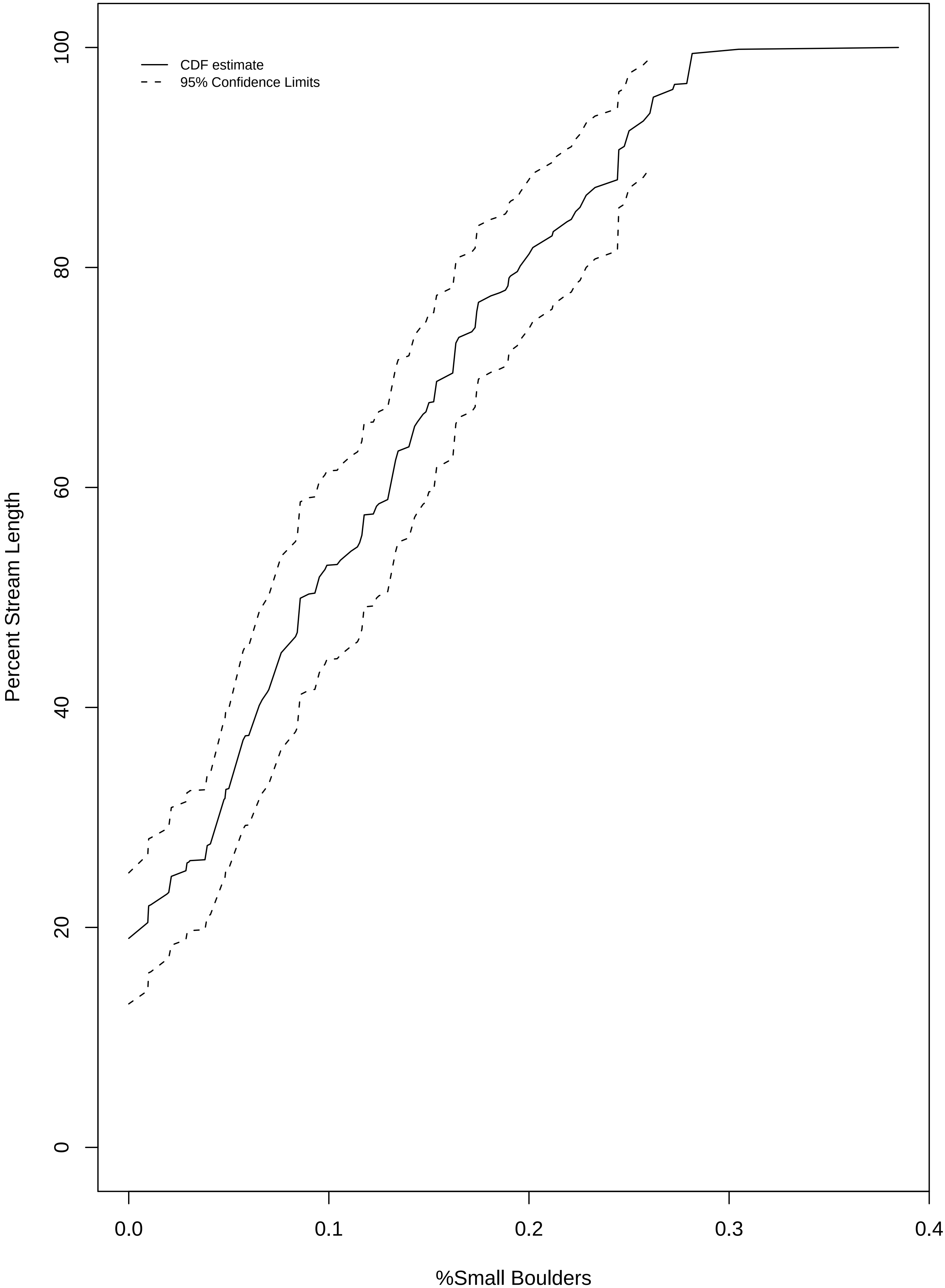


TBW Watershed %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
%Bedrock

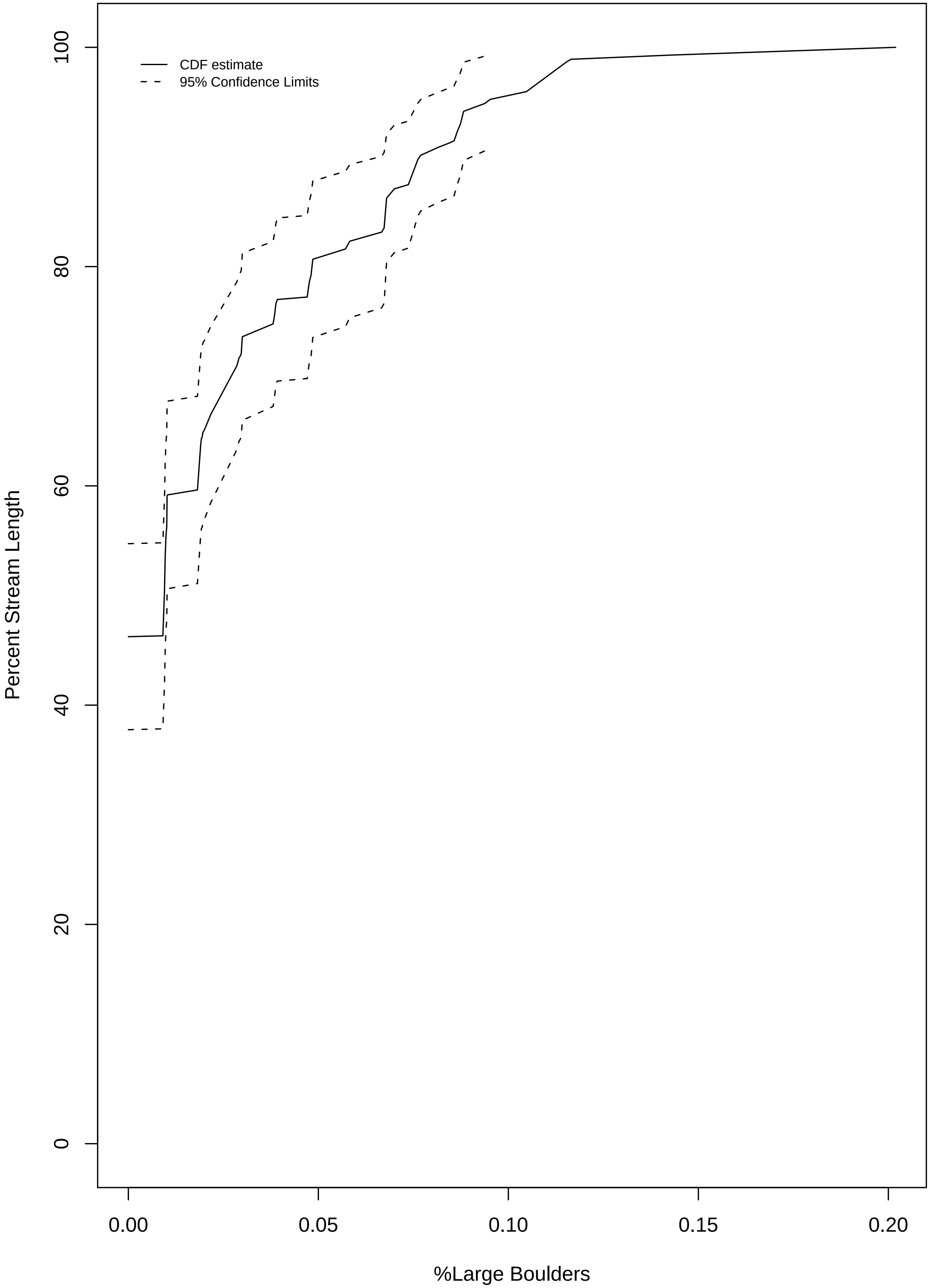

TBW Watershed SAFN * D_cbf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
SAFN * D_cbf

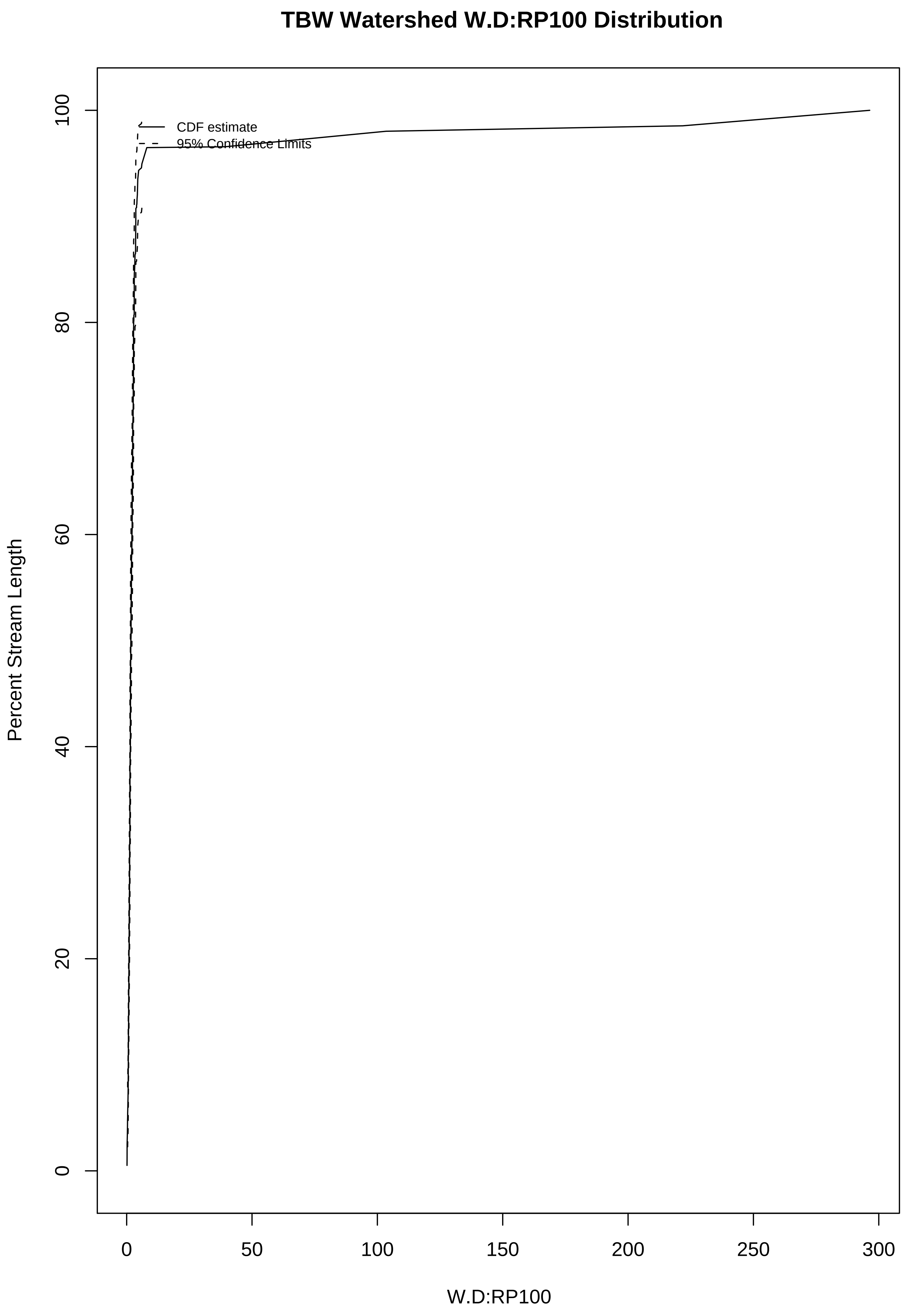

TBW Watershed %Cobbles Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
%Cobbles

TBW Watershed %Small Boulders Distribution

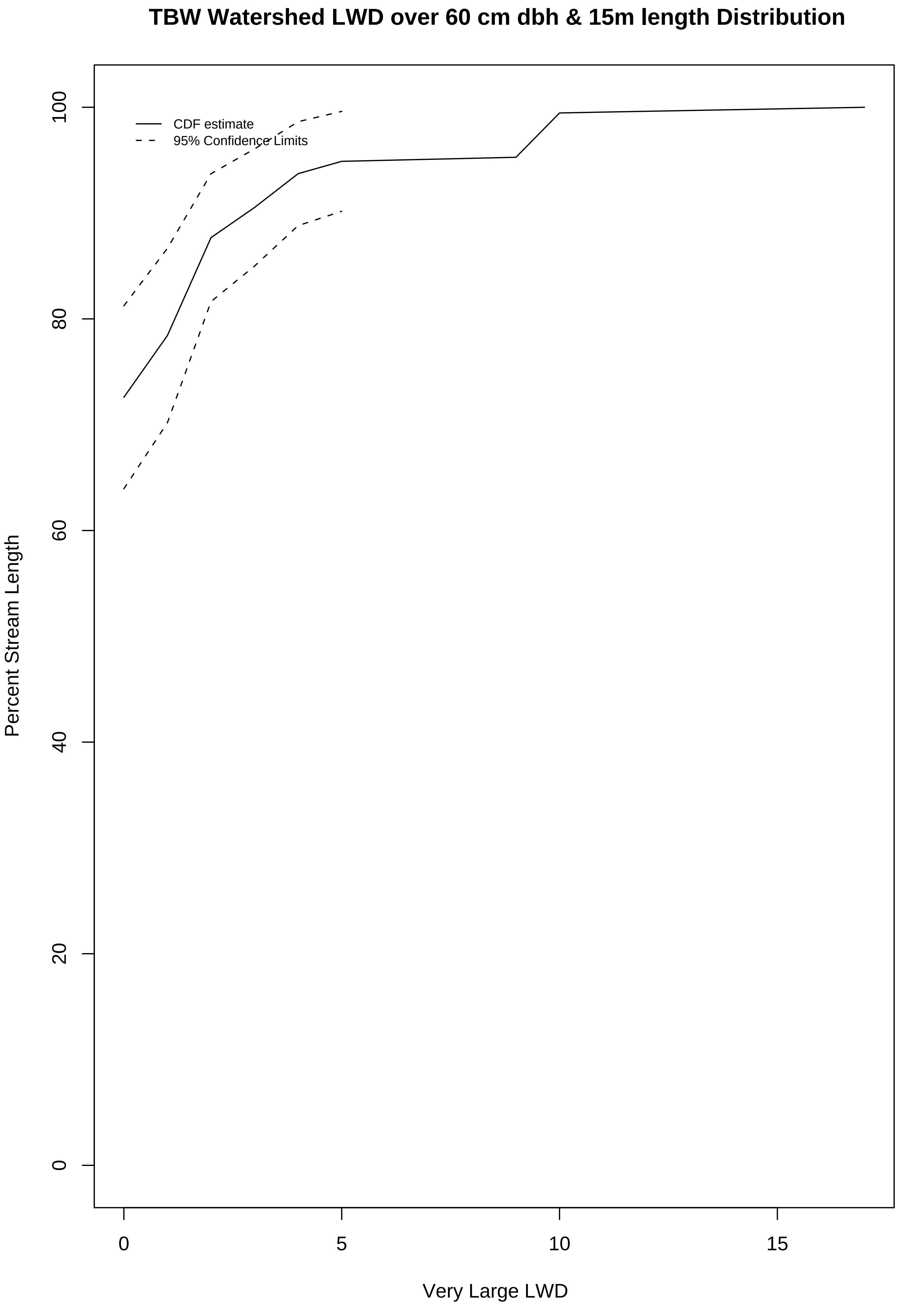


TBW Watershed %Large Boudlers Distribution

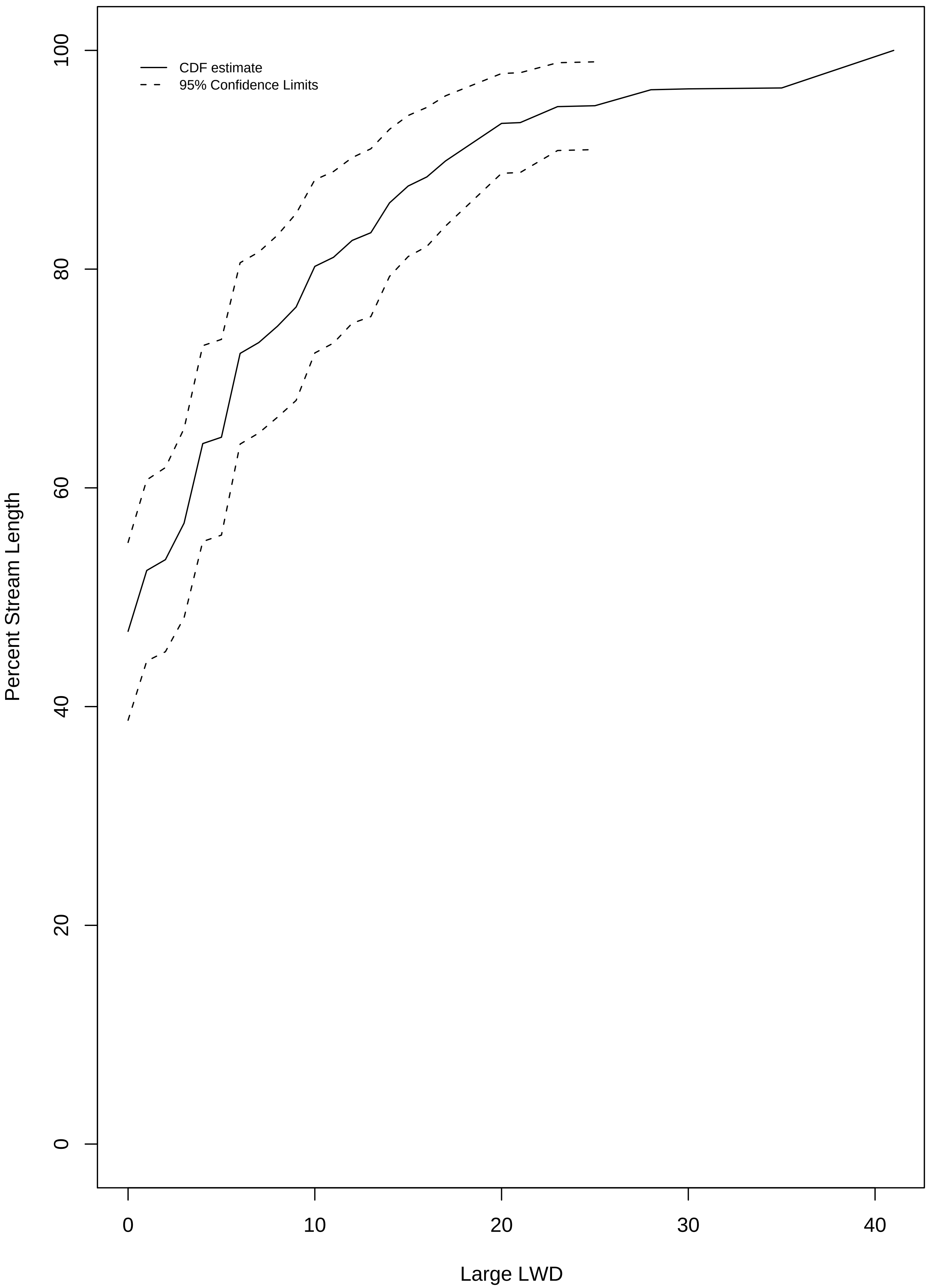


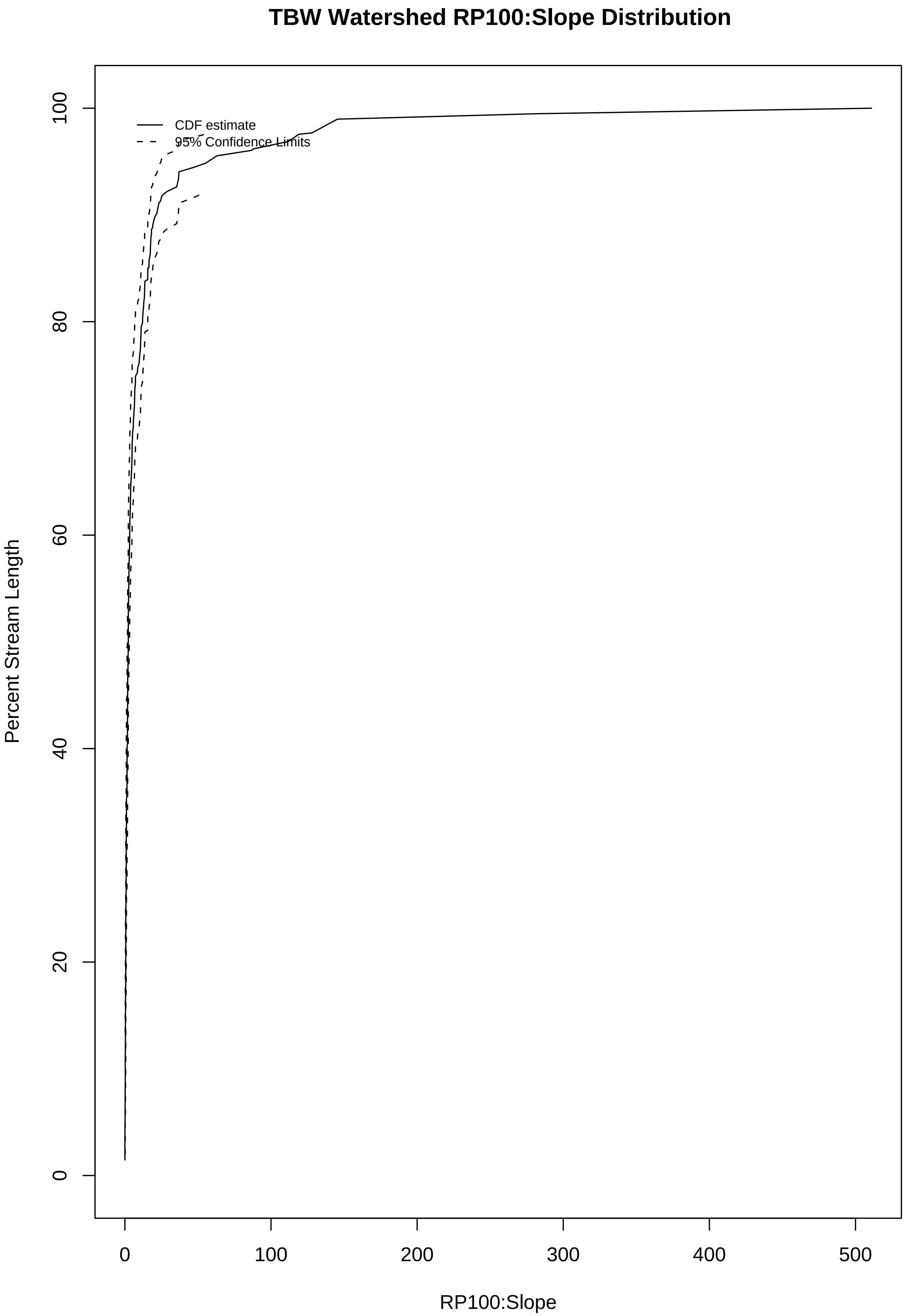


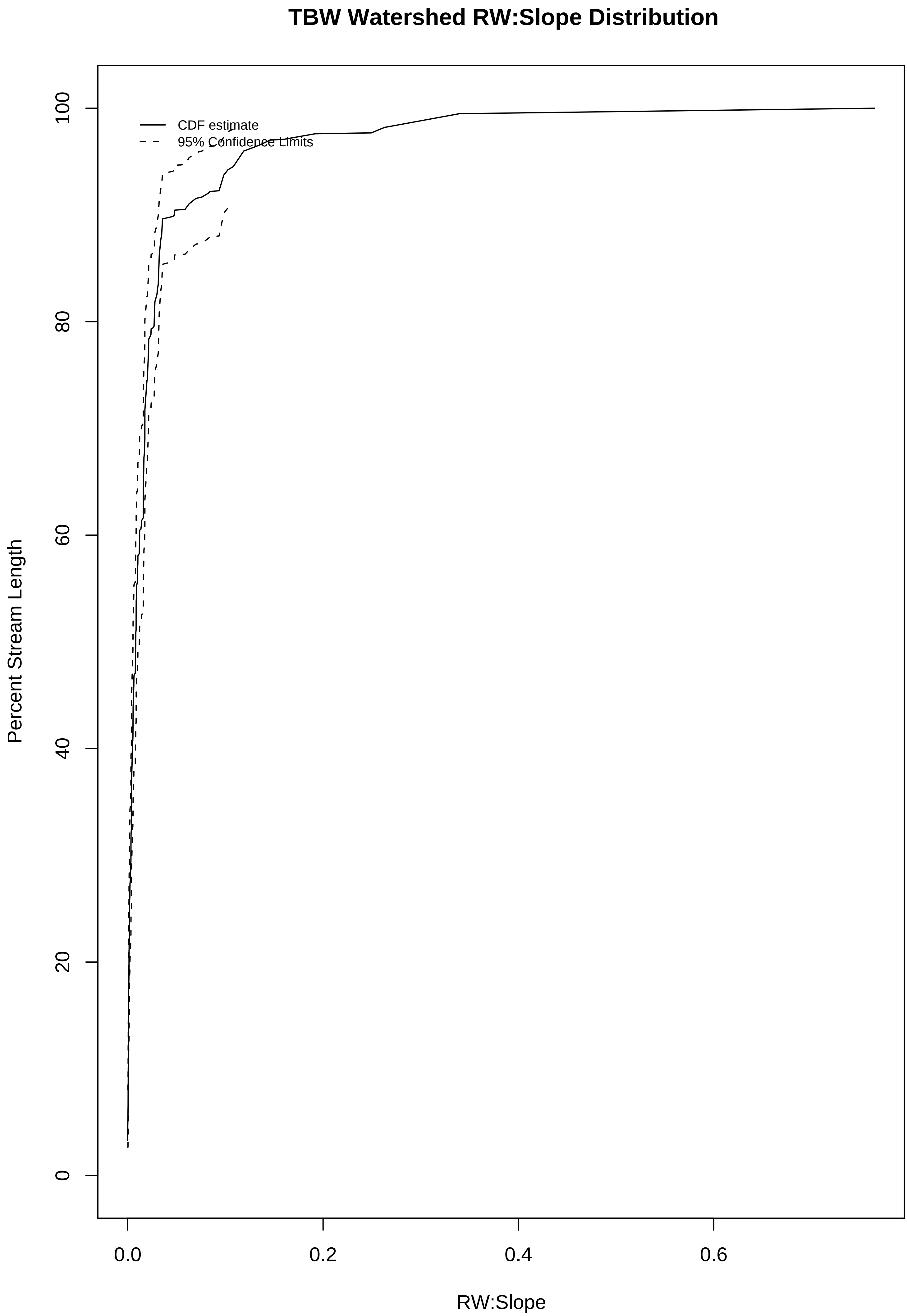
TBW Watershed W.D:RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
W.D:RP100
0
20
40
60
80
100
0
50
100
150
200
250
300


TBW Watershed LWD over 60 cm dbh & 15m length Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
5
10
15
Very Large LWD

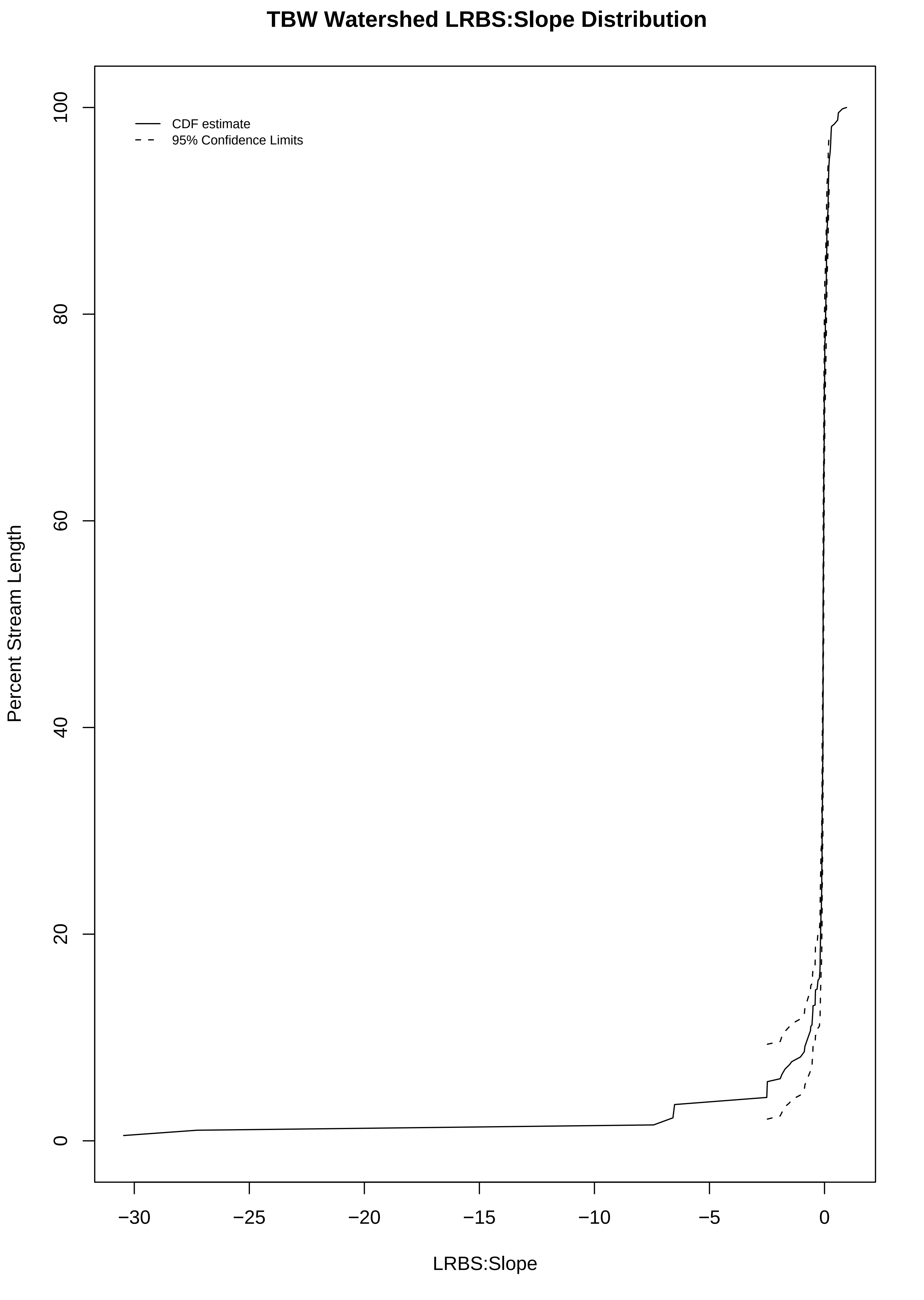
TBW Watershed TBW Watershed LWD over 60 cm dbh Distribution



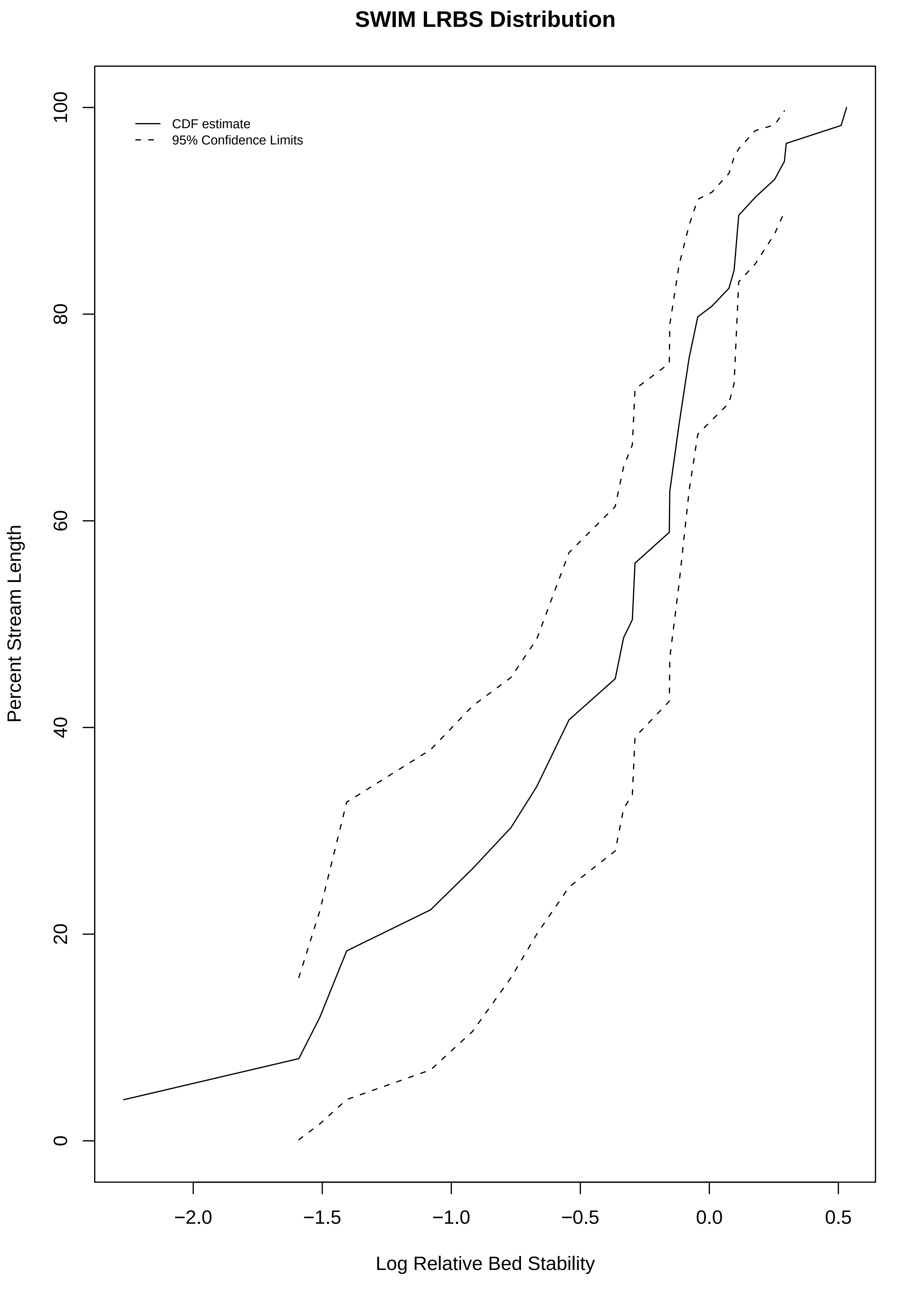

TBW Watershed RP100:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
100
200
300
400
500
RP100:Slope



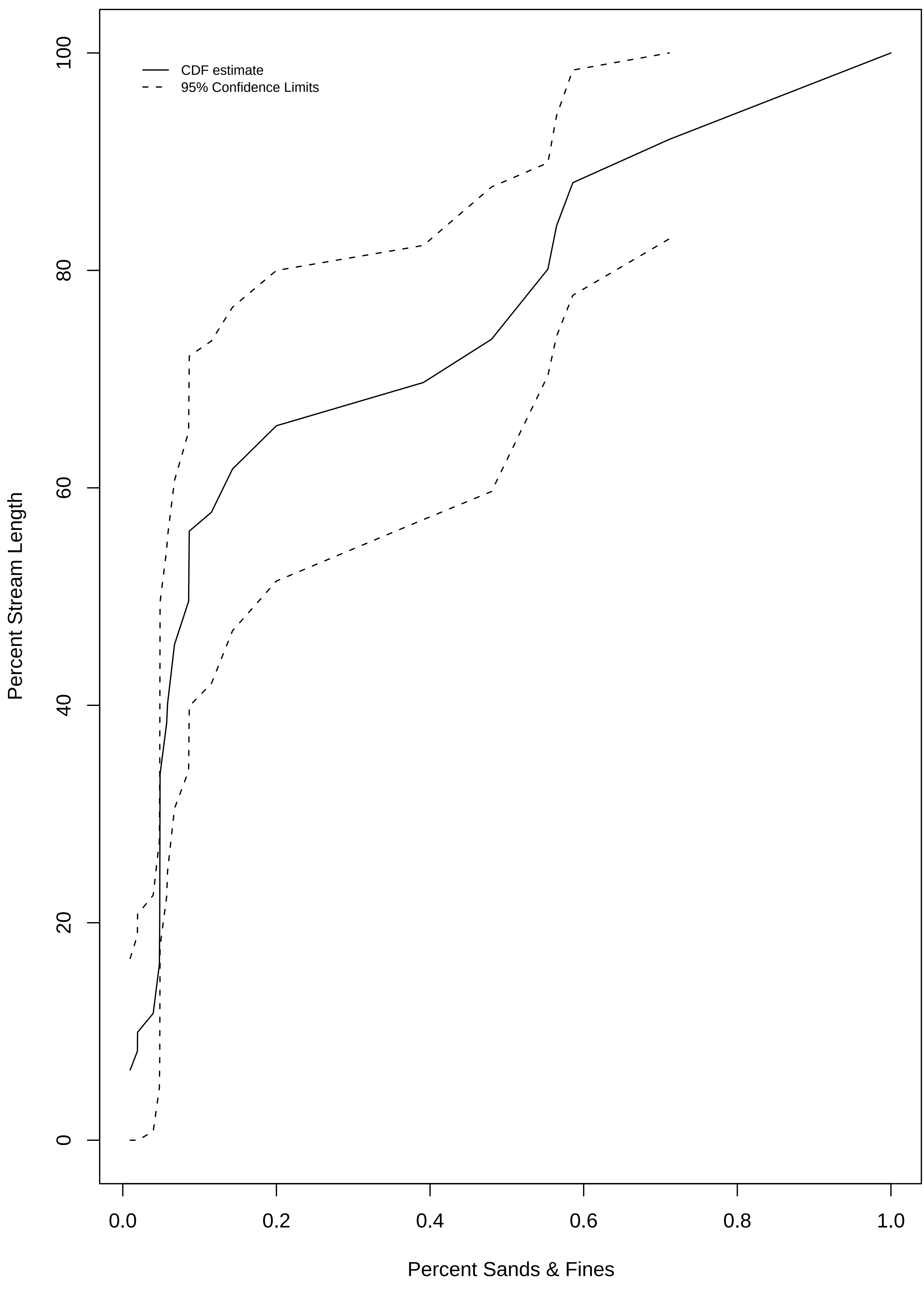
TBW Watershed RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
RW:Slope

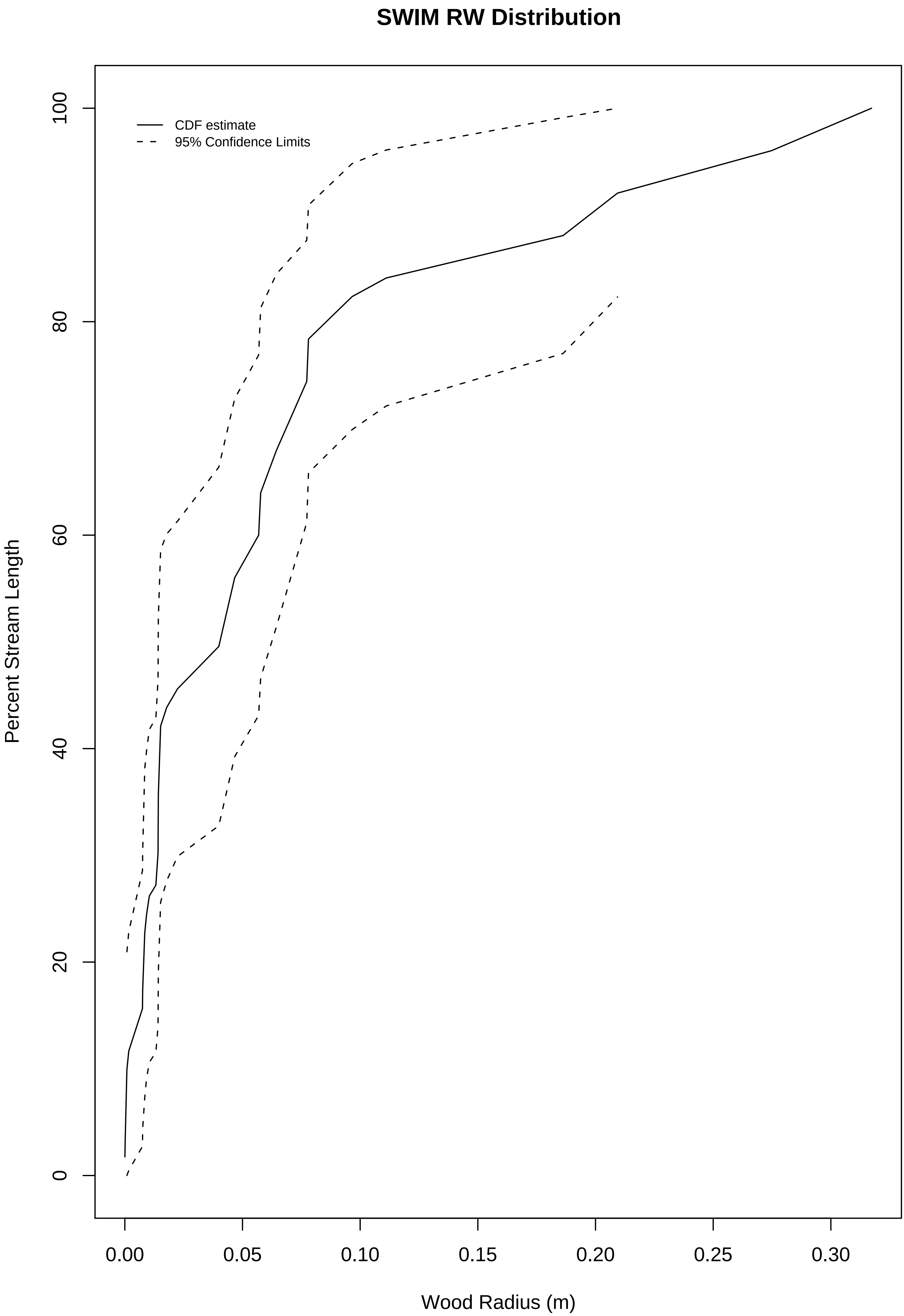


TBW Watershed LRBS:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−30
−25
−20
−15
−10
−5
0
LRBS:Slope

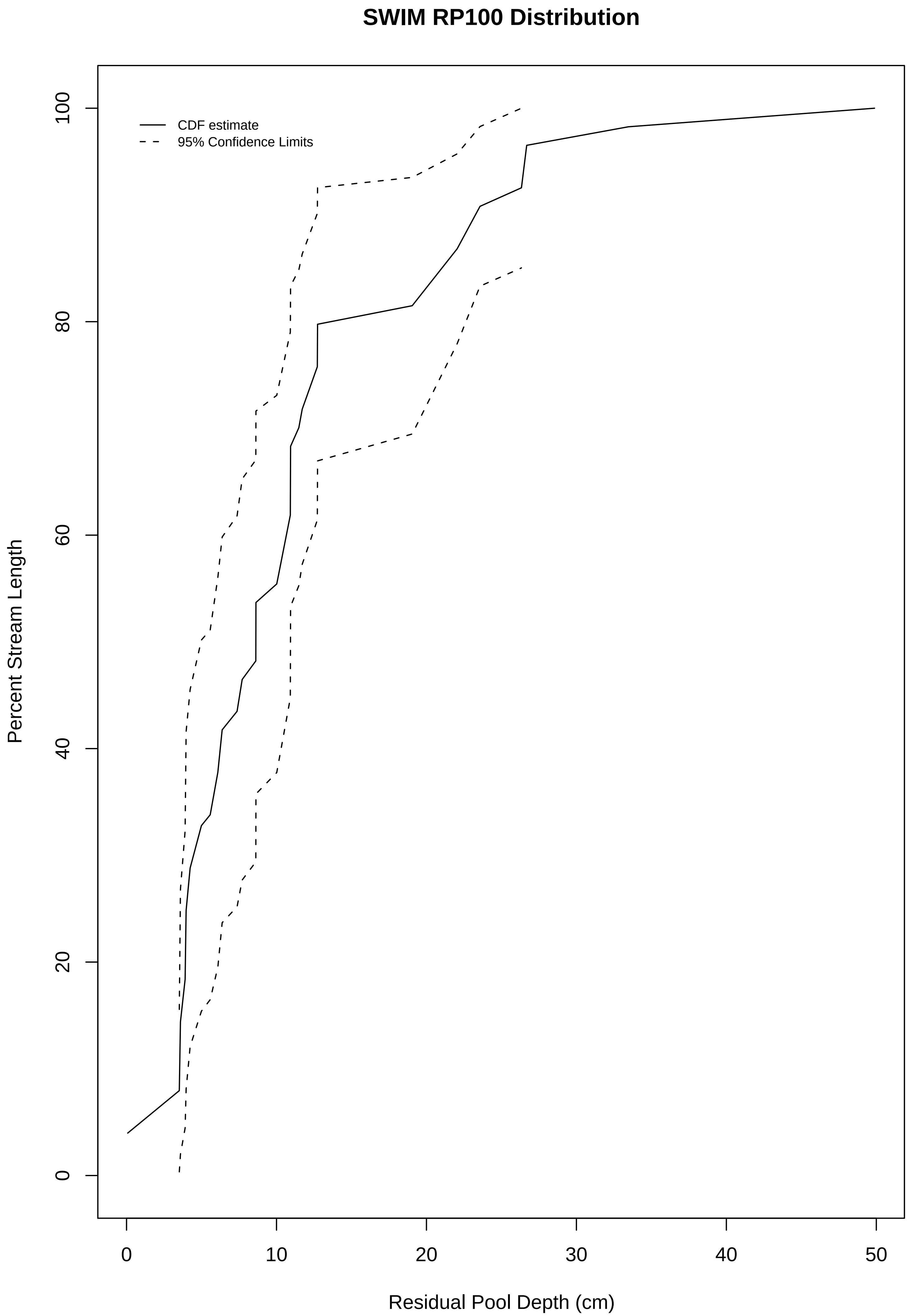

SWIM LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
Log Relative Bed Stability
0
20
40
60
80
100
−2.0
−1.5
−1.0
−0.5
0.0
0.5

SWIM %SAFN Distribution

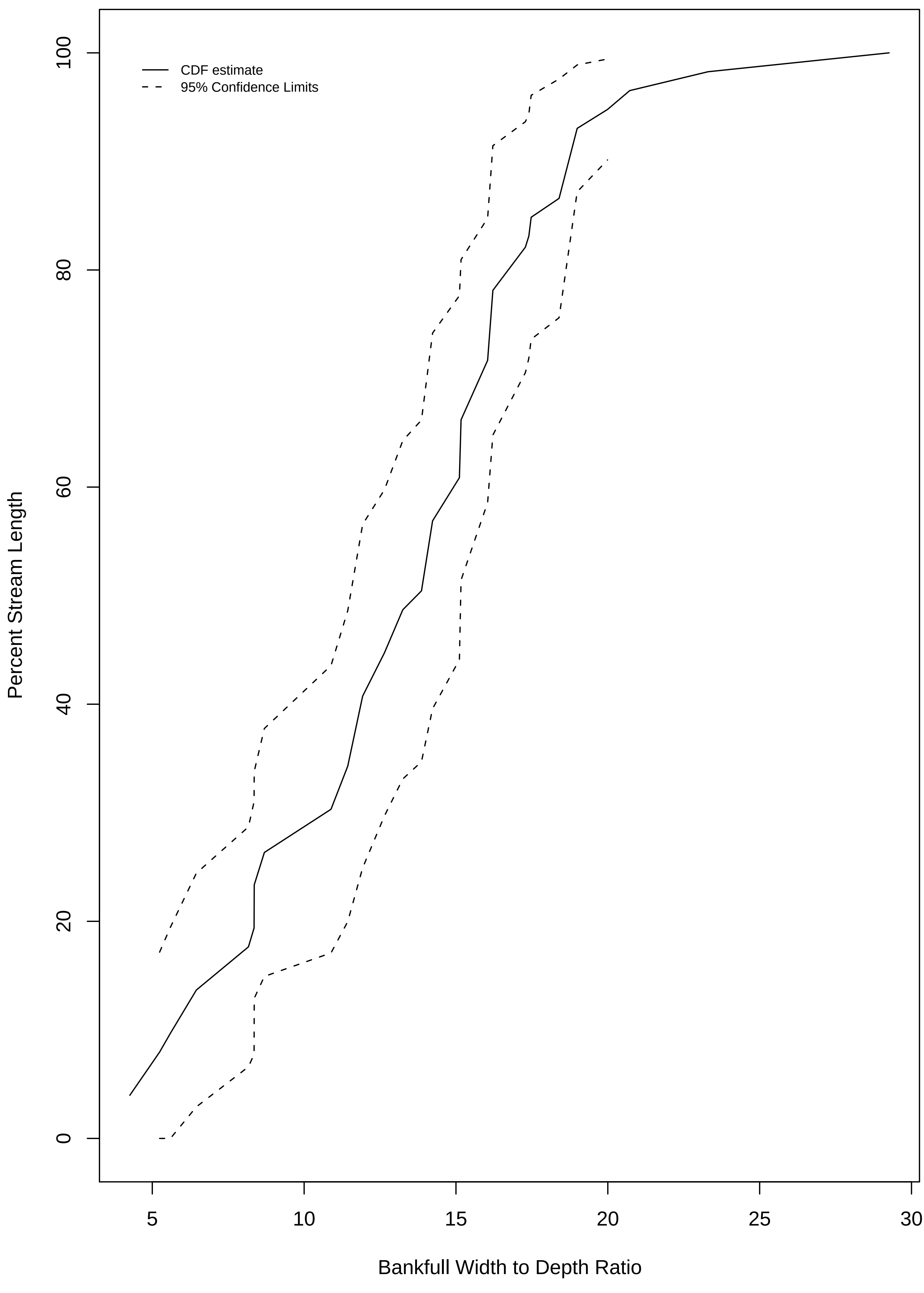




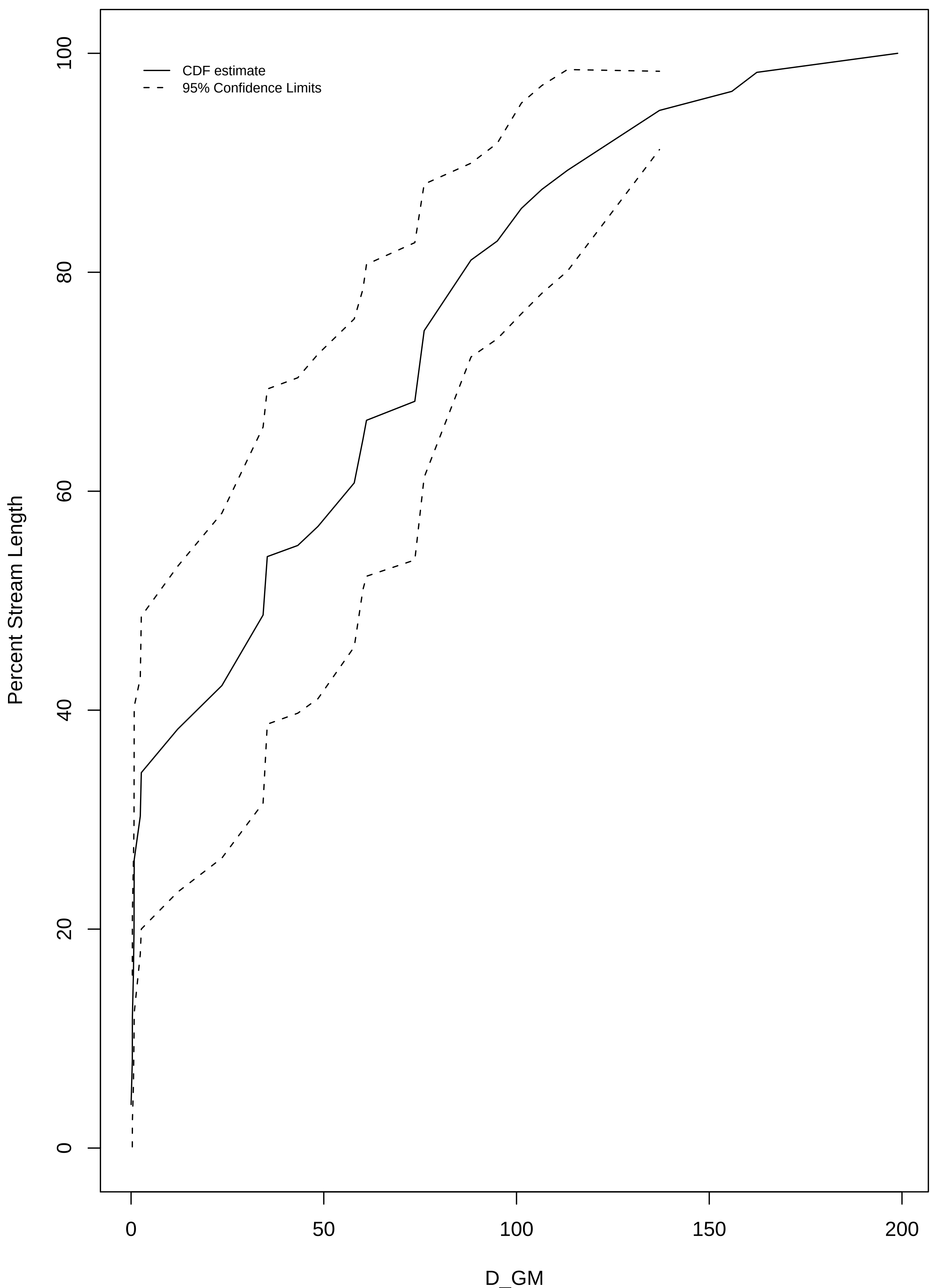
SWIM RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Wood Radius (m)

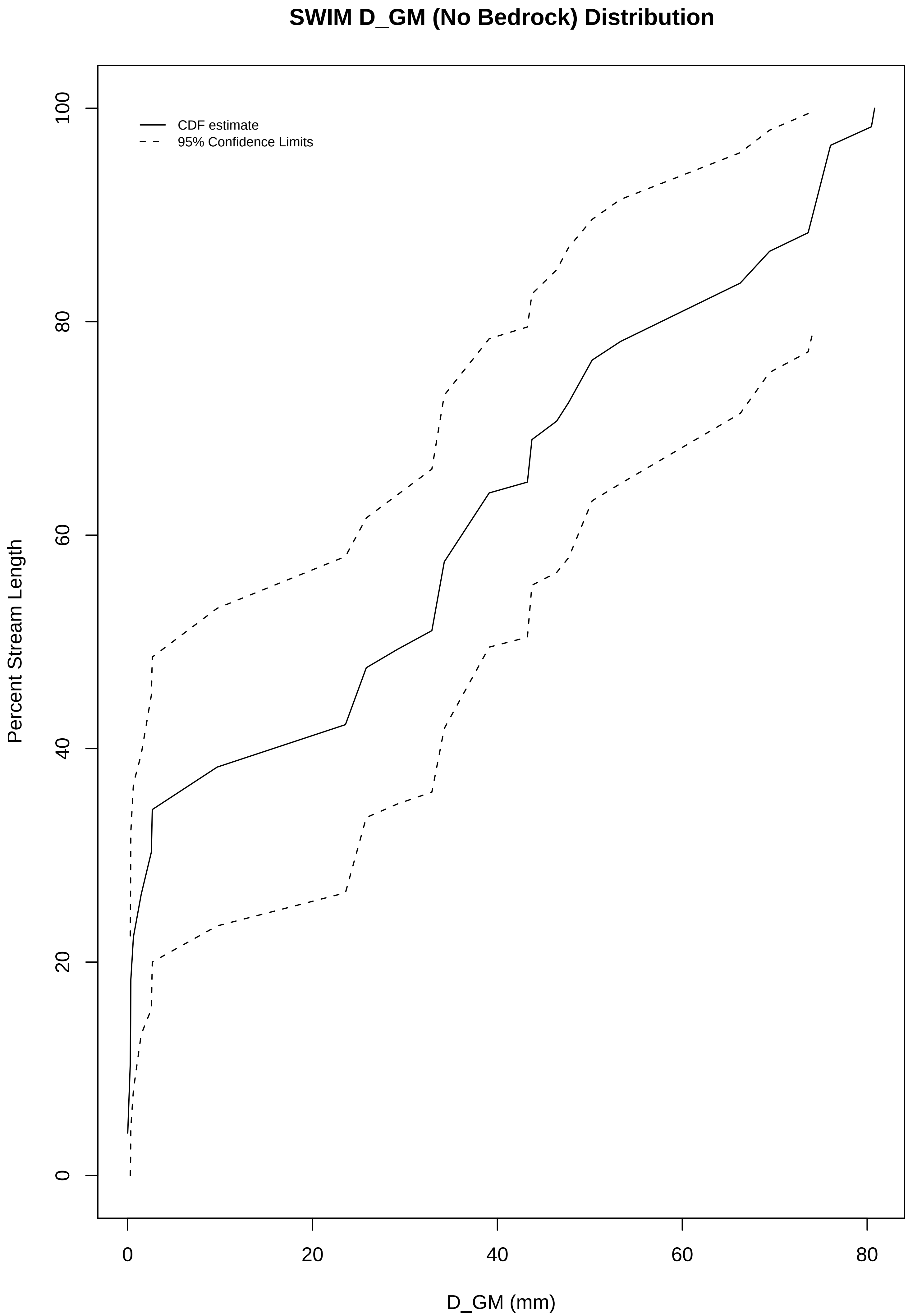

SWIM RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
10
20
30
40
50
Residual Pool Depth (cm)

SWIM W:D Distribution

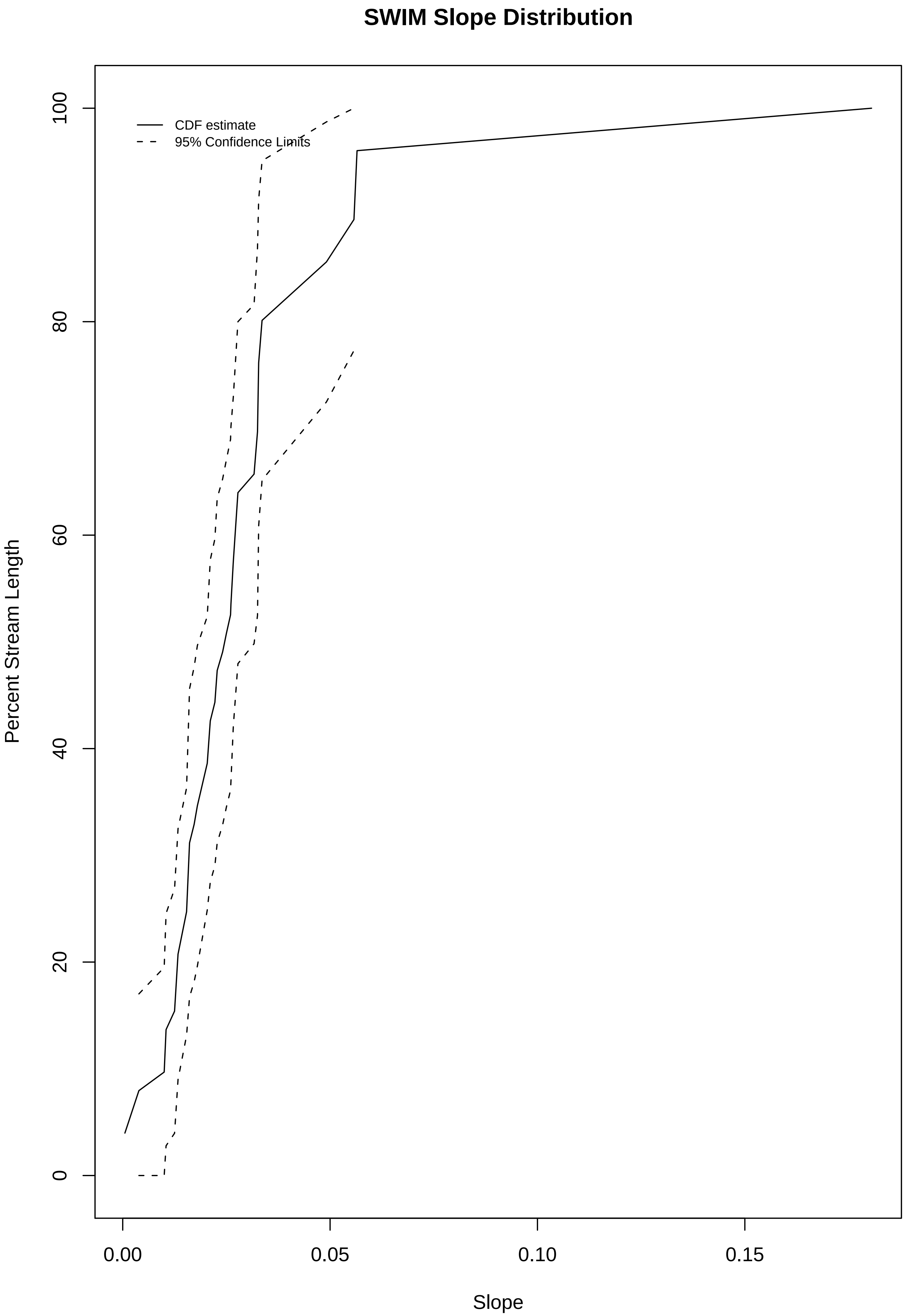


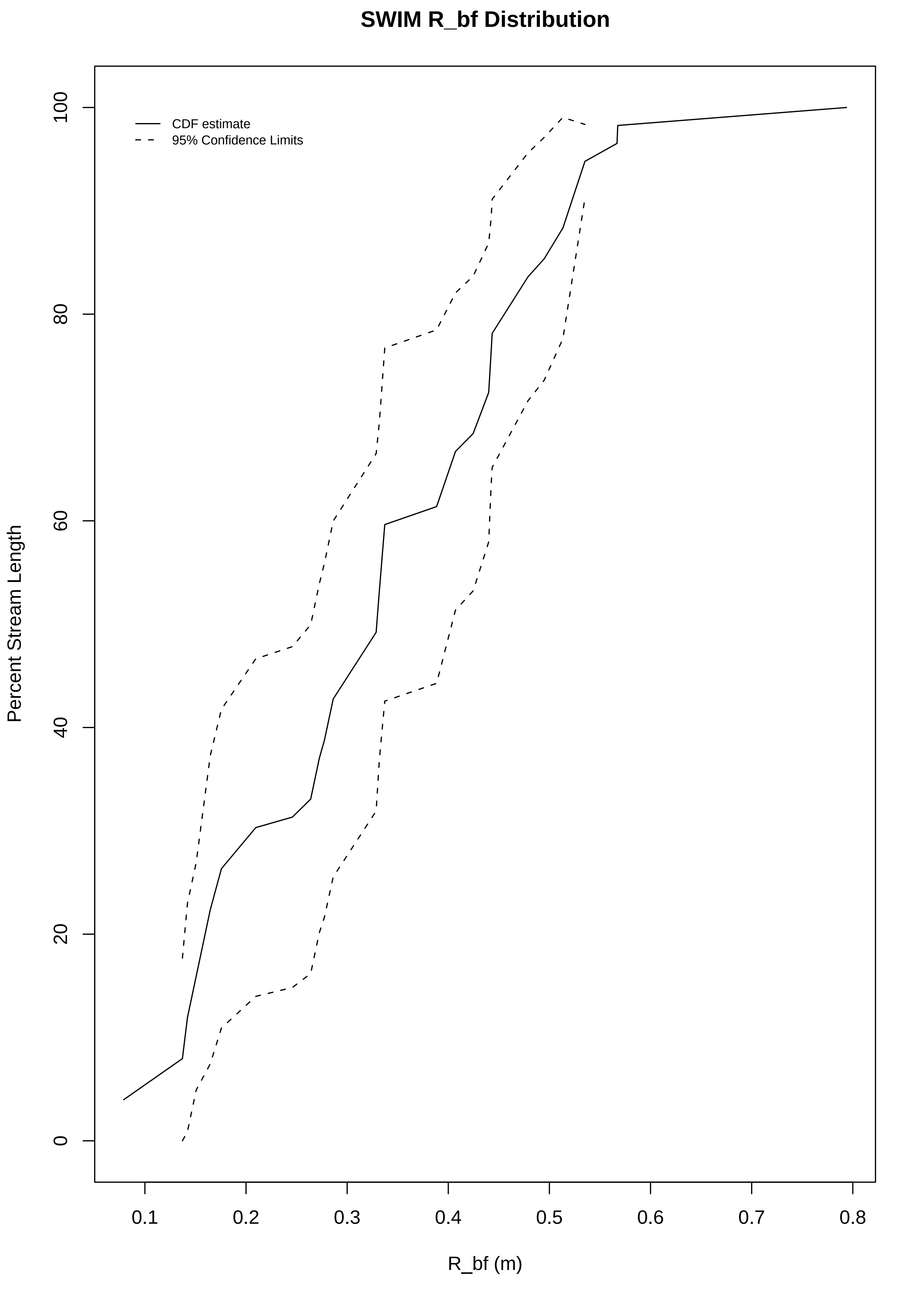
SWIM D_GM (mm) Distribution

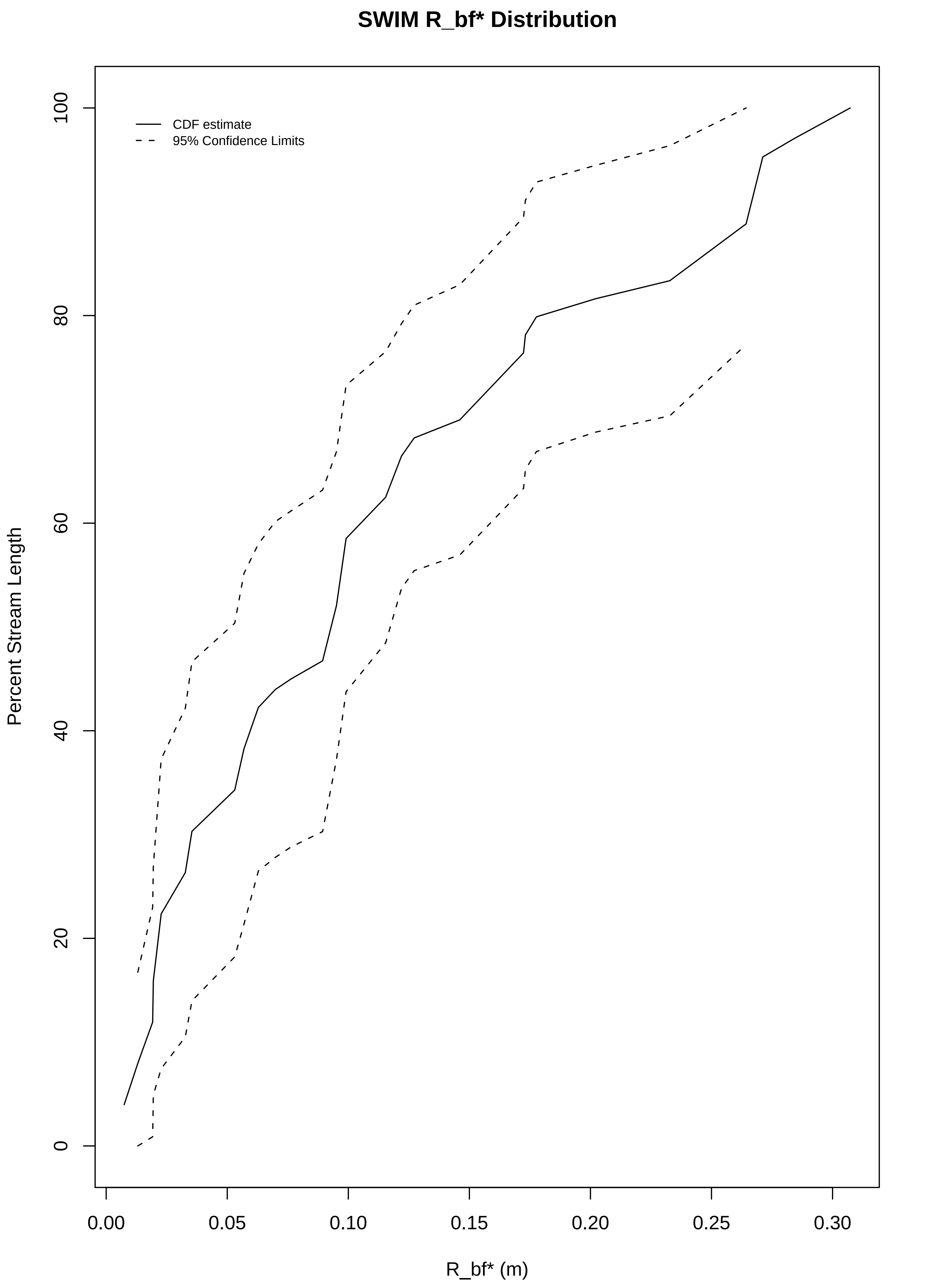


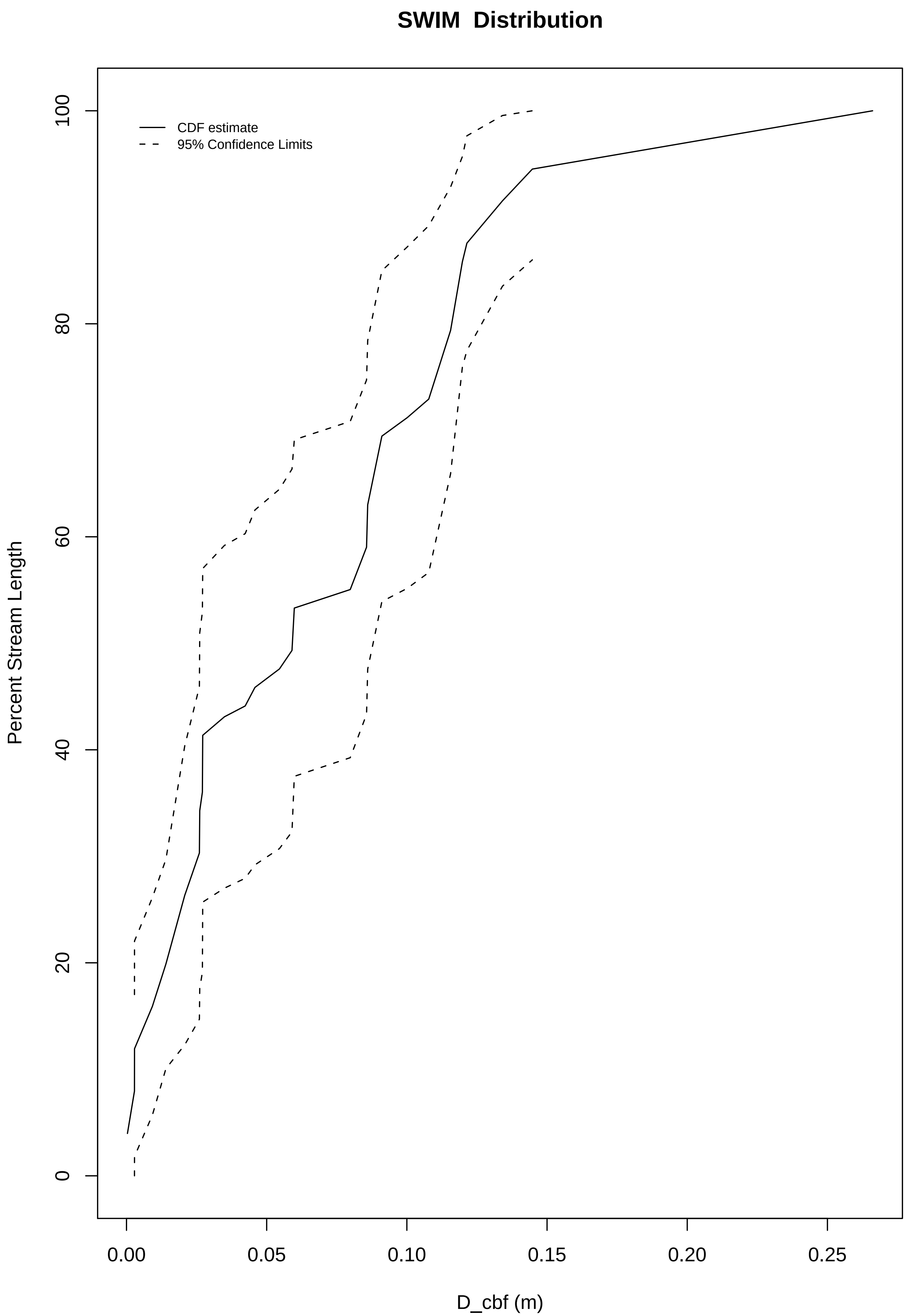


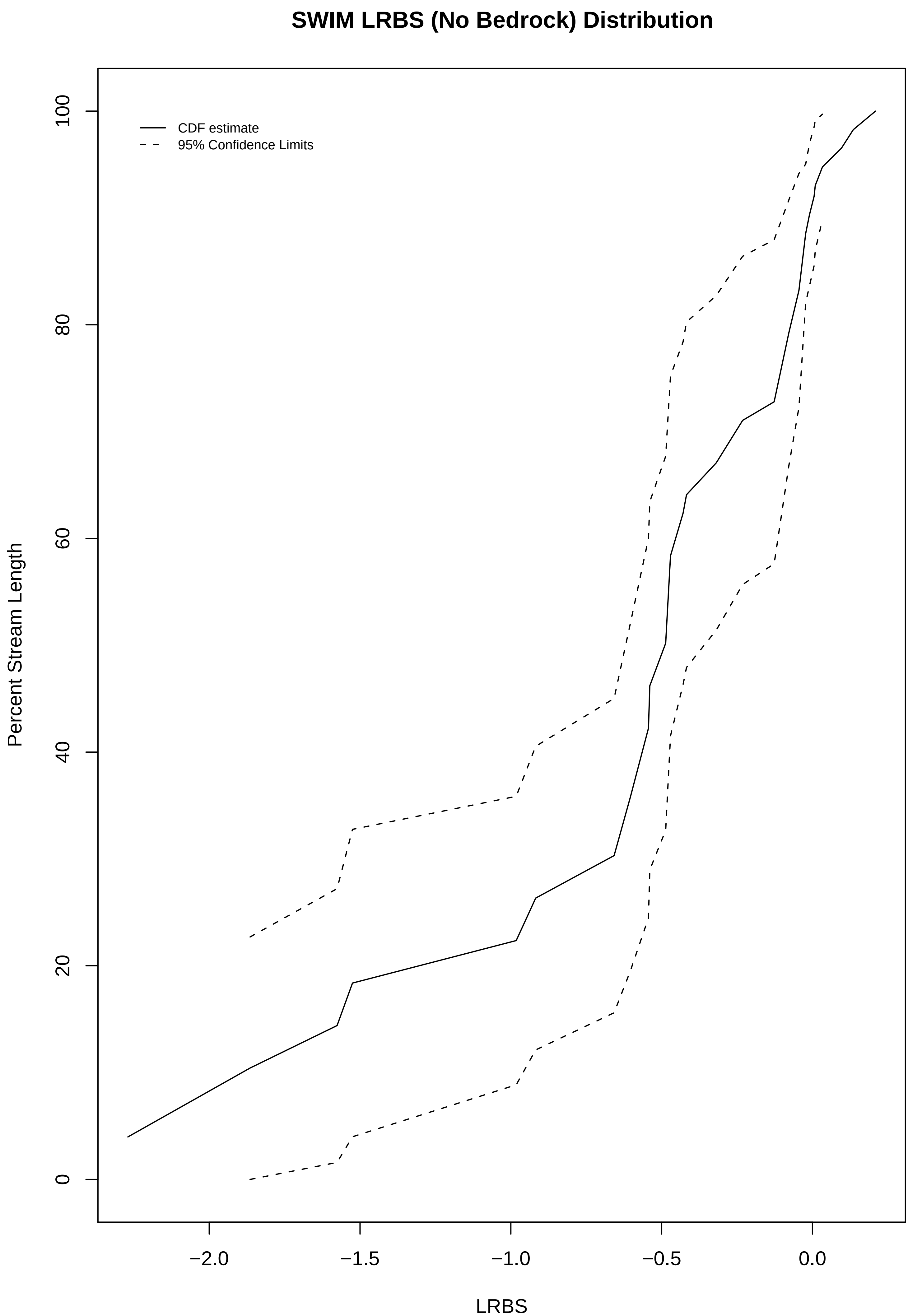
SWIM D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
20
40
60
80
D_GM (mm)

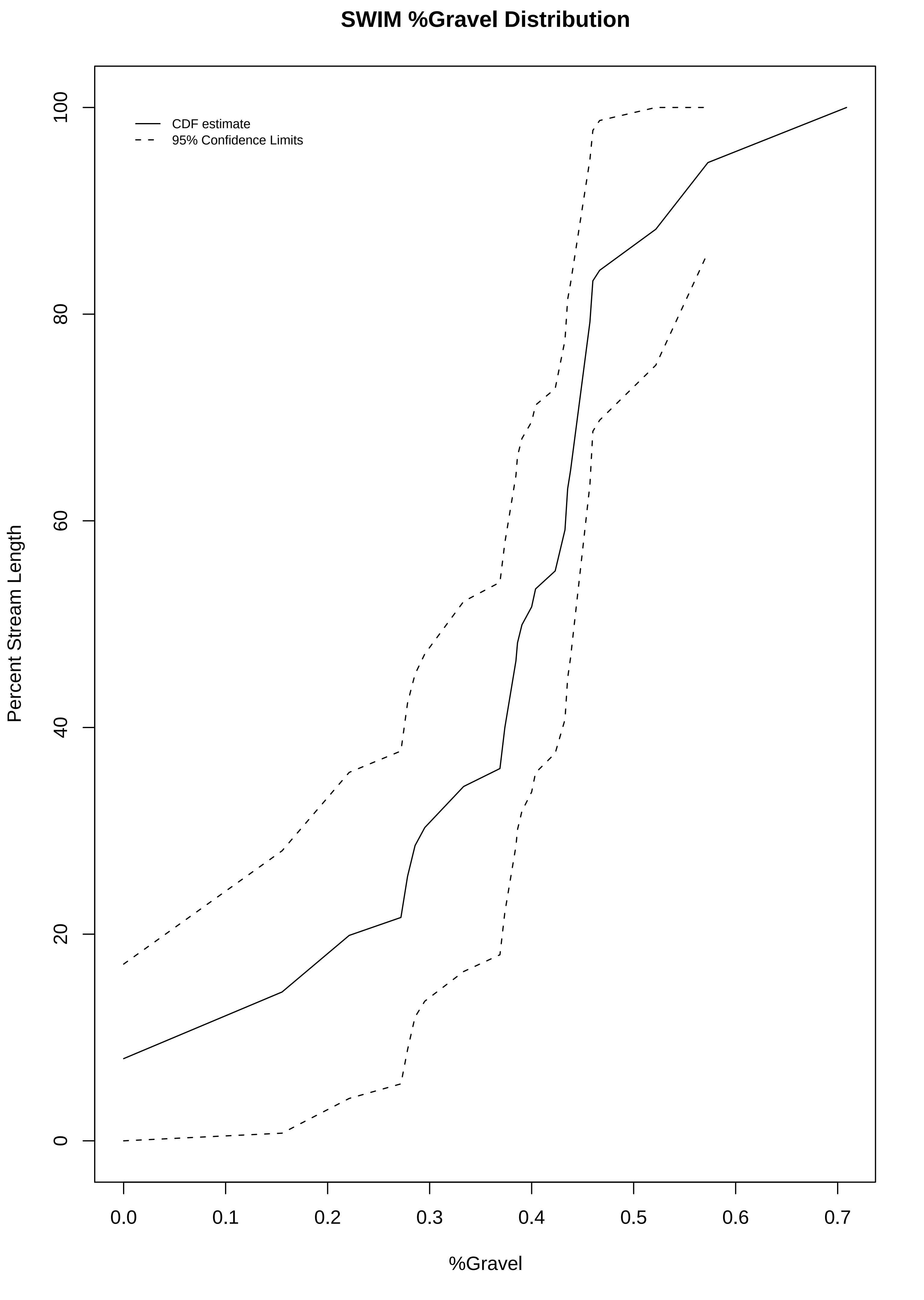

SWIM Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
Slope
0.00
0.05
0.10
0.15

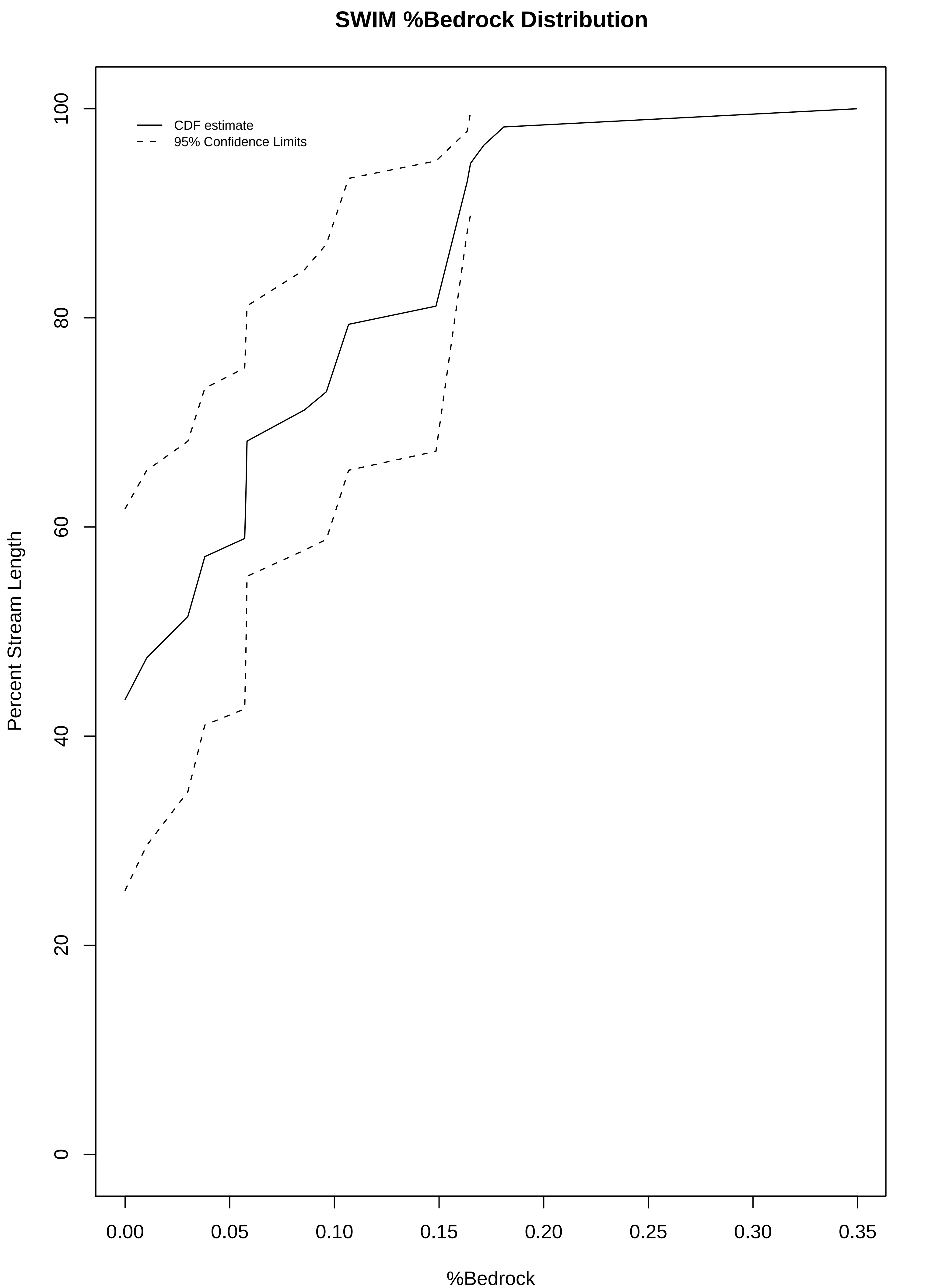

SWIM R_bf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
R_bf (m)


SWIM R_bf* Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
R_bf* (m)

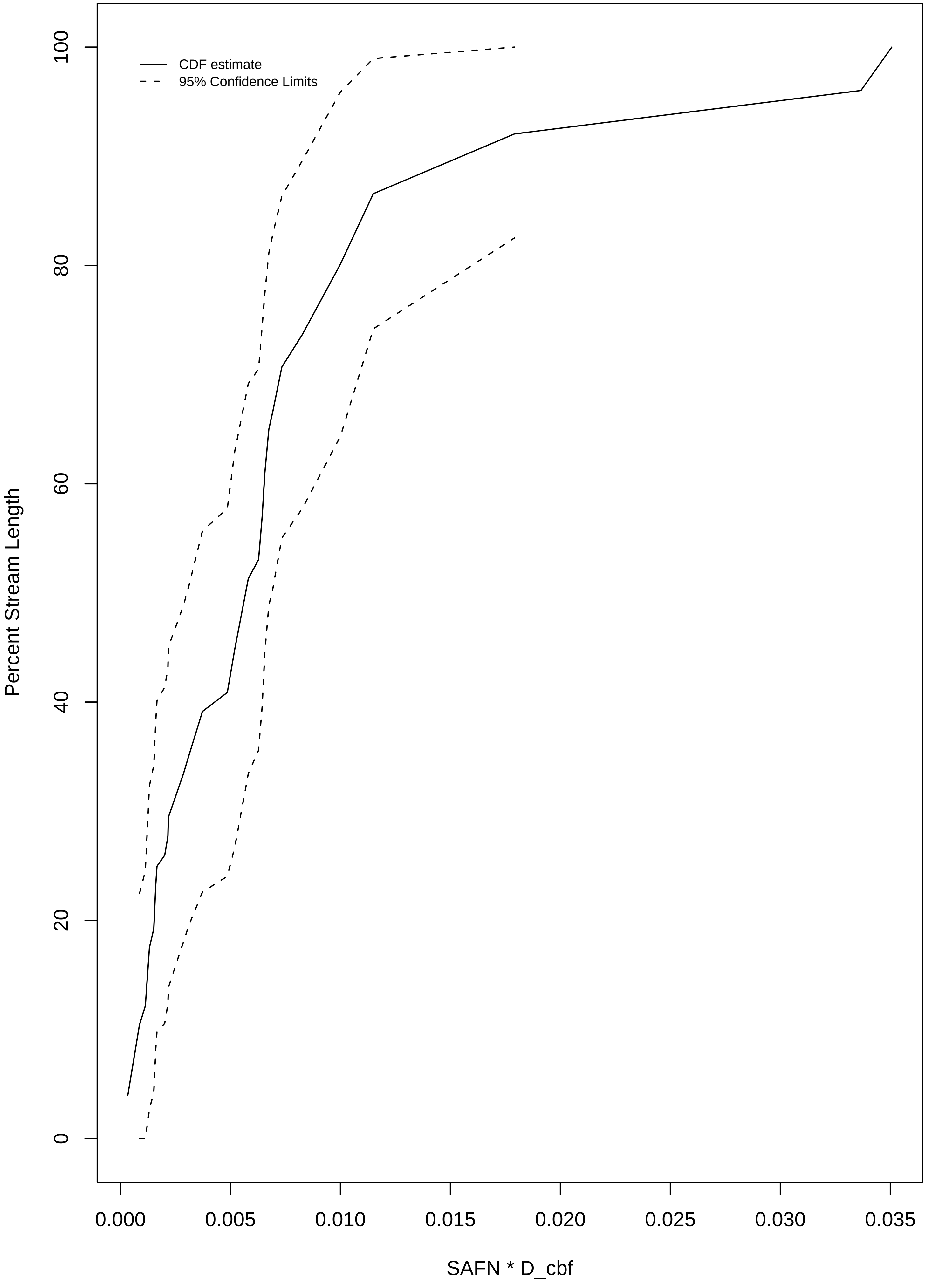

SWIM Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
D_cbf (m)

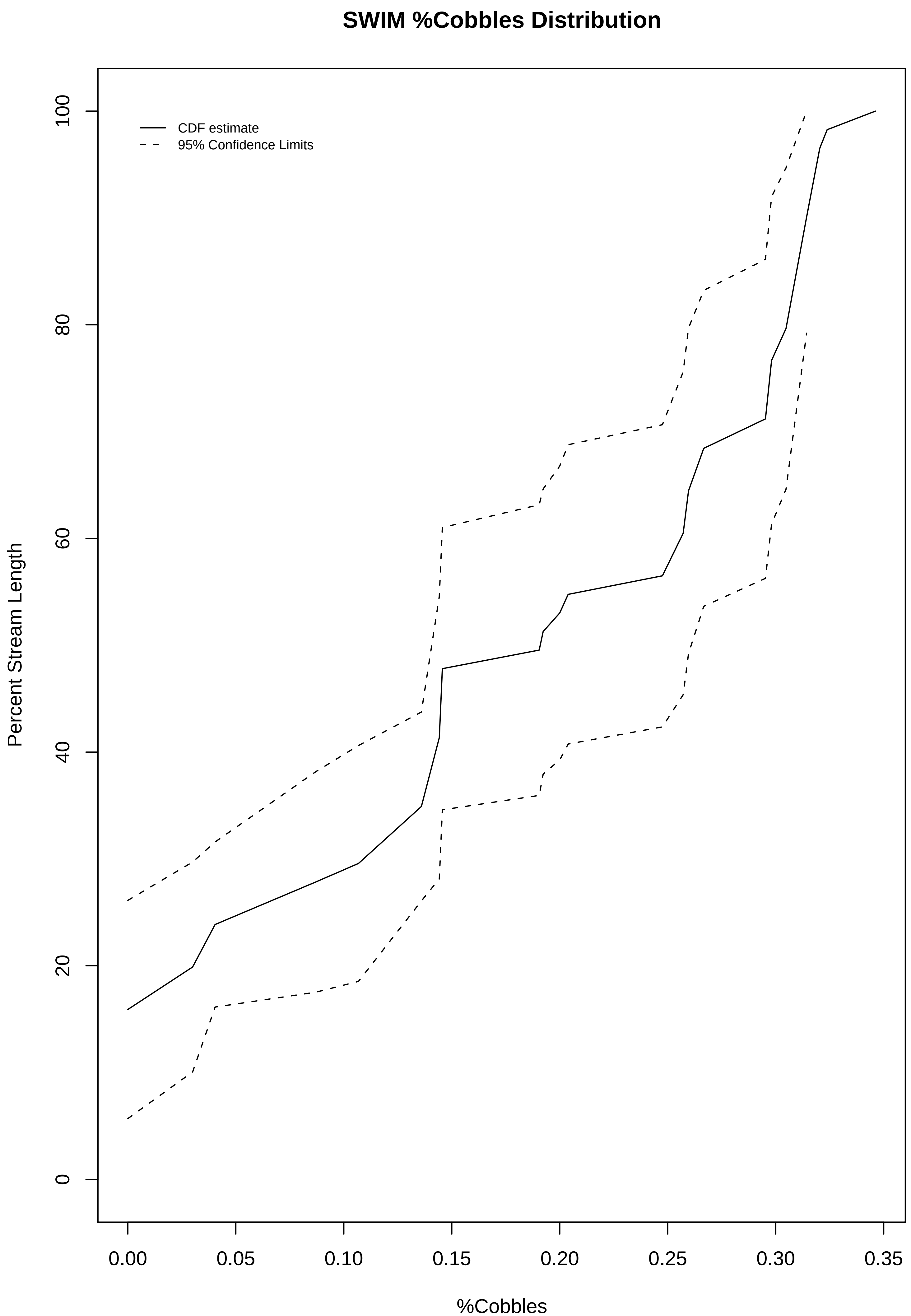

SWIM LRBS (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−2.0
−1.5
−1.0
−0.5
0.0
LRBS


SWIM %Gravel Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
%Gravel

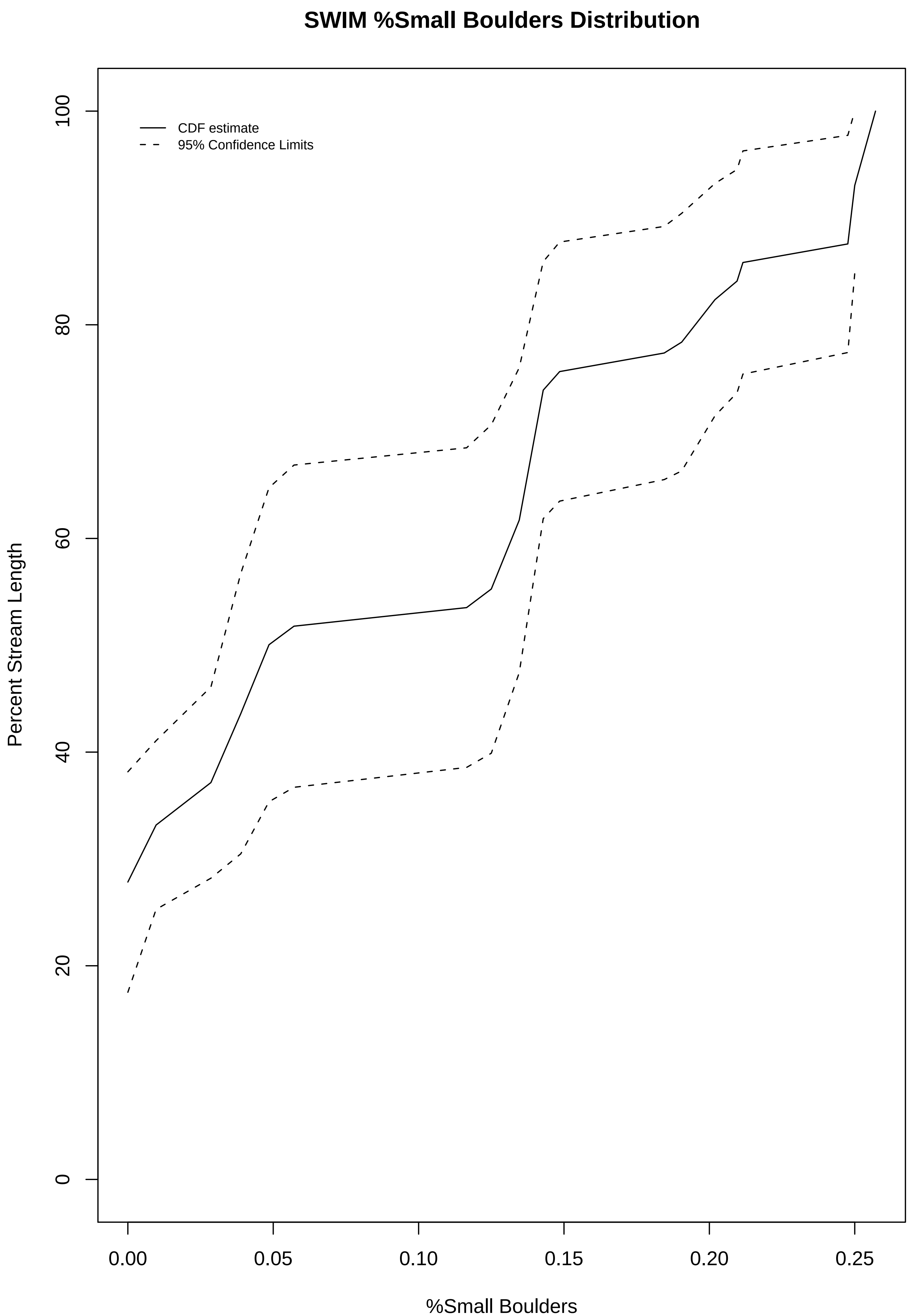

SWIM %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
%Bedrock
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

SWIM SAFN * D_cbf Distribution

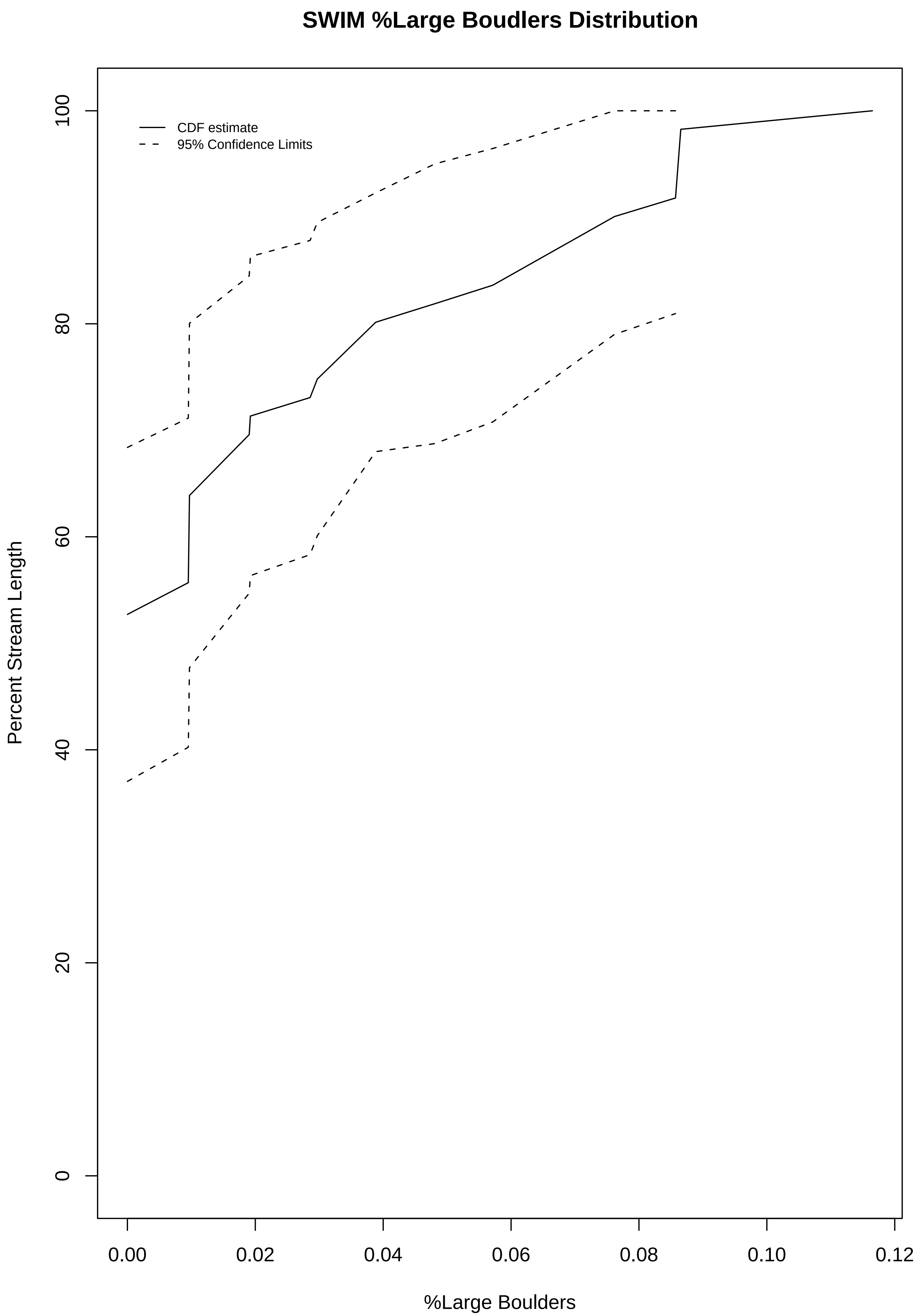


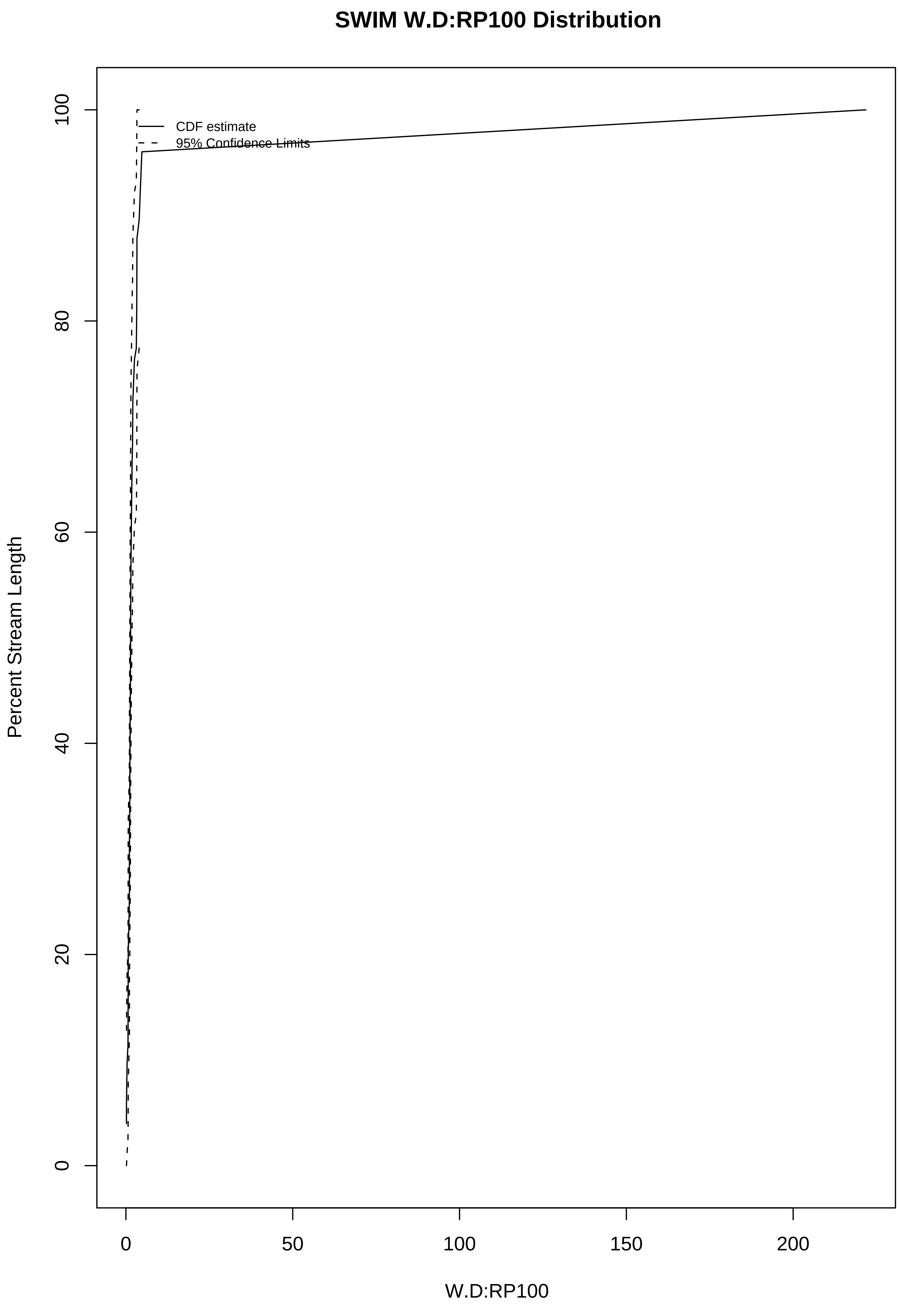


SWIM %Cobbles Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
%Cobbles

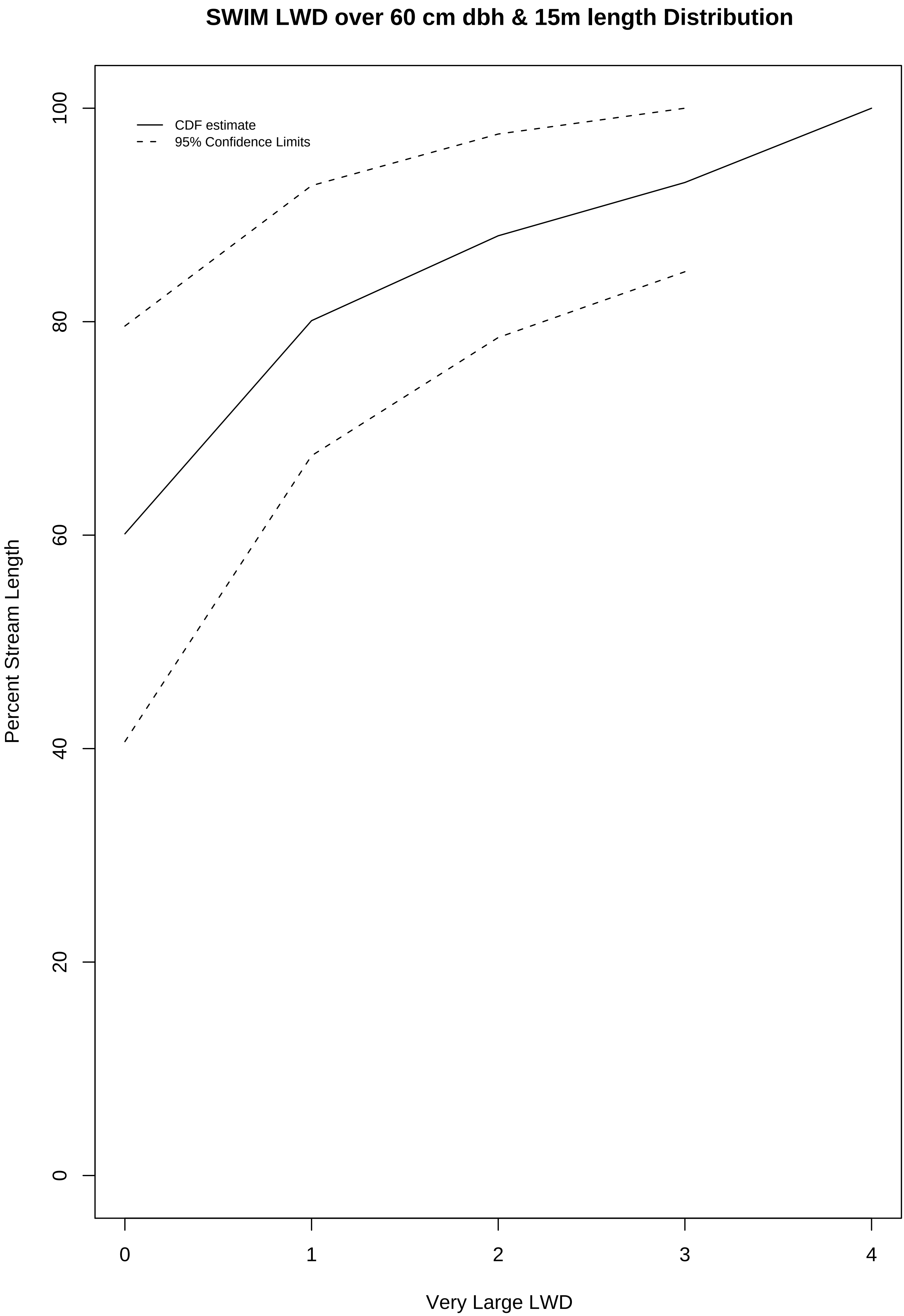


SWIM %Small Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
%Small Boulders

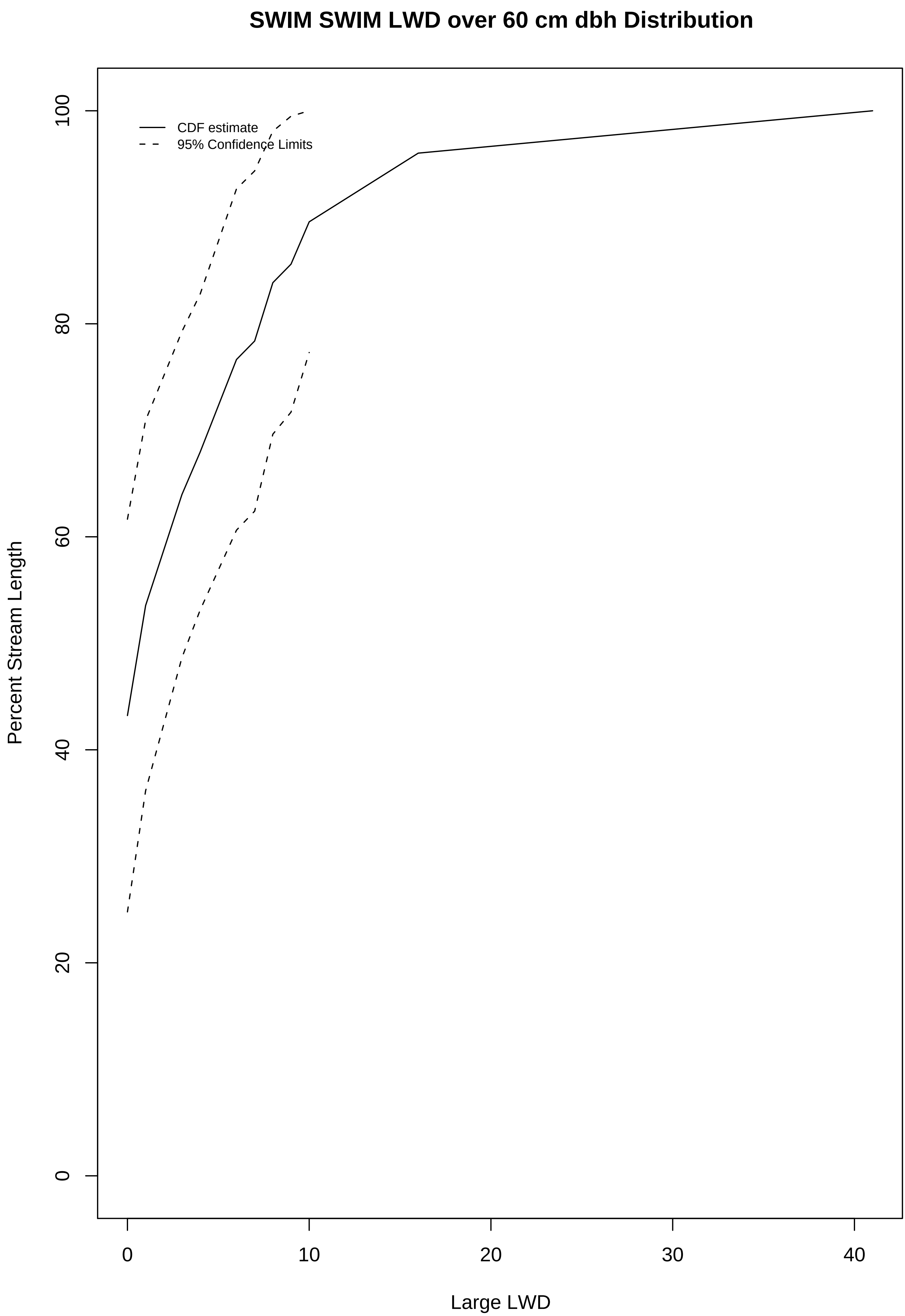

SWIM %Large Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.02
0.04
0.06
0.08
0.10
0.12
%Large Boulders



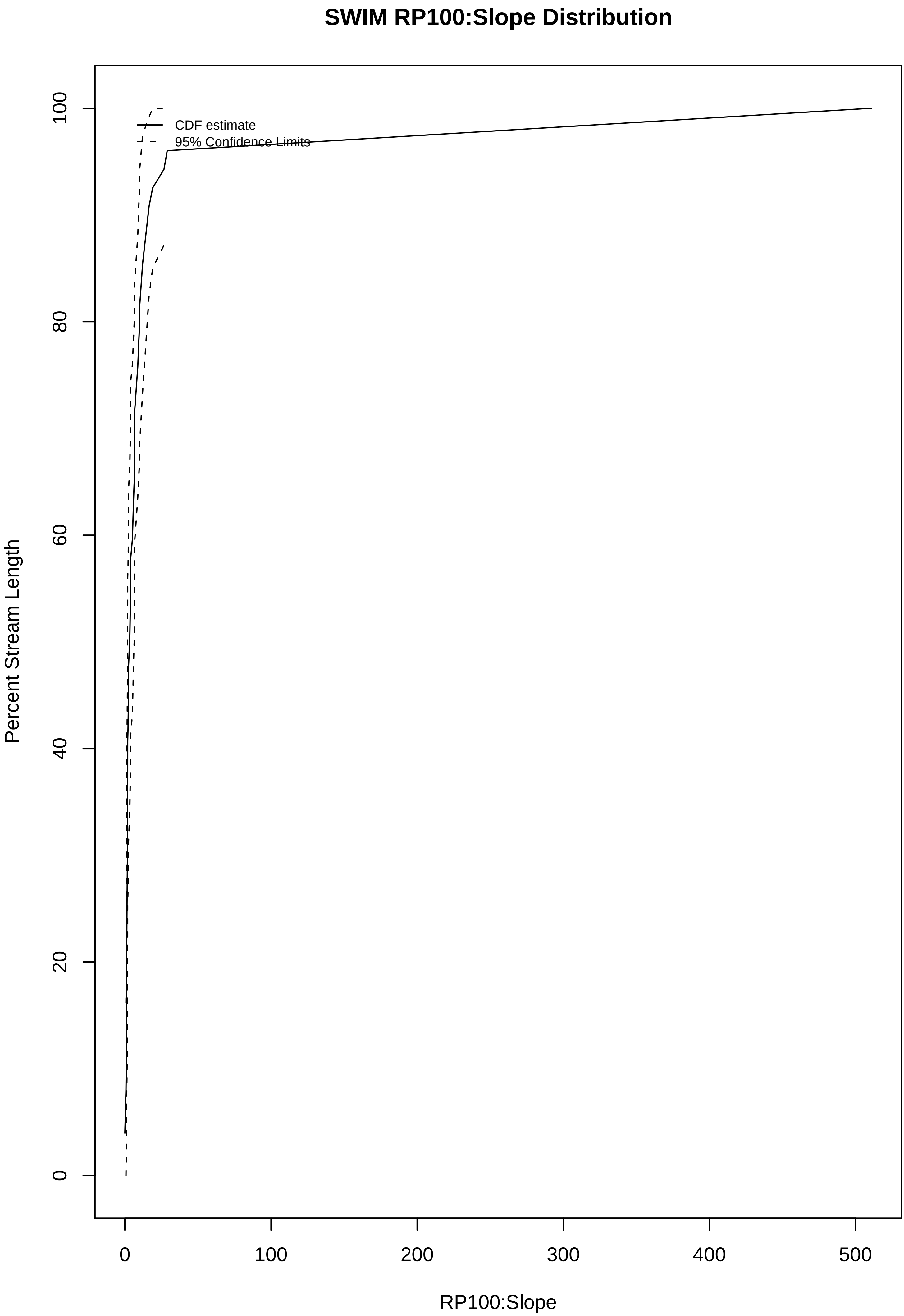
SWIM W.D:RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
W.D:RP100
0
20
40
60
80
100
0
50
100
150
200

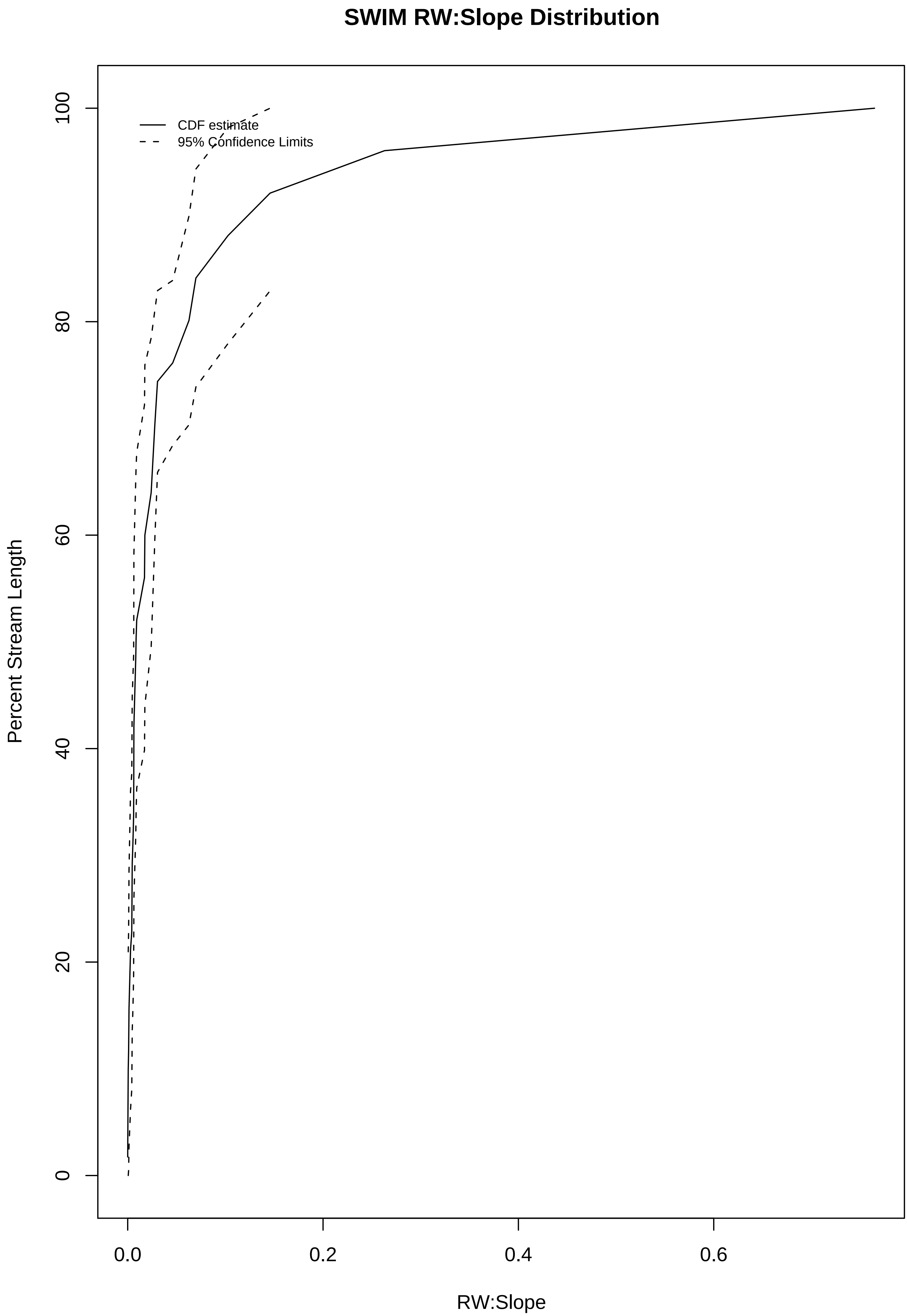


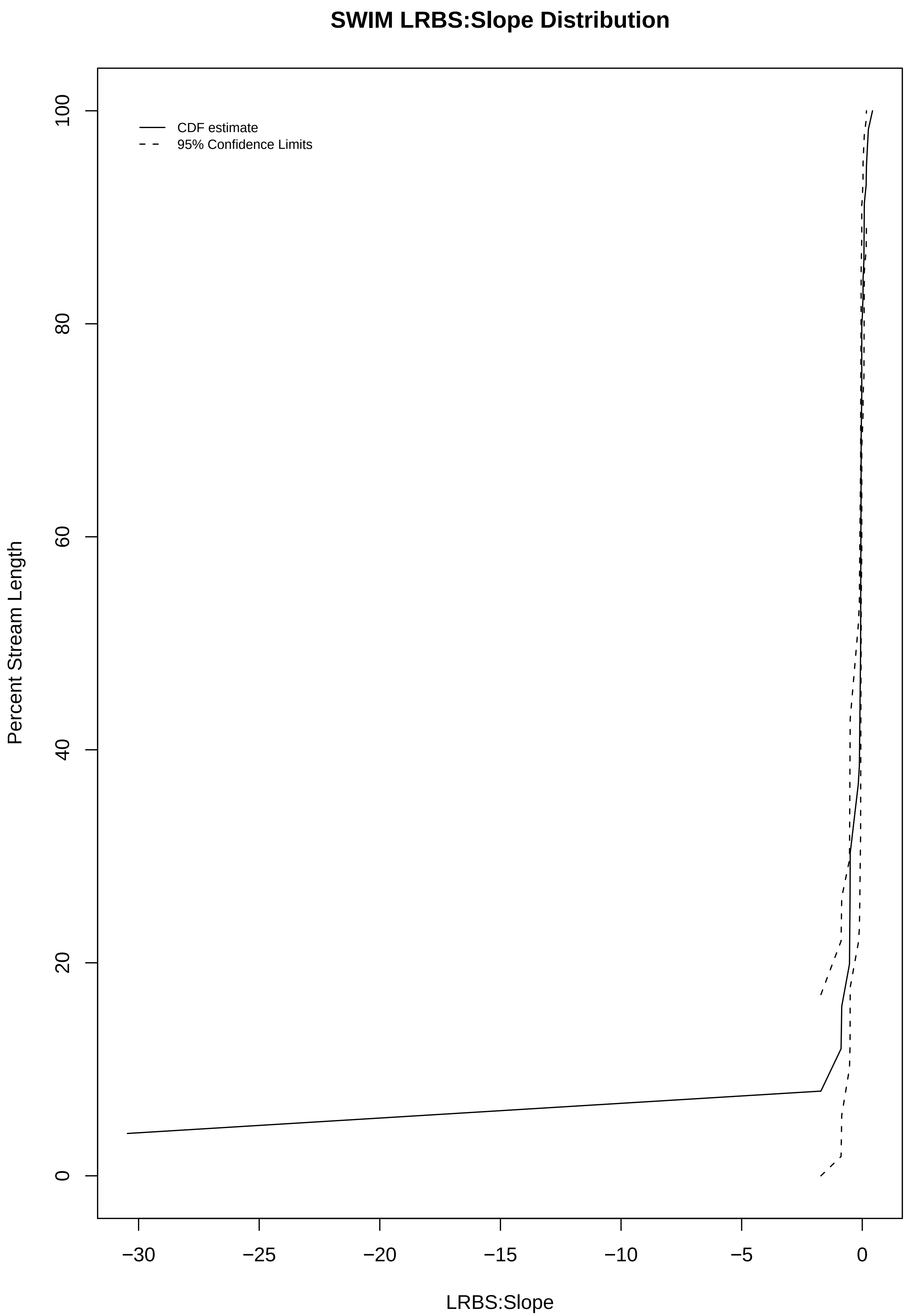
SWIM LWD over 60 cm dbh & 15m length Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
Very Large LWD
0
1
2
3
4

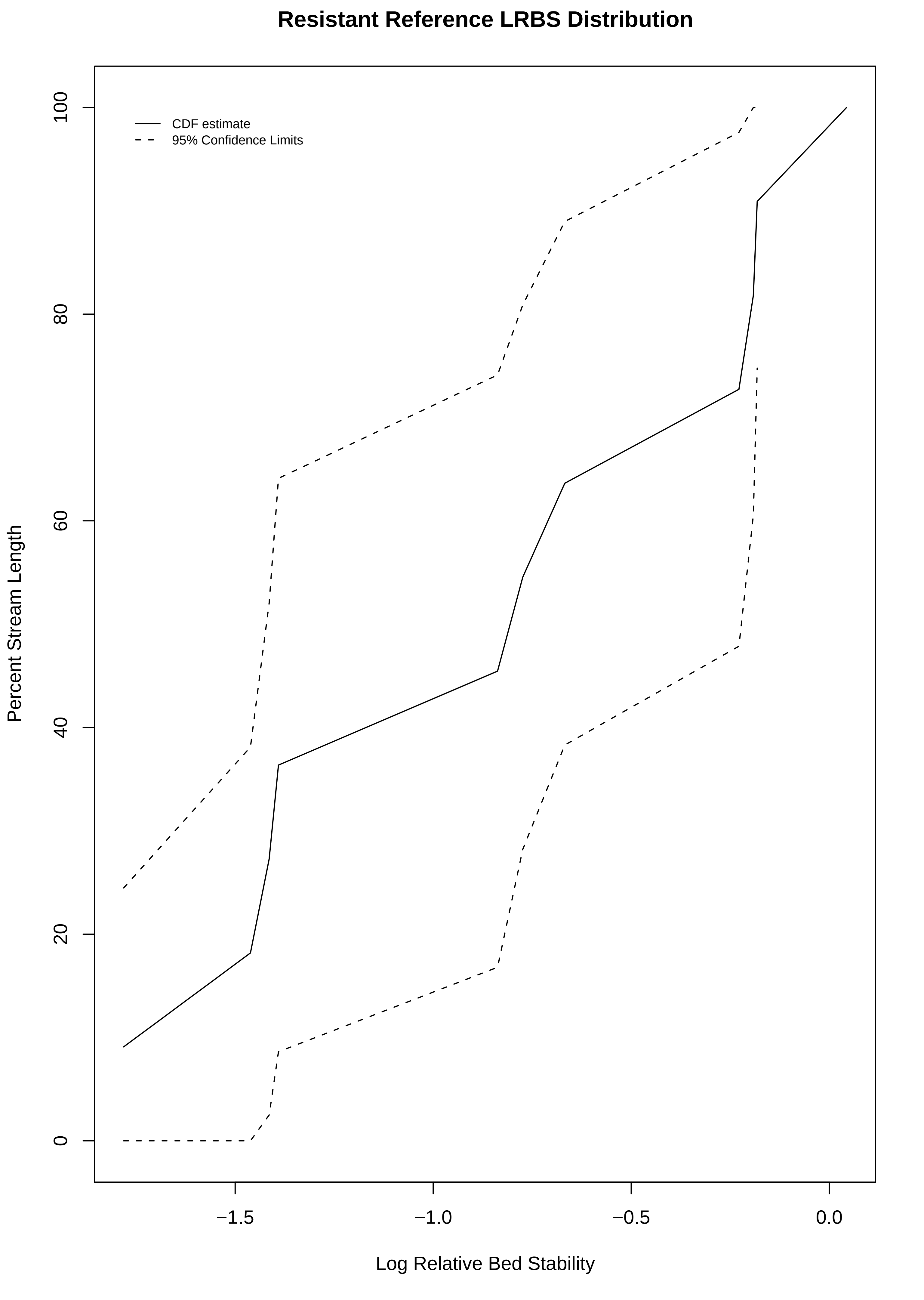


SWIM SWIM LWD over 60 cm dbh Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
10
20
30
40
Large LWD

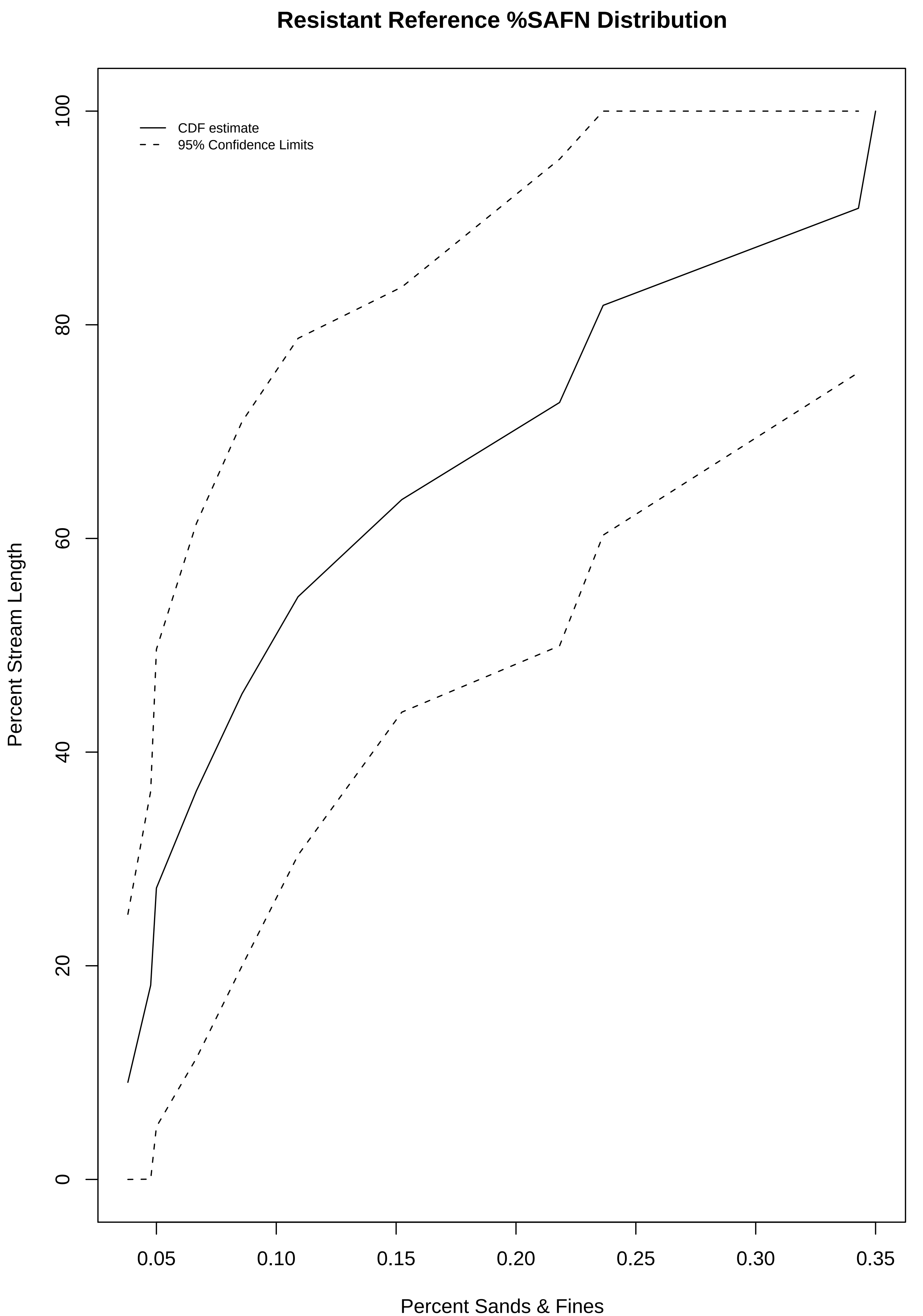

SWIM RP100:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
RP100:Slope
0
20
40
60
80
100
0
100
200
300
400
500


SWIM RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
RW:Slope

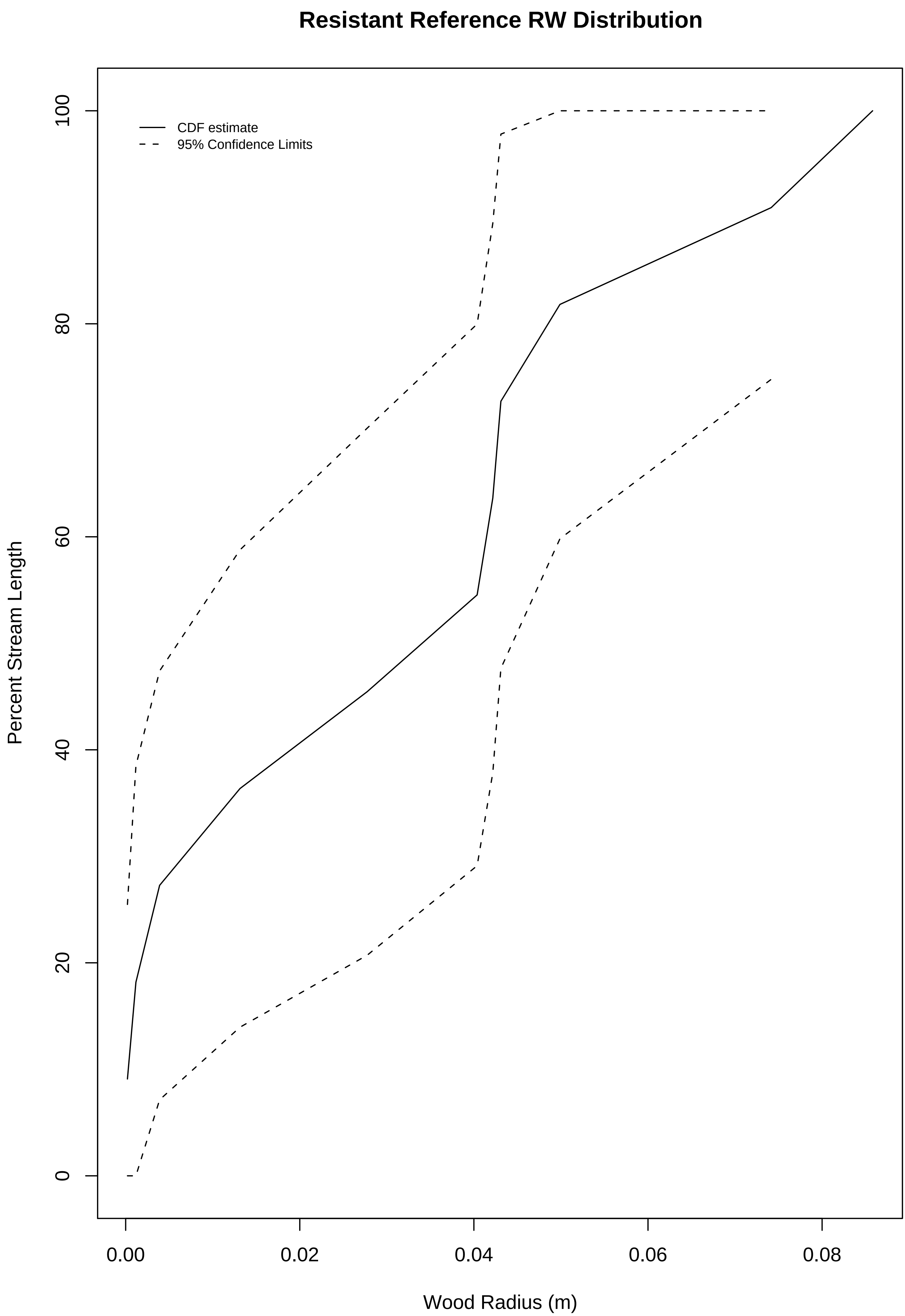

SWIM LRBS:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−30
−25
−20
−15
−10
−5
0
LRBS:Slope



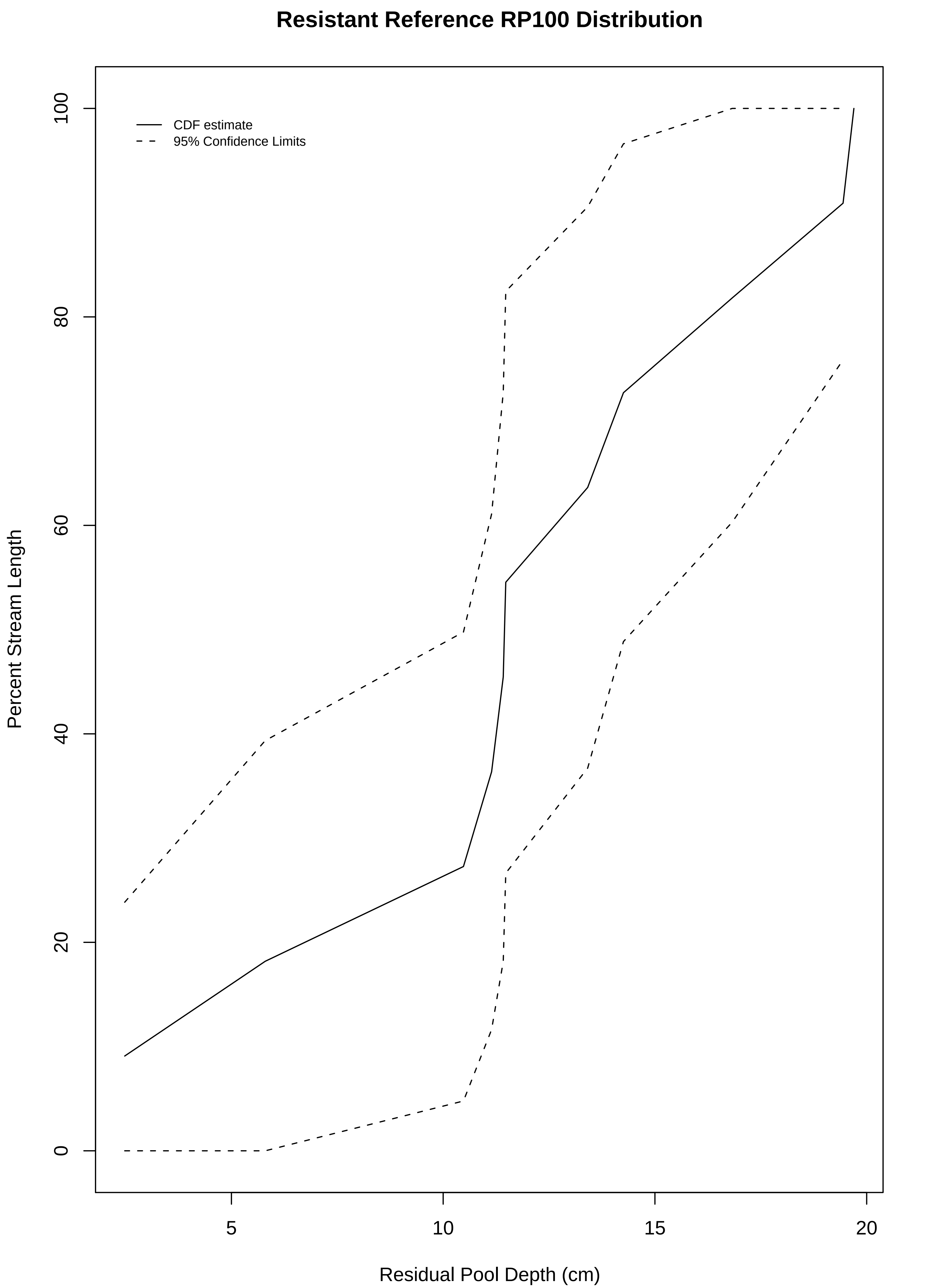
Resistant Reference LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−1.5
−1.0
−0.5
0.0
Log Relative Bed Stability

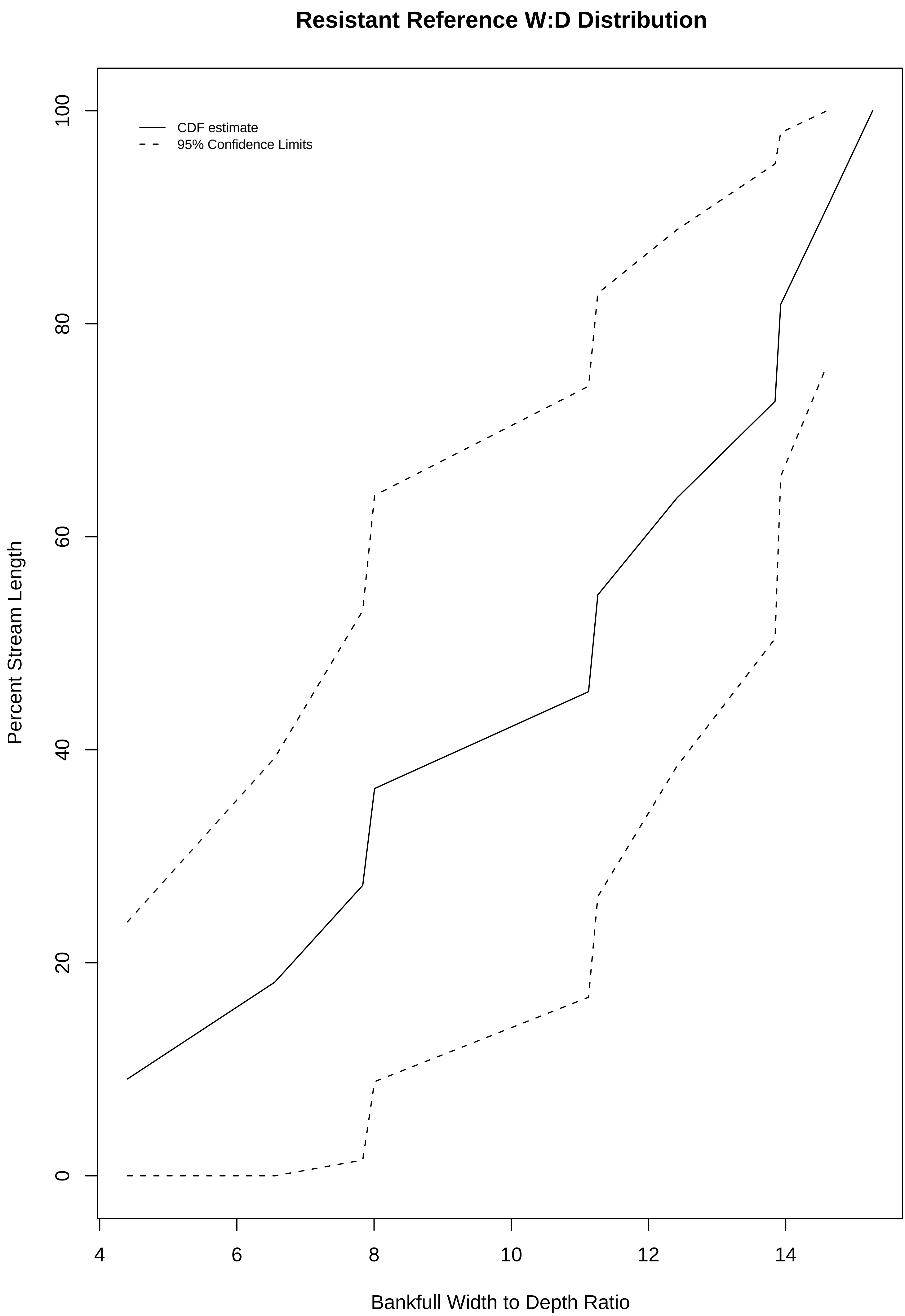


Resistant Reference %SAFN Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Percent Sands & Fines



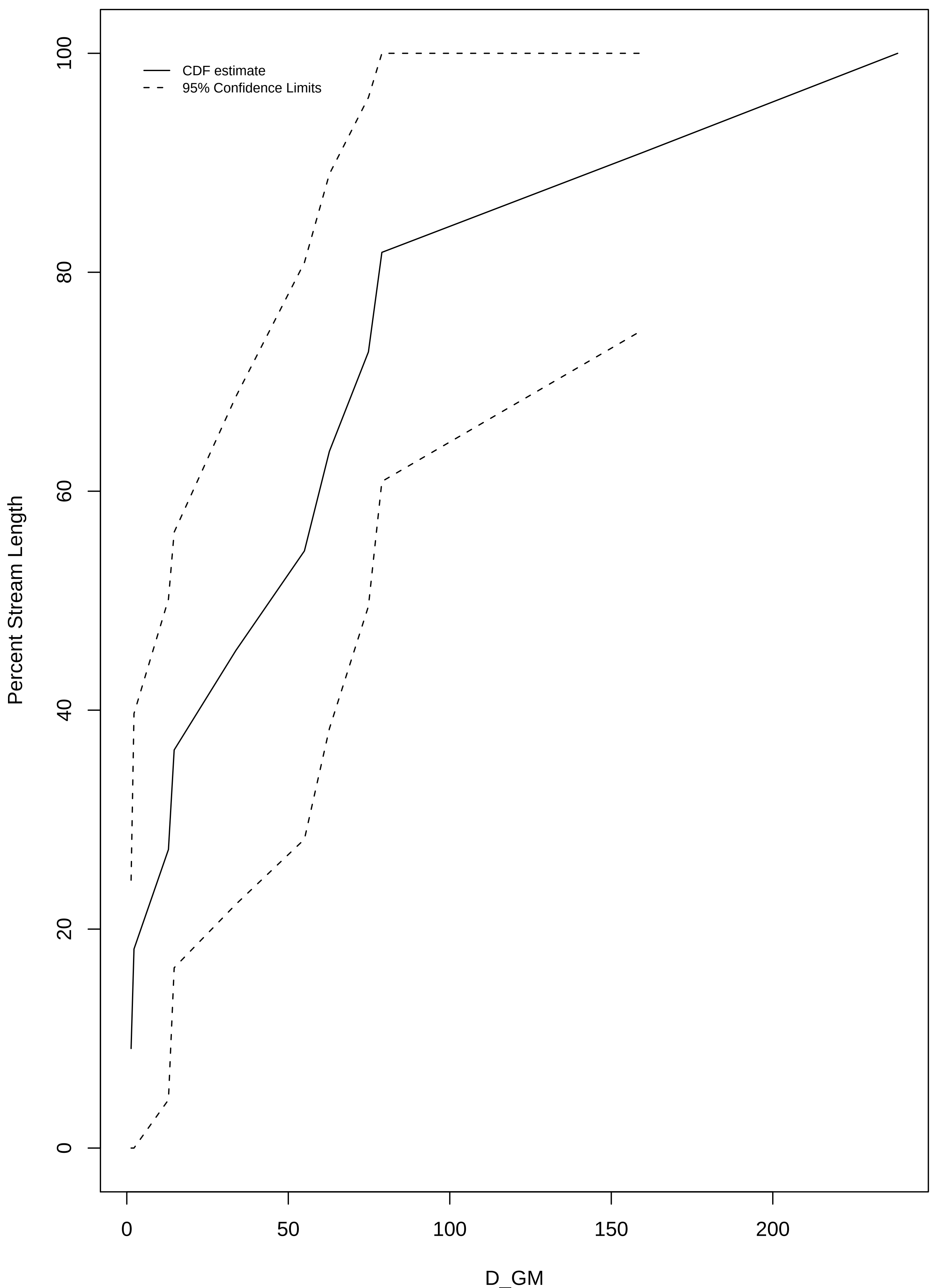
Resistant Reference RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.02
0.04
0.06
0.08
Wood Radius (m)

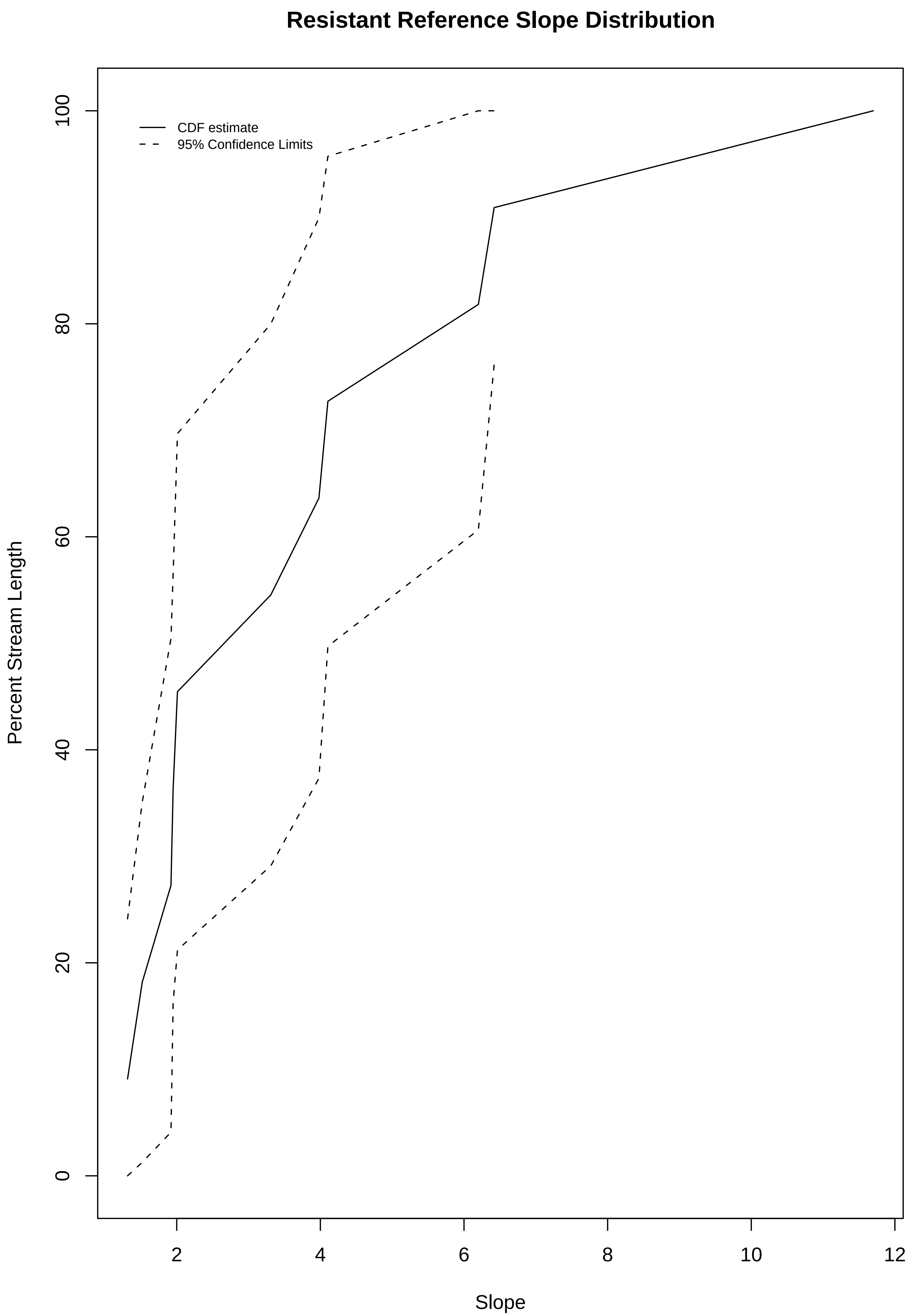

Resistant Reference RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
5
10
15
20
Residual Pool Depth (cm)



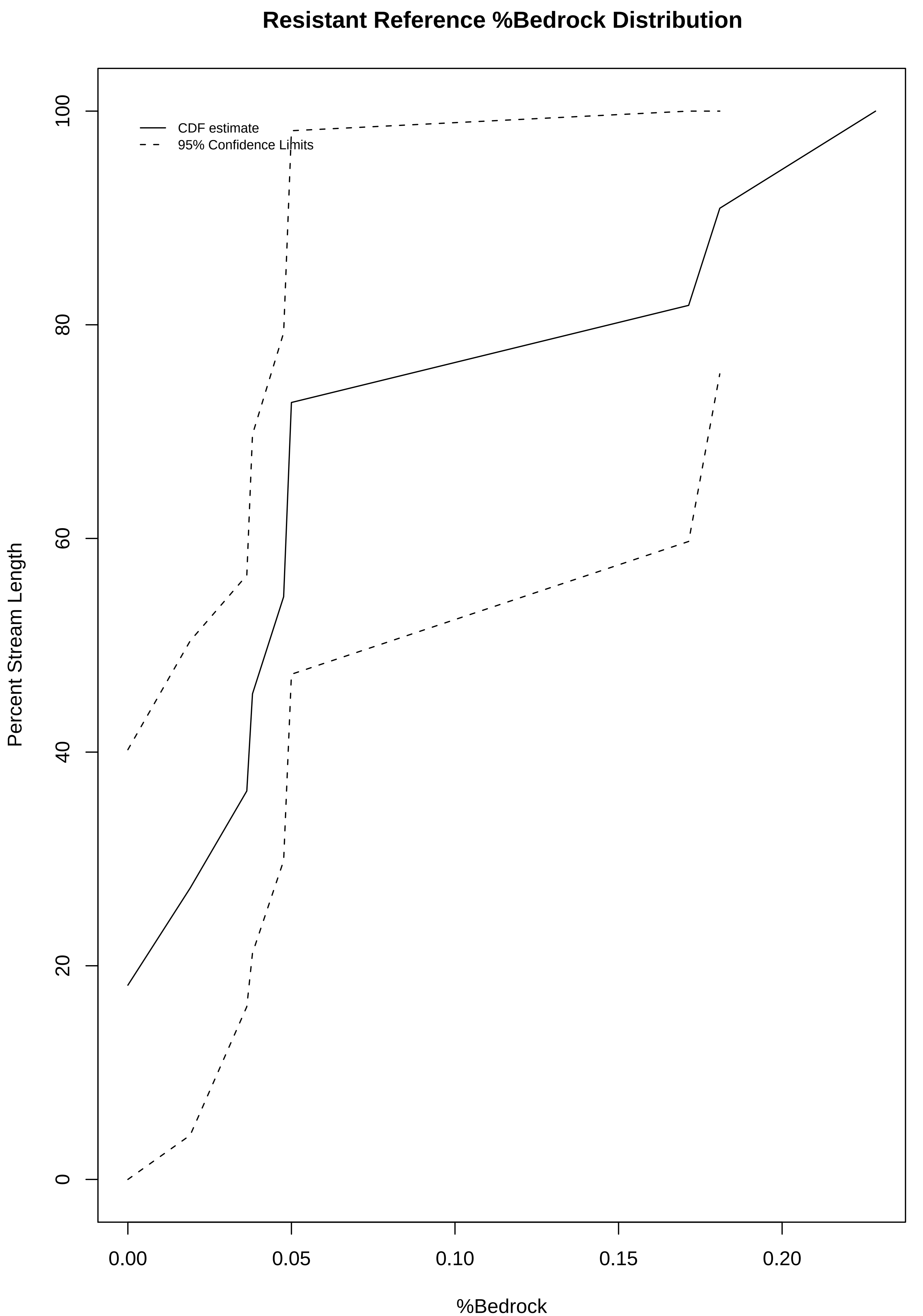
Resistant Reference W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
4
6
8
10
12
14
Bankfull Width to Depth Ratio

Resistant Reference D_GM (mm) Distribution

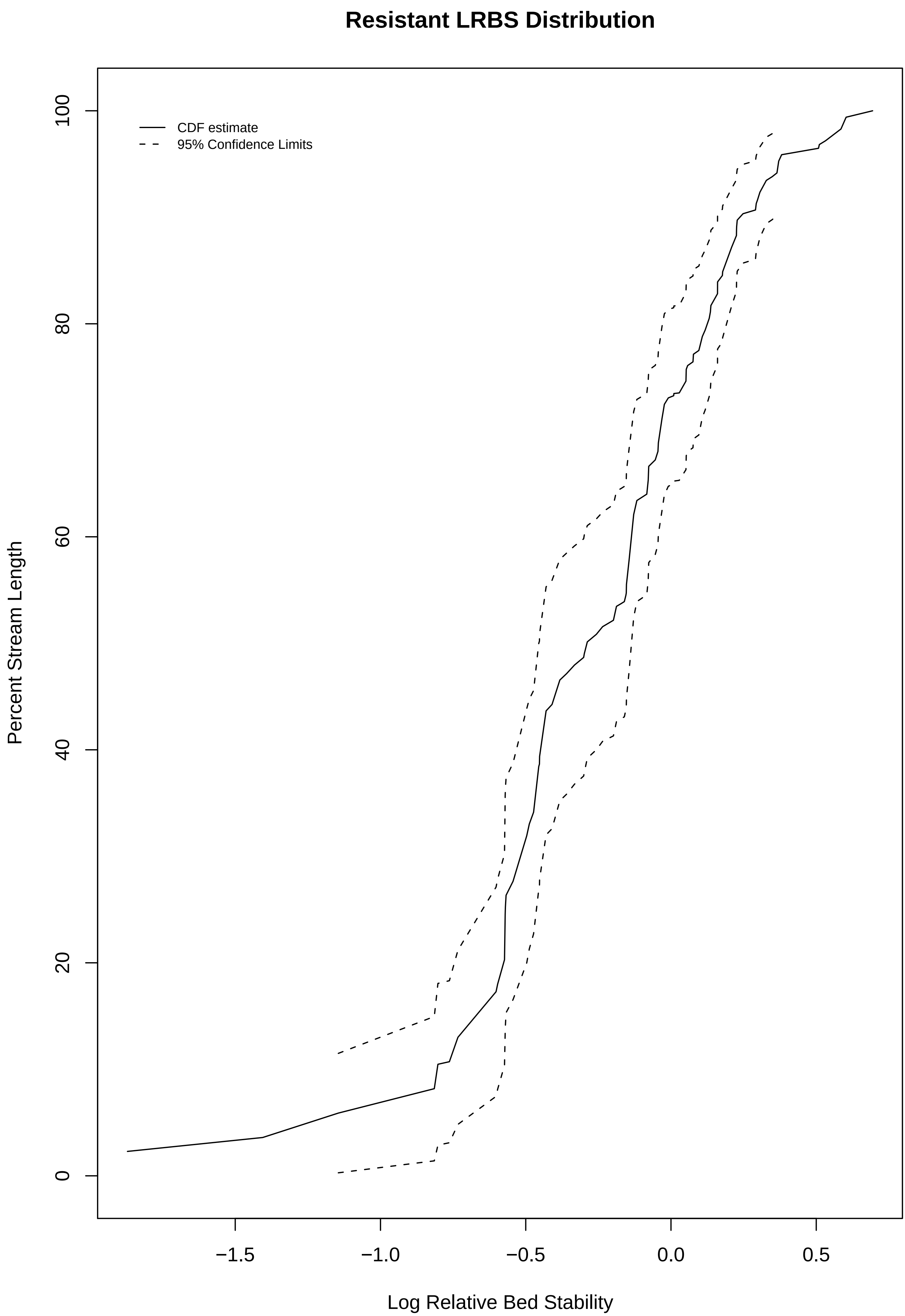




Resistant Reference Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
2
4
6
8
10
12
Slope

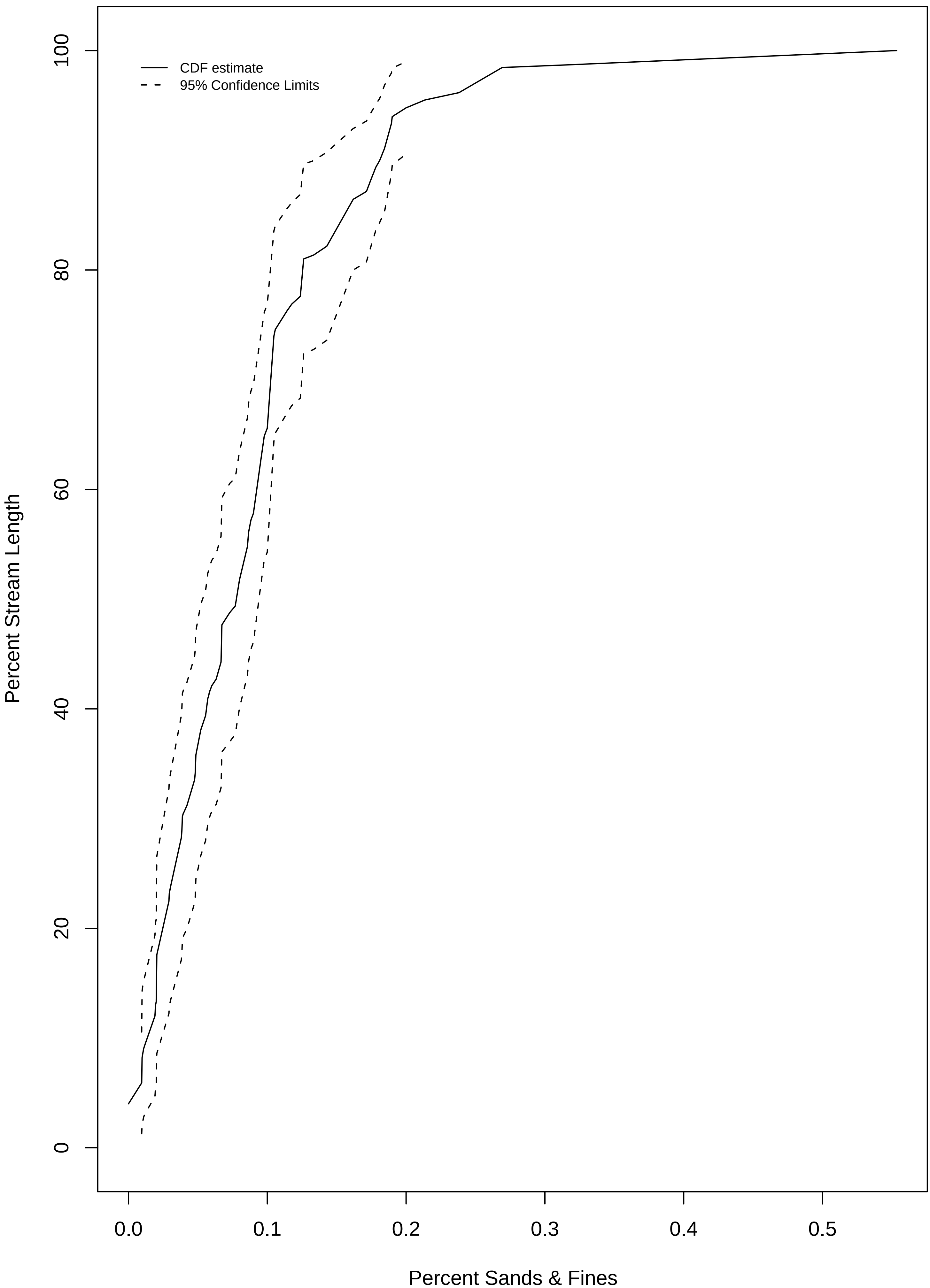


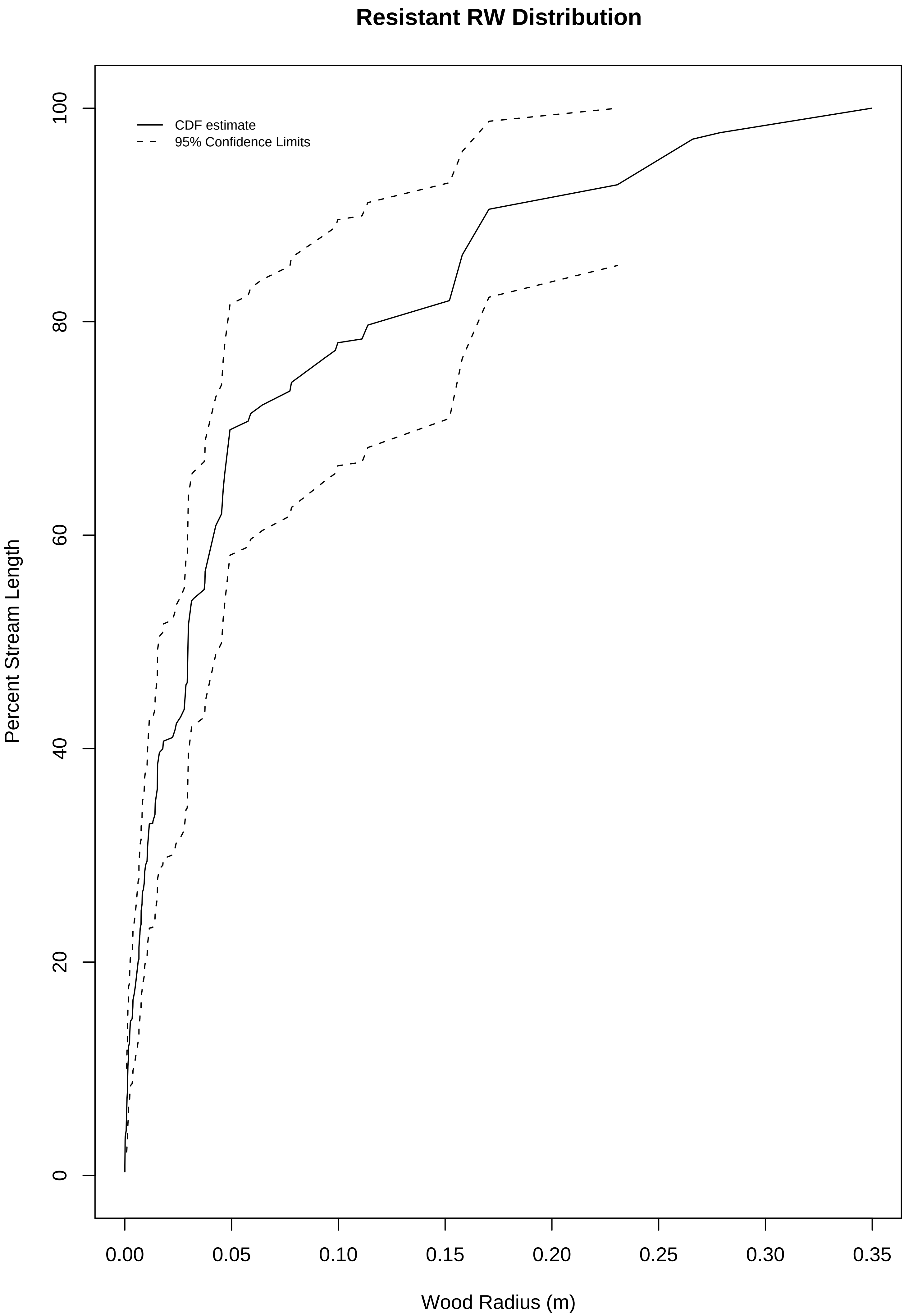
Resistant Reference %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
%Bedrock

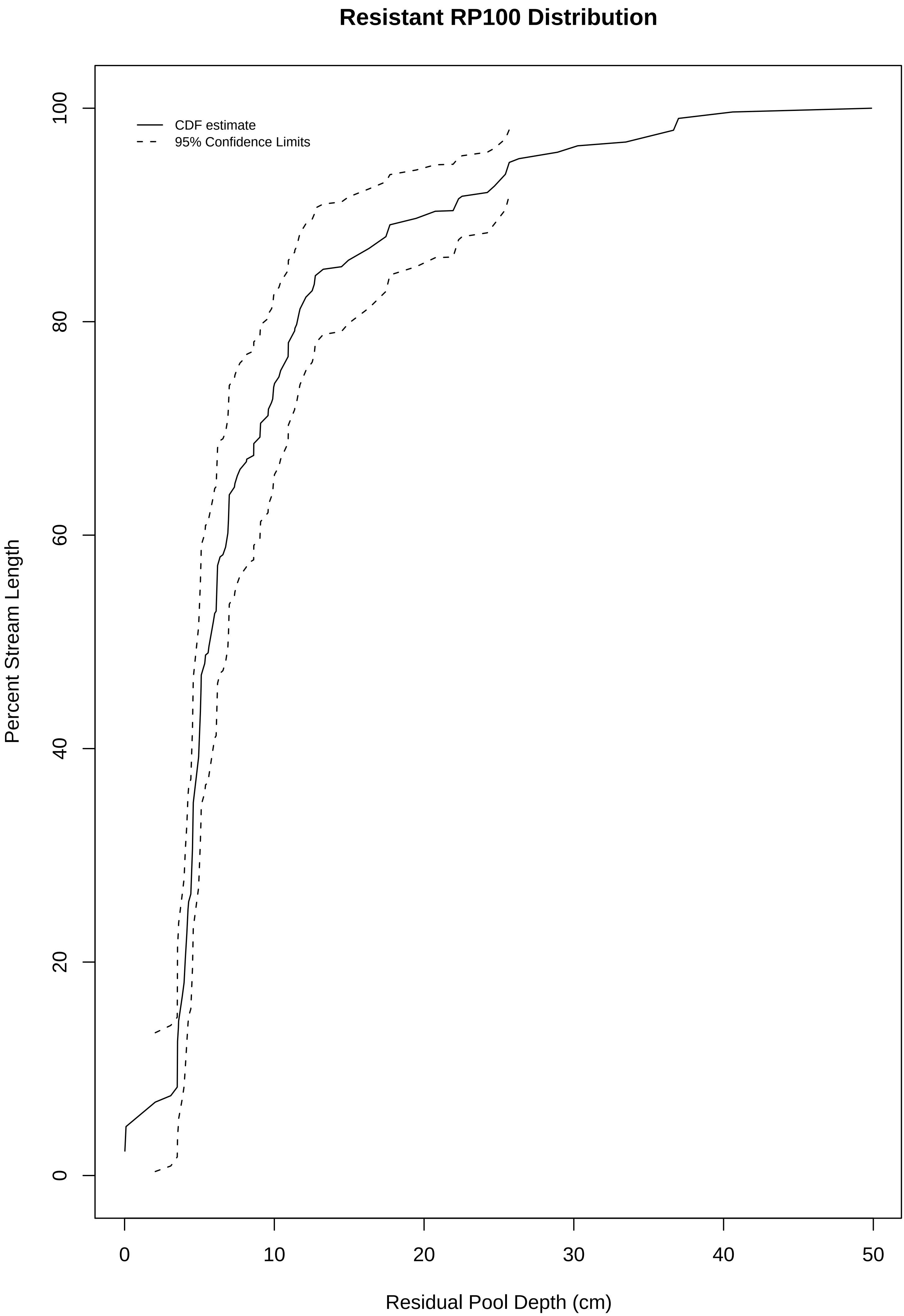


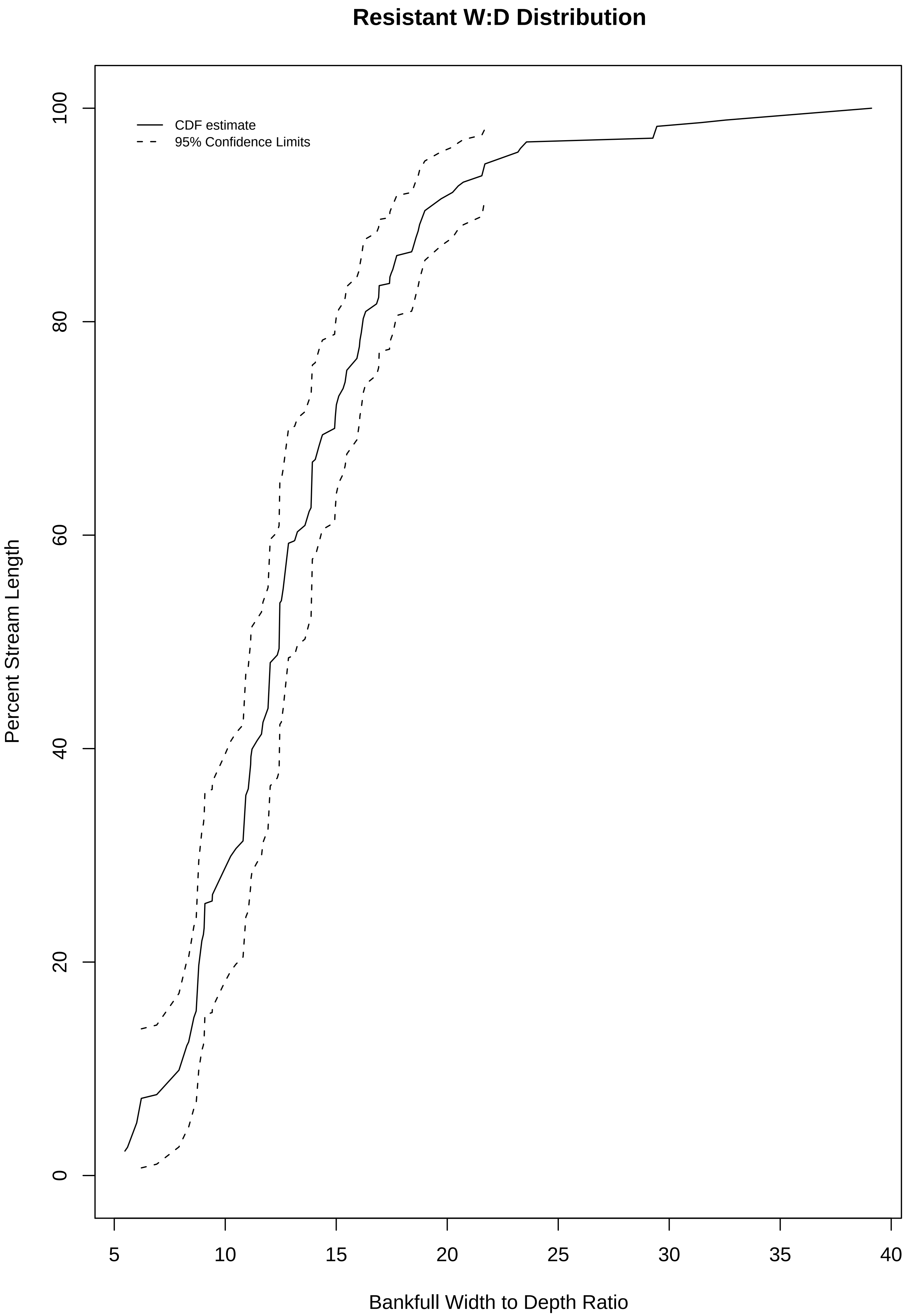
Resistant LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−1.5
−1.0
−0.5
0.0
0.5
Log Relative Bed Stability

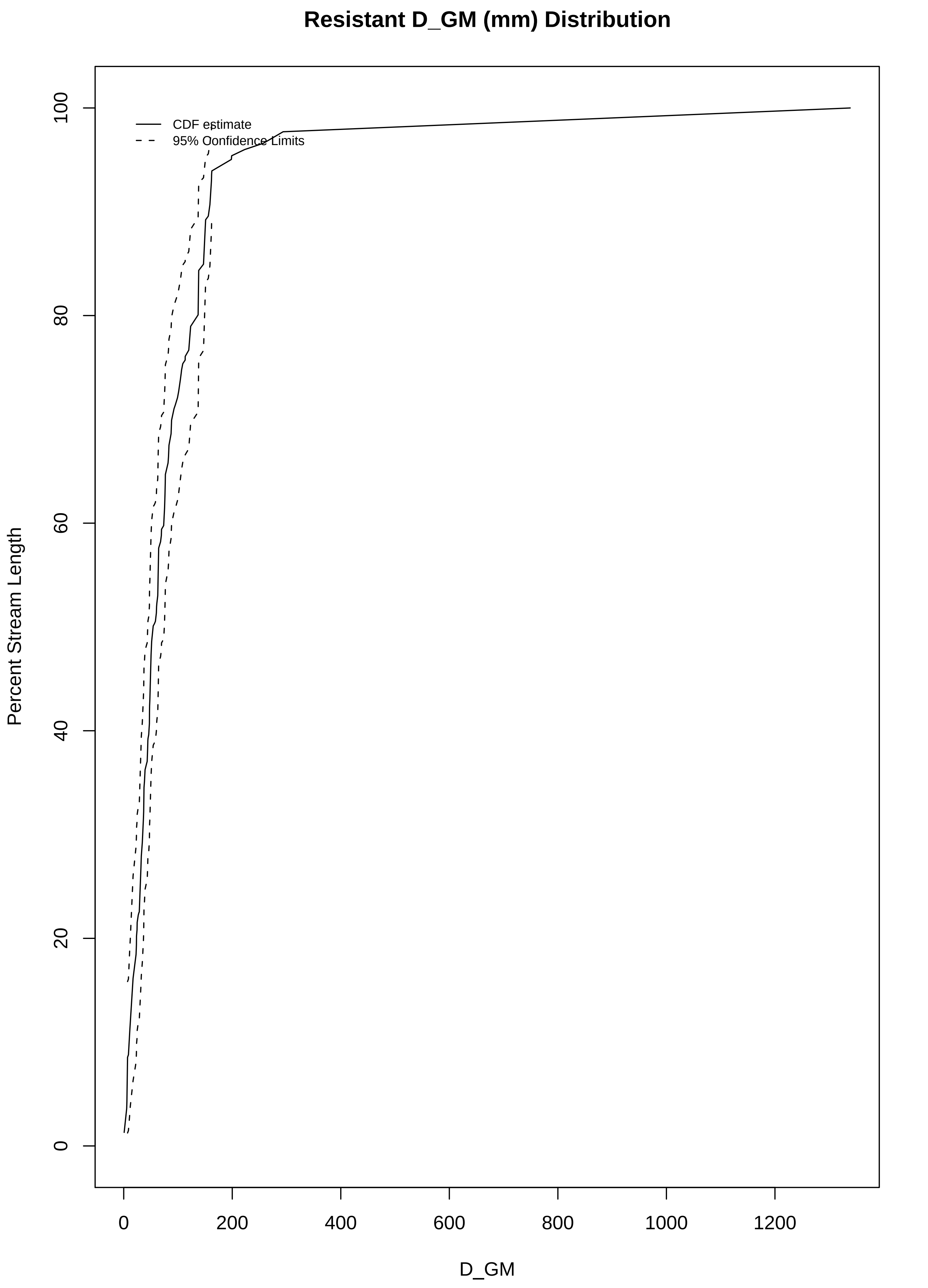
Resistant %SAFN Distribution



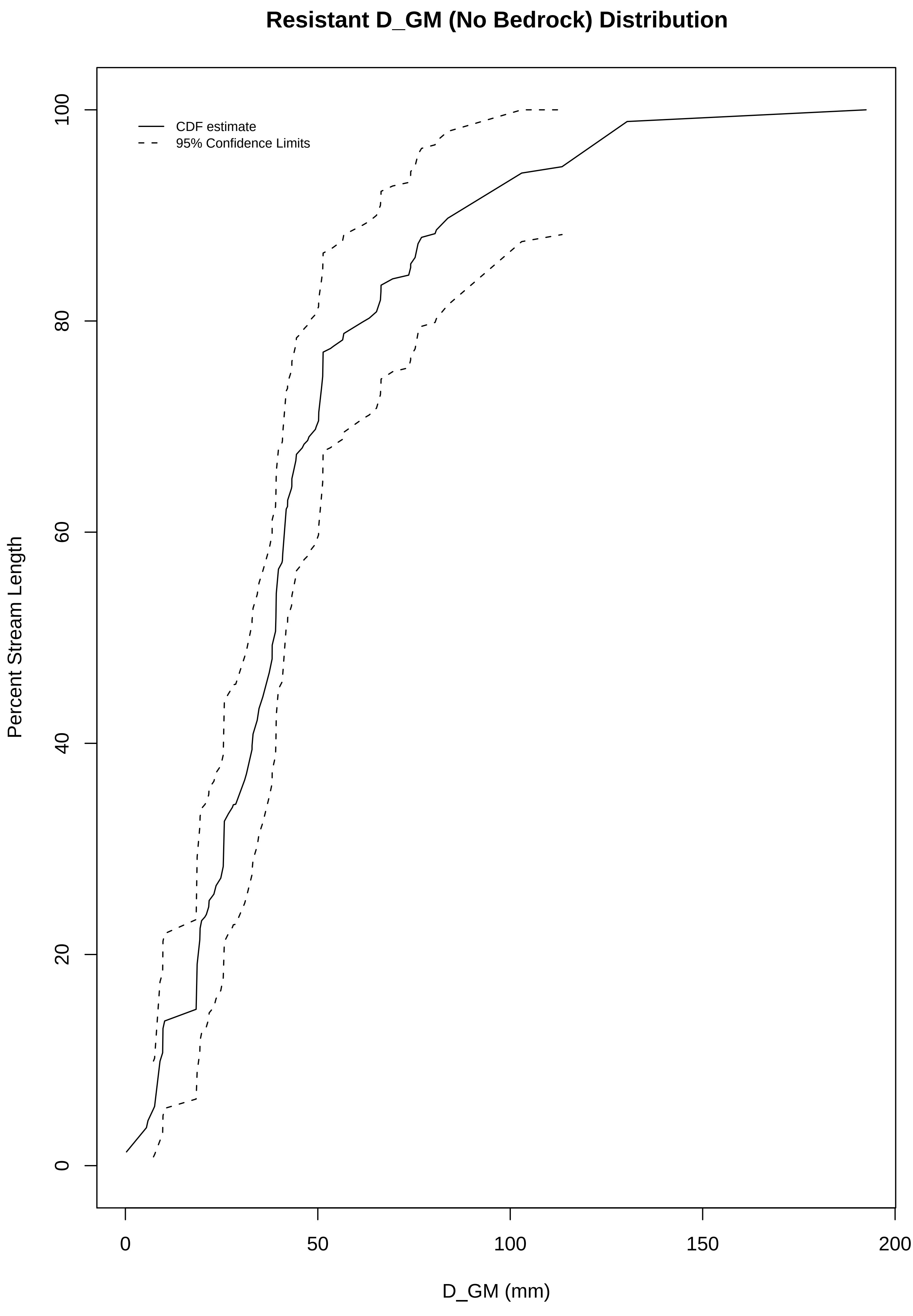

Resistant RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Wood Radius (m)


Resistant RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
10
20
30
40
50
Residual Pool Depth (cm)


Resistant W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
5
10
15
20
25
30
35
40
Bankfull Width to Depth Ratio

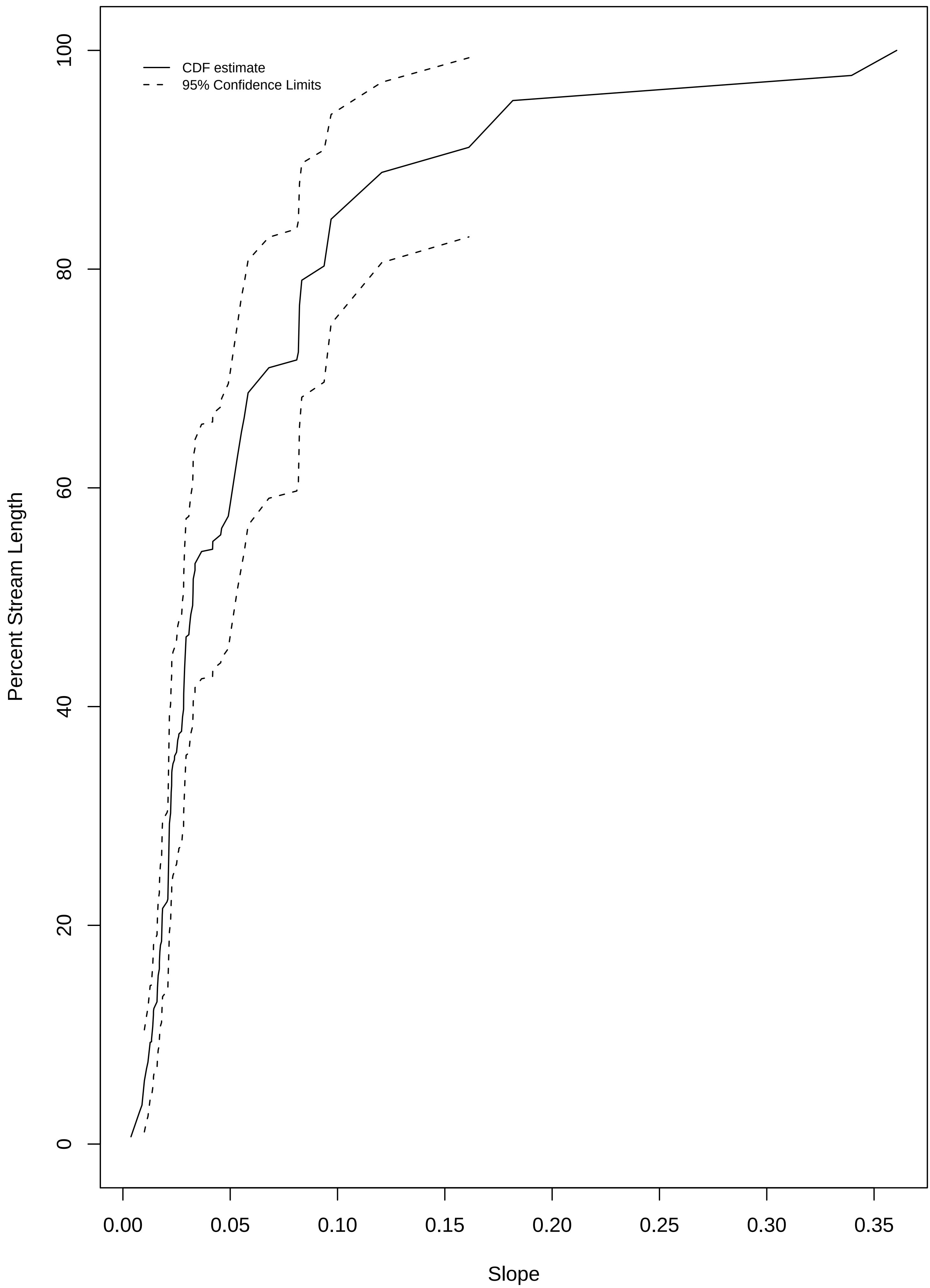


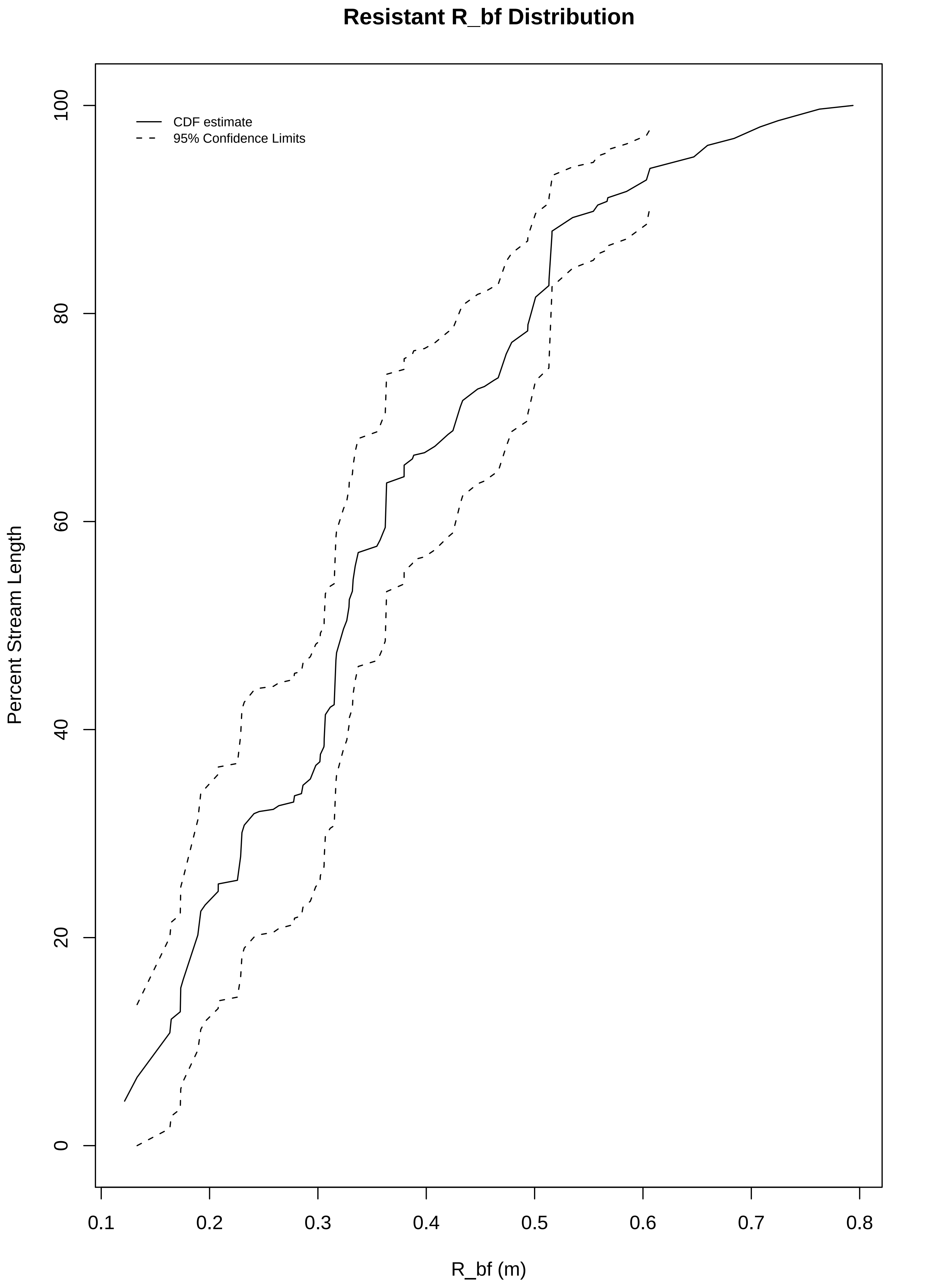
Resistant D_GM (mm) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
200
400
600
800
1000
1200
D_GM

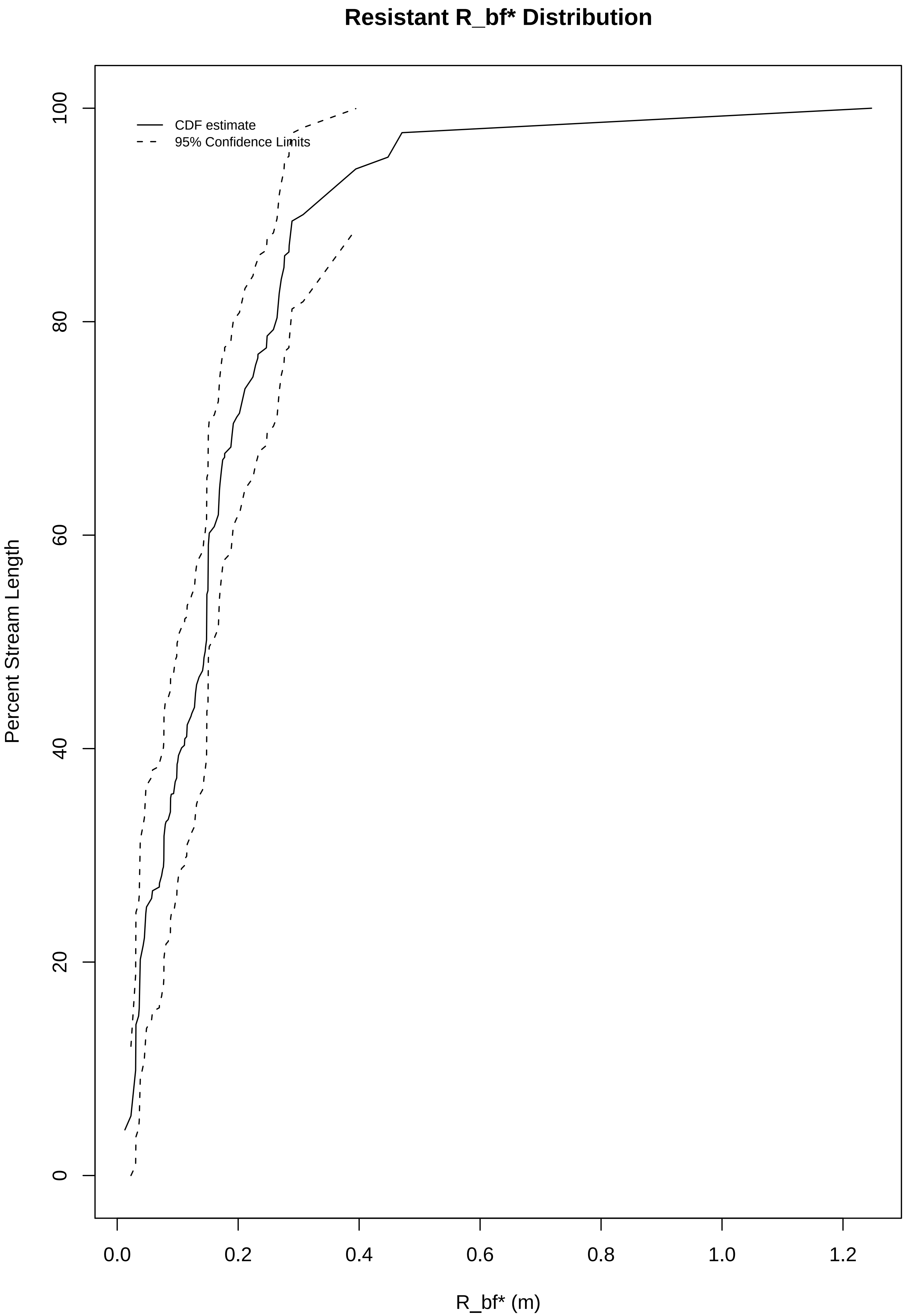


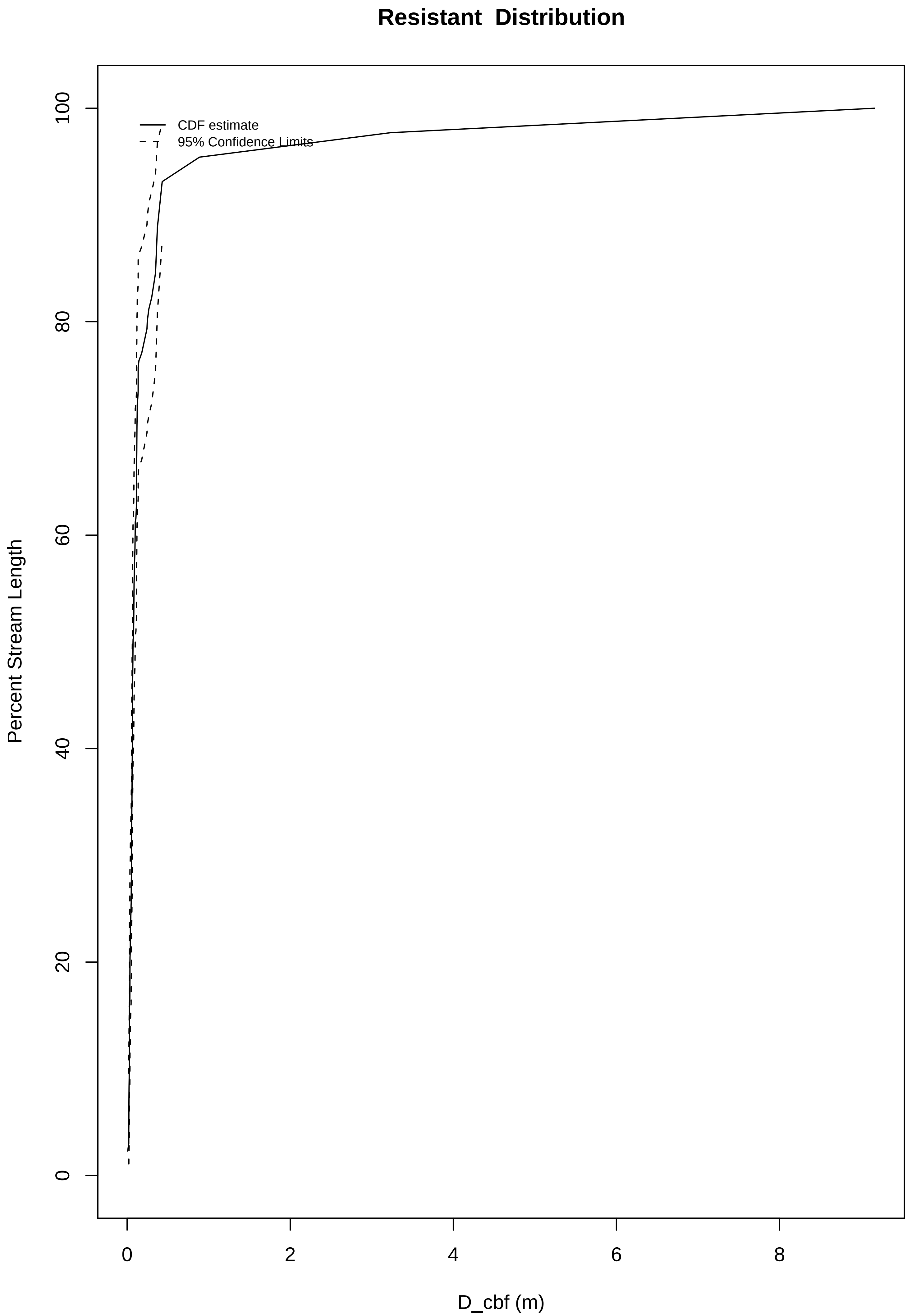
Resistant D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
50
100
150
200
D_GM (mm)

Resistant Slope Distribution



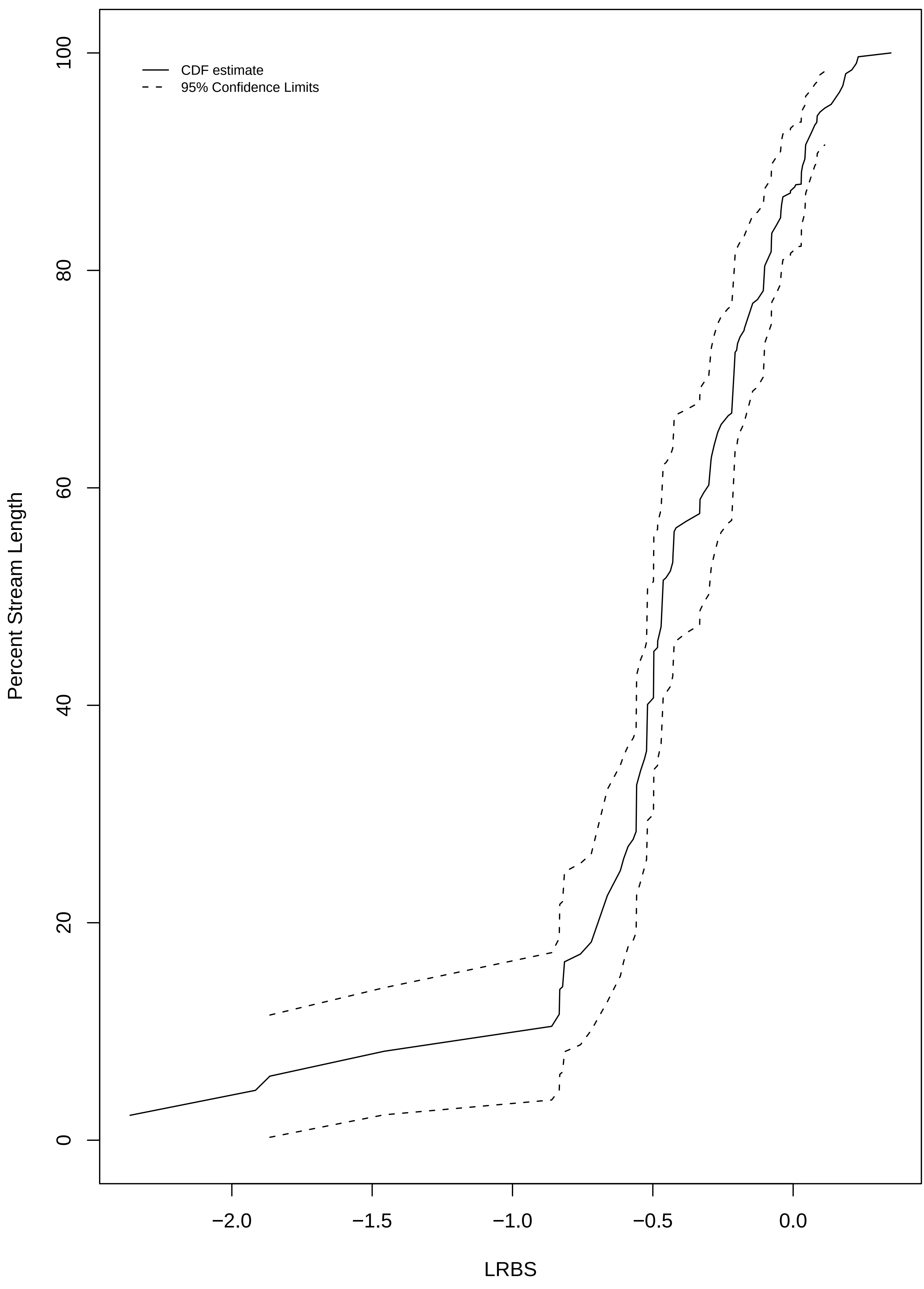

Resistant R_bf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
R_bf (m)

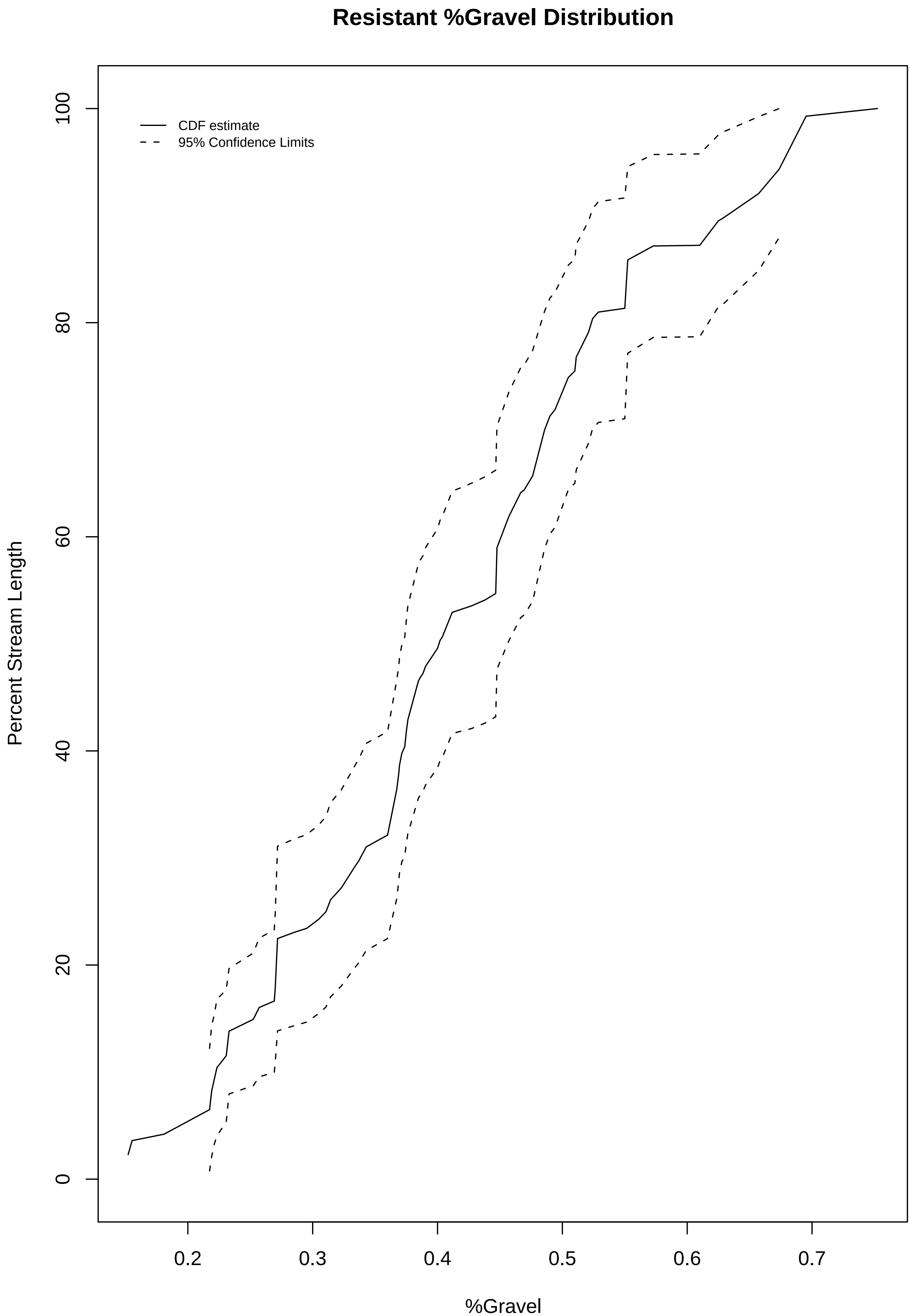

Resistant R_bf* Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0
1.2
R_bf* (m)



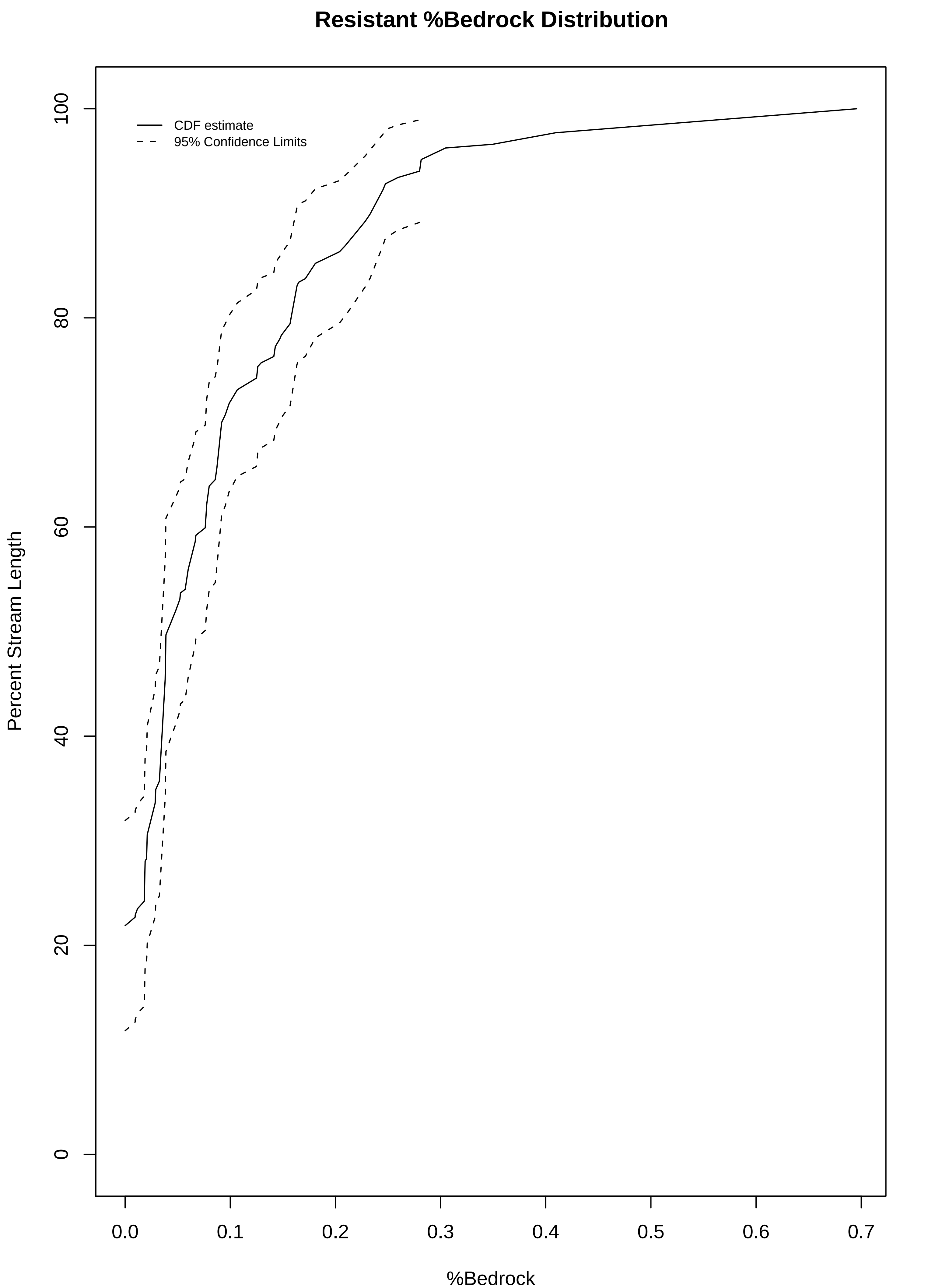
Resistant Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
2
4
6
8
D_cbf (m)

Resistant LRBS (No Bedrock) Distribution

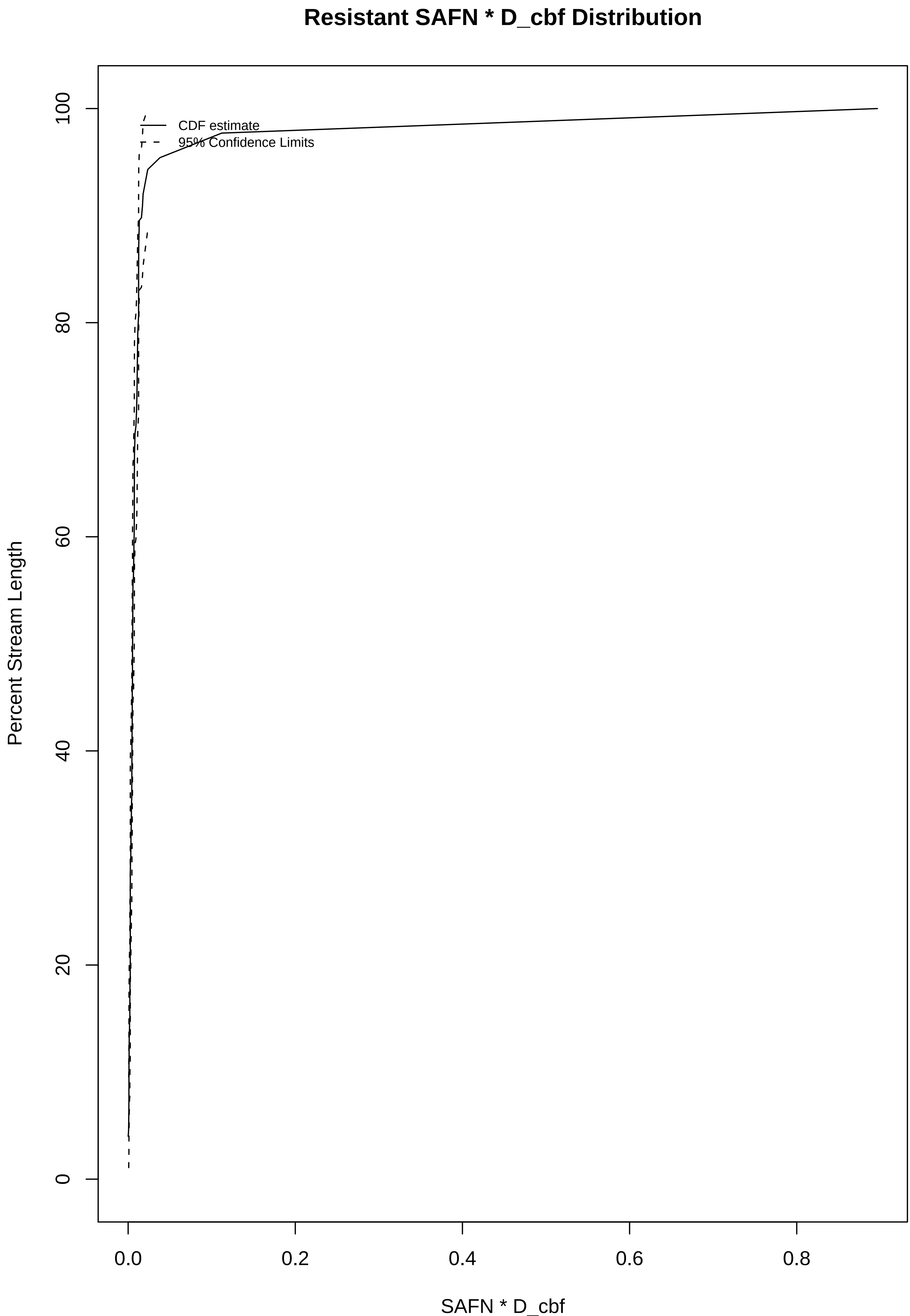


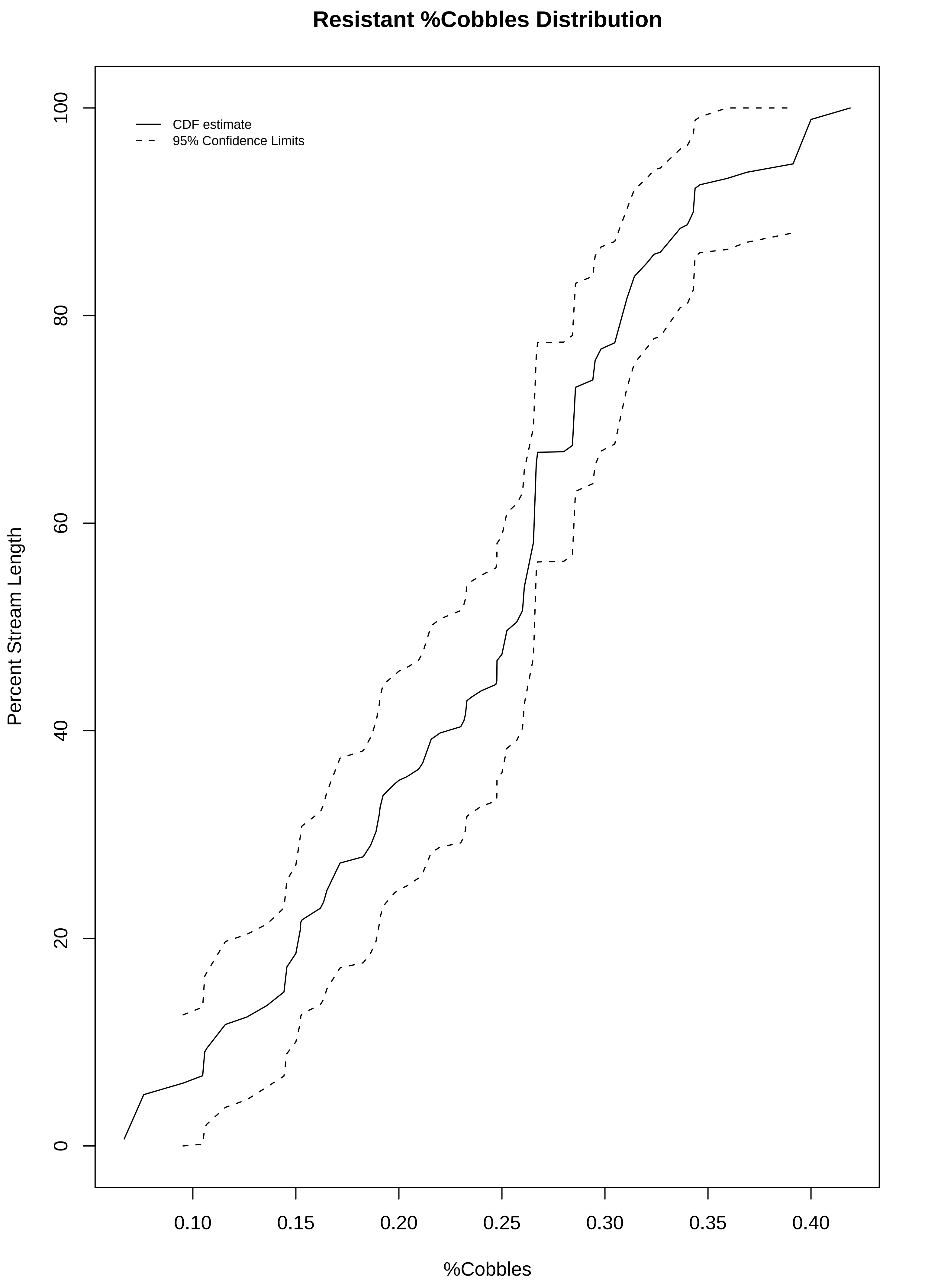


Resistant %Gravel Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.2
0.3
0.4
0.5
0.6
0.7
%Gravel

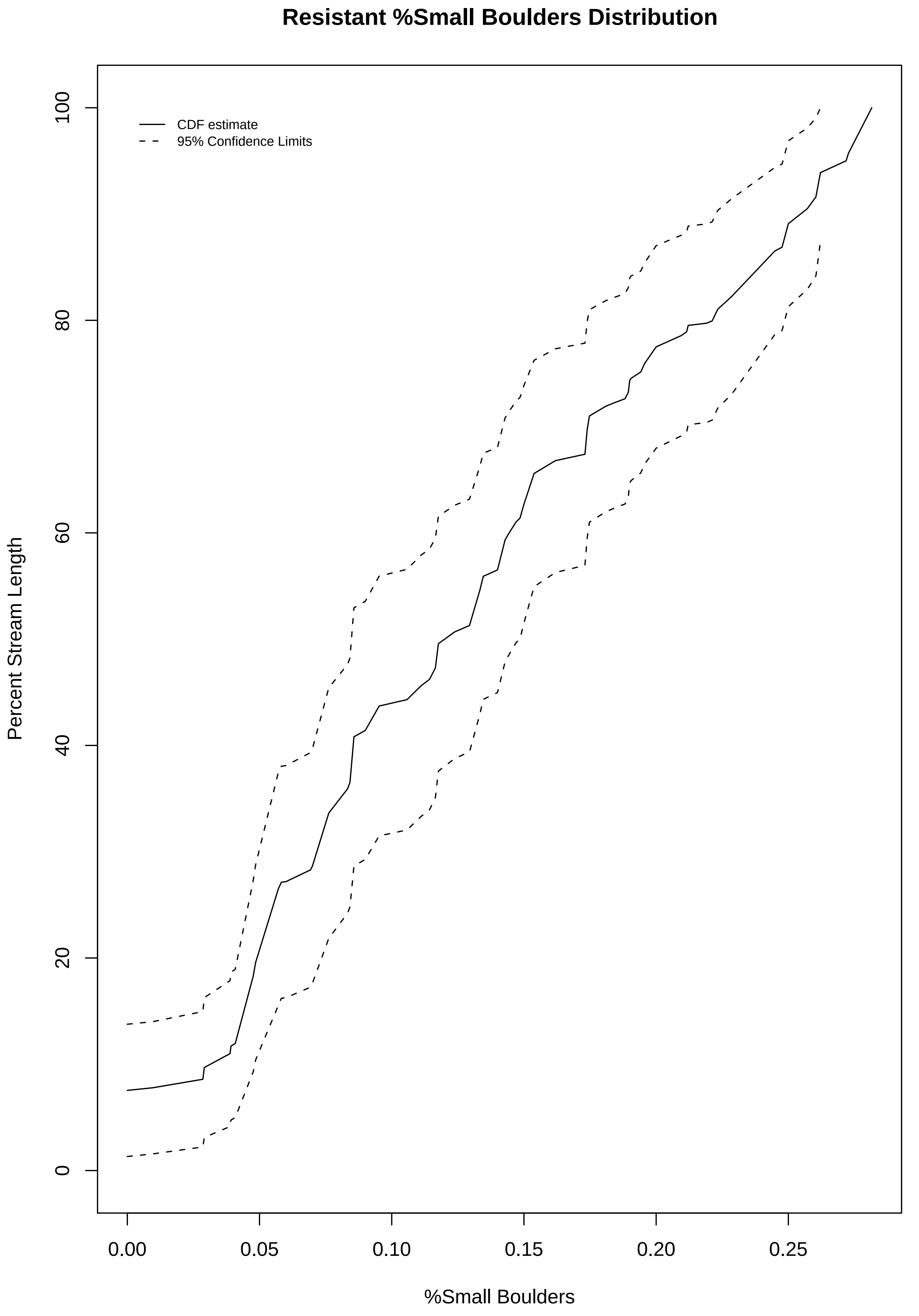


Resistant %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
%Bedrock

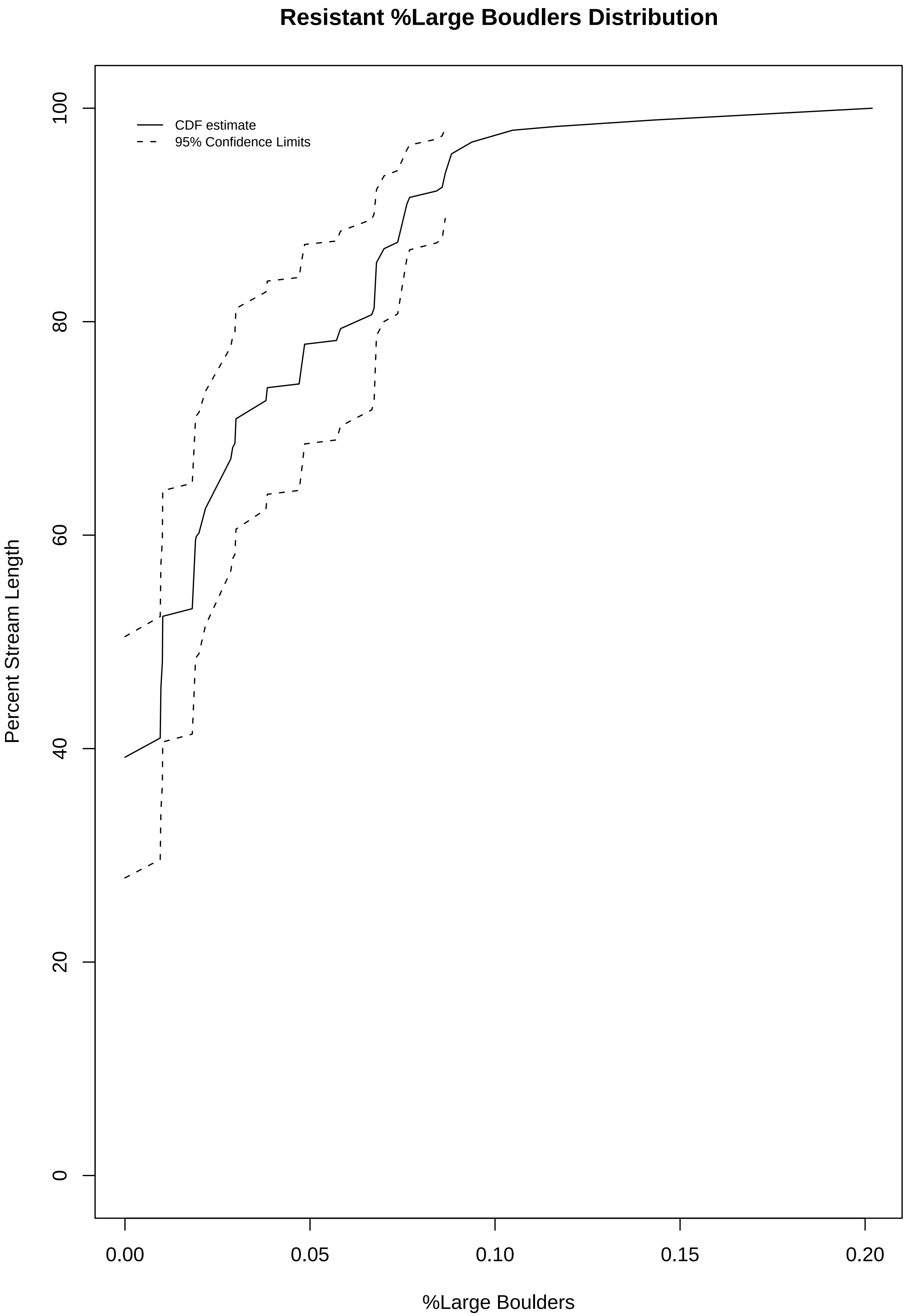

Resistant SAFN * D_cbf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
SAFN * D_cbf

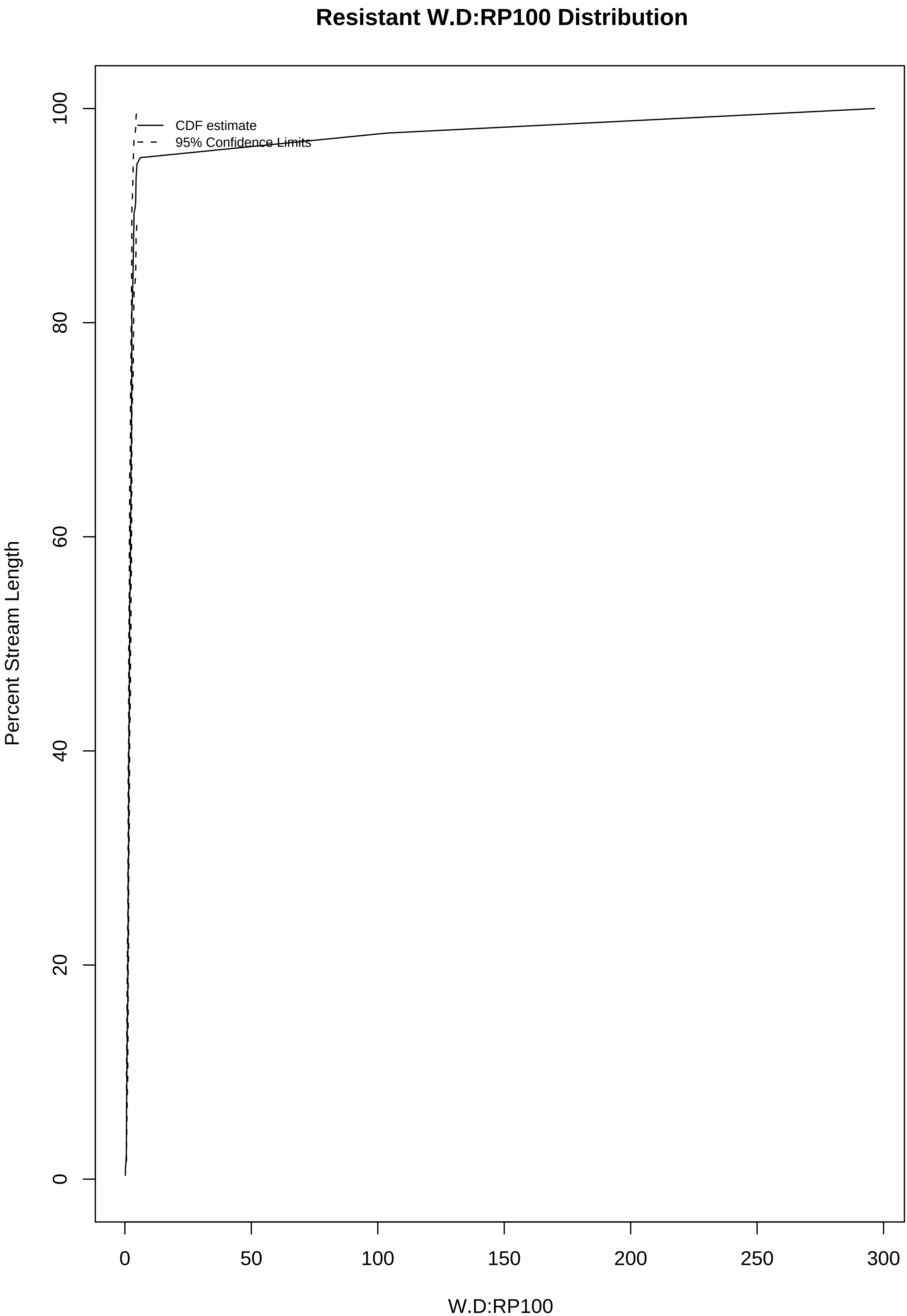


Resistant %Cobbles Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.10
0.15
0.20
0.25
0.30
0.35
0.40
%Cobbles

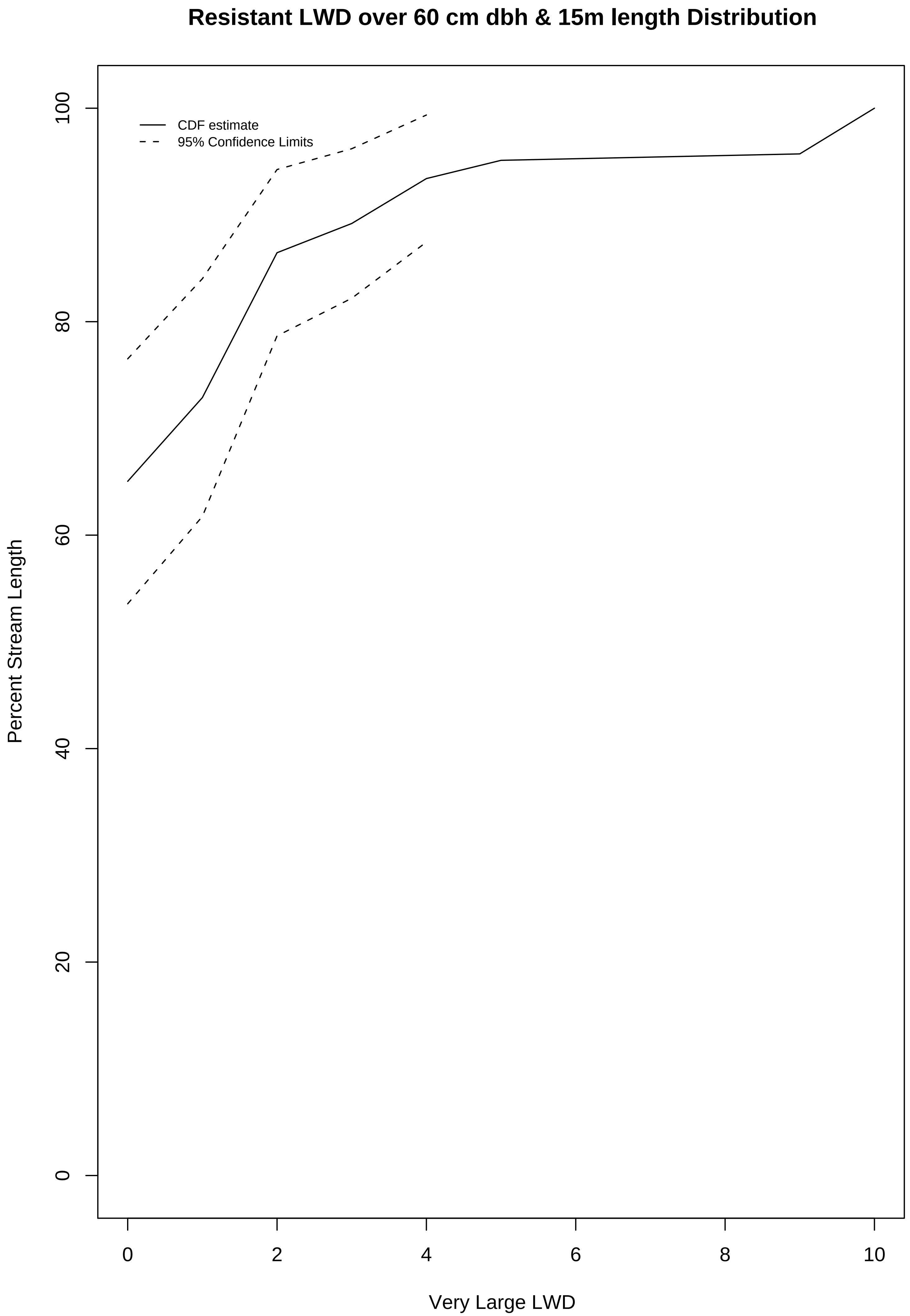


Resistant %Small Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
%Small Boulders

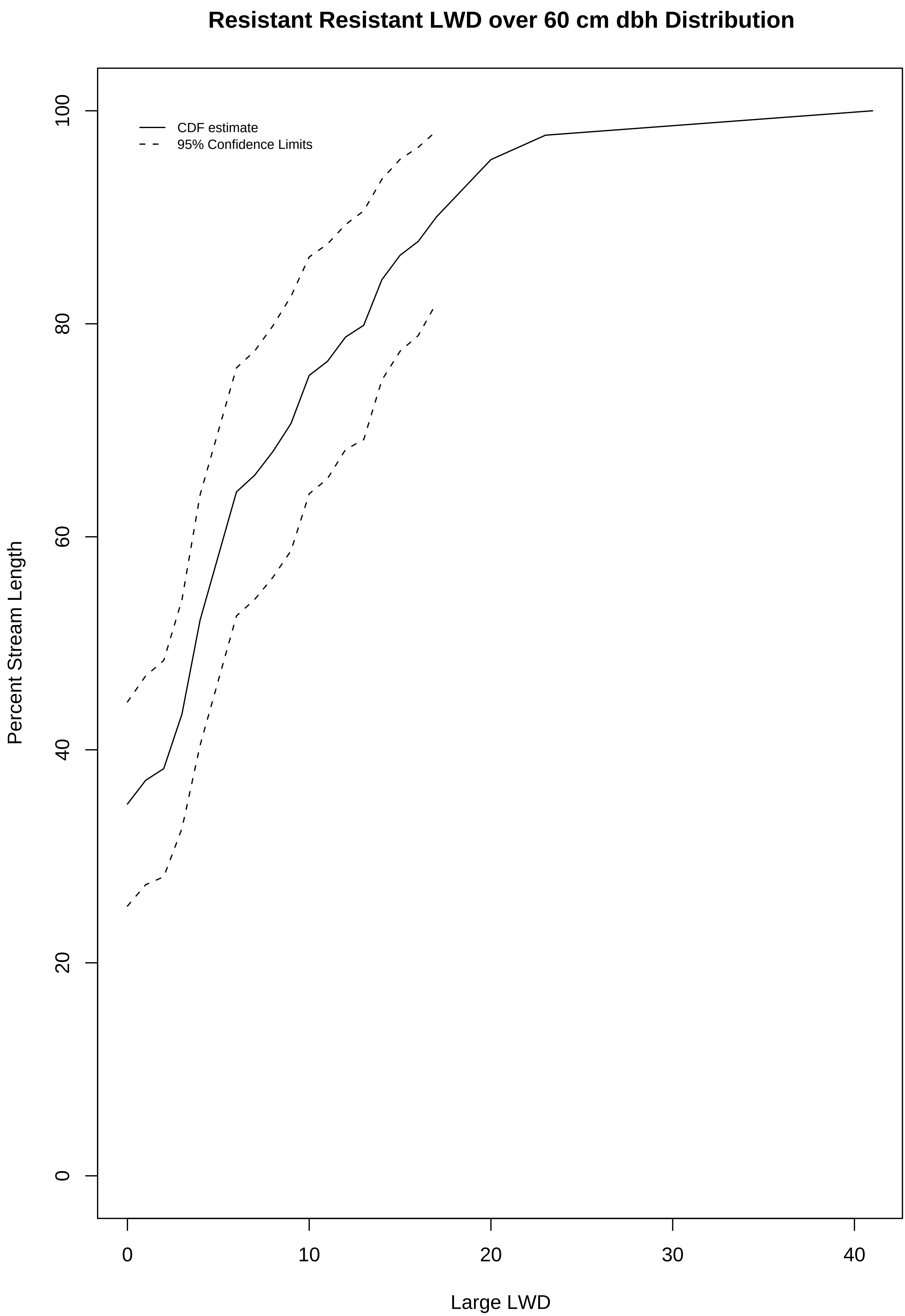

Resistant %Large Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
%Large Boulders

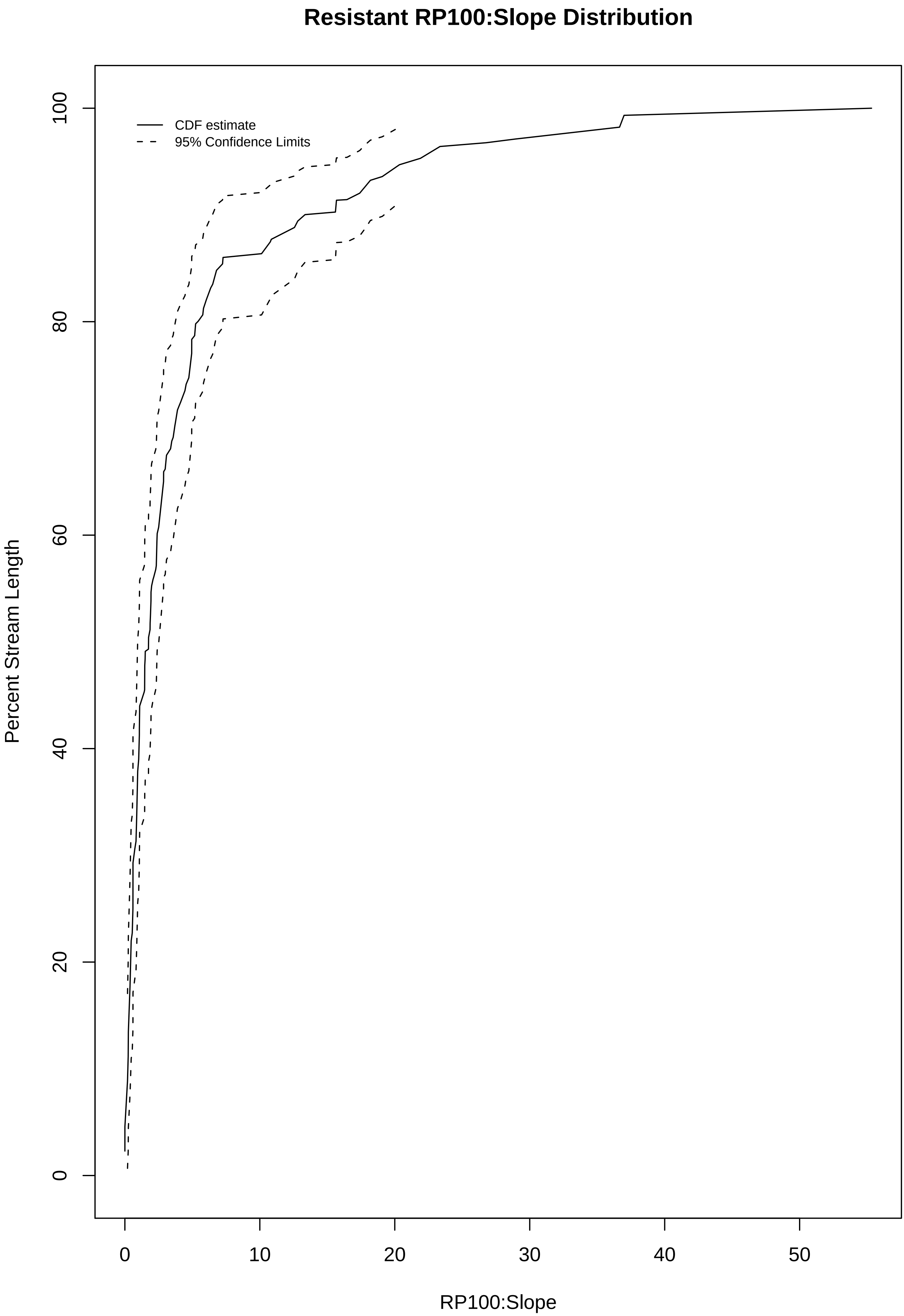


Resistant W.D:RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
W.D:RP100
0
20
40
60
80
100
0
50
100
150
200
250
300

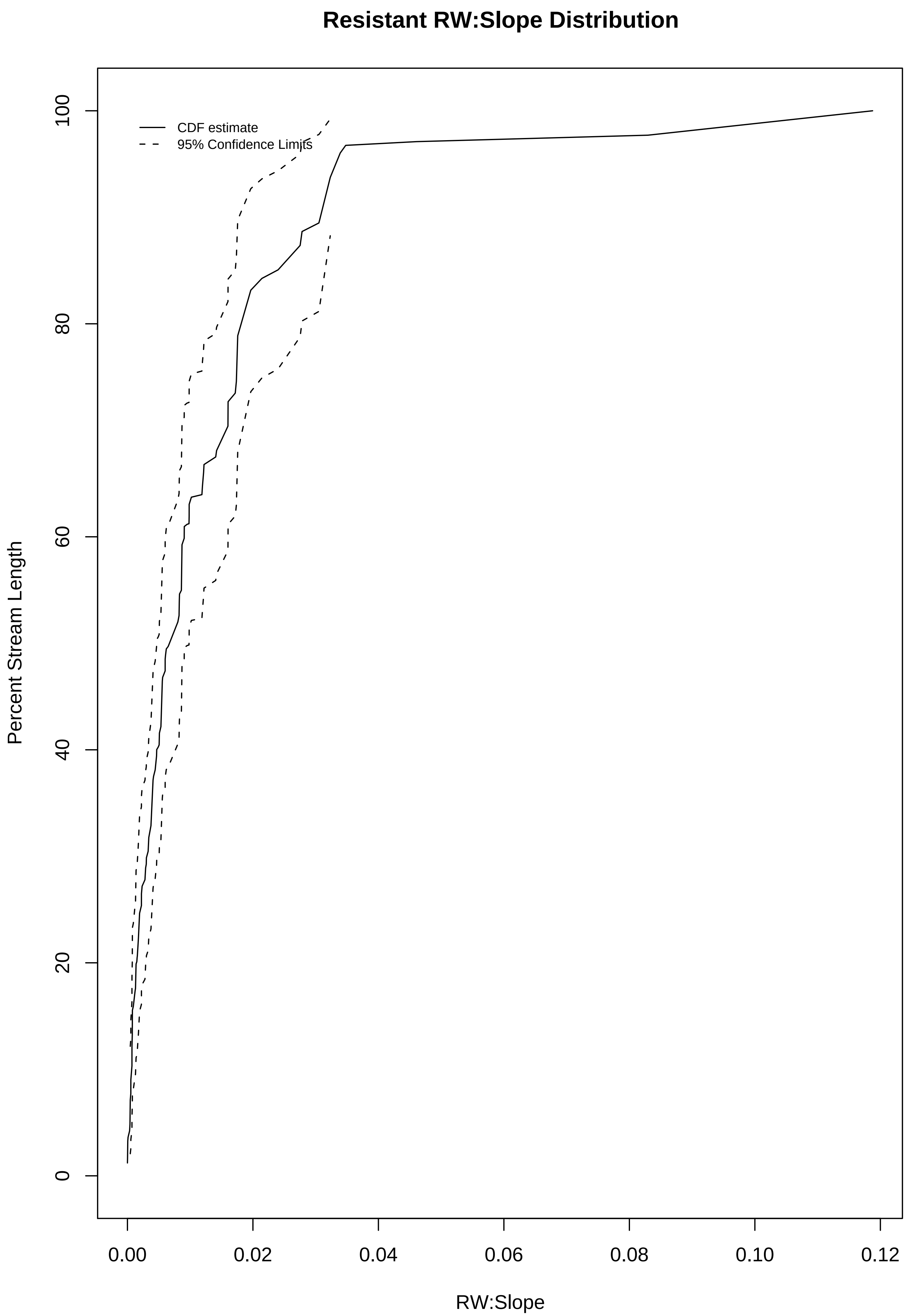


Resistant LWD over 60 cm dbh & 15m length Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
2
4
6
8
10
Very Large LWD

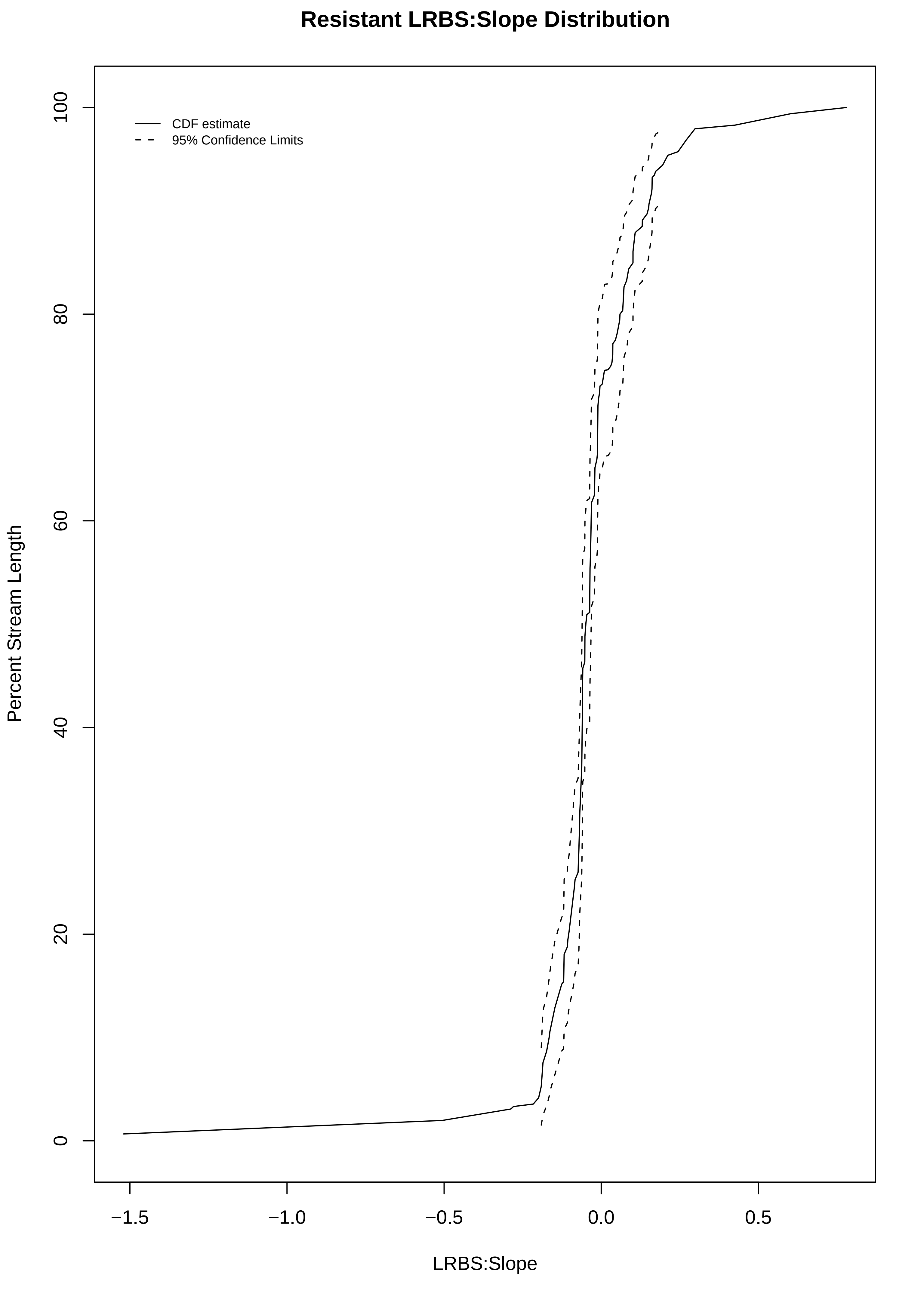

Resistant Resistant LWD over 60 cm dbh Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
10
20
30
40
Large LWD



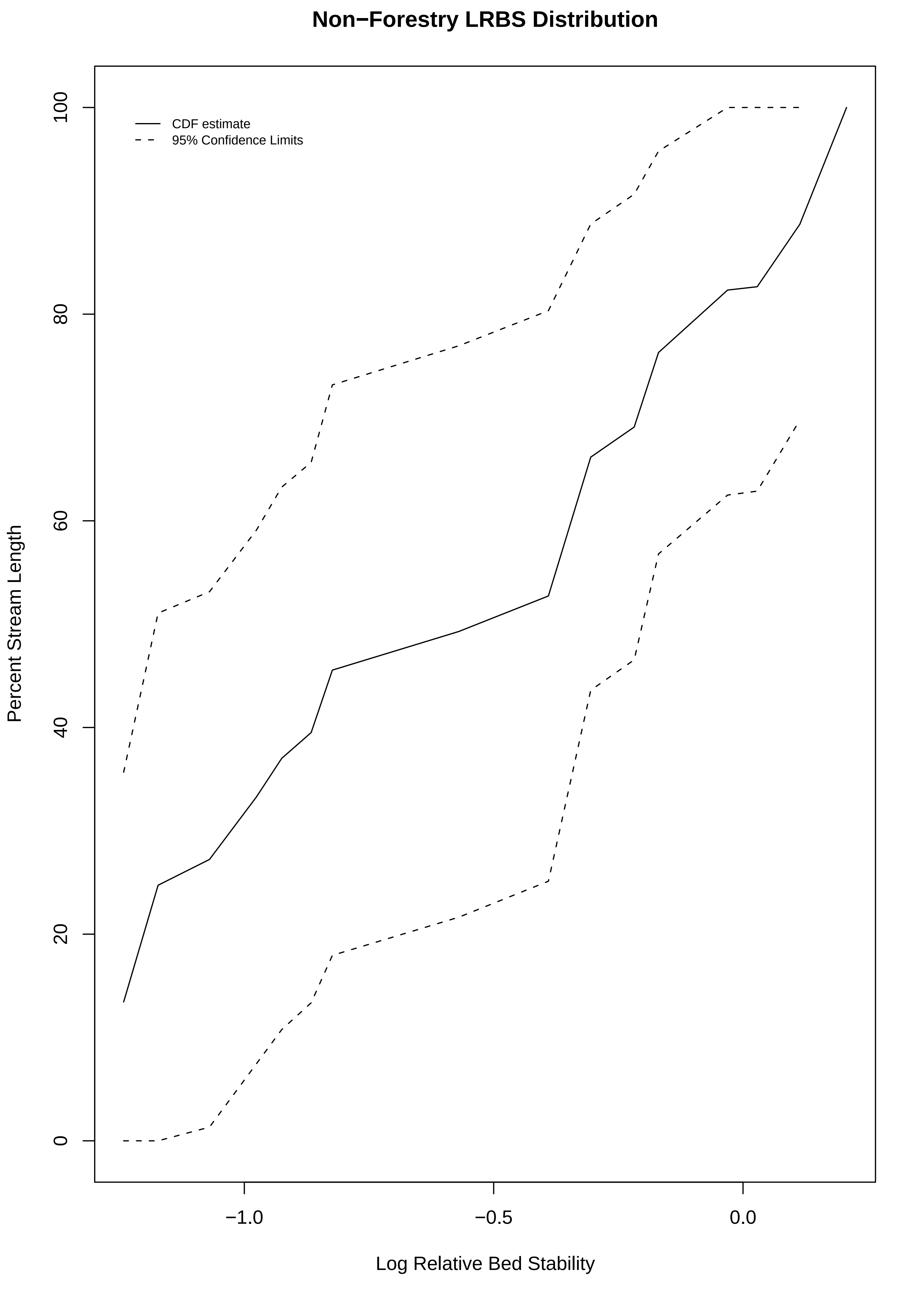
Resistant RP100:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
10
20
30
40
50
RP100:Slope

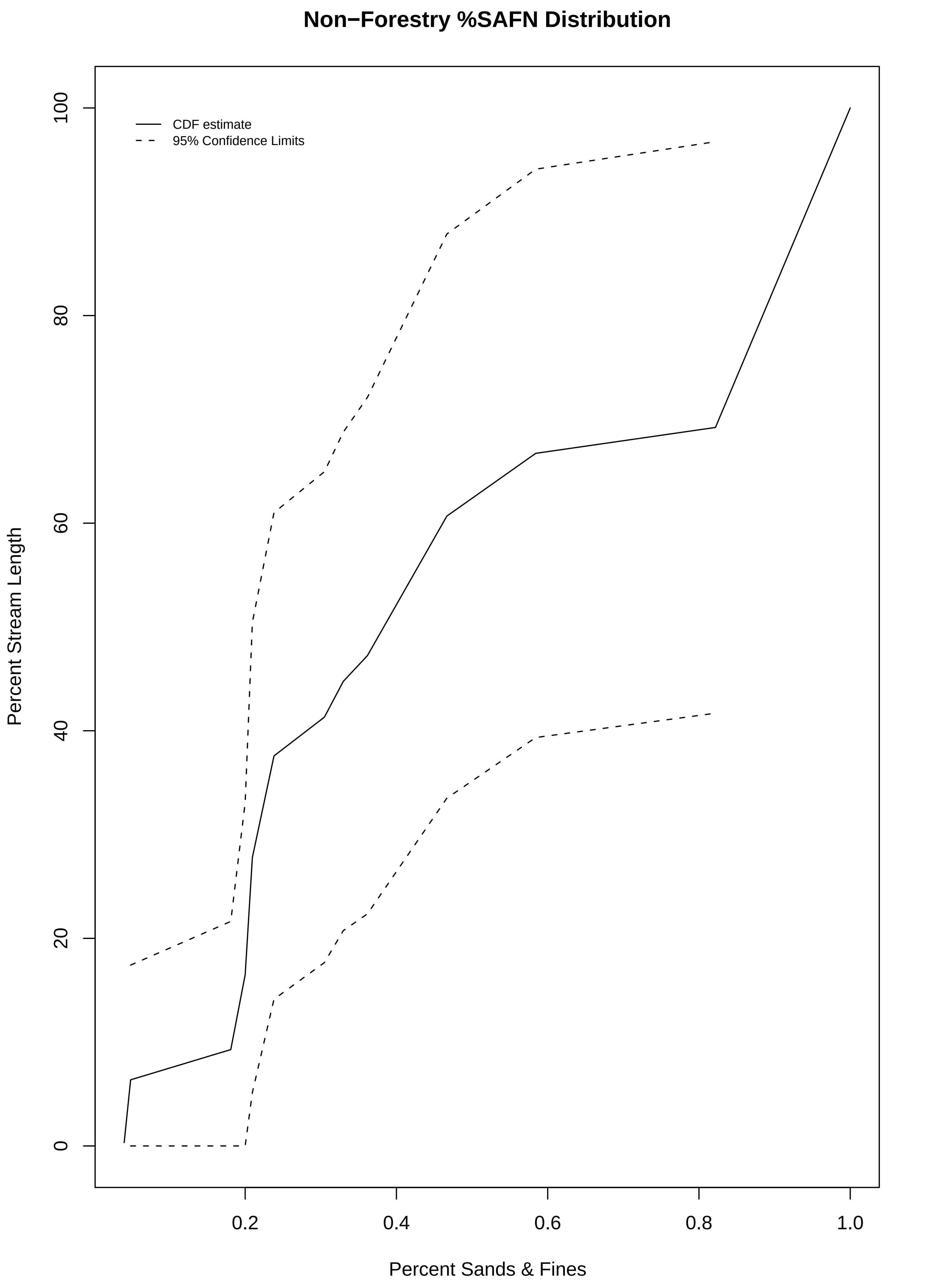


Resistant RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.02
0.04
0.06
0.08
0.10
0.12
RW:Slope

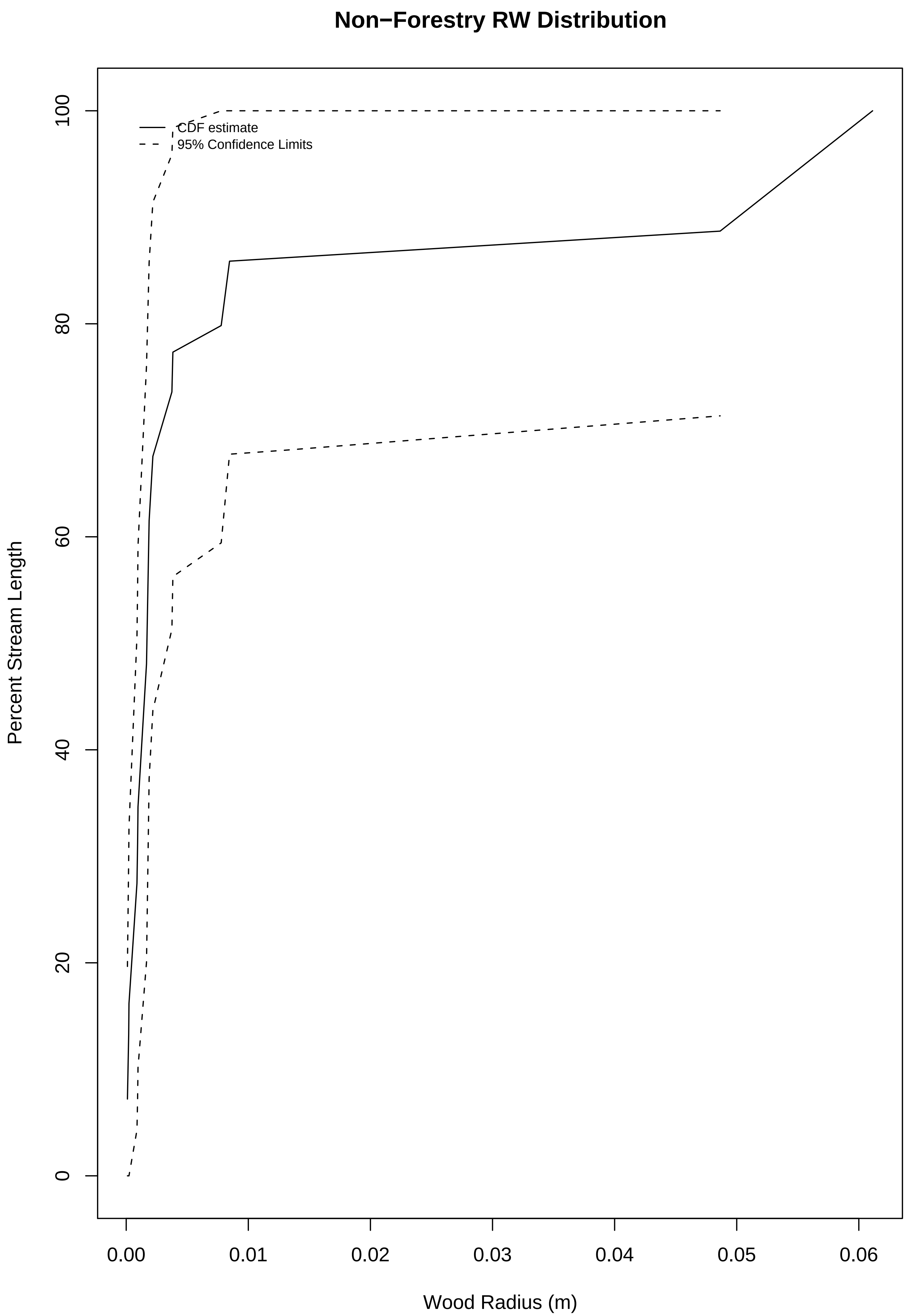


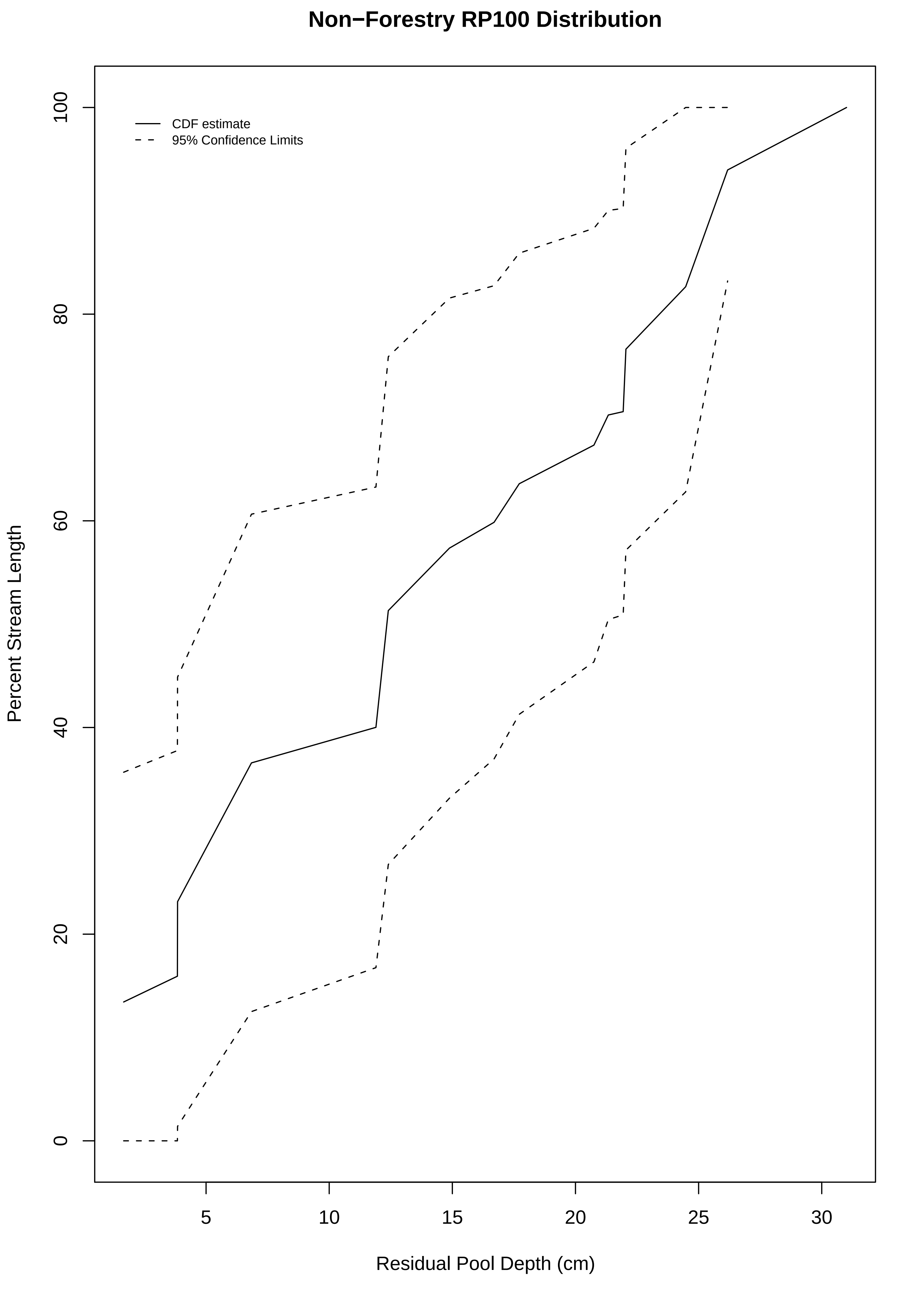
Resistant LRBS:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−1.5
−1.0
−0.5
0.0
0.5
LRBS:Slope


Non−Forestry LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−1.0
−0.5
0.0
Log Relative Bed Stability

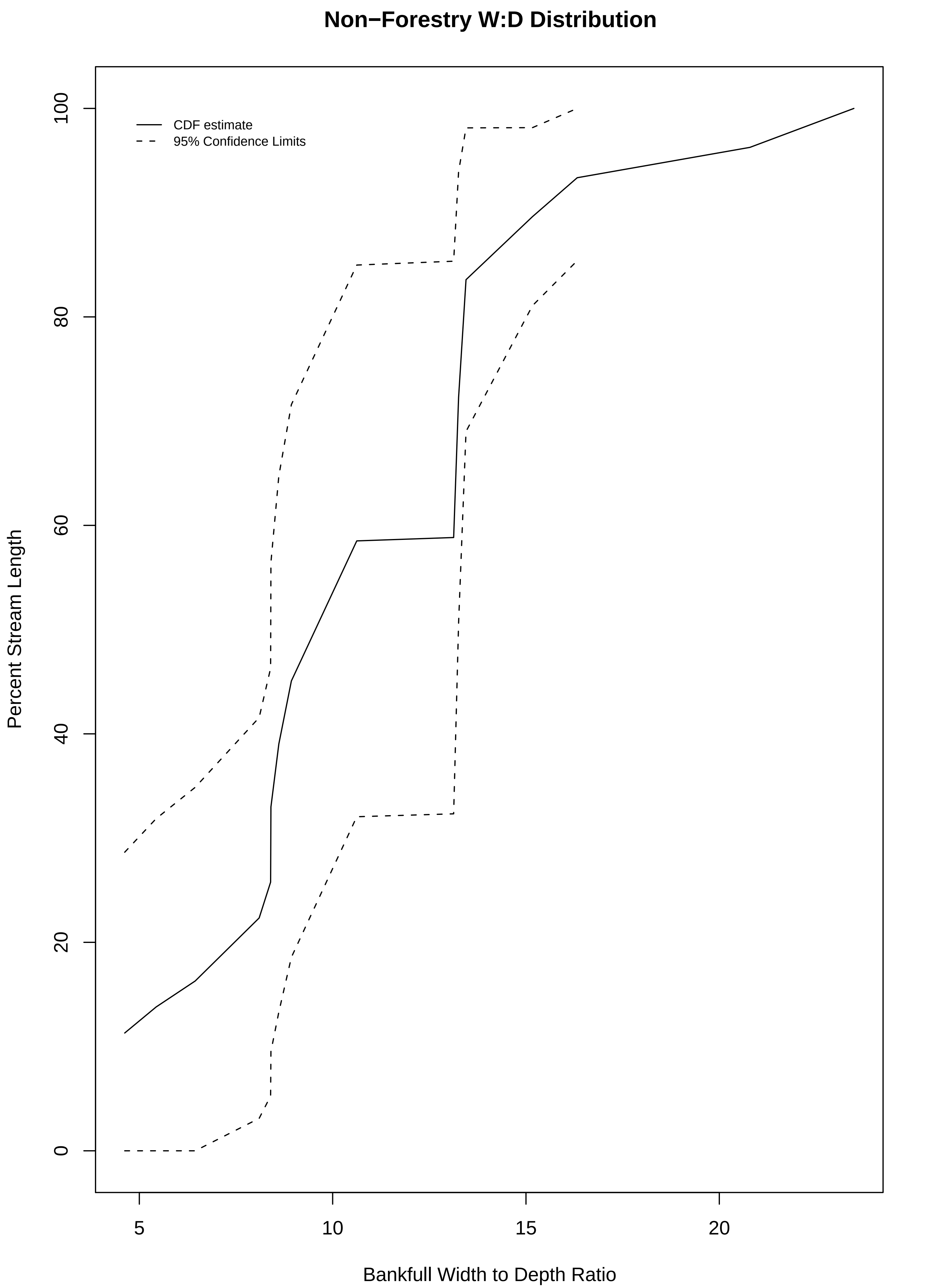


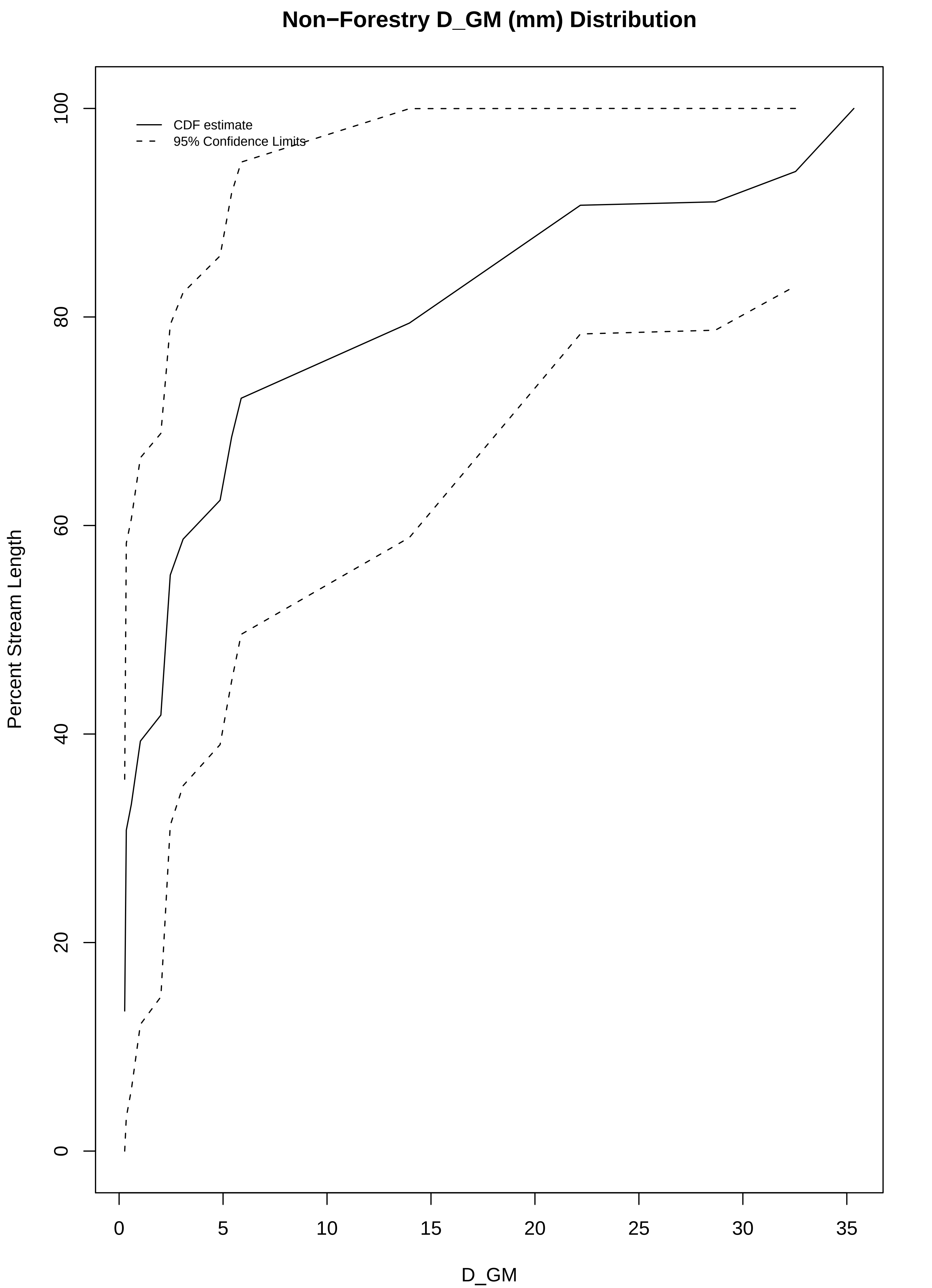
Non−Forestry %SAFN Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.2
0.4
0.6
0.8
1.0
Percent Sands & Fines

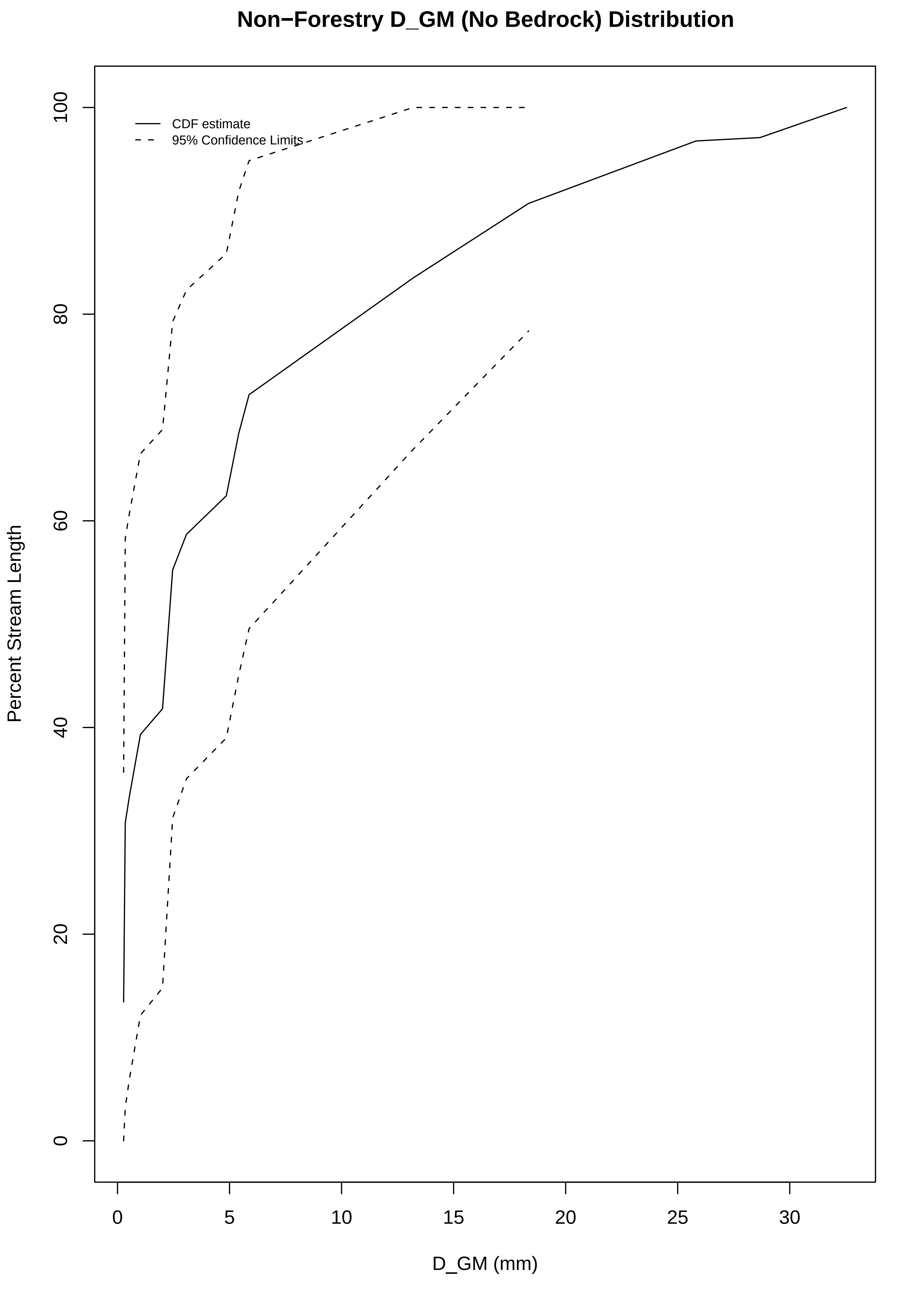

Non−Forestry RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.01
0.02
0.03
0.04
0.05
0.06
Wood Radius (m)



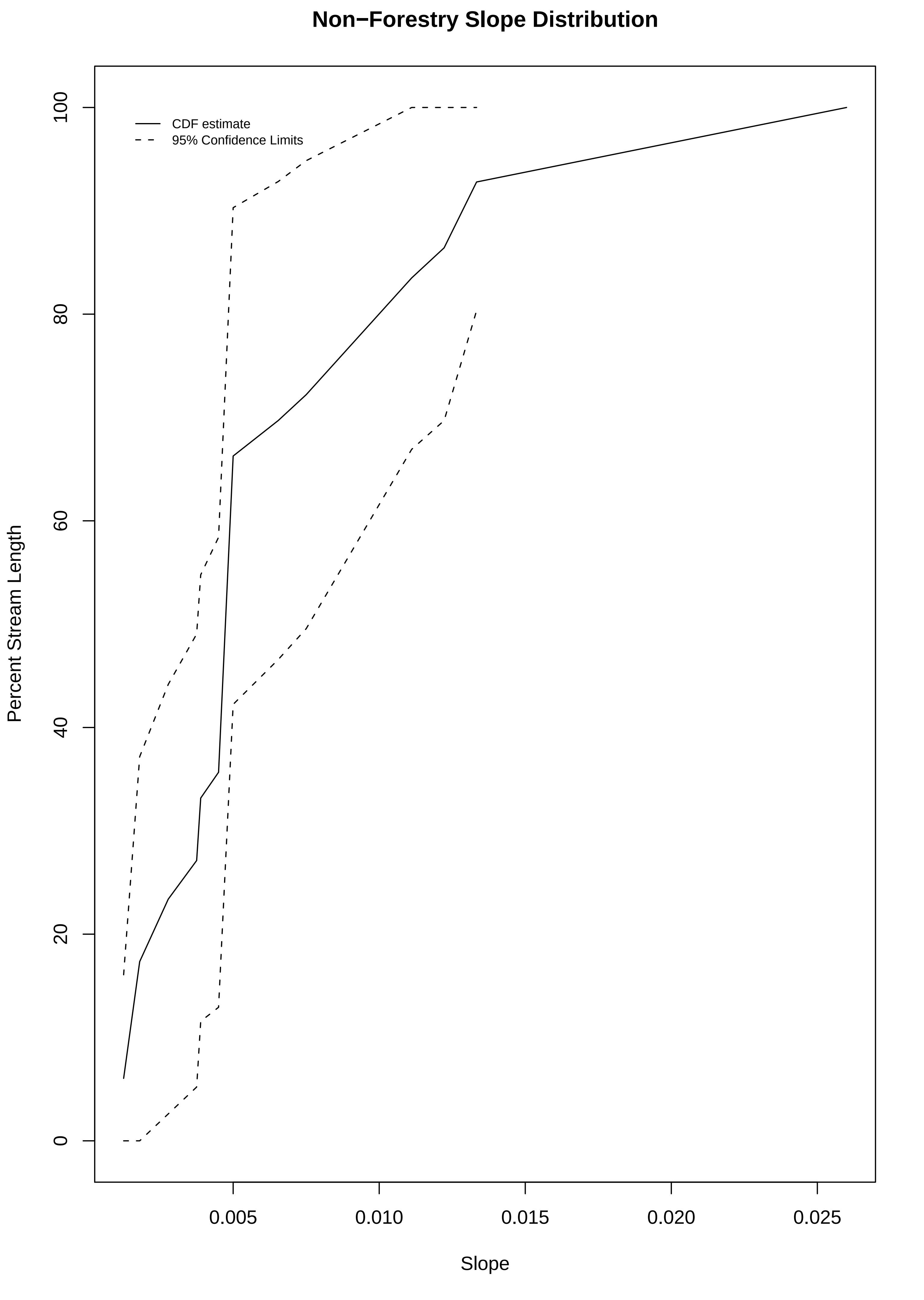
Non−Forestry RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
5
10
15
20
25
30
Residual Pool Depth (cm)


Non−Forestry W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
5
10
15
20
Bankfull Width to Depth Ratio

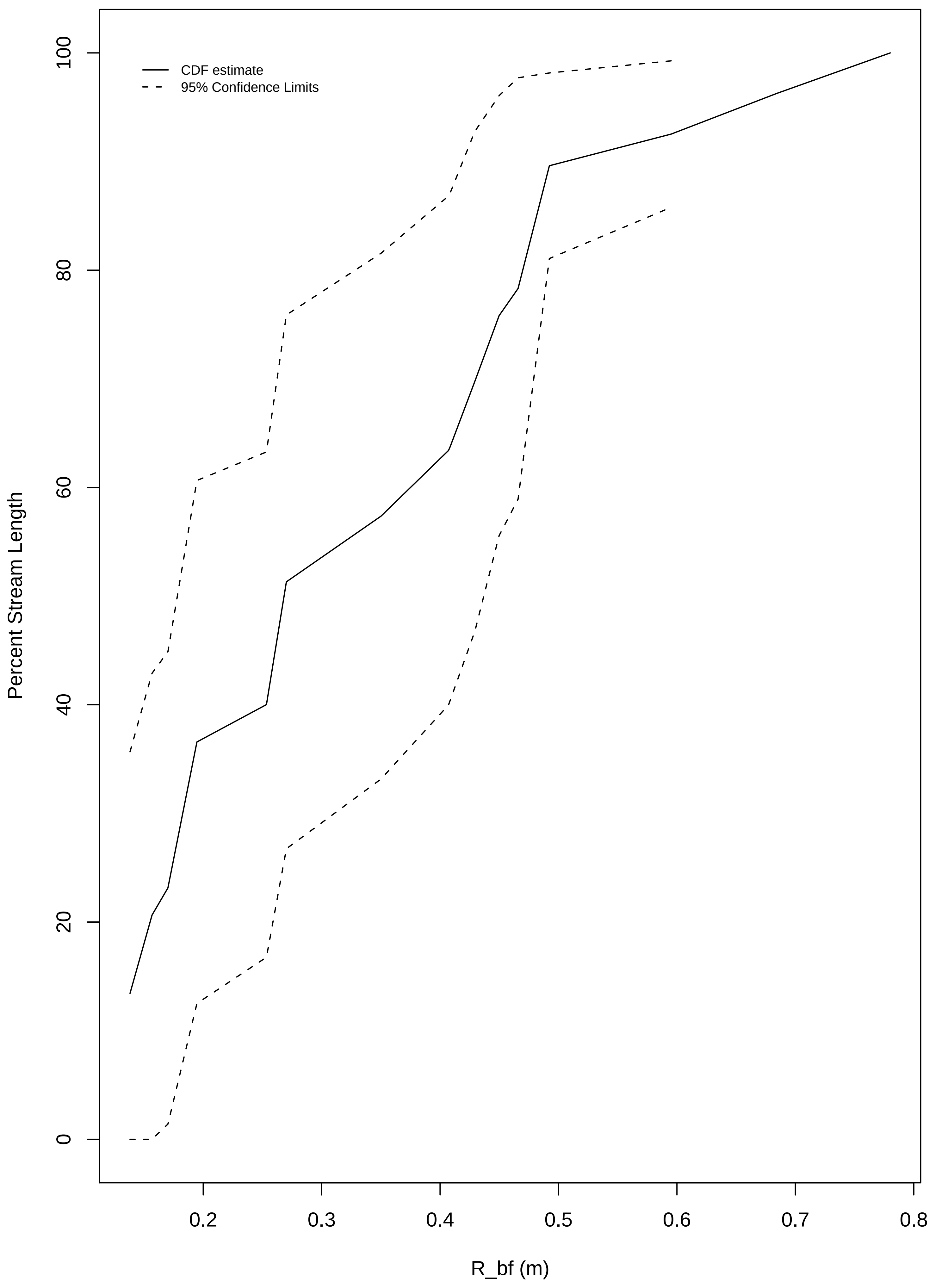

Non−Forestry D_GM (mm) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
5
10
15
20
25
30
35
D_GM

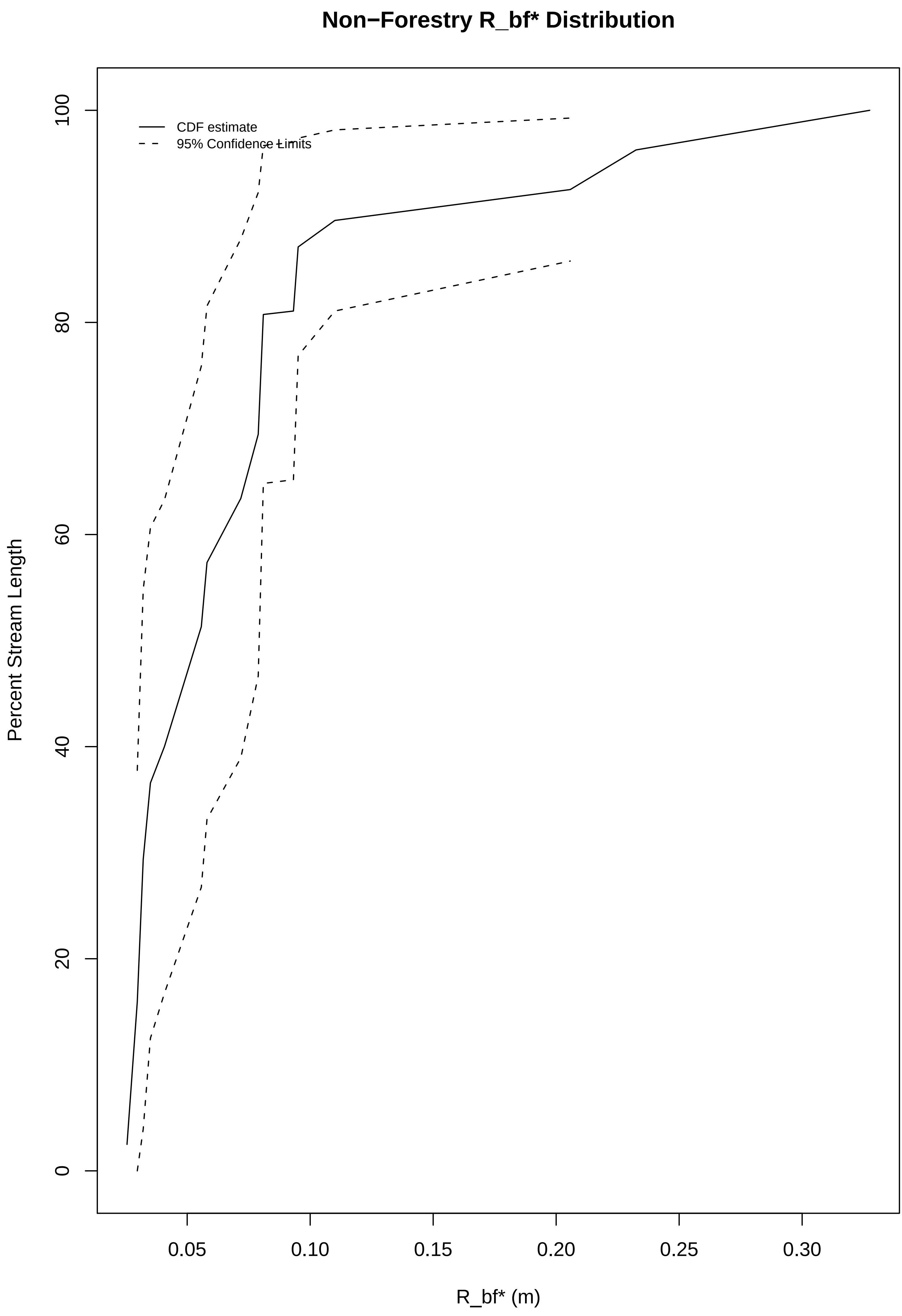


Non−Forestry D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
5
10
15
20
25
30
D_GM (mm)

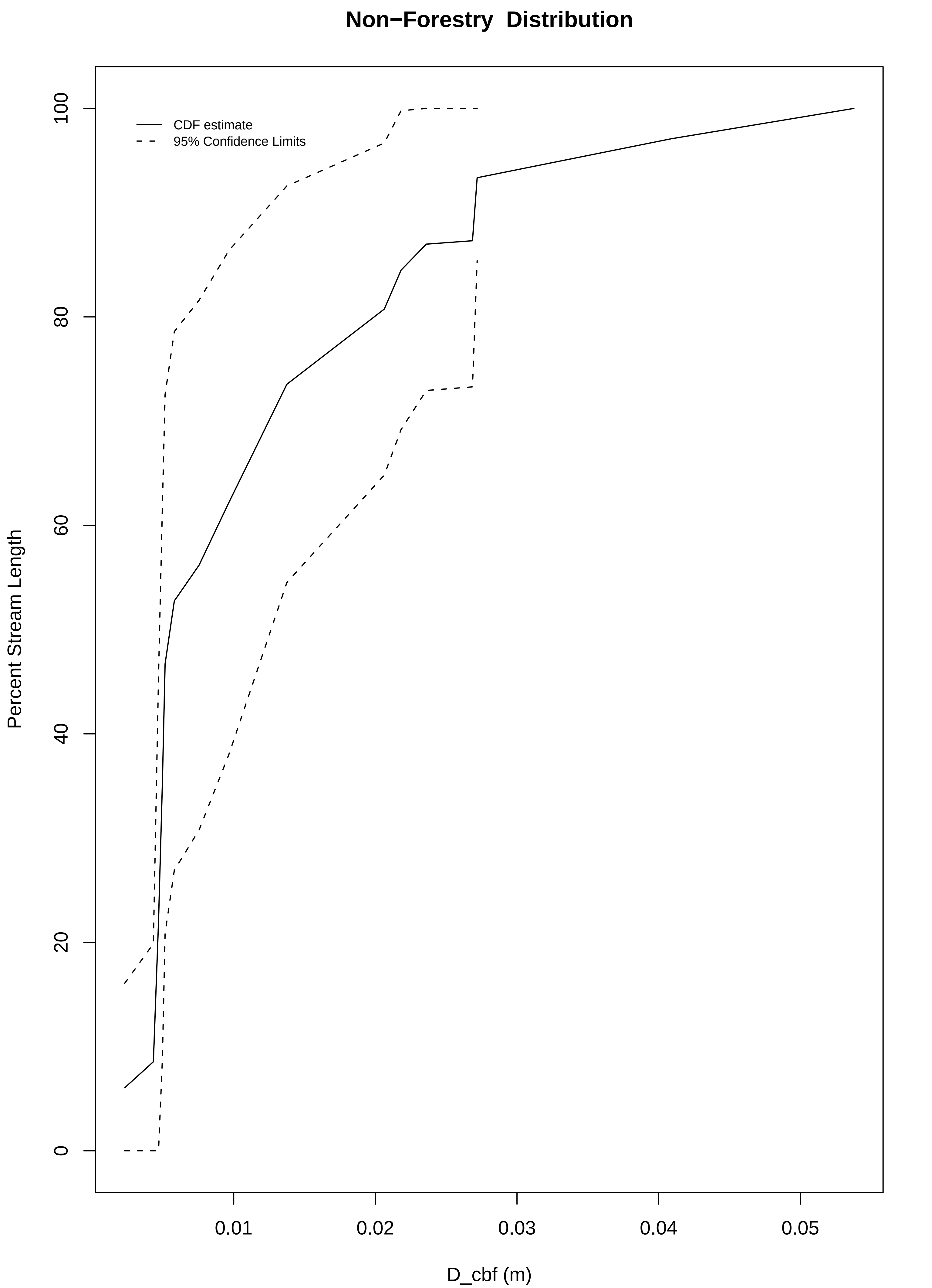

Non−Forestry Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.005
0.010
0.015
0.020
0.025
Slope

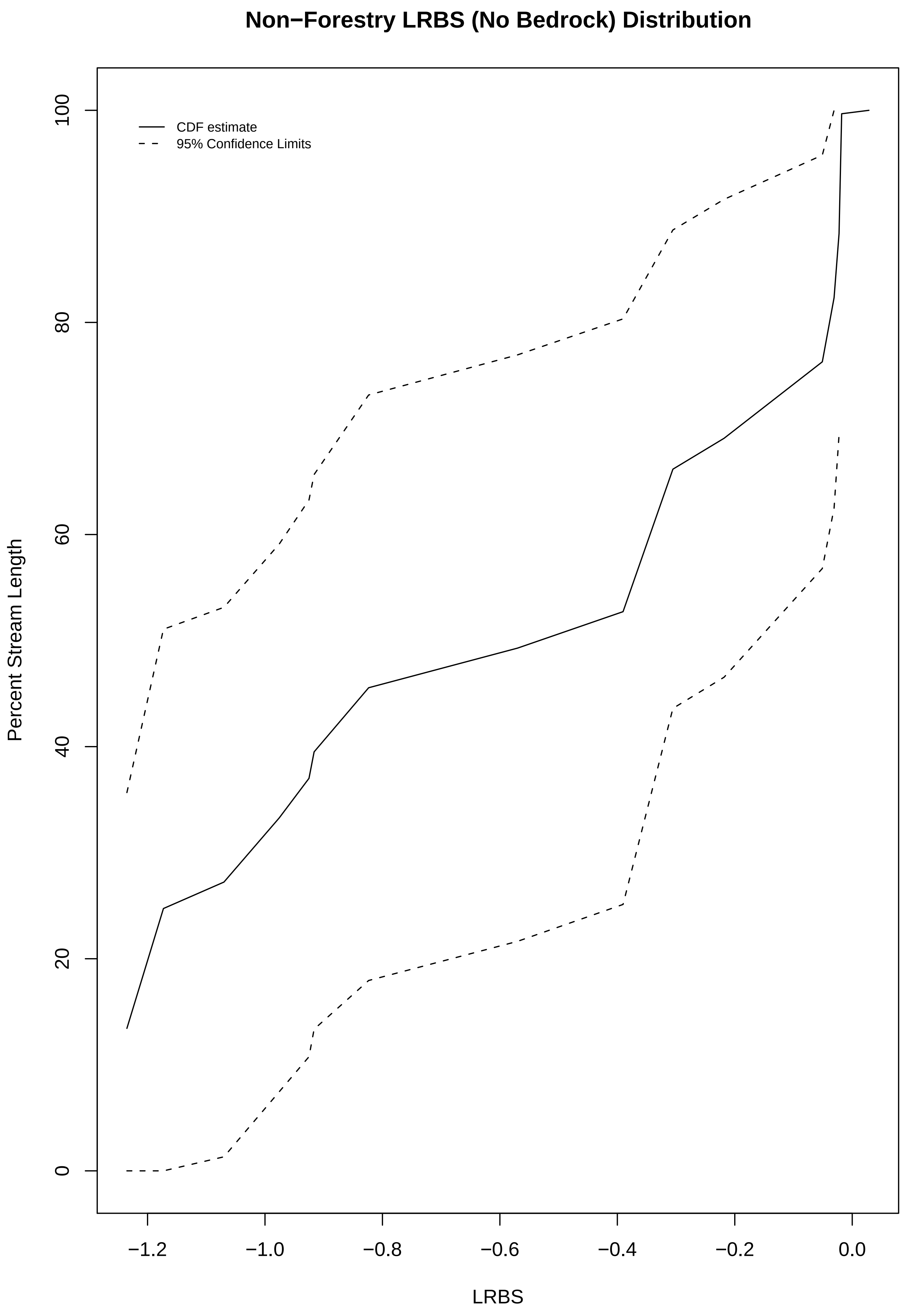
Non−Forestry R_bf Distribution



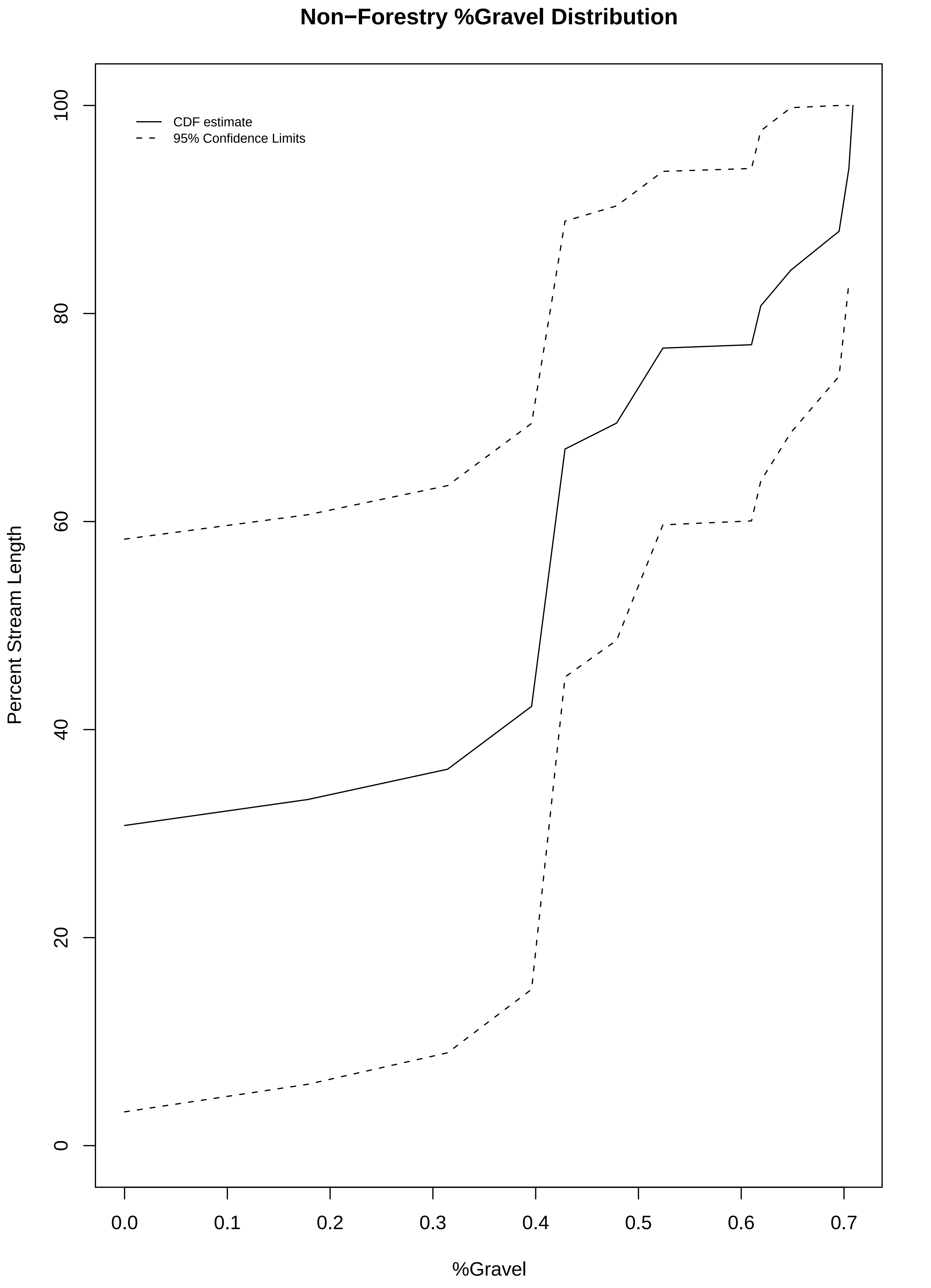


Non−Forestry R_bf* Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.05
0.10
0.15
0.20
0.25
0.30
R_bf* (m)

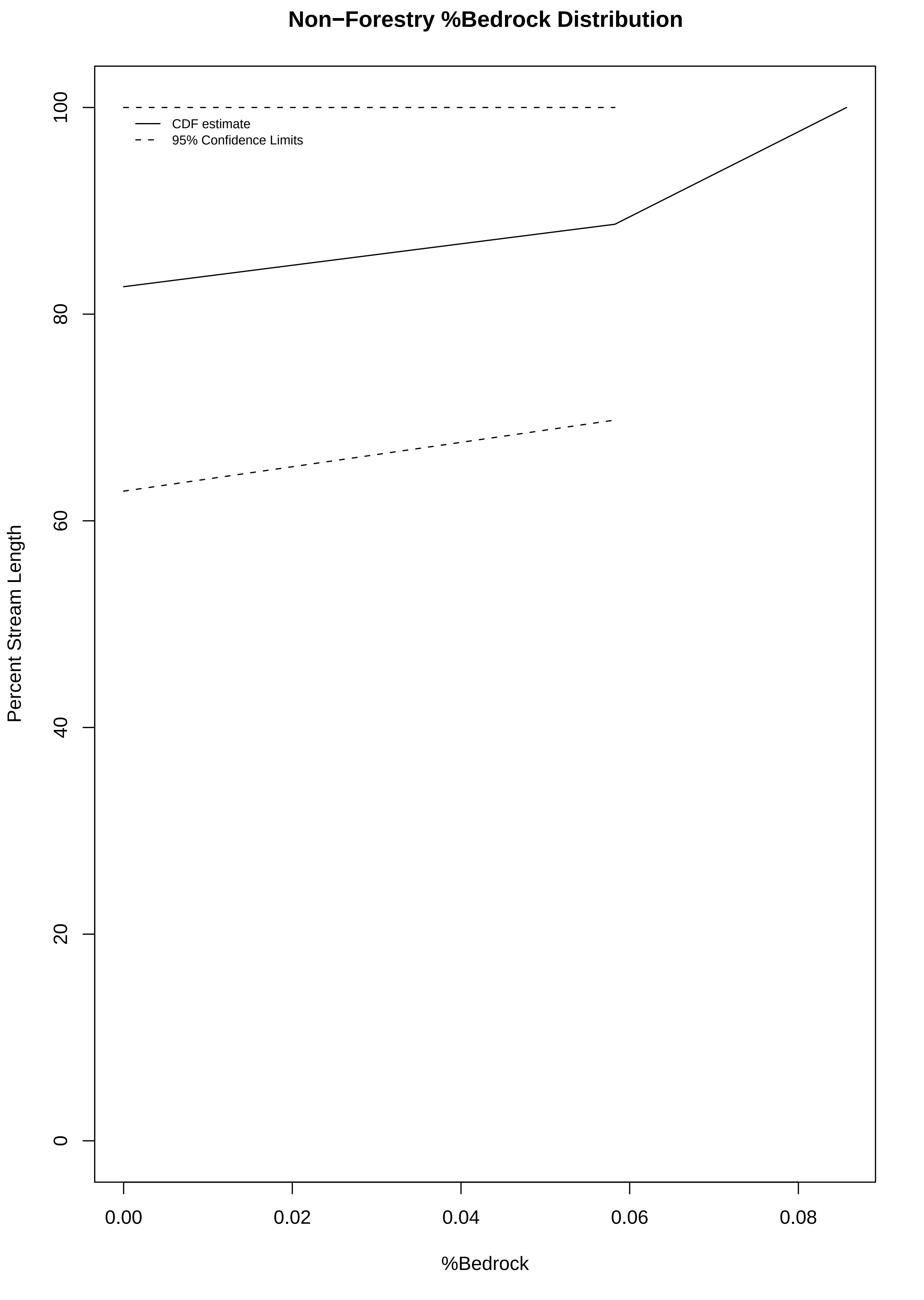

Non−Forestry Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.01
0.02
0.03
0.04
0.05
D_cbf (m)

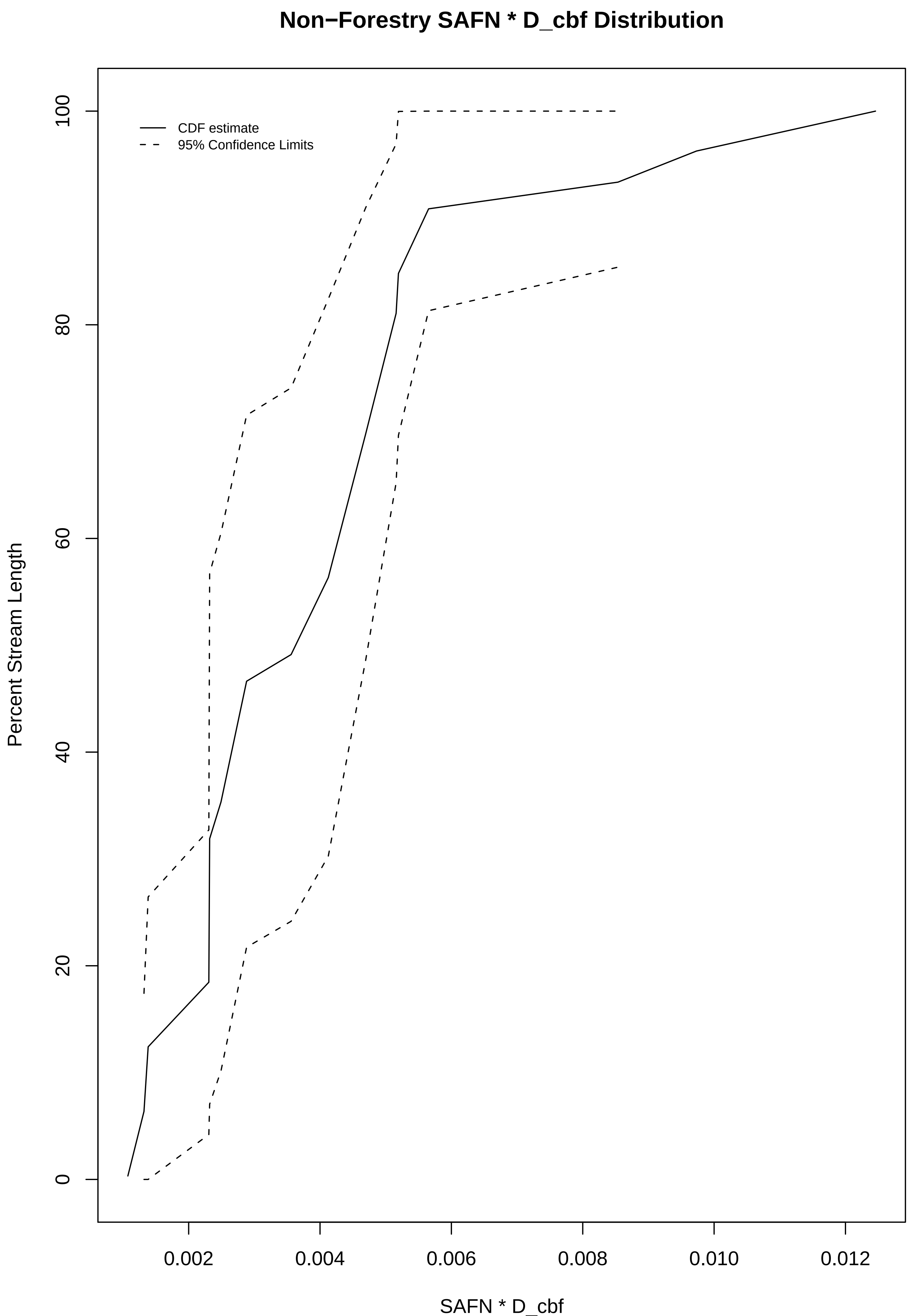


Non−Forestry LRBS (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−1.2
−1.0
−0.8
−0.6
−0.4
−0.2
0.0
LRBS

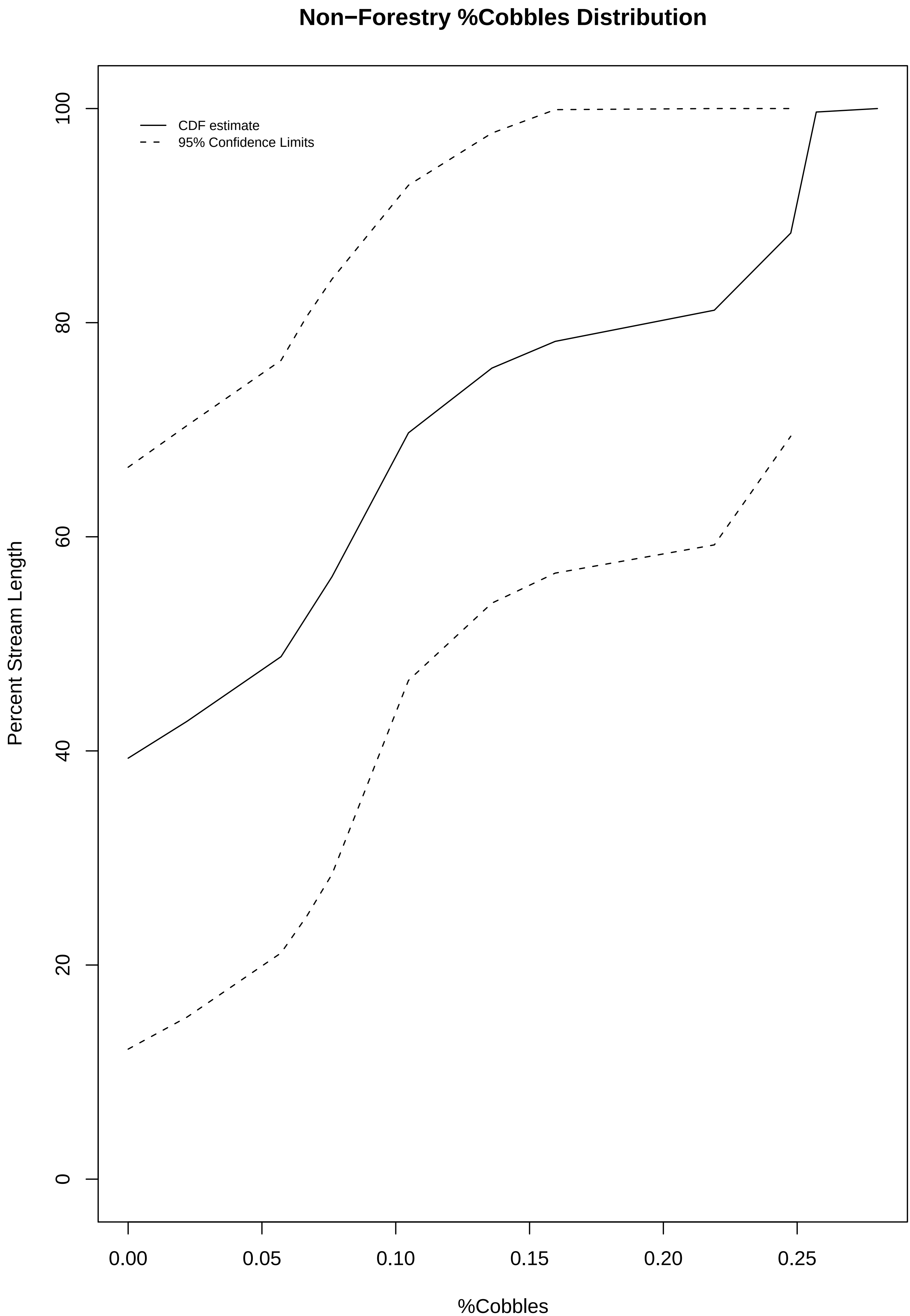


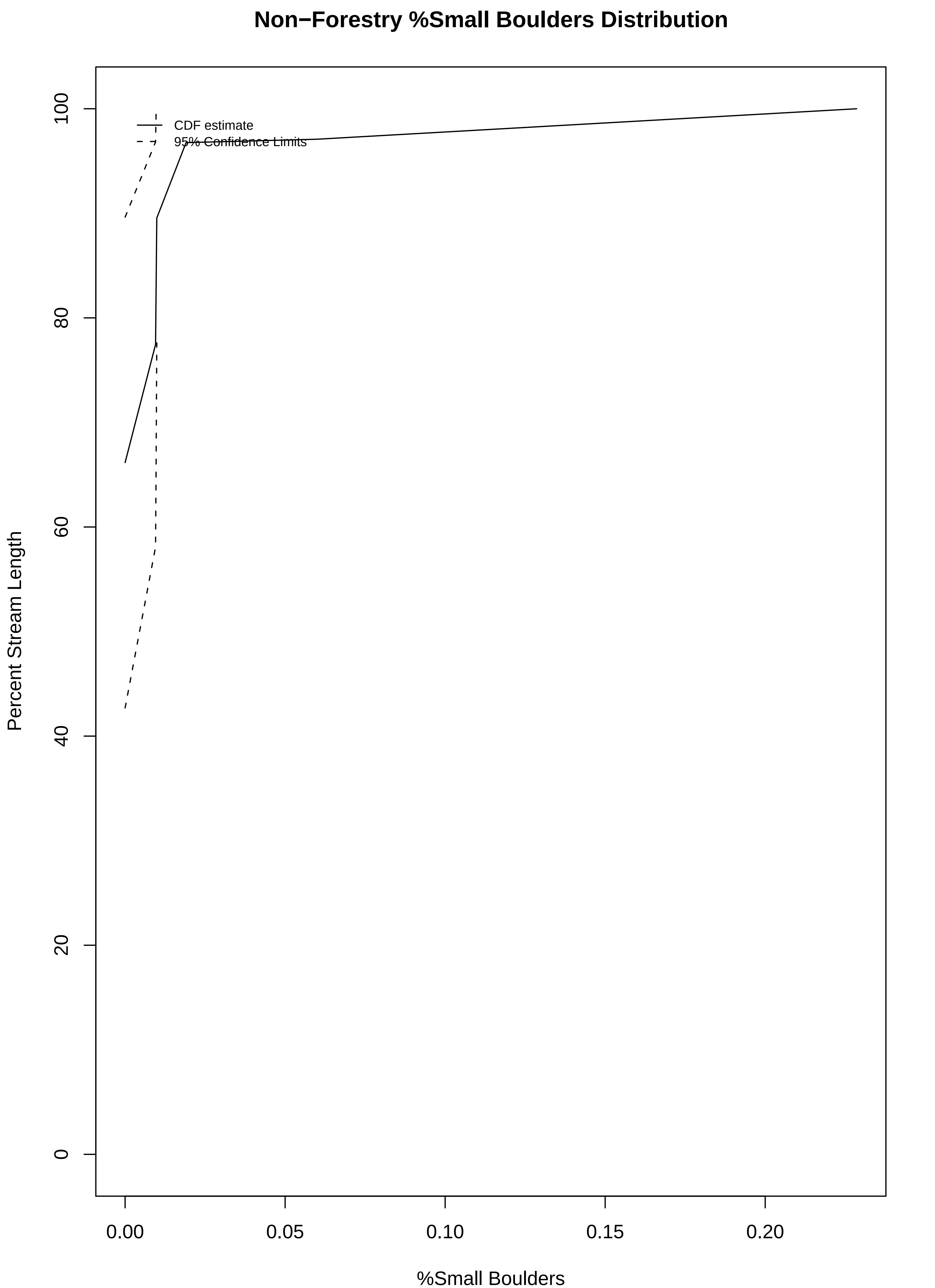
Non−Forestry %Gravel Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
%Gravel

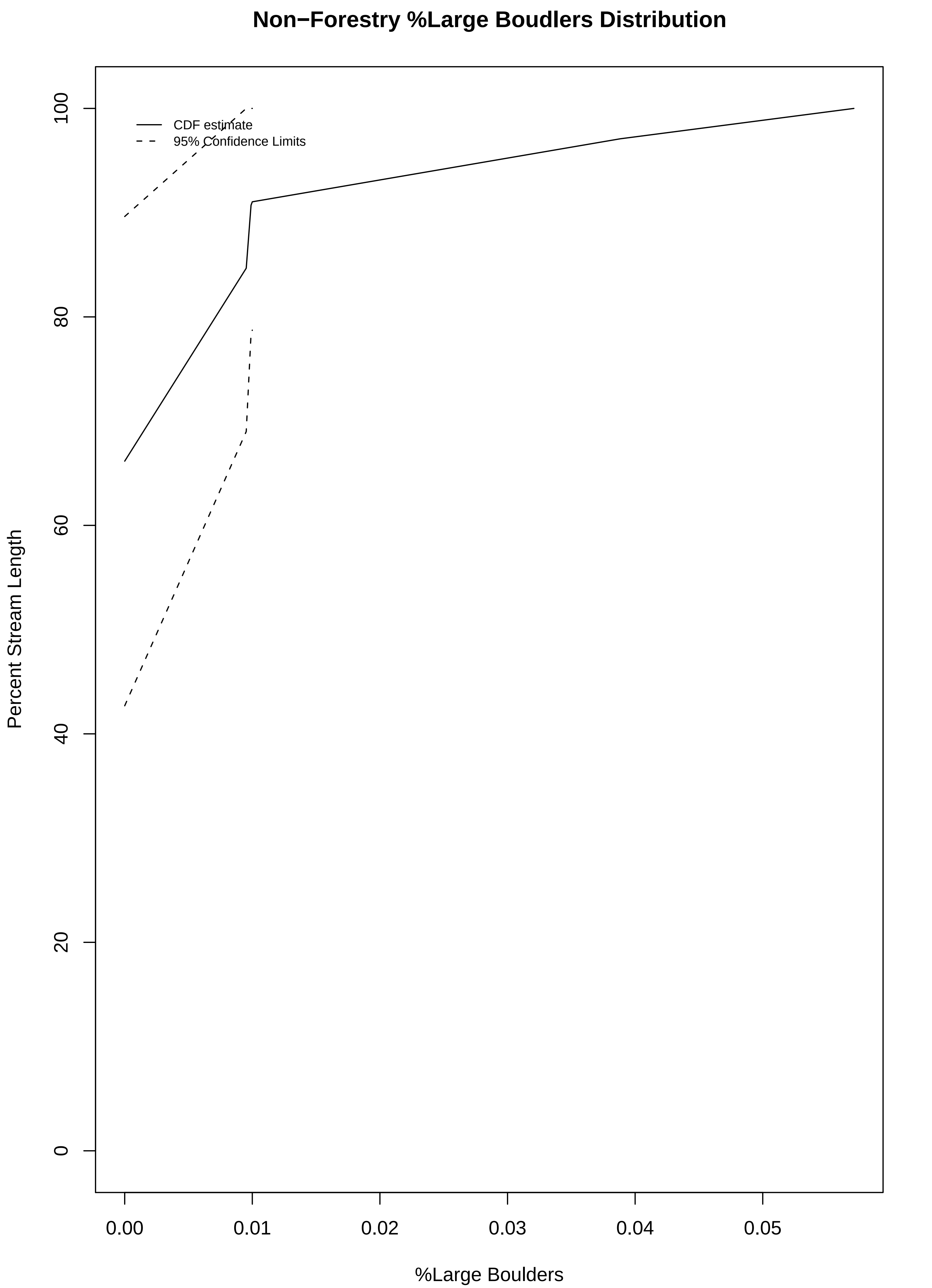

Non−Forestry %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.02
0.04
0.06
0.08
%Bedrock



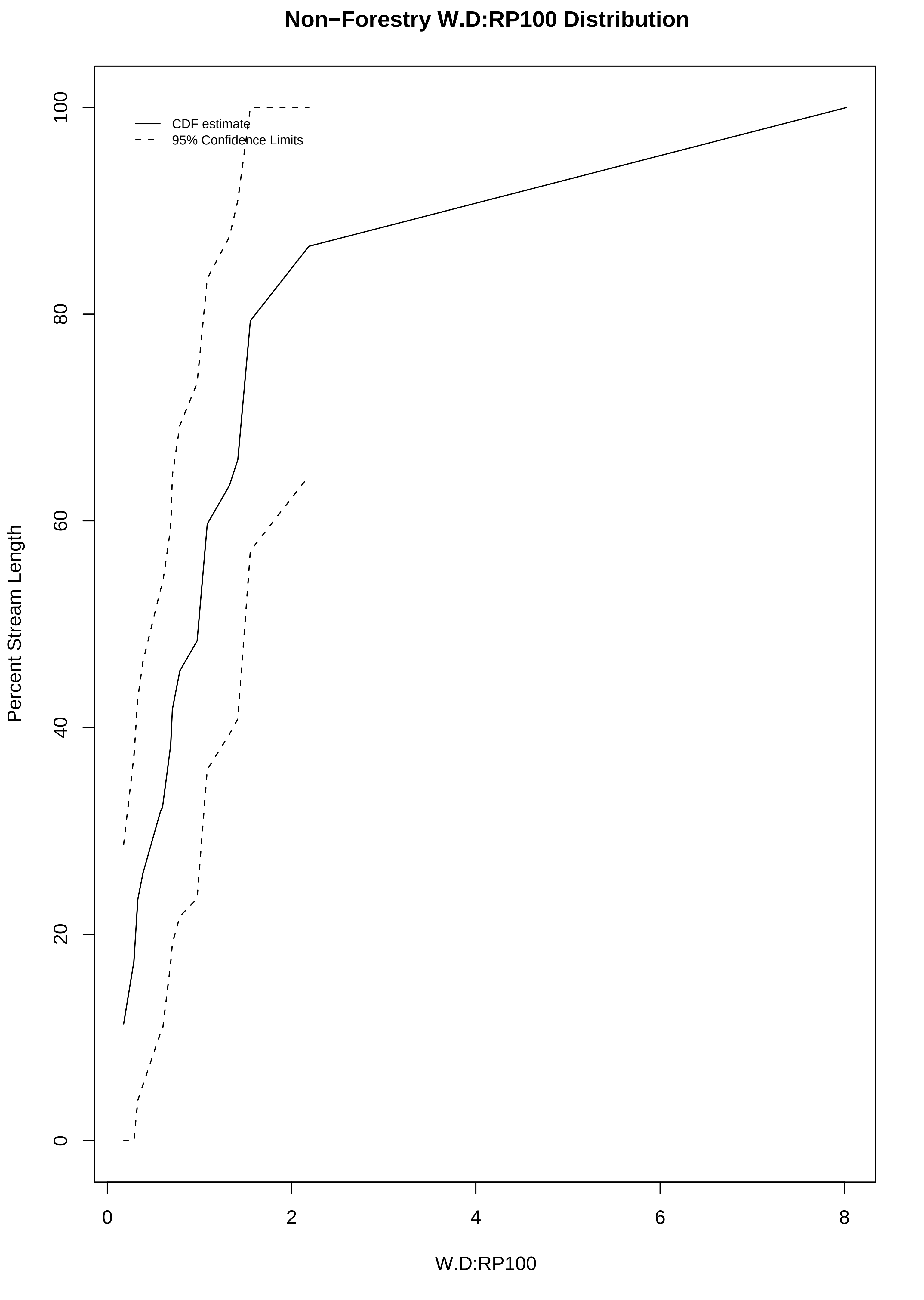
Non−Forestry SAFN * D_cbf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.002
0.004
0.006
0.008
0.010
0.012
SAFN * D_cbf

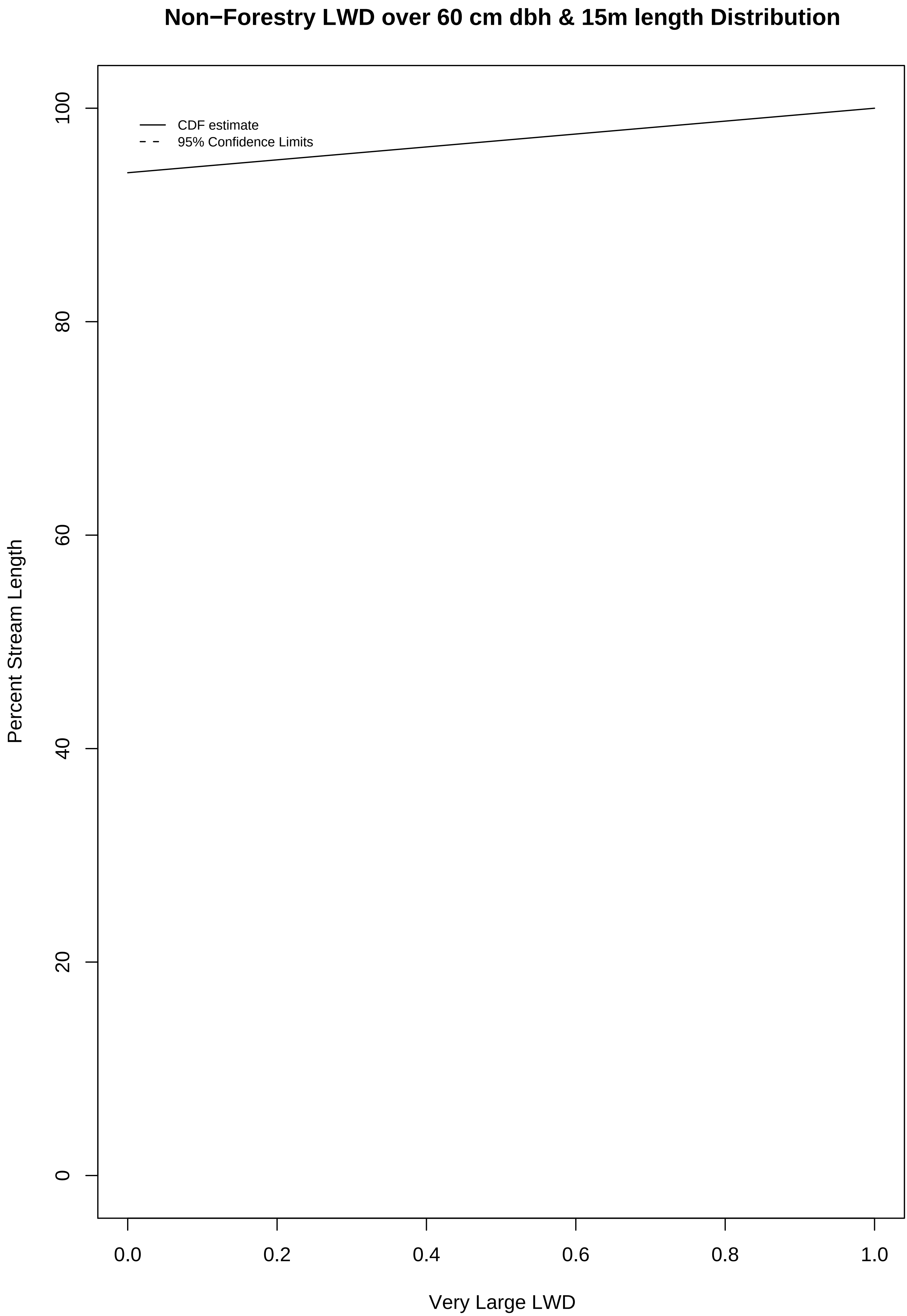

Non−Forestry %Cobbles Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
%Cobbles
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25

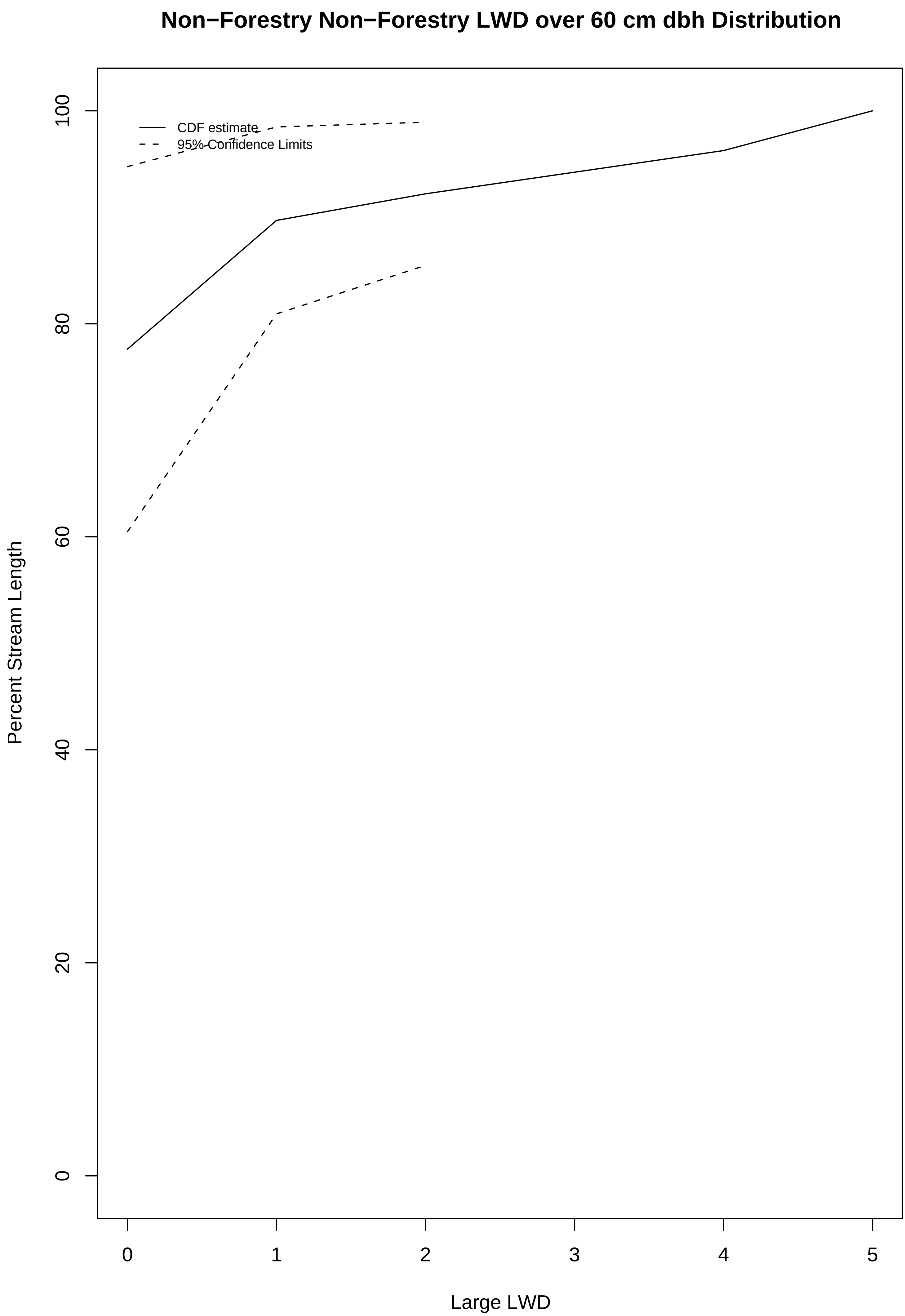

Non−Forestry %Small Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
%Small Boulders



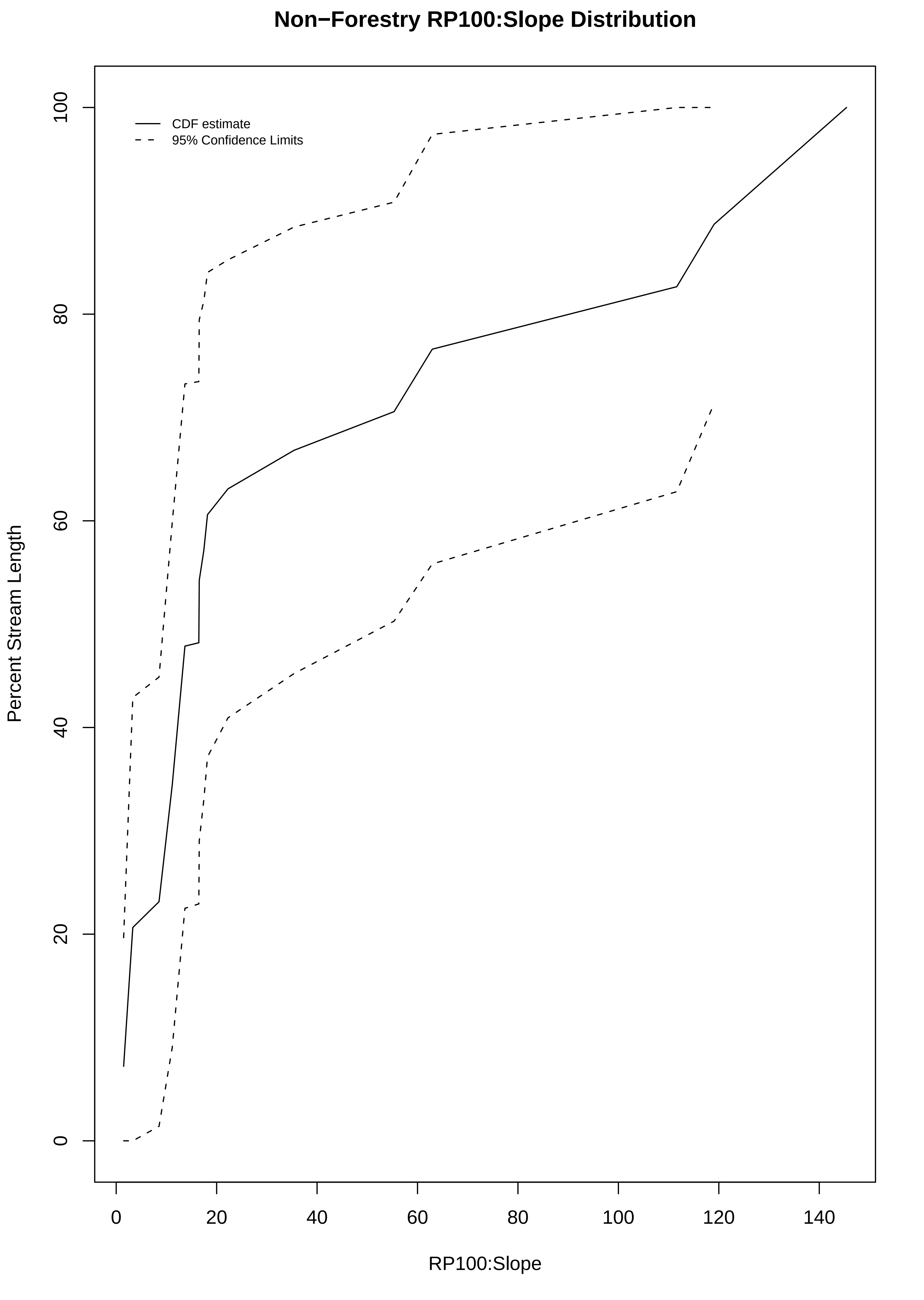
Non−Forestry %Large Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.01
0.02
0.03
0.04
0.05
%Large Boulders


Non−Forestry W.D:RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
W.D:RP100
0
20
40
60
80
100
0
2
4
6
8

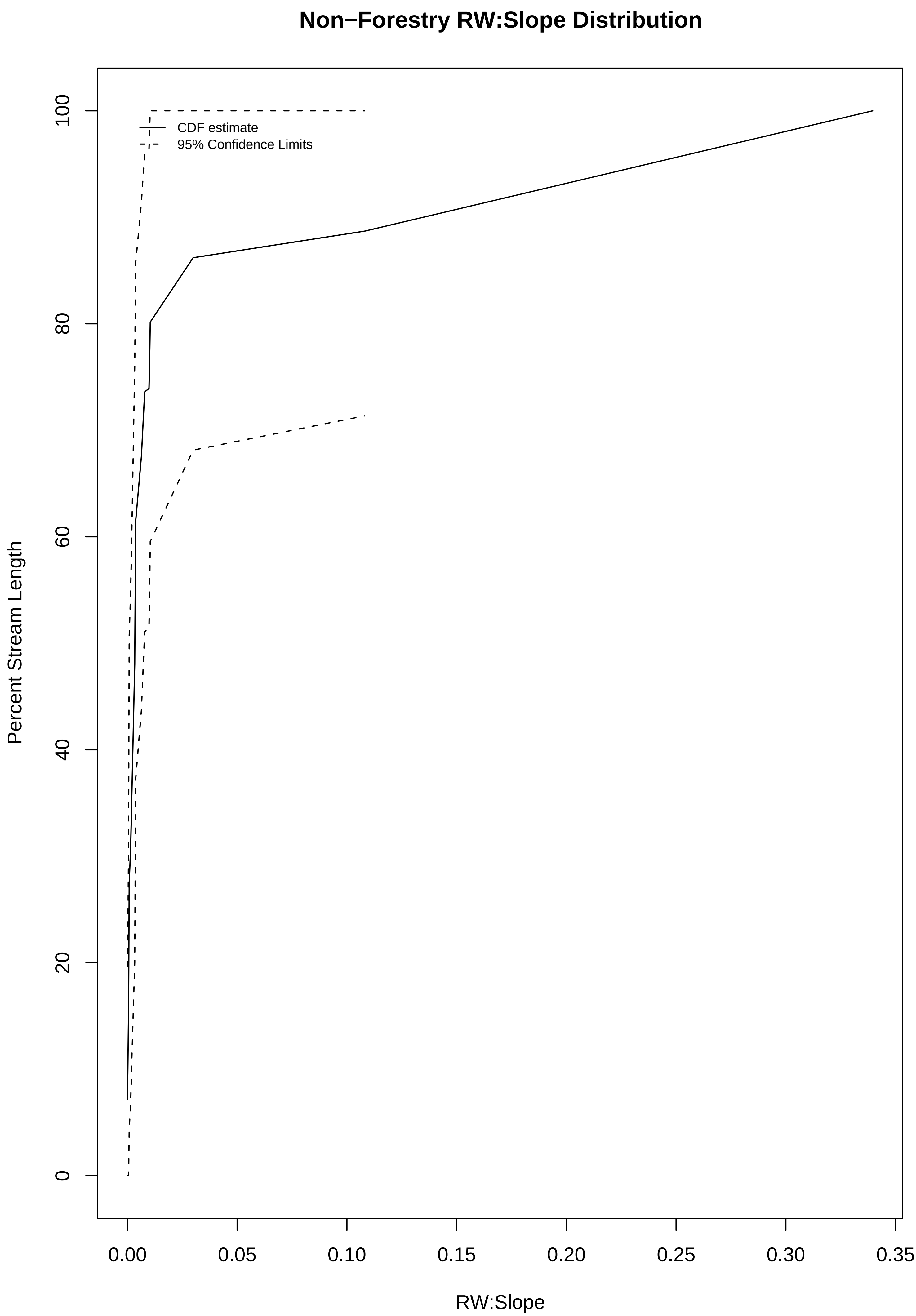

Non−Forestry LWD over 60 cm dbh & 15m length Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0
Very Large LWD

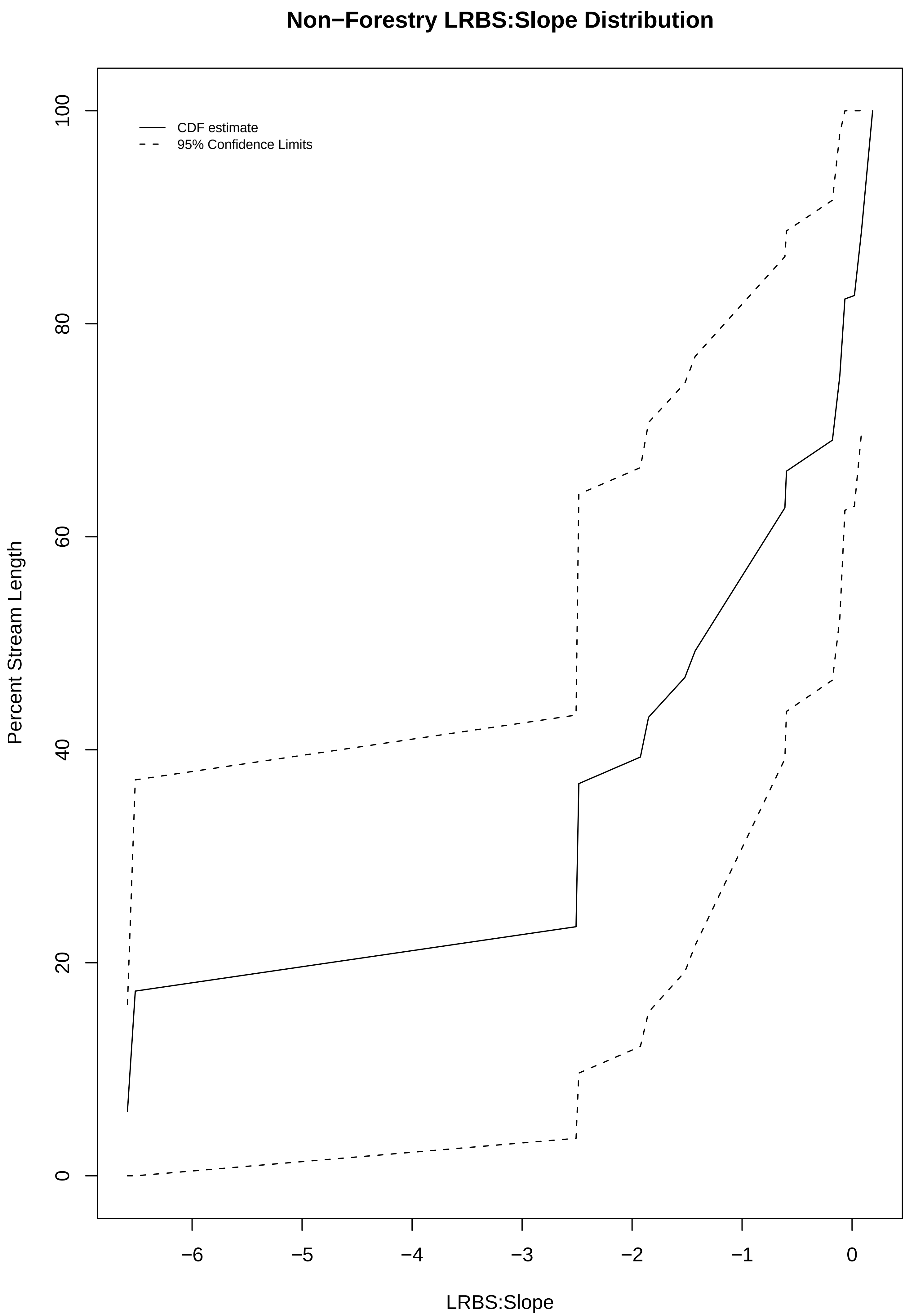


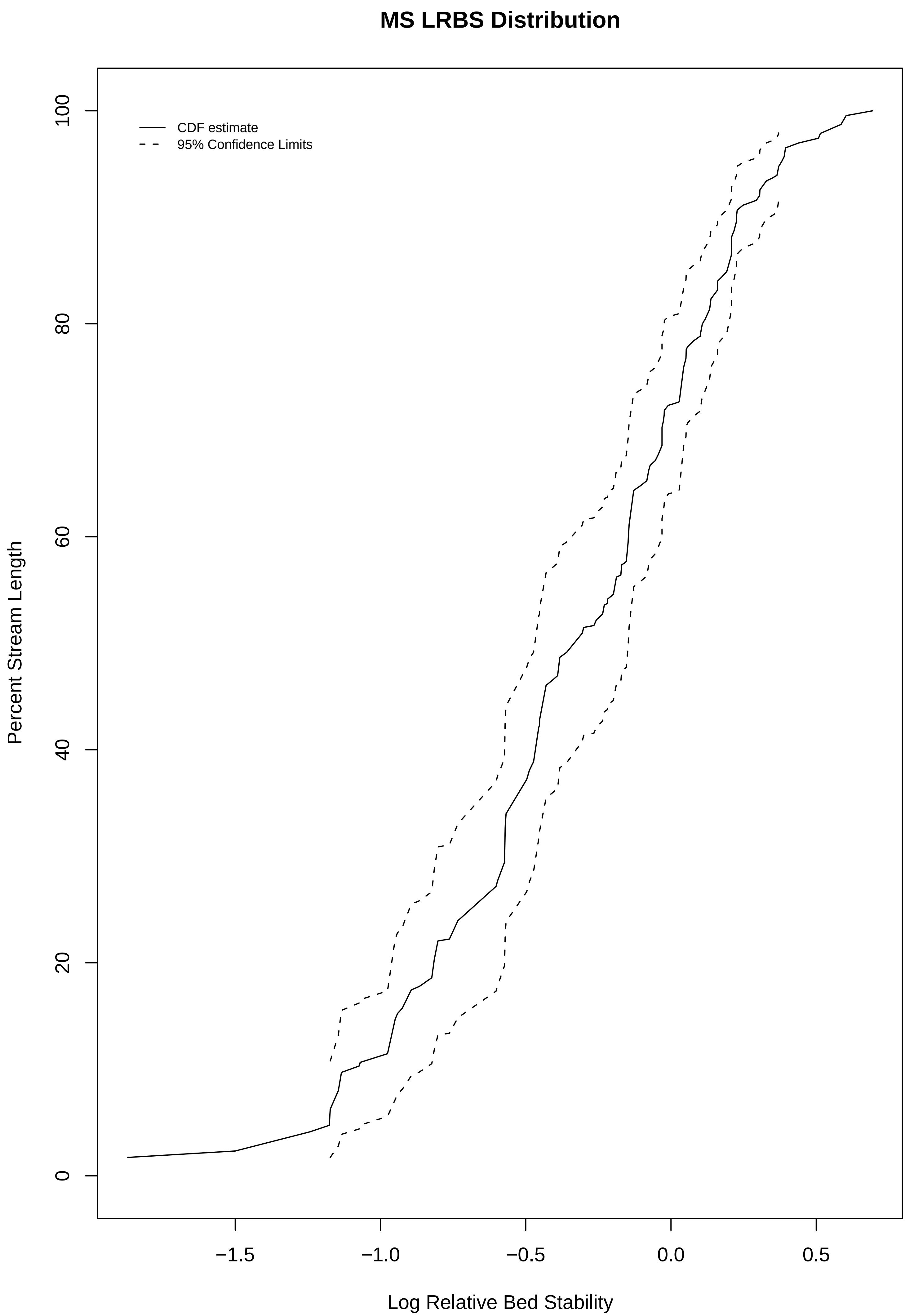
Non−Forestry Non−Forestry LWD over 60 cm dbh Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
1
2
3
4
5
Large LWD

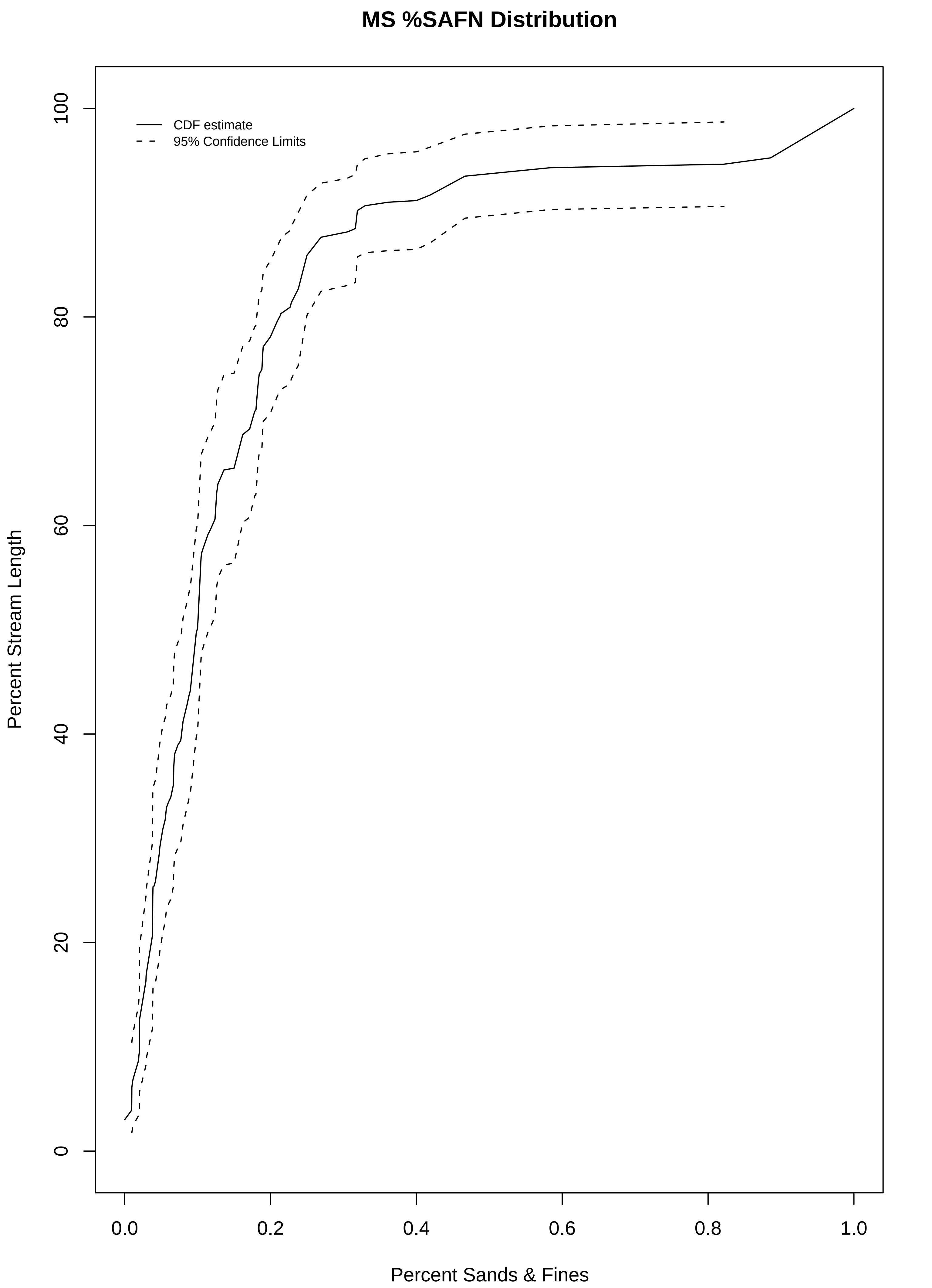


Non−Forestry RP100:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
20
40
60
80
100
120
140
RP100:Slope

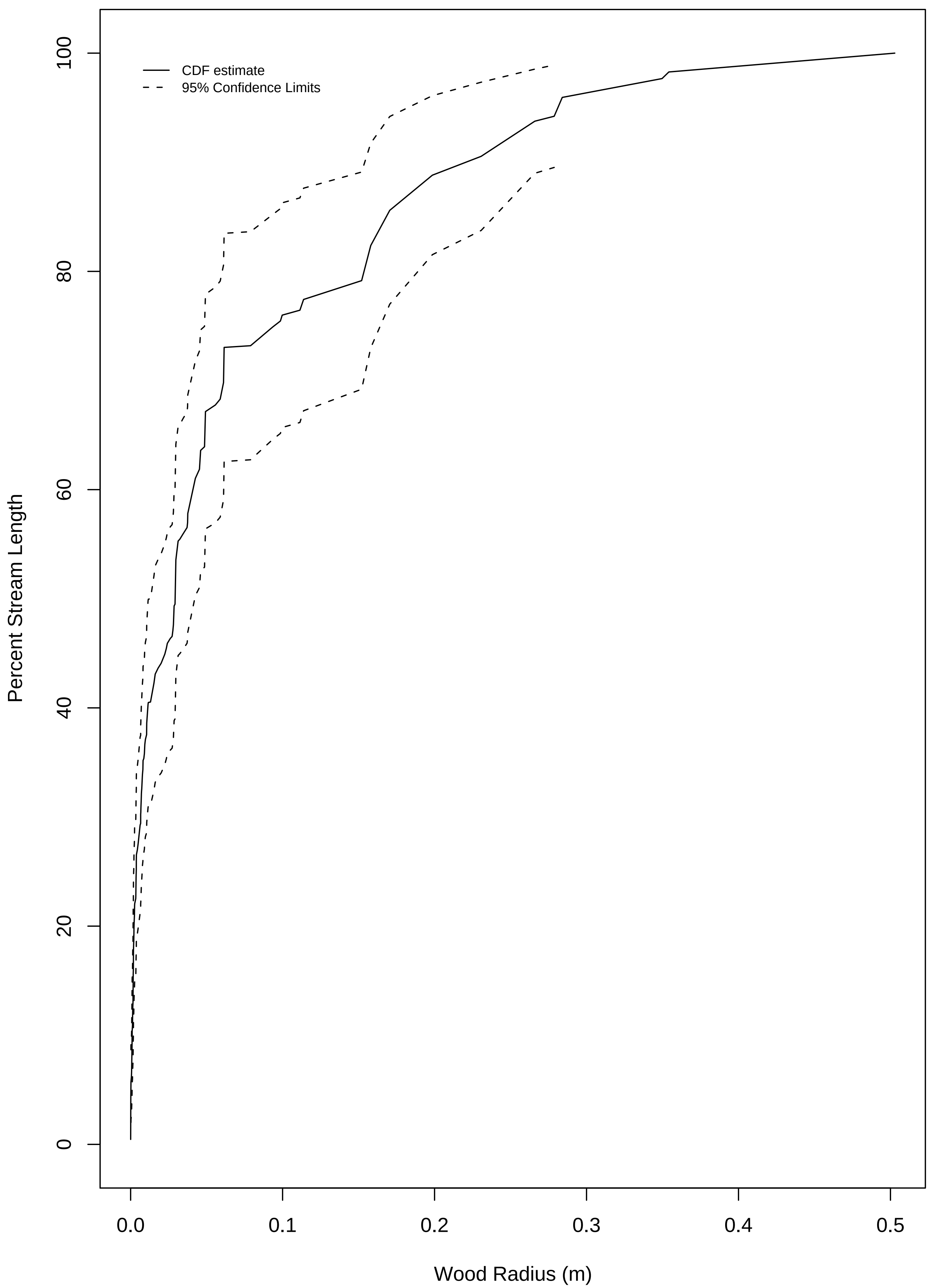

Non−Forestry RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
RW:Slope

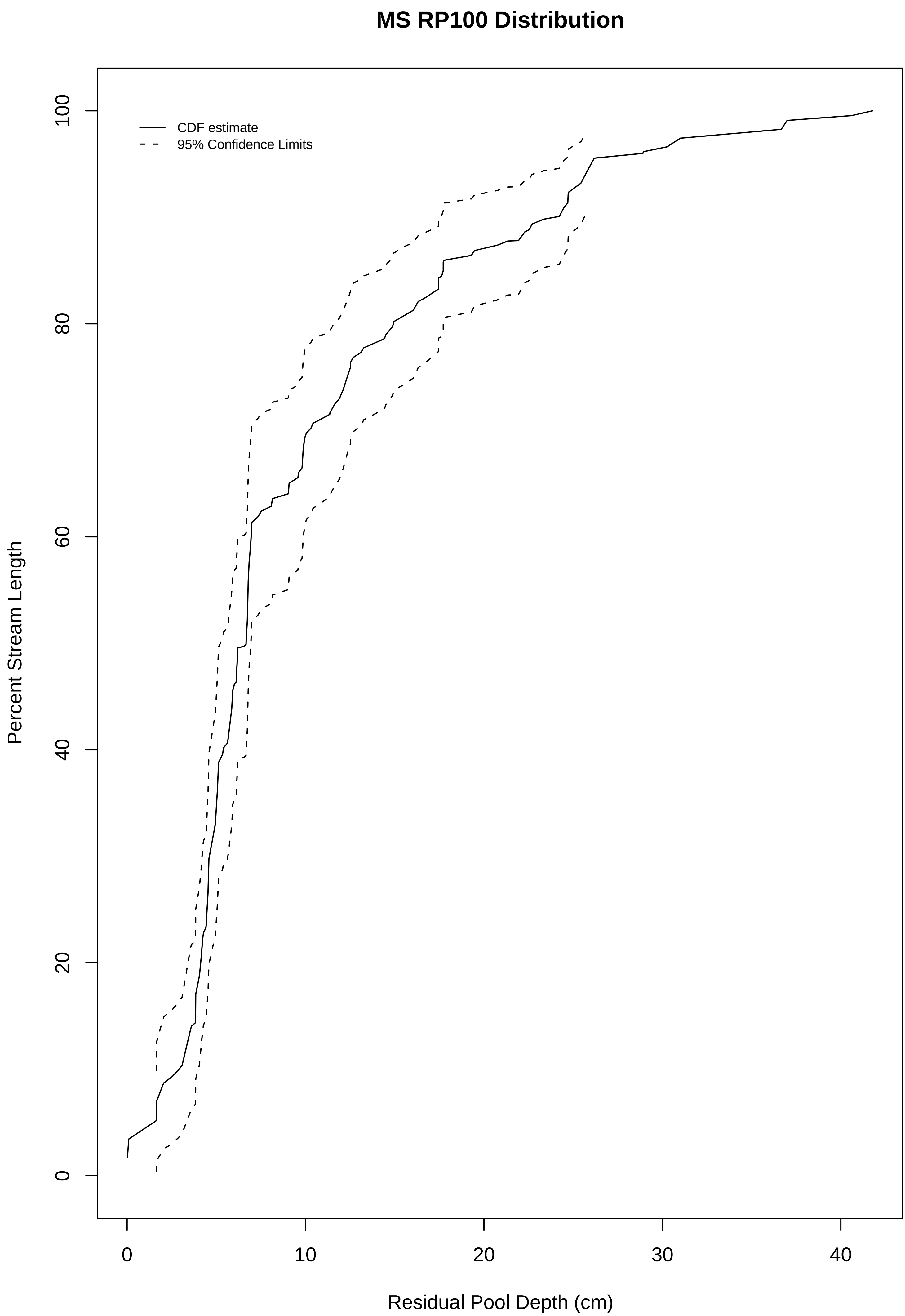

Non−Forestry LRBS:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−6
−5
−4
−3
−2
−1
0
LRBS:Slope


MS LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−1.5
−1.0
−0.5
0.0
0.5
Log Relative Bed Stability

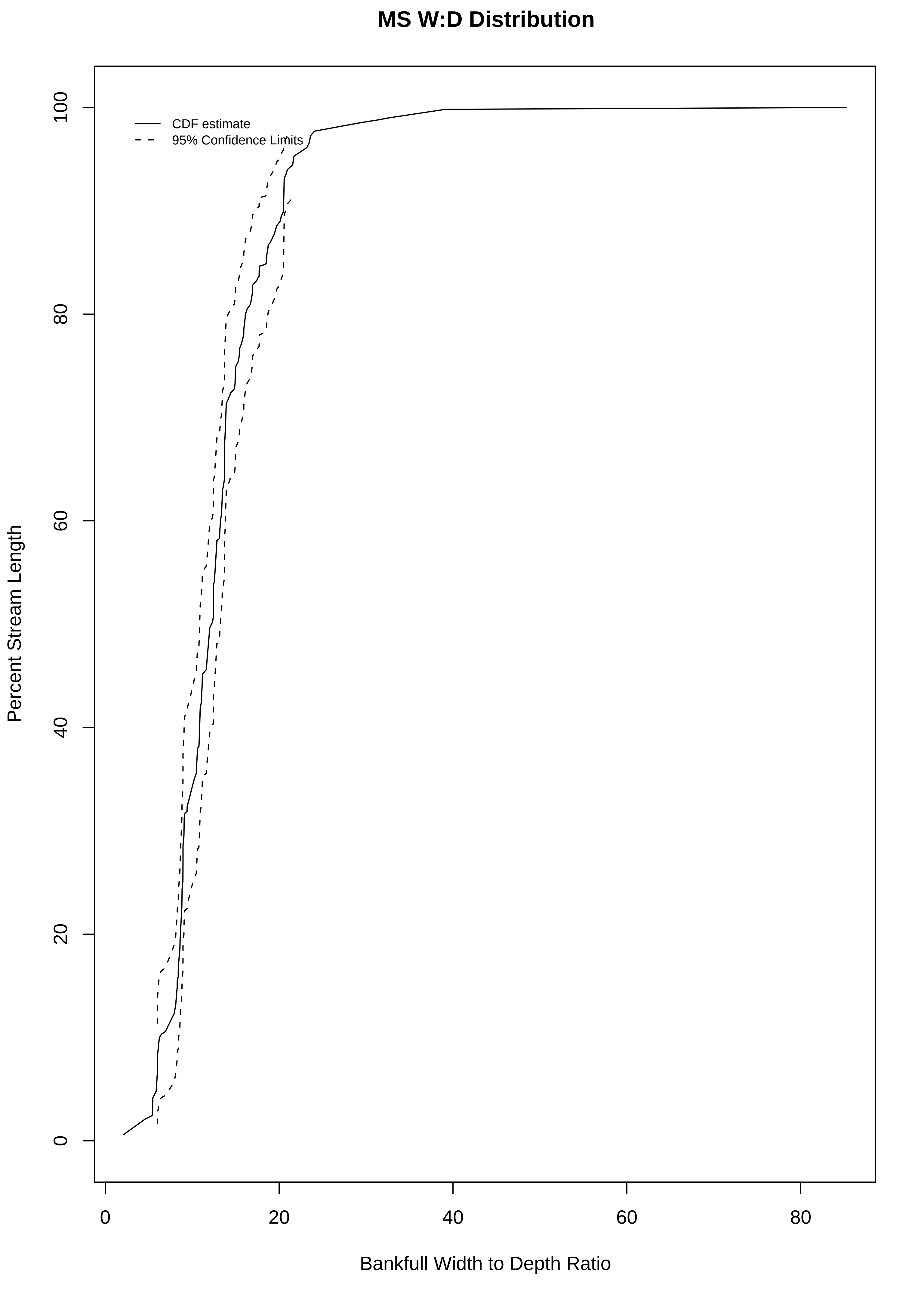

MS %SAFN Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0
Percent Sands & Fines

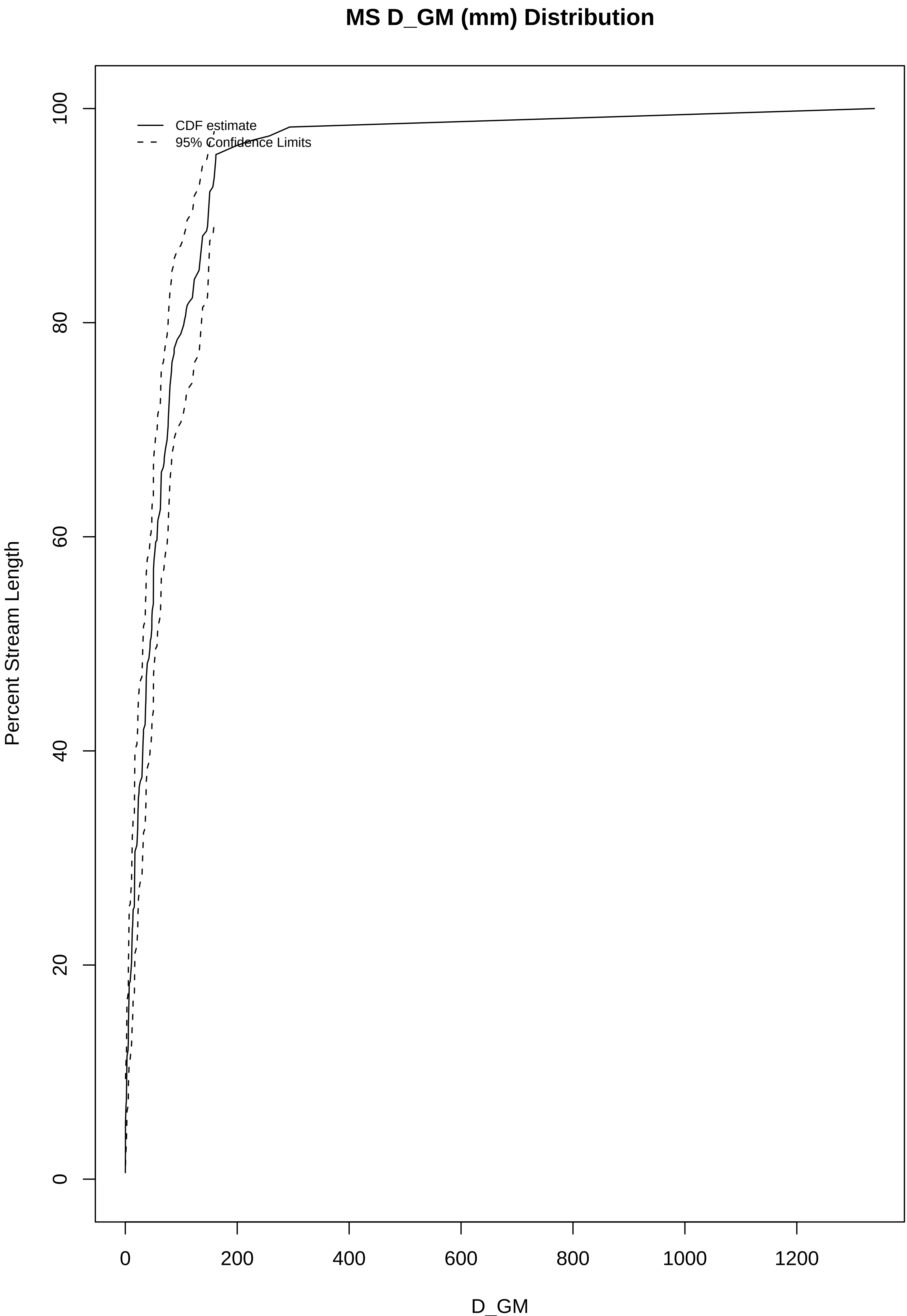
MS RW Distribution

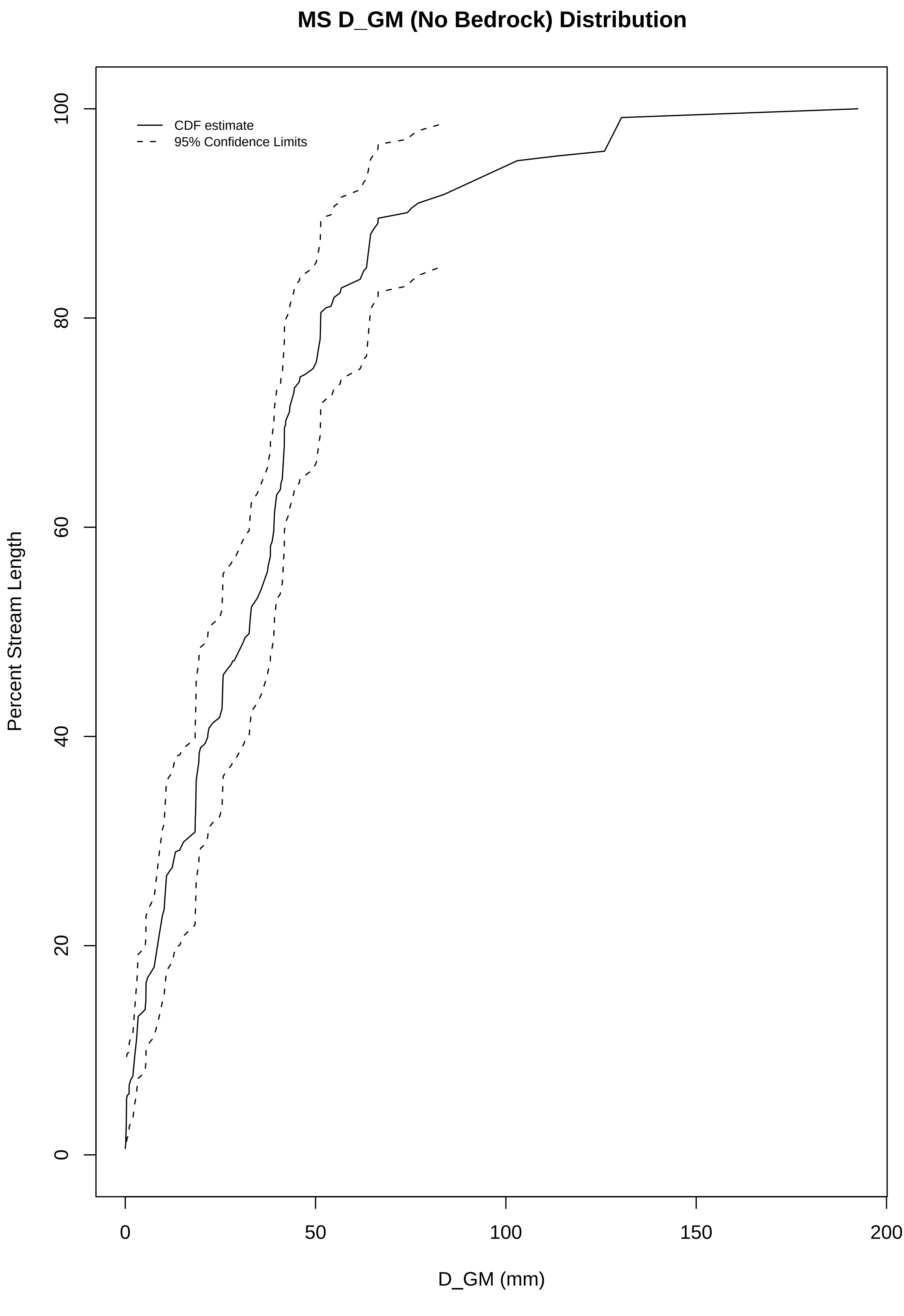


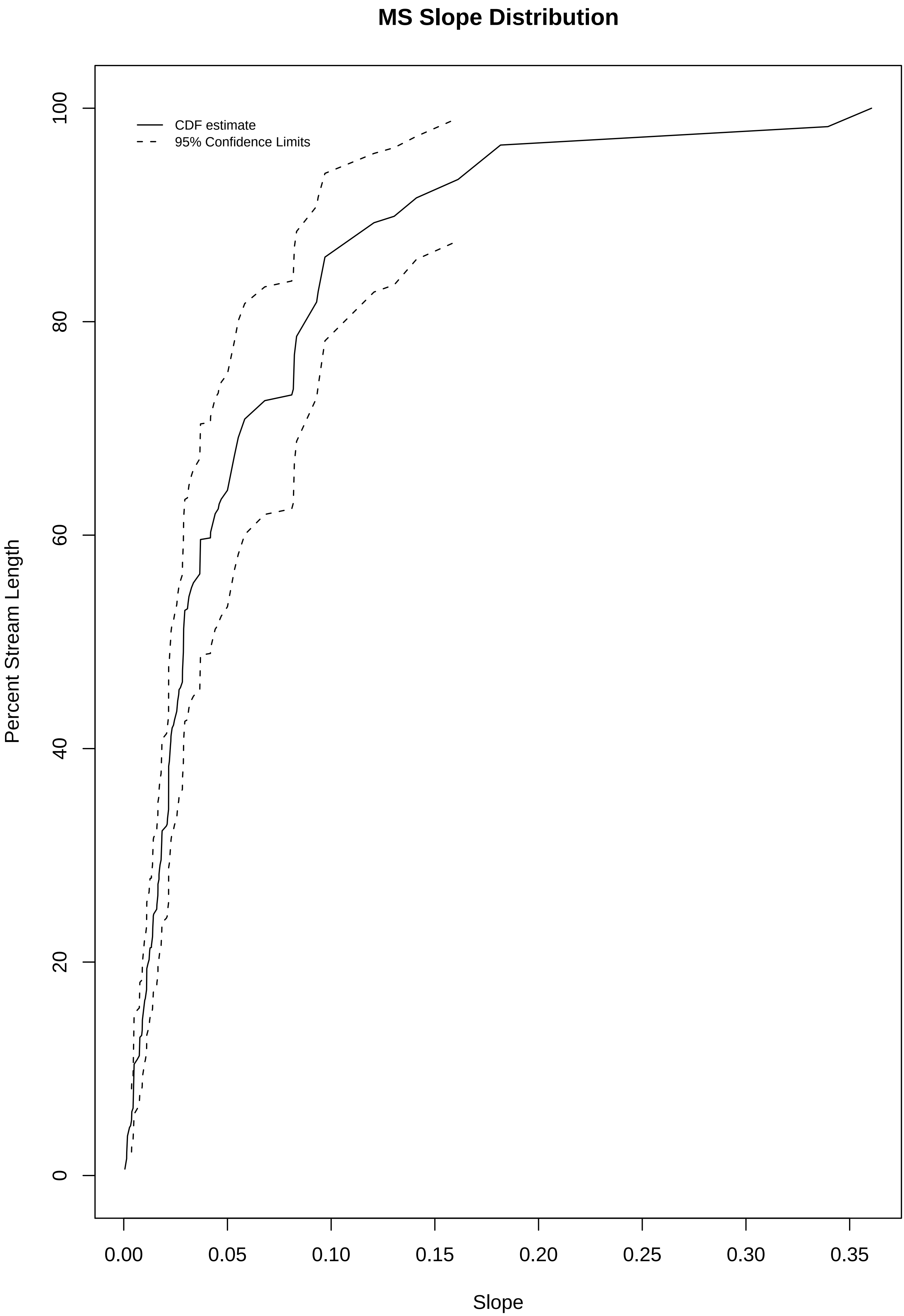


MS RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
10
20
30
40
Residual Pool Depth (cm)

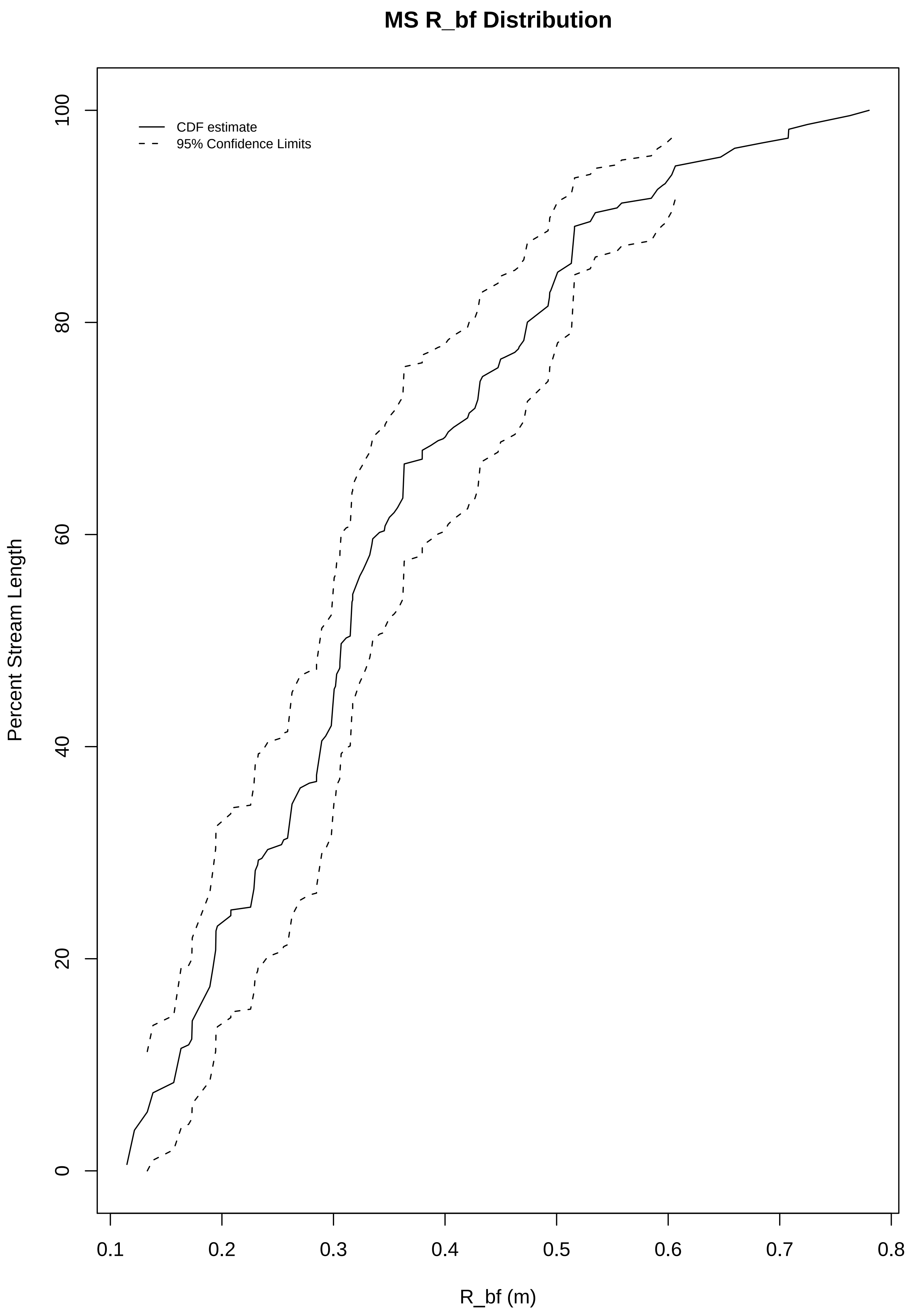

MS W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
20
40
60
80
Bankfull Width to Depth Ratio

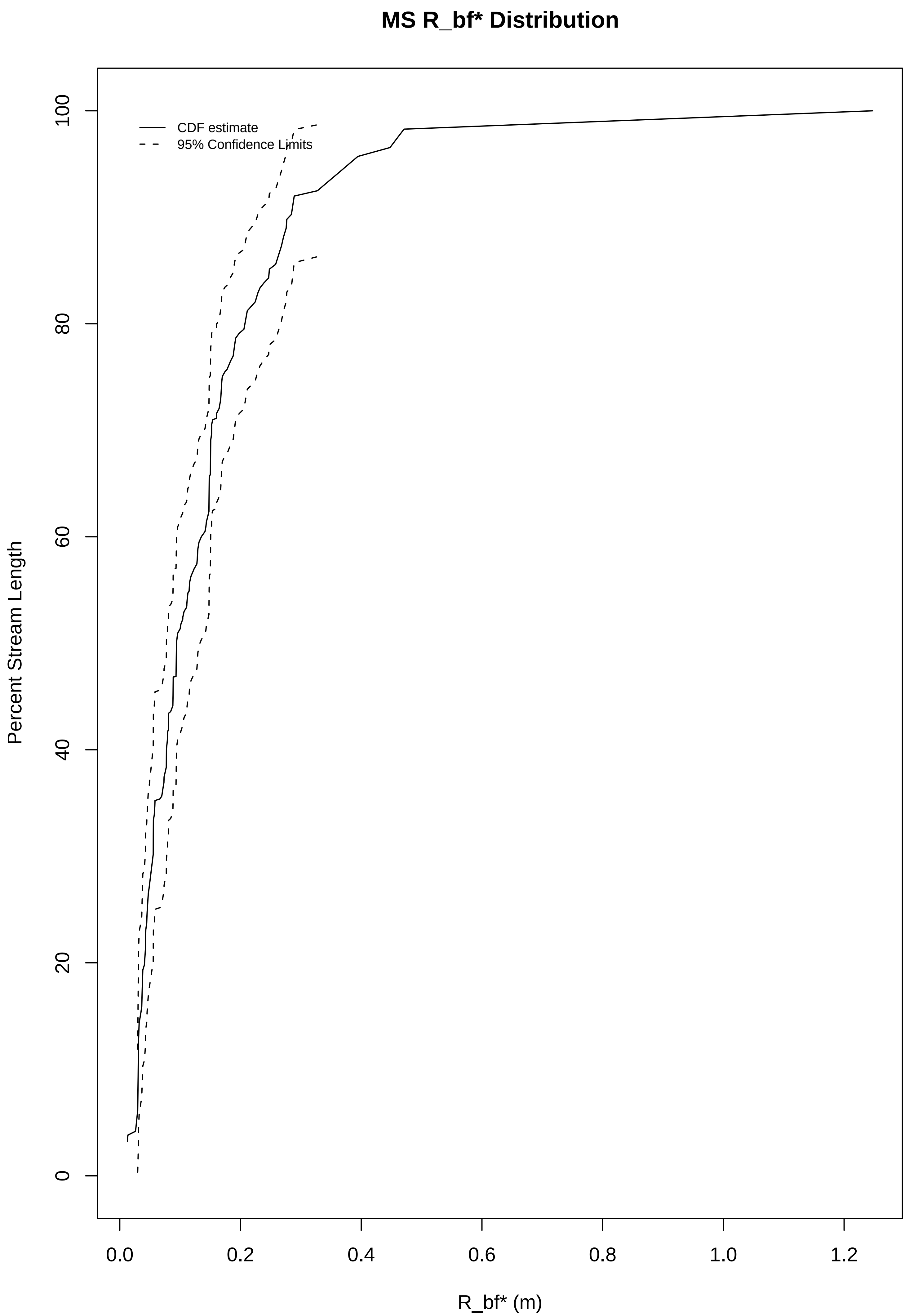

MS D_GM (mm) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
200
400
600
800
1000
1200
D_GM


MS D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
50
100
150
200
D_GM (mm)

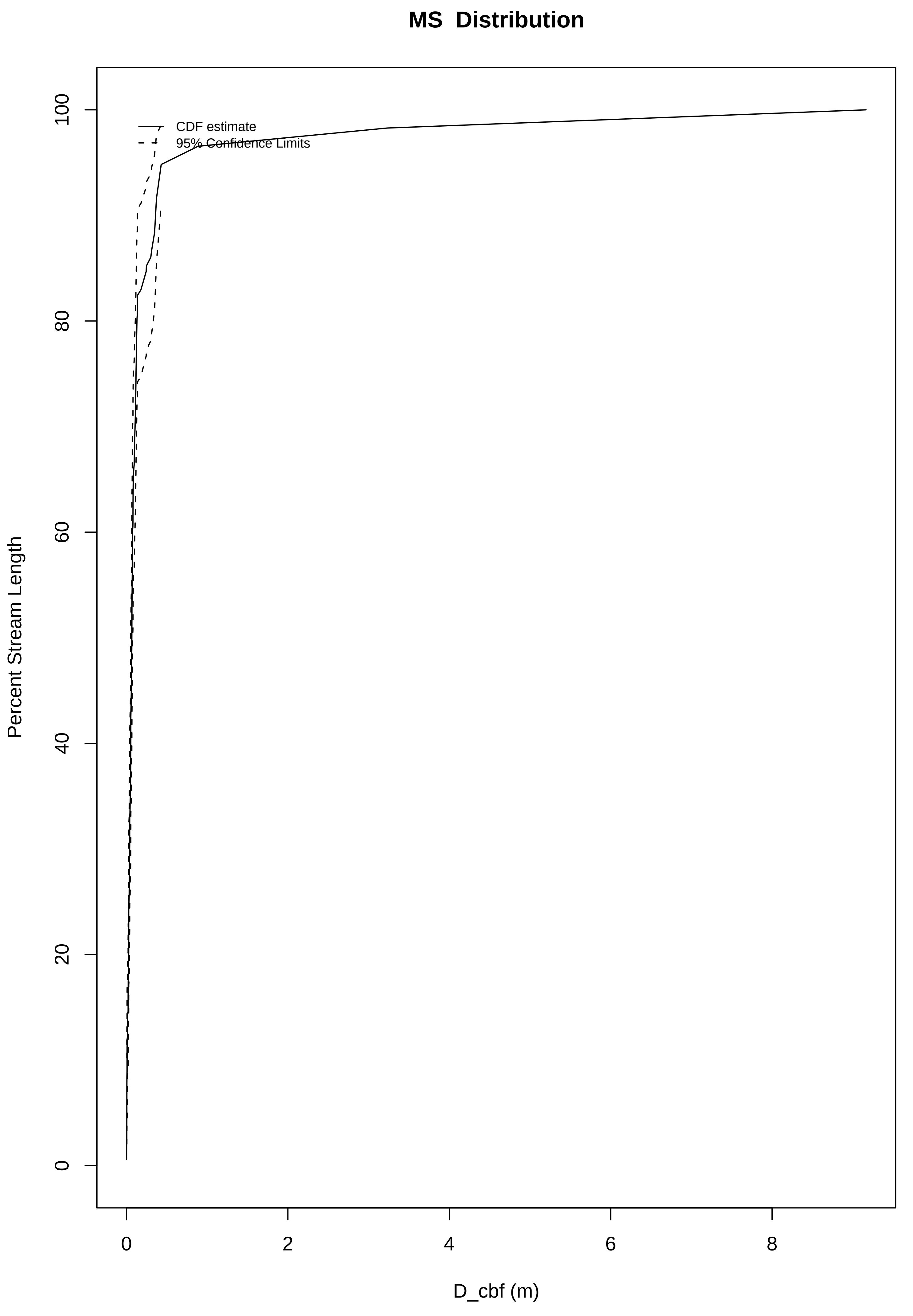


MS Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Slope

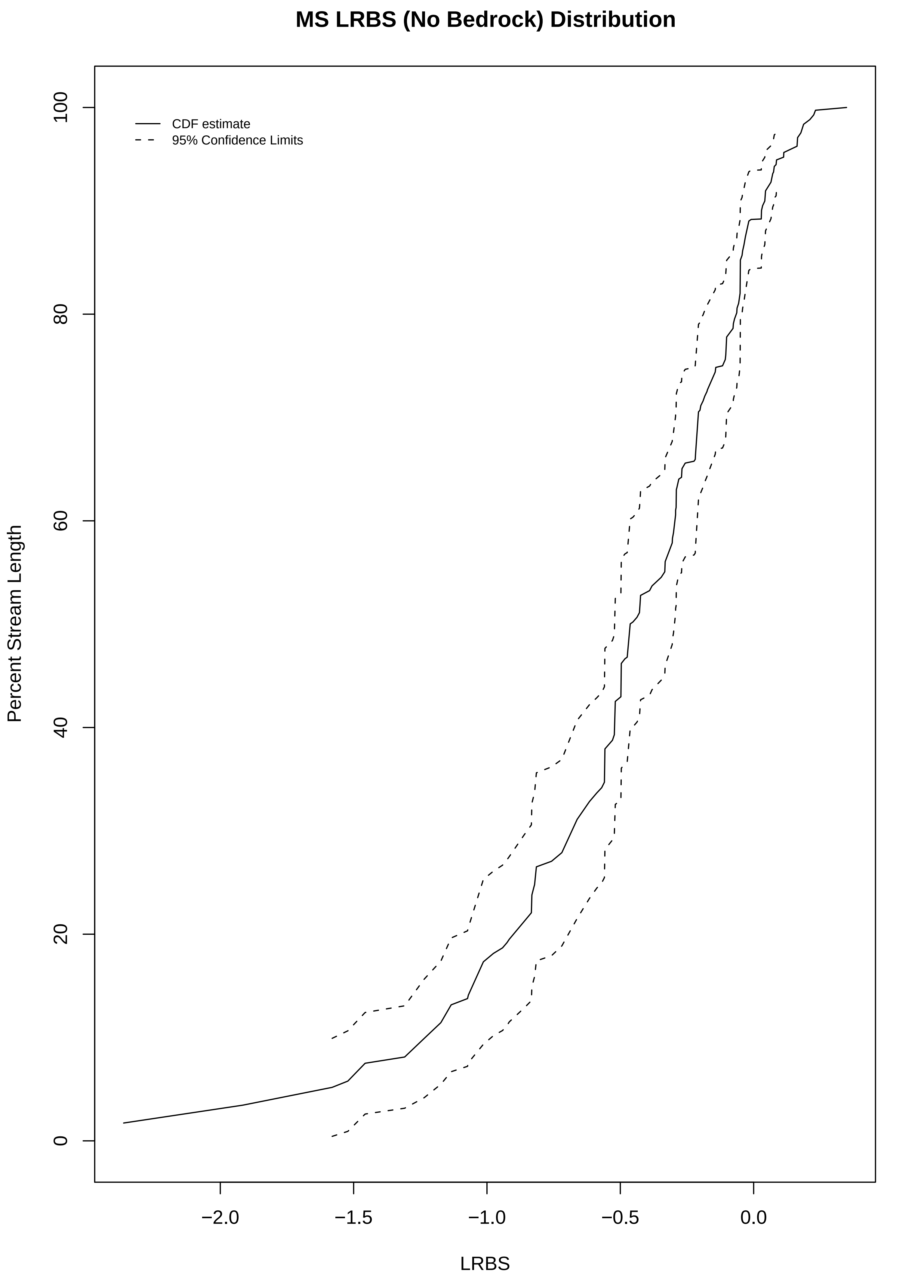

MS R_bf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
R_bf (m)

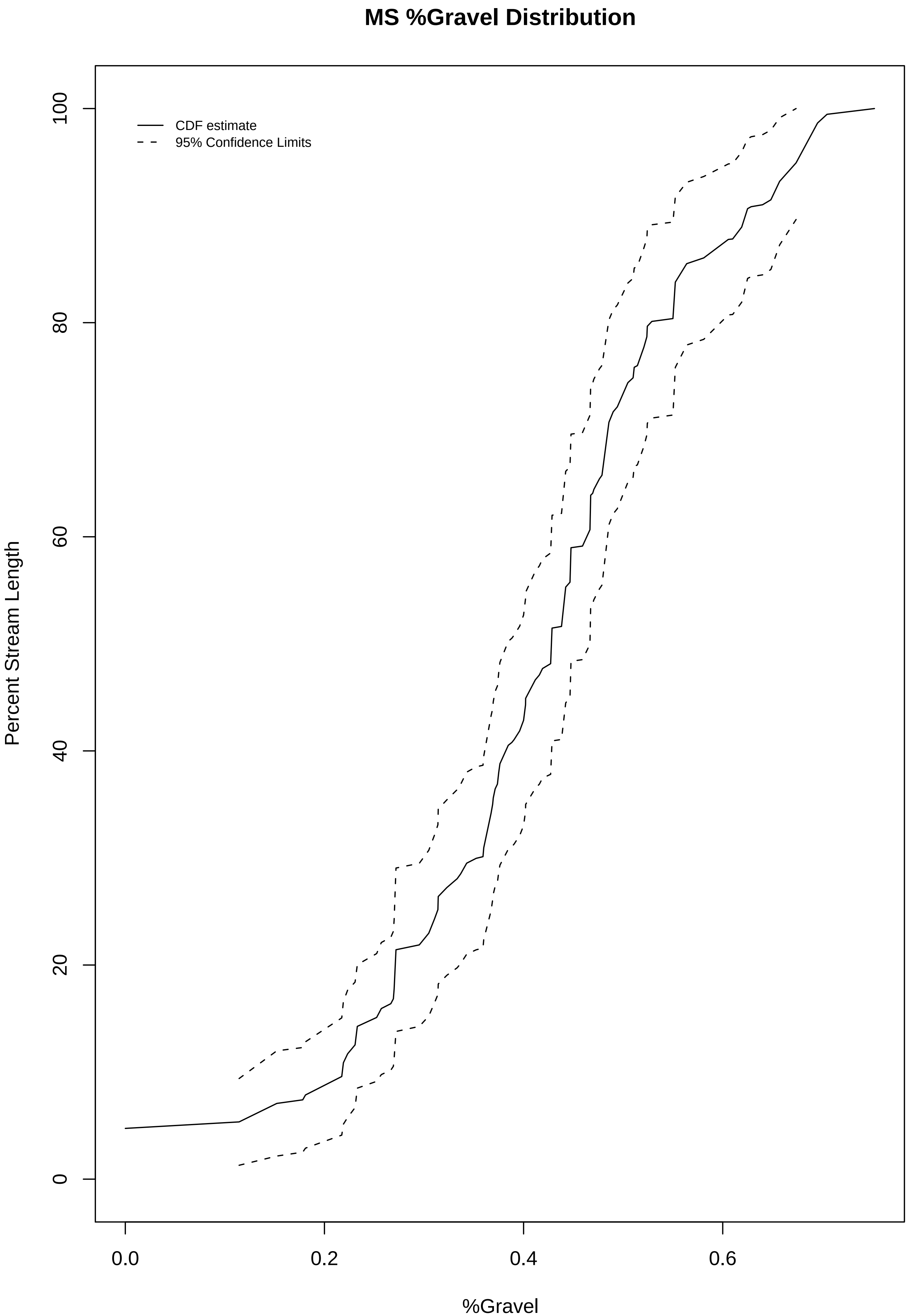


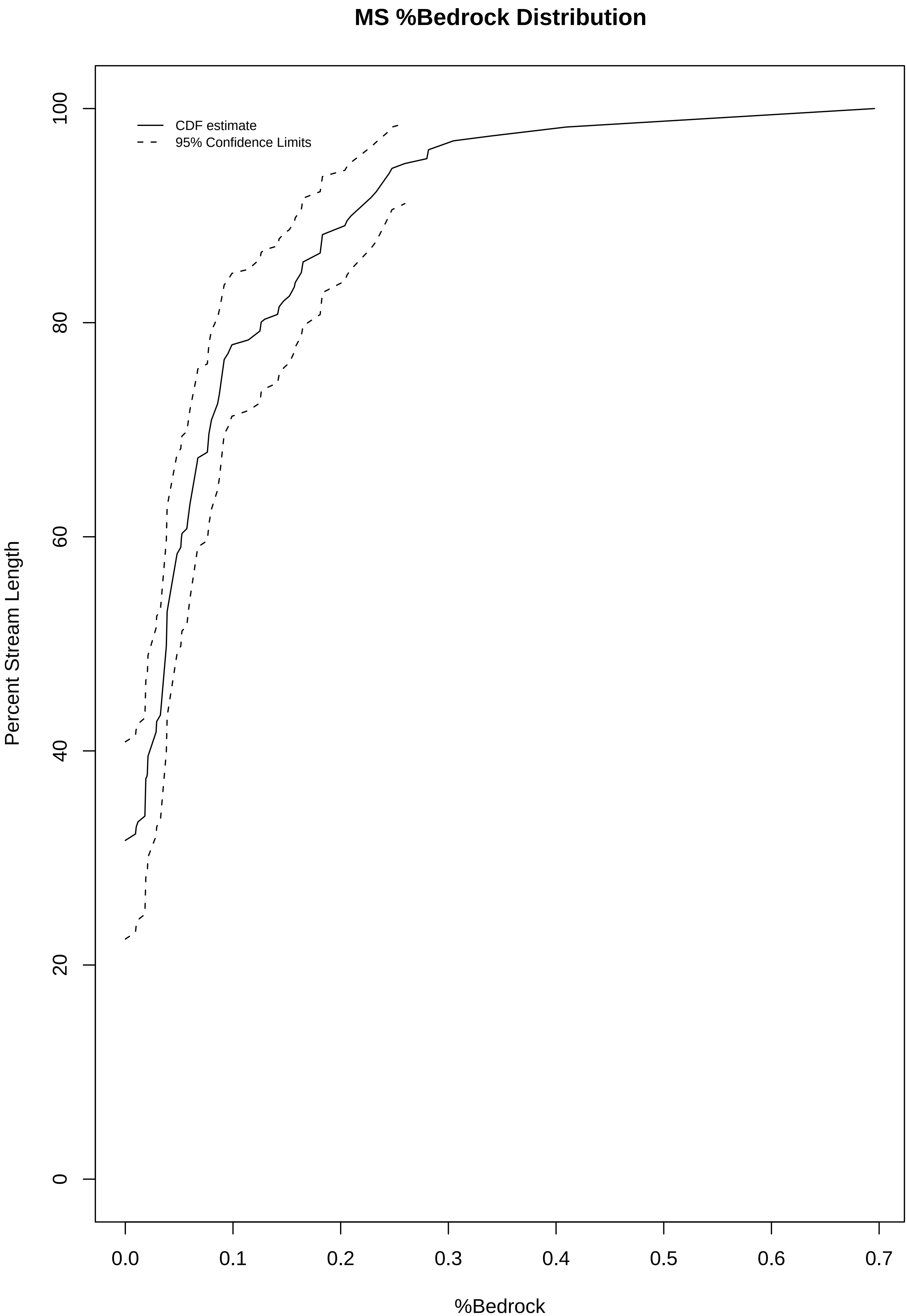
MS R_bf* Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0
1.2
R_bf* (m)



MS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
2
4
6
8
D_cbf (m)

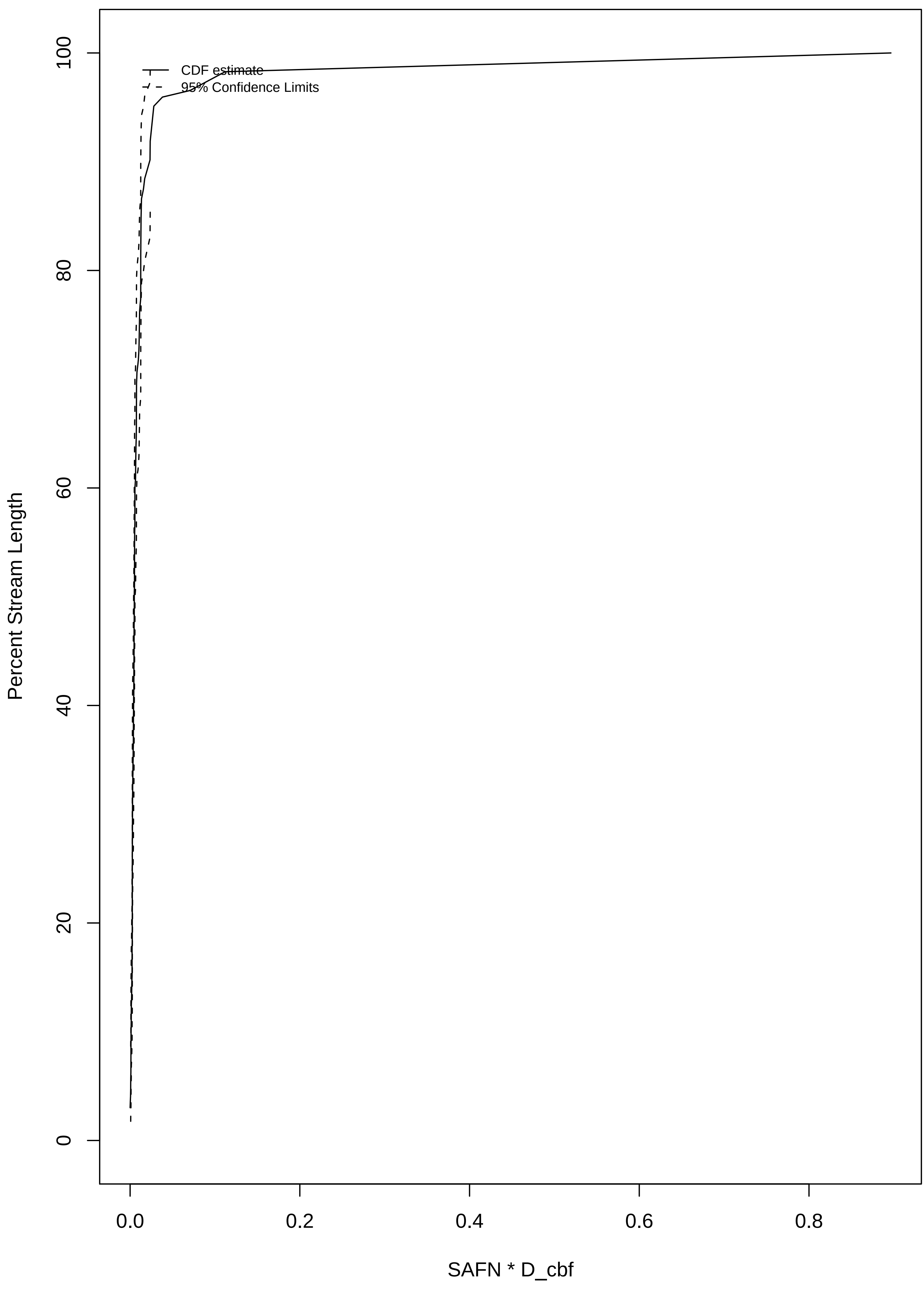

MS LRBS (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−2.0
−1.5
−1.0
−0.5
0.0
LRBS

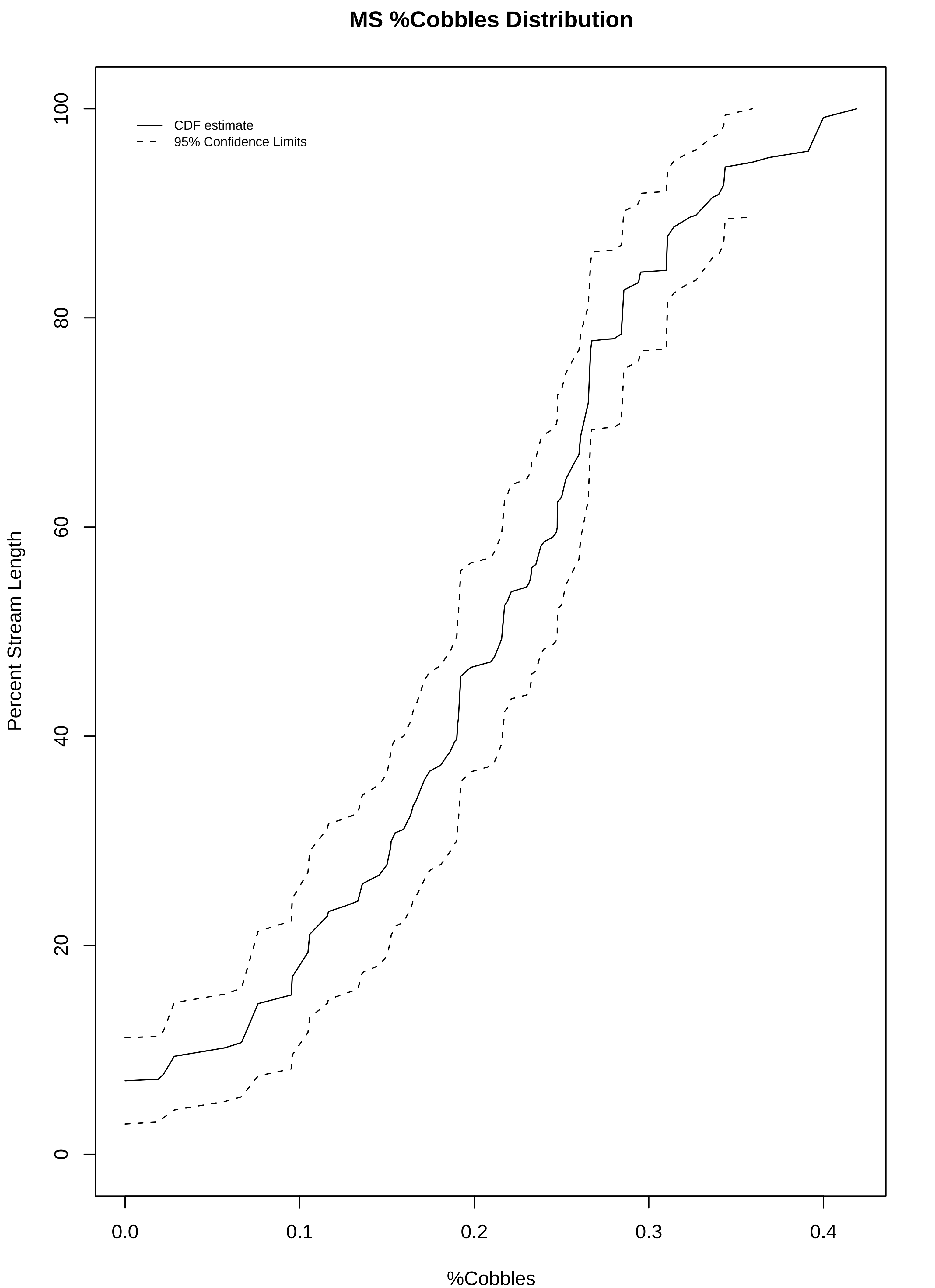

MS %Gravel Distribution
CDF estimate
95% Confidence Limits
0
20
40
60
80
100
Percent Stream Length
0.0
0.2
0.4
0.6
%Gravel

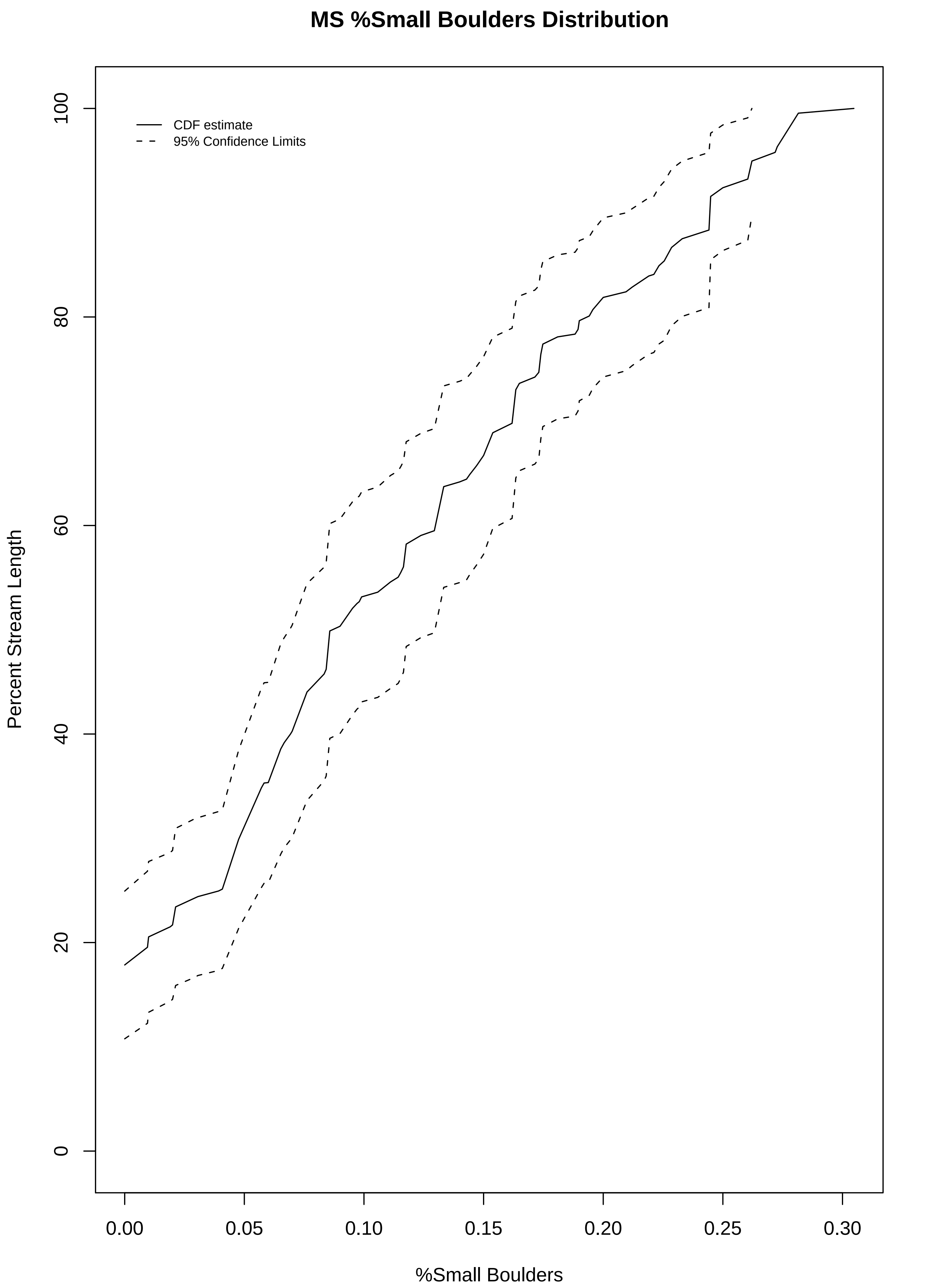


MS %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
%Bedrock

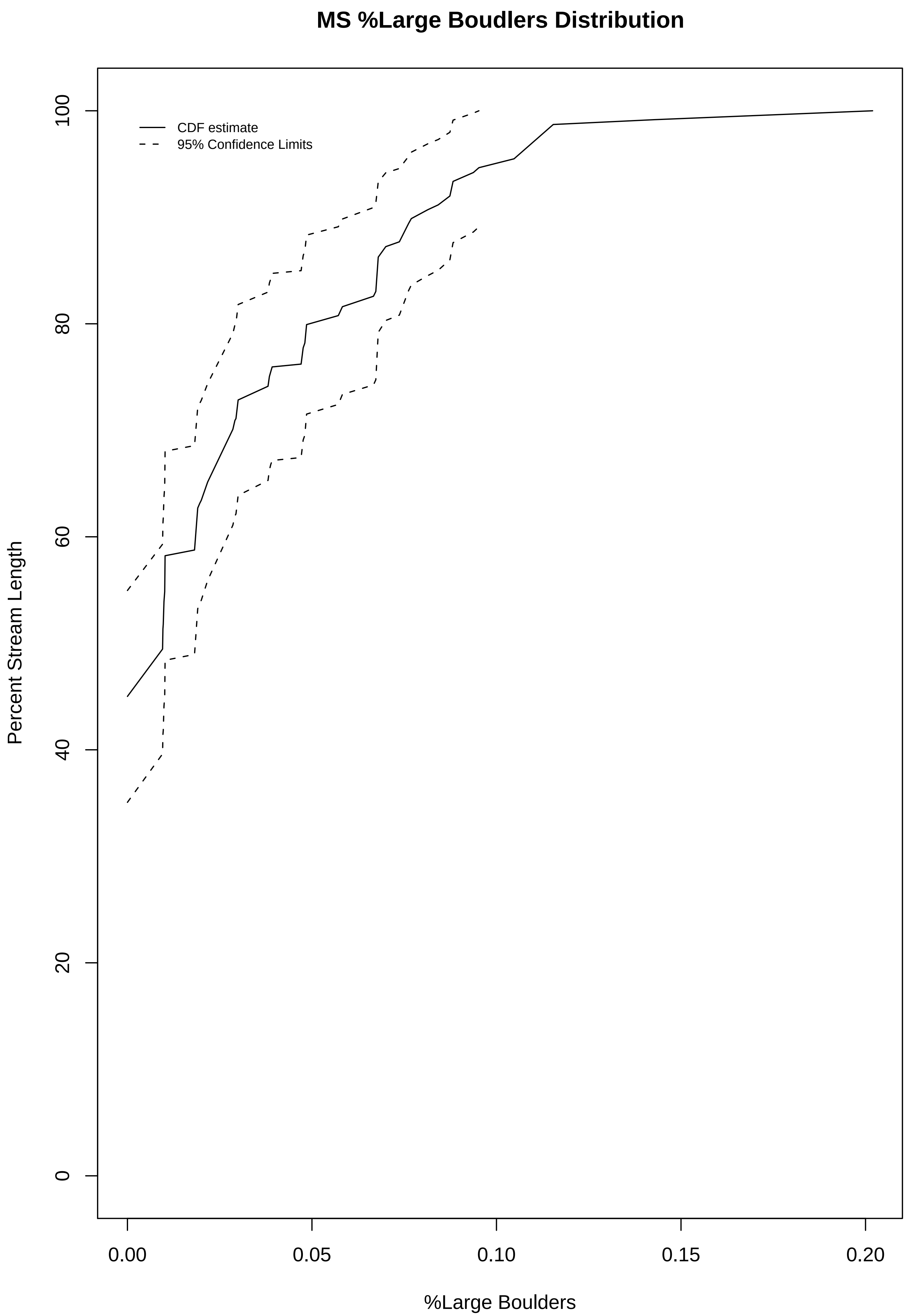
MS SAFN * D_cbf Distribution



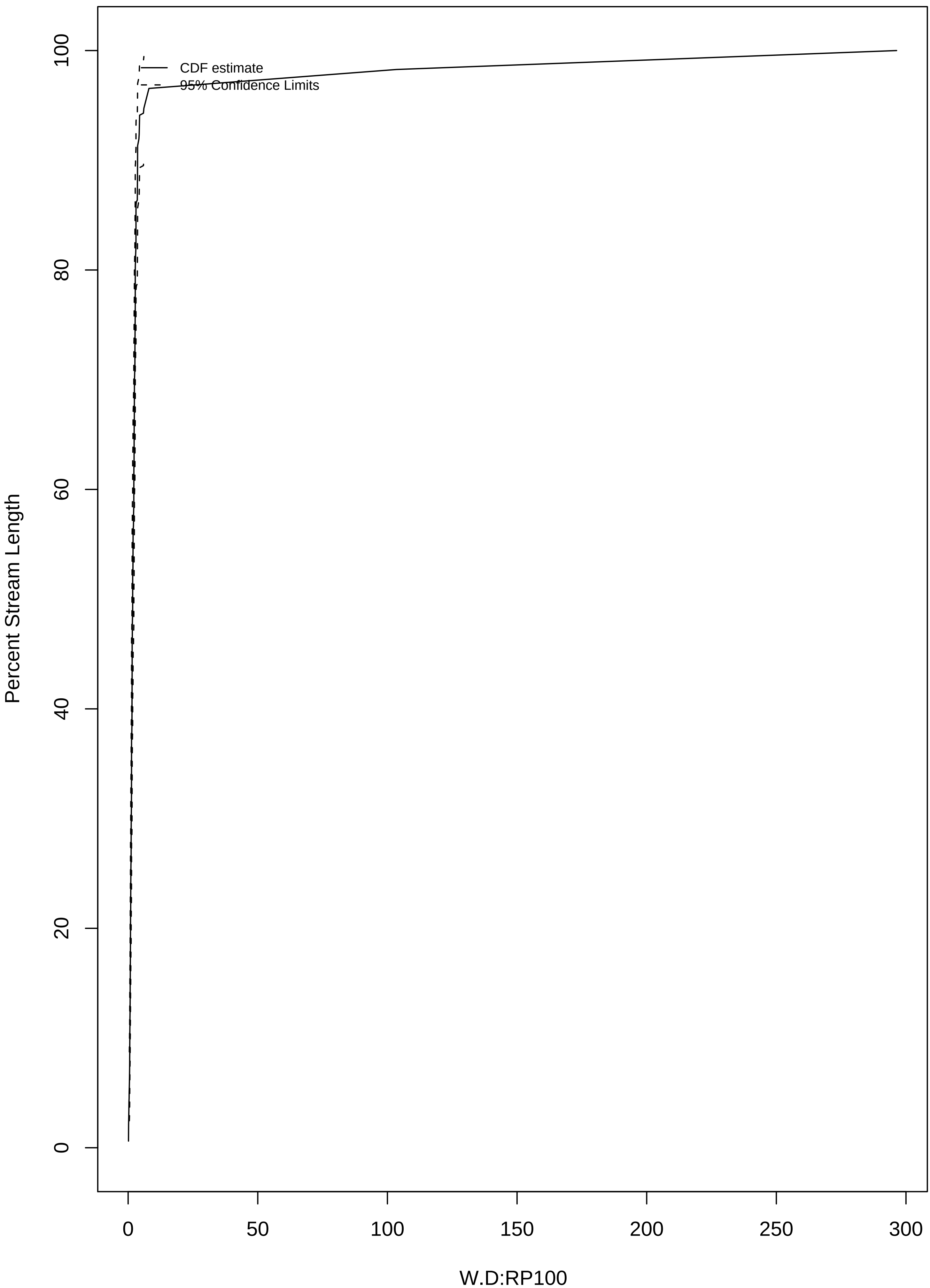

MS %Cobbles Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
%Cobbles

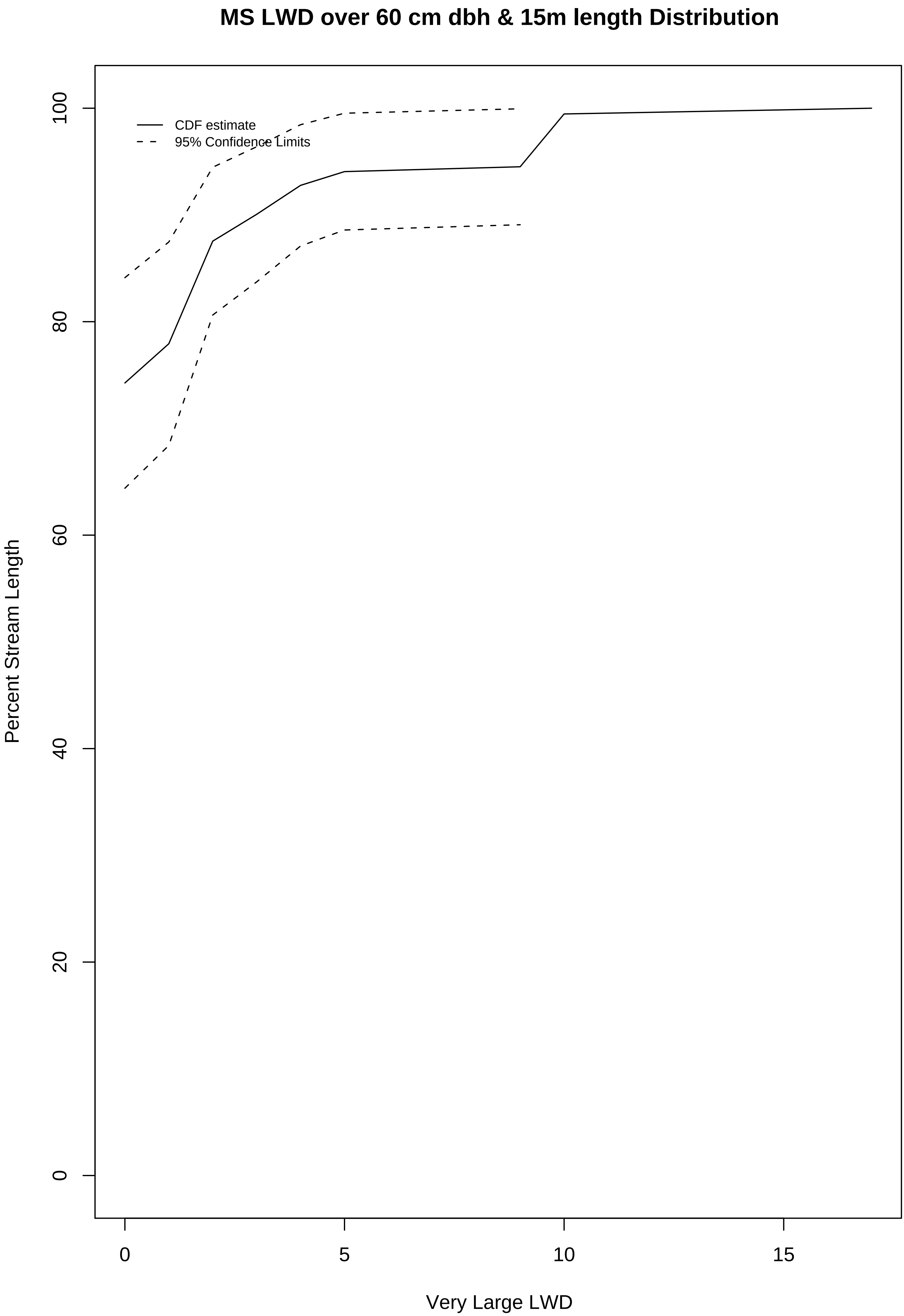


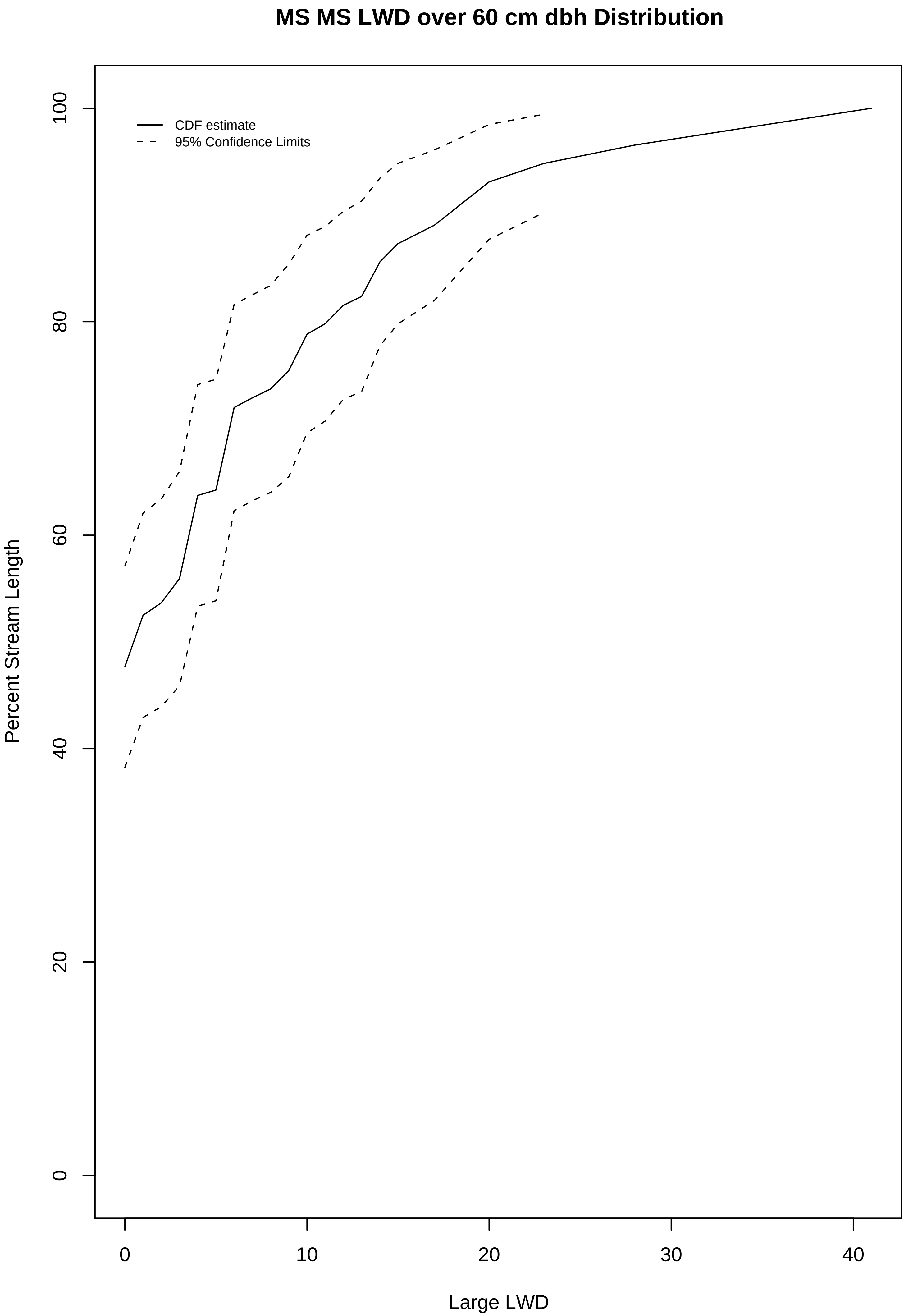
MS %Small Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
%Small Boulders


MS %Large Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
%Large Boulders

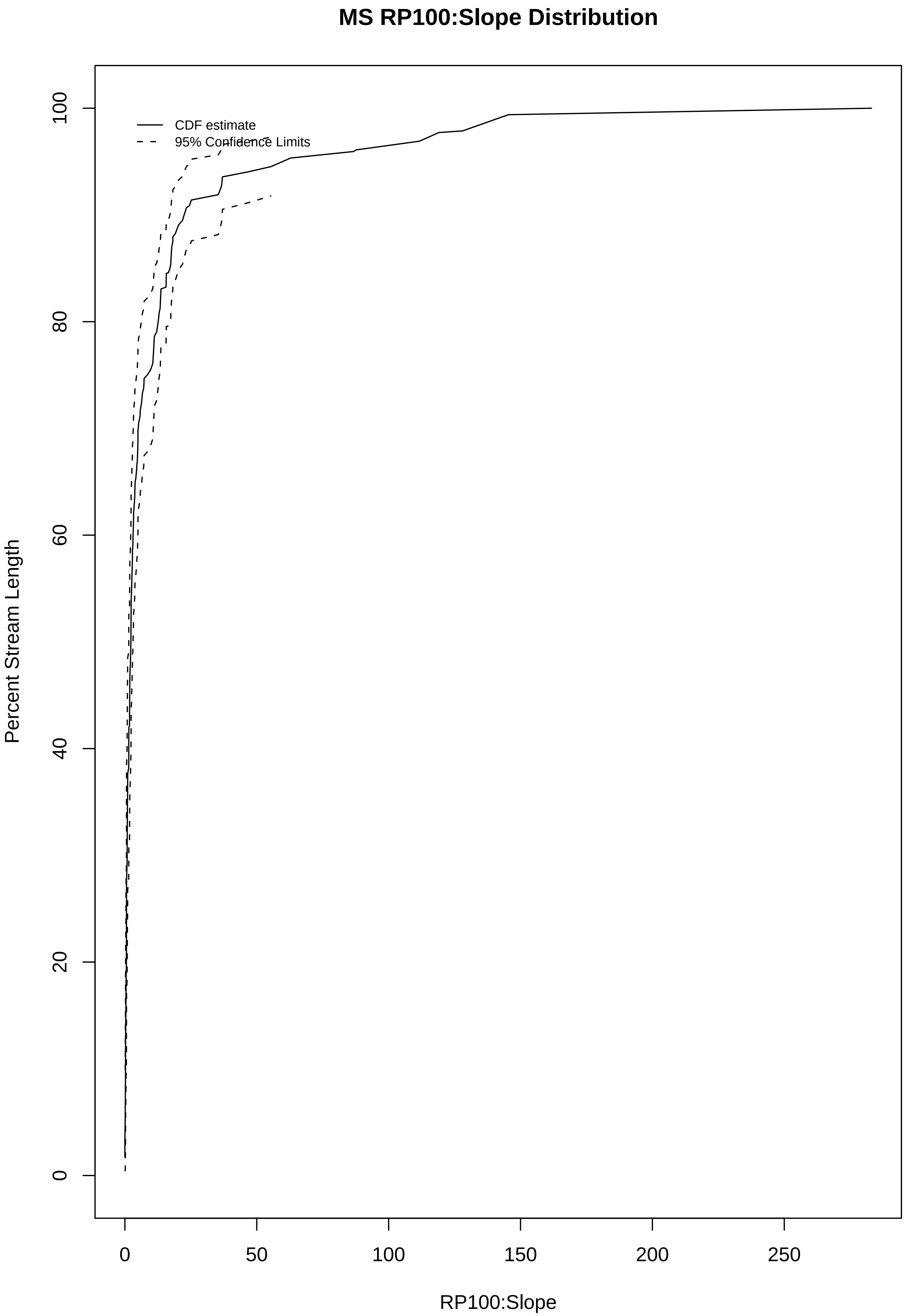
MS W.D:RP100 Distribution



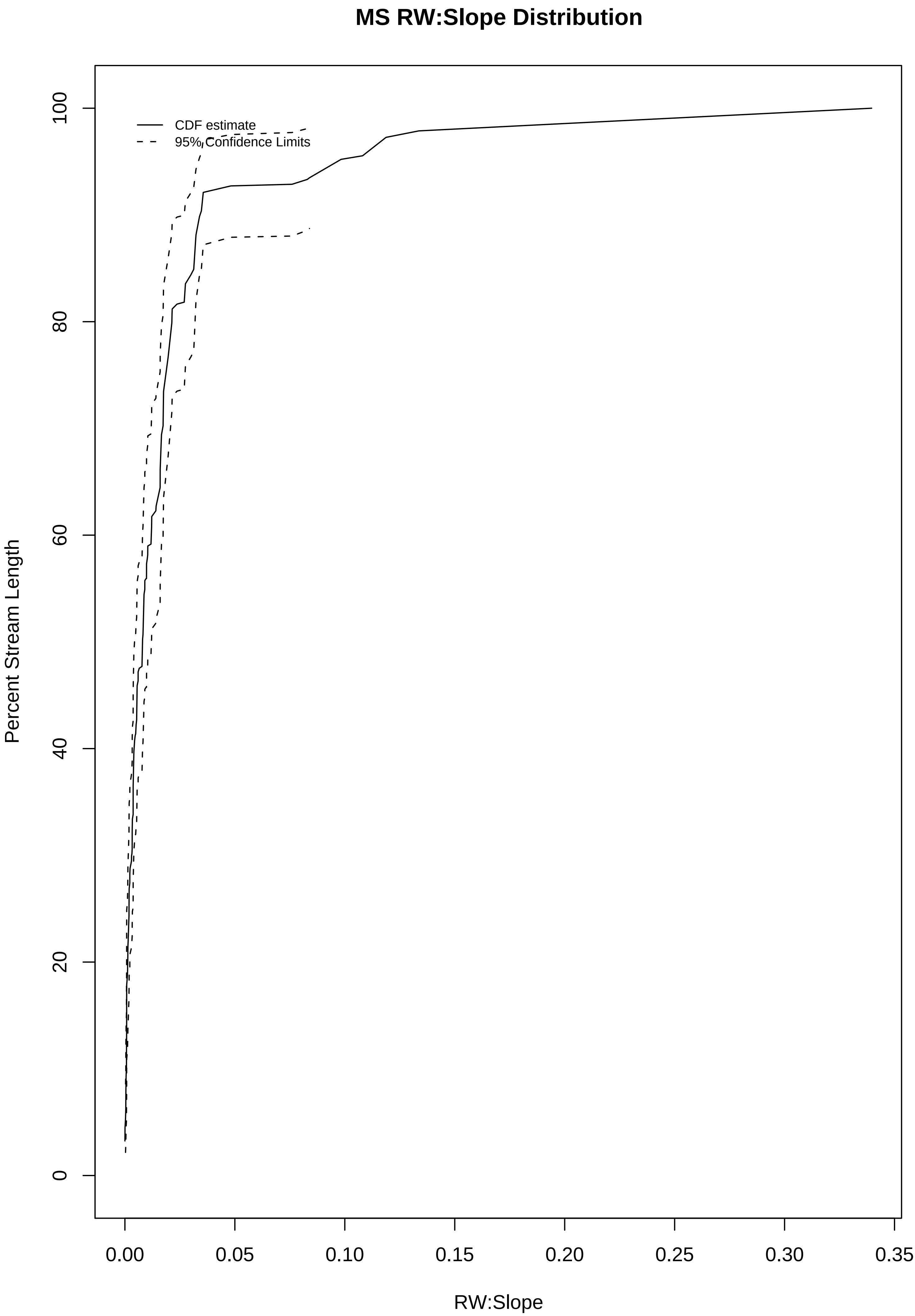

MS LWD over 60 cm dbh & 15m length Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
5
10
15
Very Large LWD



MS MS LWD over 60 cm dbh Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
Large LWD
0
20
40
60
80
100
0
10
20
30
40

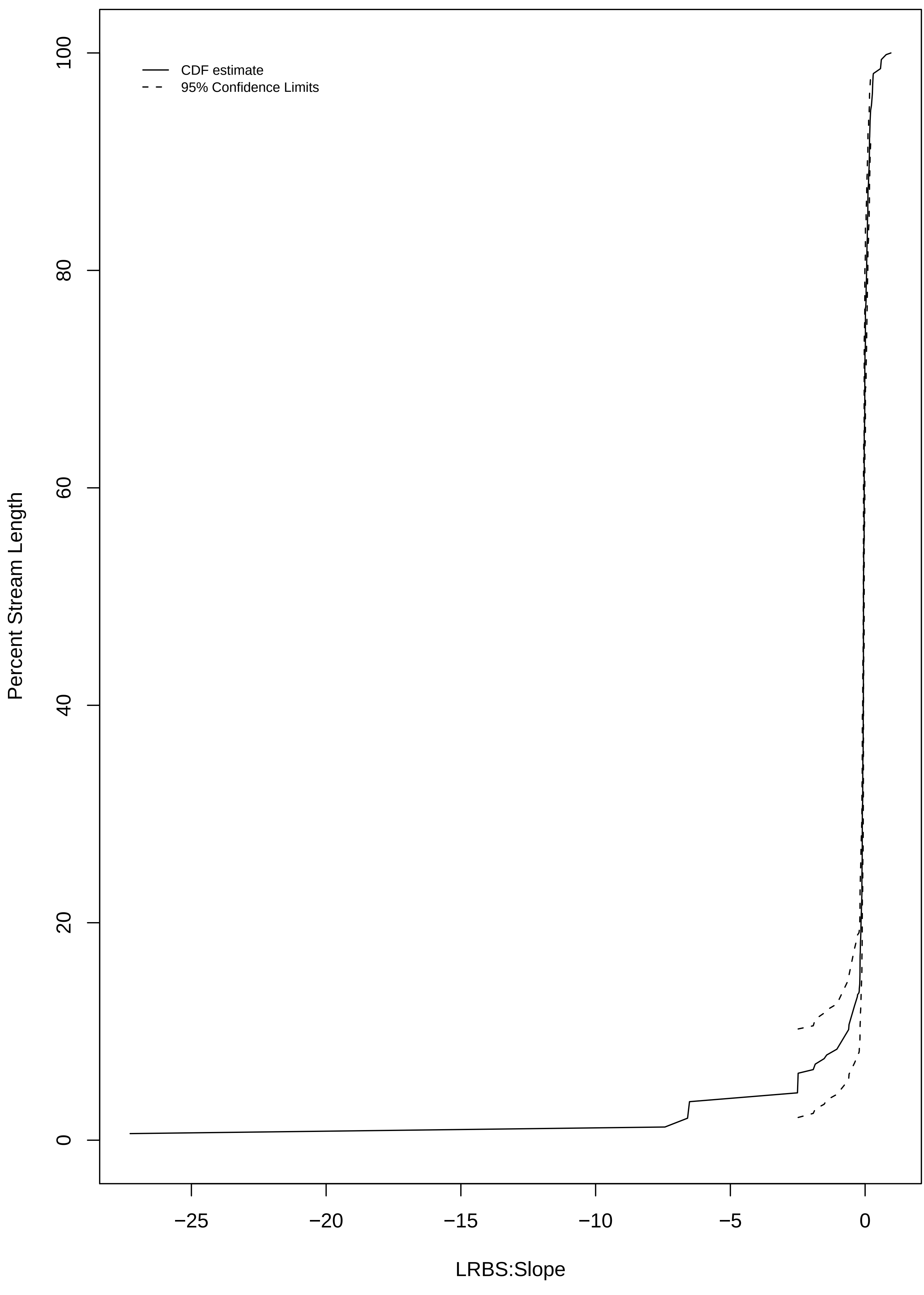


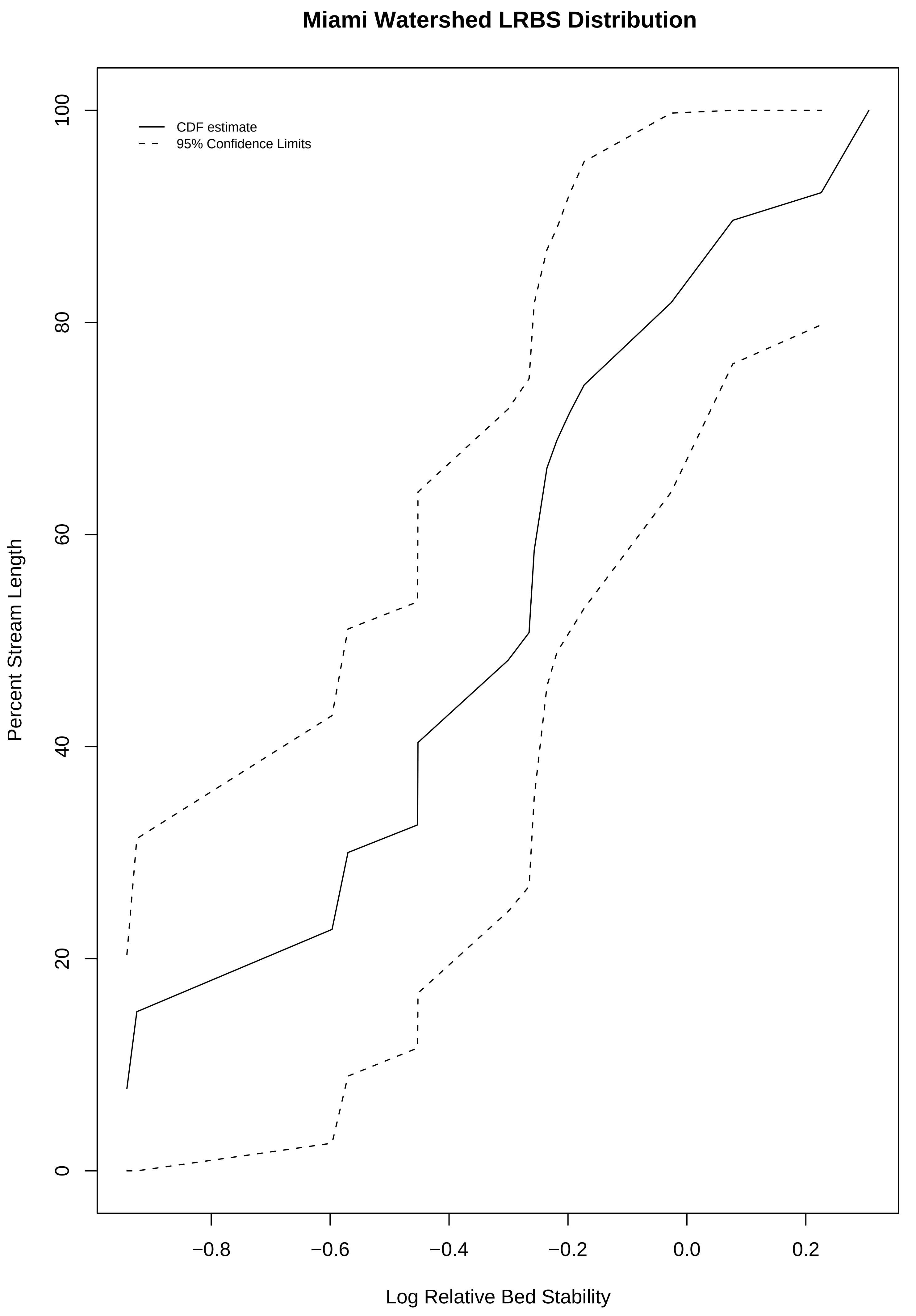
MS RP100:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
50
100
150
200
250
RP100:Slope



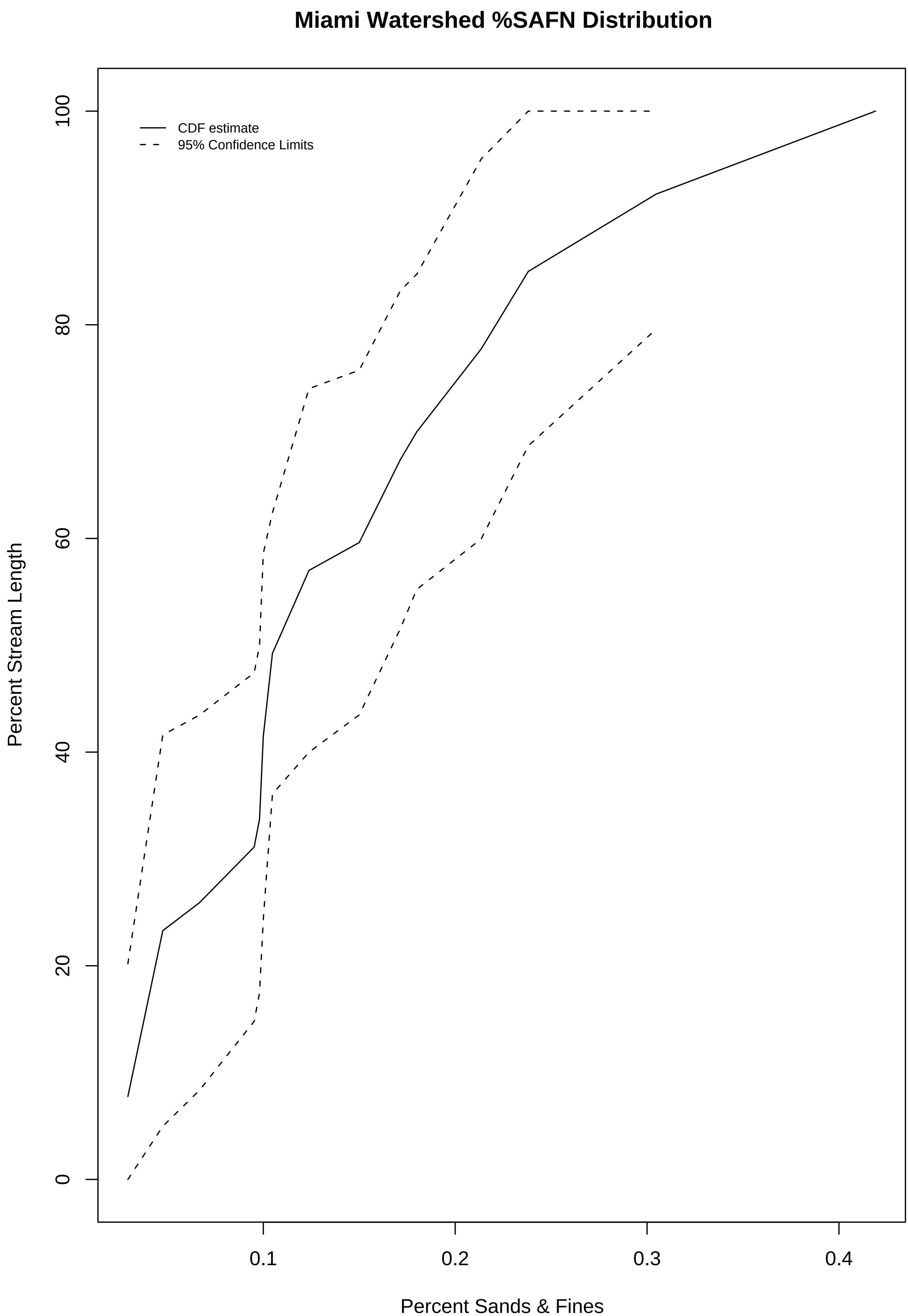
MS RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
RW:Slope

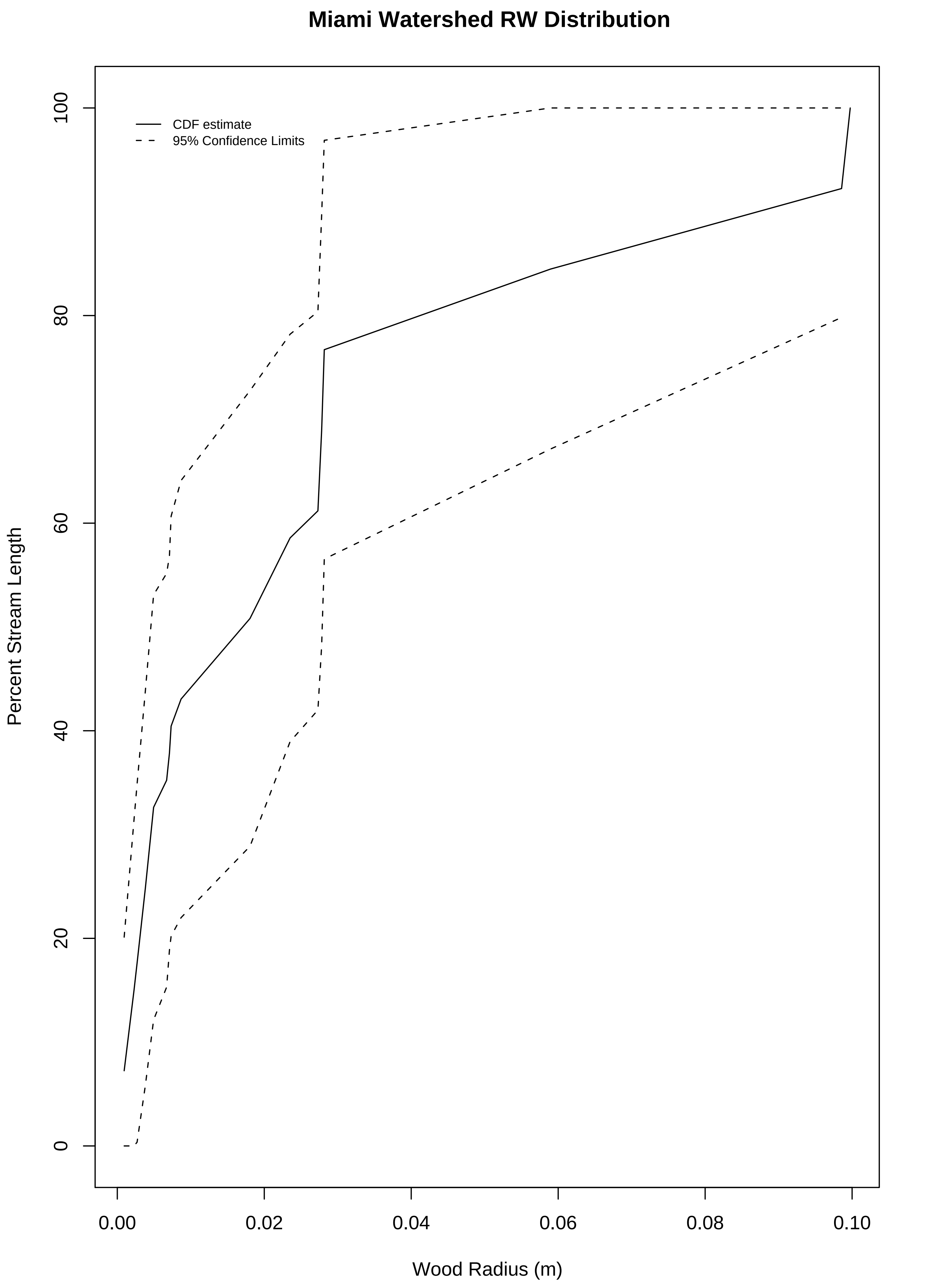
MS LRBS:Slope Distribution



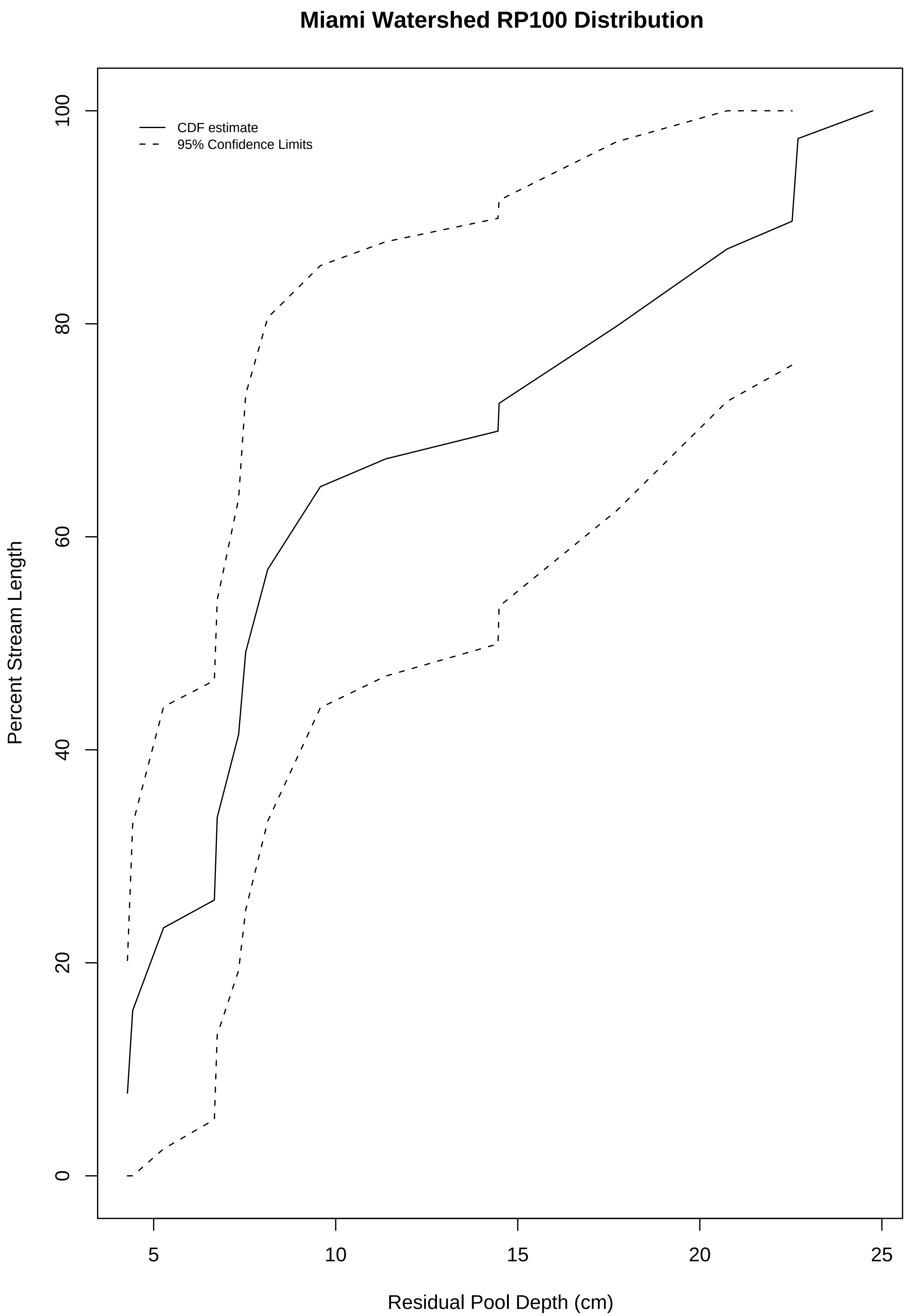


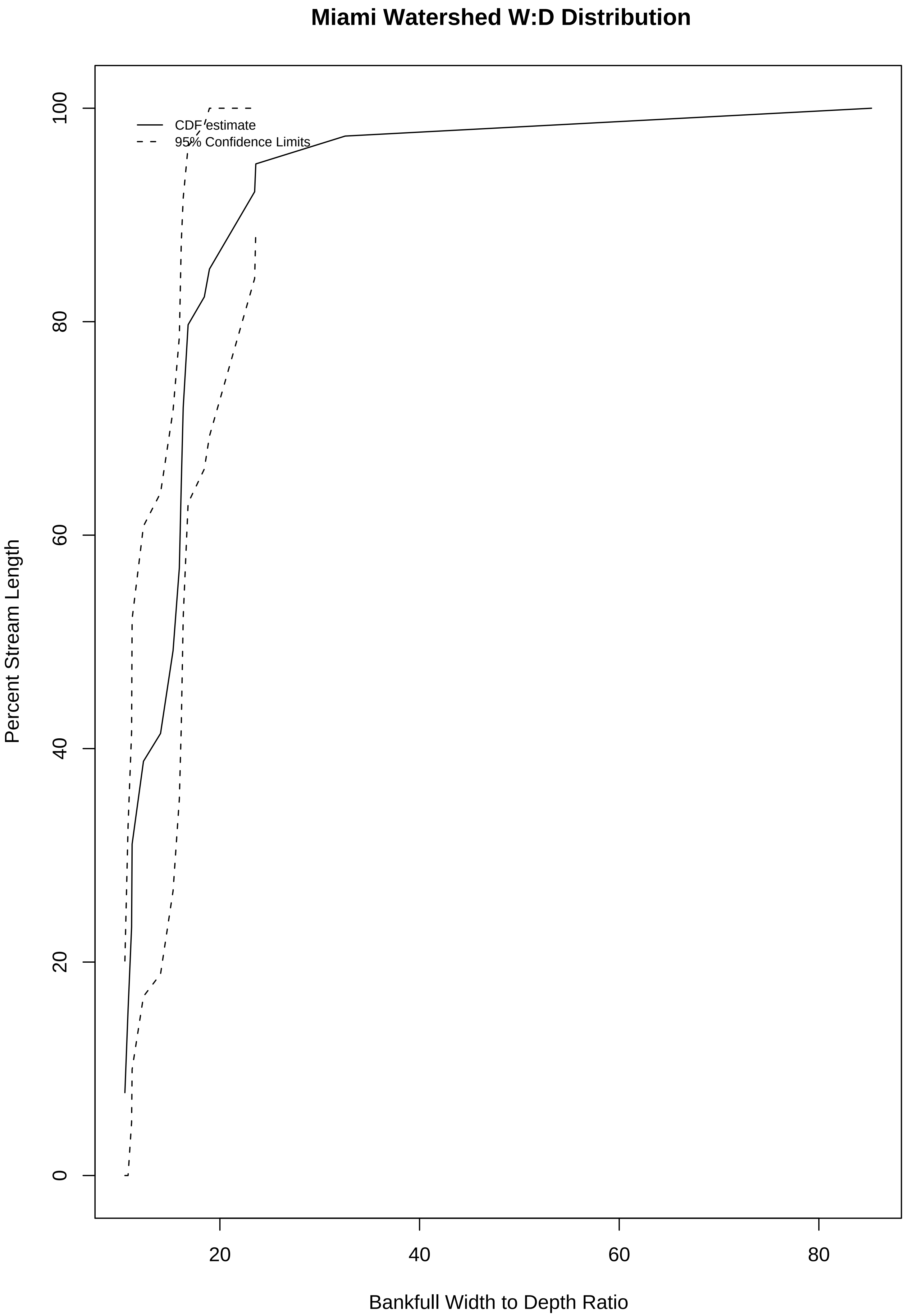
Miami Watershed LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−0.8
−0.6
−0.4
−0.2
0.0
0.2
Log Relative Bed Stability


Miami Watershed %SAFN Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
Percent Sands & Fines

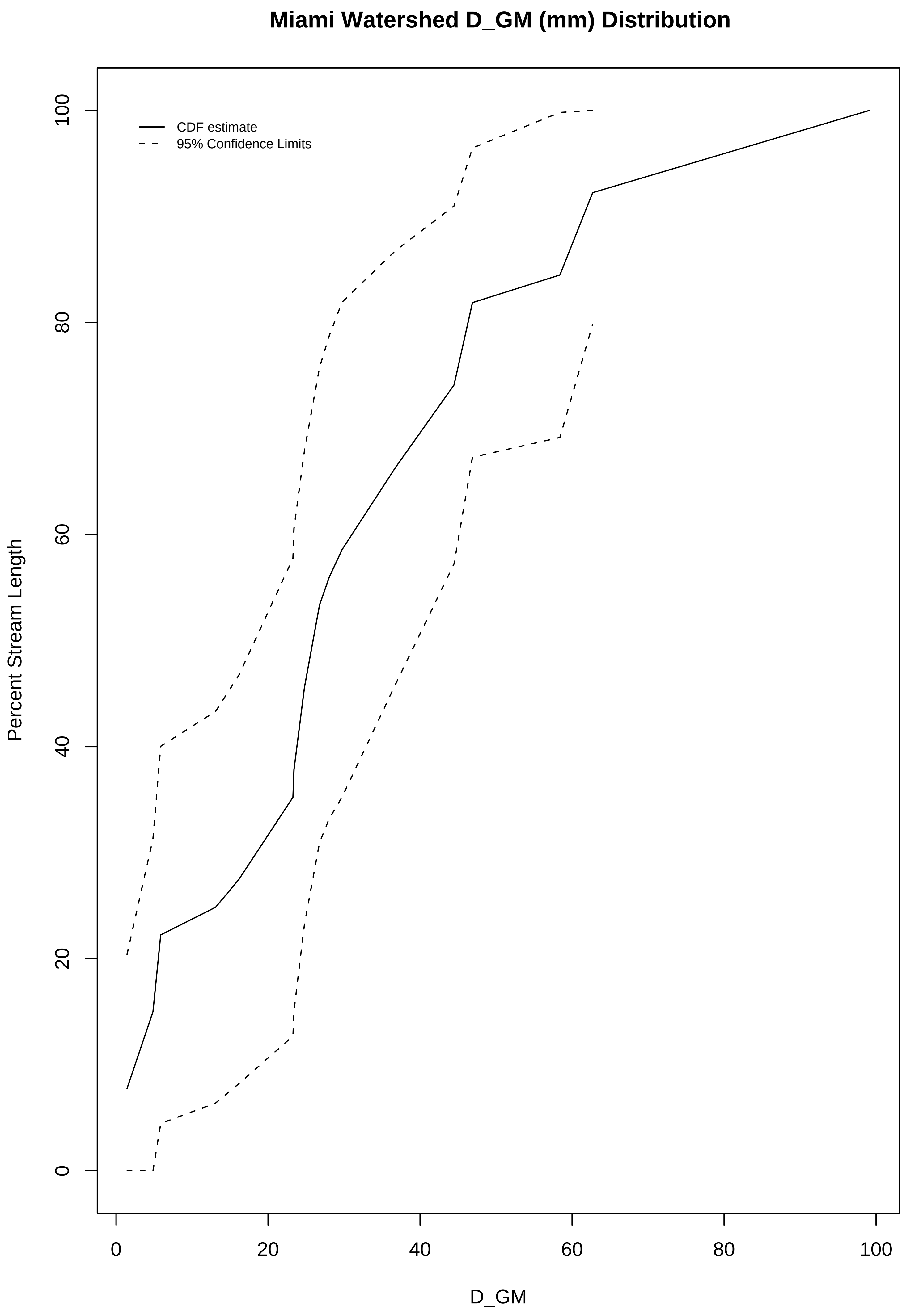


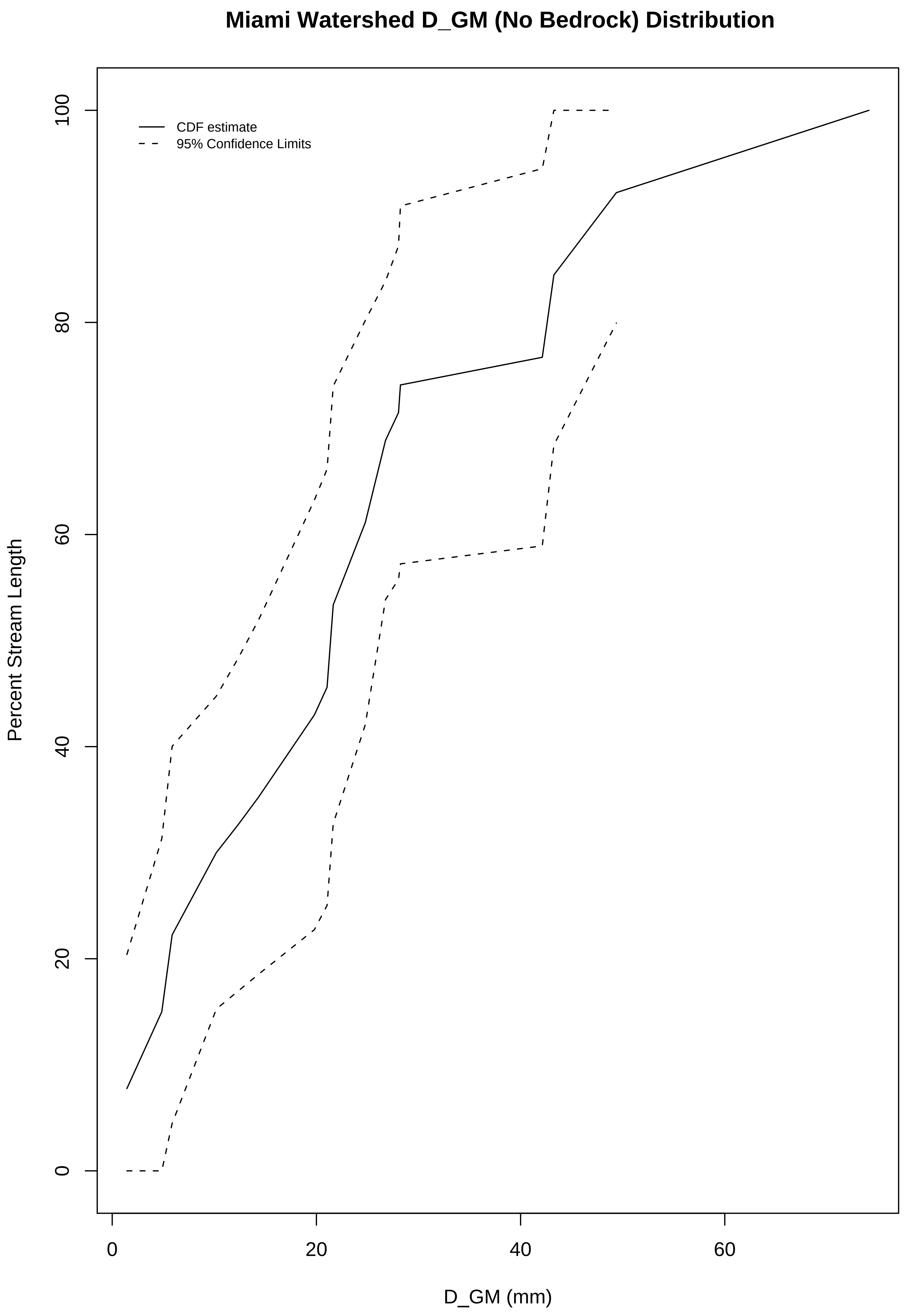
Miami Watershed RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.02
0.04
0.06
0.08
0.10
Wood Radius (m)

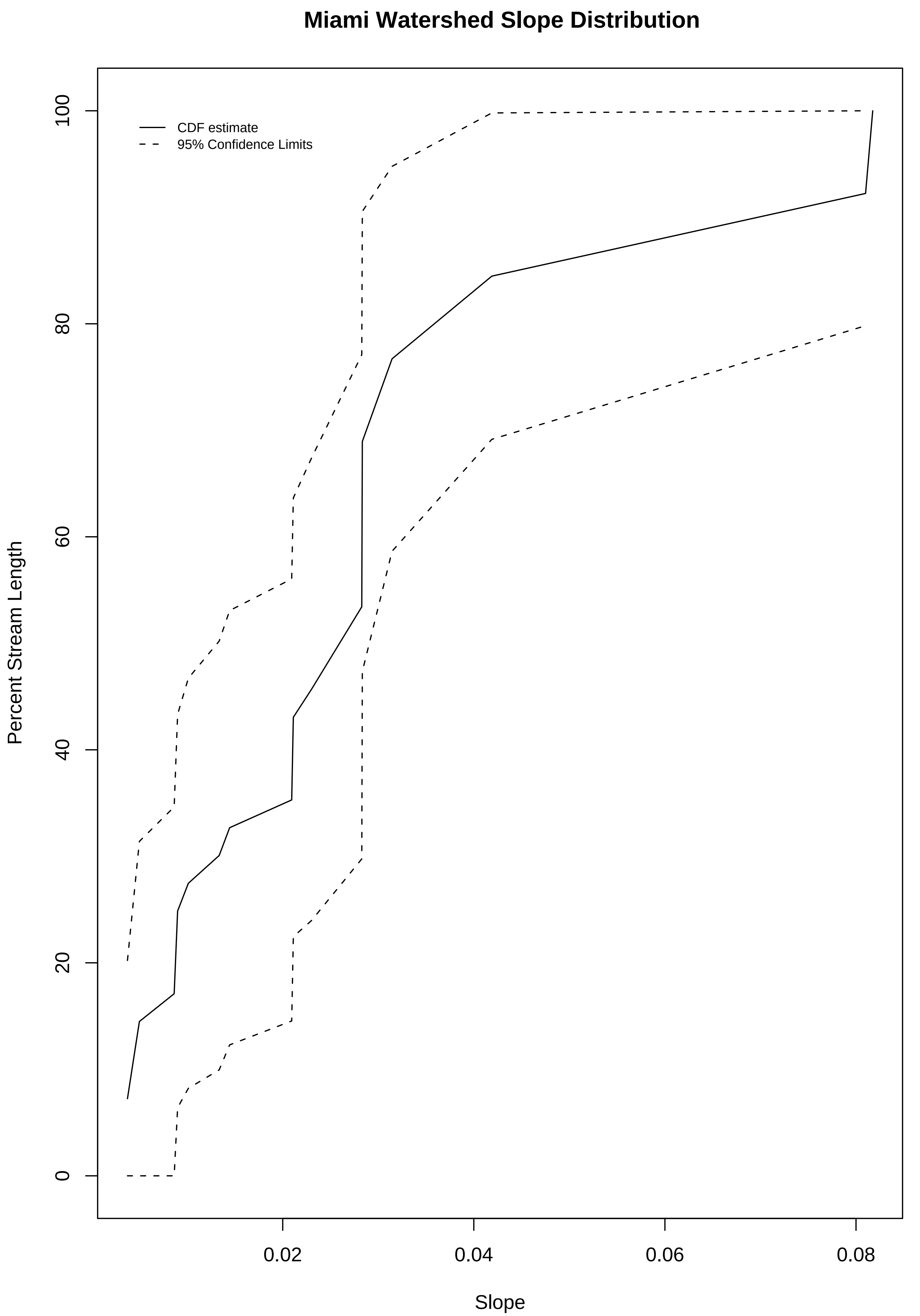

Miami Watershed RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
5
10
15
20
25
Residual Pool Depth (cm)

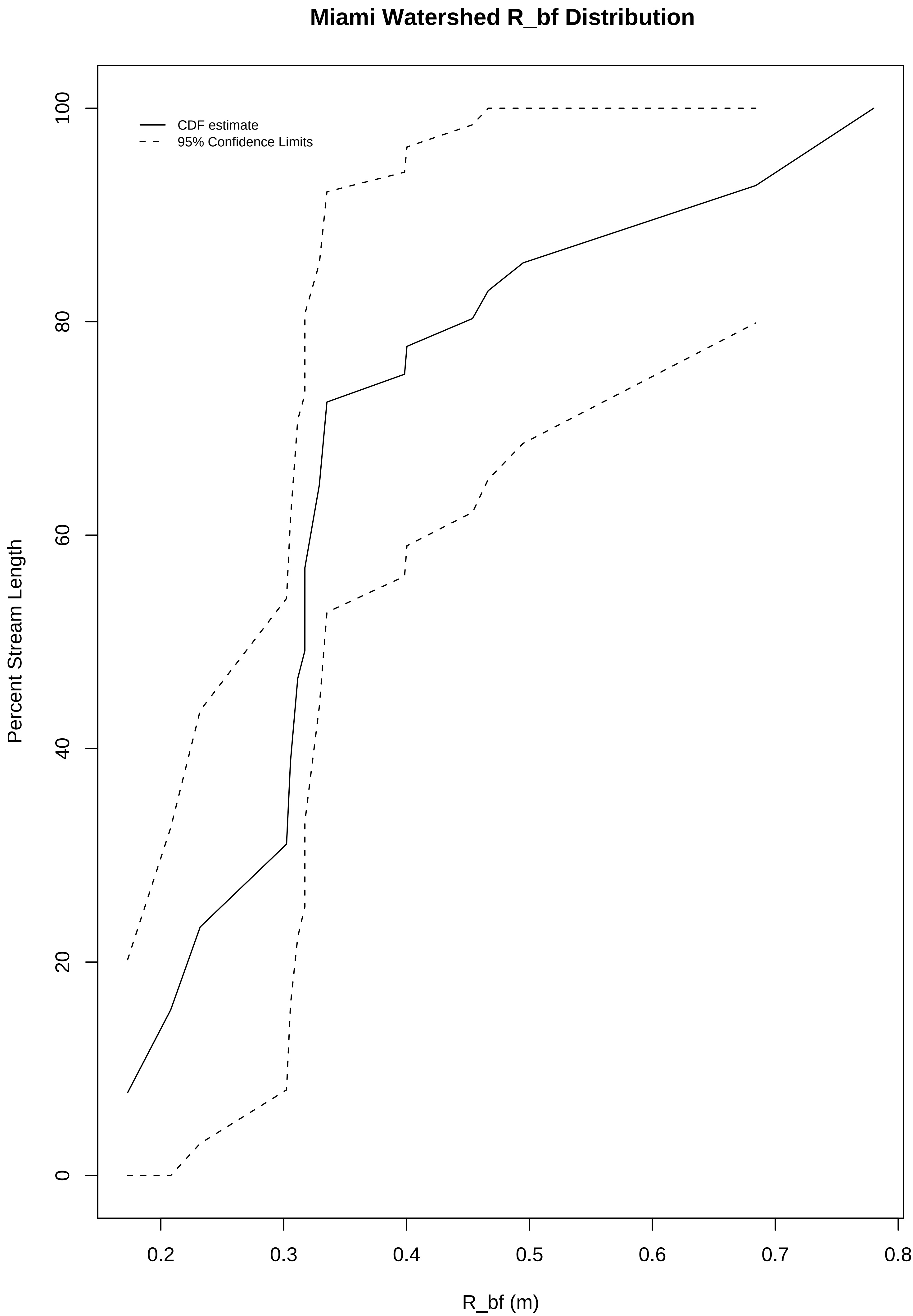


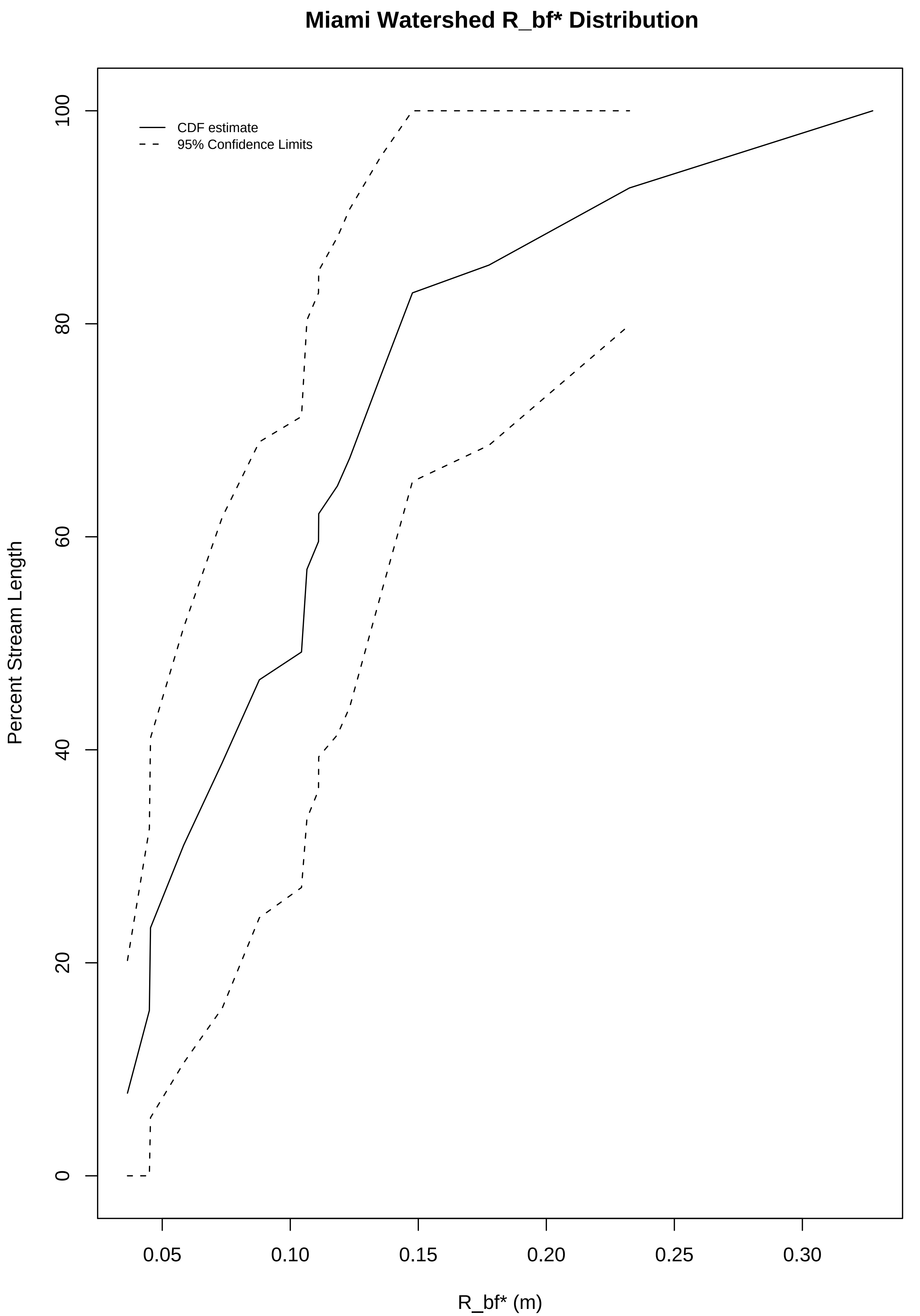
Miami Watershed W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
20
40
60
80
Bankfull Width to Depth Ratio

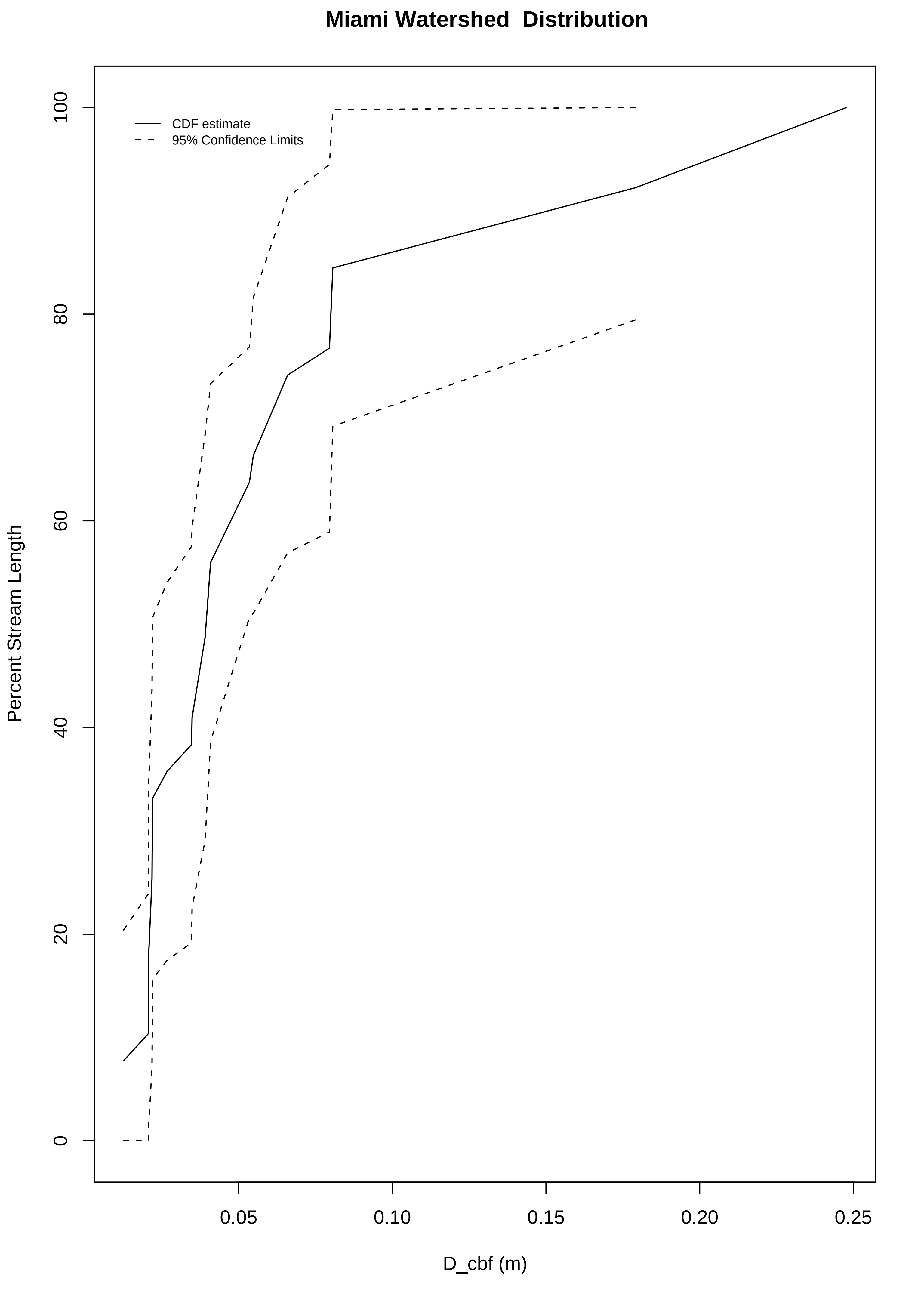

Miami Watershed D_GM (mm) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
D_GM
0
20
40
60
80
100

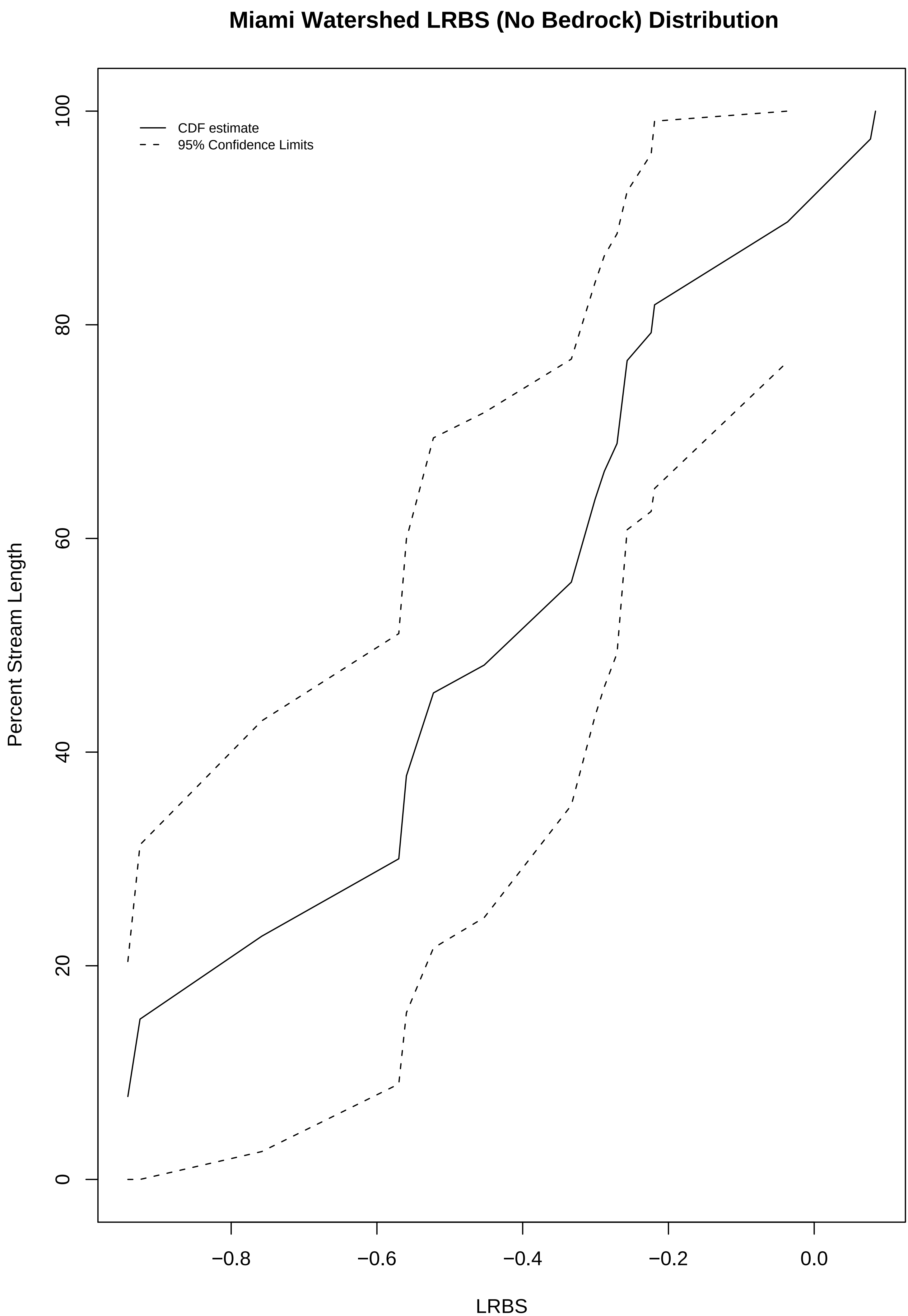

Miami Watershed D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
D_GM (mm)
0
20
40
60
80
100
0
20
40
60


Miami Watershed Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.02
0.04
0.06
0.08
Slope

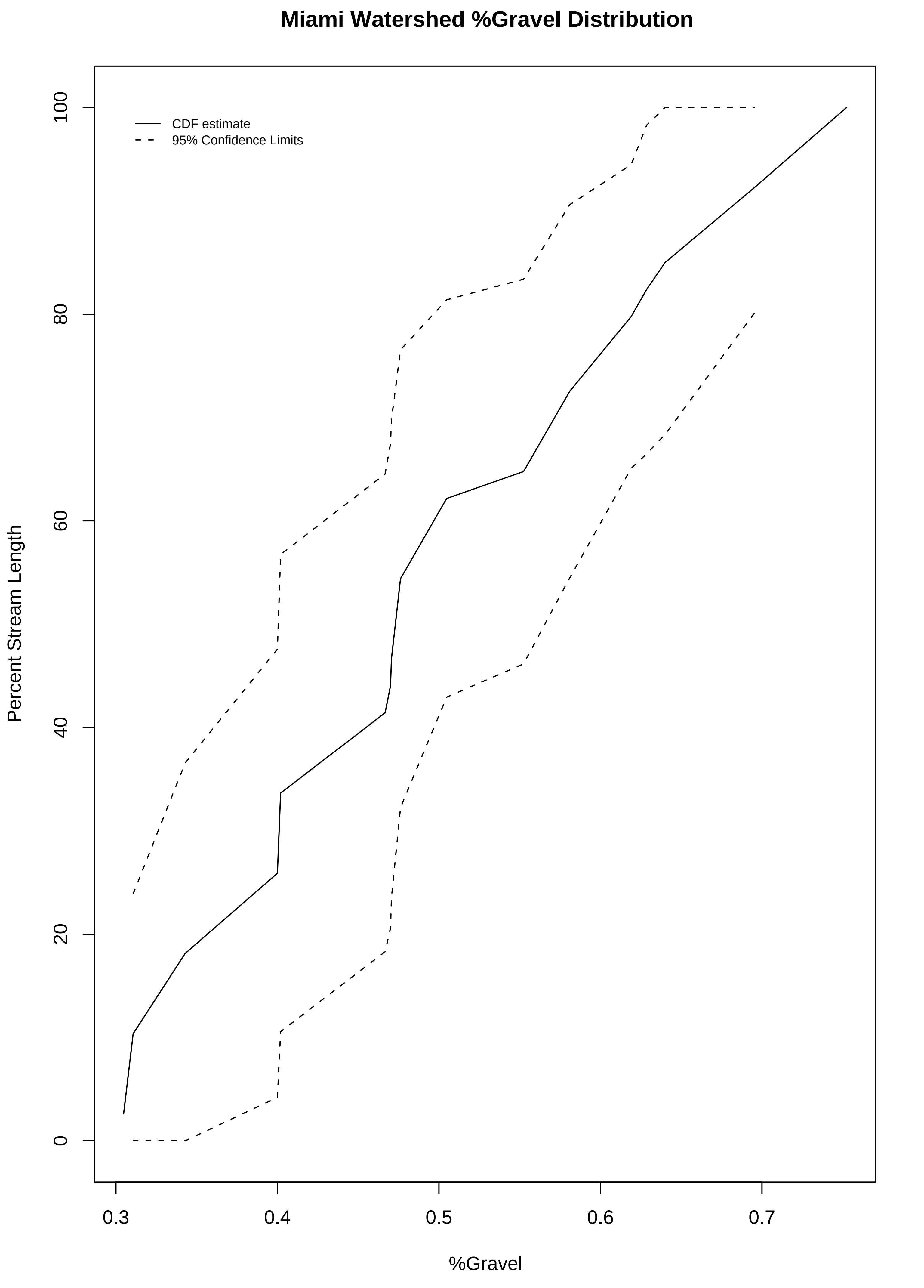

Miami Watershed R_bf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.2
0.3
0.4
0.5
0.6
0.7
0.8
R_bf (m)


Miami Watershed R_bf* Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.05
0.10
0.15
0.20
0.25
0.30
R_bf* (m)

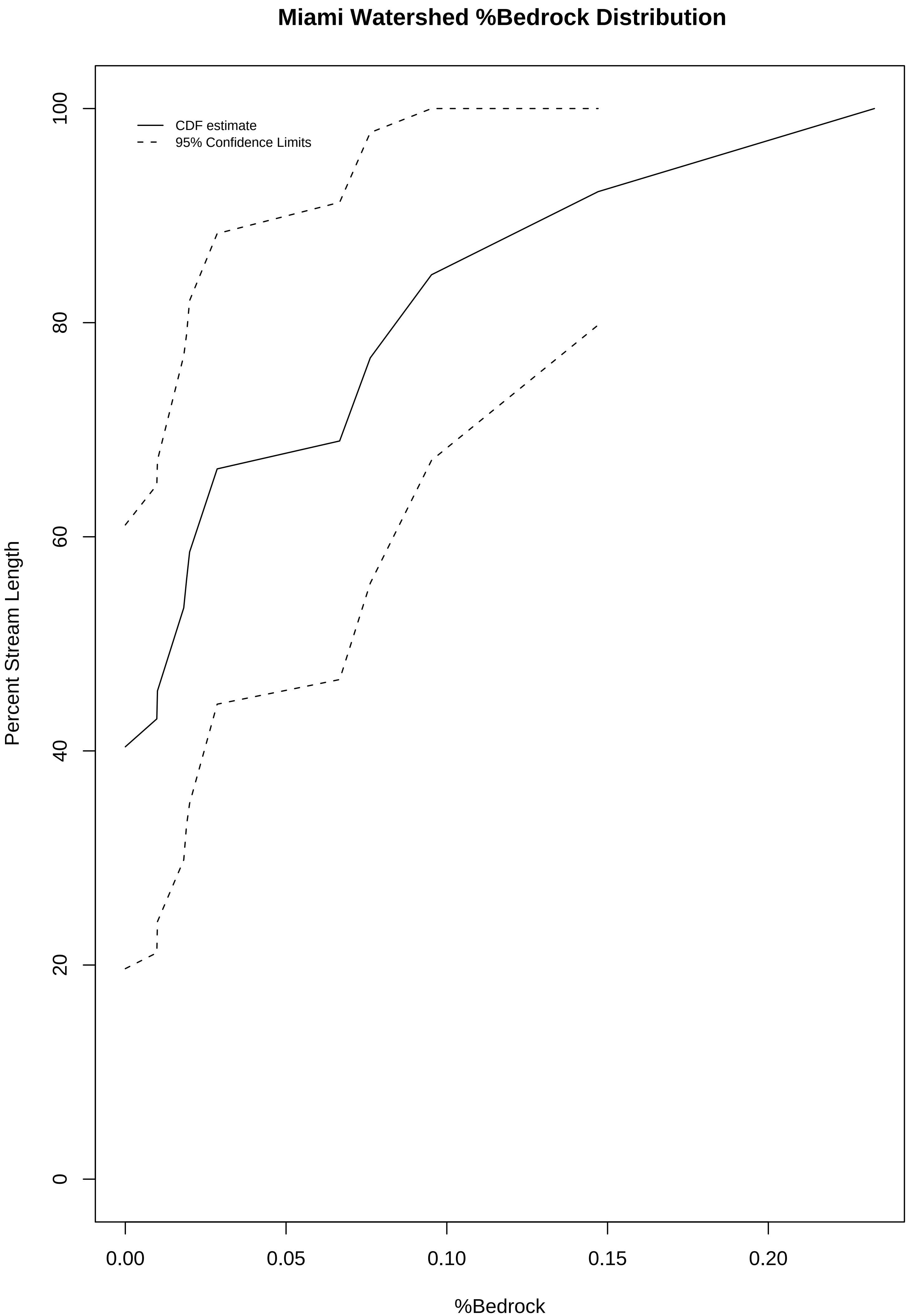

Miami Watershed Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.05
0.10
0.15
0.20
0.25
D_cbf (m)



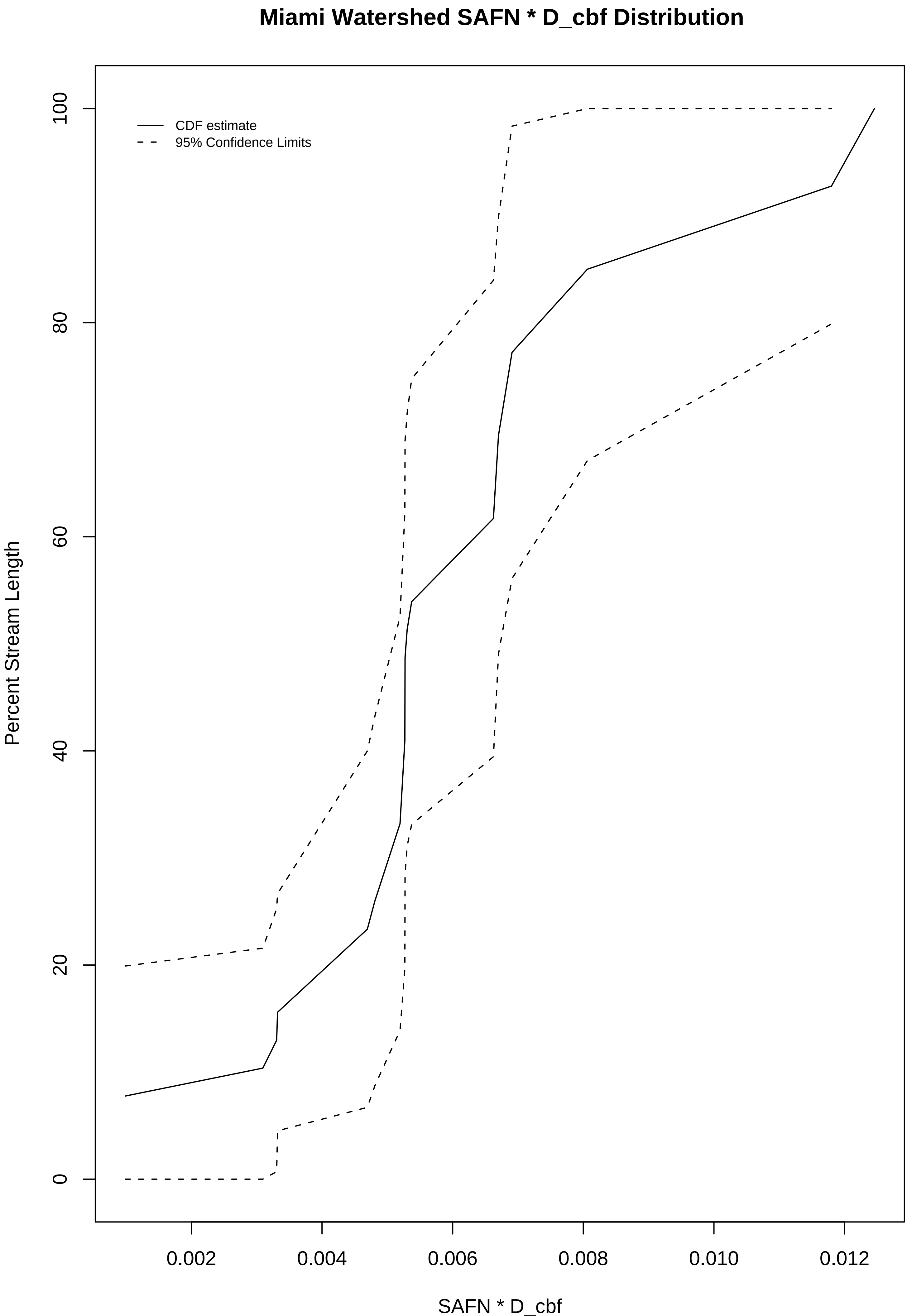
Miami Watershed LRBS (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
LRBS
−0.8
−0.6
−0.4
−0.2
0.0

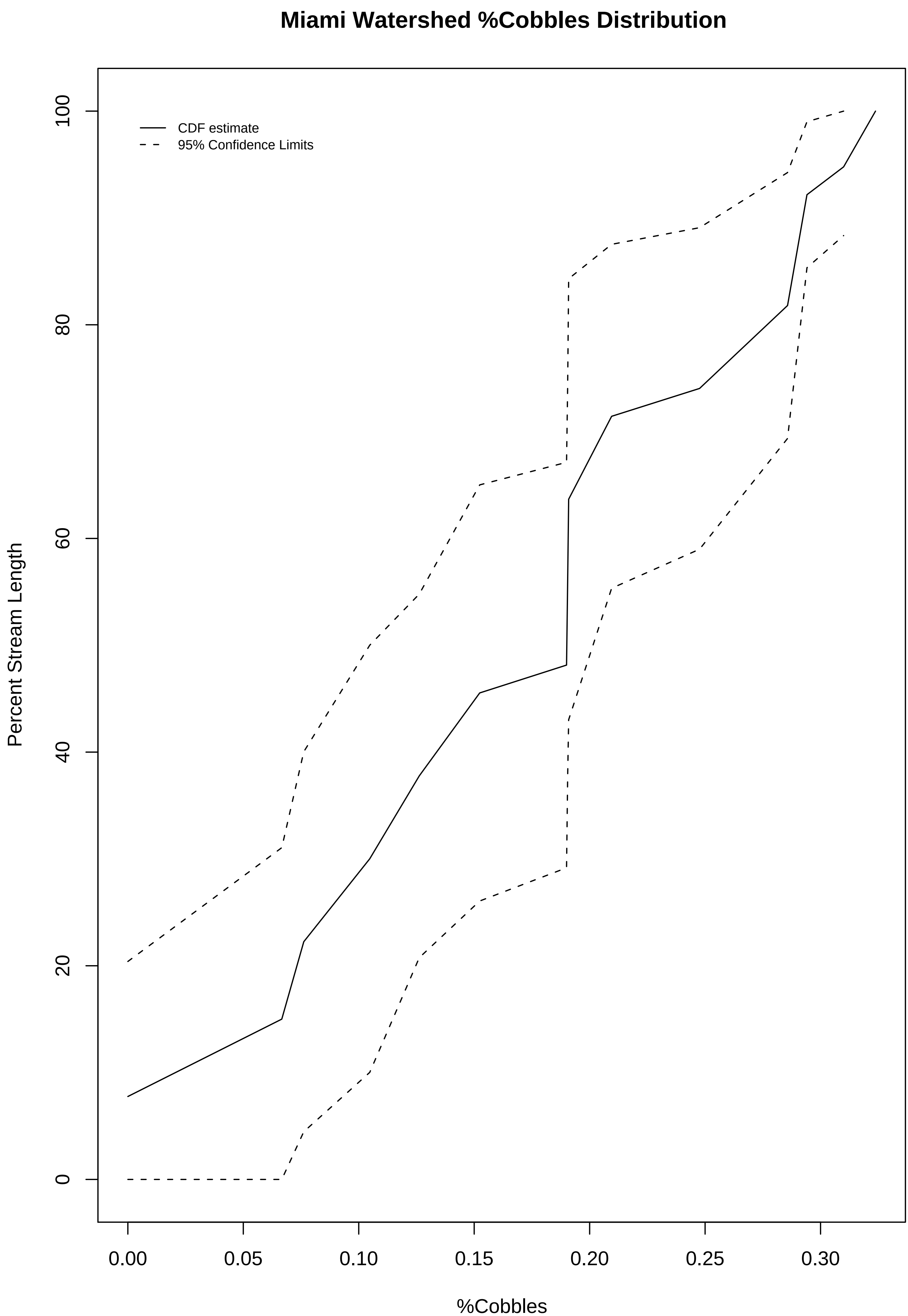


Miami Watershed %Gravel Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.3
0.4
0.5
0.6
0.7
%Gravel

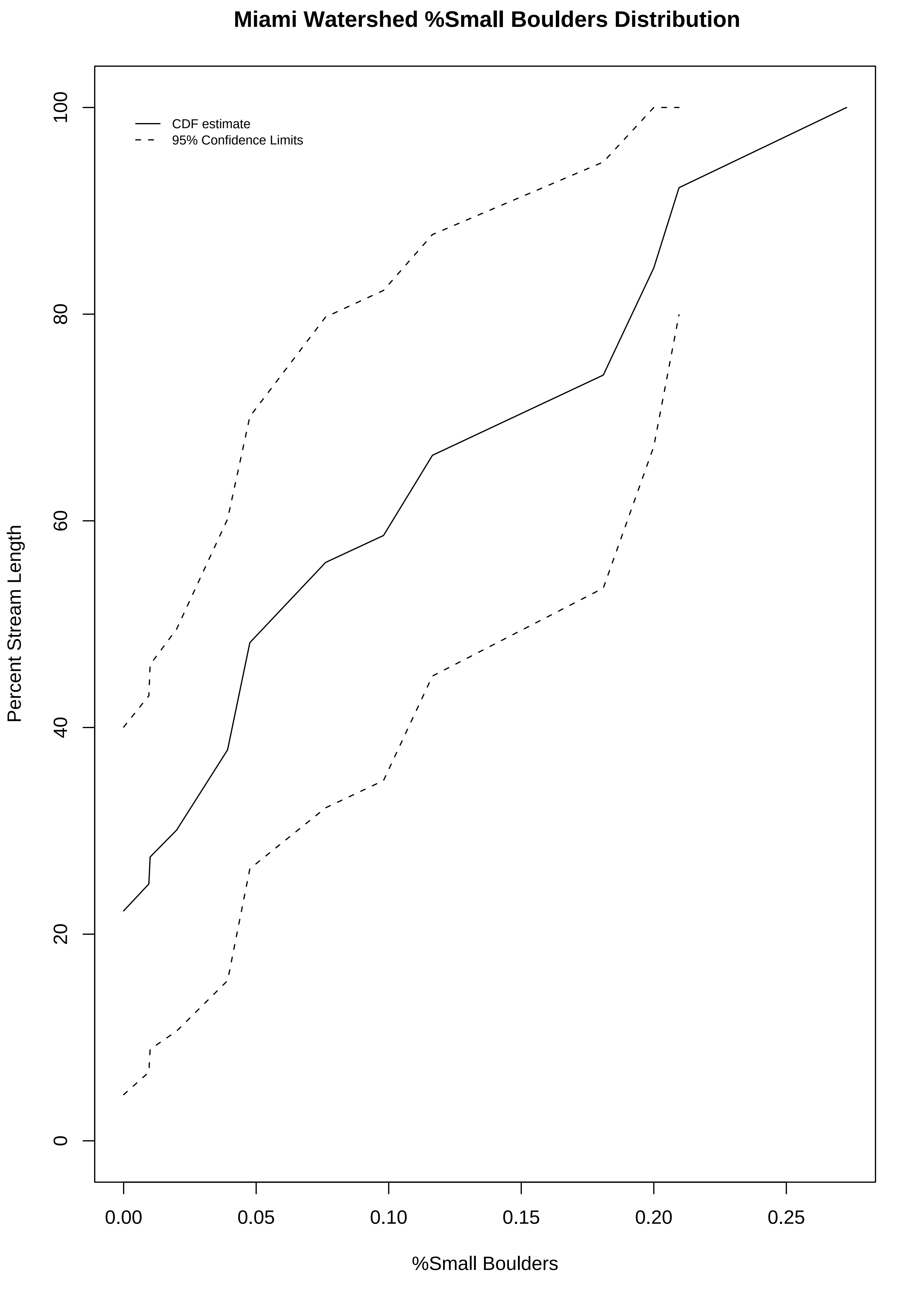


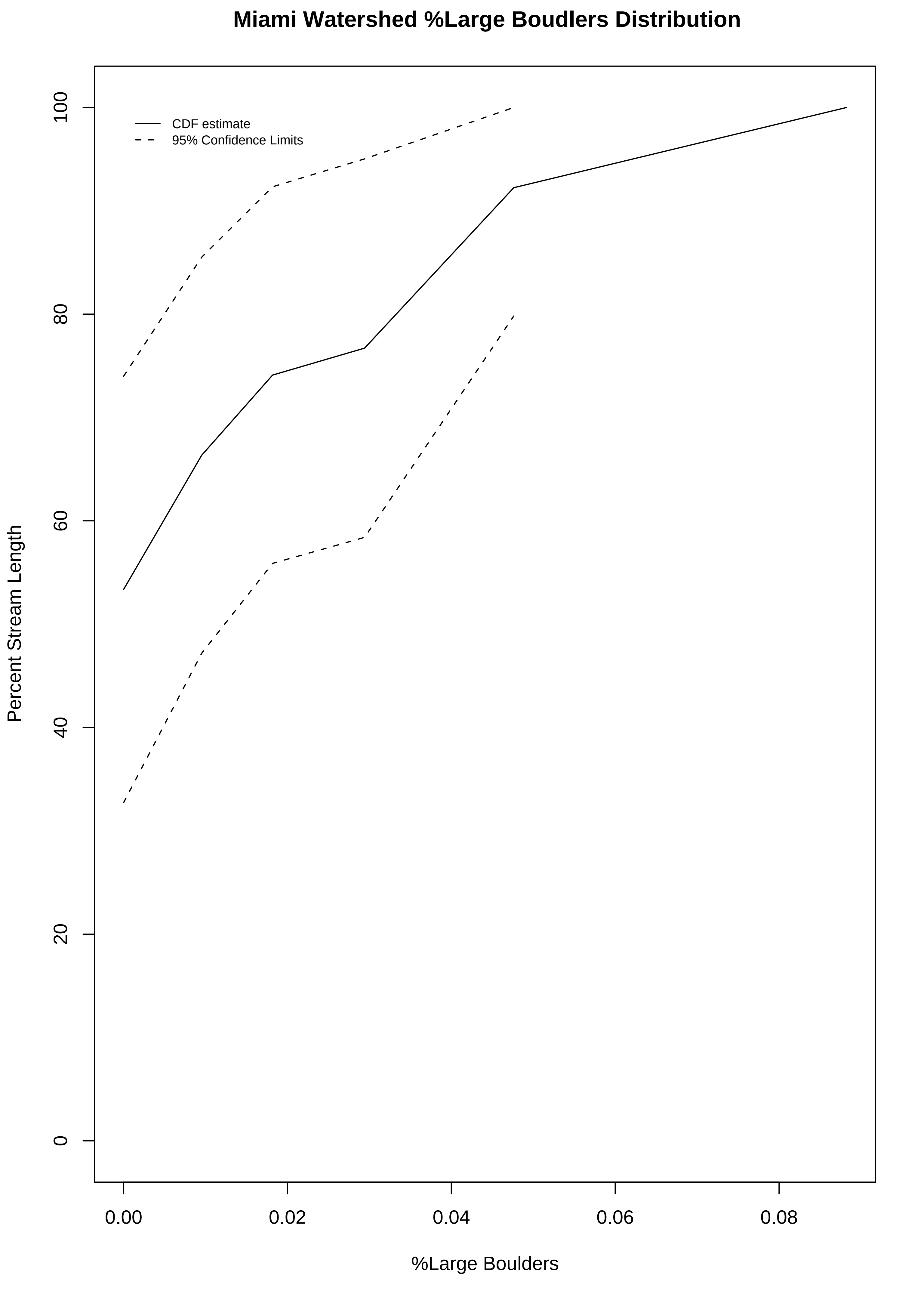
Miami Watershed %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
%Bedrock
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20

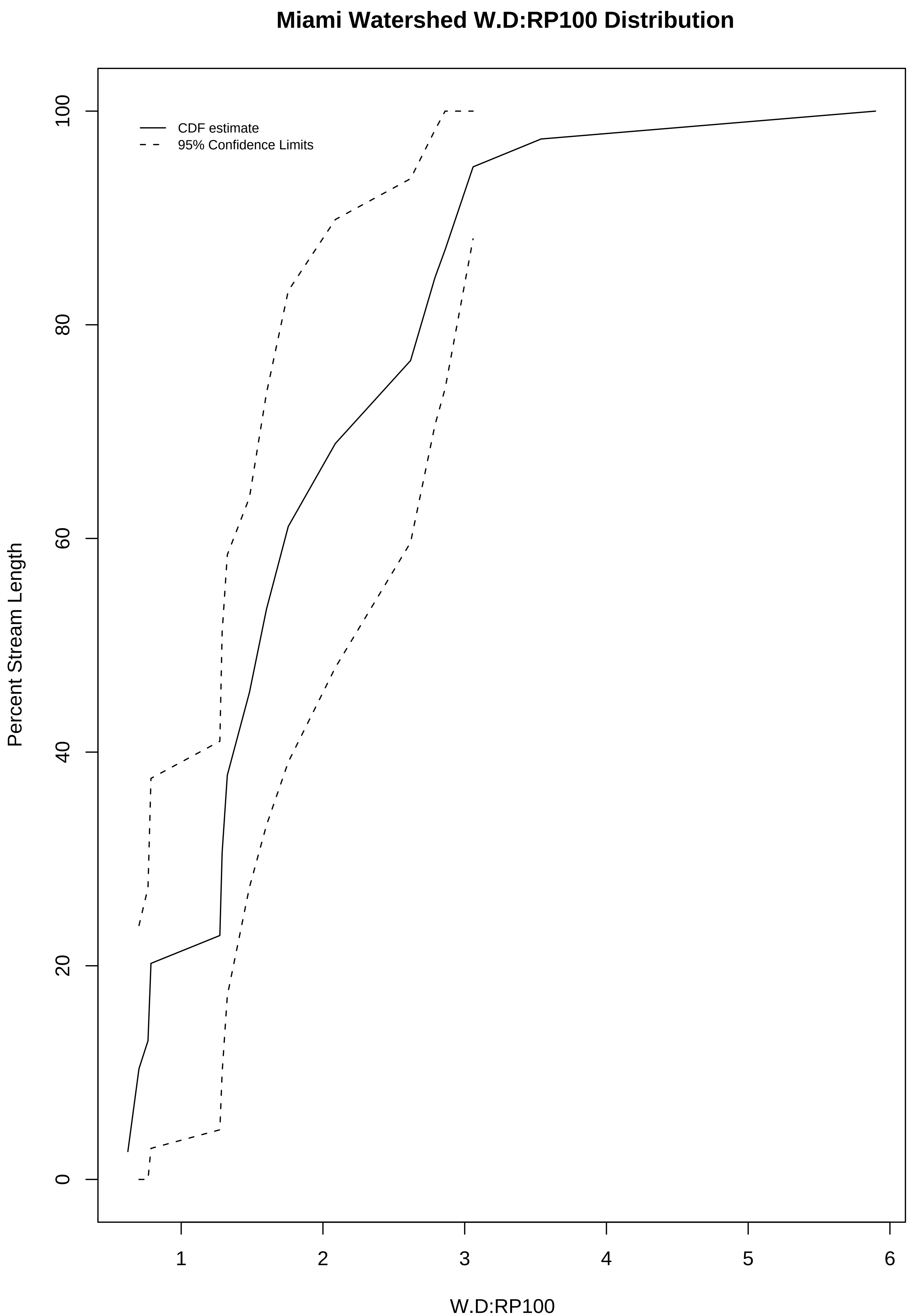

Miami Watershed SAFN * D_cbf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.002
0.004
0.006
0.008
0.010
0.012
SAFN * D_cbf



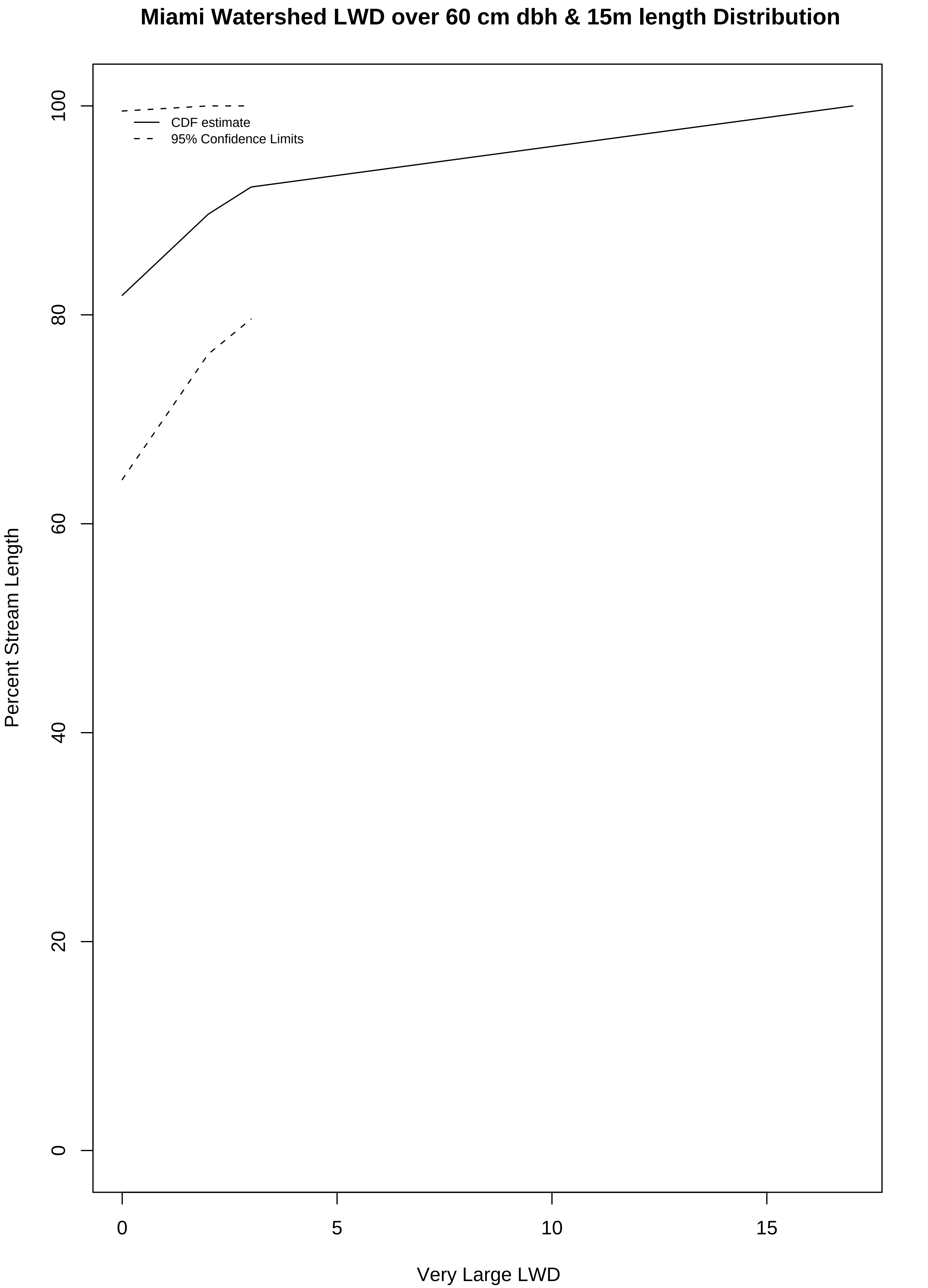
Miami Watershed %Cobbles Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
%Cobbles


Miami Watershed %Small Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
%Small Boulders

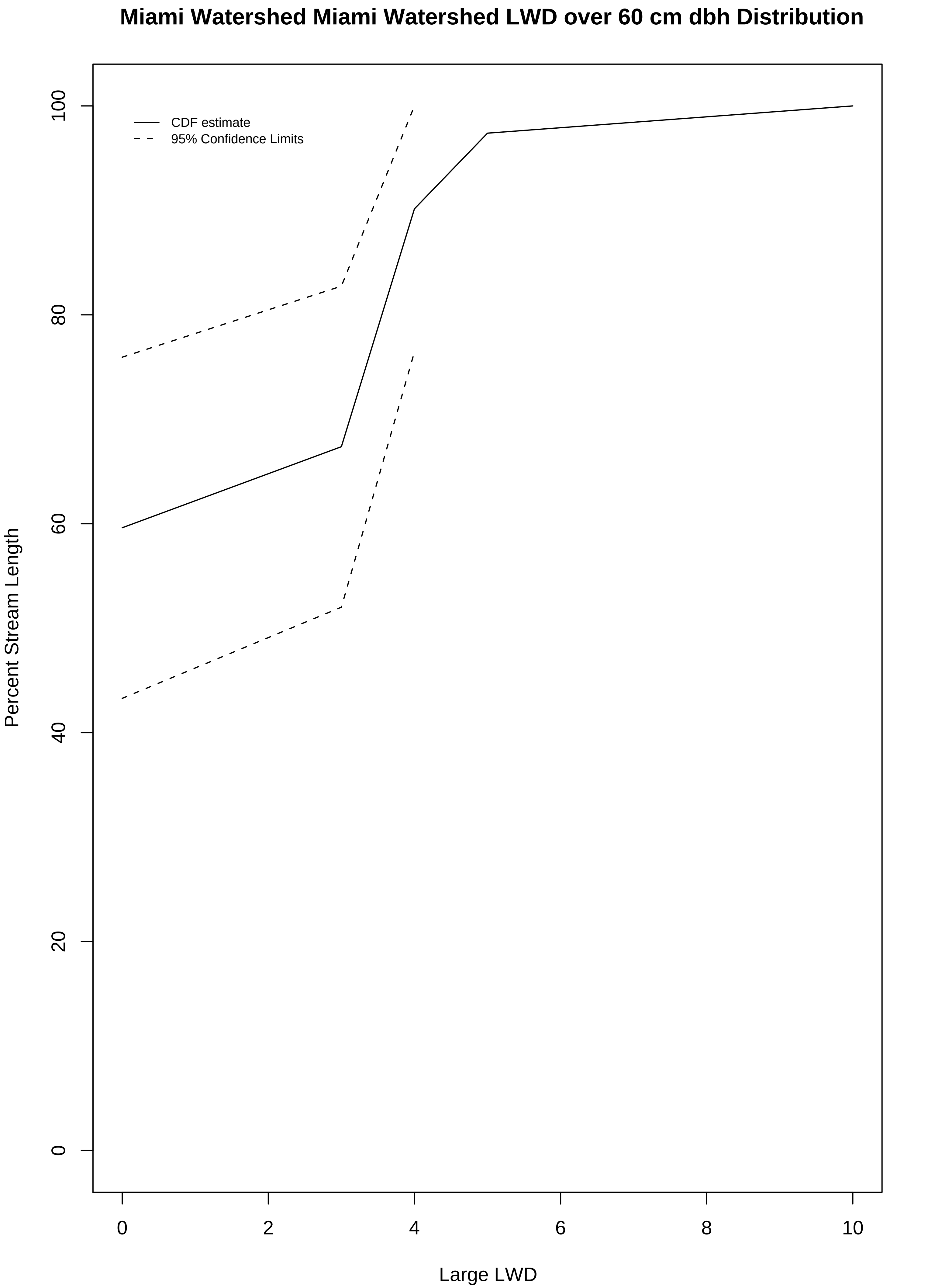

Miami Watershed %Large Boudlers Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.02
0.04
0.06
0.08
%Large Boulders

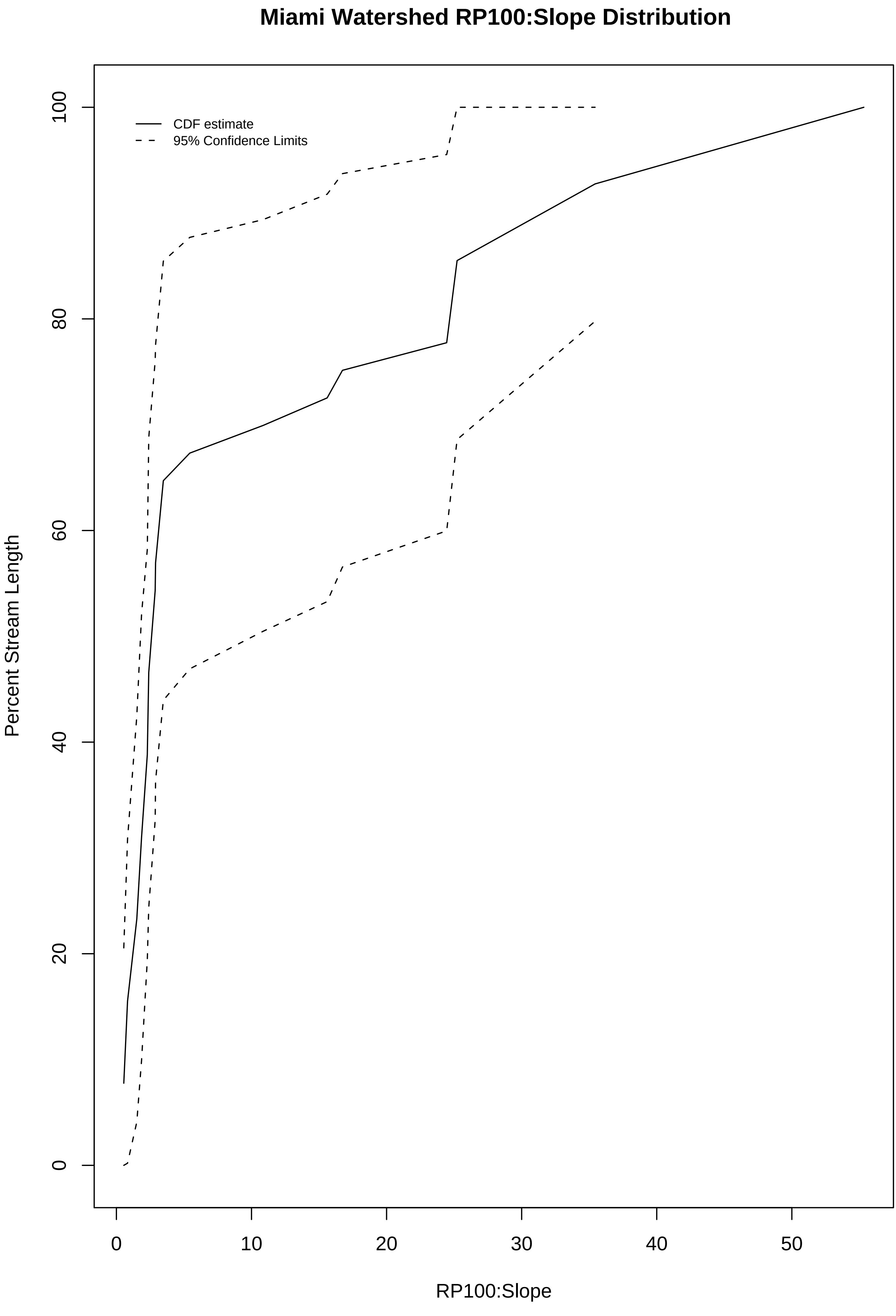


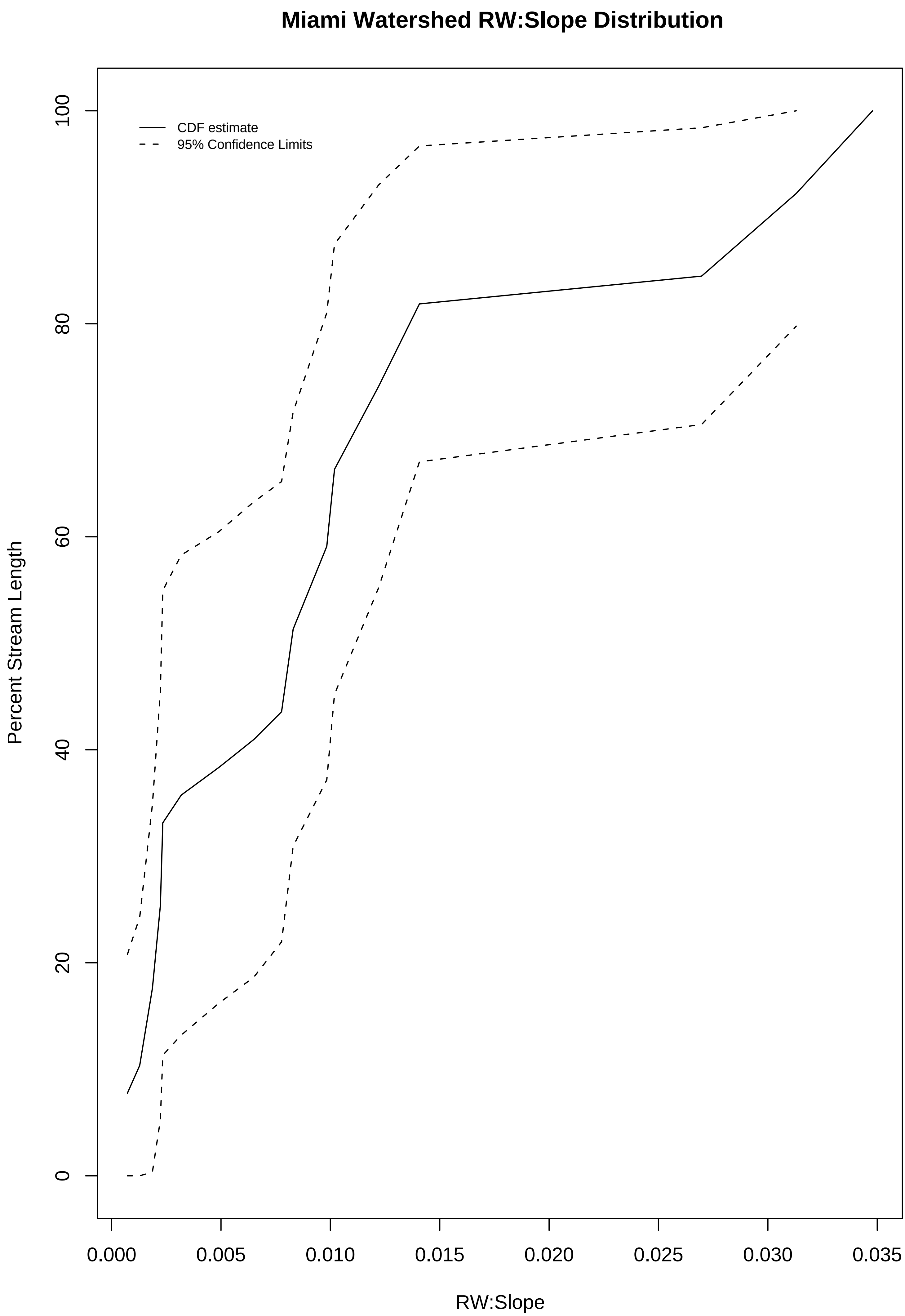
Miami Watershed W.D:RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
1
2
3
4
5
6
W.D:RP100

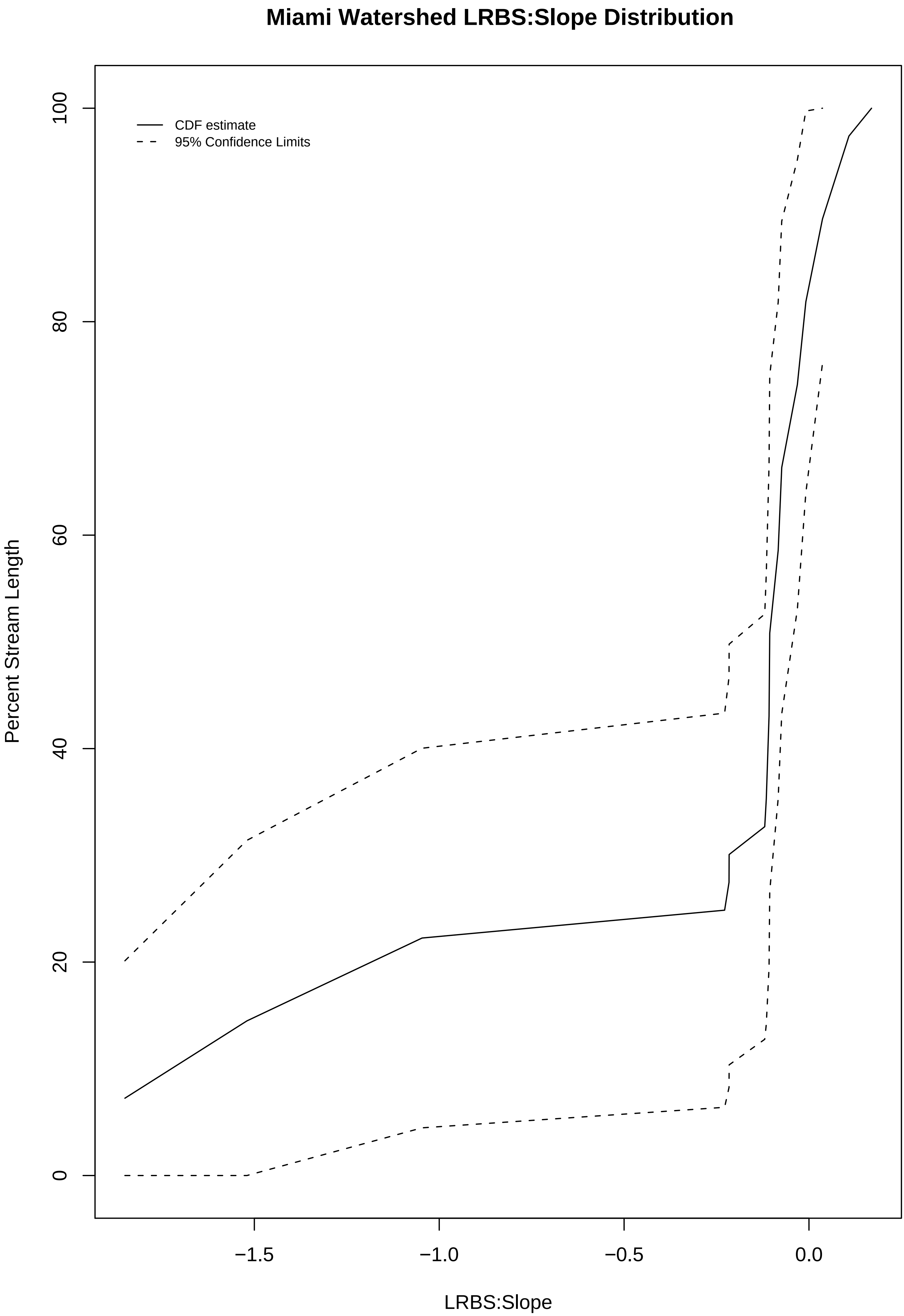


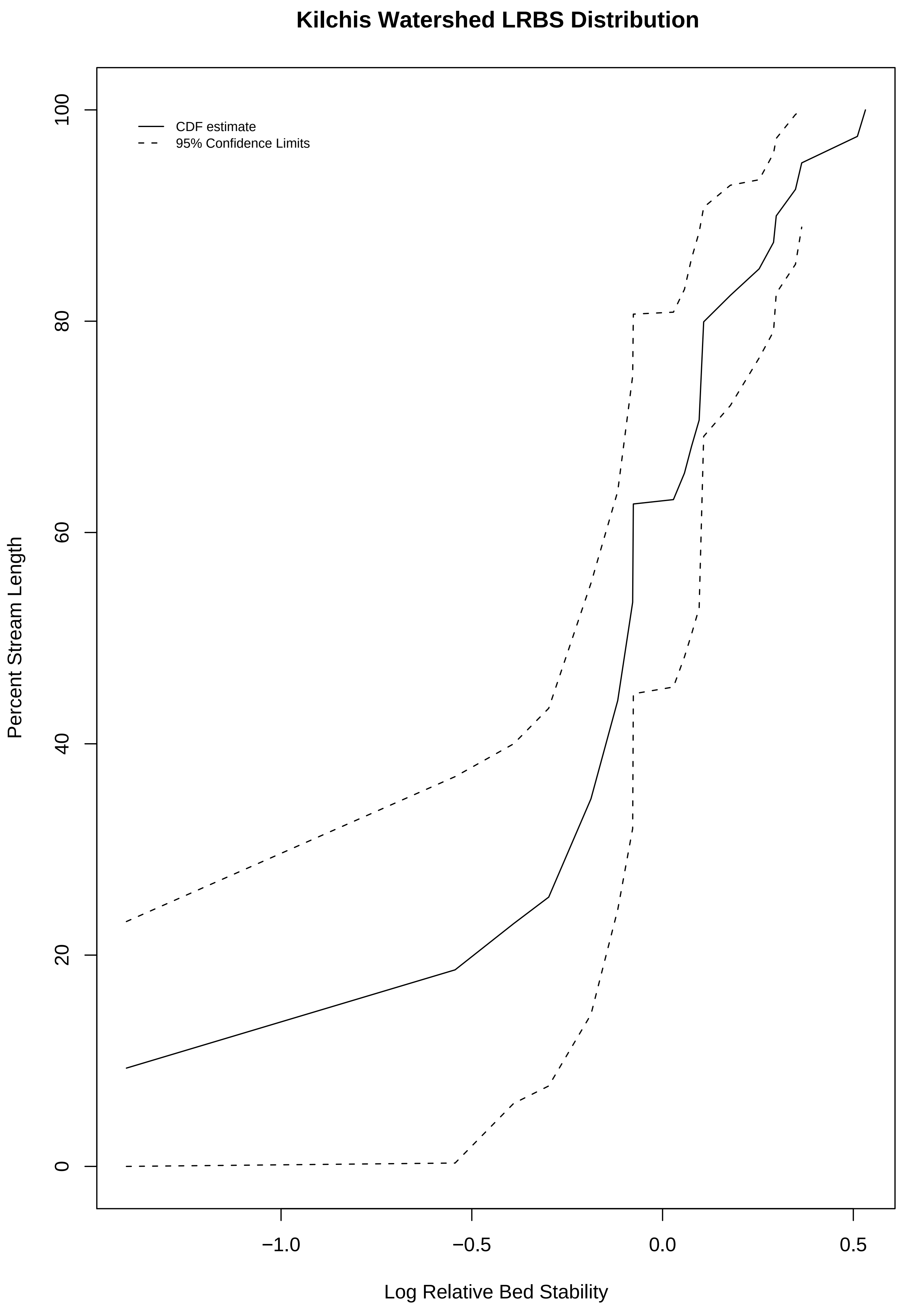
Miami Watershed LWD over 60 cm dbh & 15m length Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
5
10
15
Very Large LWD

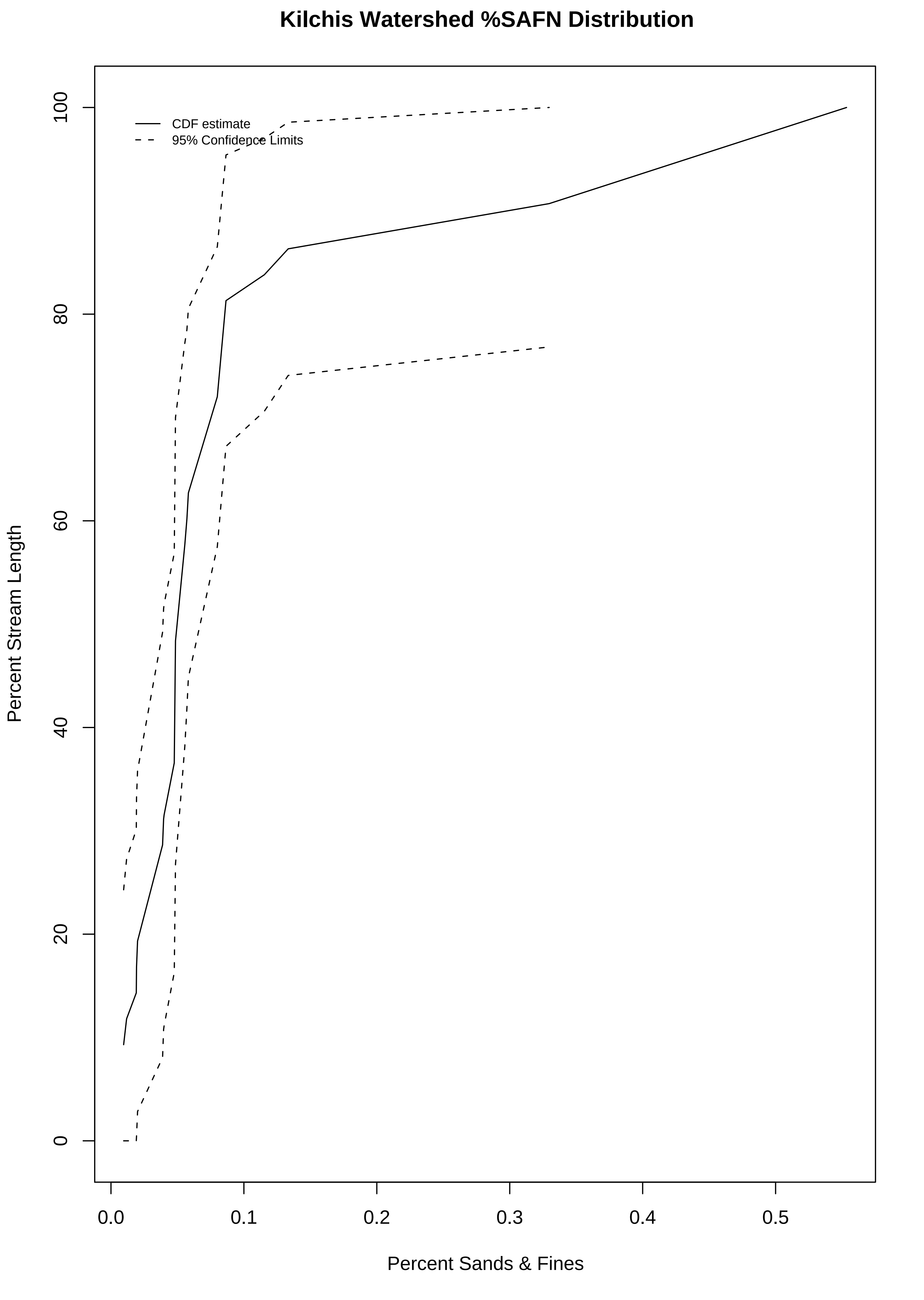

Miami Watershed Miami Watershed LWD over 60 cm dbh Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
Large LWD
0
20
40
60
80
100
0
2
4
6
8
10

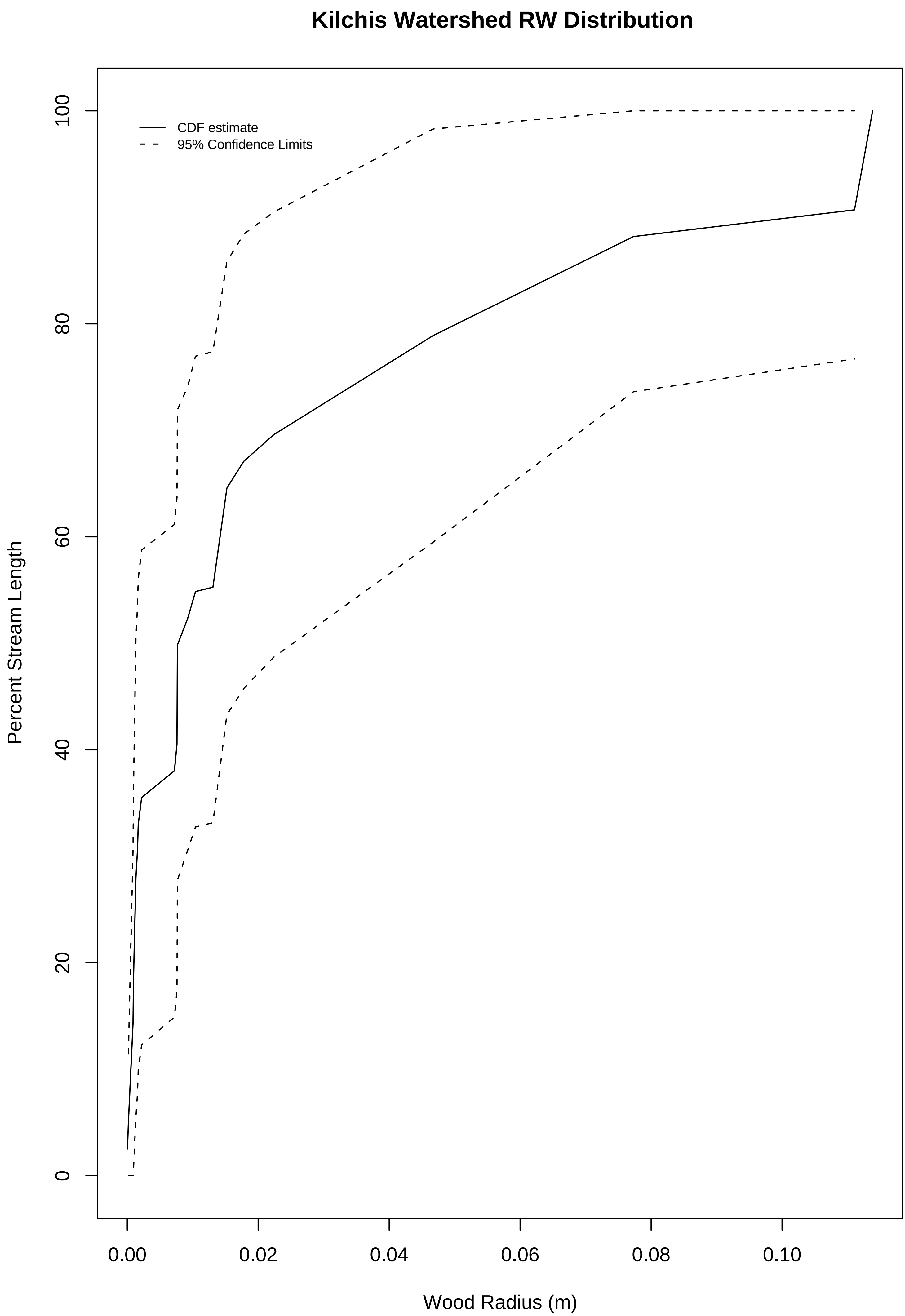

Miami Watershed RP100:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
10
20
30
40
50
RP100:Slope


Miami Watershed RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
RW:Slope


Miami Watershed LRBS:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−1.5
−1.0
−0.5
0.0
LRBS:Slope

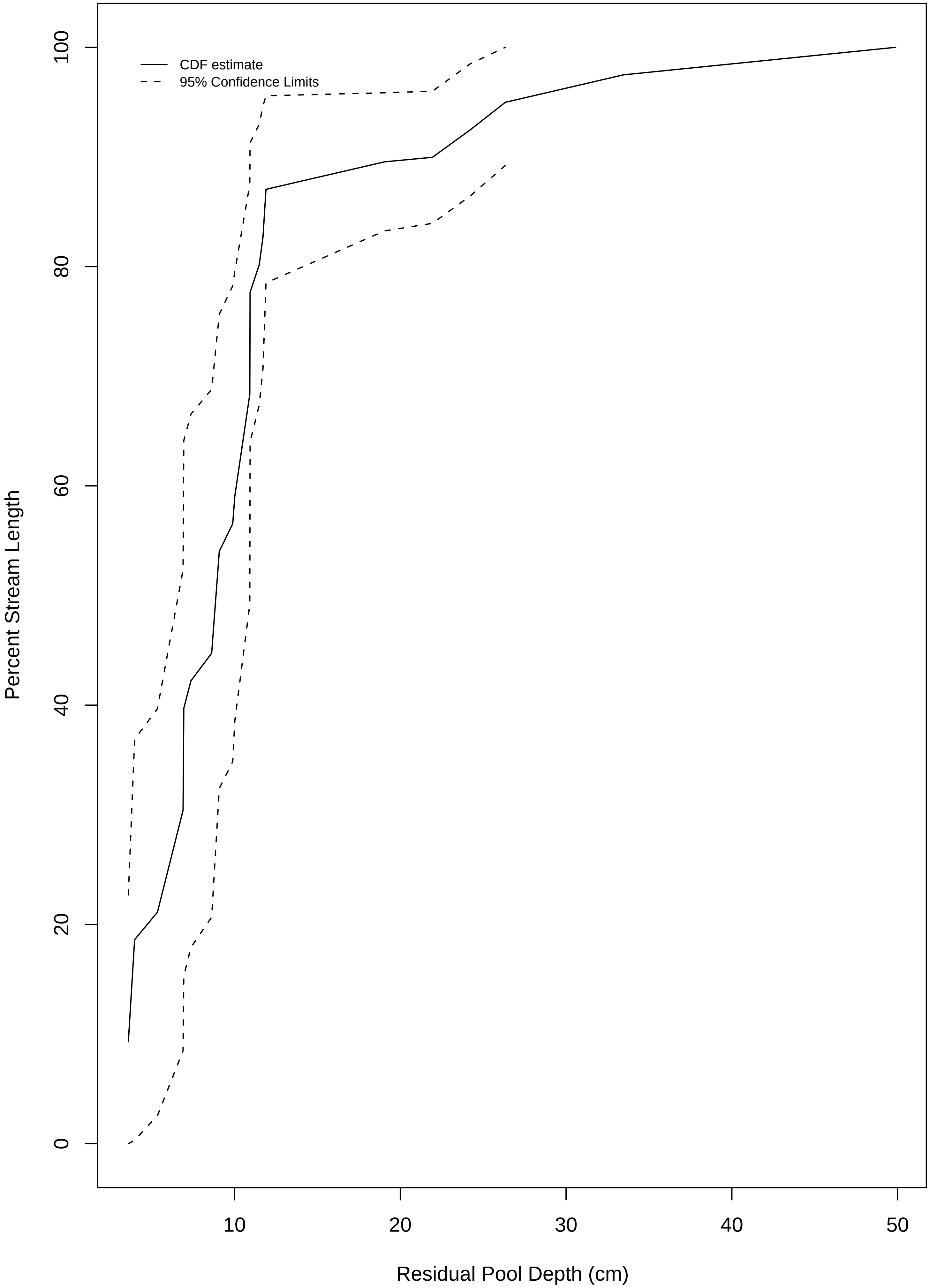

Kilchis Watershed LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−1.0
−0.5
0.0
0.5
Log Relative Bed Stability

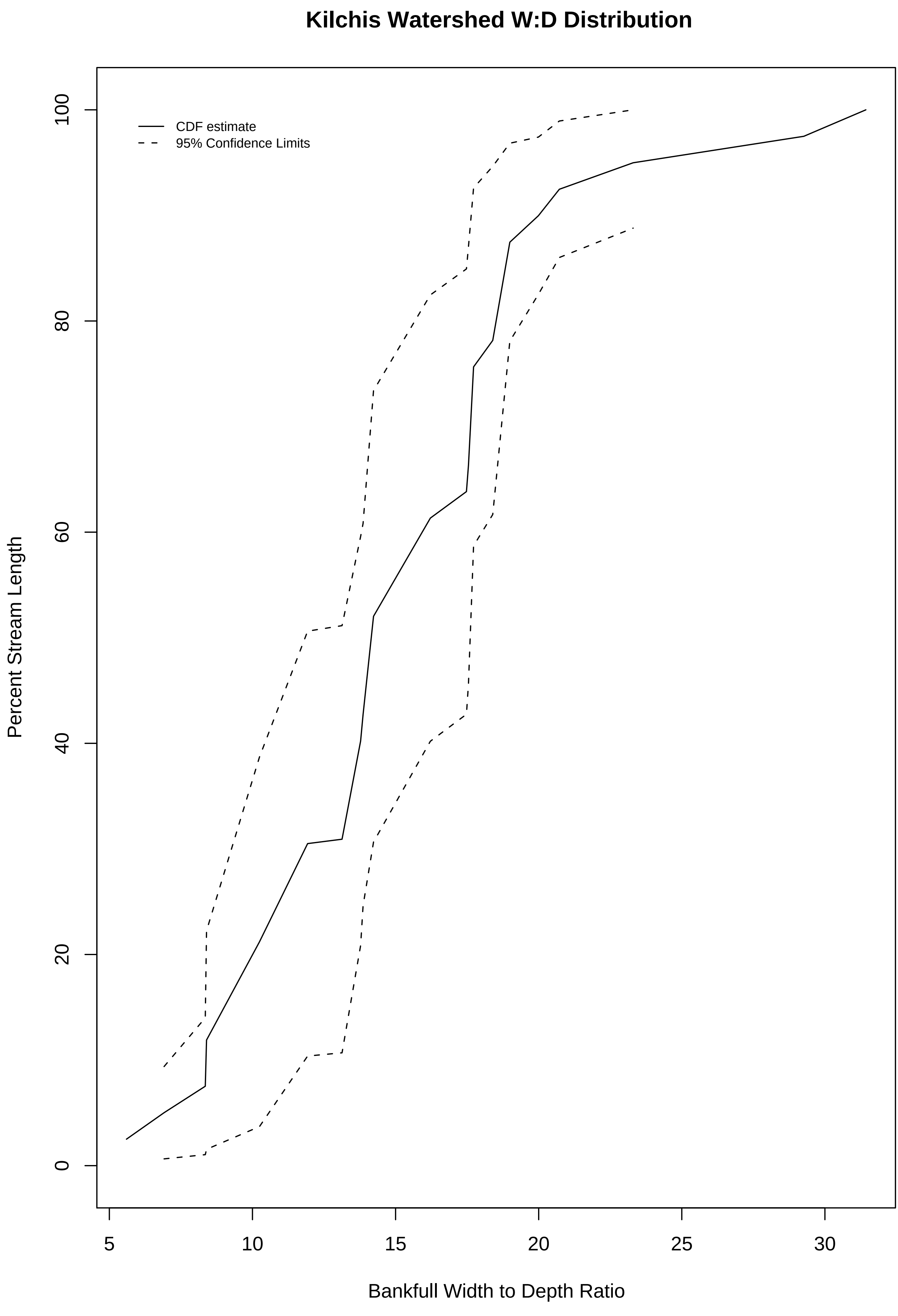

Kilchis Watershed %SAFN Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
Percent Sands & Fines



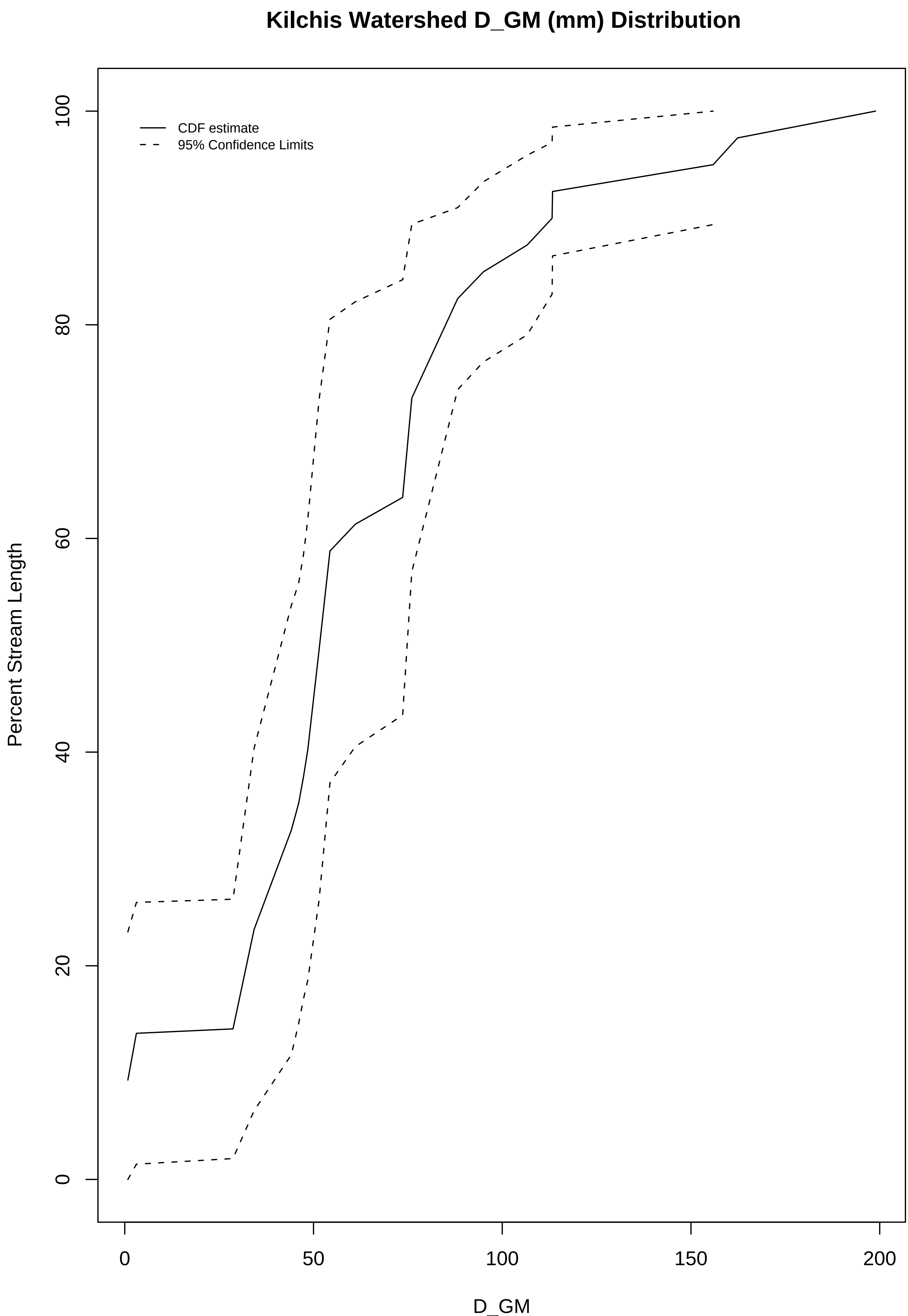
Kilchis Watershed RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.02
0.04
0.06
0.08
0.10
Wood Radius (m)

Kilchis Watershed RP100 Distribution

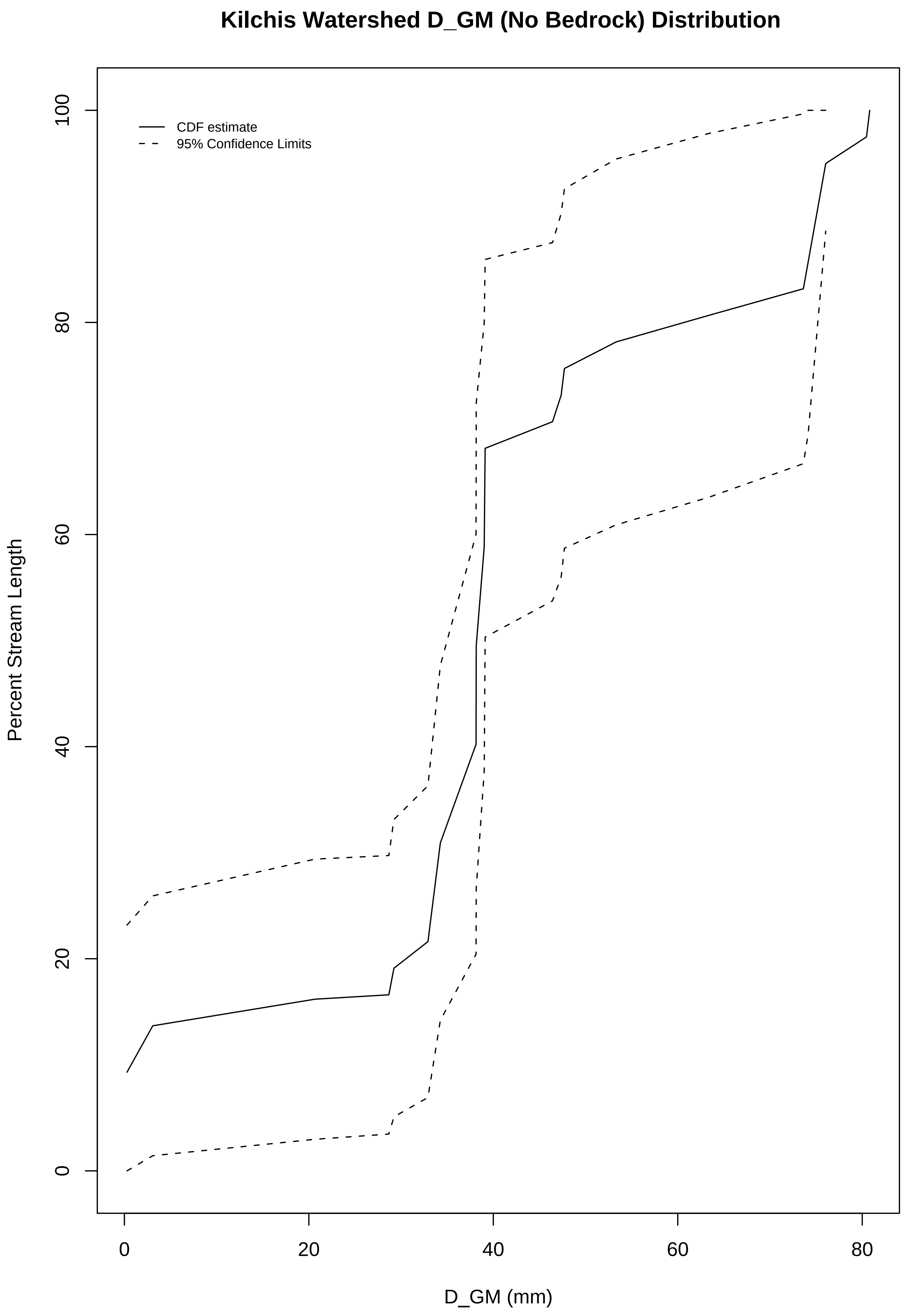




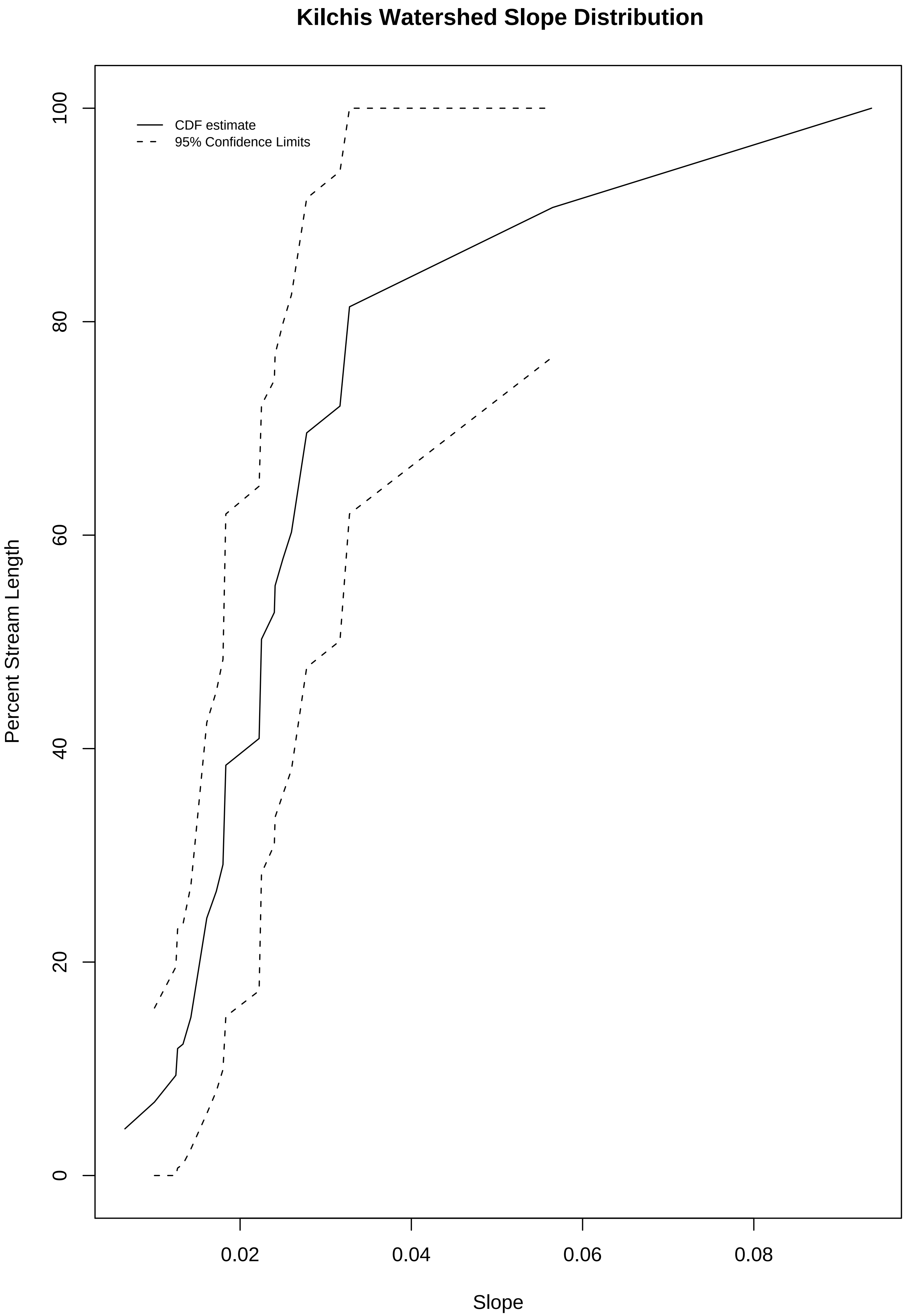
Kilchis Watershed W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
5
10
15
20
25
30
Bankfull Width to Depth Ratio

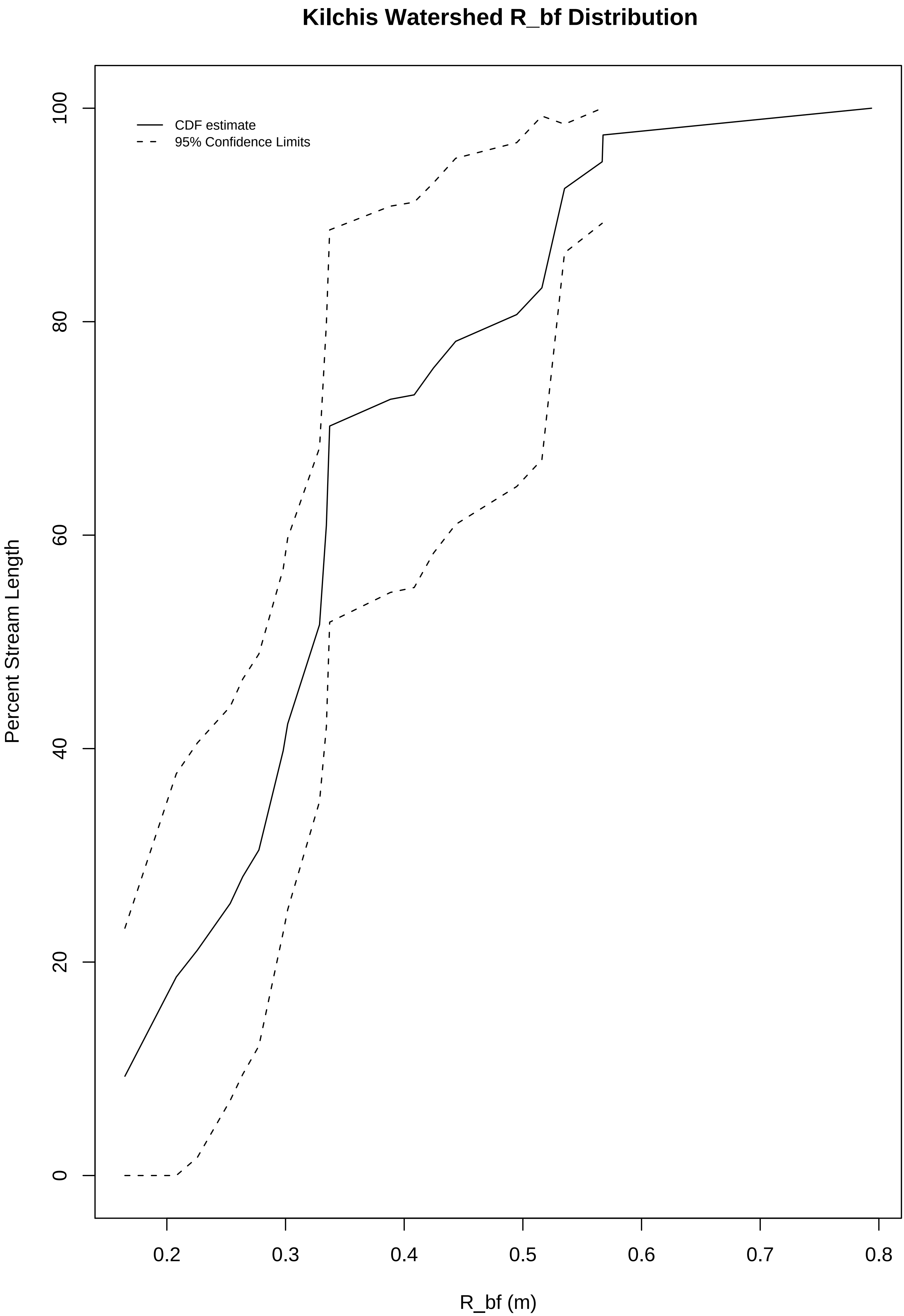


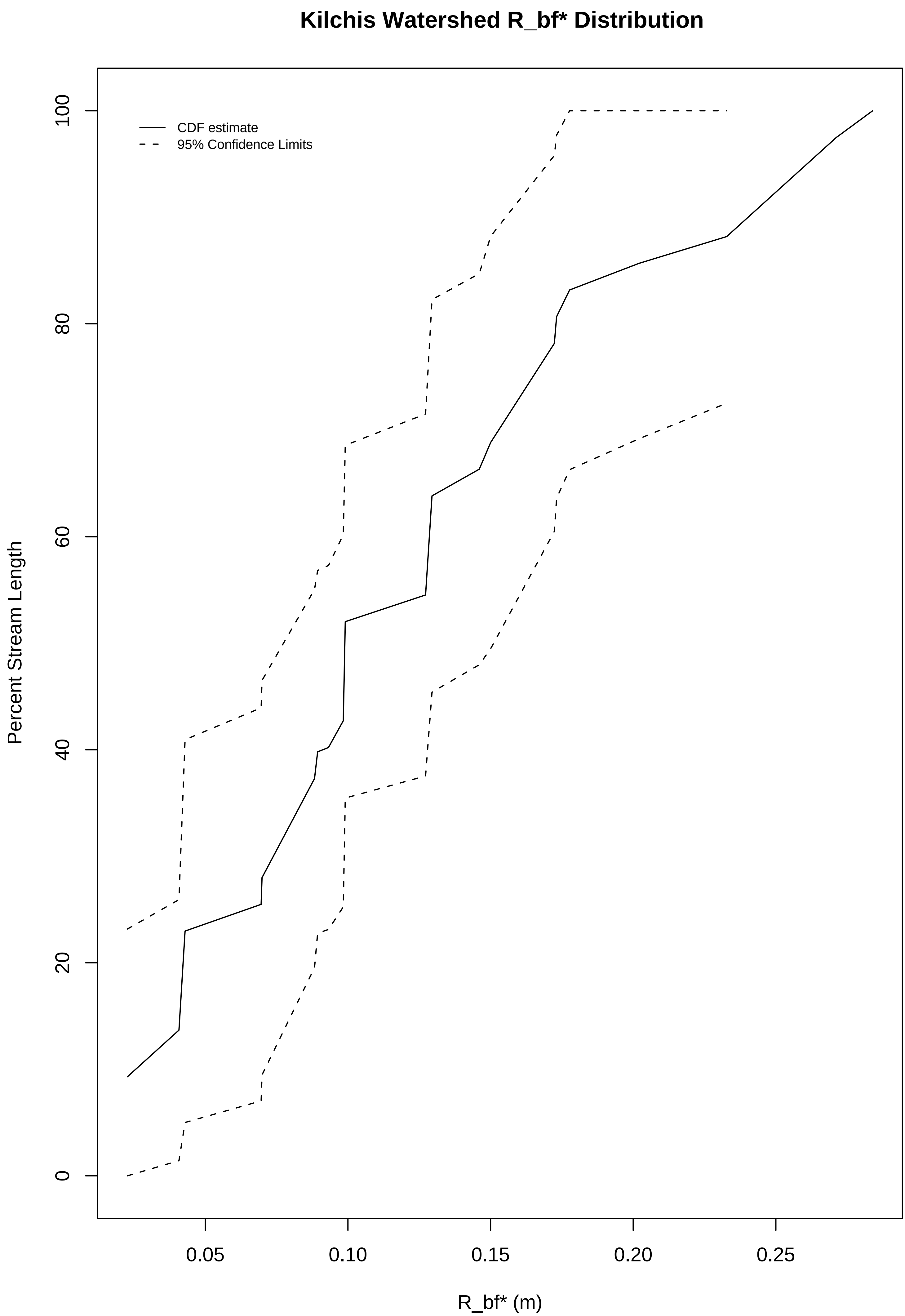
Kilchis Watershed D_GM (mm) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
50
100
150
200
D_GM



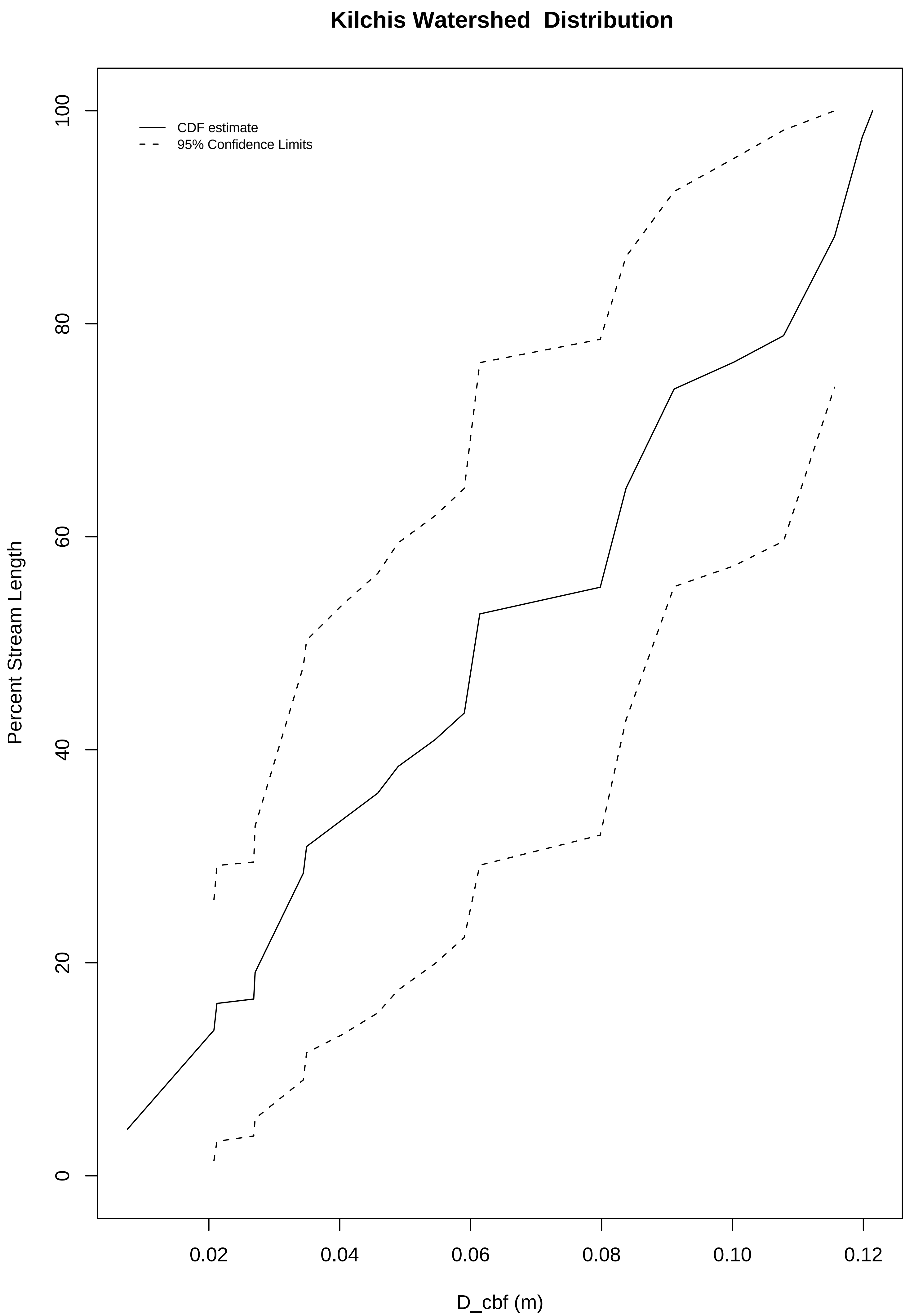
Kilchis Watershed D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
D_GM (mm)
0
20
40
60
80


Kilchis Watershed Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.02
0.04
0.06
0.08
Slope


Kilchis Watershed R_bf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.2
0.3
0.4
0.5
0.6
0.7
0.8
R_bf (m)

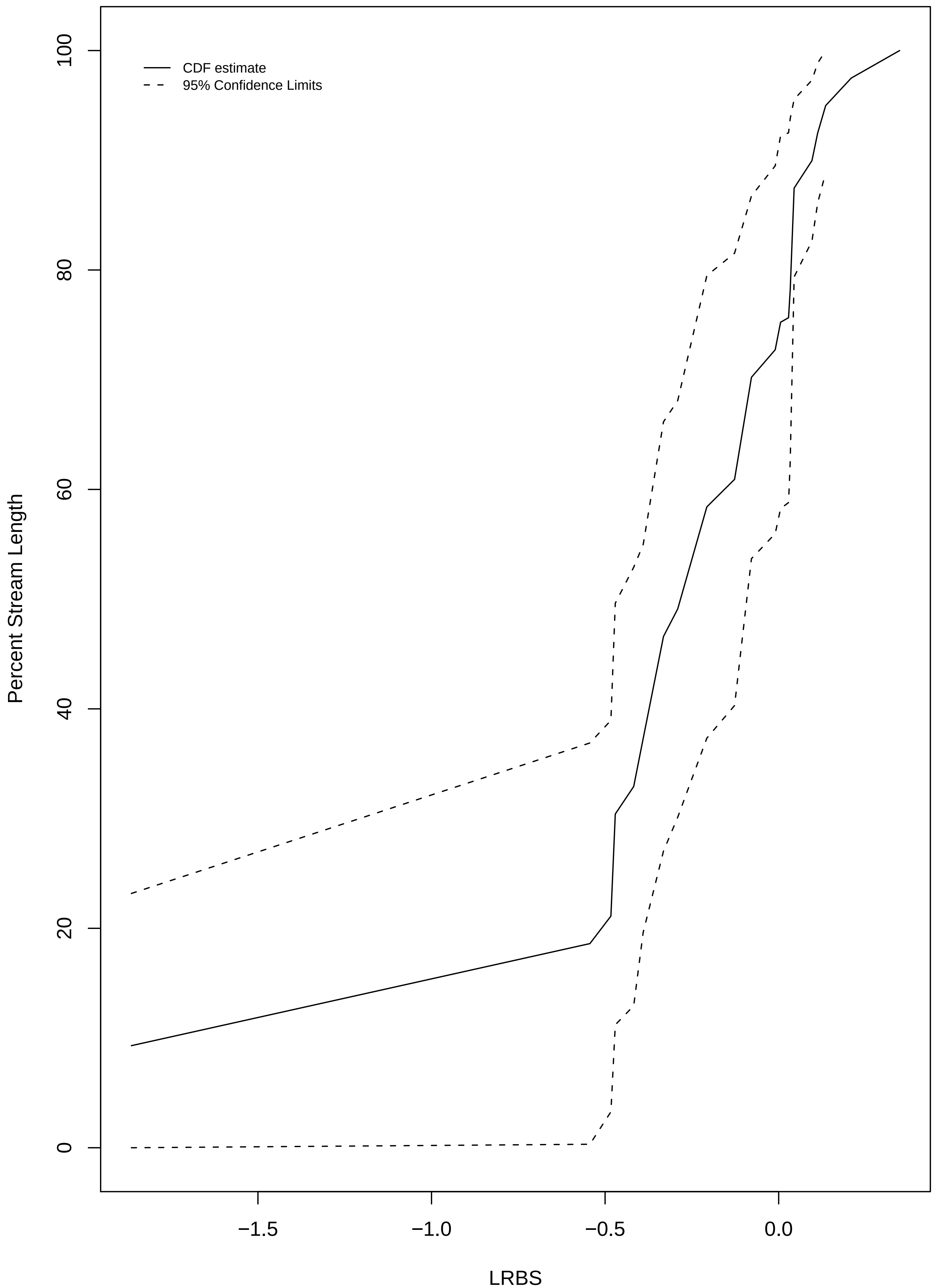


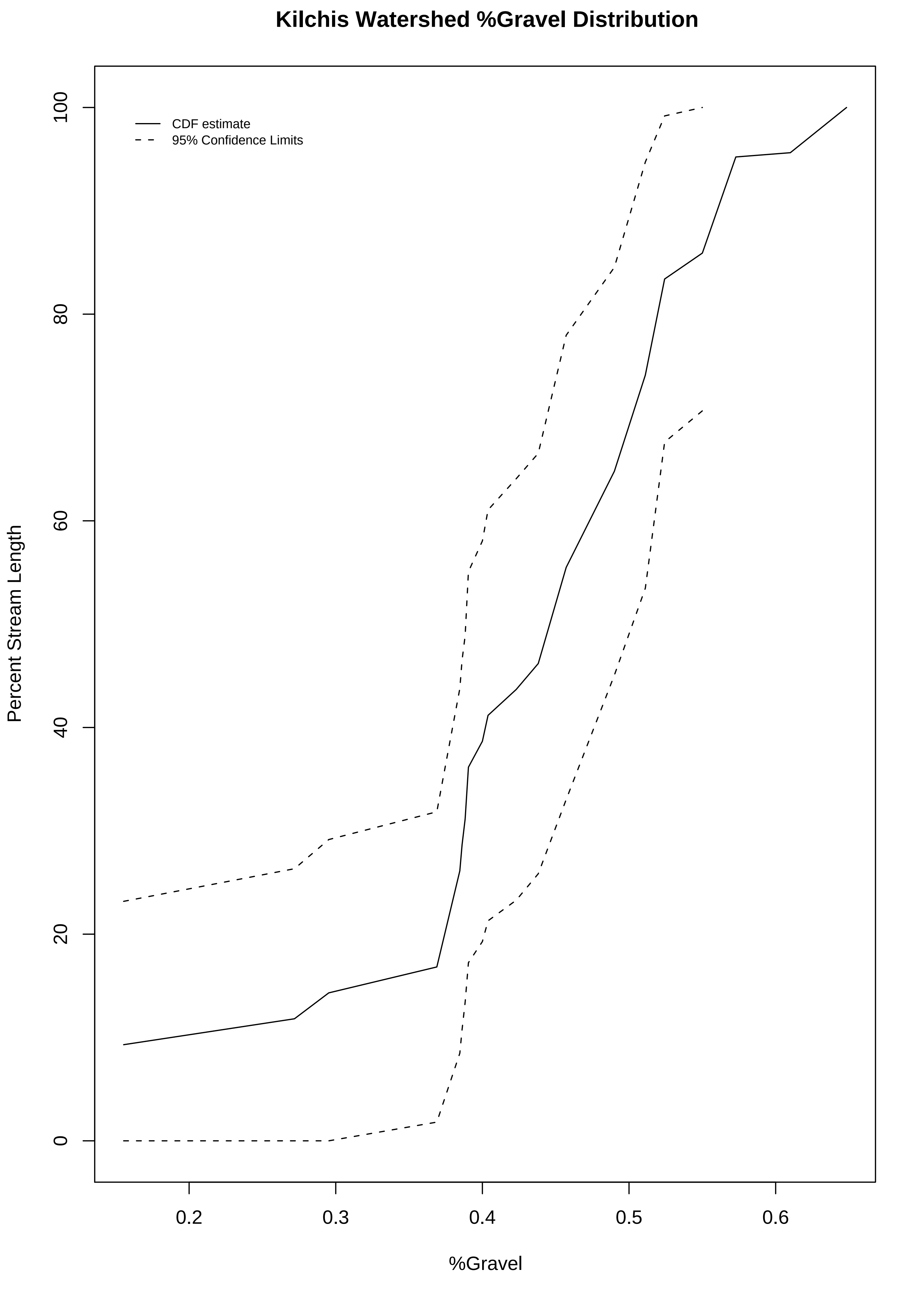
Kilchis Watershed R_bf* Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.05
0.10
0.15
0.20
0.25
R_bf* (m)



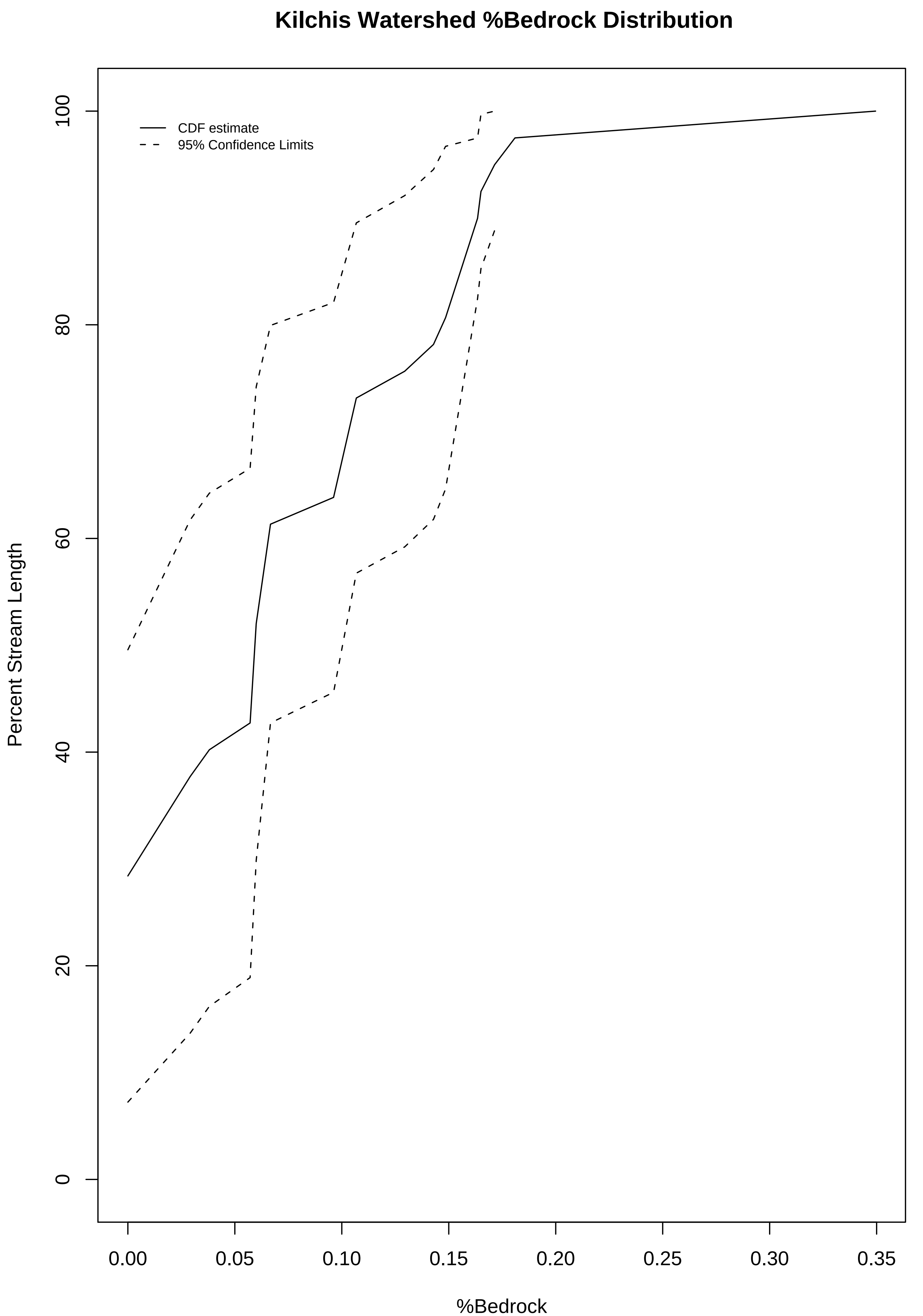
Kilchis Watershed Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.02
0.04
0.06
0.08
0.10
0.12
D_cbf (m)

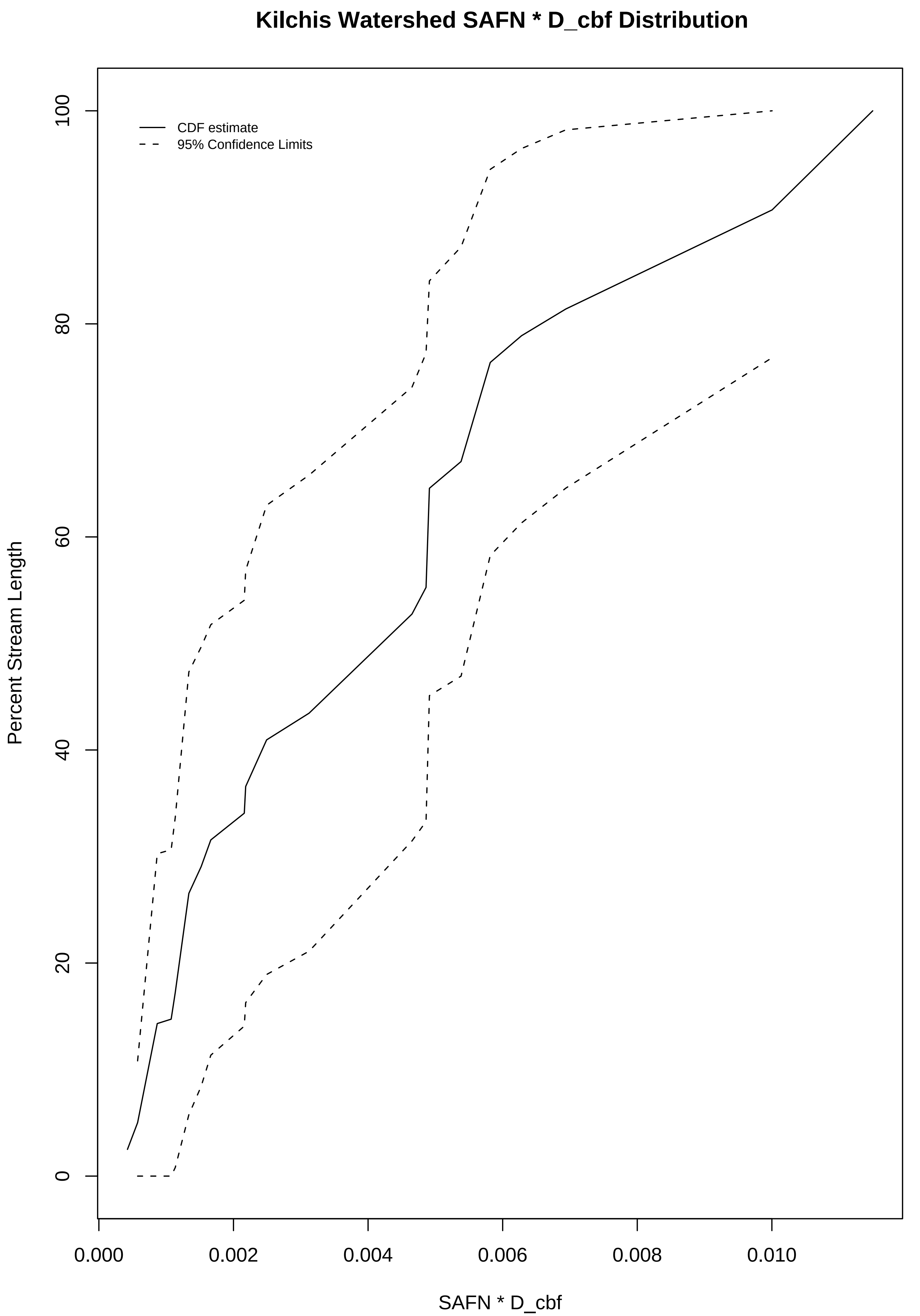
Kilchis Watershed LRBS (No Bedrock) Distribution



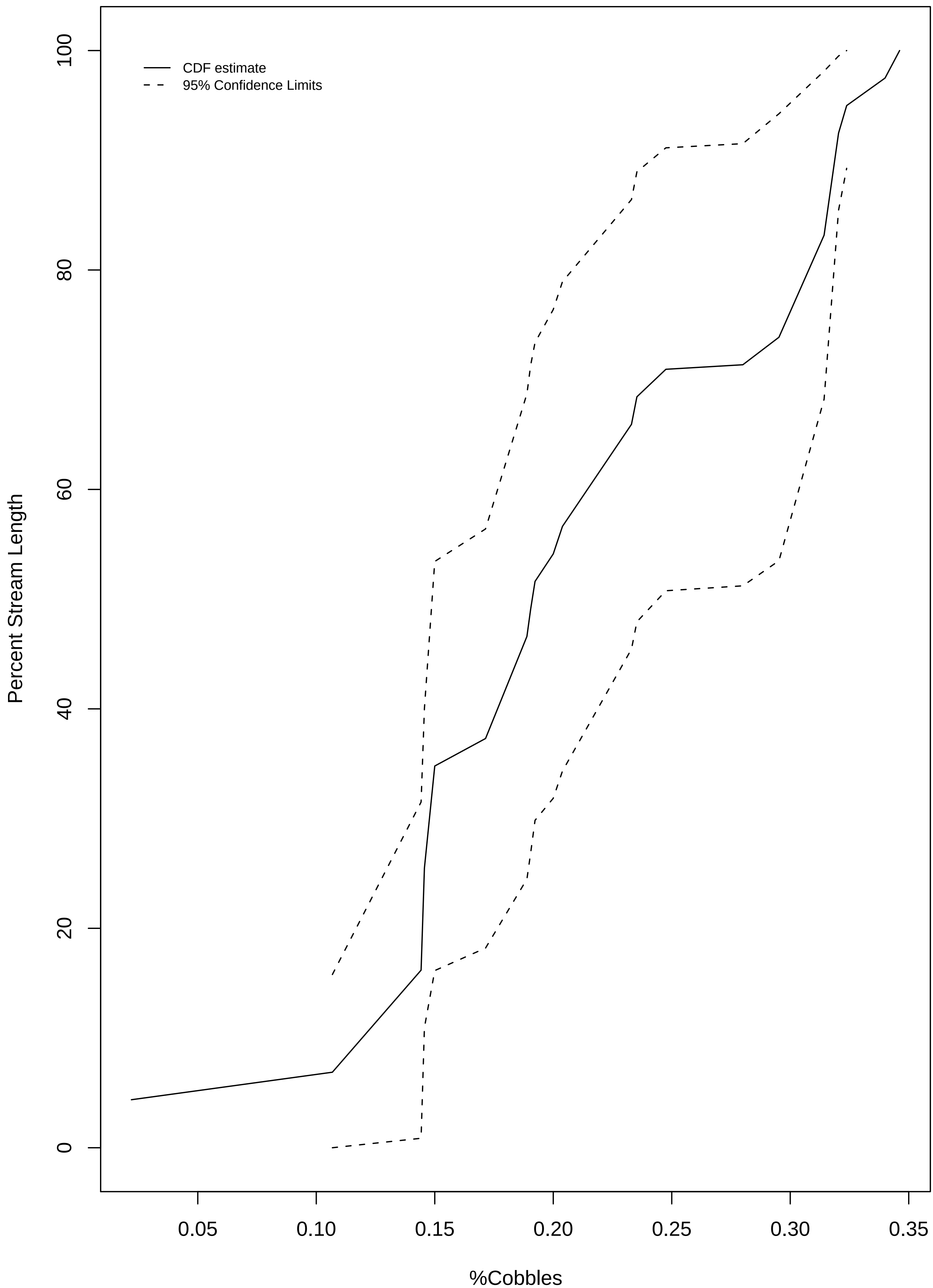


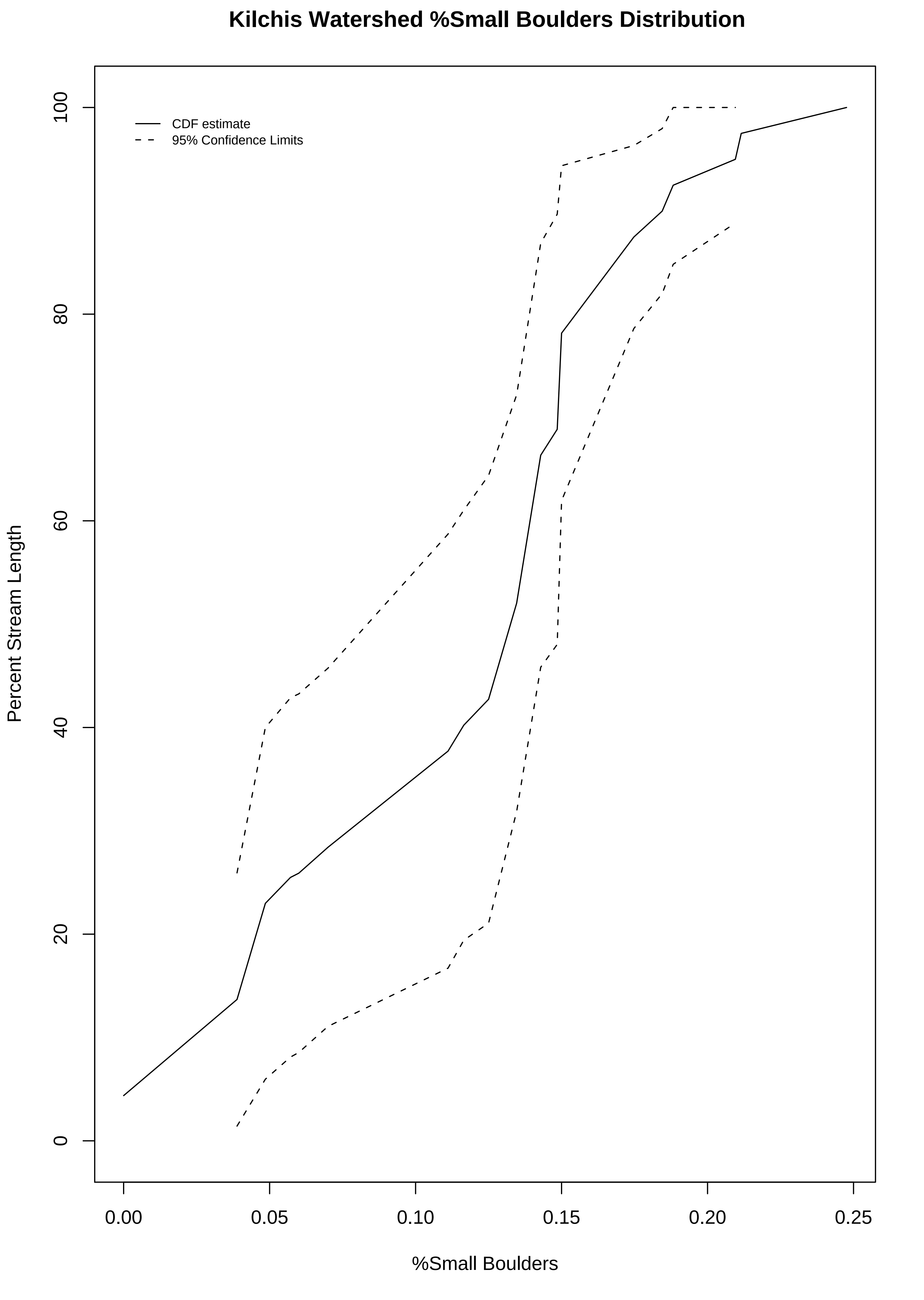
Kilchis Watershed %Gravel Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.2
0.3
0.4
0.5
0.6
%Gravel

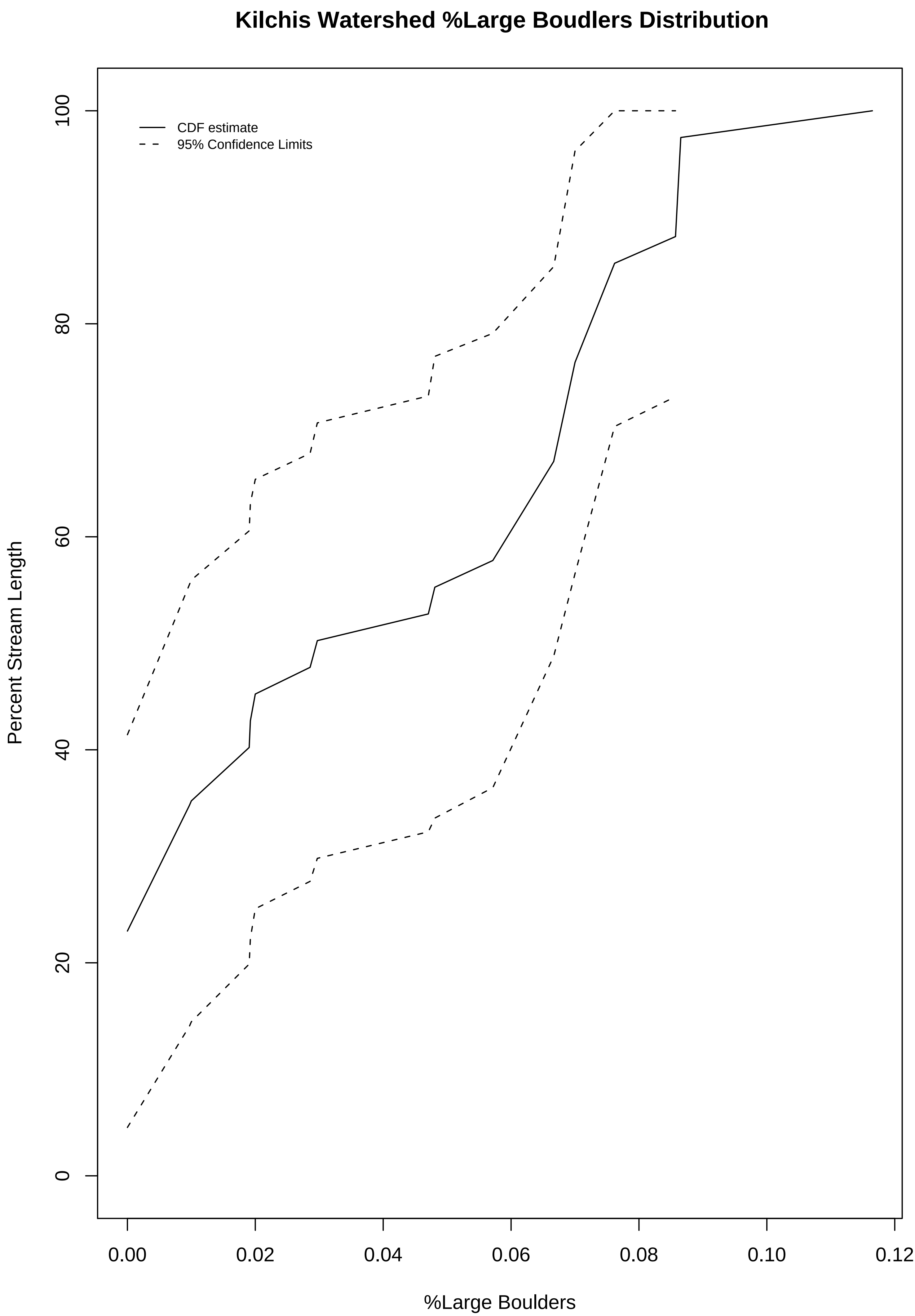

Kilchis Watershed %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
%Bedrock

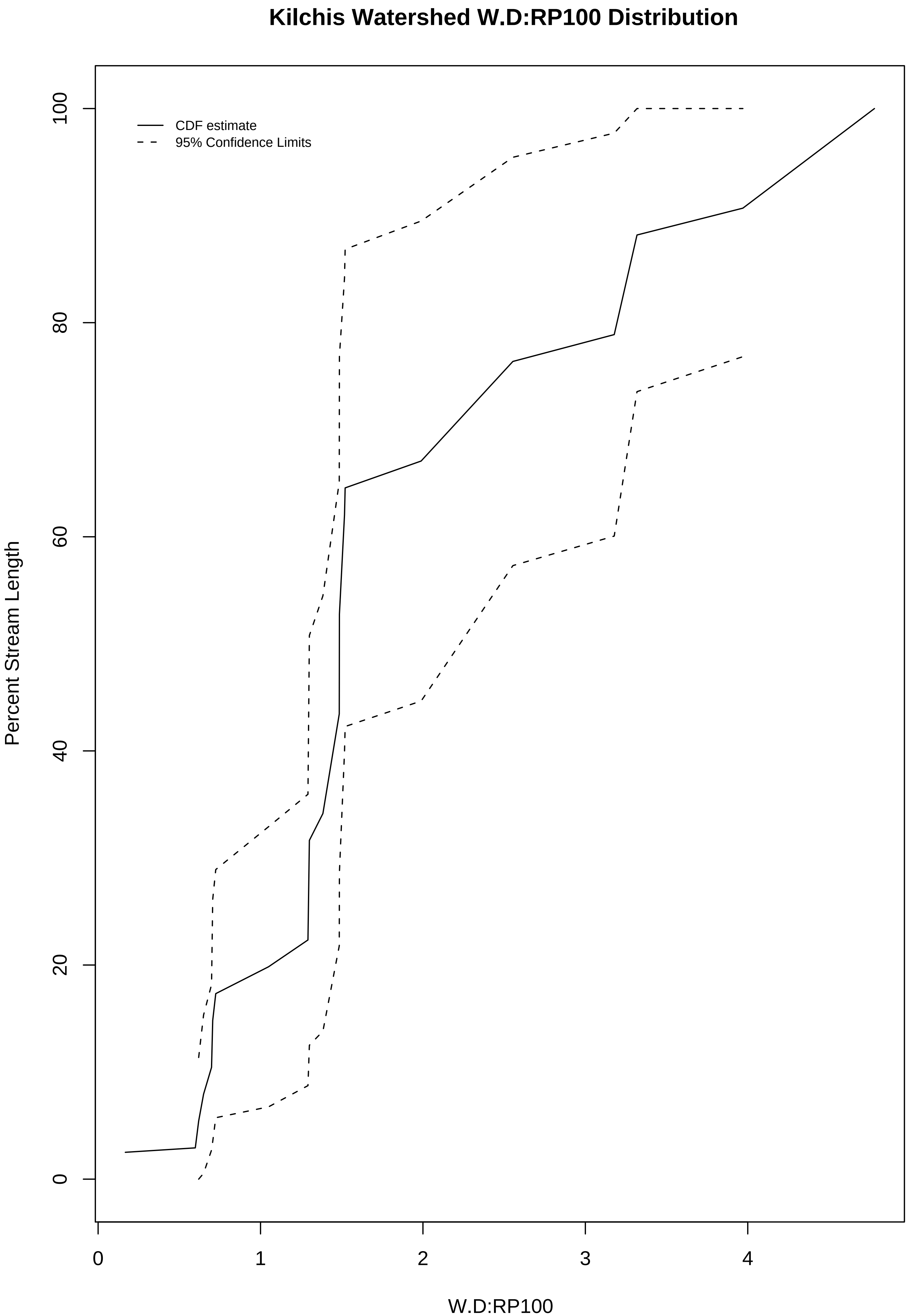

Kilchis Watershed SAFN * D_cbf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.000
0.002
0.004
0.006
0.008
0.010
SAFN * D_cbf

Kilchis Watershed %Cobbles Distribution

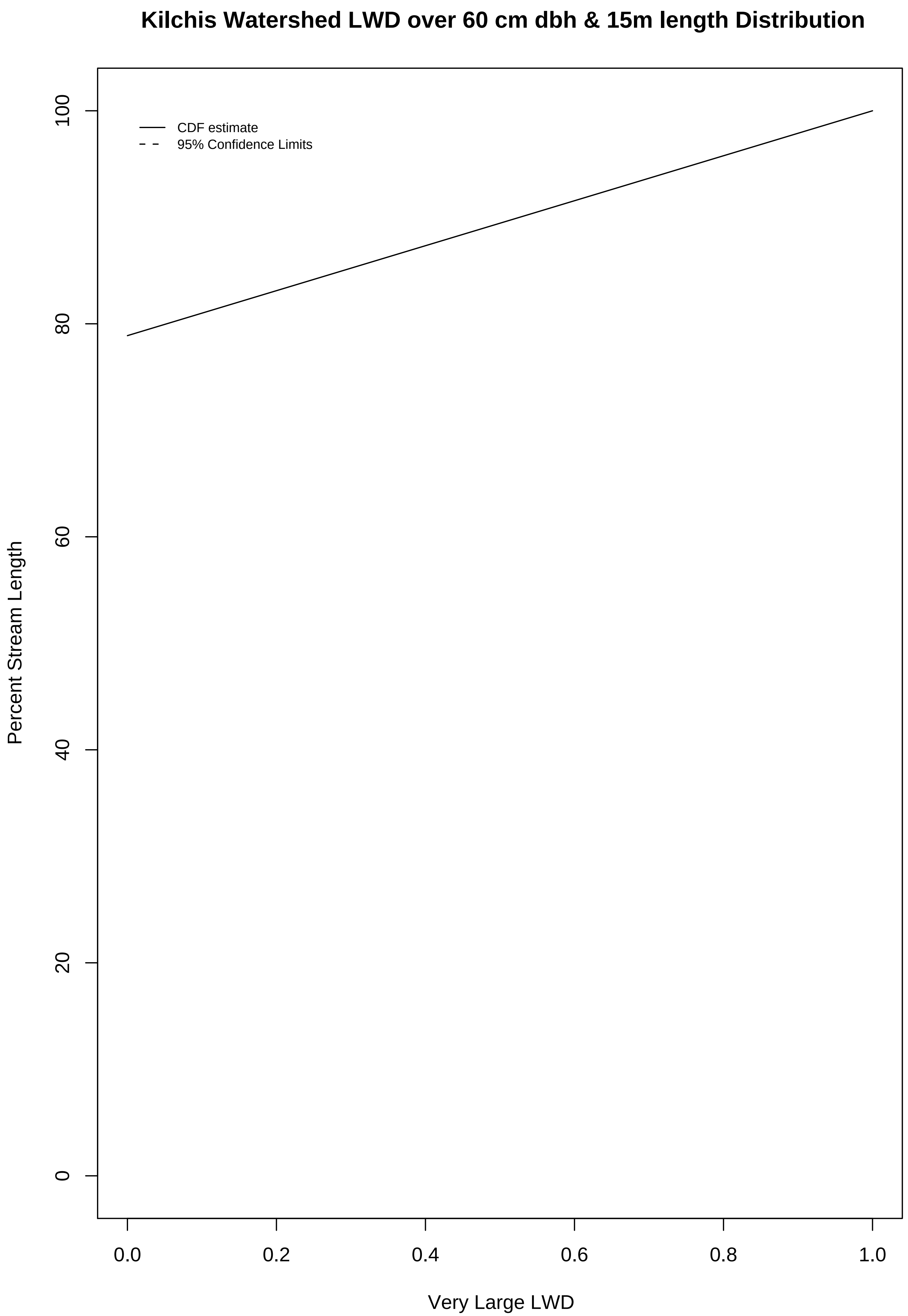


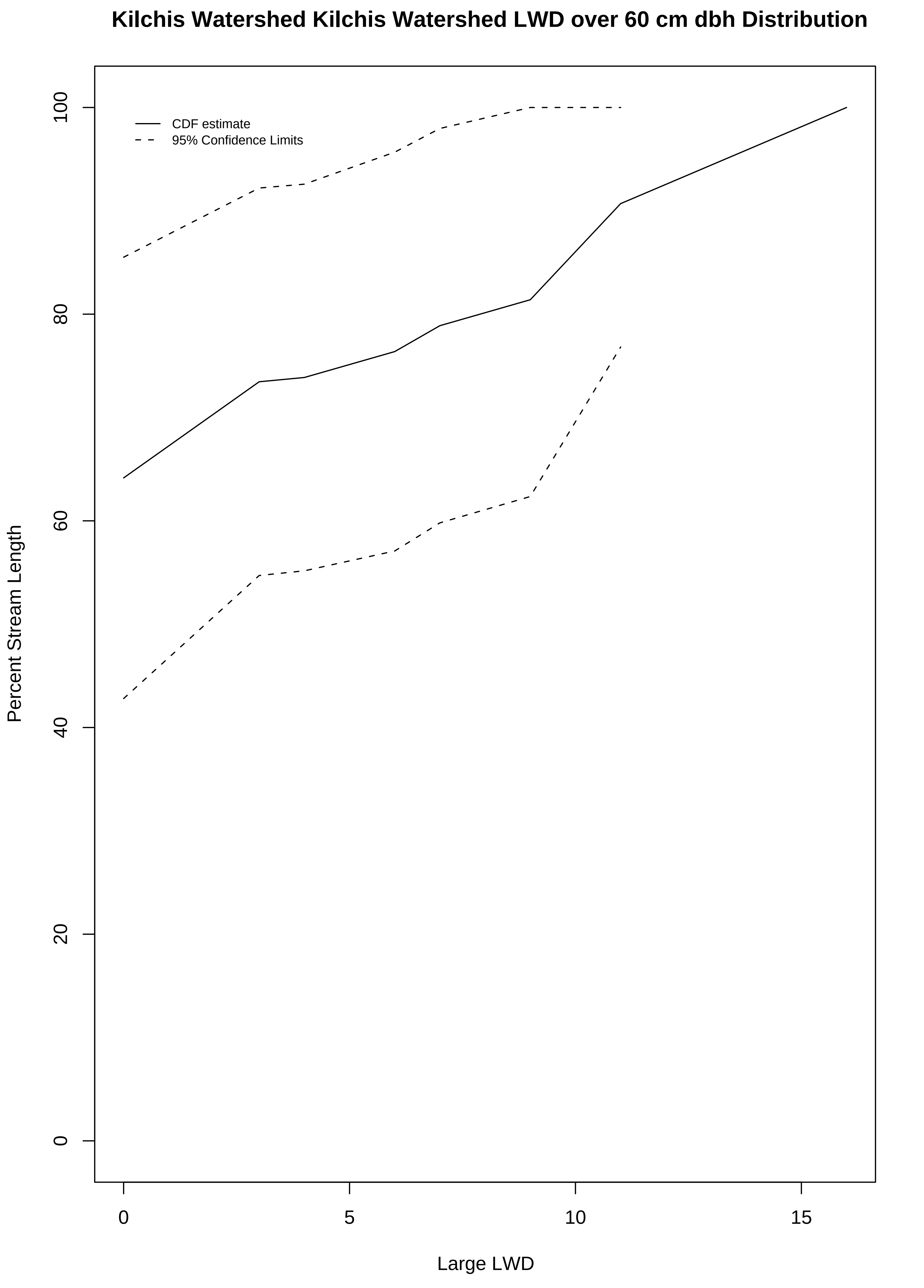

Kilchis Watershed %Small Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
%Small Boulders


Kilchis Watershed %Large Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
%Large Boulders
0
20
40
60
80
100
0.00
0.02
0.04
0.06
0.08
0.10
0.12

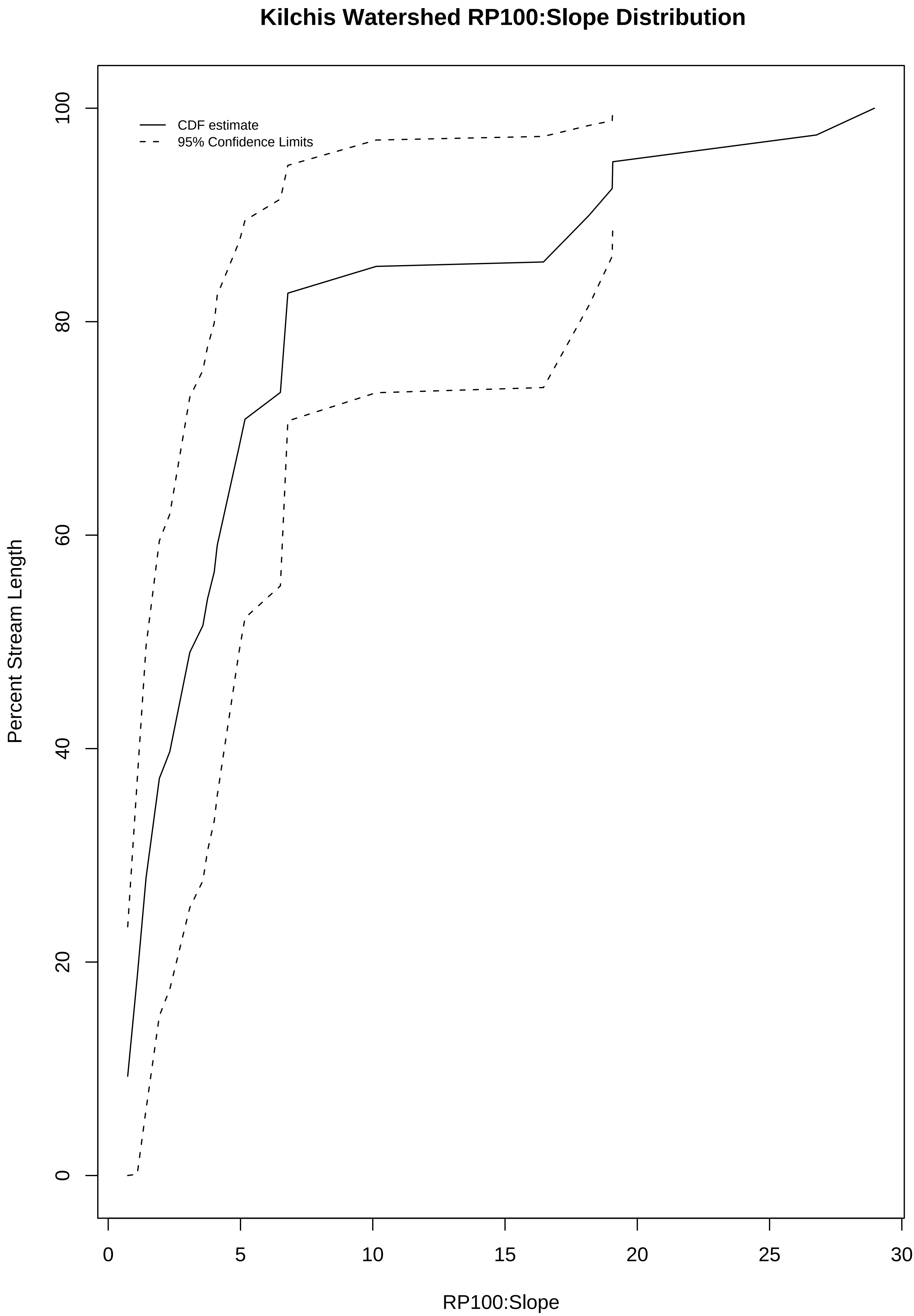


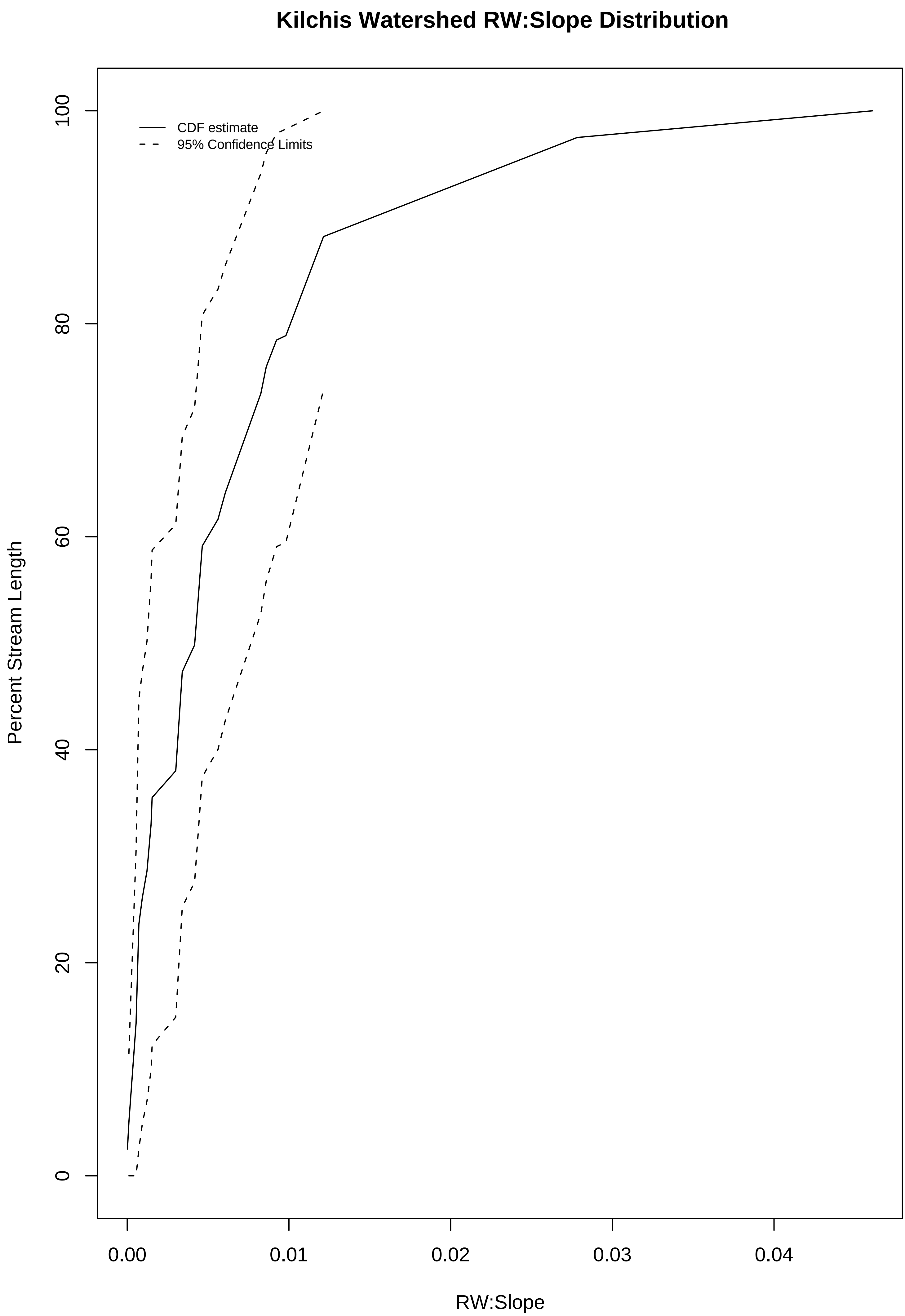
Kilchis Watershed W.D:RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
W.D:RP100
0
20
40
60
80
100
0
1
2
3
4


Kilchis Watershed LWD over 60 cm dbh & 15m length Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0
Very Large LWD

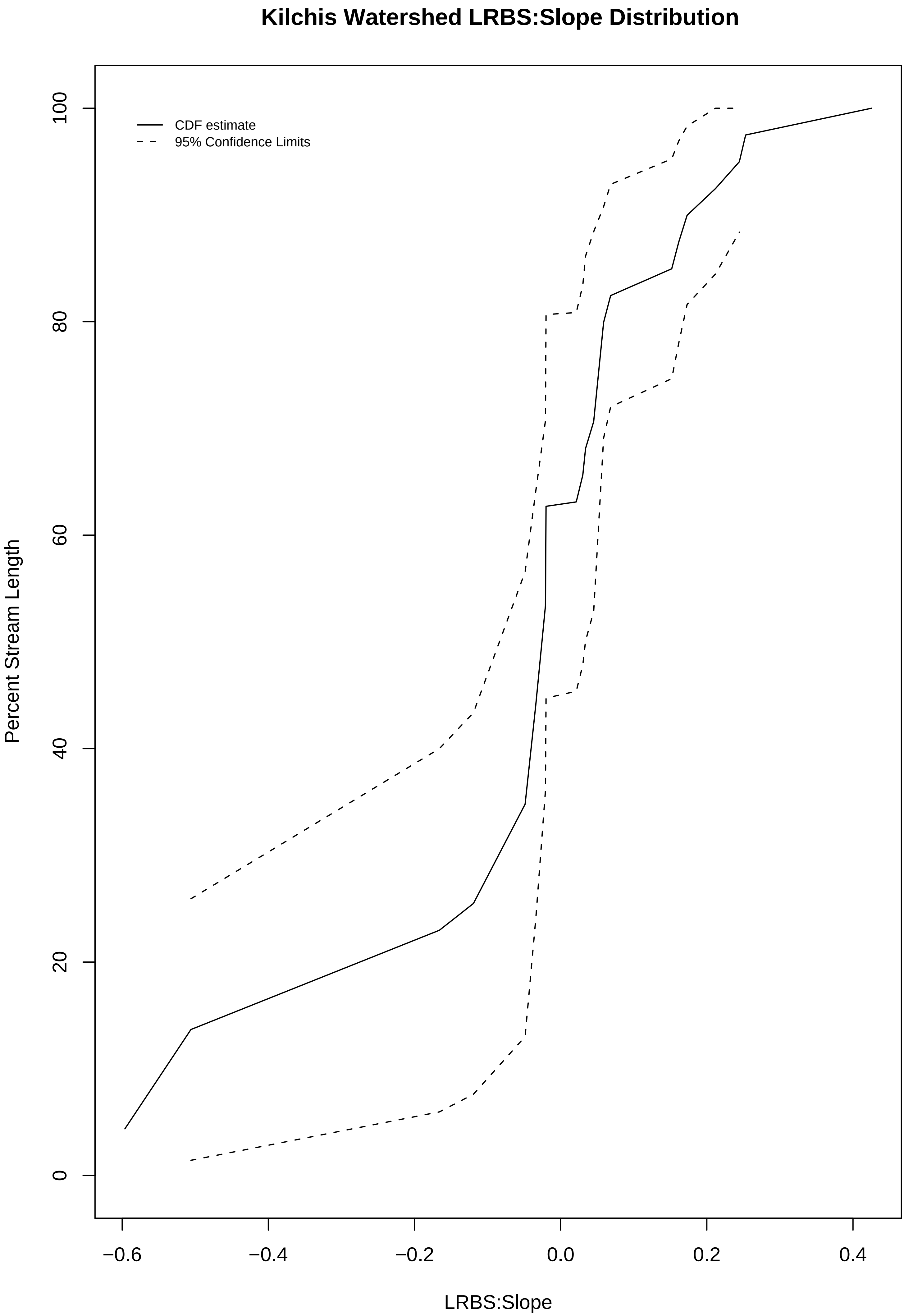


Kilchis Watershed Kilchis Watershed LWD over 60 cm dbh Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
5
10
15
Large LWD

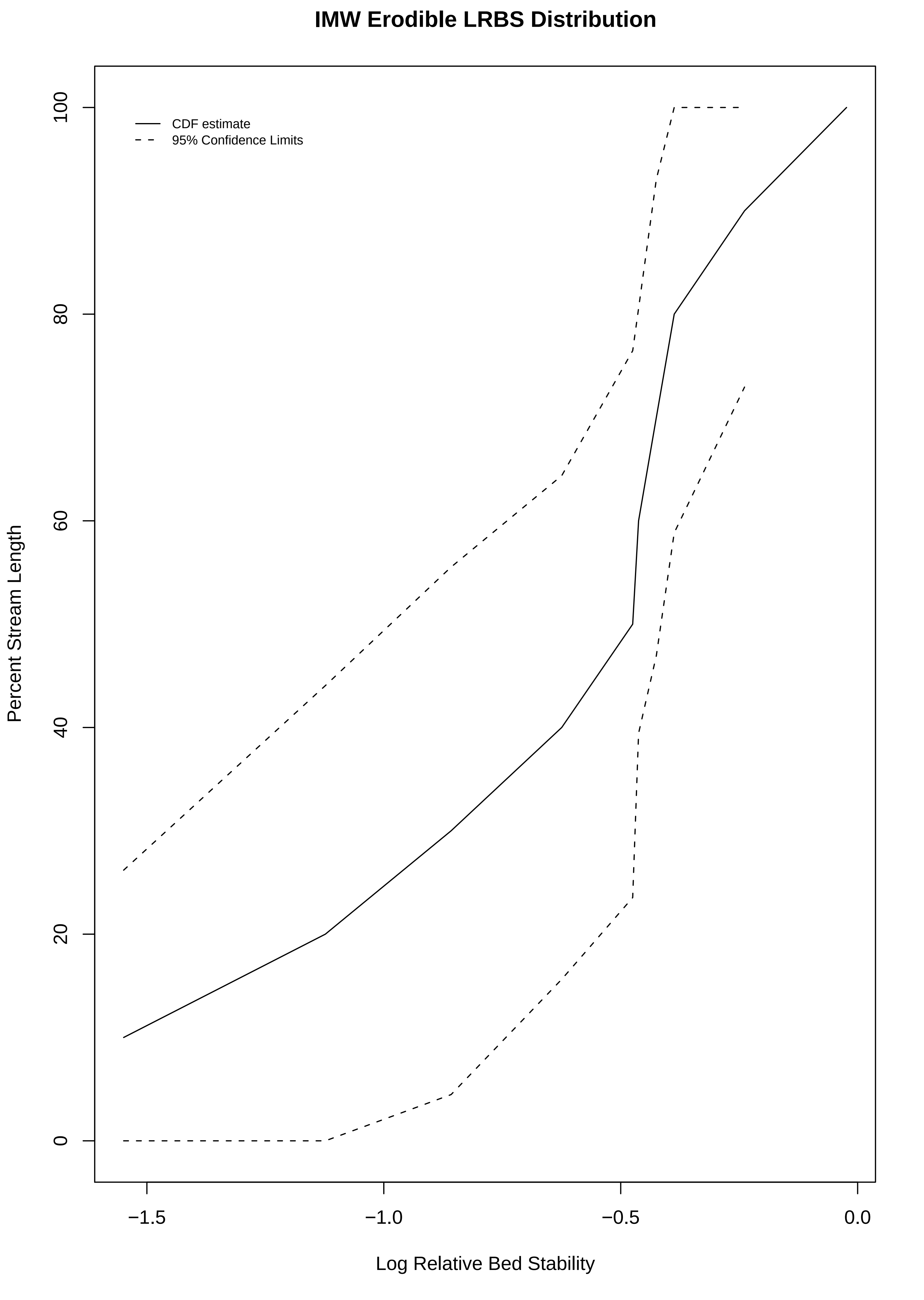

Kilchis Watershed RP100:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
RP100:Slope
0
5
10
15
20
25
30

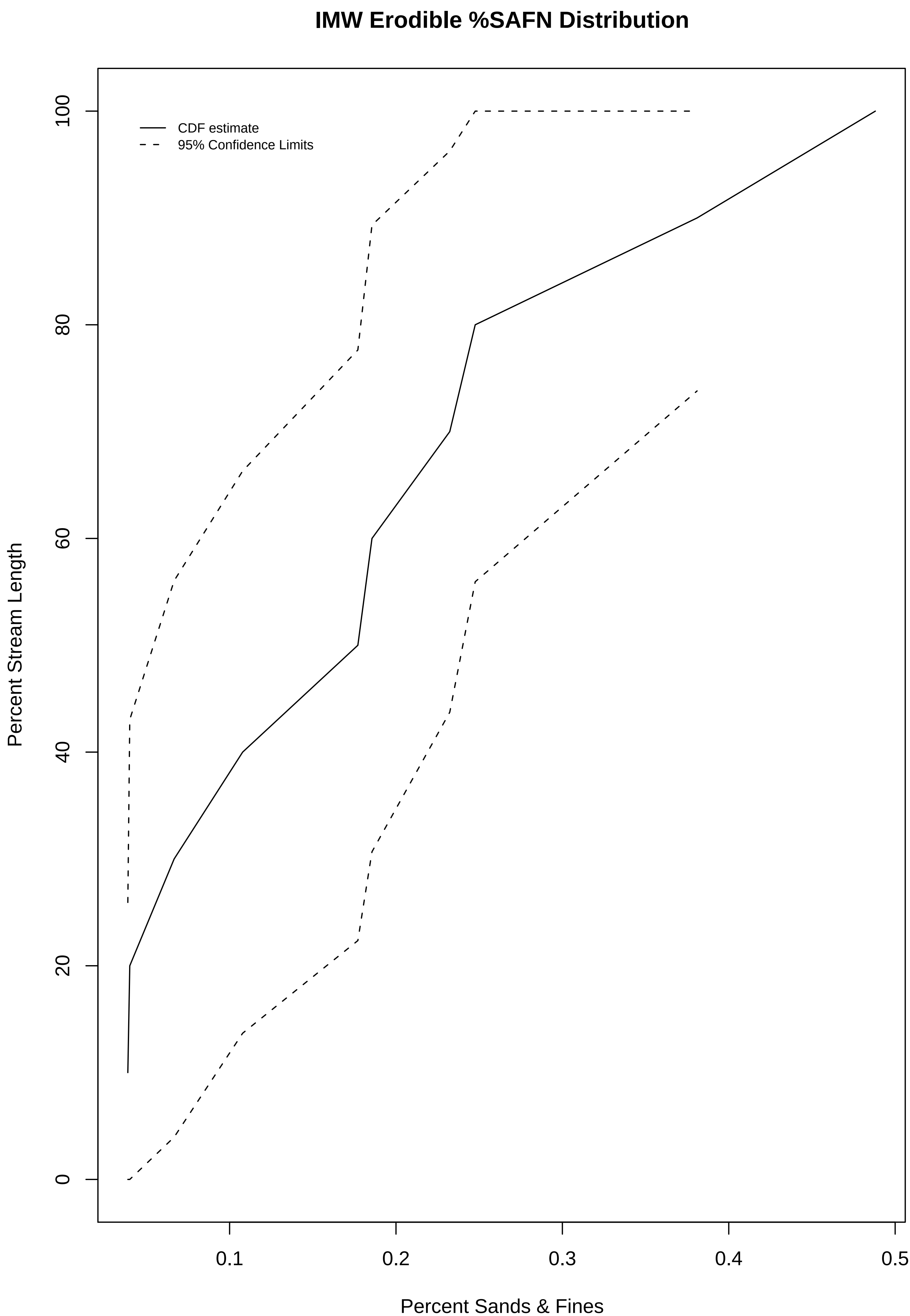


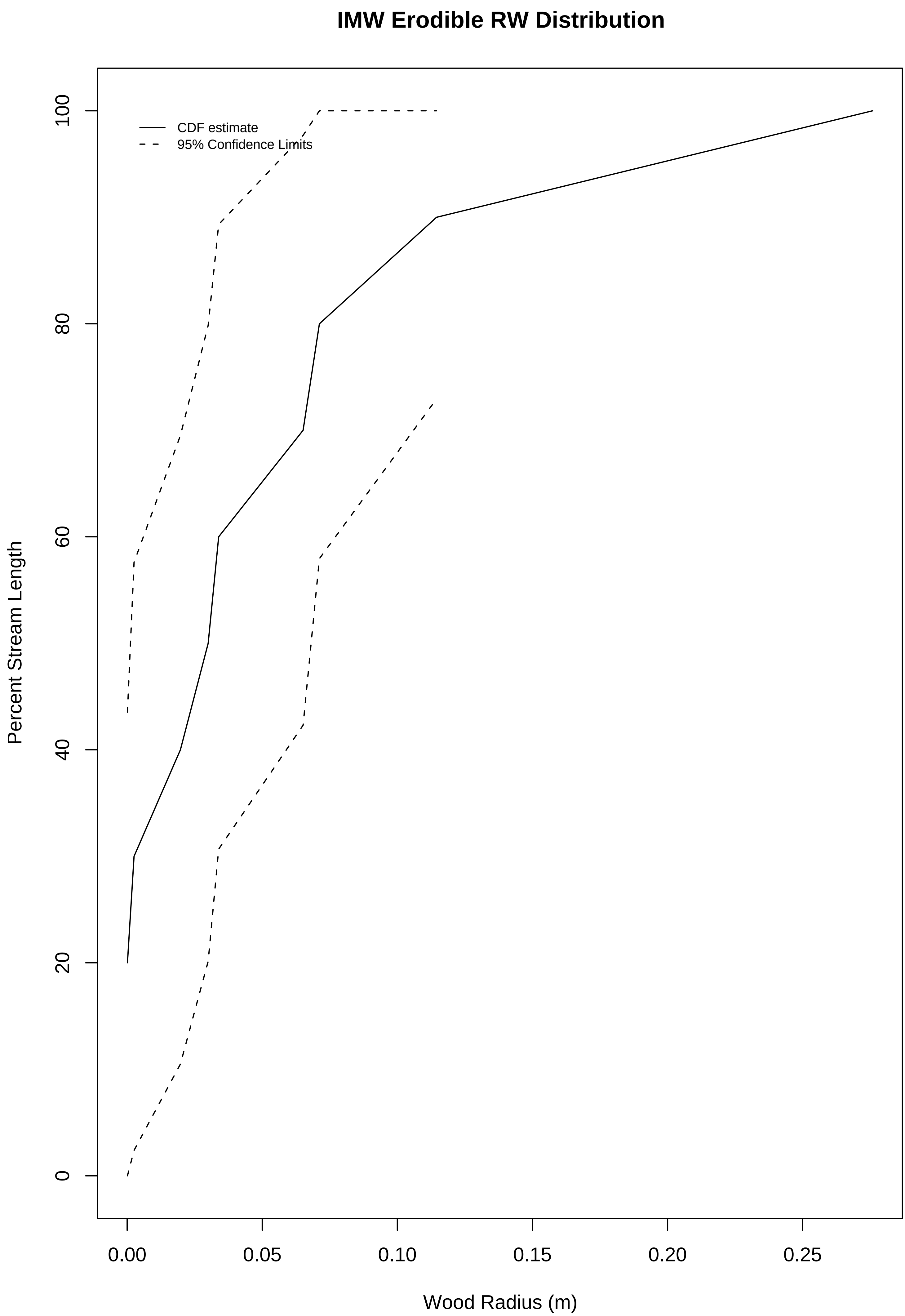
Kilchis Watershed RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.01
0.02
0.03
0.04
RW:Slope



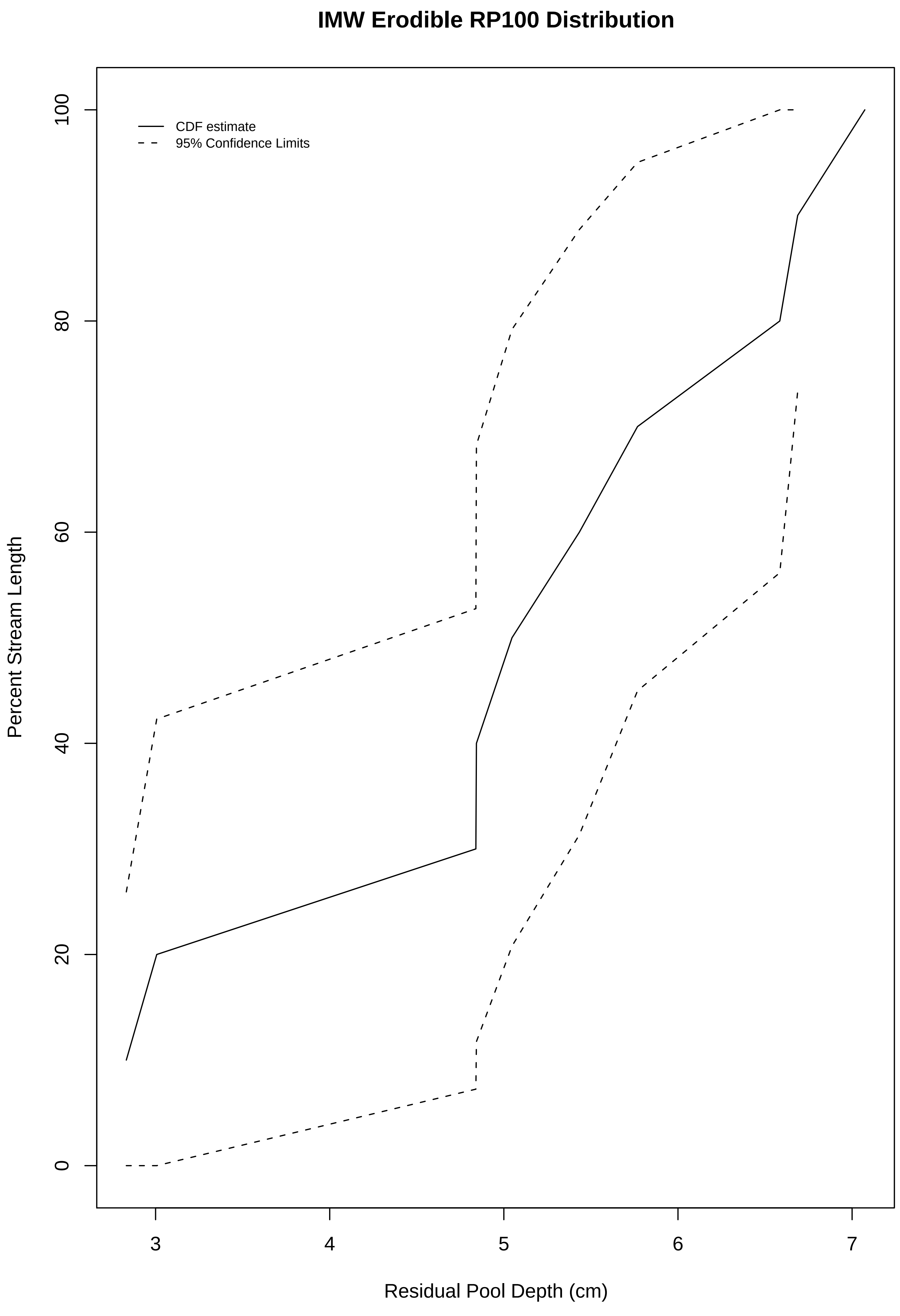
Kilchis Watershed LRBS:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
LRBS:Slope
0
20
40
60
80
100
−0.6
−0.4
−0.2
0.0
0.2
0.4

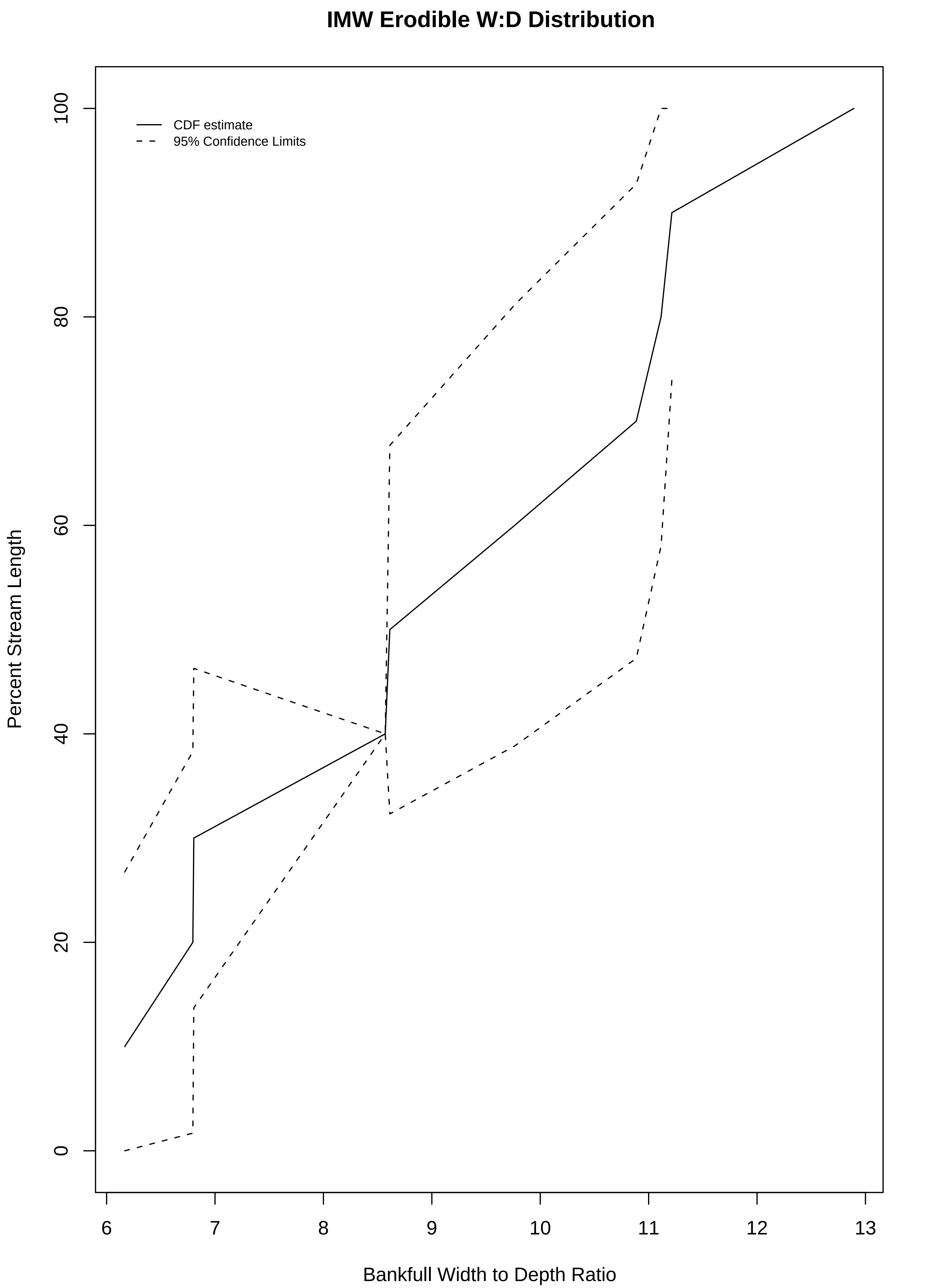

IMW Erodible LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−1.5
−1.0
−0.5
0.0
Log Relative Bed Stability

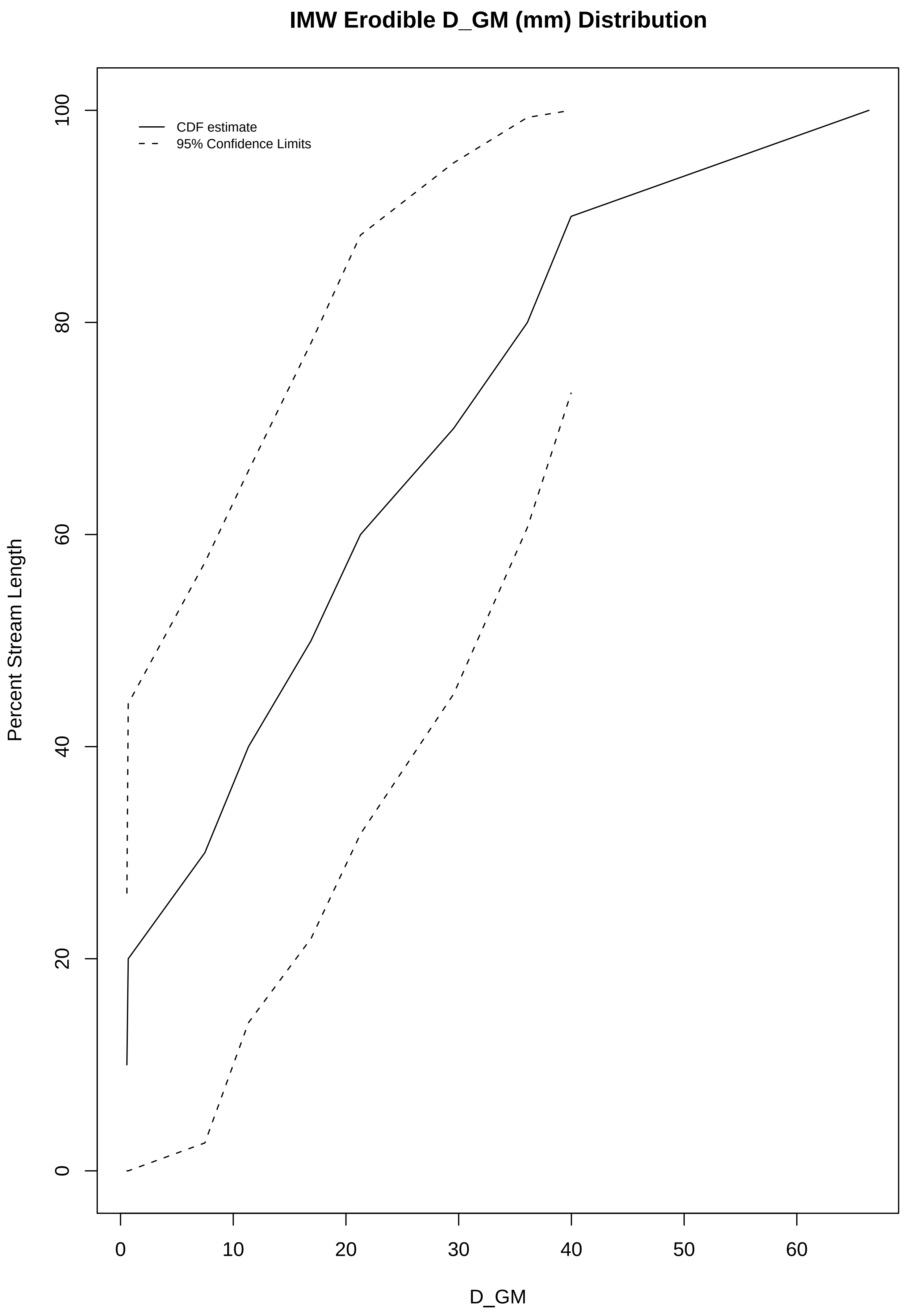

IMW Erodible %SAFN Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
Percent Sands & Fines
0
20
40
60
80
100
0.1
0.2
0.3
0.4
0.5



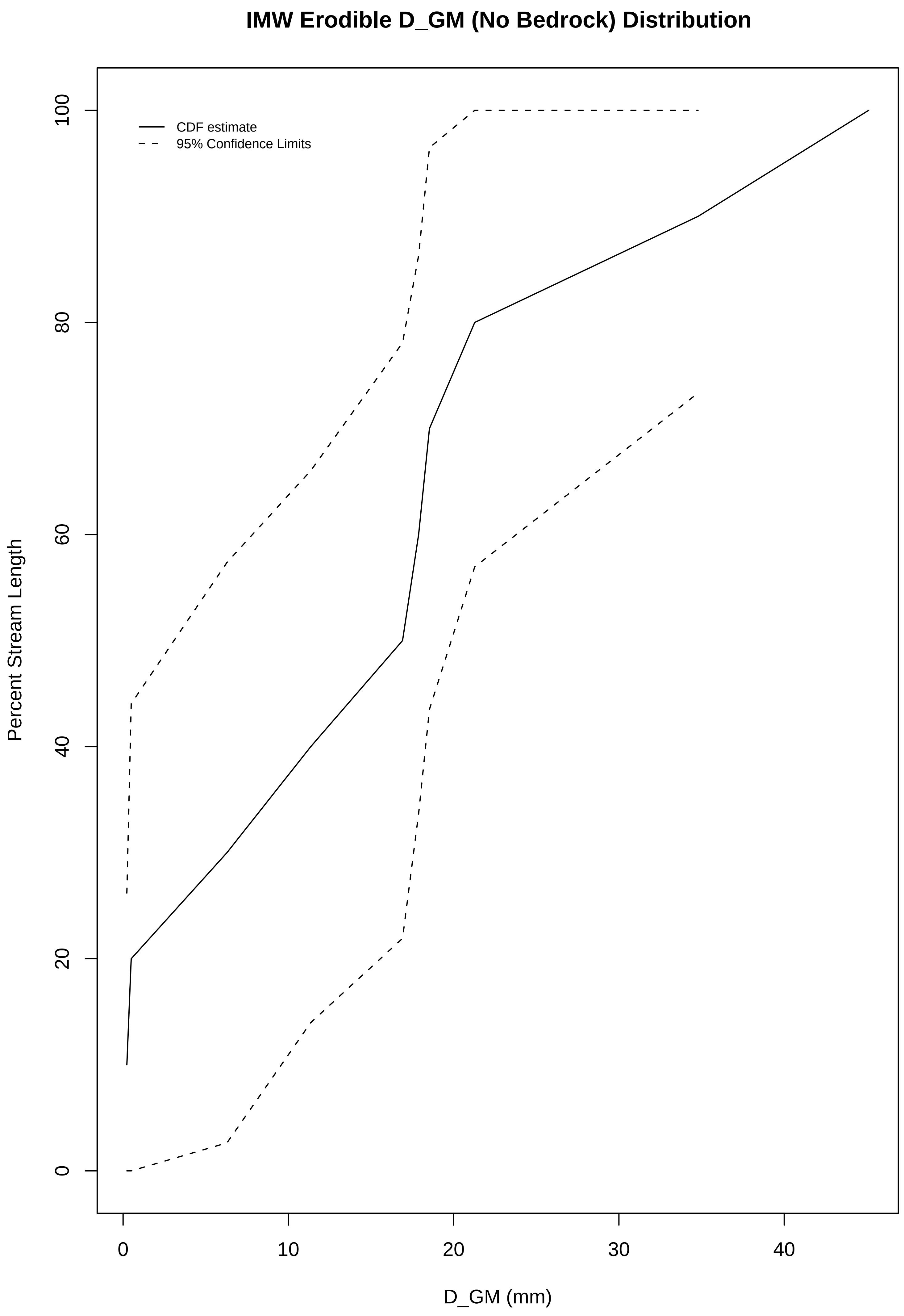
IMW Erodible RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
Wood Radius (m)

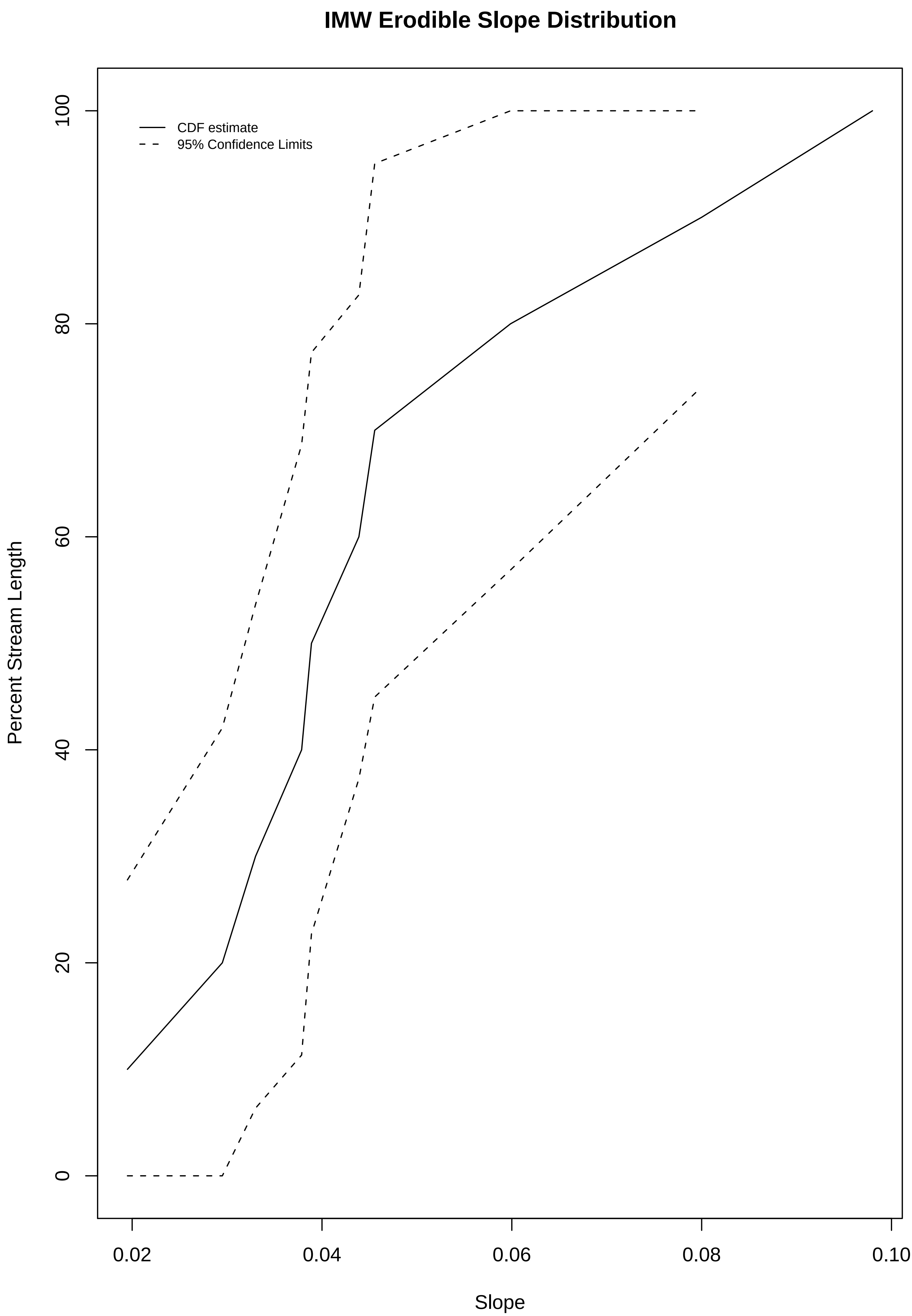

IMW Erodible RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
3
4
5
6
7
Residual Pool Depth (cm)

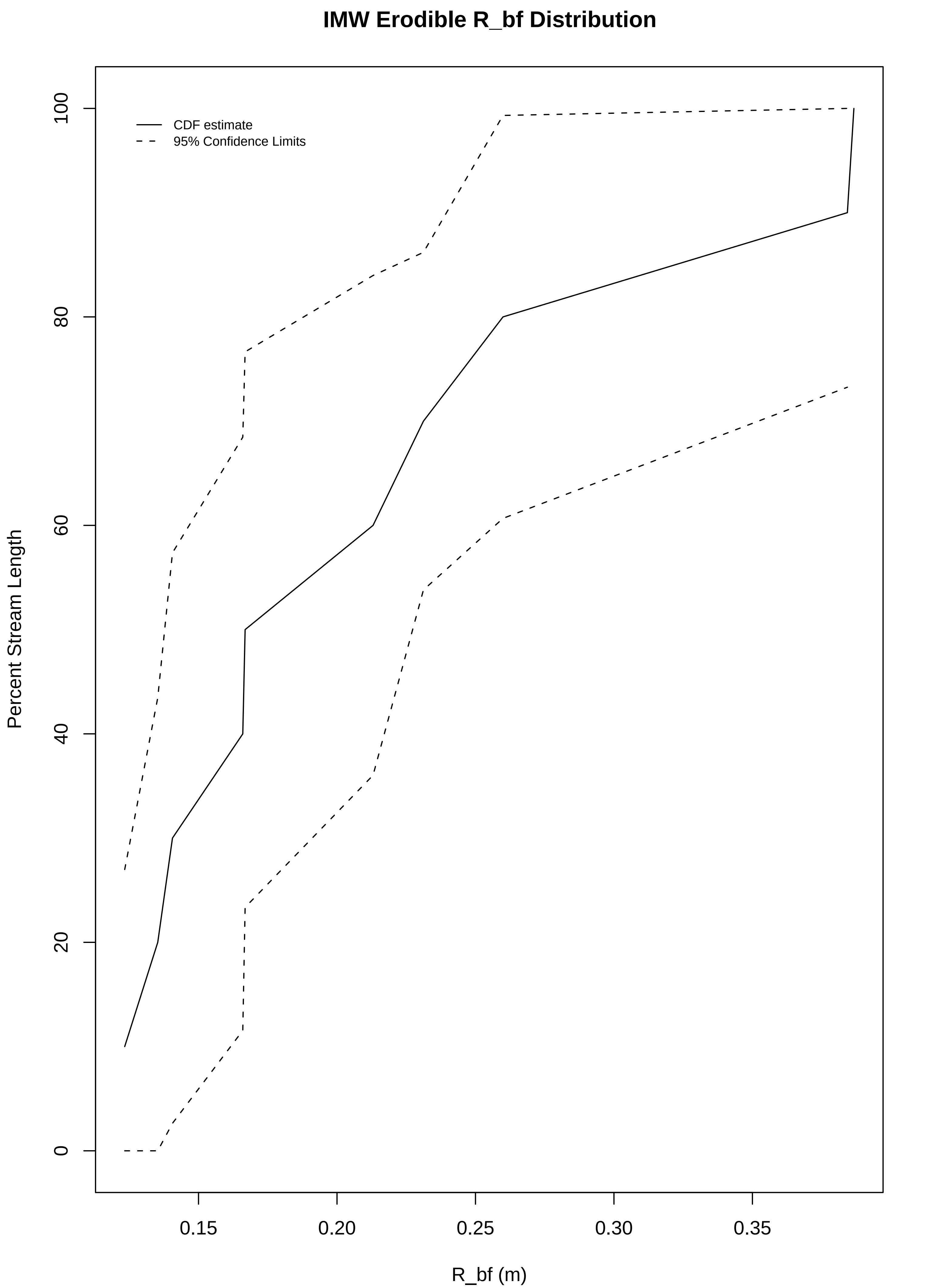

IMW Erodible W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
6
7
8
9
10
11
12
13
Bankfull Width to Depth Ratio



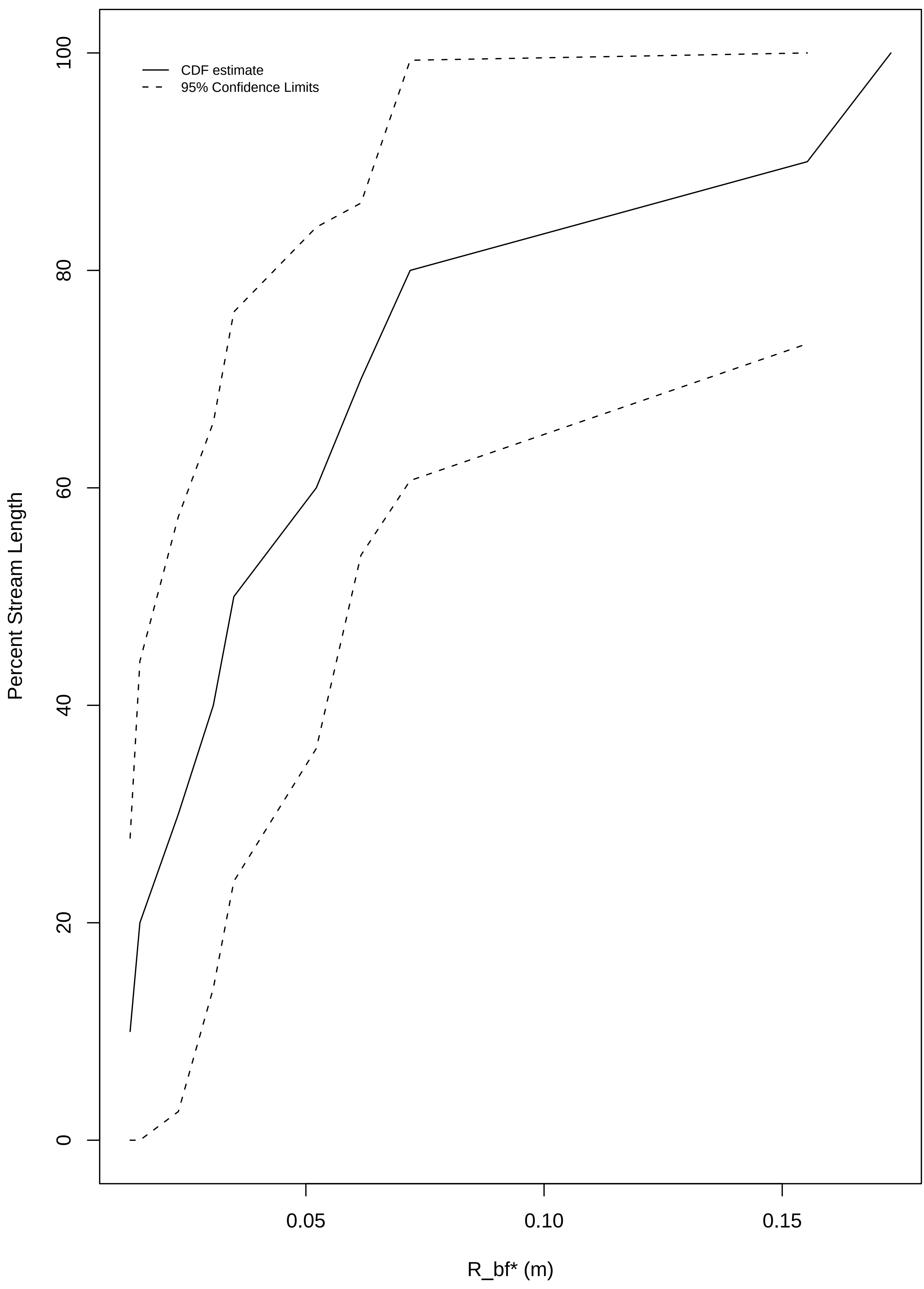
IMW Erodible D_GM (mm) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
10
20
30
40
50
60
D_GM

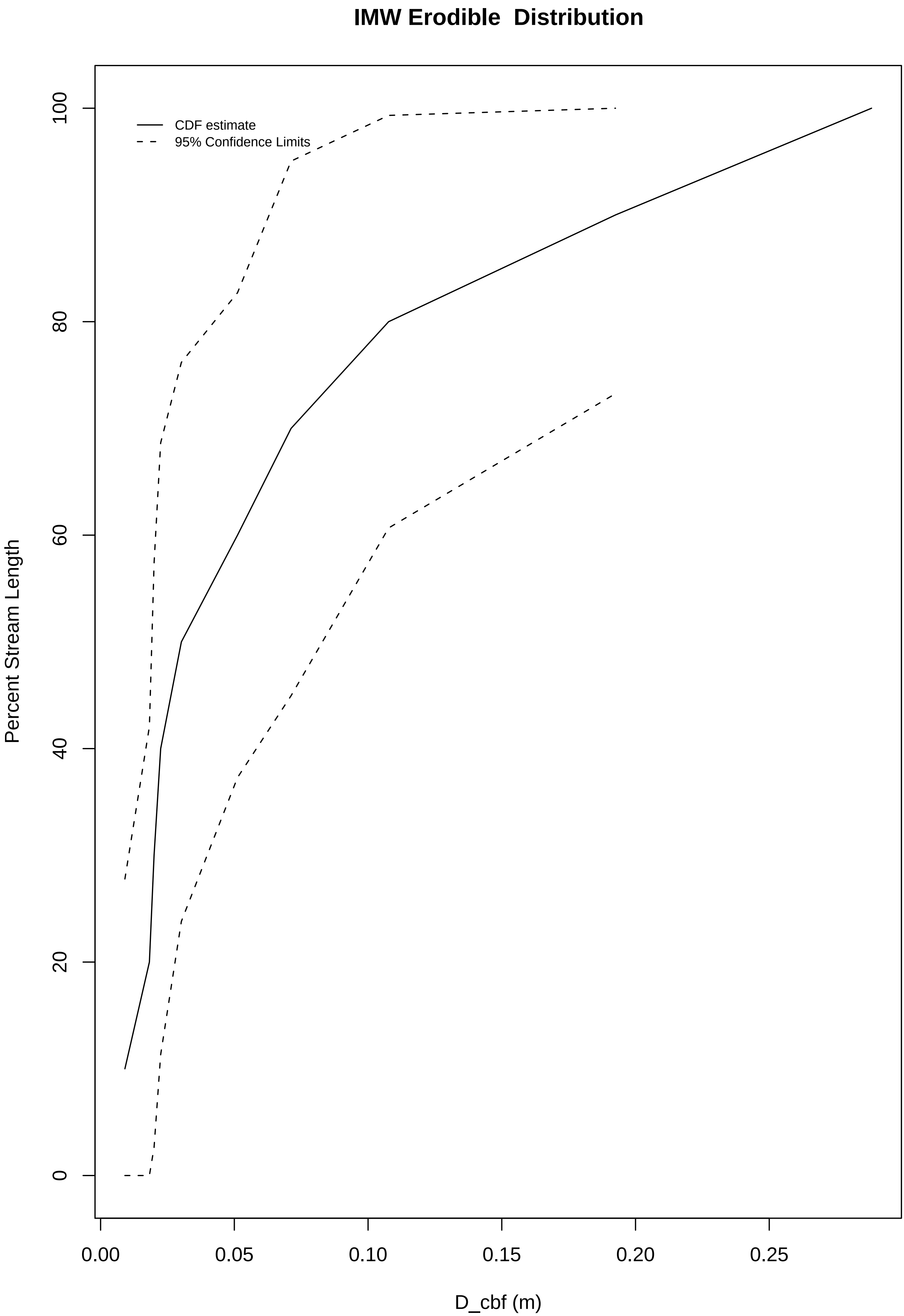

IMW Erodible D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
10
20
30
40
D_GM (mm)

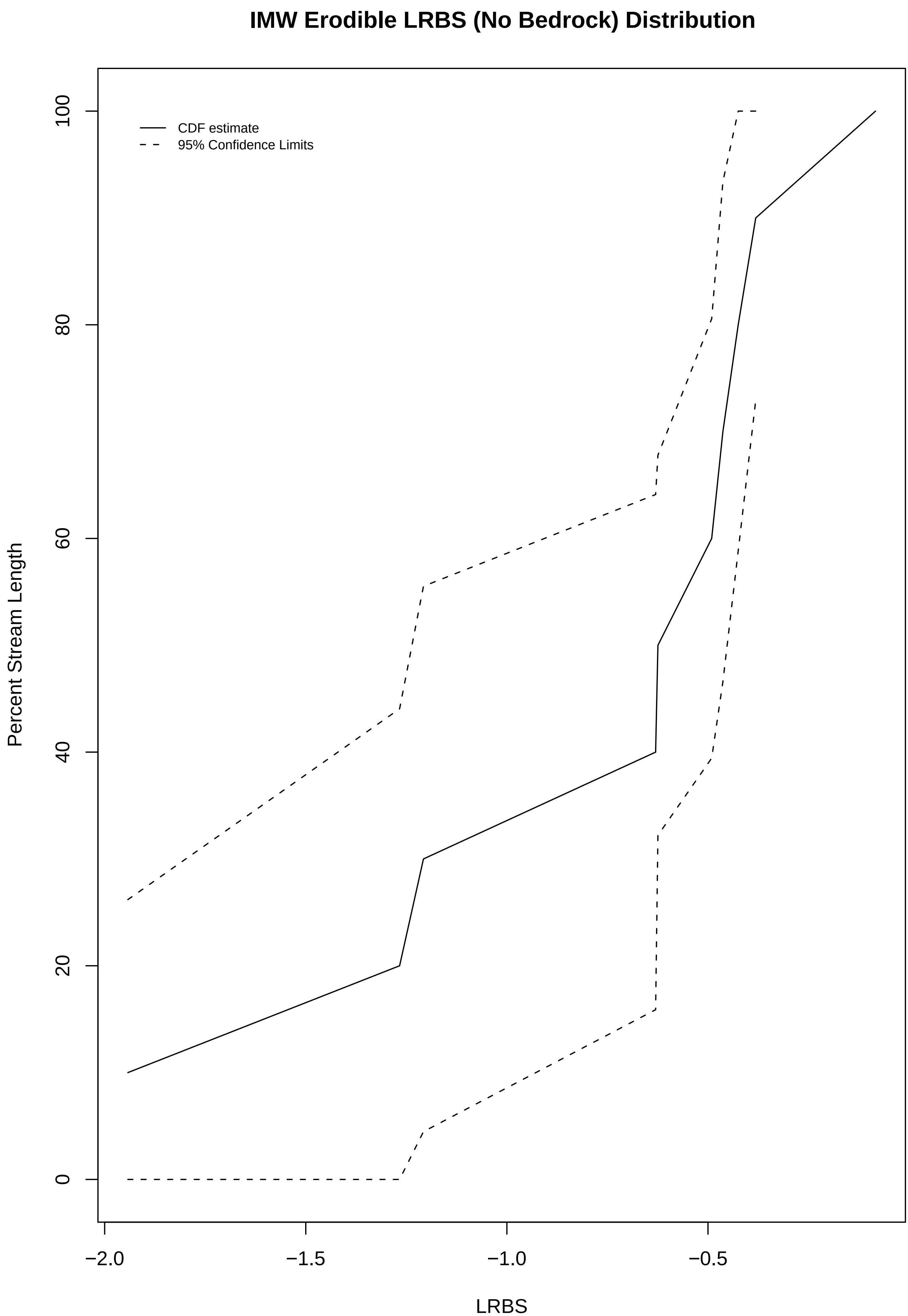

IMW Erodible Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
Slope
0.02
0.04
0.06
0.08
0.10

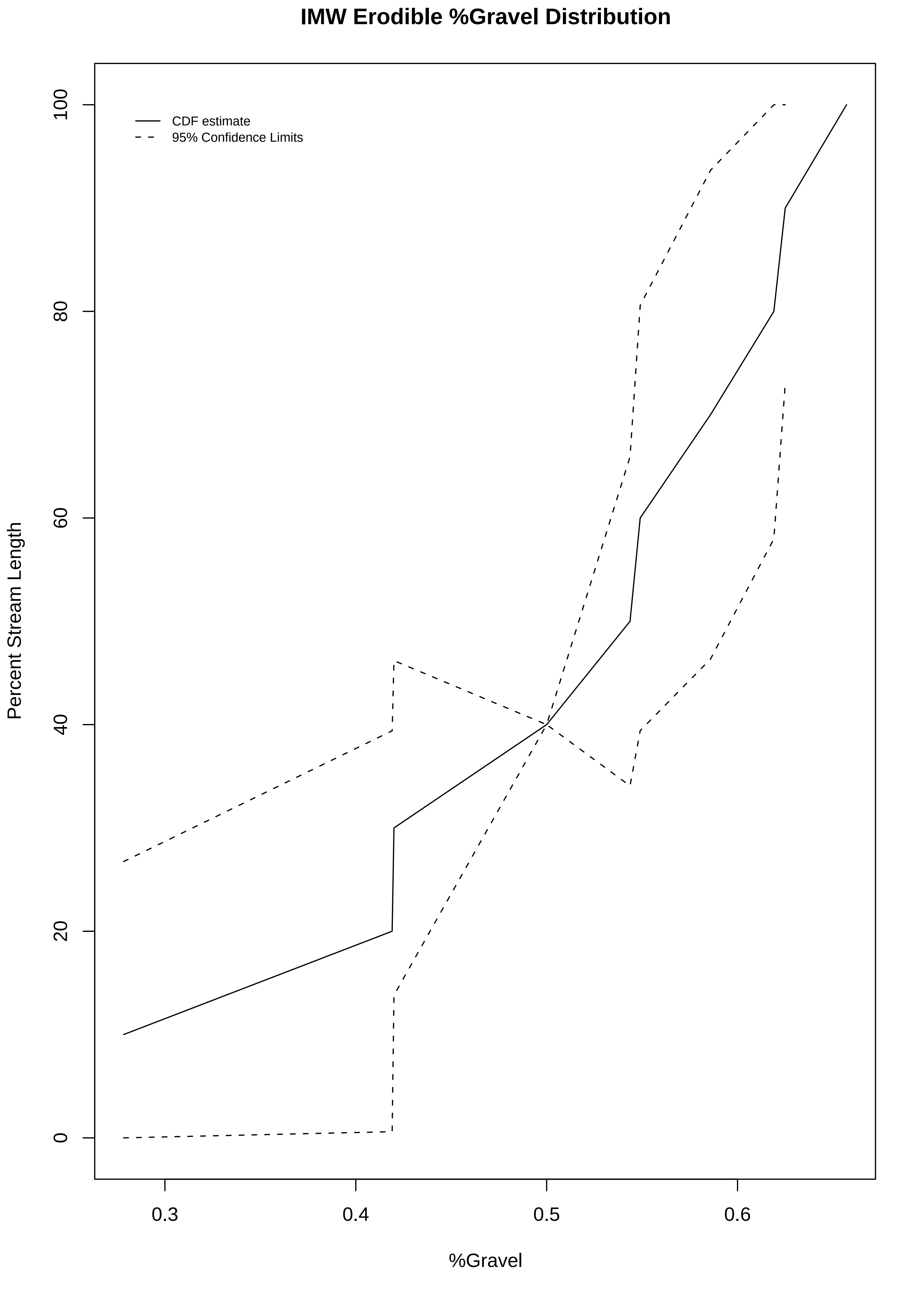

IMW Erodible R_bf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.15
0.20
0.25
0.30
0.35
R_bf (m)

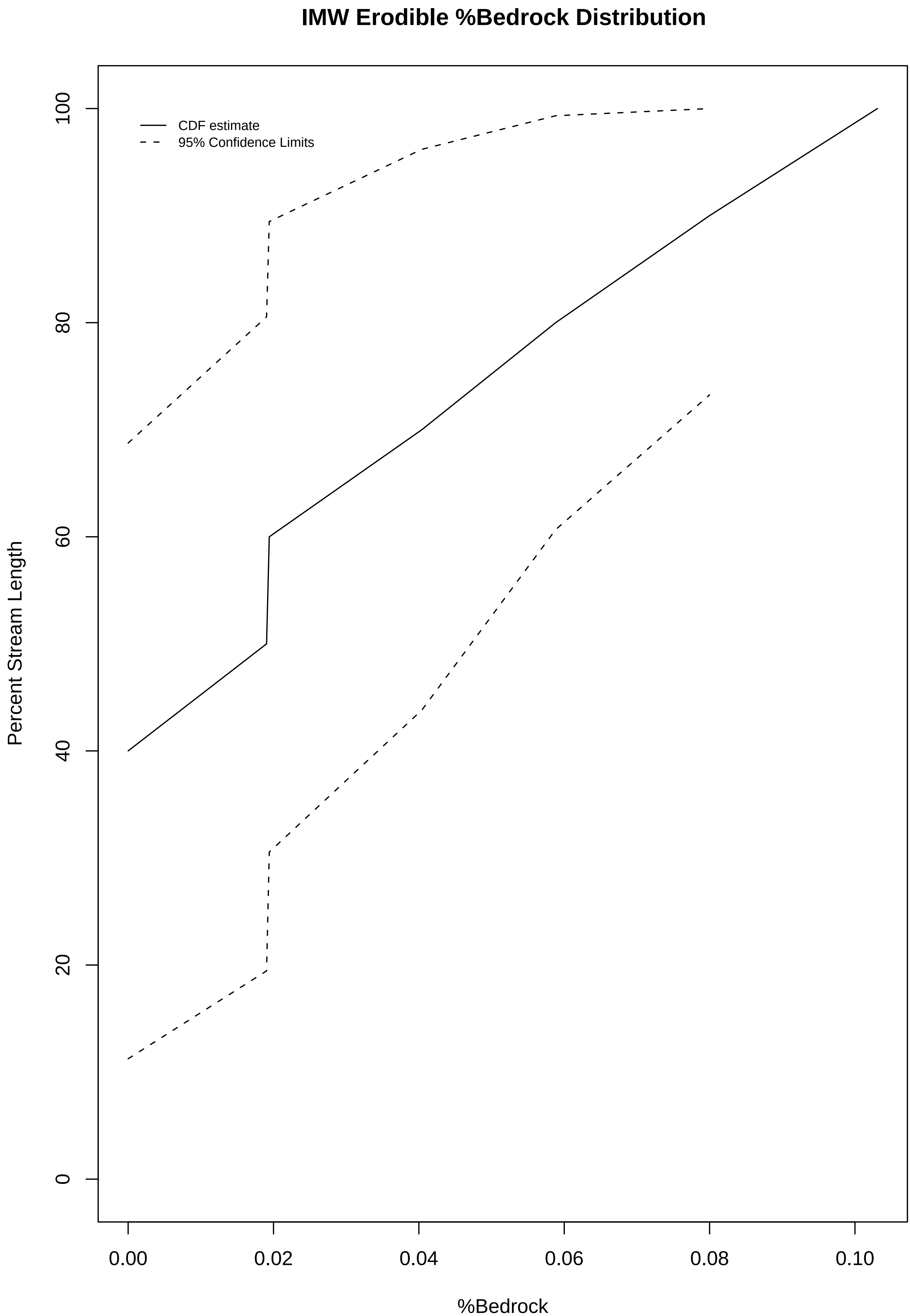
IMW Erodible R_bf* Distribution

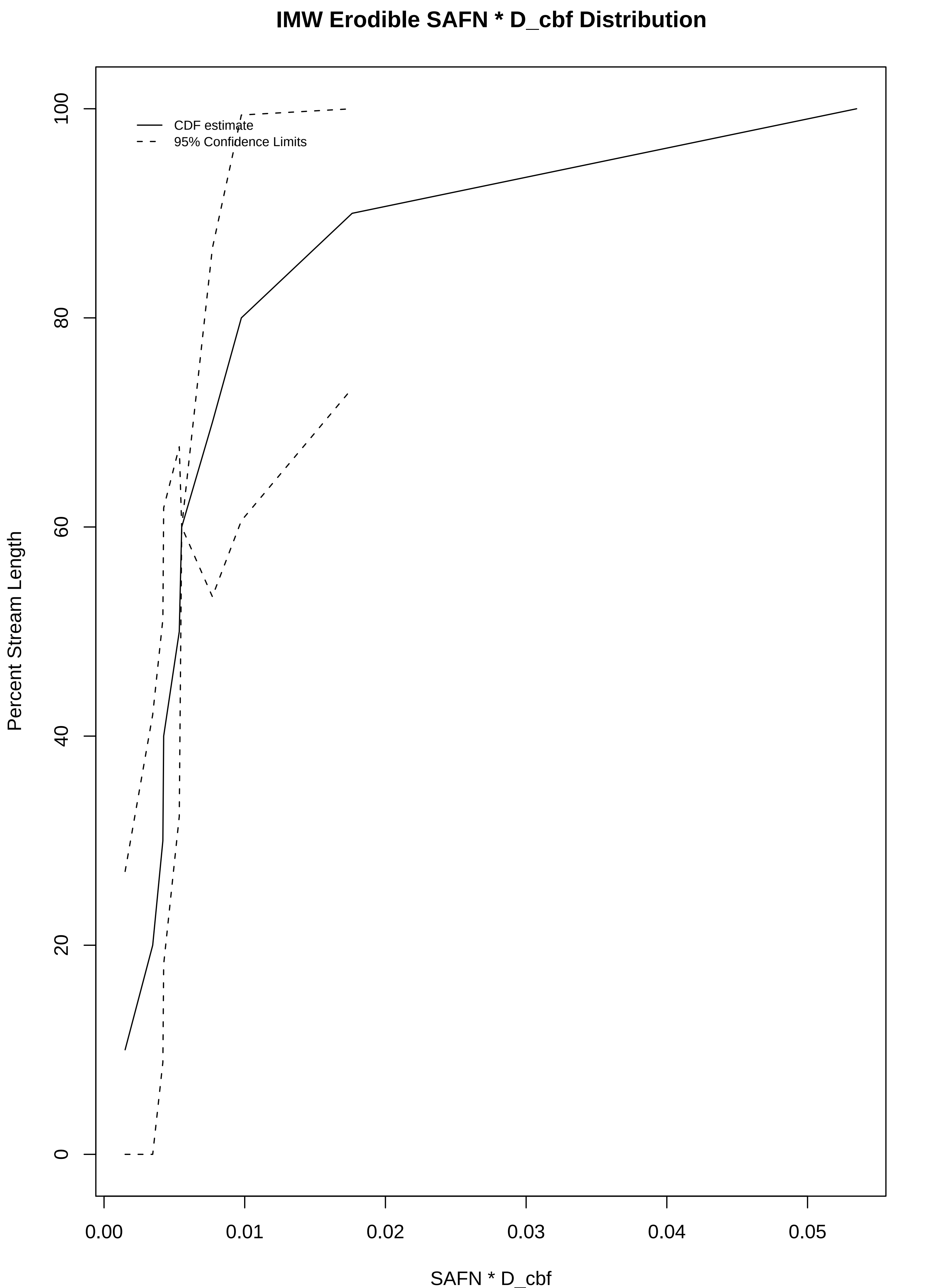



IMW Erodible Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
D_cbf (m)

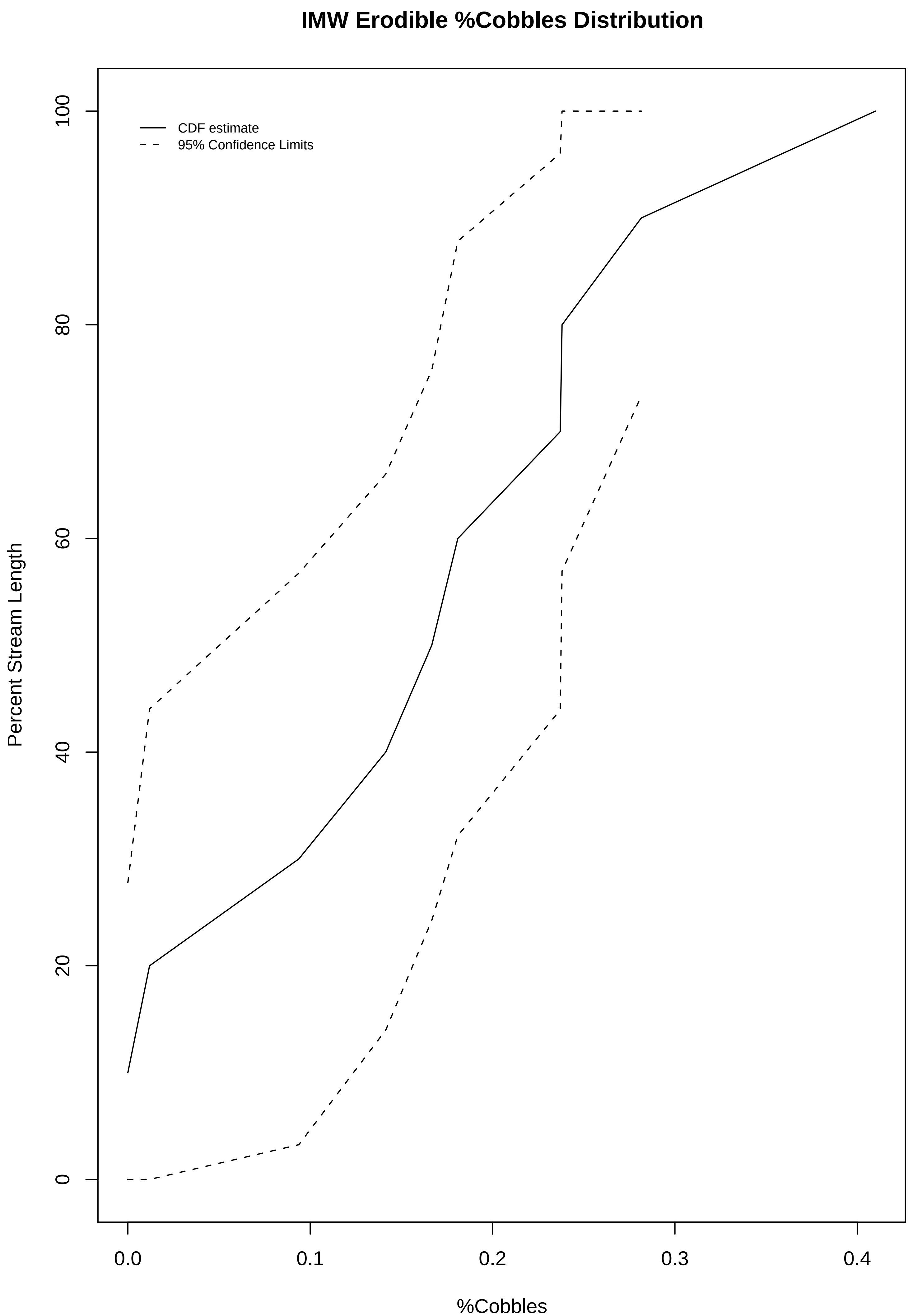

IMW Erodible LRBS (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−2.0
−1.5
−1.0
−0.5
LRBS


IMW Erodible %Gravel Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.3
0.4
0.5
0.6
%Gravel

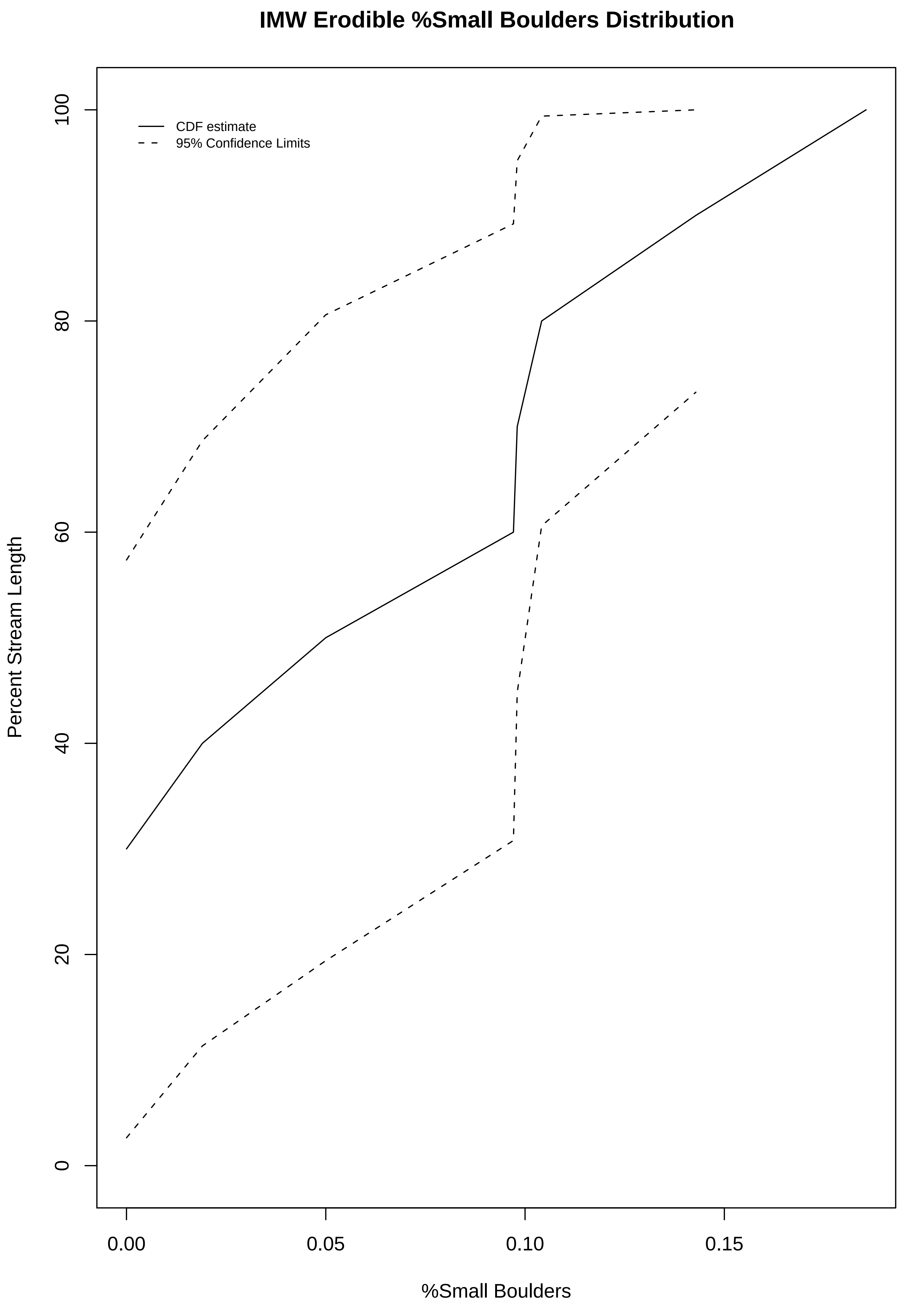

IMW Erodible %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.02
0.04
0.06
0.08
0.10
%Bedrock

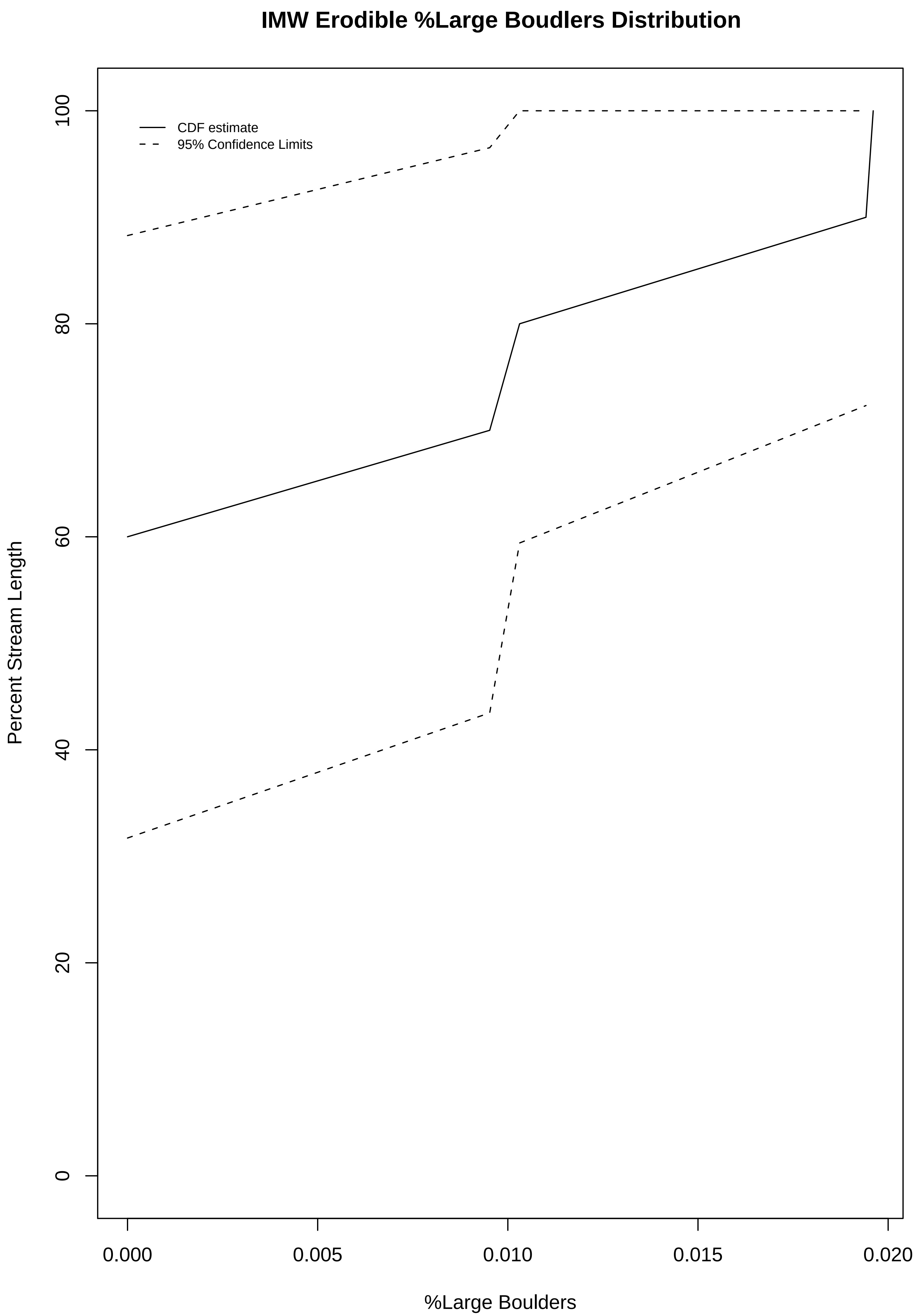


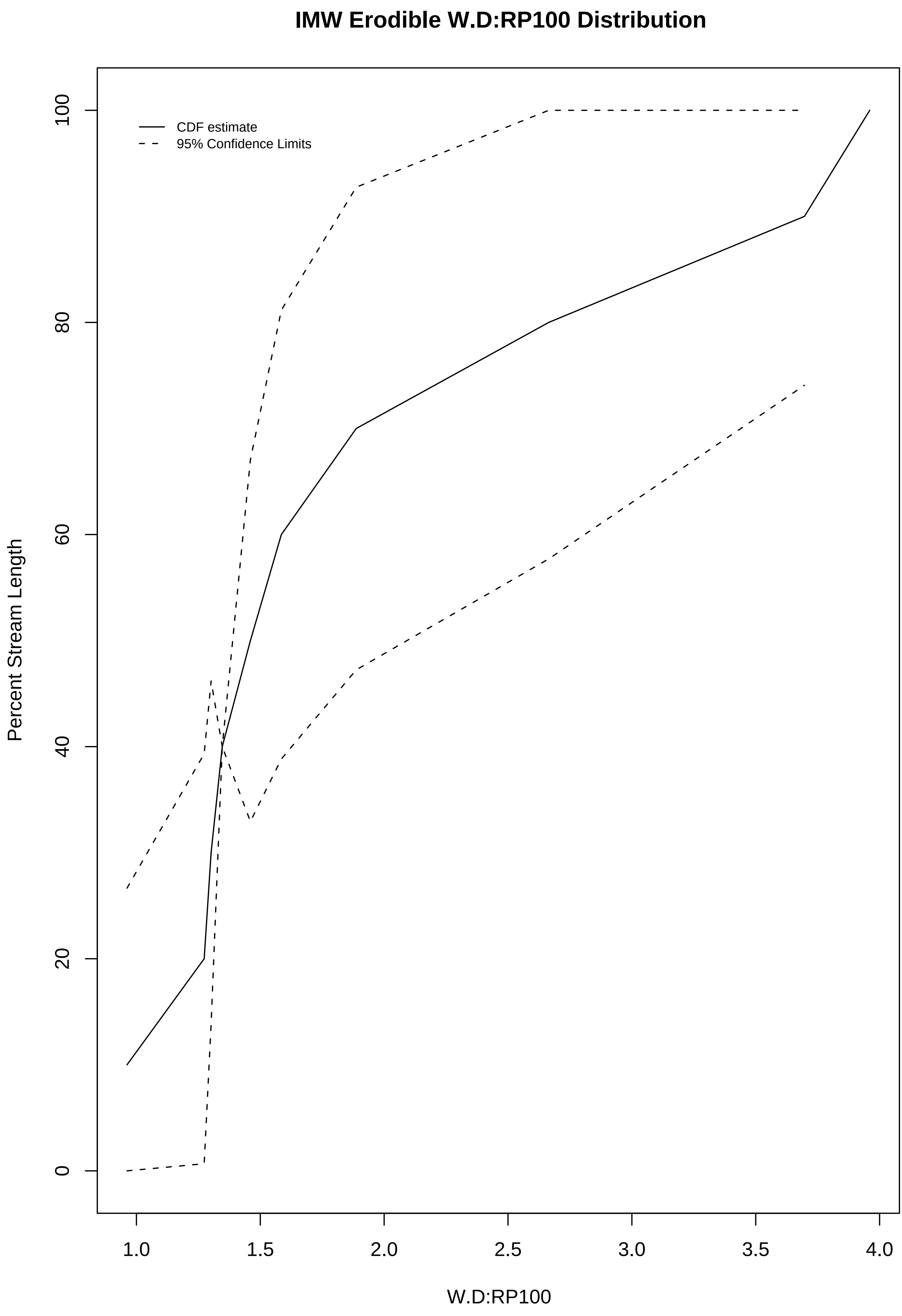
IMW Erodible SAFN * D_cbf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.01
0.02
0.03
0.04
0.05
SAFN * D_cbf



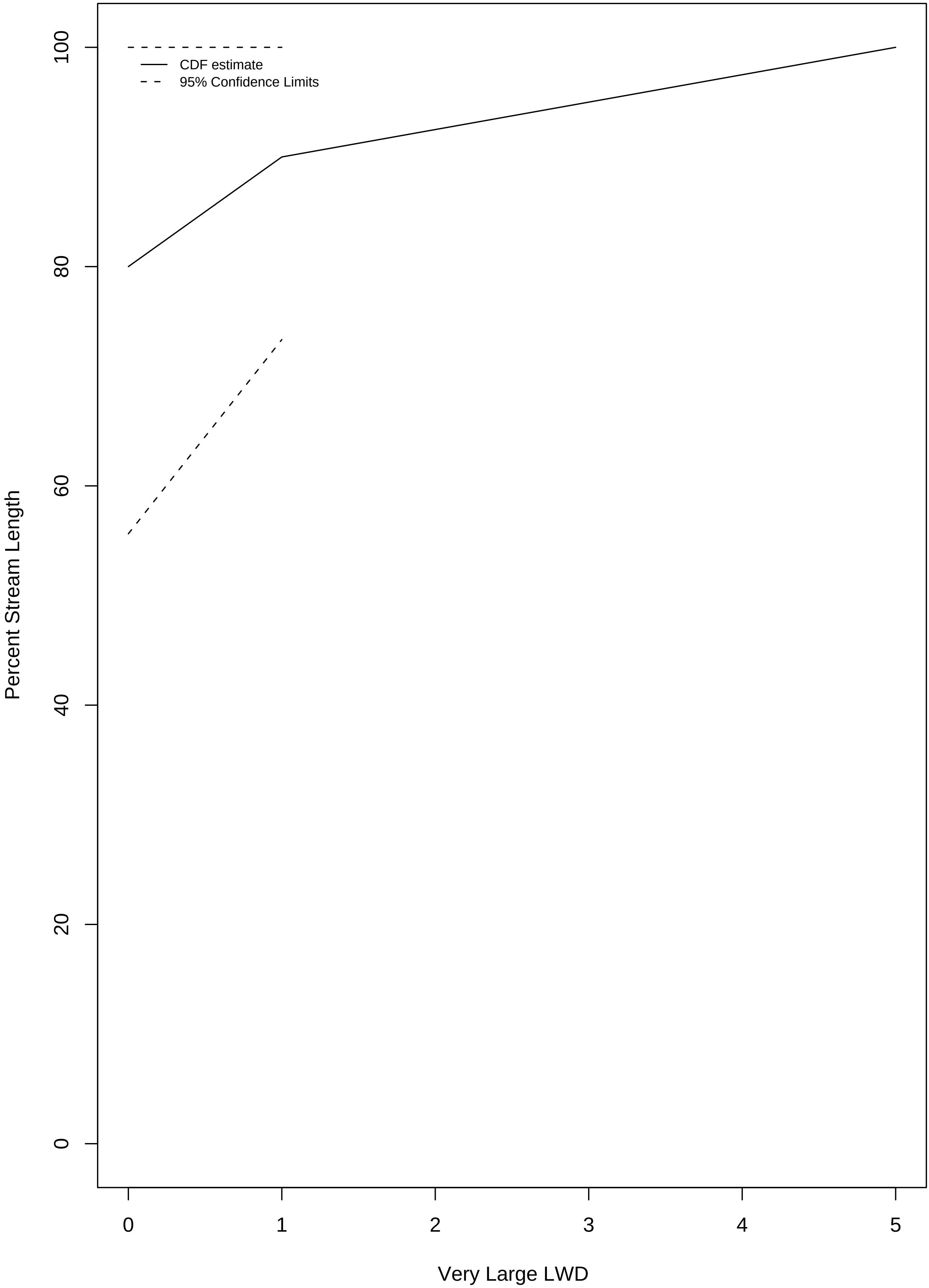
IMW Erodible %Cobbles Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
%Cobbles
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4


IMW Erodible %Small Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
%Small Boulders

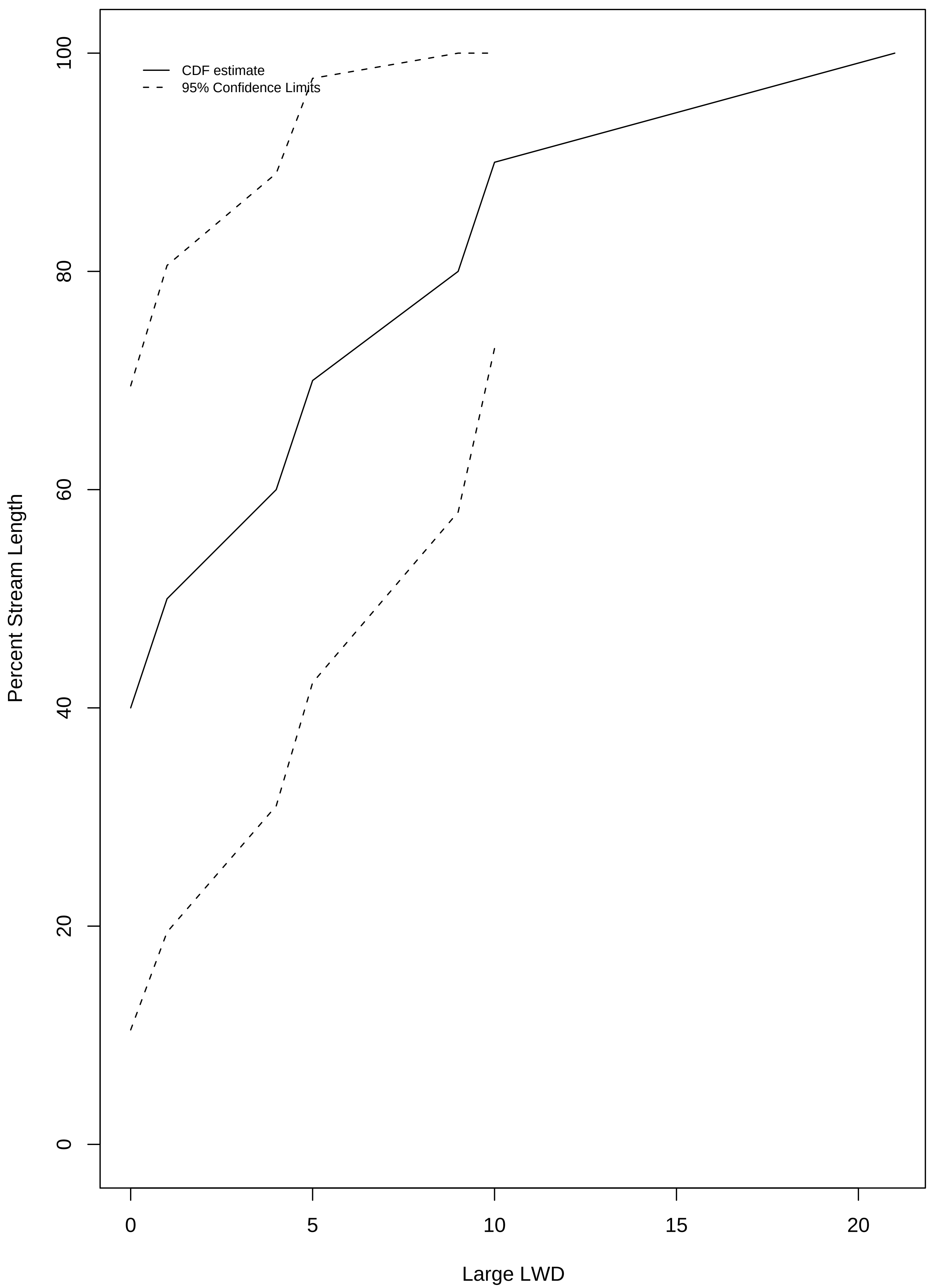

IMW Erodible %Large Boudlers Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.000
0.005
0.010
0.015
0.020
%Large Boulders

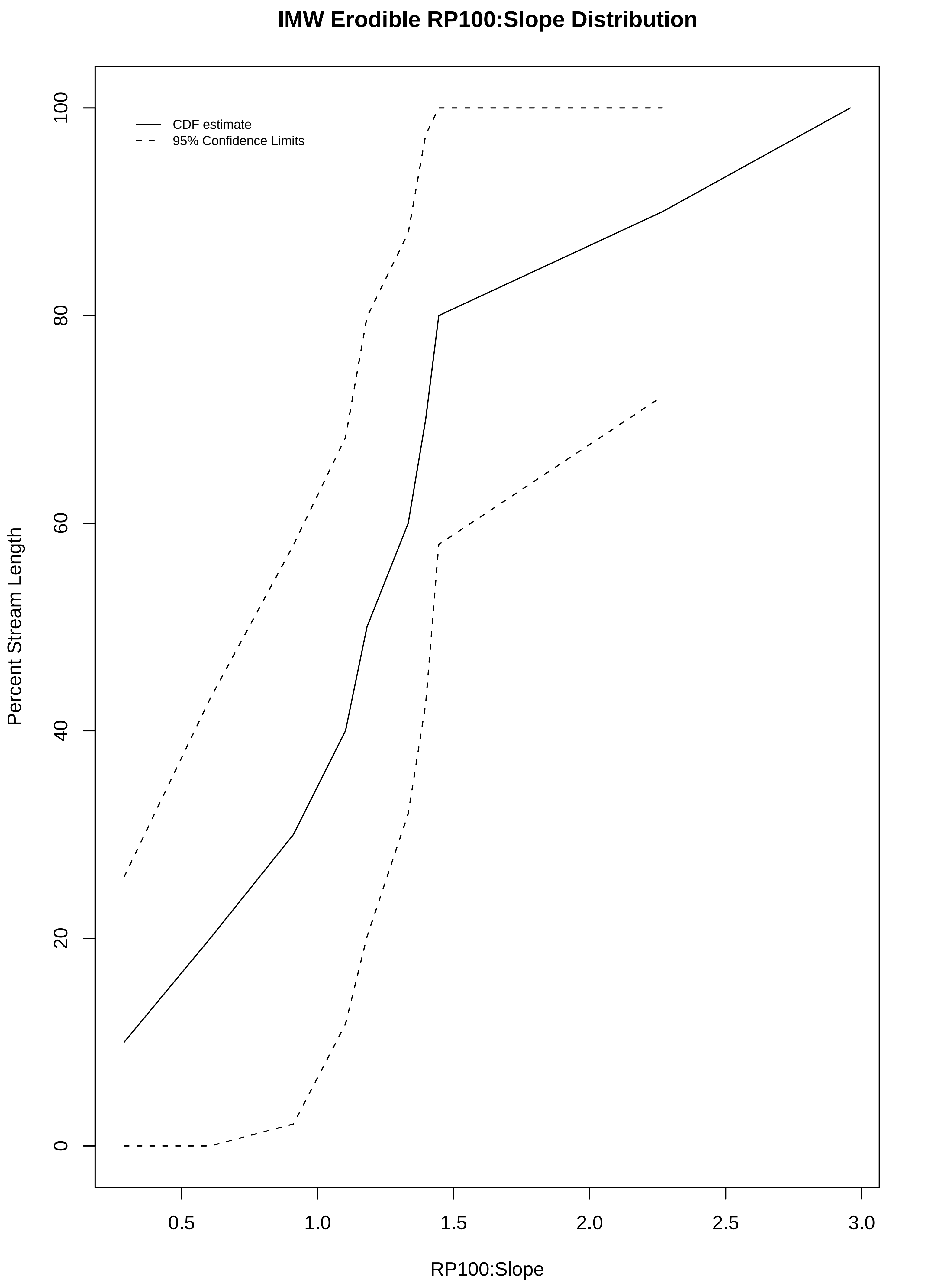

IMW Erodible W.D:RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
1.0
1.5
2.0
2.5
3.0
3.5
4.0
W.D:RP100

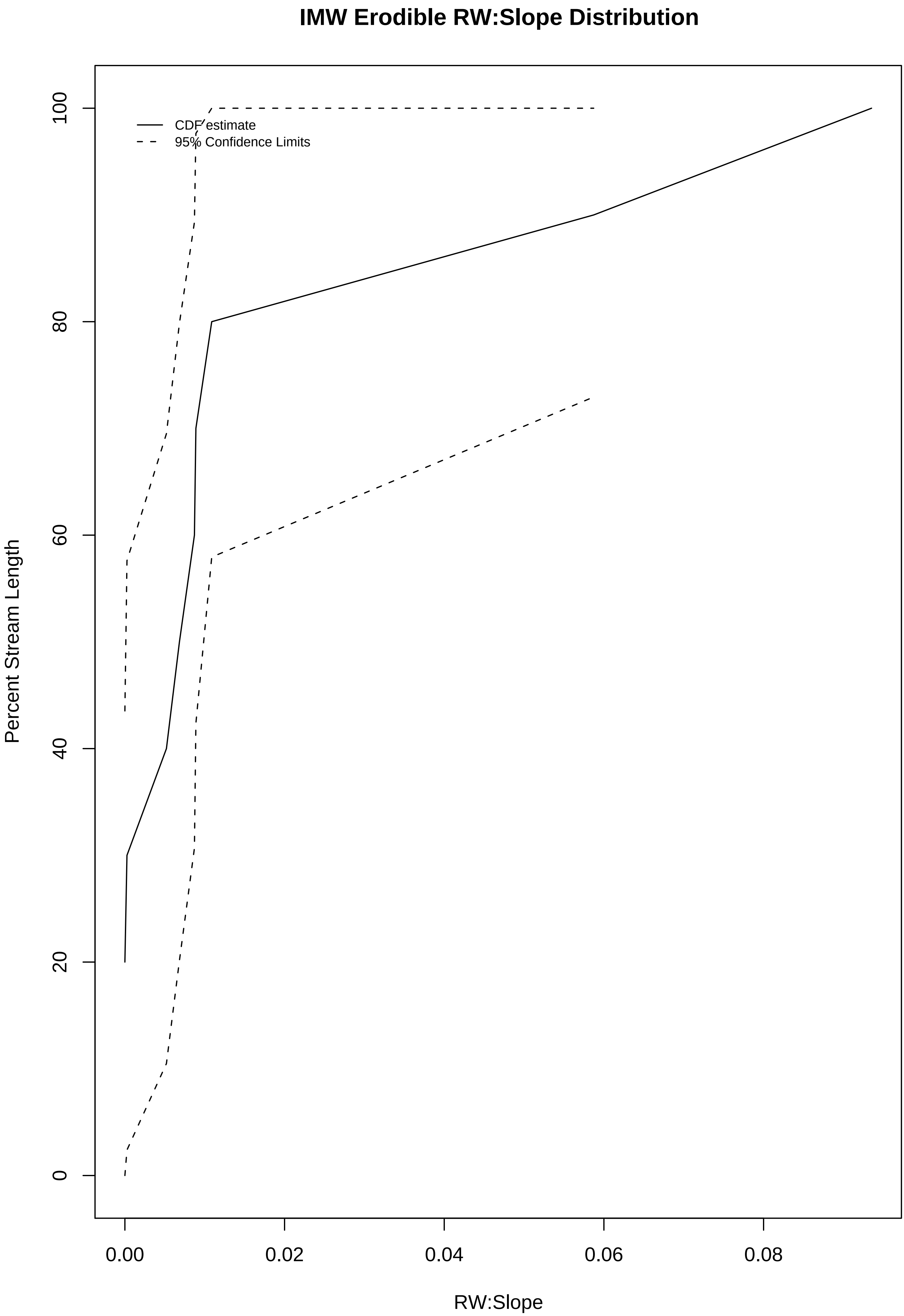
IMW Erodible LWD over 60 cm dbh & 15m length Distribution

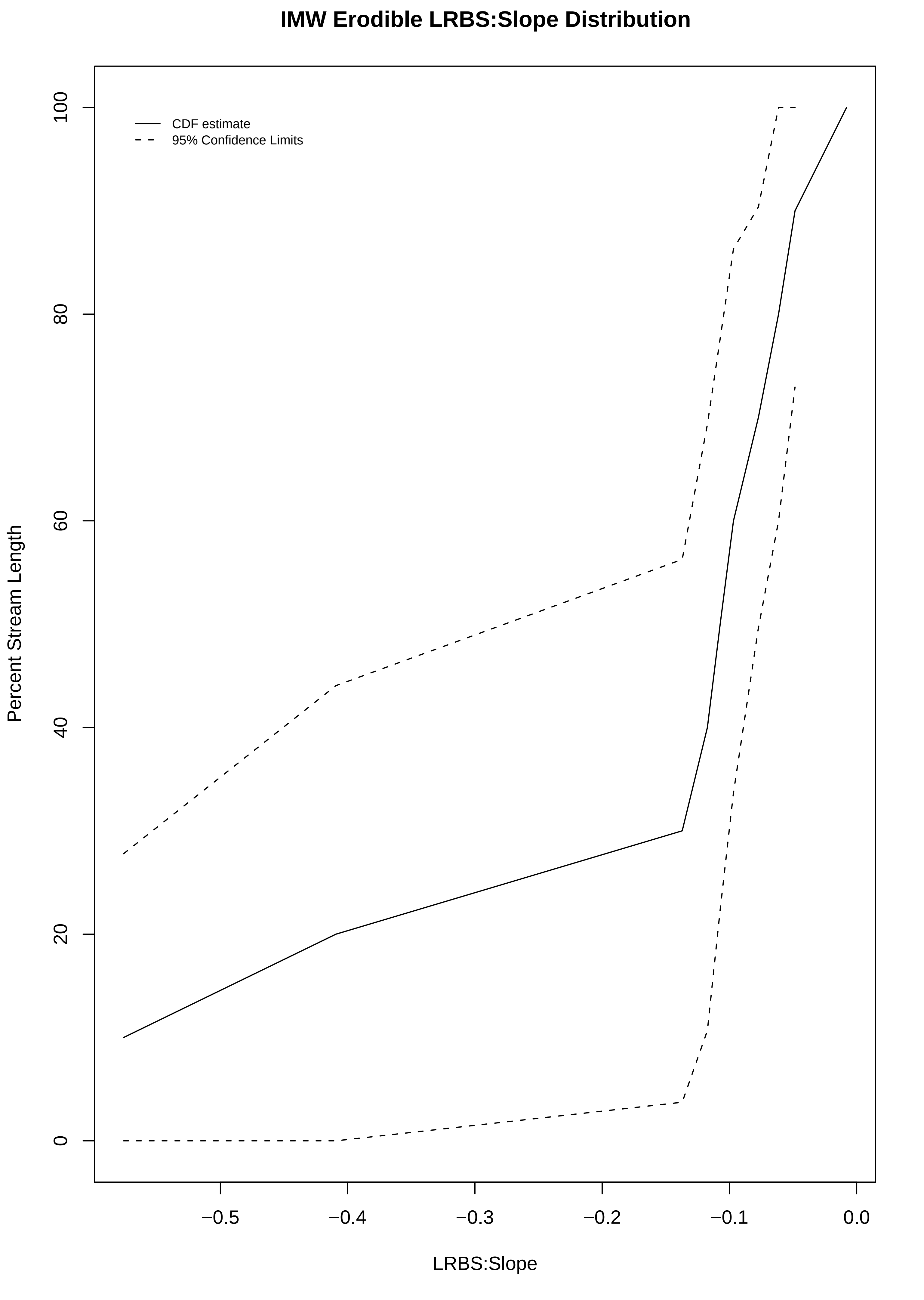


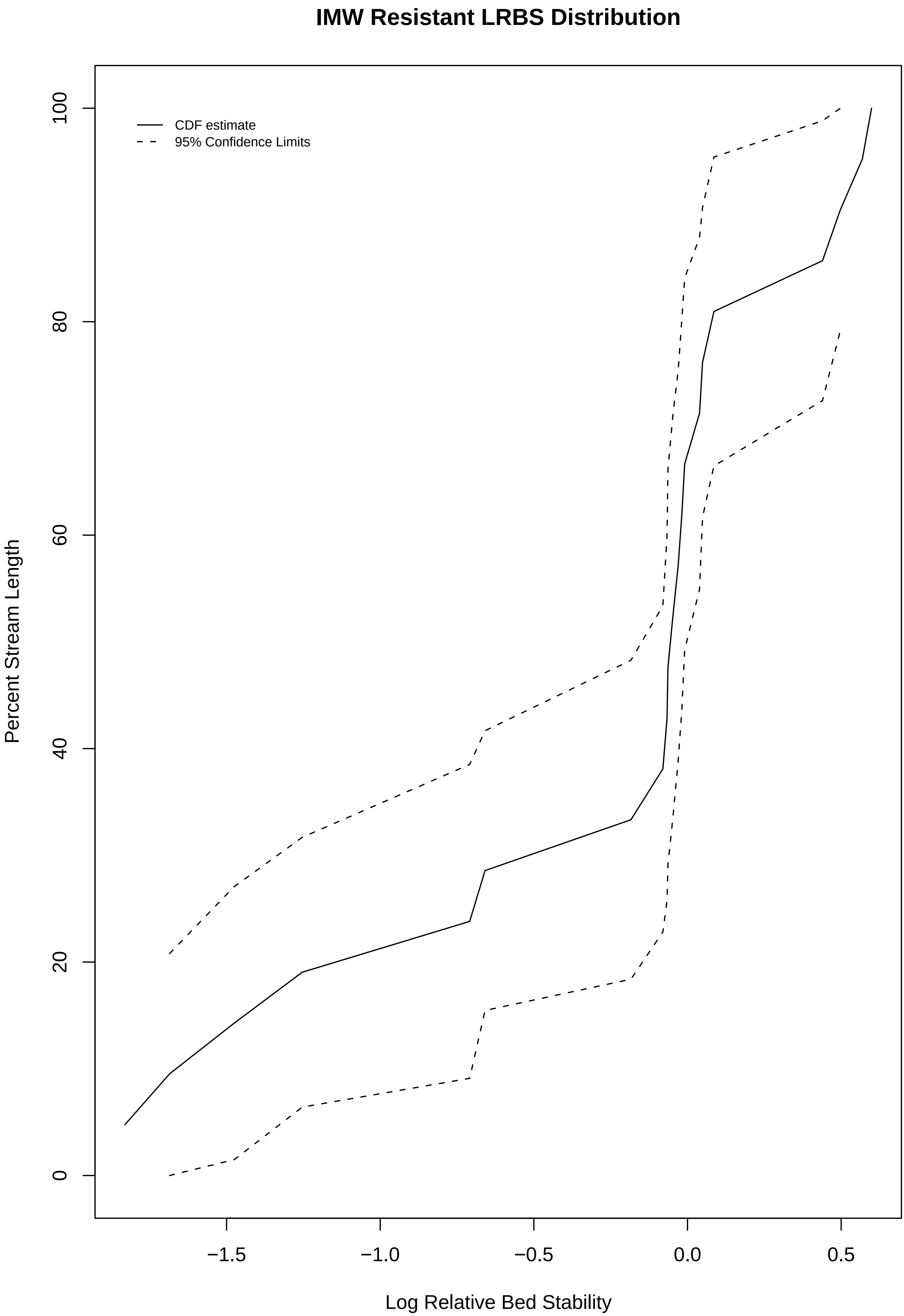
IMW Erodible LWD over 60 cm dbh Distribution

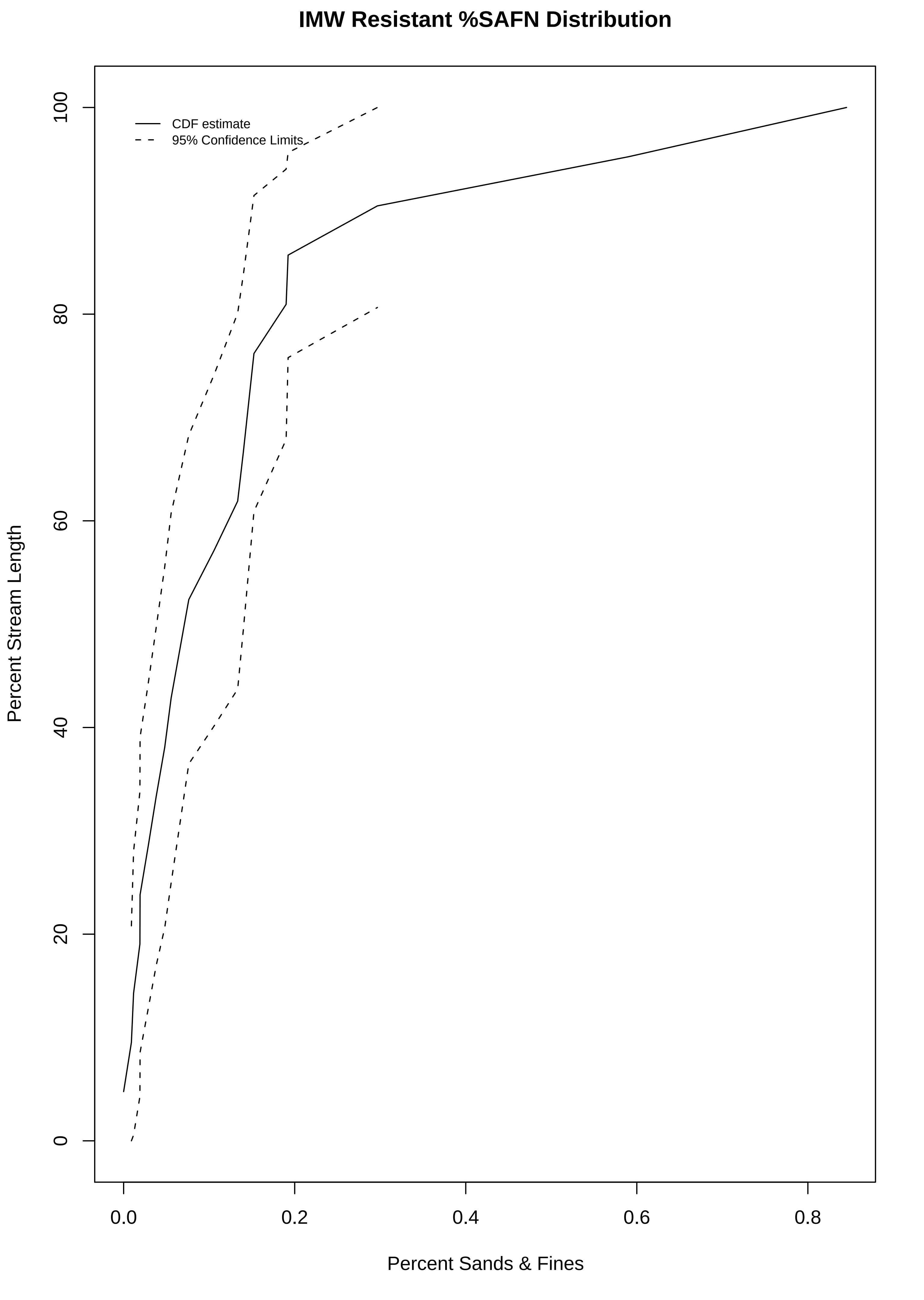


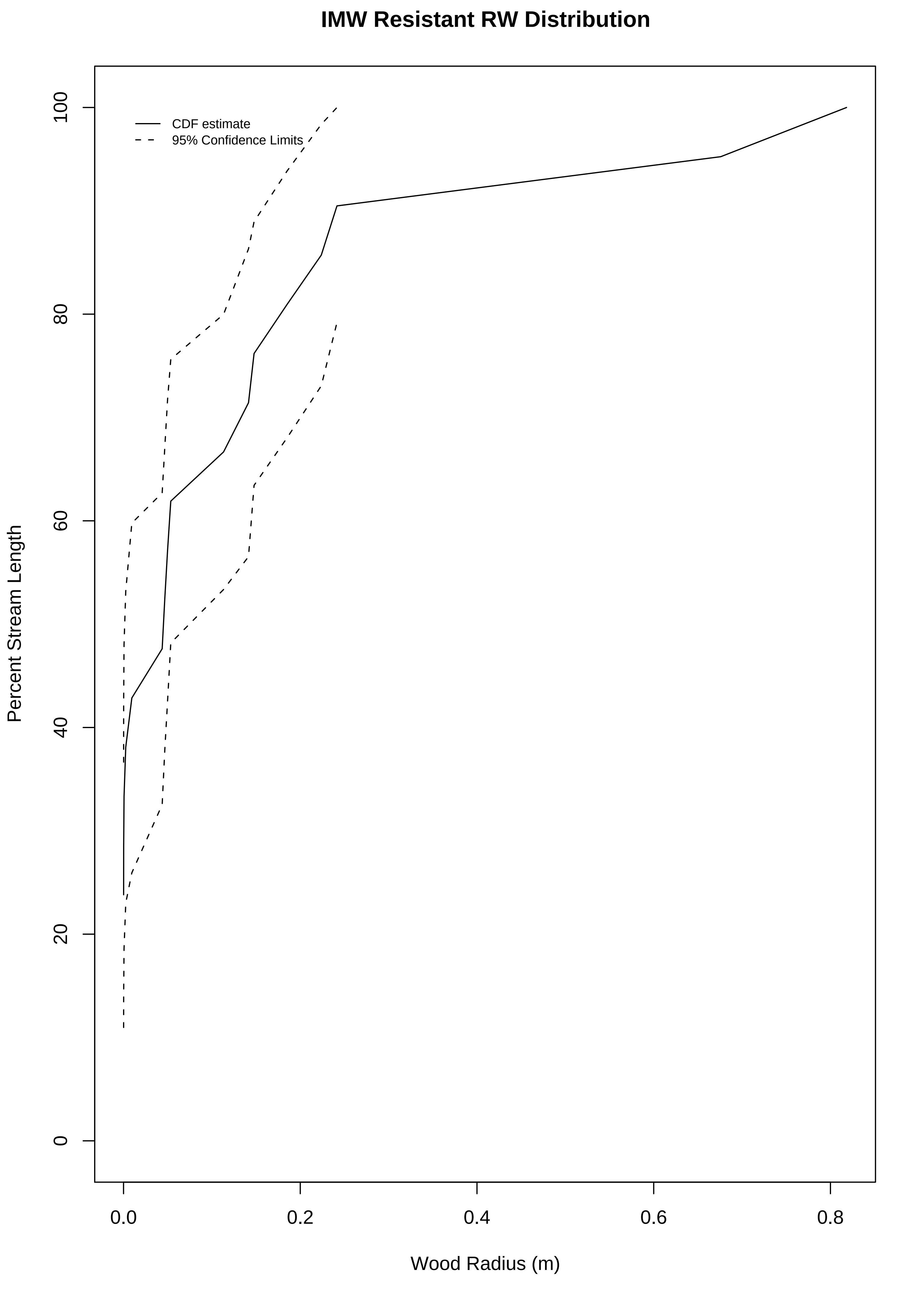

IMW Erodible RP100:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.5
1.0
1.5
2.0
2.5
3.0
RP100:Slope

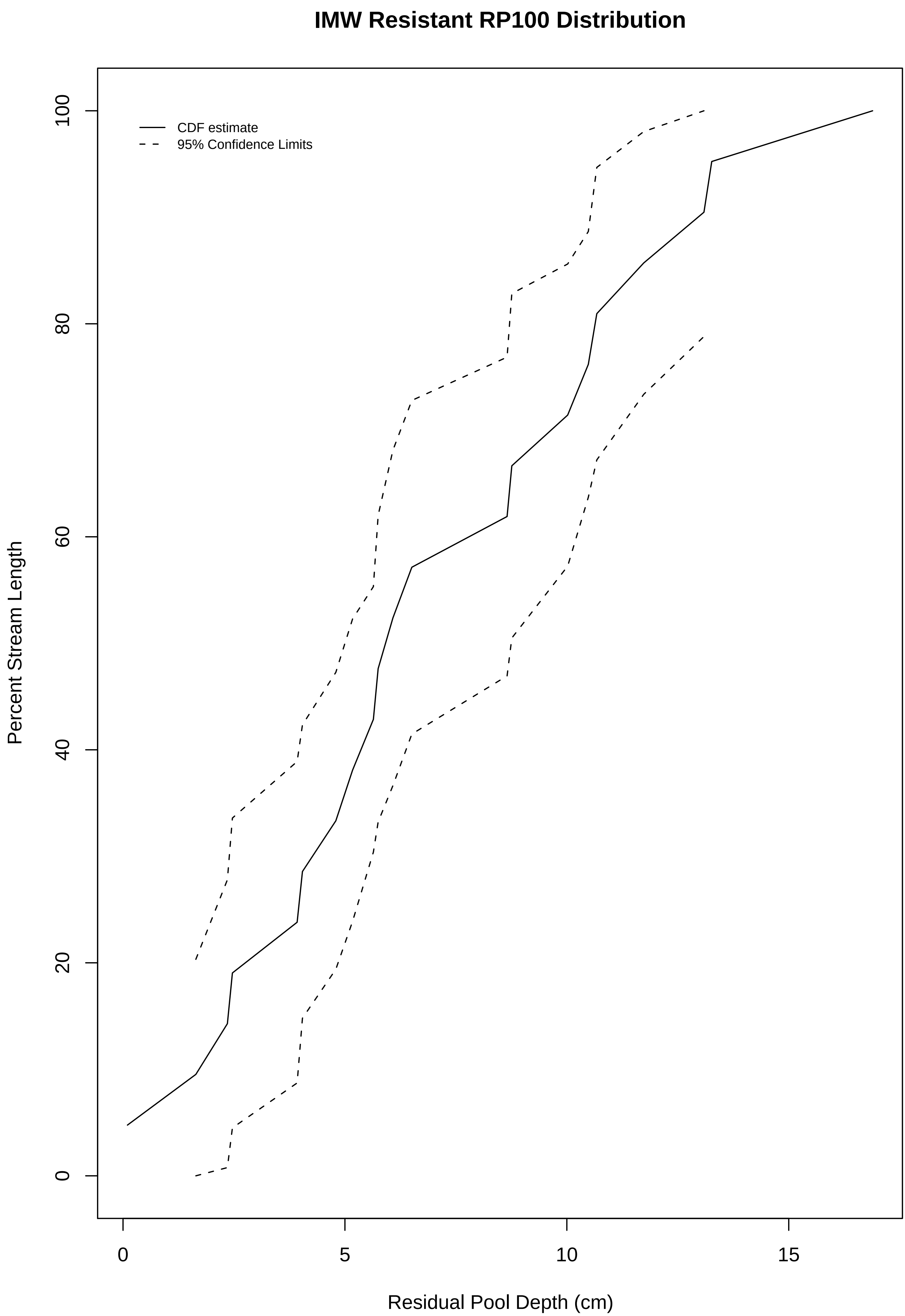

IMW Erodible RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.02
0.04
0.06
0.08
RW:Slope


IMW Erodible LRBS:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
LRBS:Slope

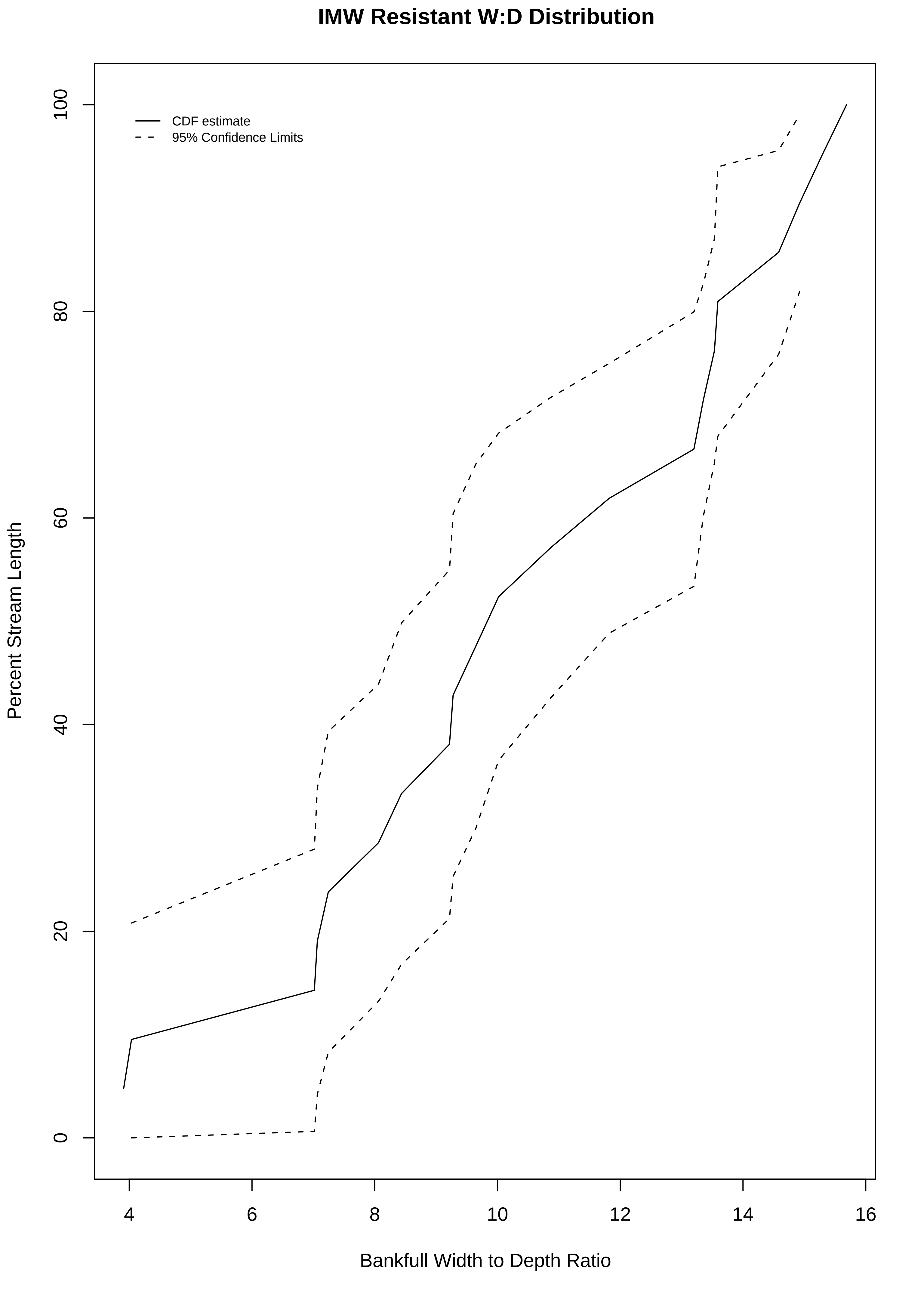

IMW Resistant LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−1.5
−1.0
−0.5
0.0
0.5
Log Relative Bed Stability

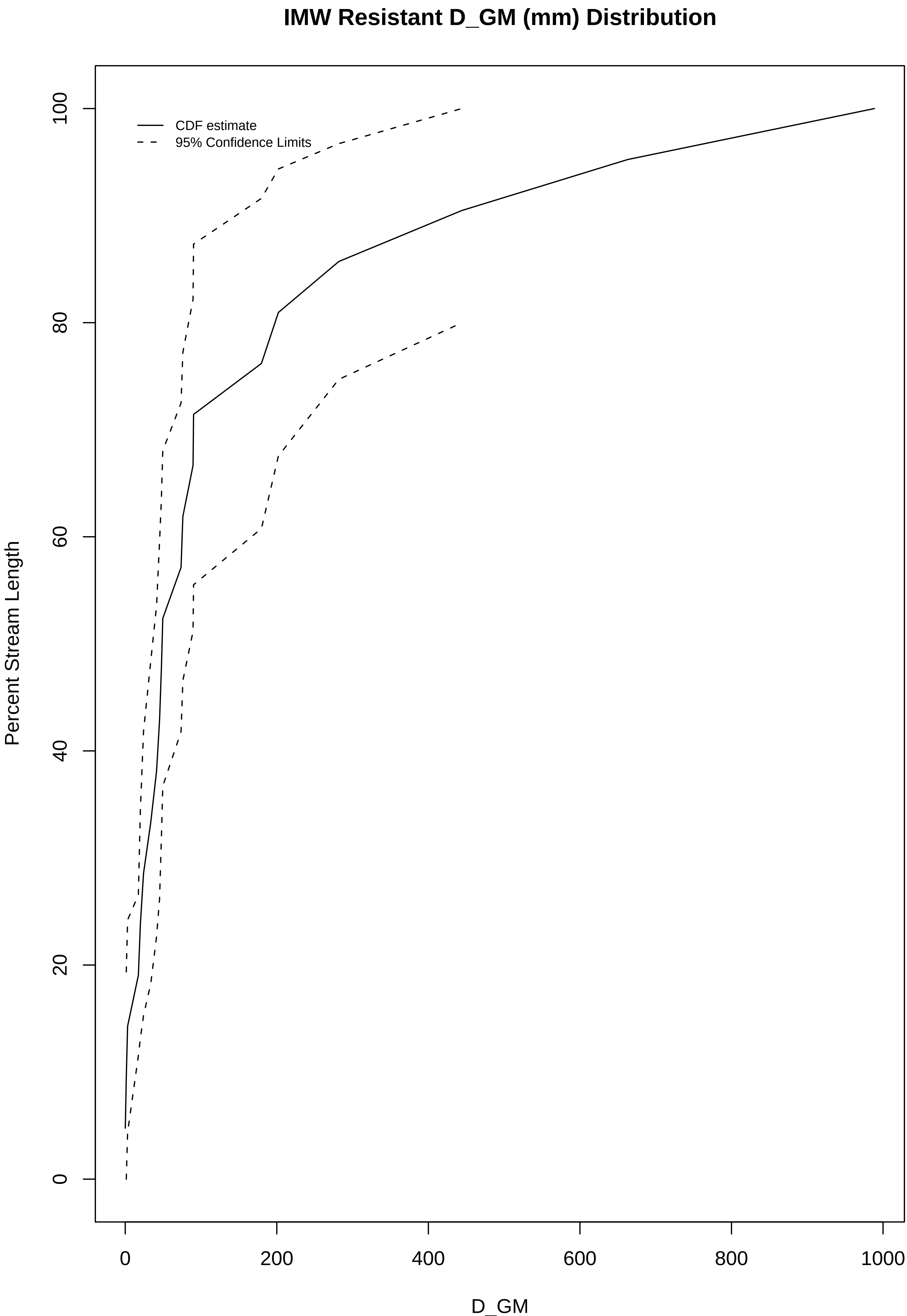

IMW Resistant %SAFN Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
Percent Sands & Fines
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8

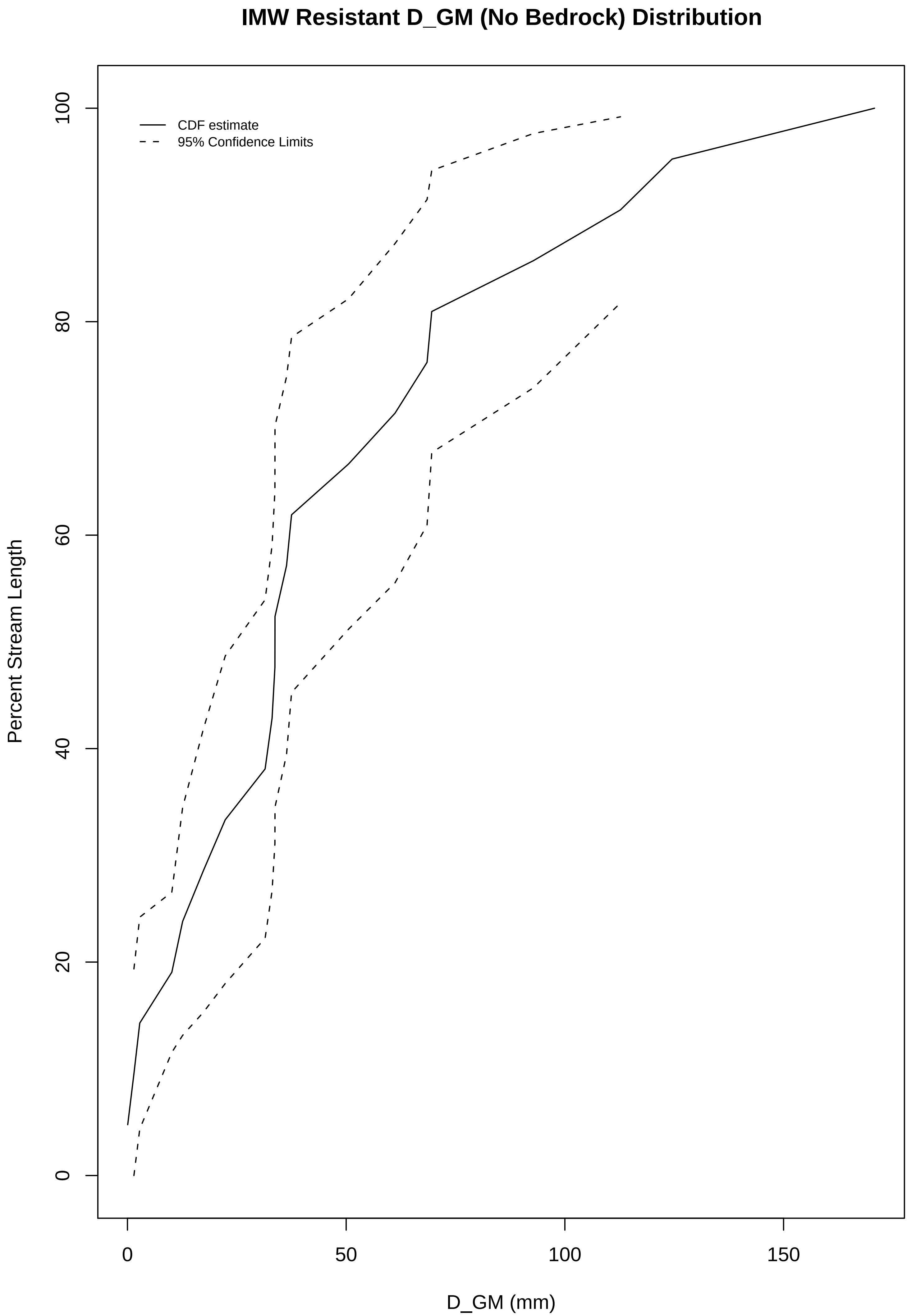

IMW Resistant RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
Wood Radius (m)

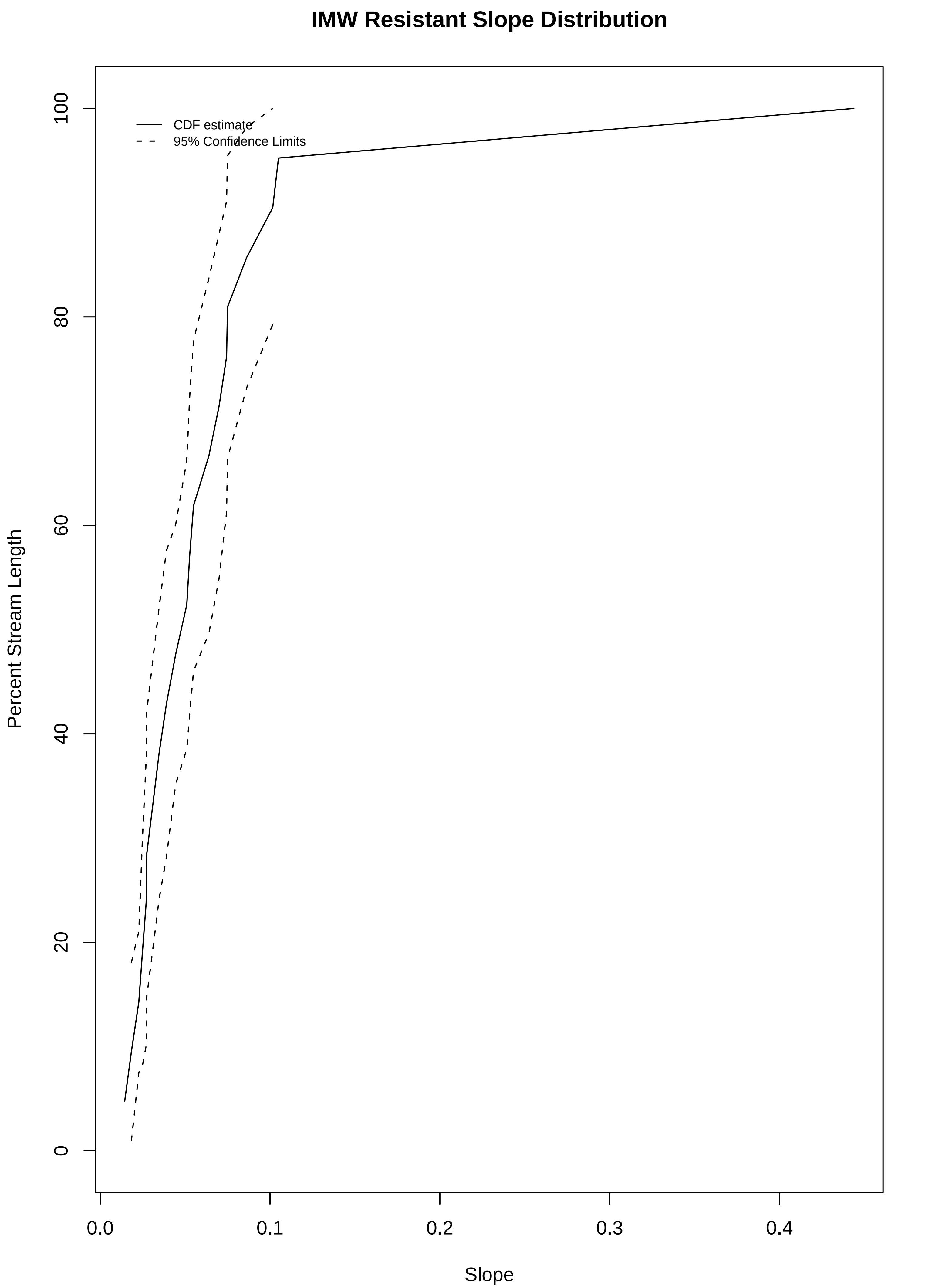


IMW Resistant RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
5
10
15
Residual Pool Depth (cm)

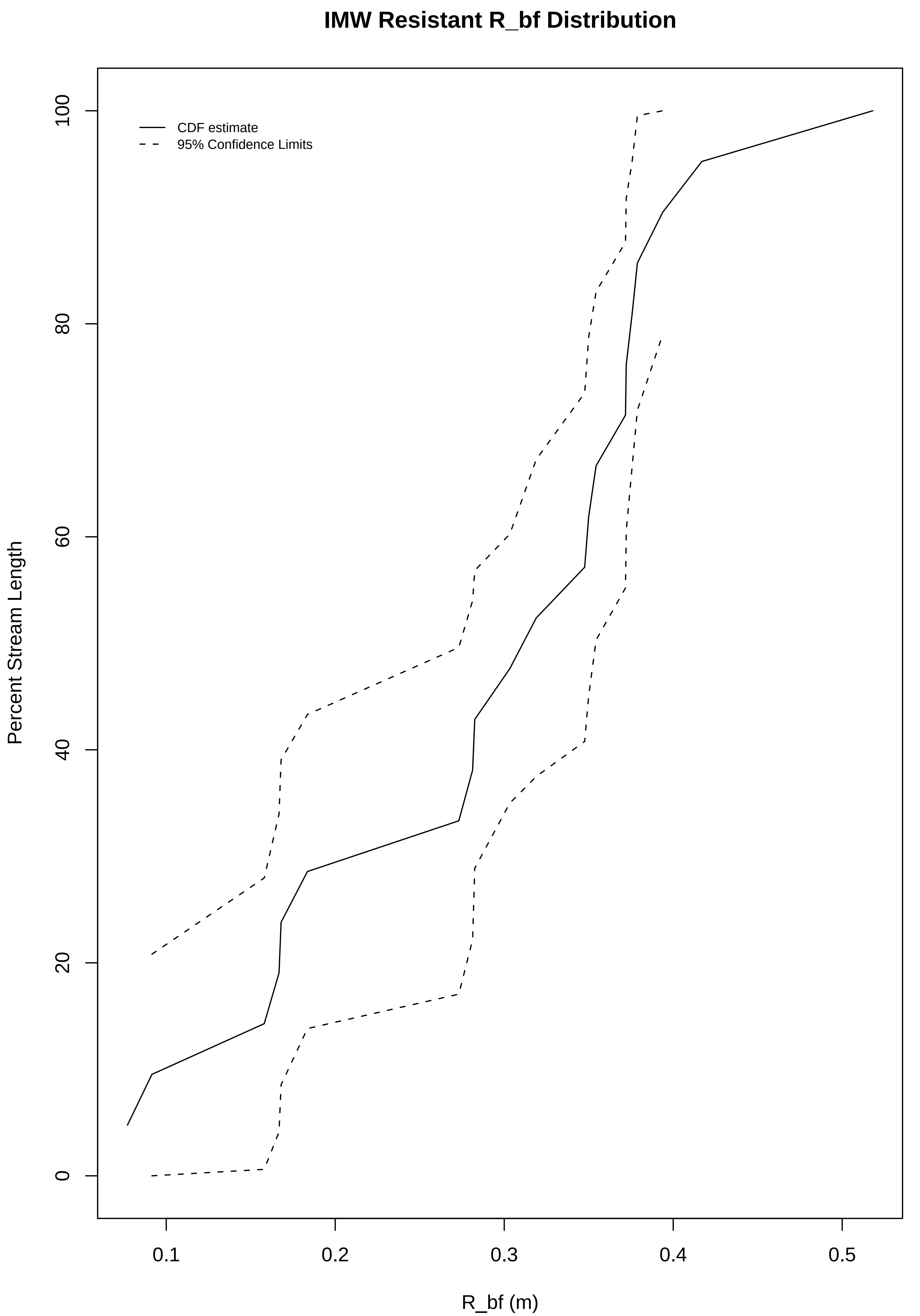

IMW Resistant W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
4
6
8
10
12
14
16
Bankfull Width to Depth Ratio

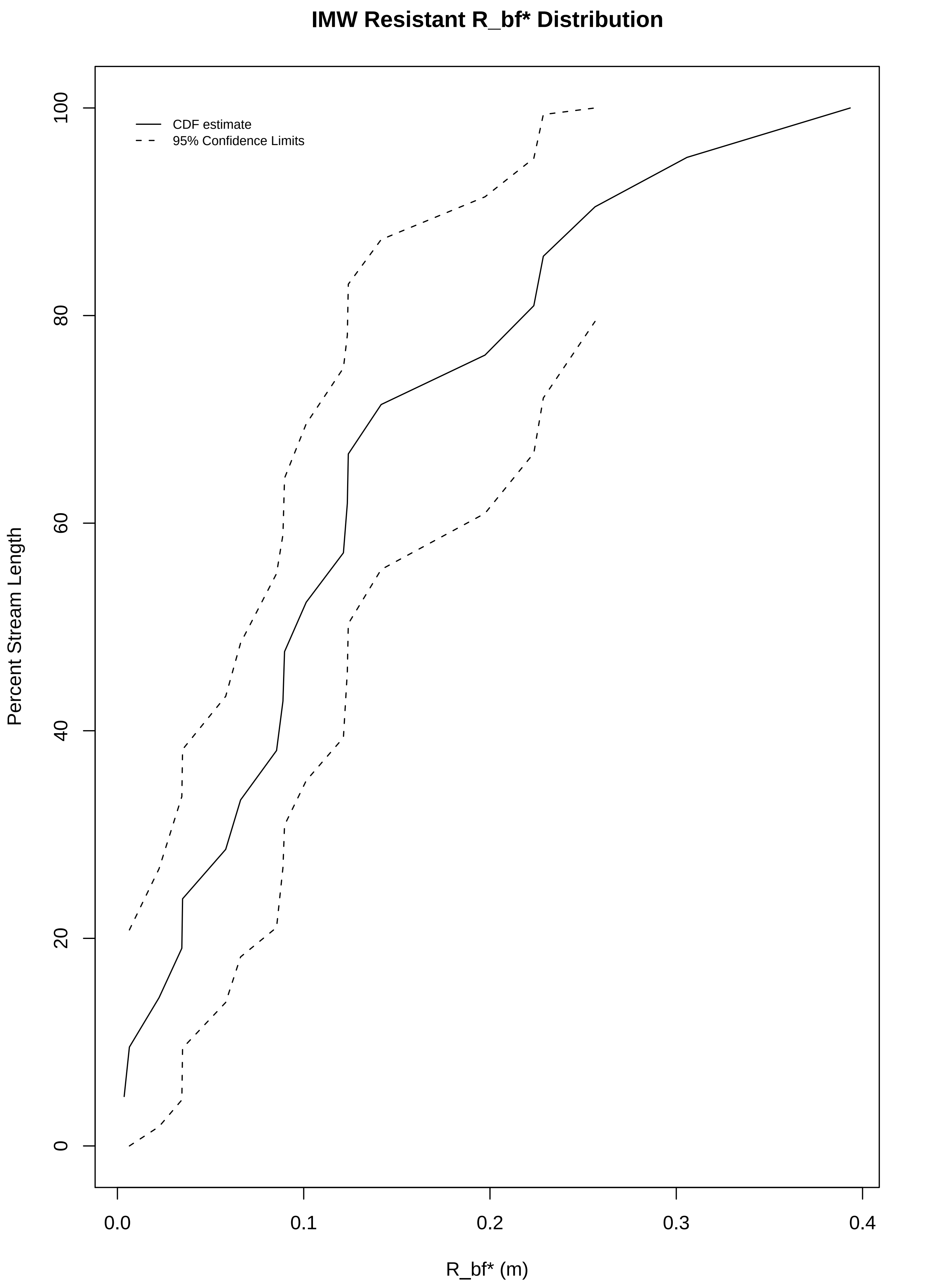

IMW Resistant D_GM (mm) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
200
400
600
800
1000
D_GM


IMW Resistant D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
50
100
150
D_GM (mm)

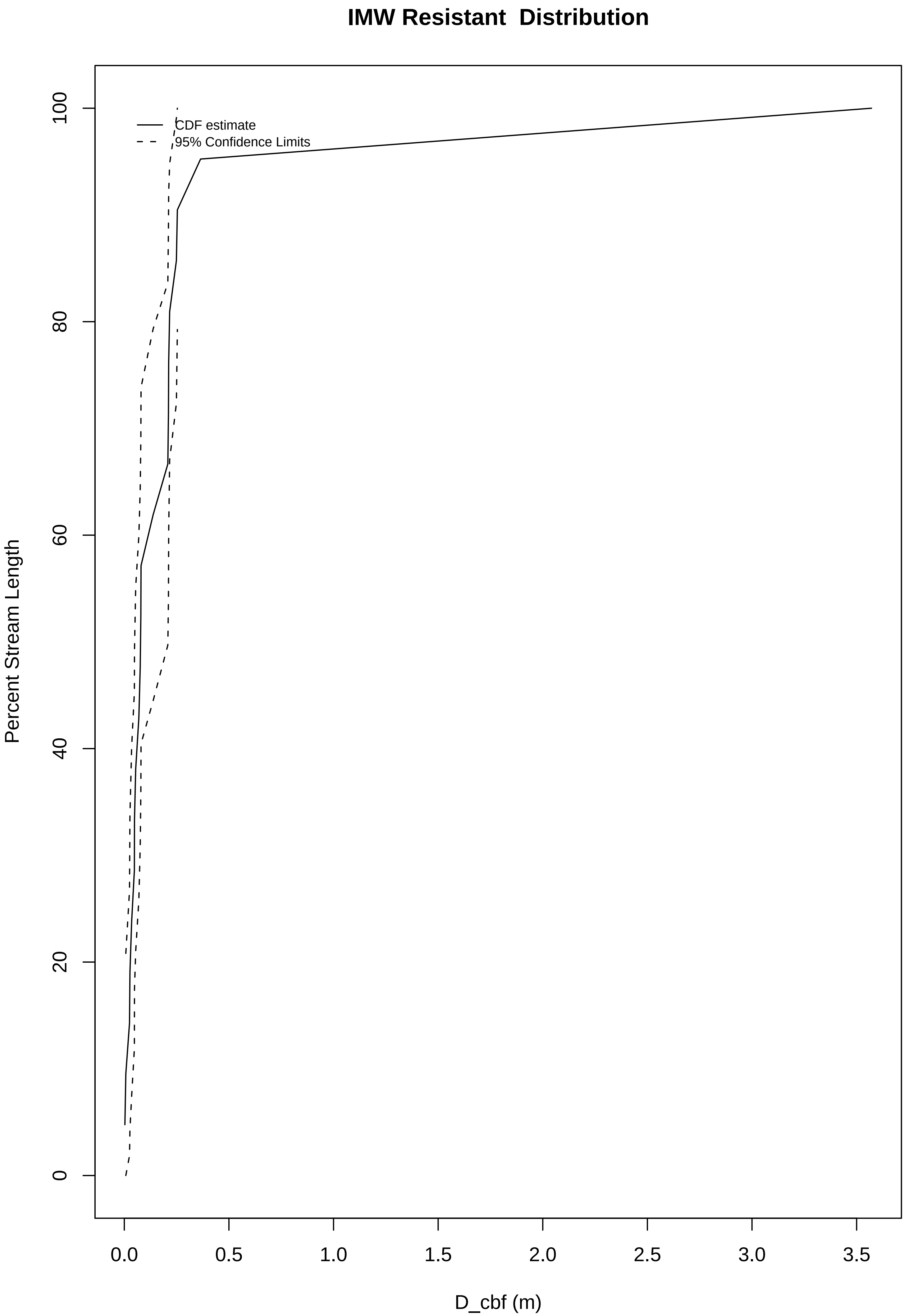


IMW Resistant Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
Slope
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4

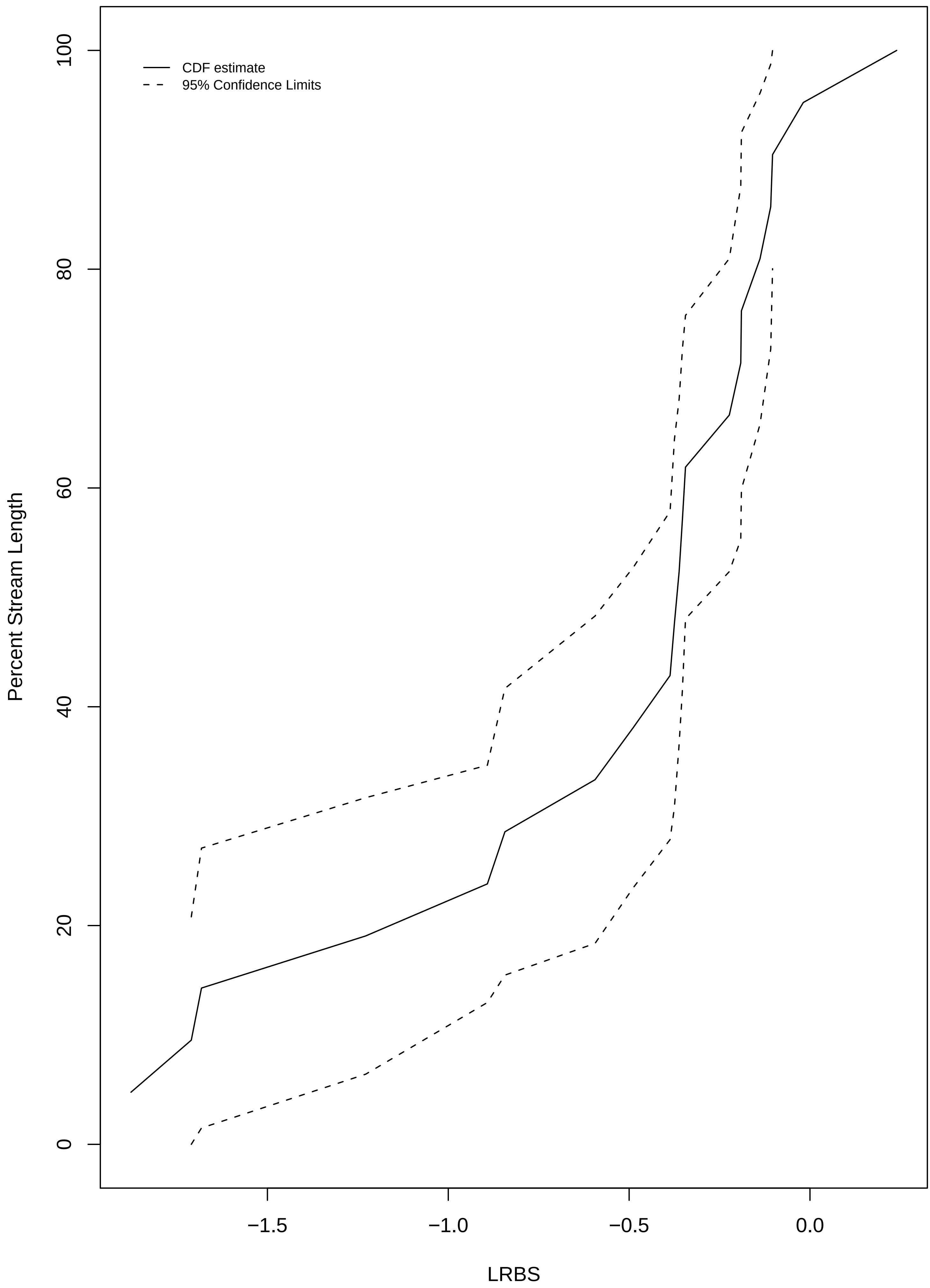

IMW Resistant R_bf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
0.5
R_bf (m)

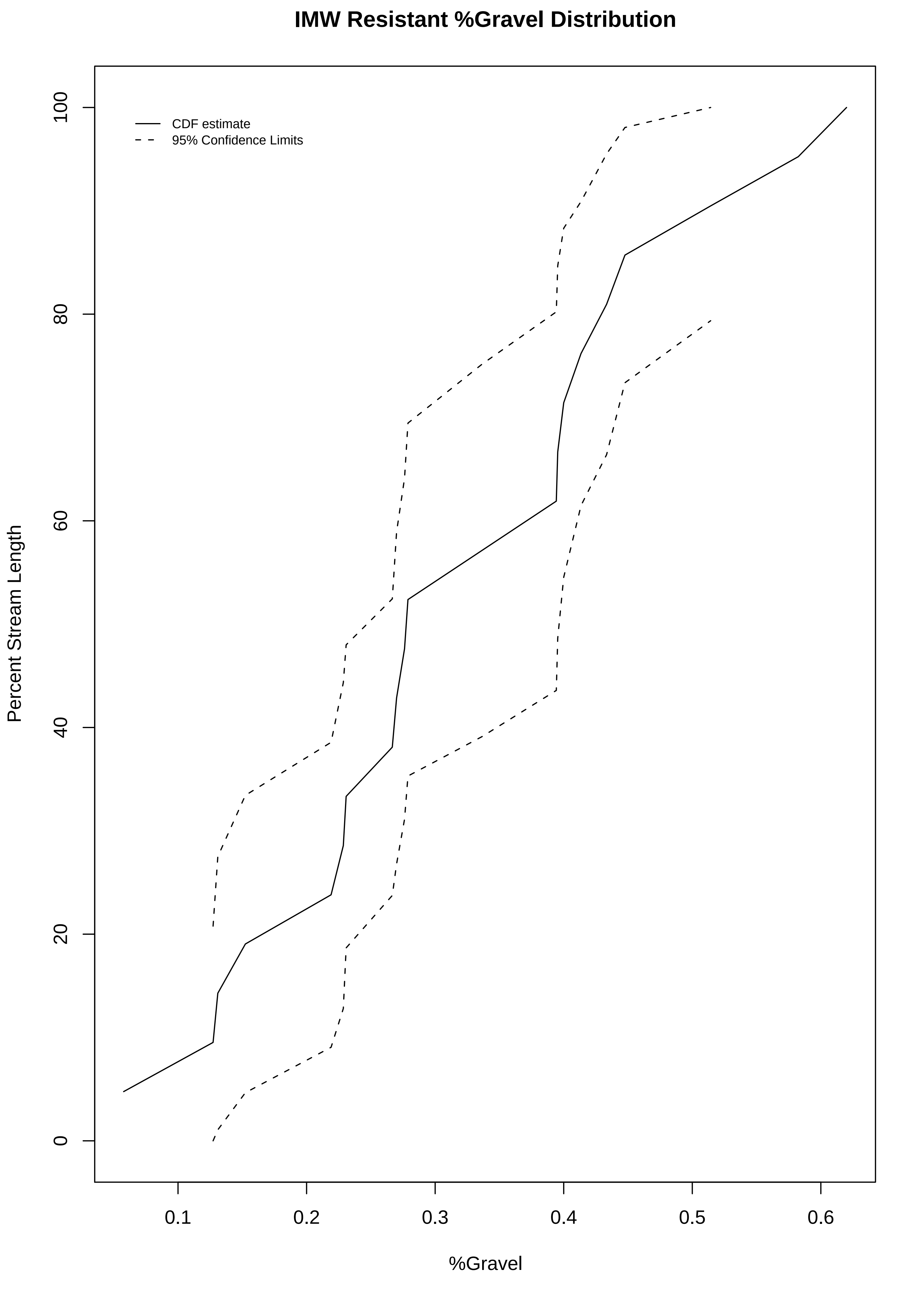


IMW Resistant R_bf* Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
R_bf* (m)

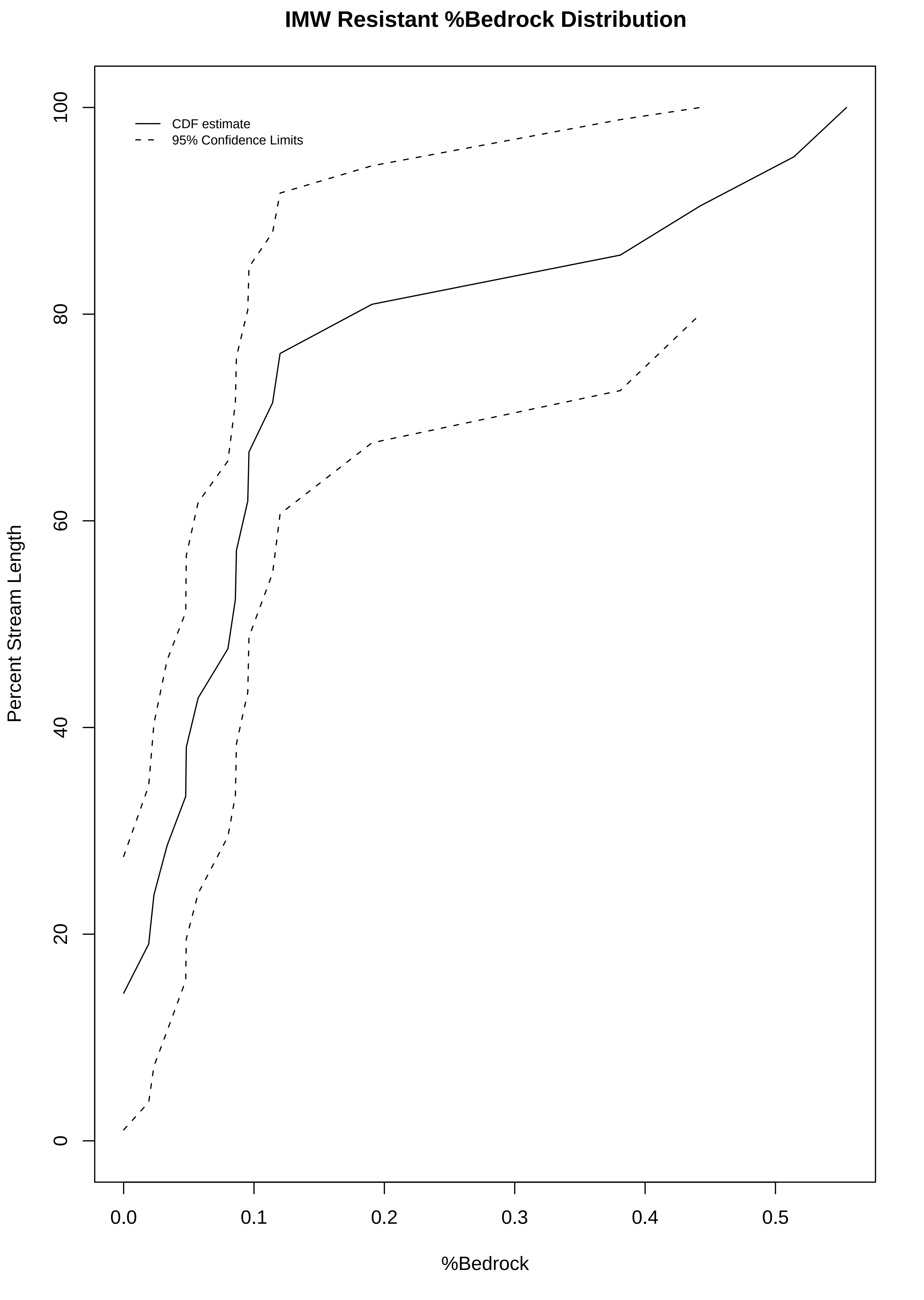

IMW Resistant Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
D_cbf (m)

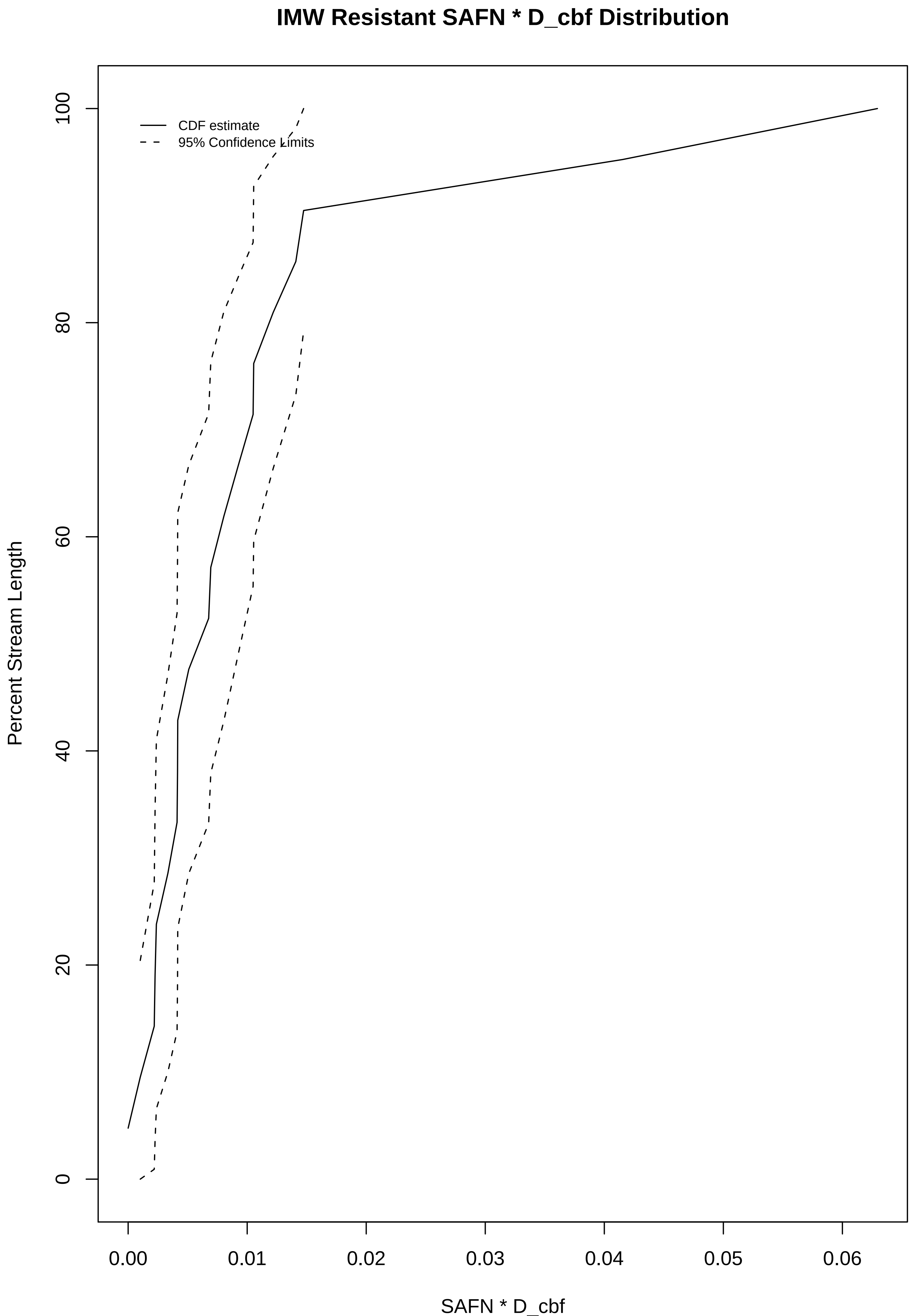
IMW Resistant LRBS (No Bedrock) Distribution



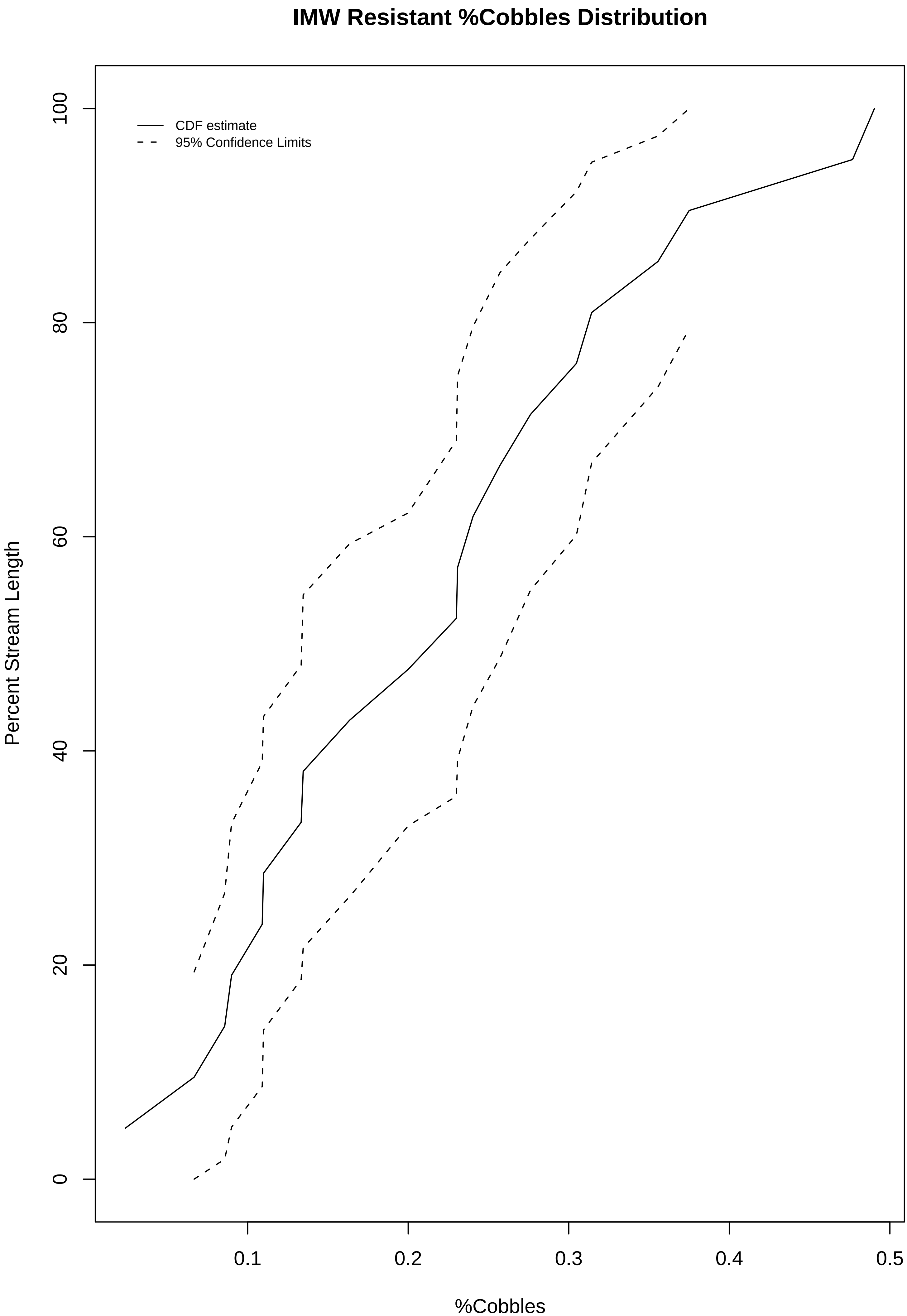


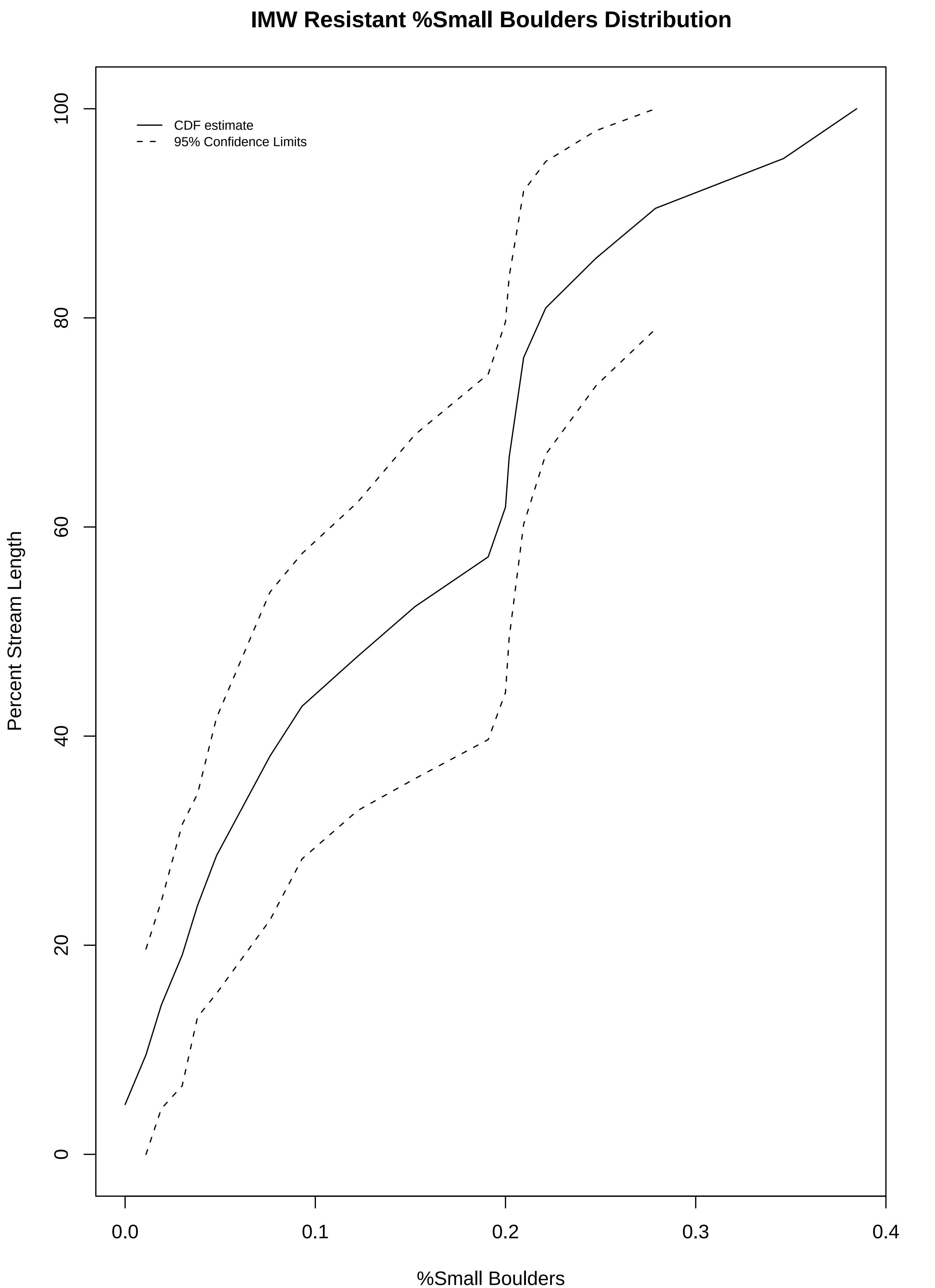
IMW Resistant %Gravel Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
0.5
0.6
%Gravel


IMW Resistant %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
%Bedrock

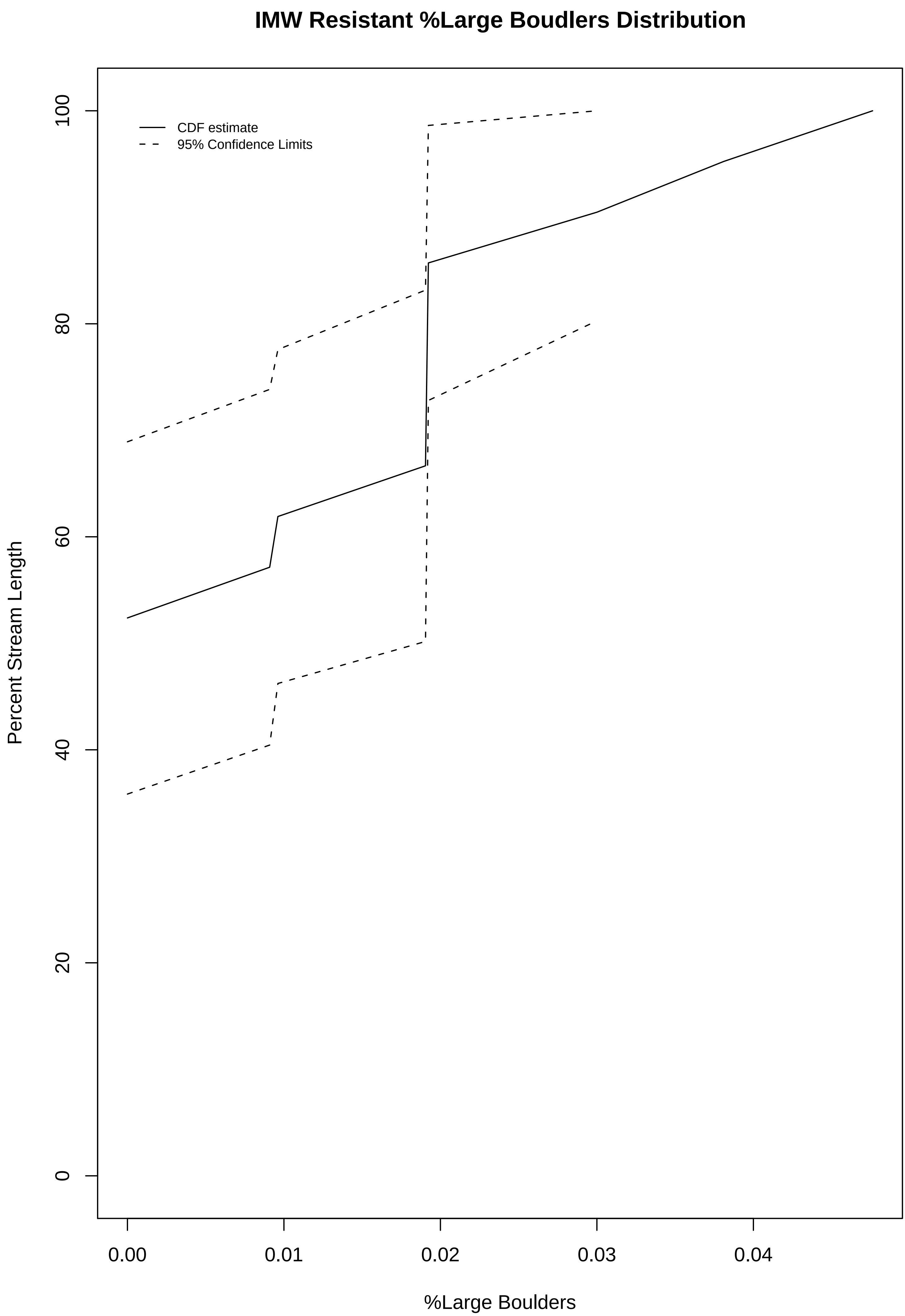


IMW Resistant SAFN * D_cbf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.01
0.02
0.03
0.04
0.05
0.06
SAFN * D_cbf

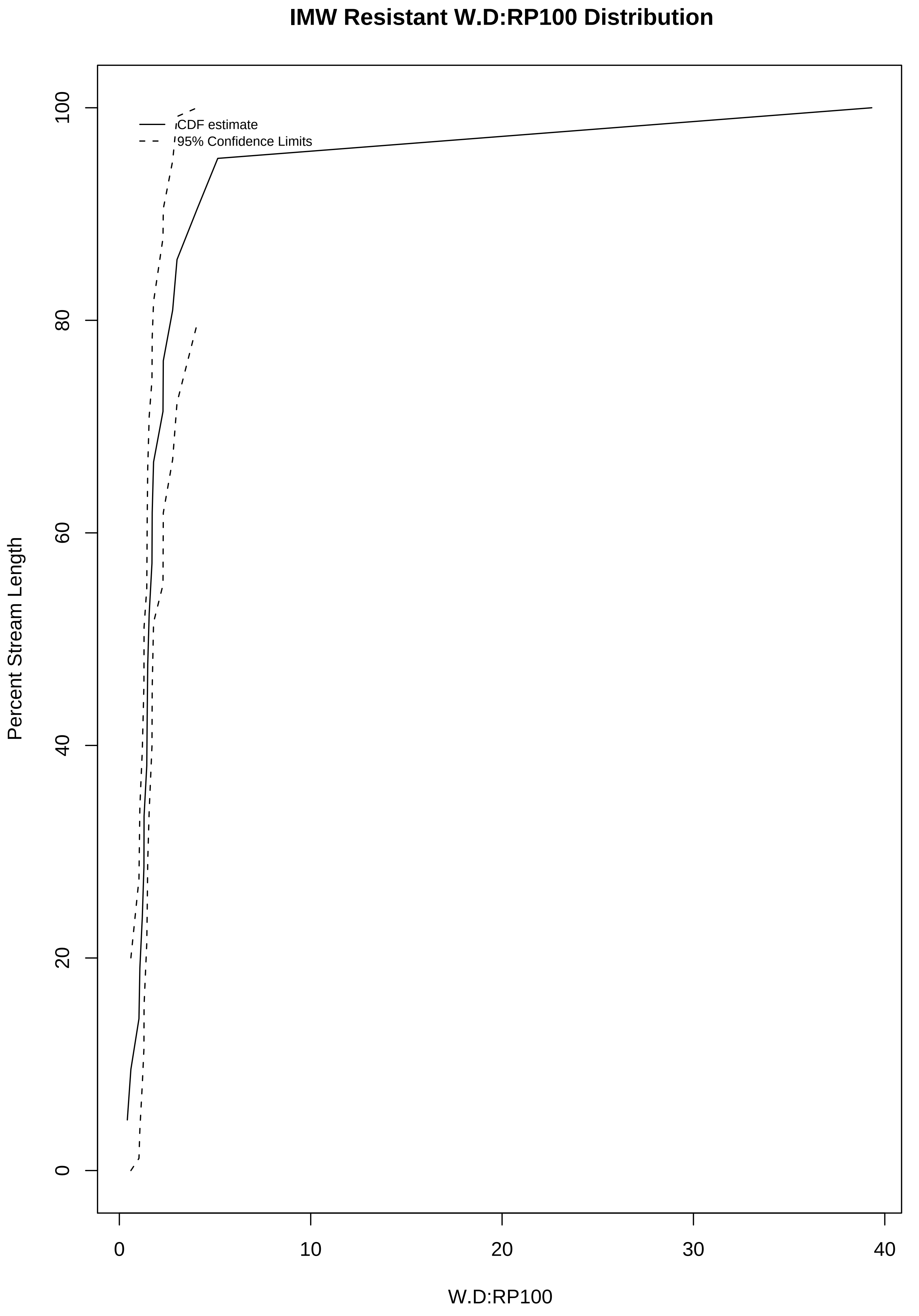

IMW Resistant %Cobbles Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
0.5
%Cobbles

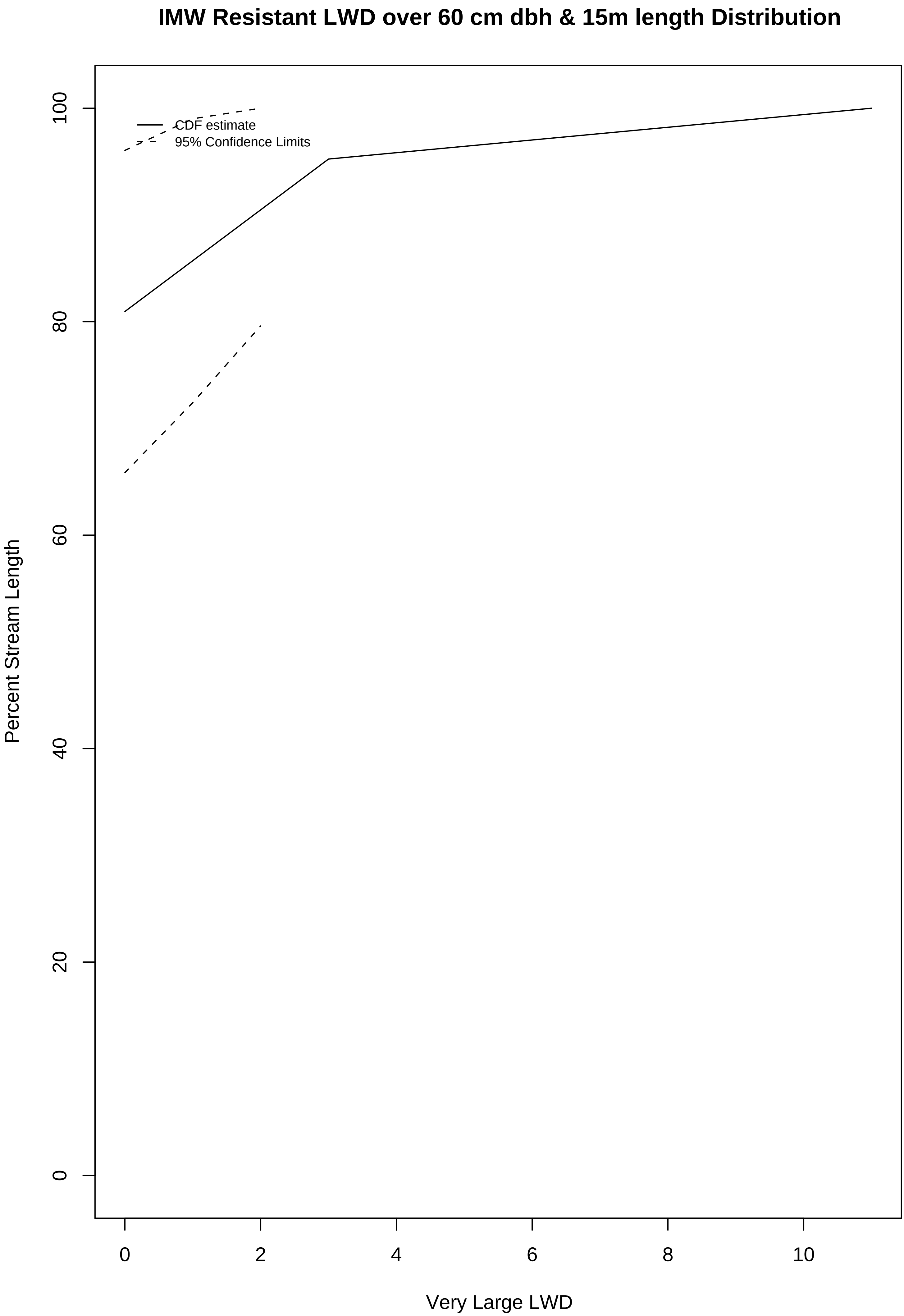


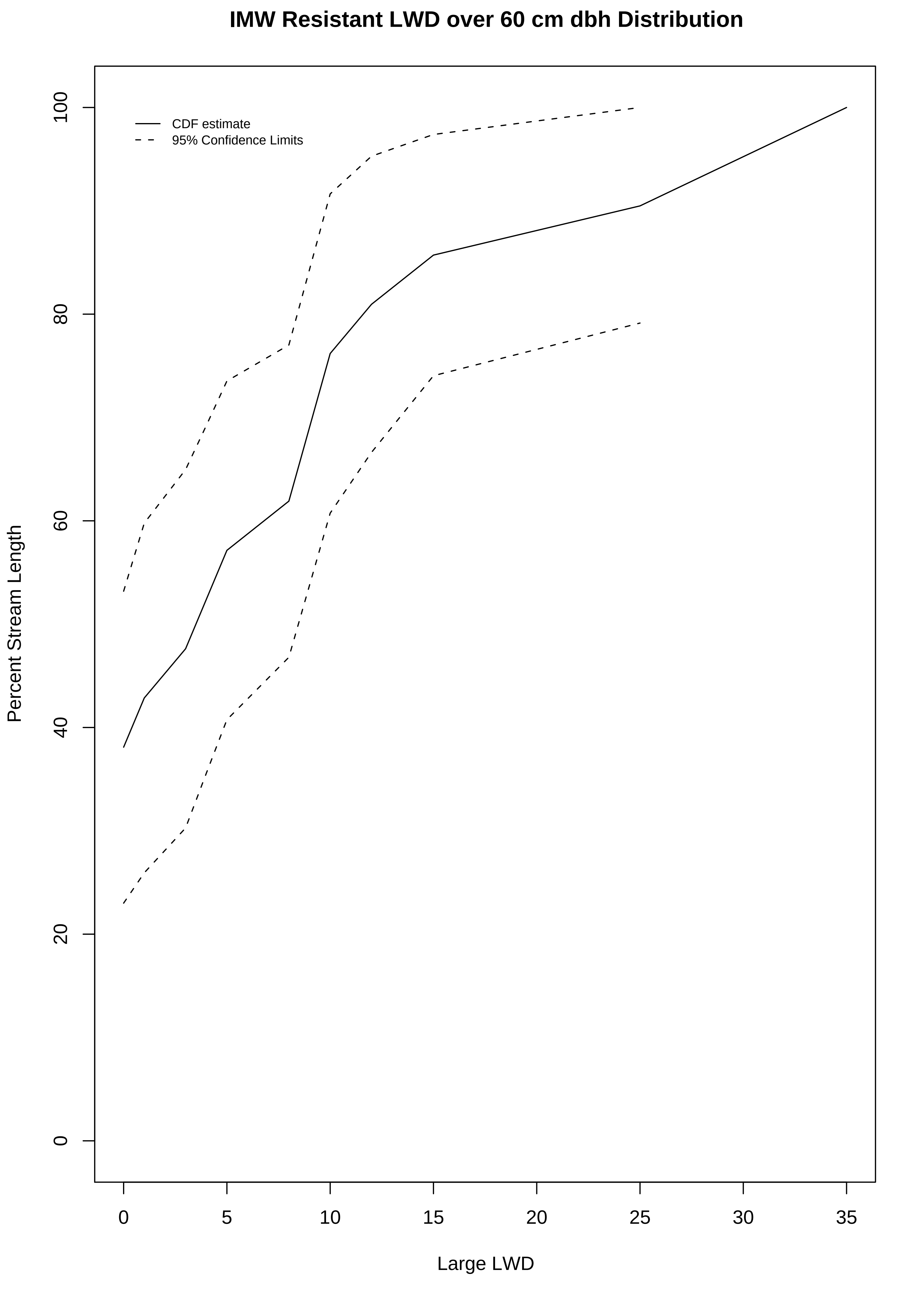
IMW Resistant %Small Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
%Small Boulders

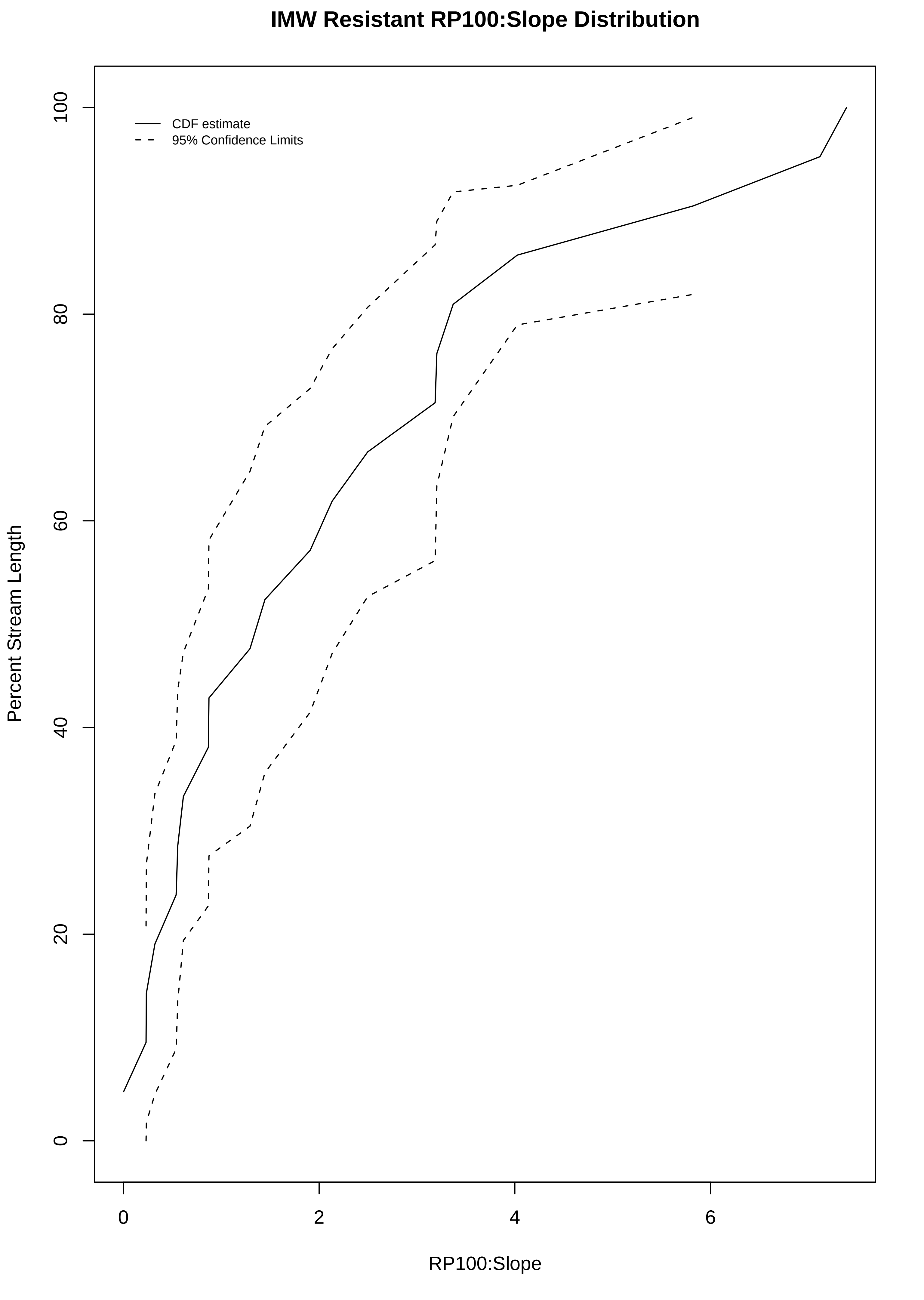


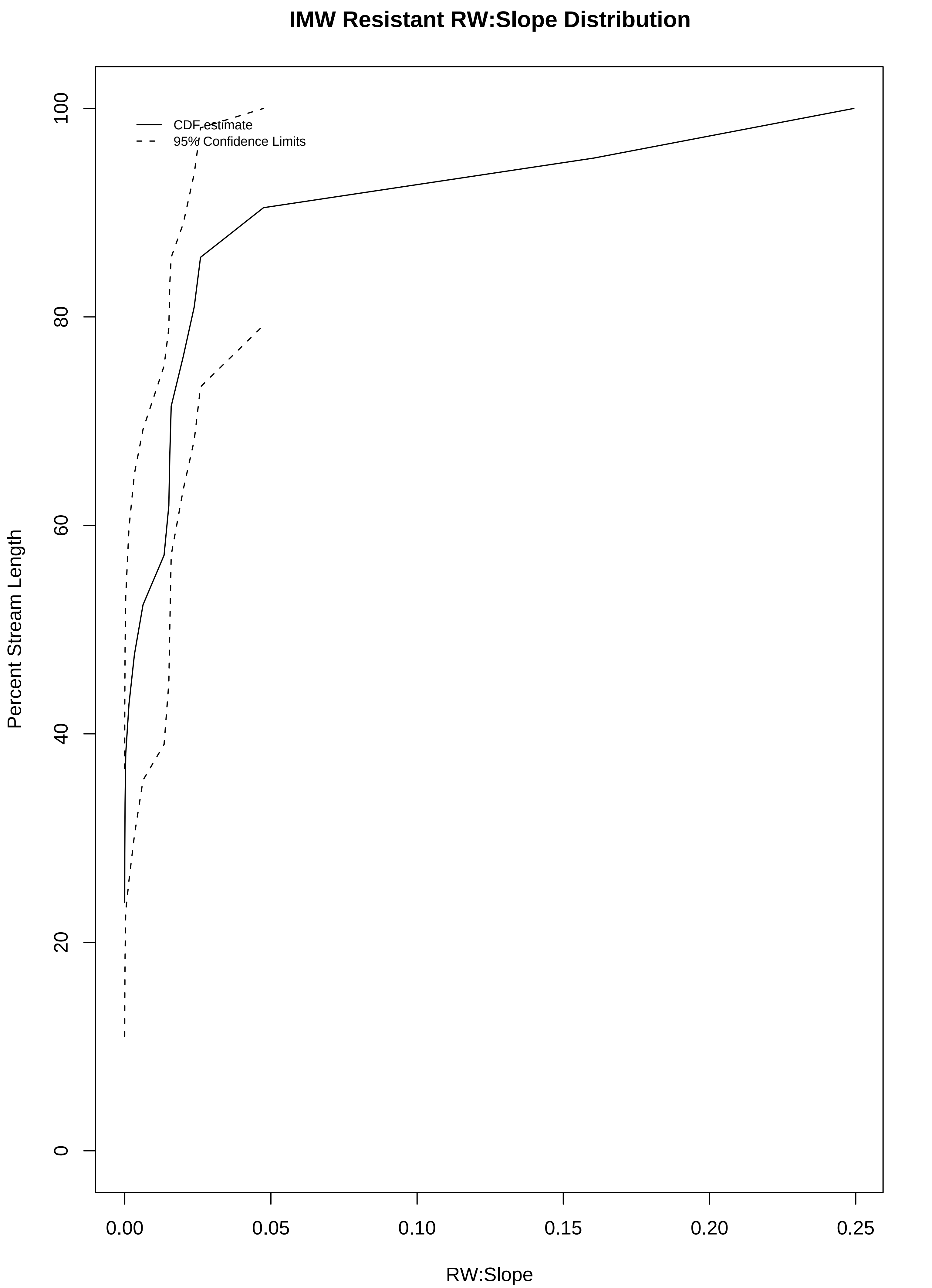
IMW Resistant %Large Boudlers Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.01
0.02
0.03
0.04
%Large Boulders


IMW Resistant W.D:RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
10
20
30
40
W.D:RP100

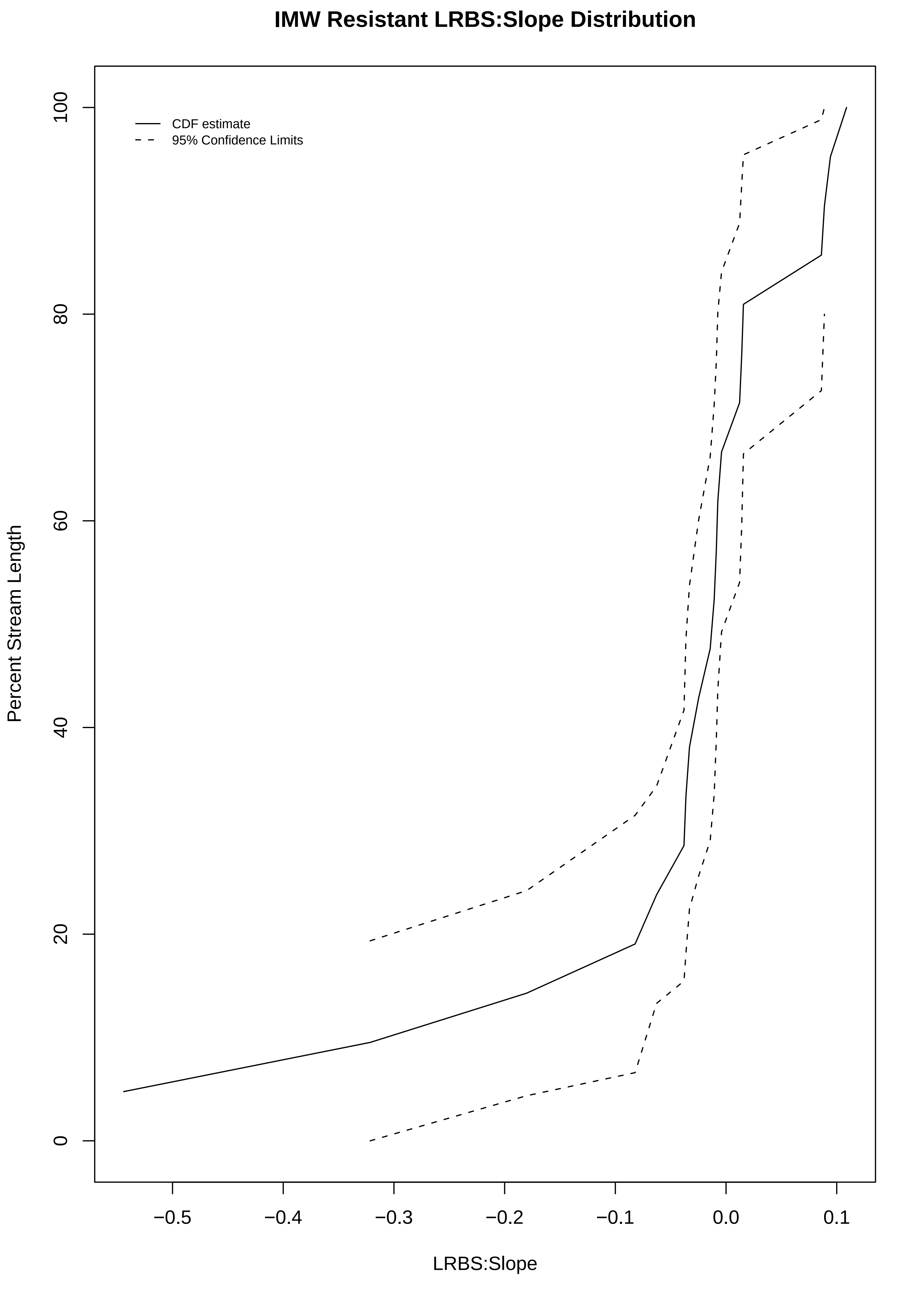

IMW Resistant LWD over 60 cm dbh & 15m length Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
Very Large LWD
0
20
40
60
80
100
0
2
4
6
8
10

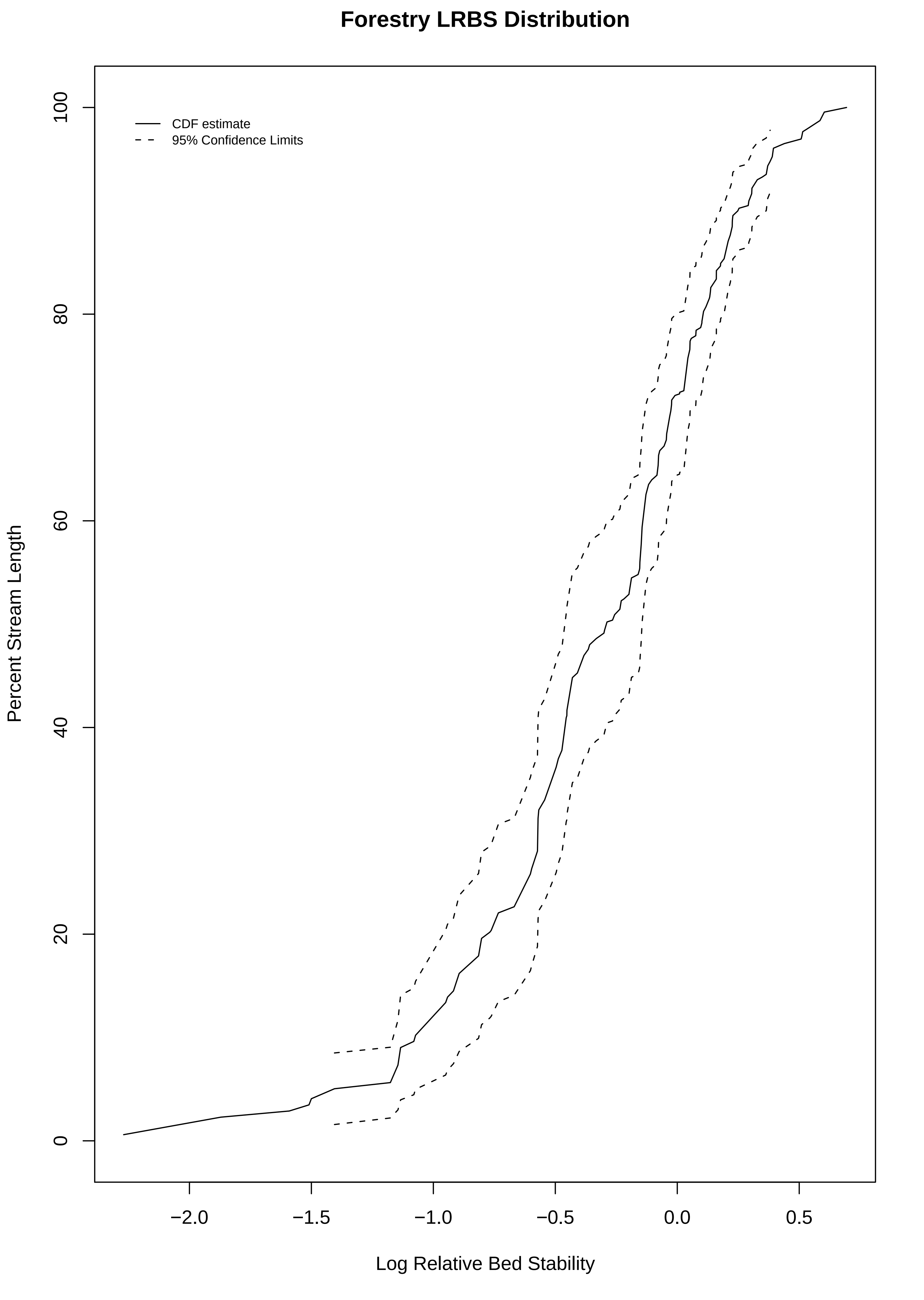

IMW Resistant LWD over 60 cm dbh Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
5
10
15
20
25
30
35
Large LWD

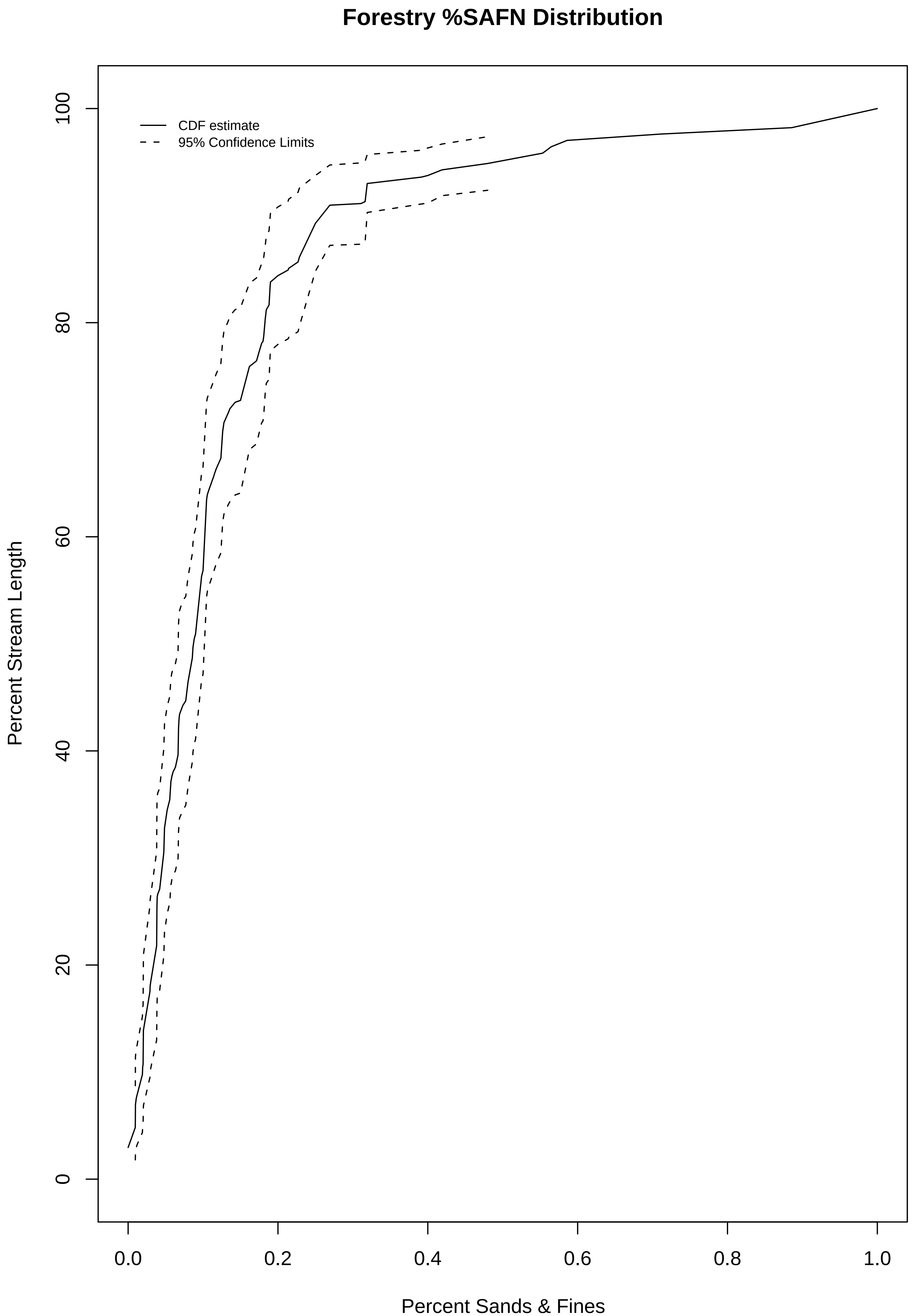

IMW Resistant RP100:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
2
4
6
RP100:Slope

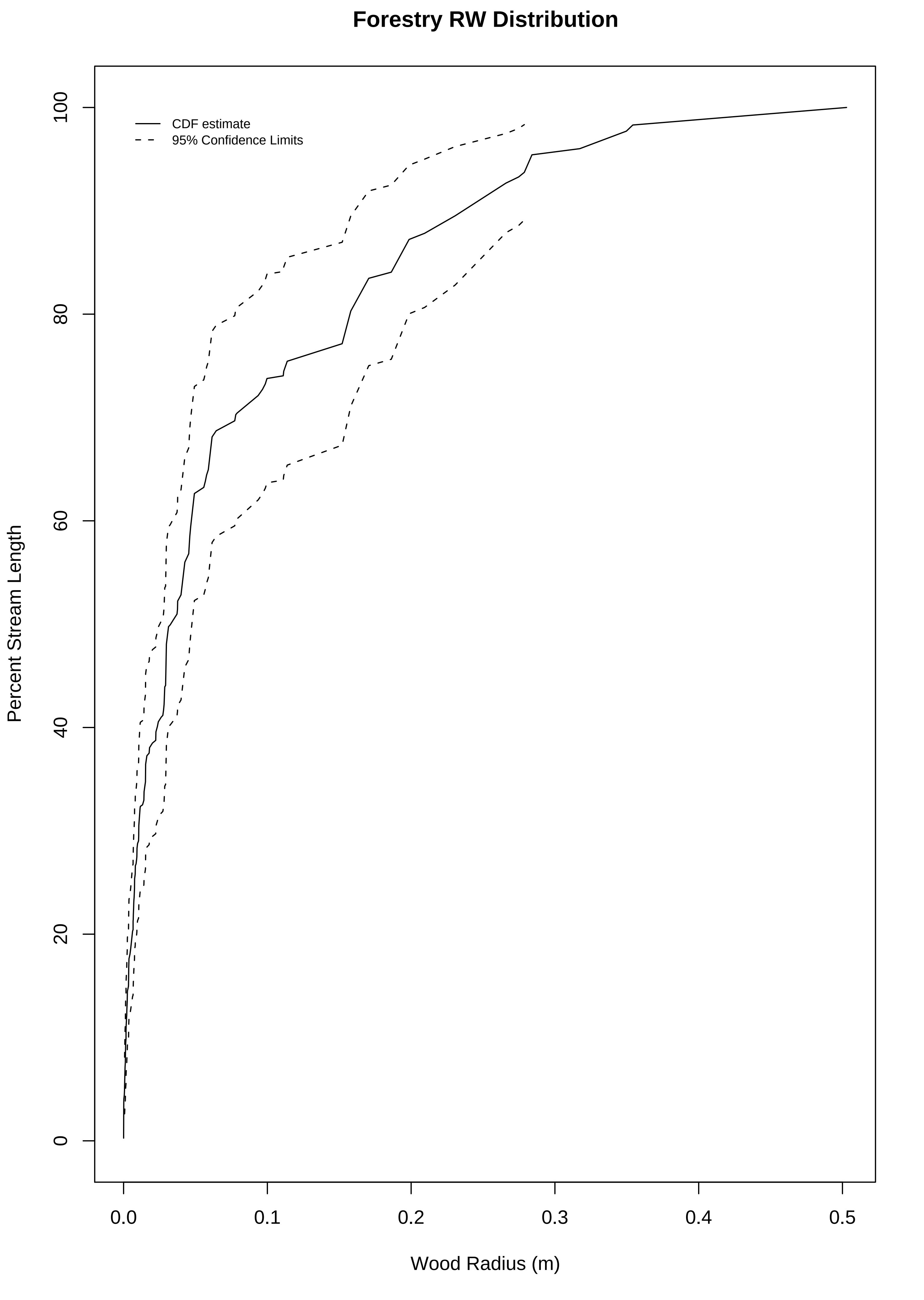


IMW Resistant RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
RW:Slope


IMW Resistant LRBS:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
0.1
LRBS:Slope

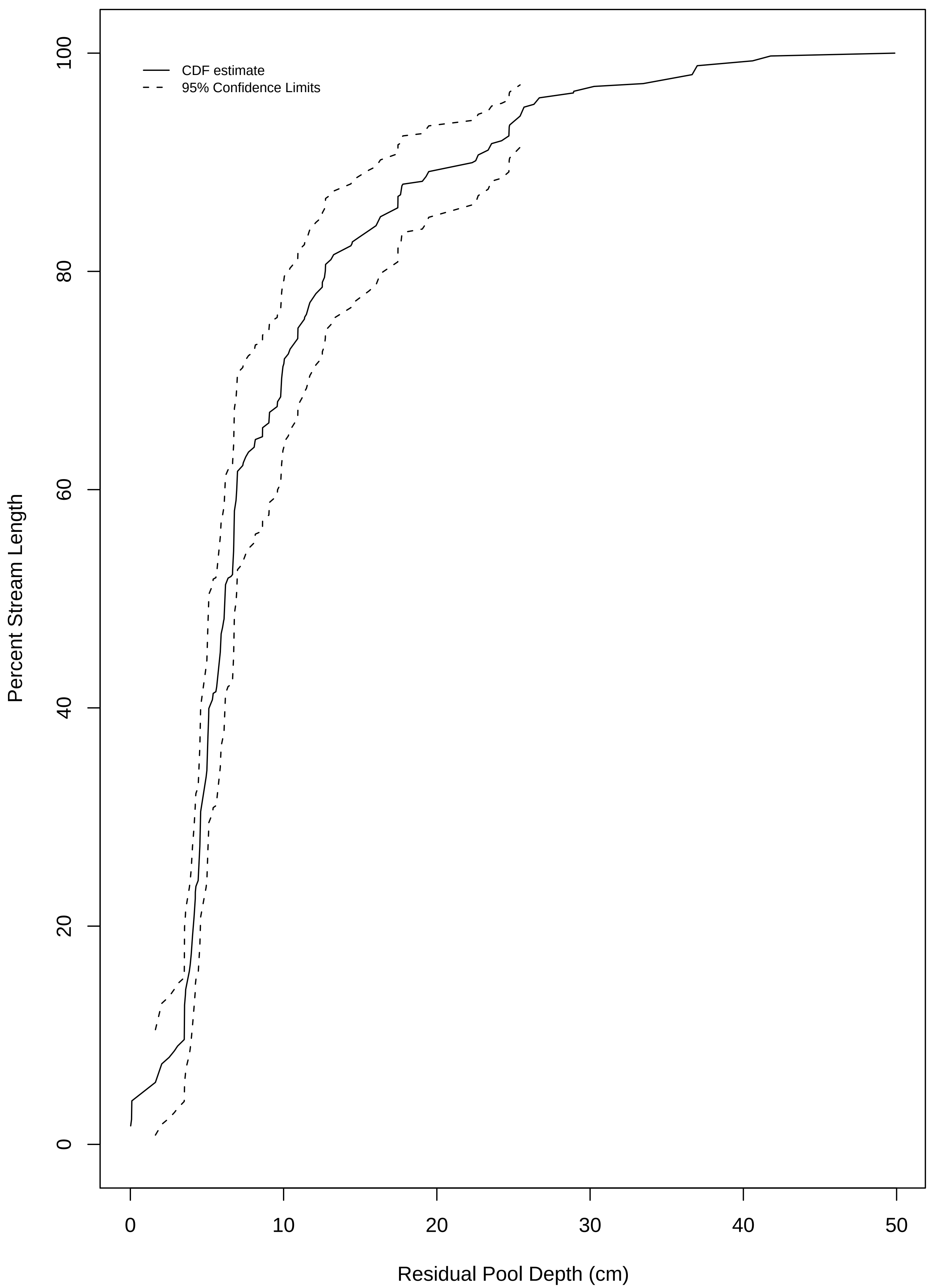

Forestry LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−2.0
−1.5
−1.0
−0.5
0.0
0.5
Log Relative Bed Stability

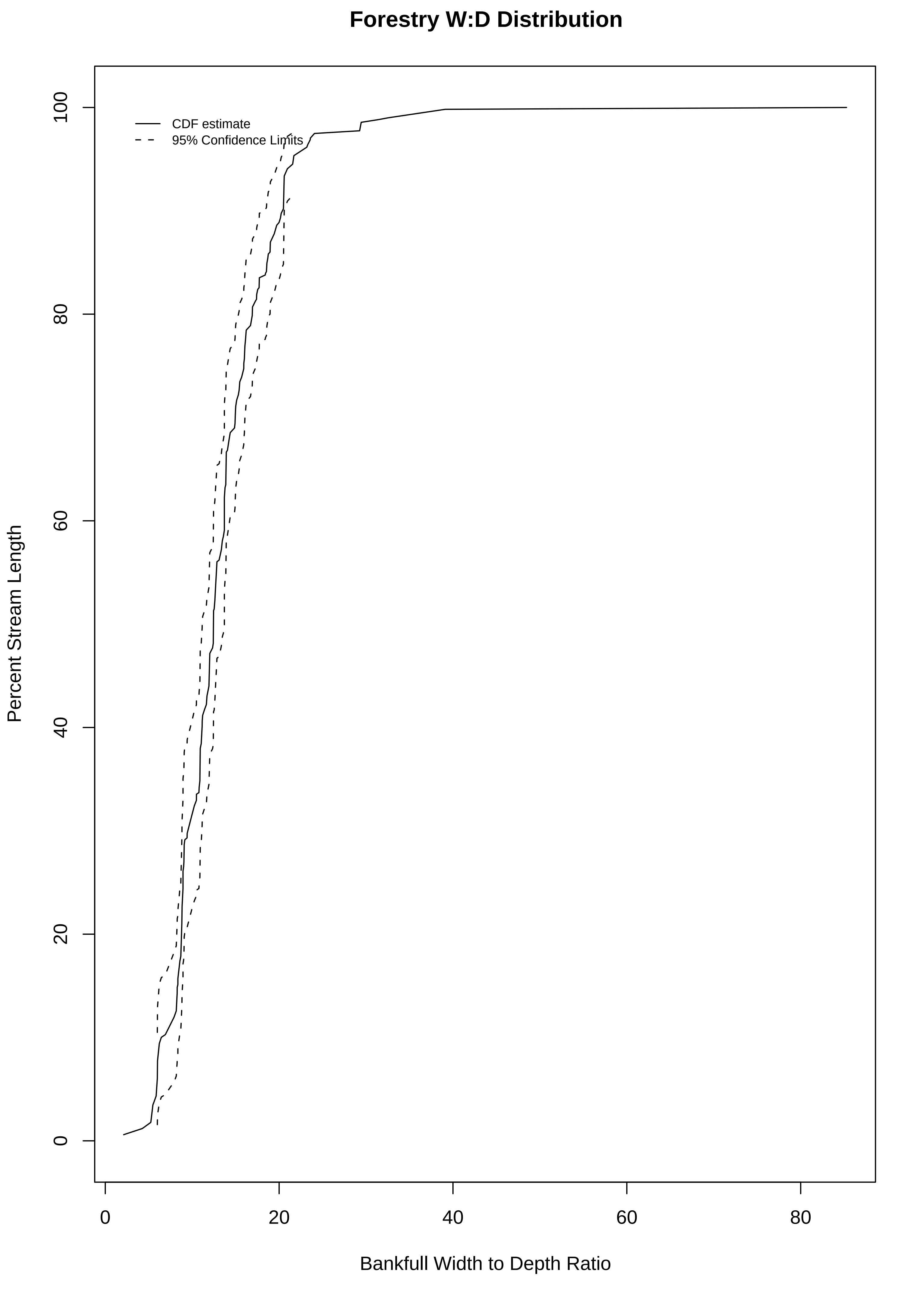

Forestry %SAFN Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0
Percent Sands & Fines



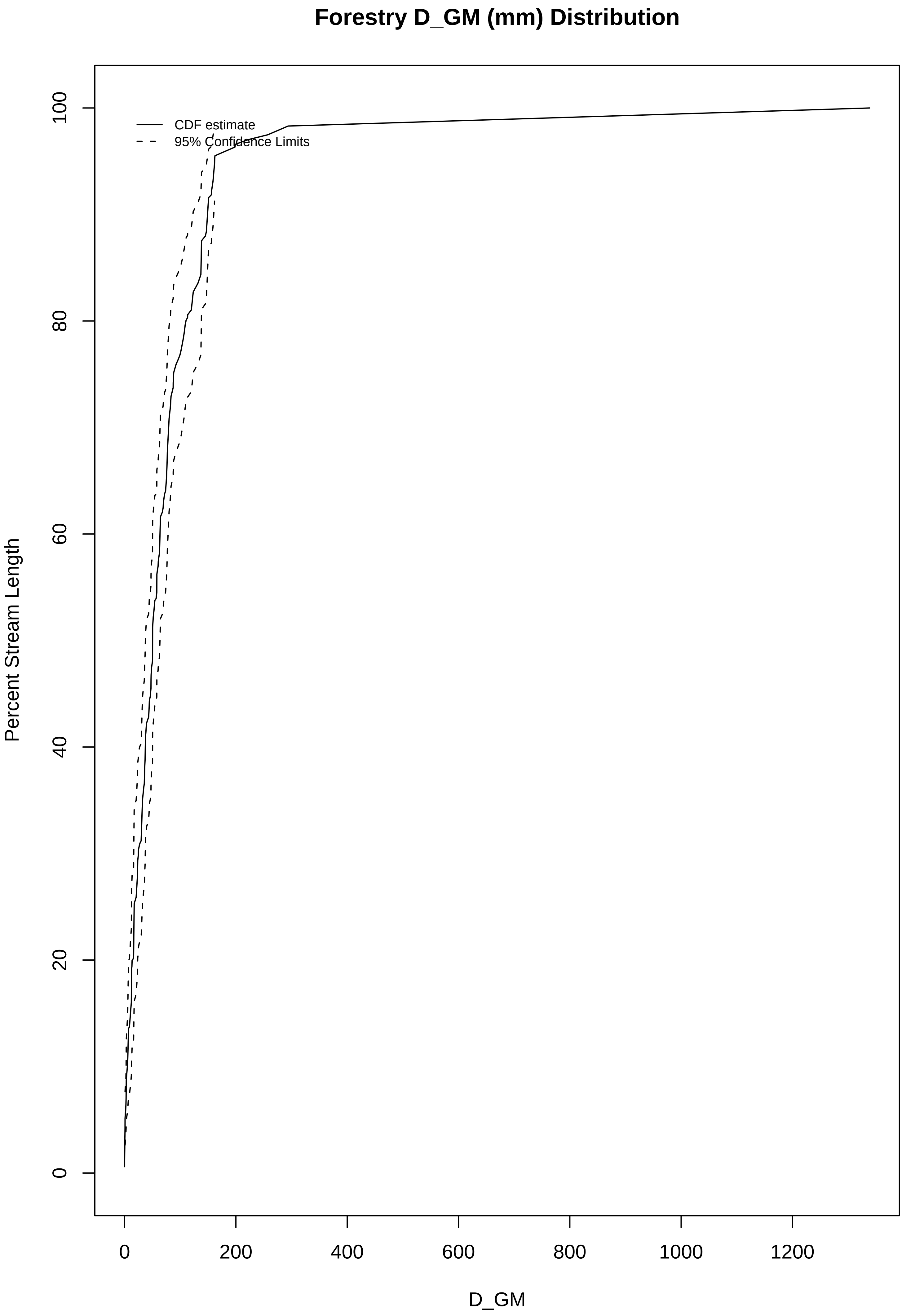
Forestry RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
Wood Radius (m)

Forestry RP100 Distribution

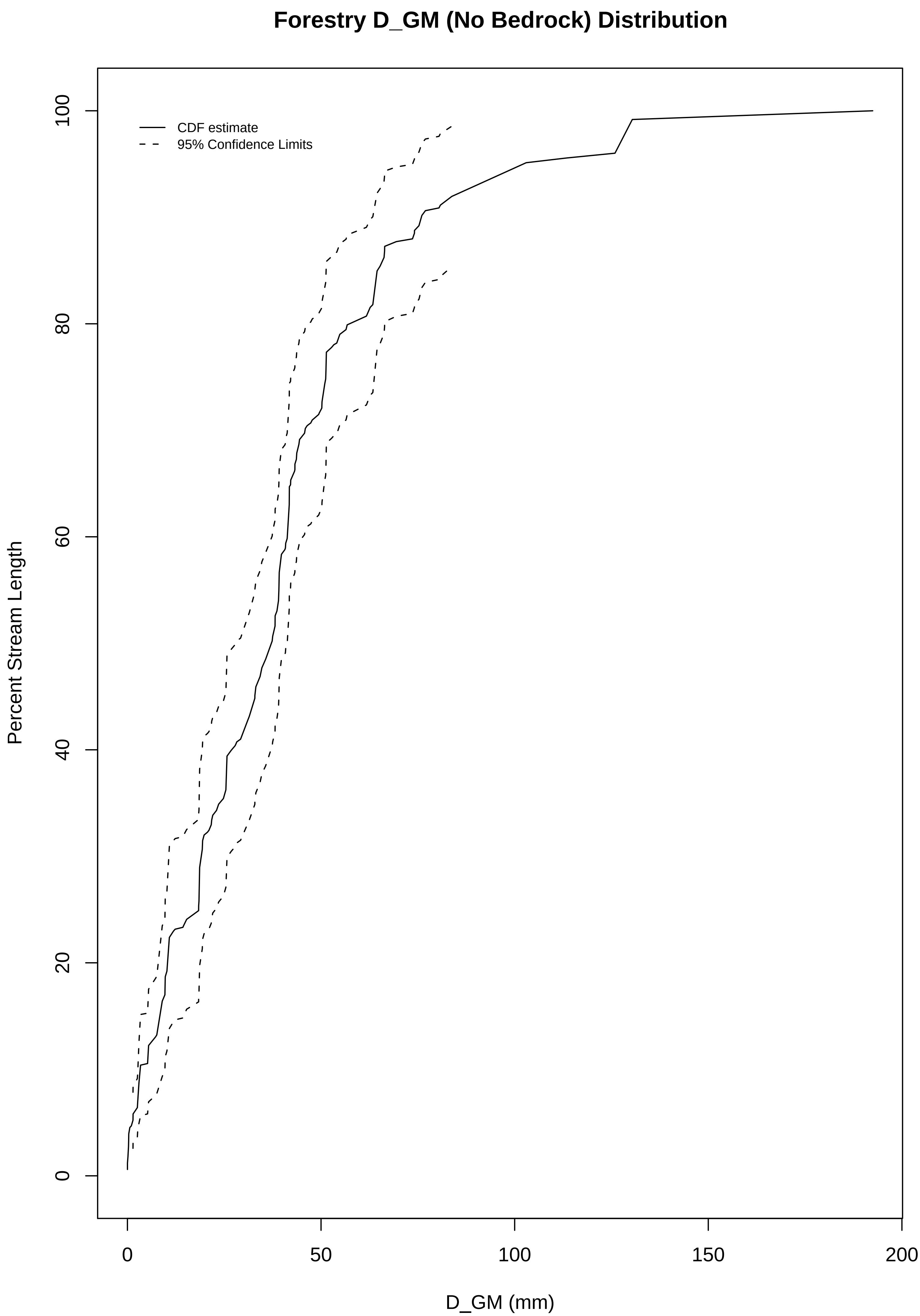




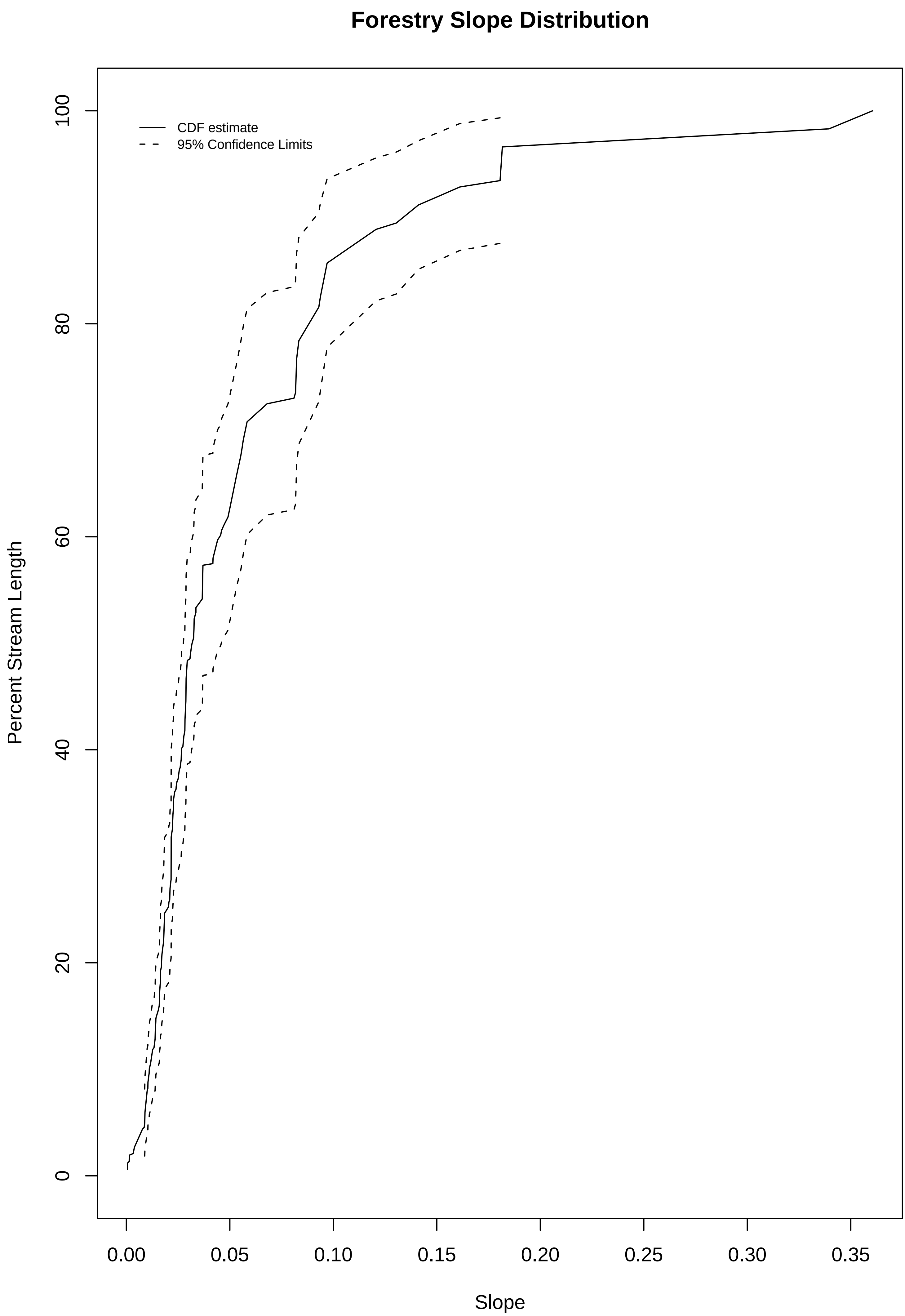
Forestry W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
Bankfull Width to Depth Ratio

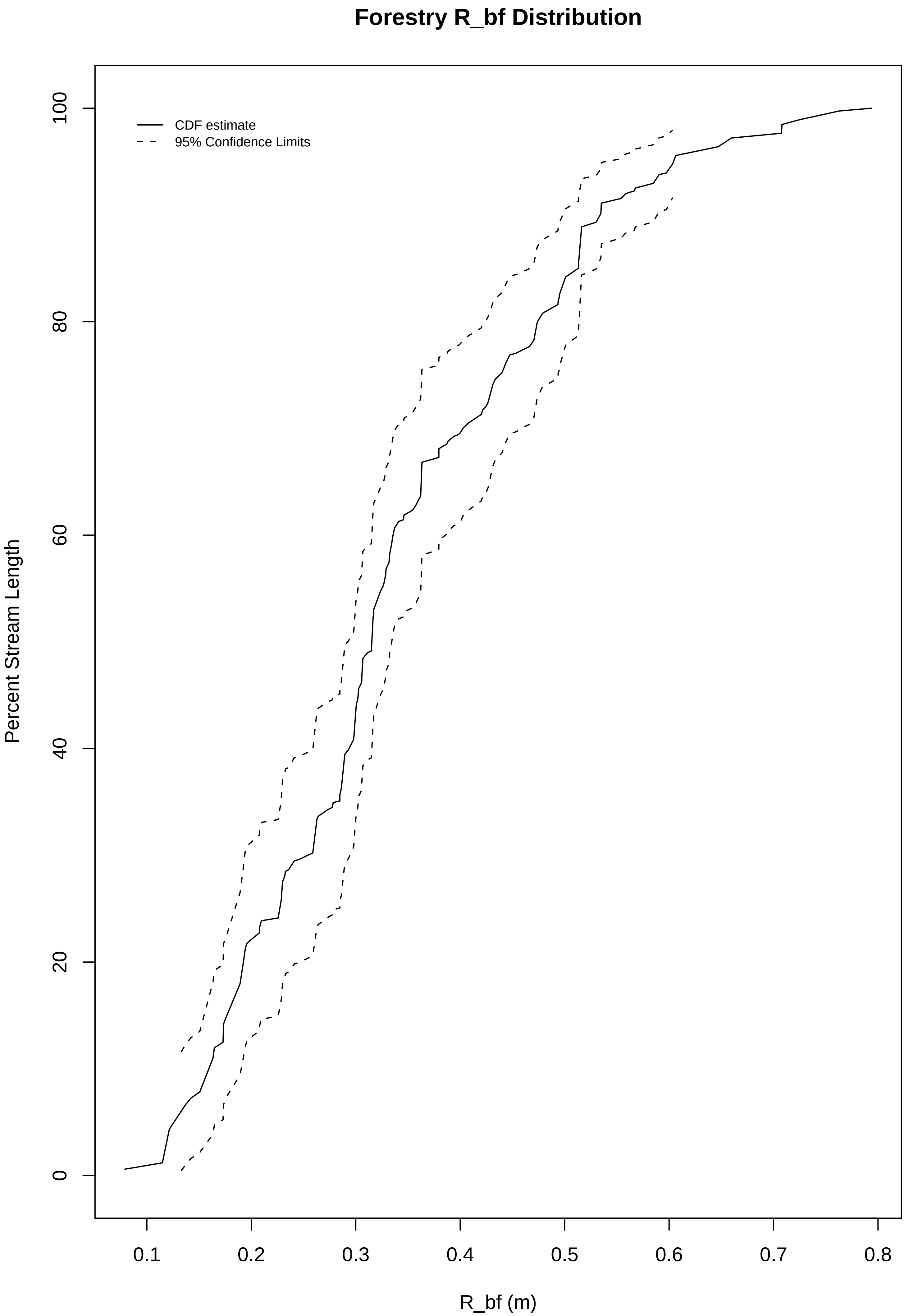


Forestry D_GM (mm) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
D_GM
0
200
400
600
800
1000
1200

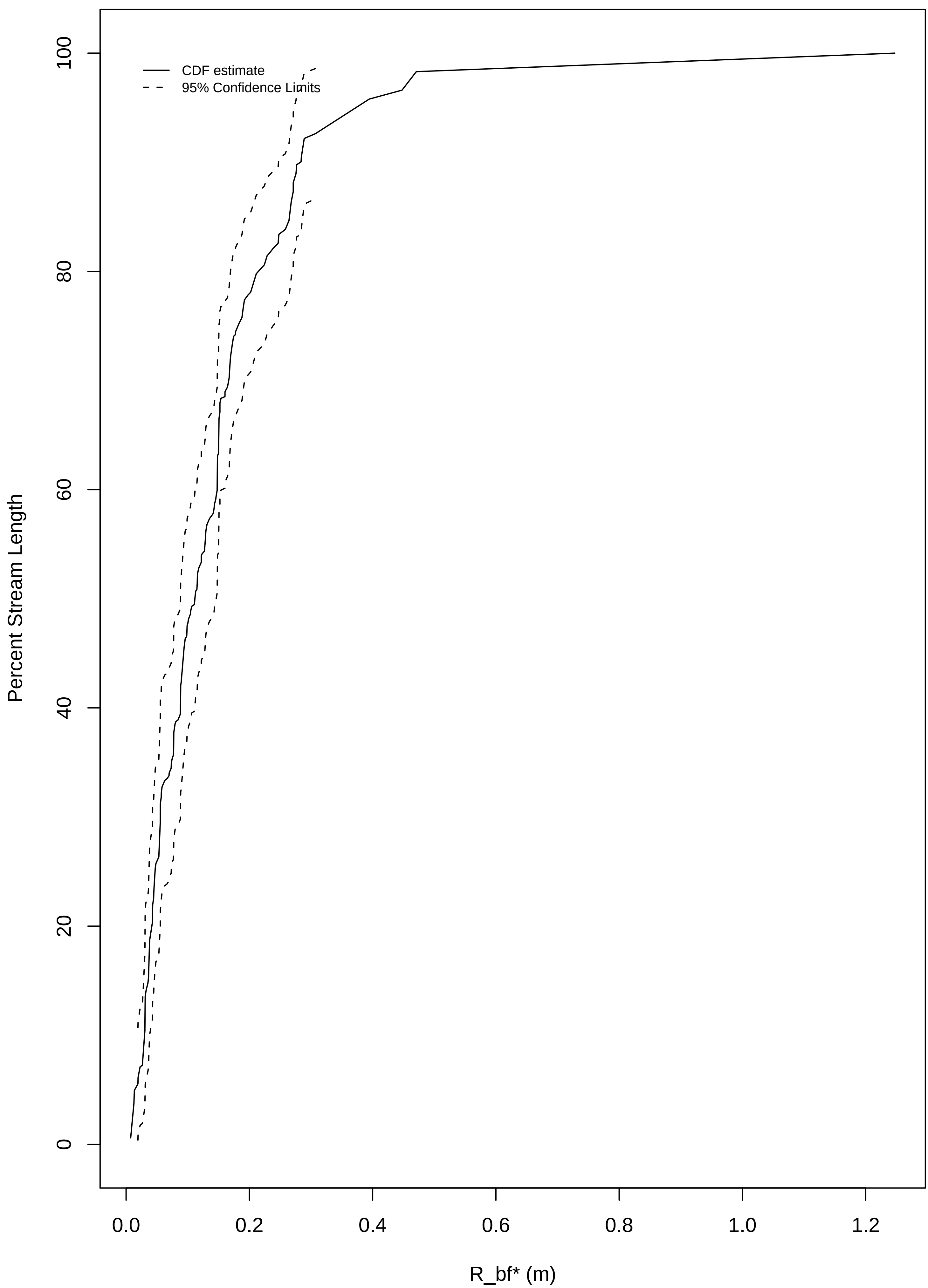


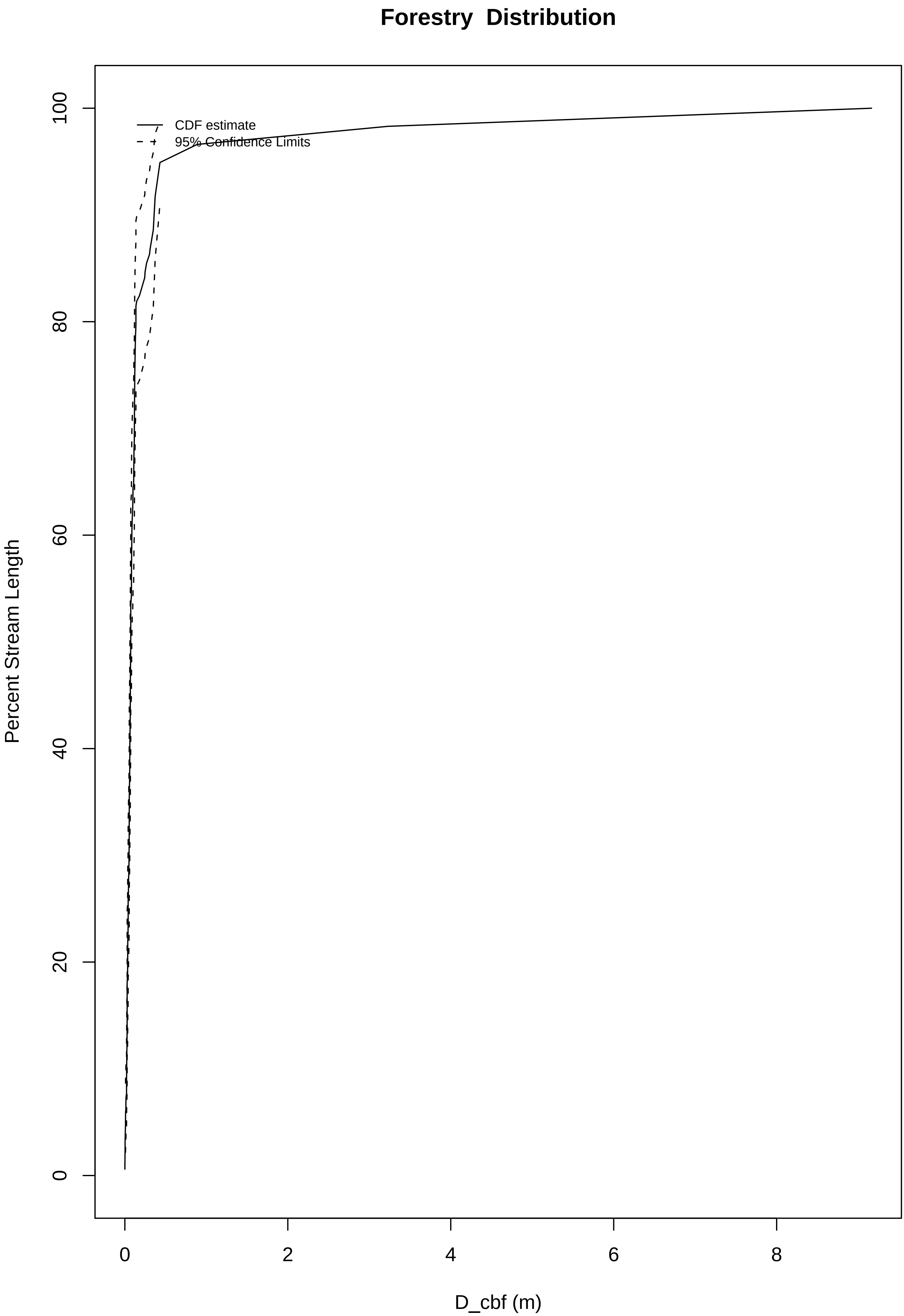
Forestry D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
50
100
150
200
D_GM (mm)

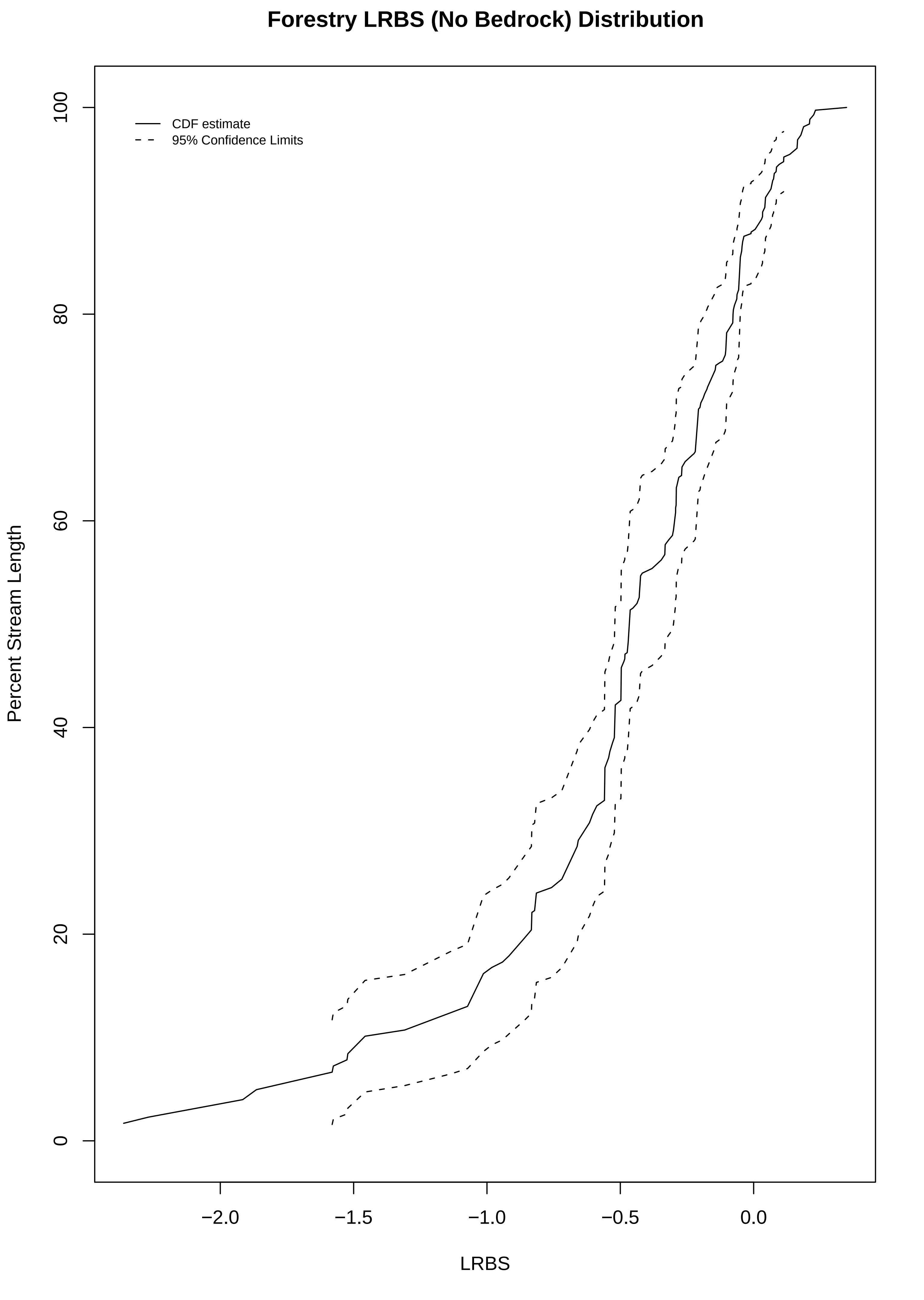

Forestry Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Slope

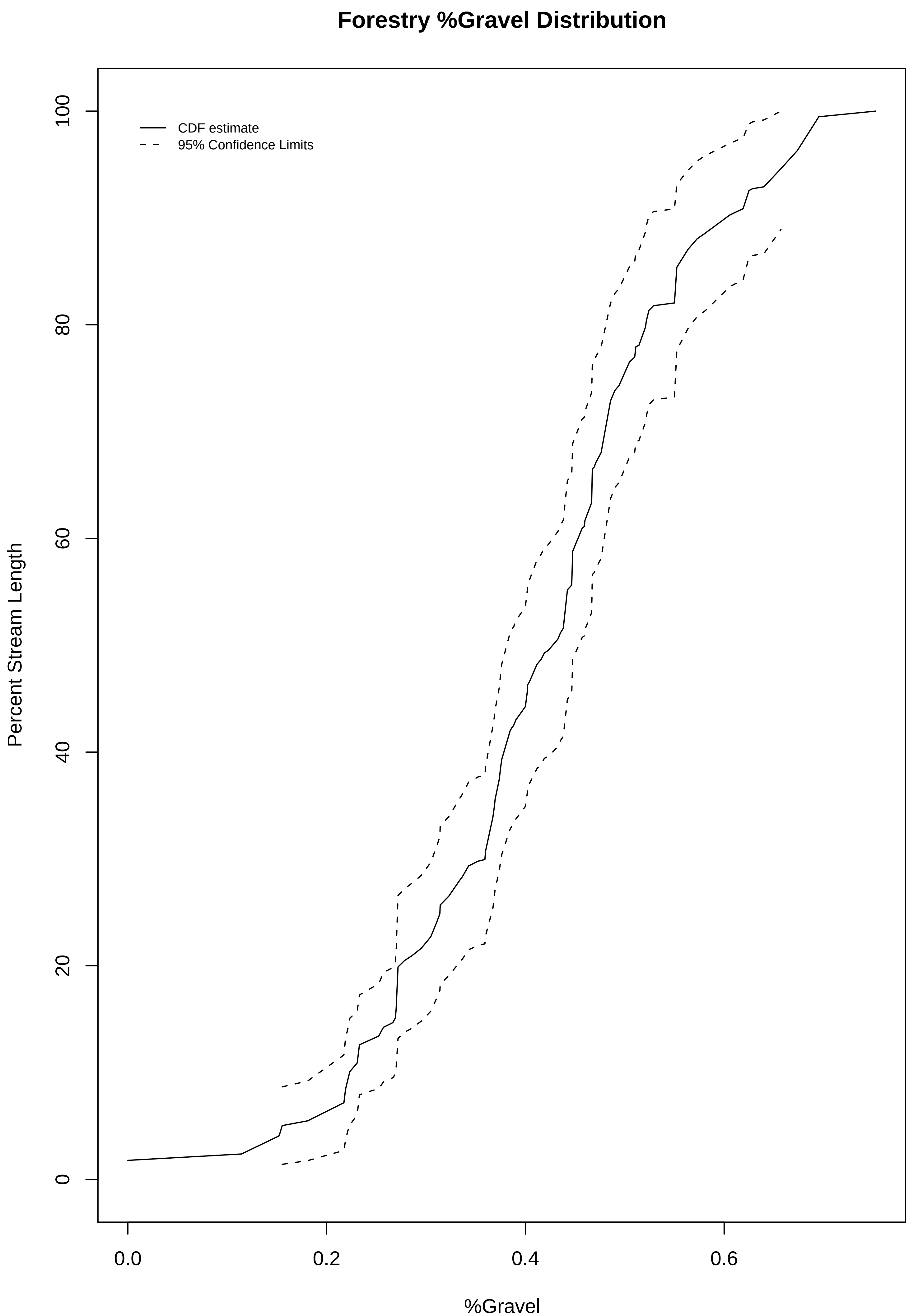

Forestry R_bf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
R_bf (m)

Forestry R_bf* Distribution



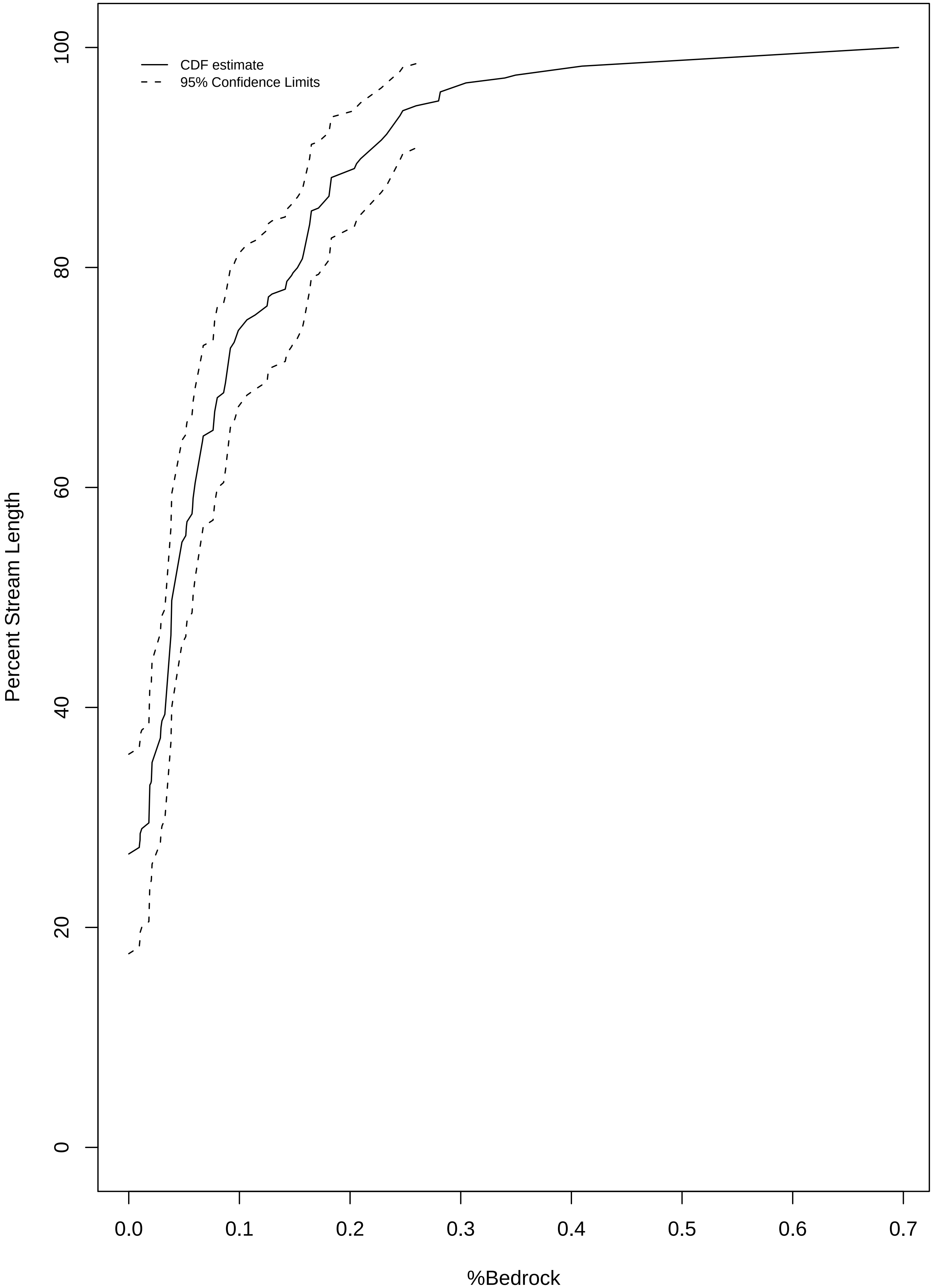

Forestry Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
2
4
6
8
D_cbf (m)

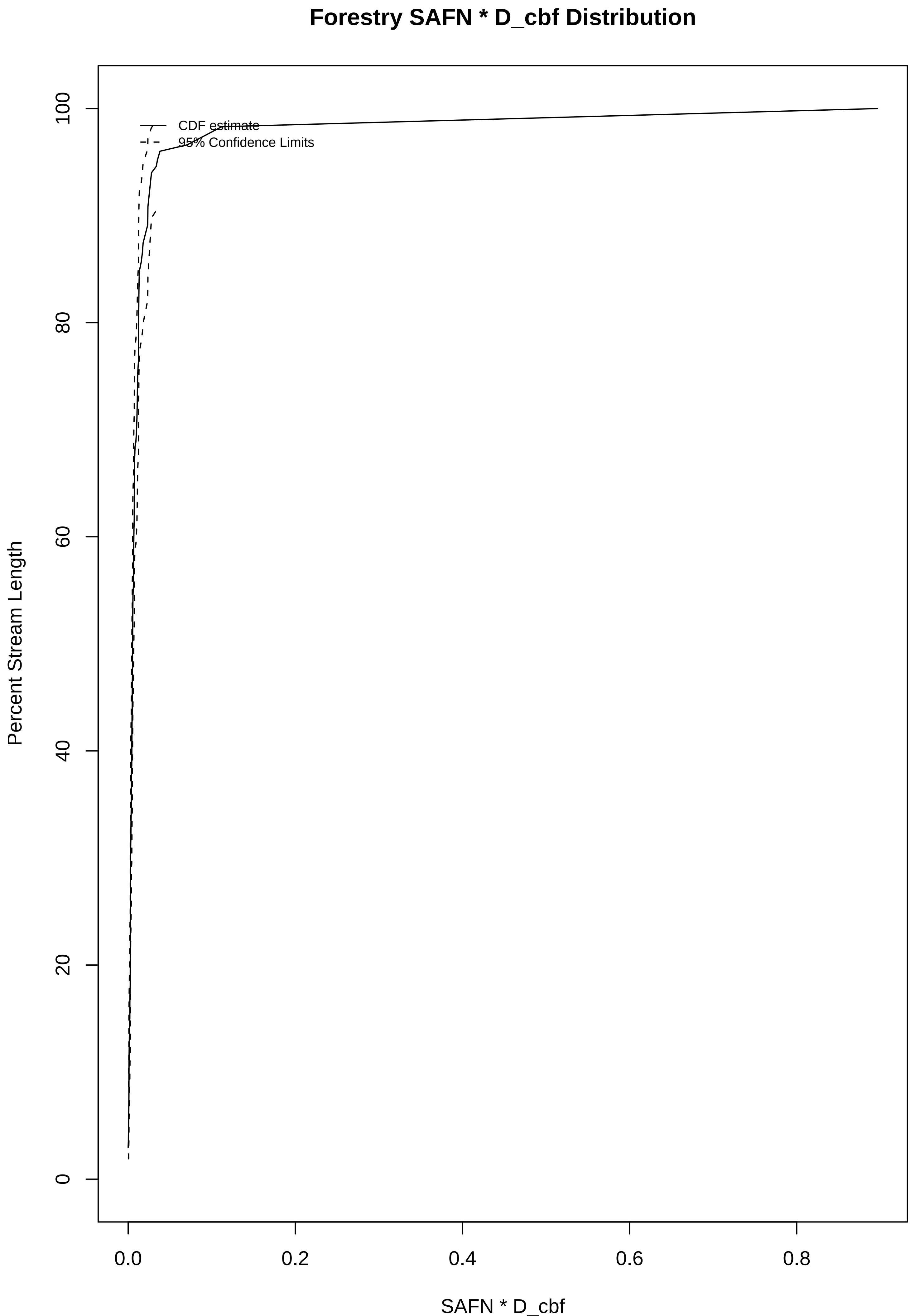

Forestry LRBS (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
LRBS
−2.0
−1.5
−1.0
−0.5
0.0



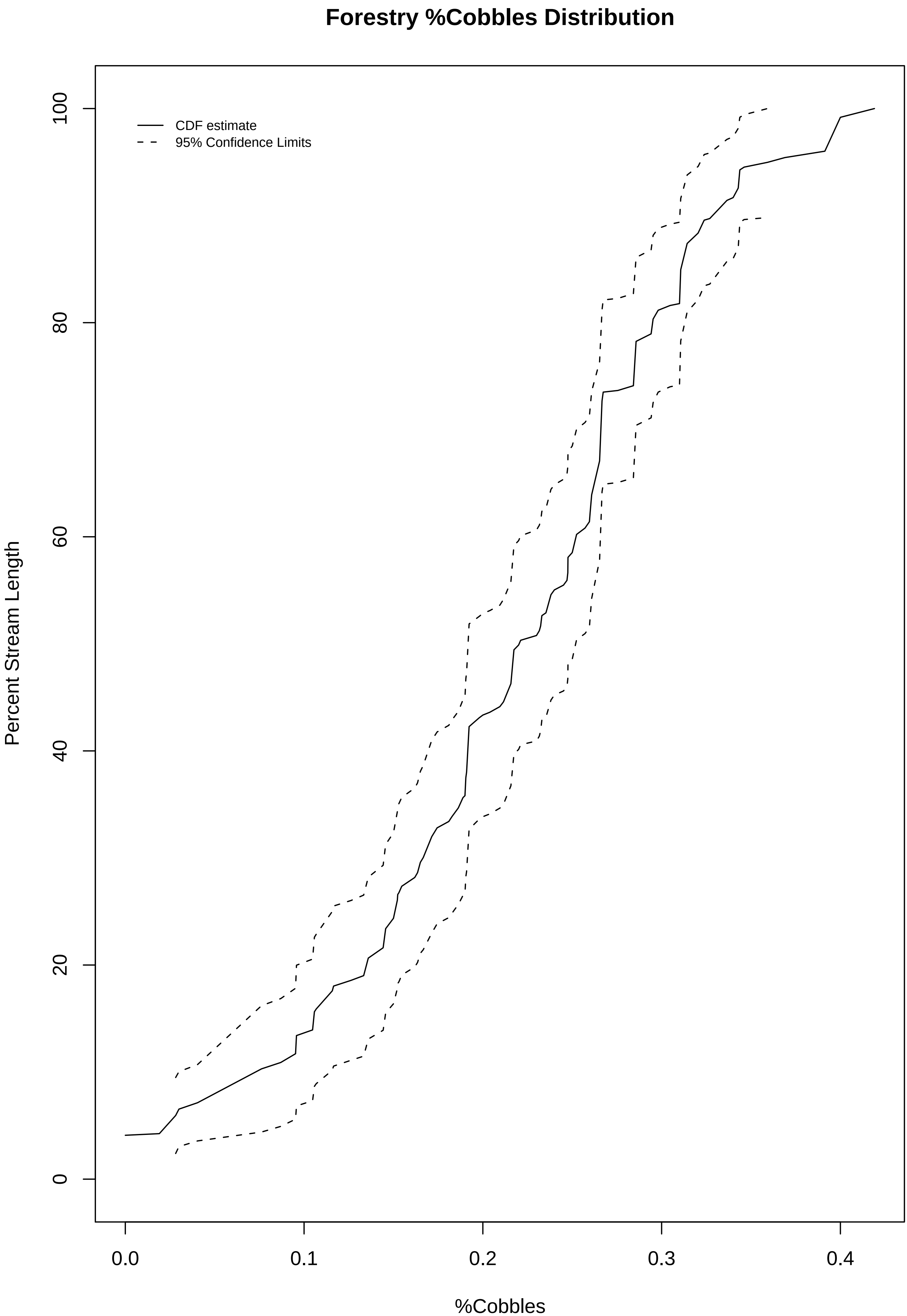
Forestry %Gravel Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
%Gravel

Forestry %Bedrock Distribution

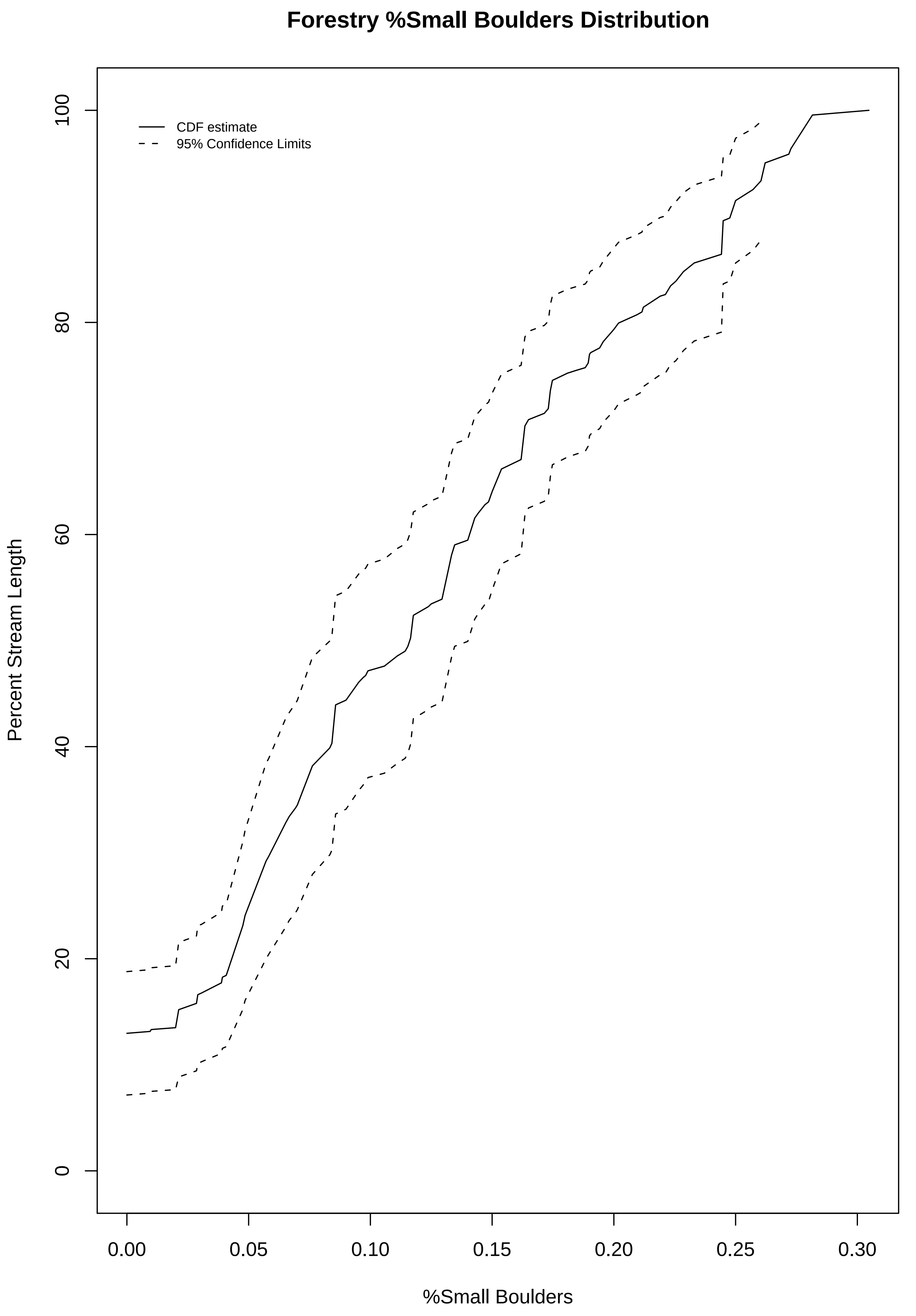




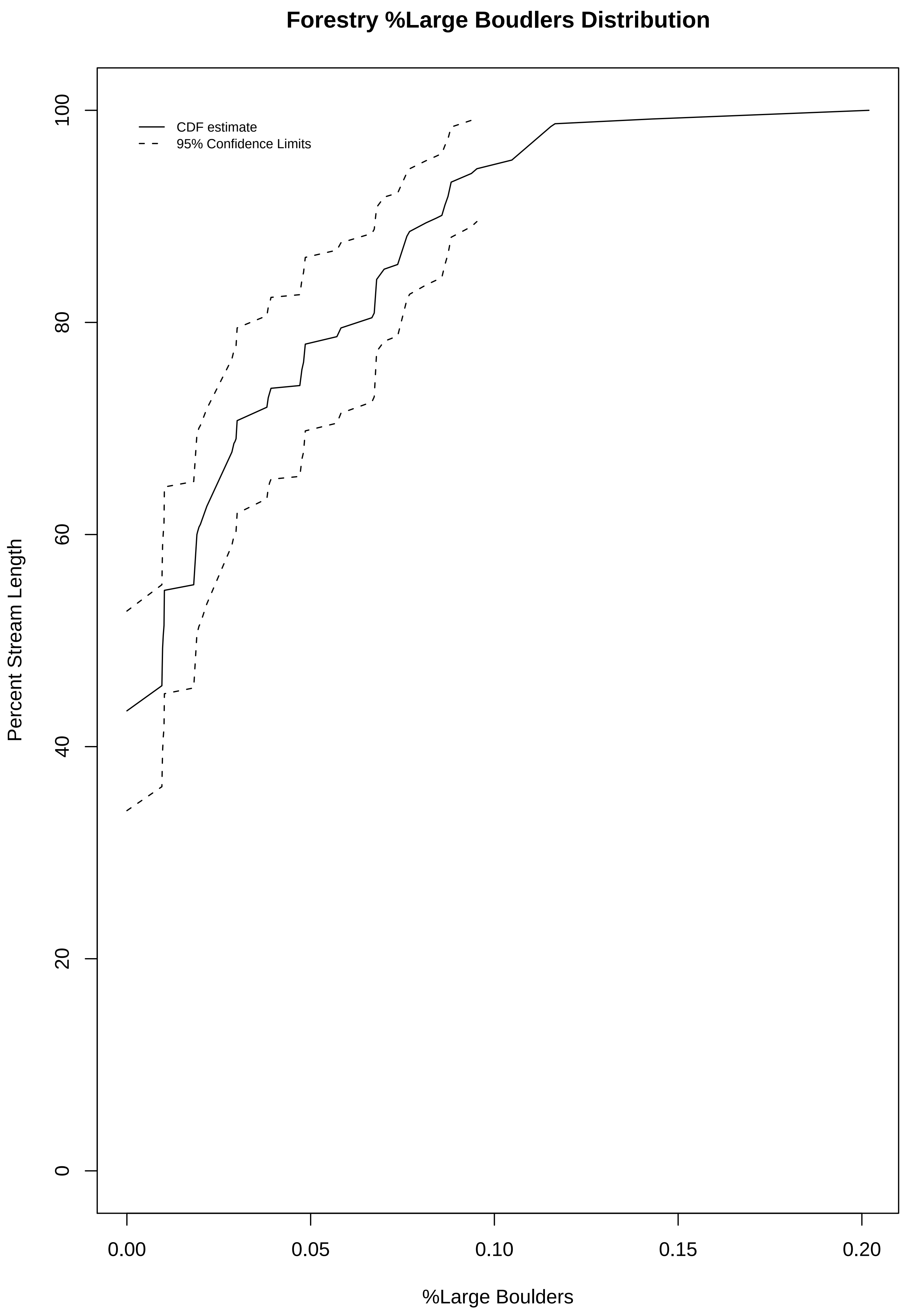
Forestry SAFN * D_cbf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
SAFN * D_cbf

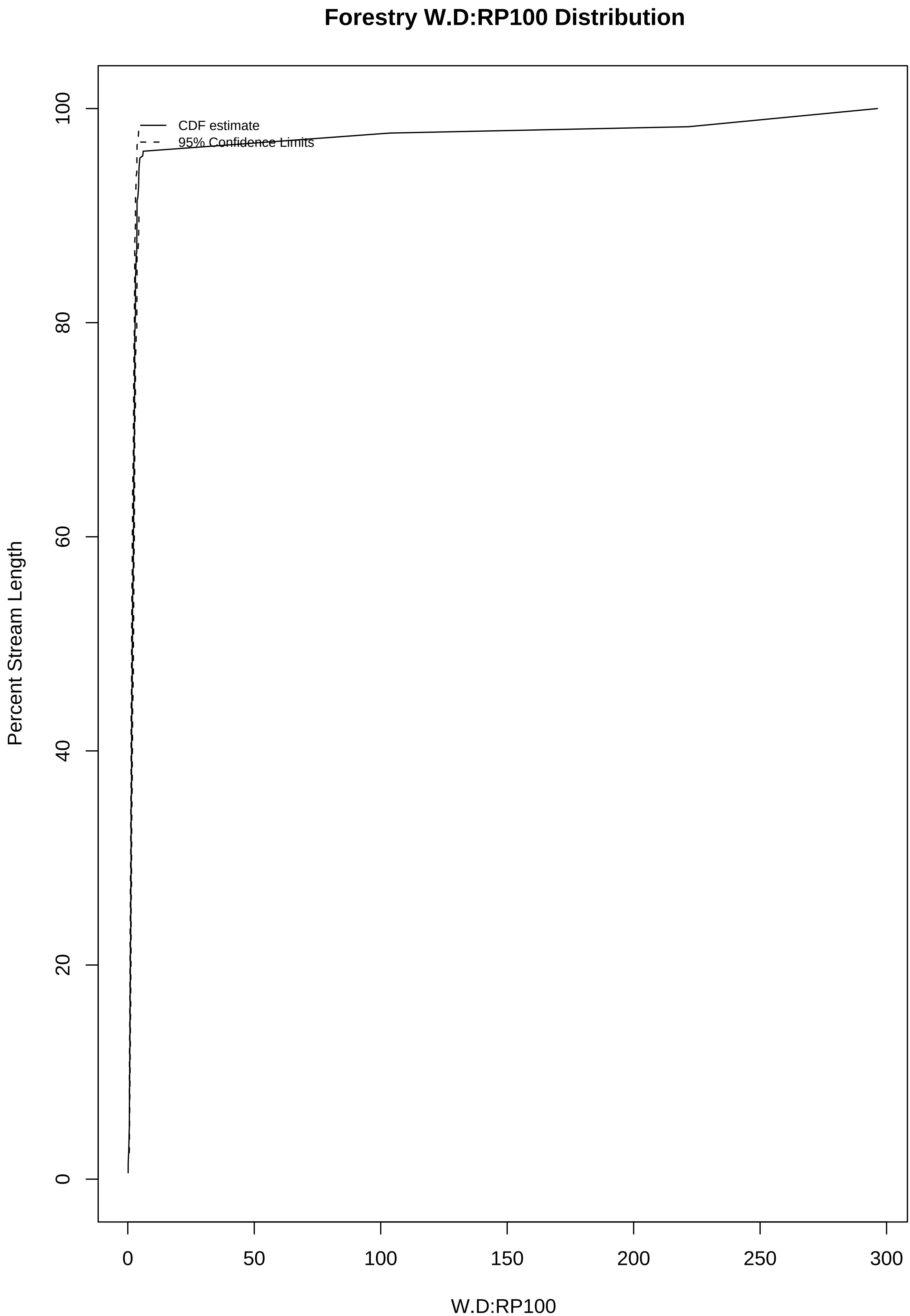


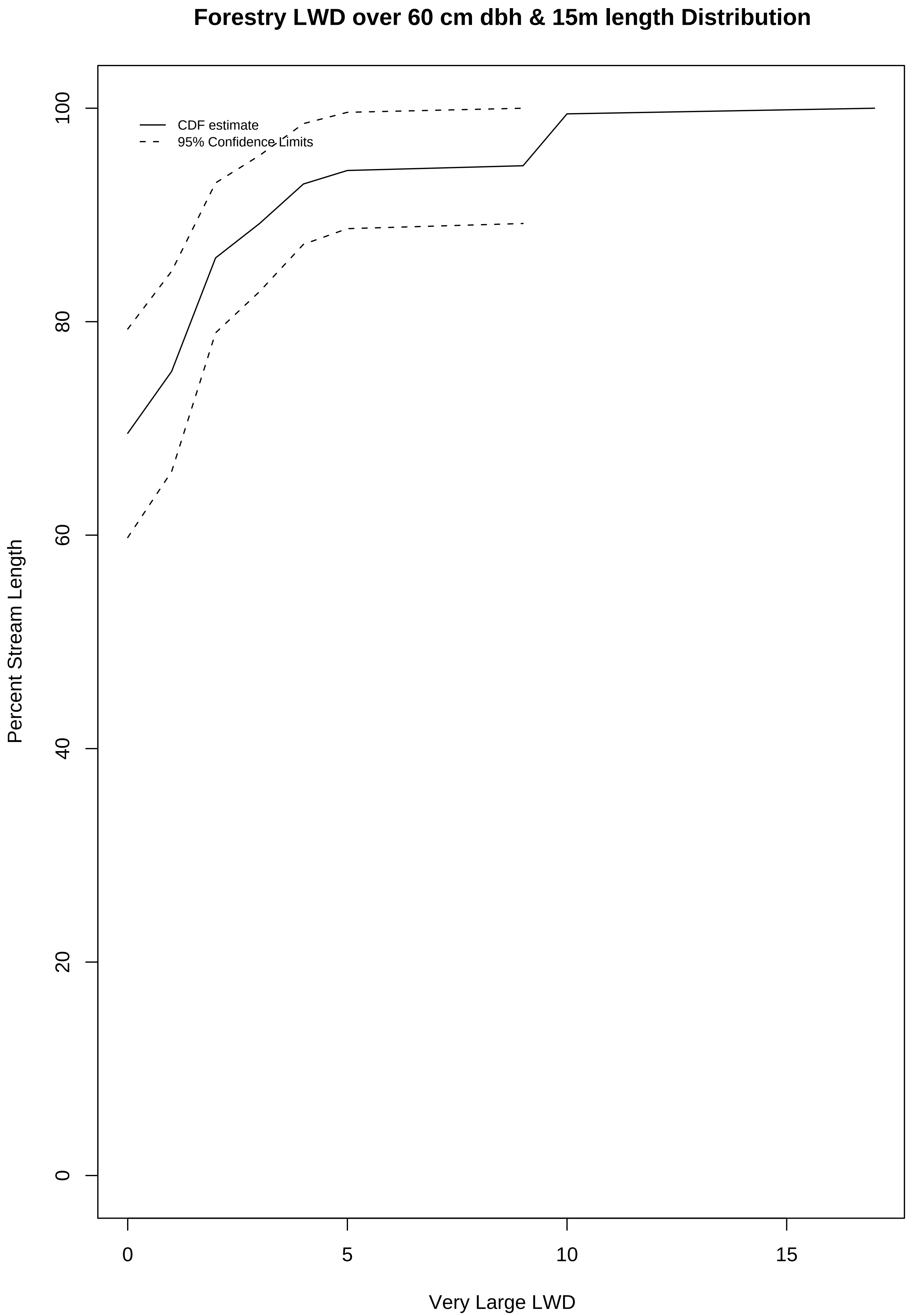
Forestry %Cobbles Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
%Cobbles



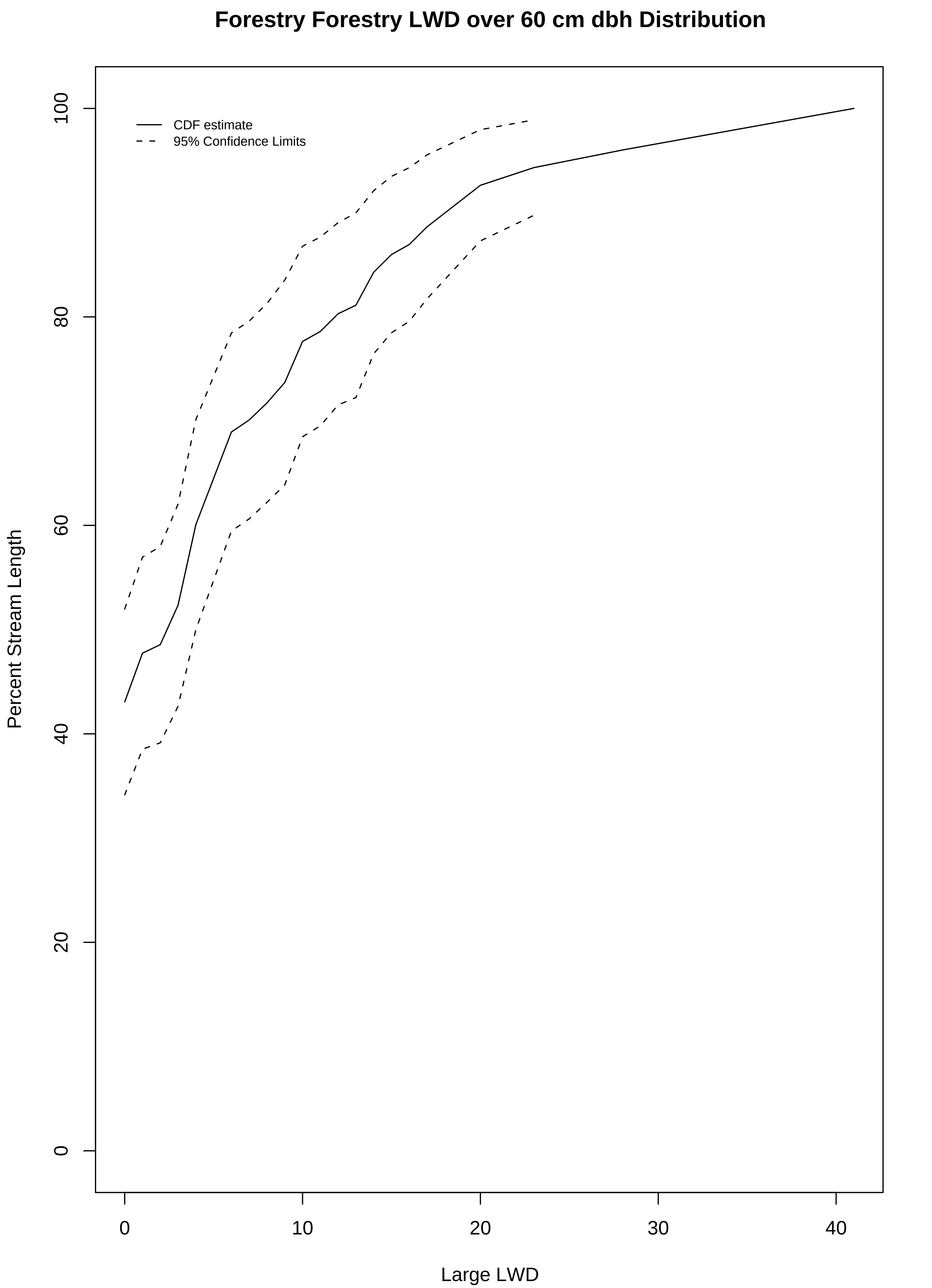
Forestry %Small Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
%Small Boulders


Forestry %Large Boudlers Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
%Large Boulders


Forestry W.D:RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
50
100
150
200
250
300
W.D:RP100

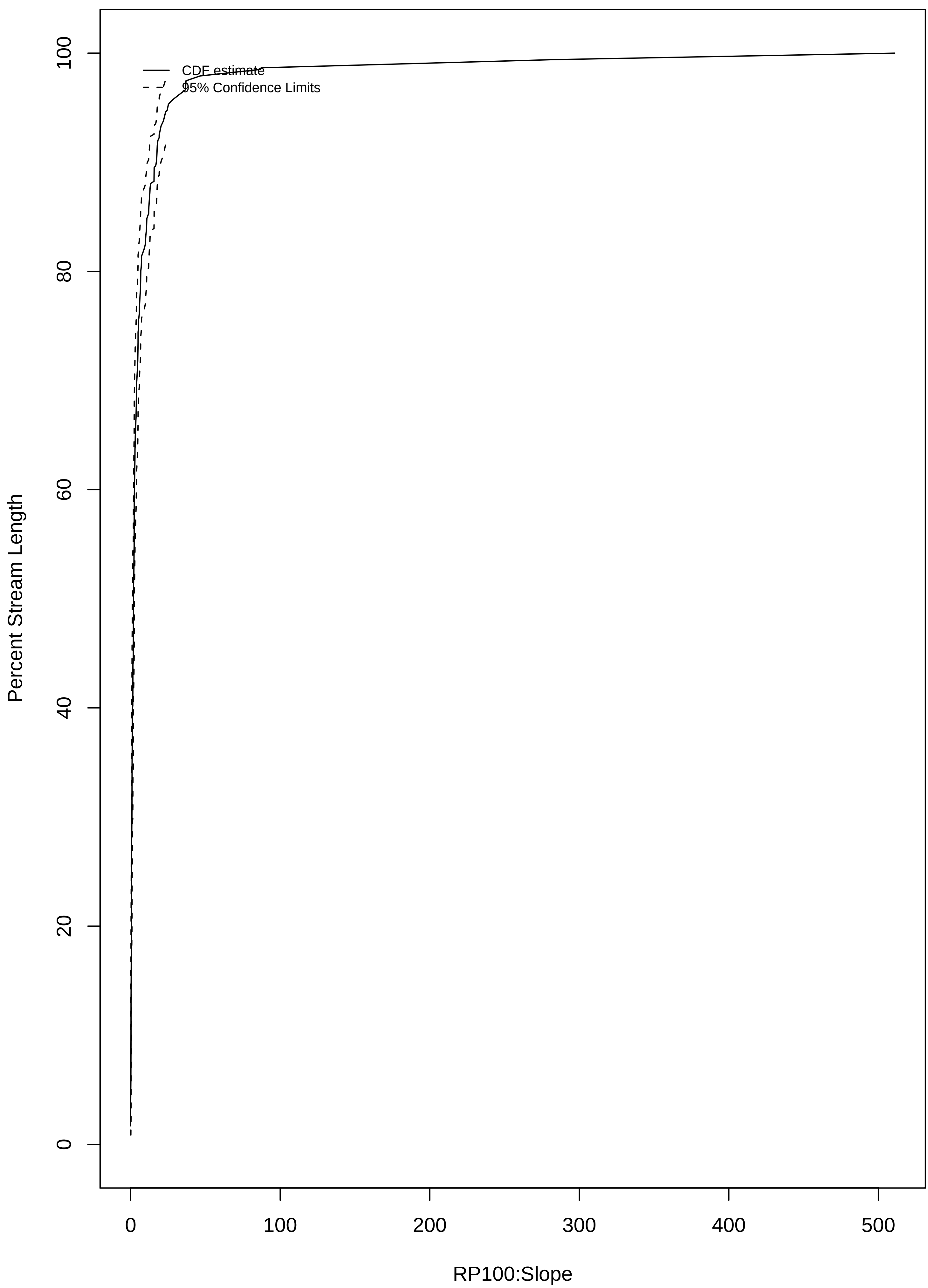


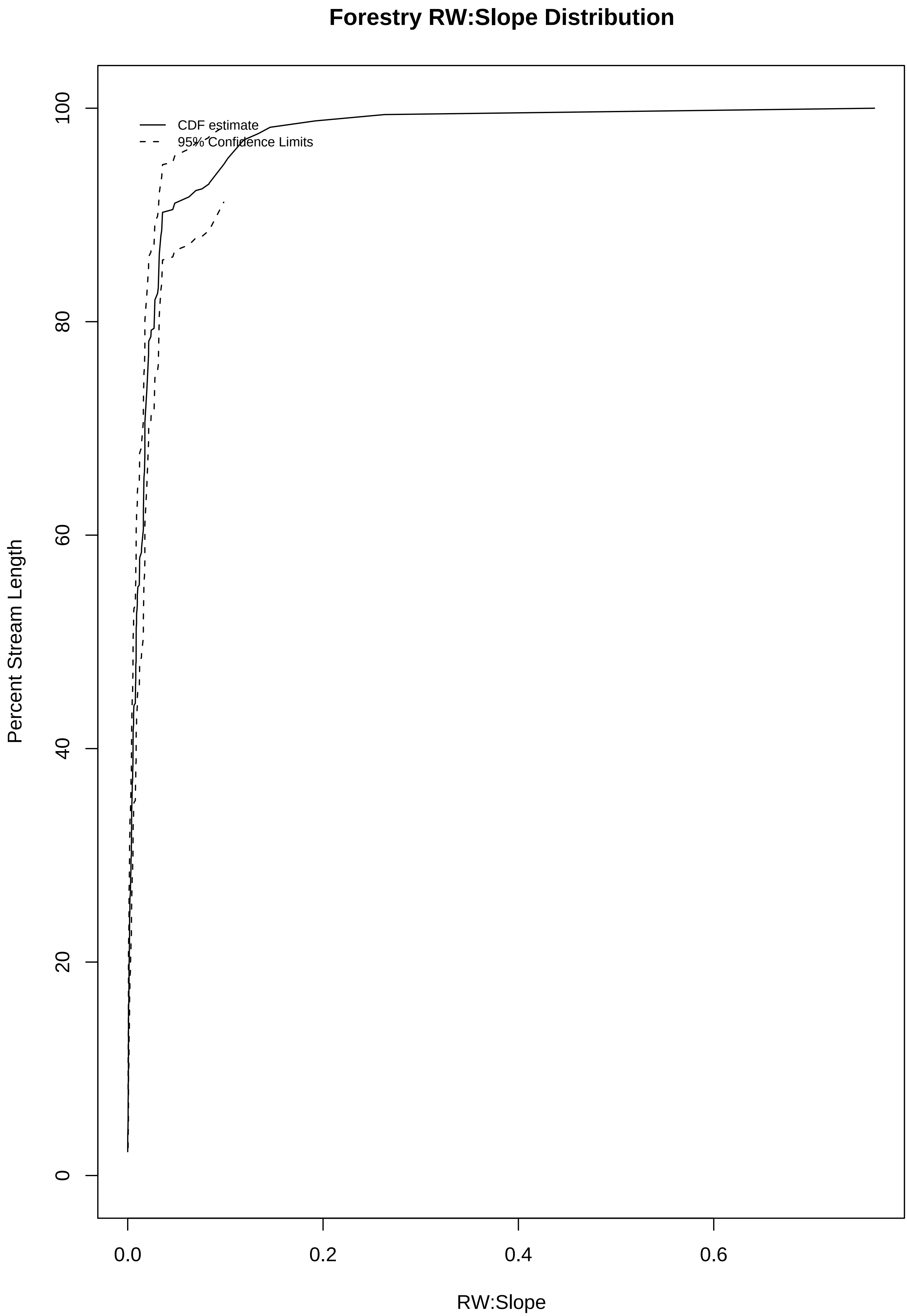
Forestry LWD over 60 cm dbh & 15m length Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
5
10
15
Very Large LWD

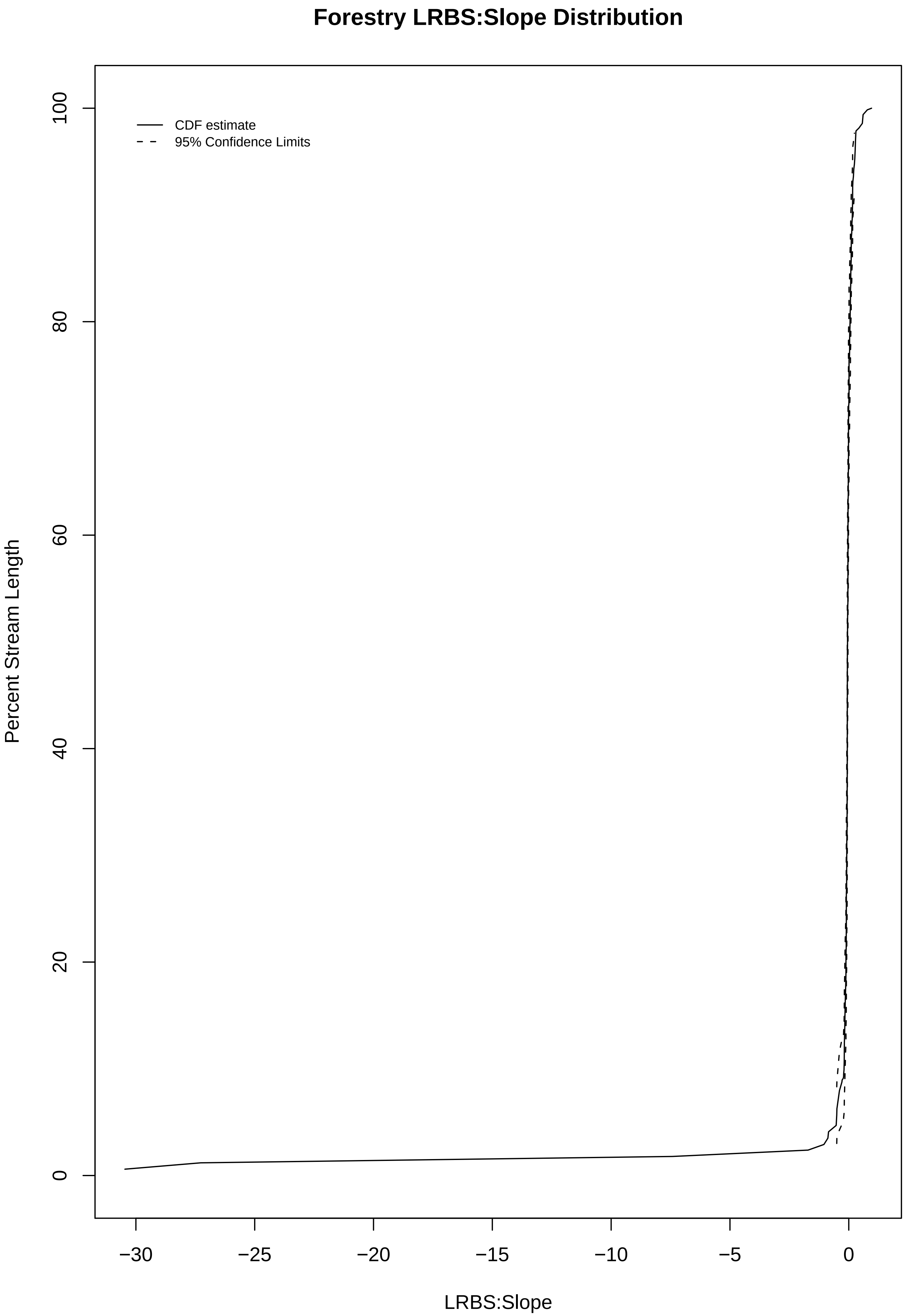


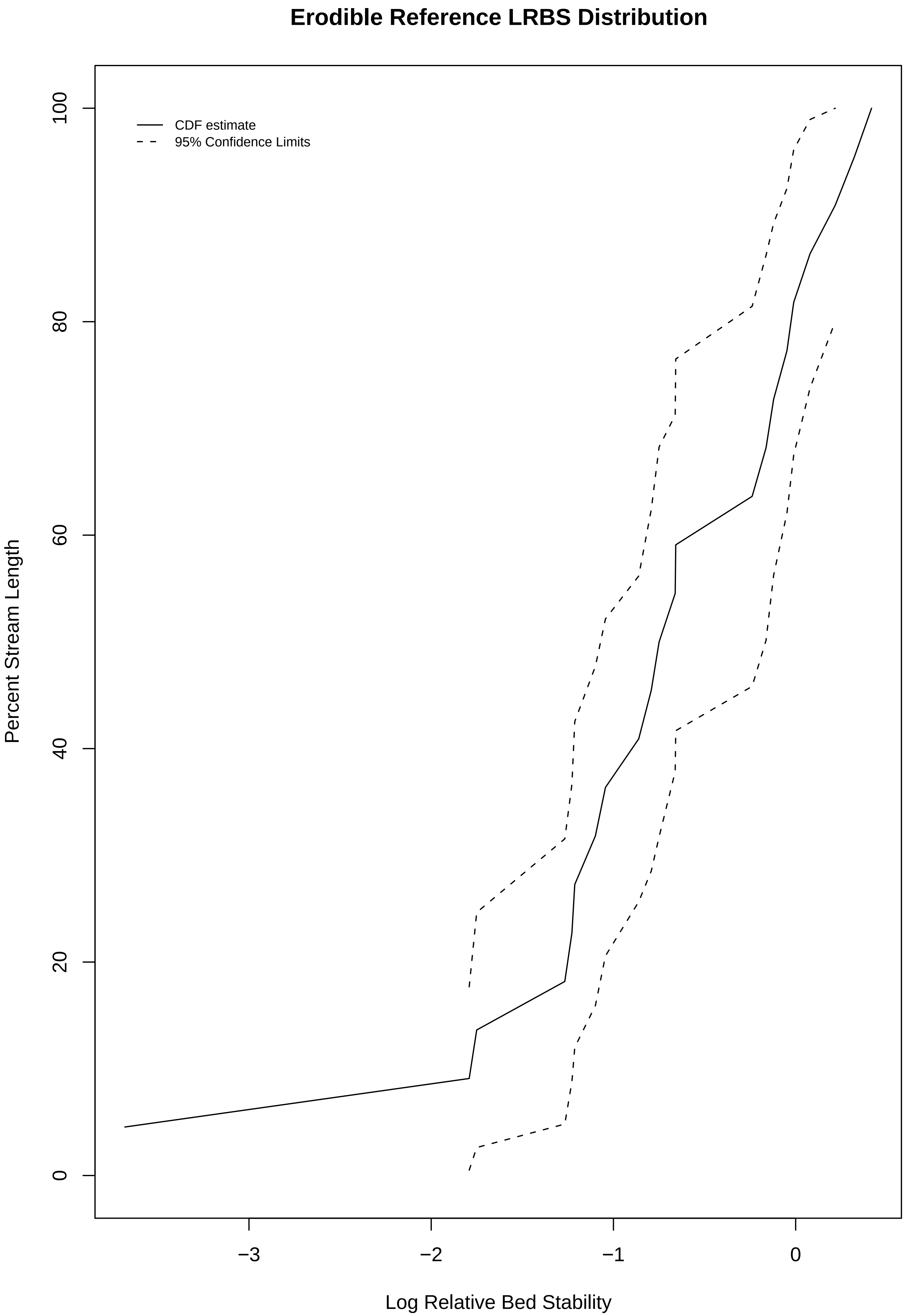
Forestry Forestry LWD over 60 cm dbh Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
10
20
30
40
Large LWD

Forestry RP100:Slope Distribution

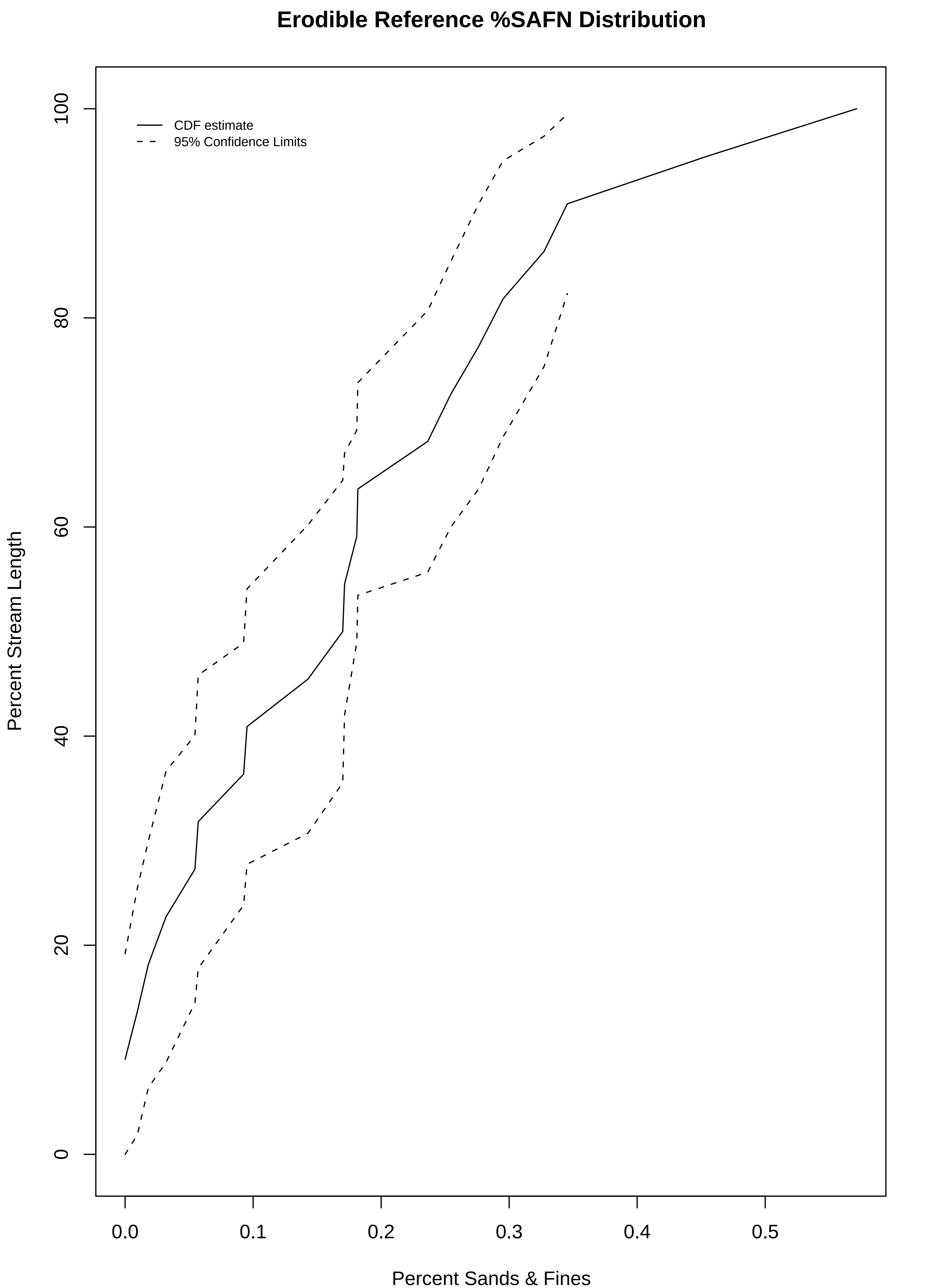



Forestry RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
RW:Slope

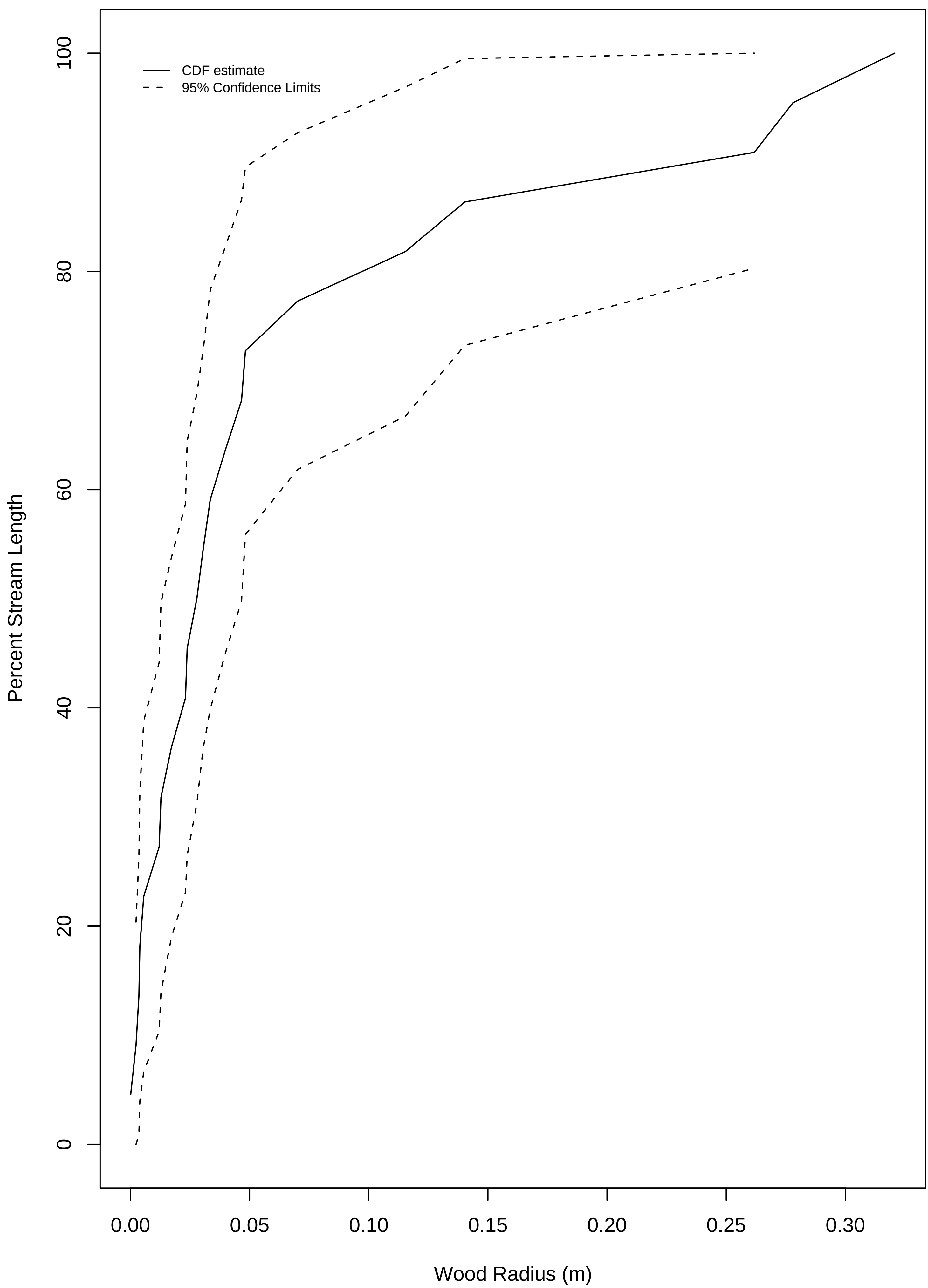

Forestry LRBS:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−30
−25
−20
−15
−10
−5
0
LRBS:Slope

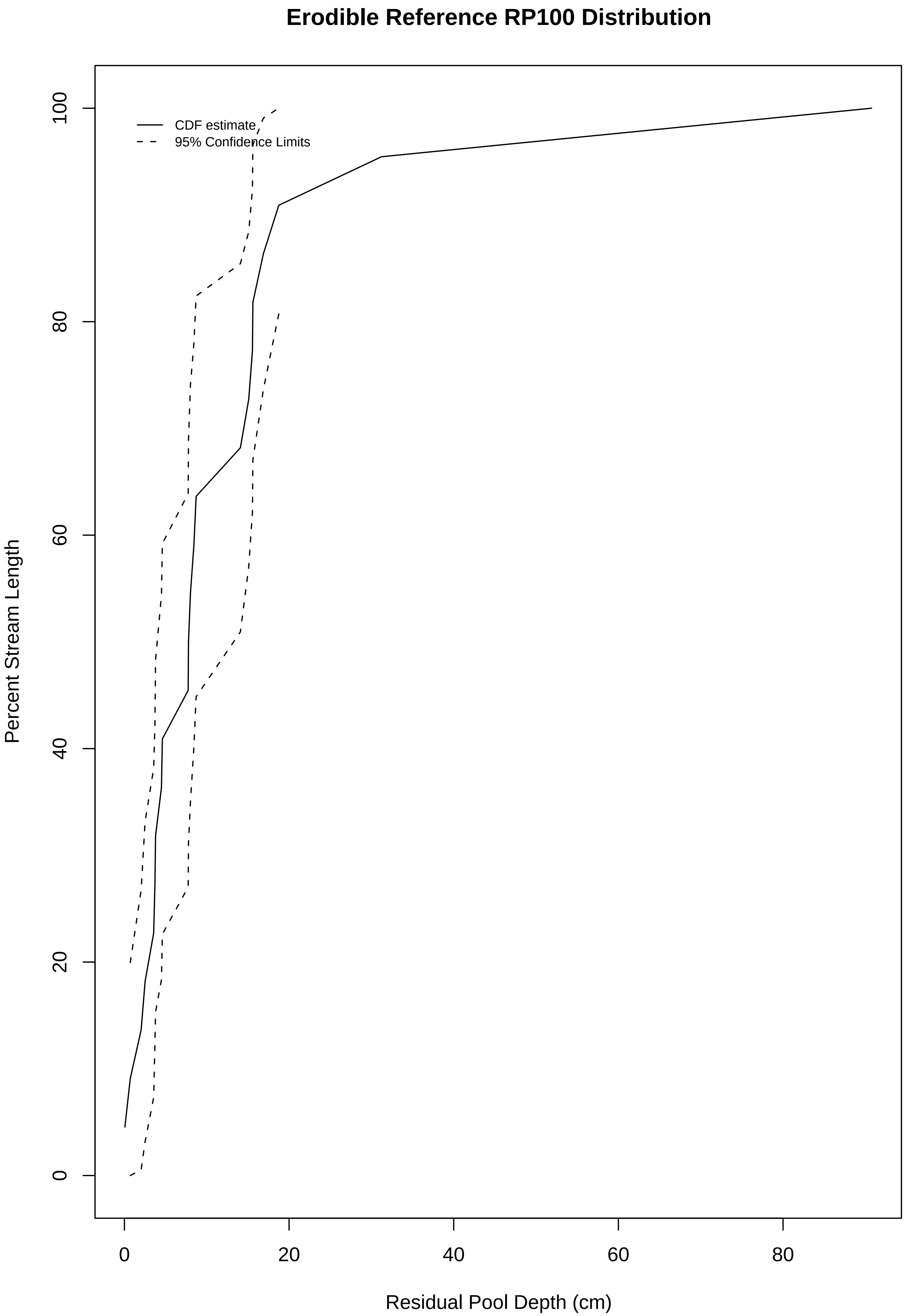


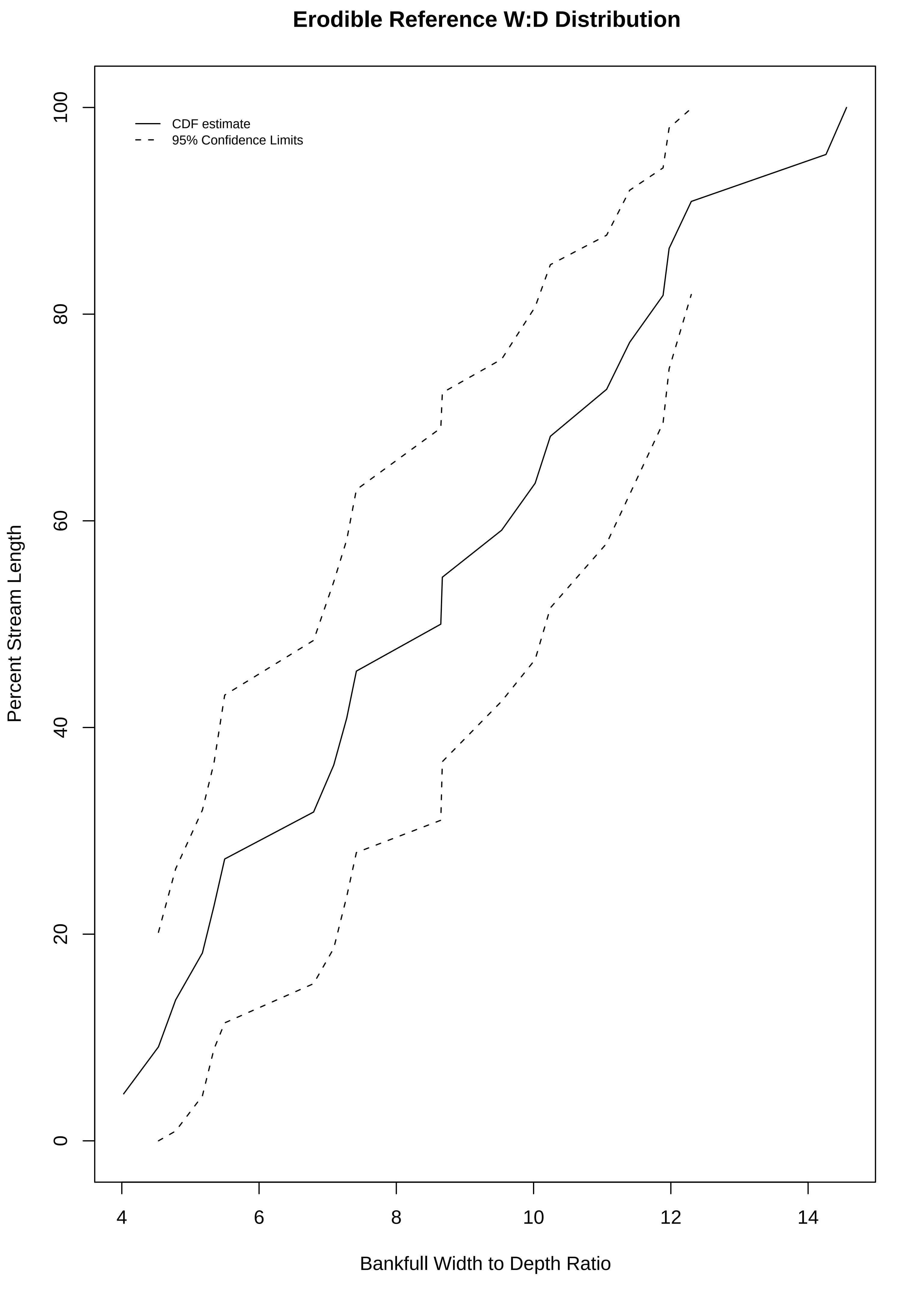
Erodible Reference LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−3
−2
−1
0
Log Relative Bed Stability


Erodible Reference %SAFN Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
Percent Sands & Fines

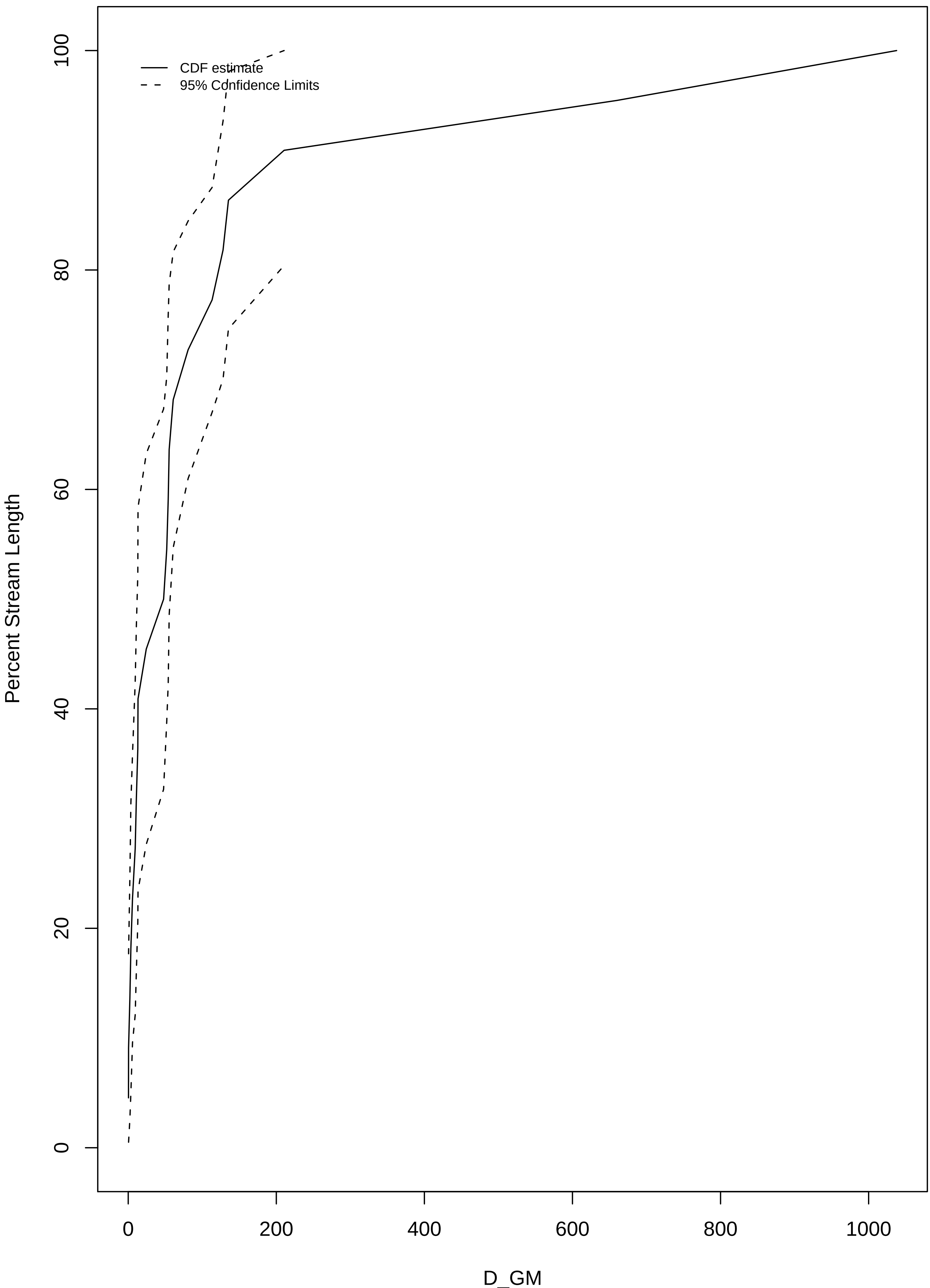
Erodible Reference RW Distribution



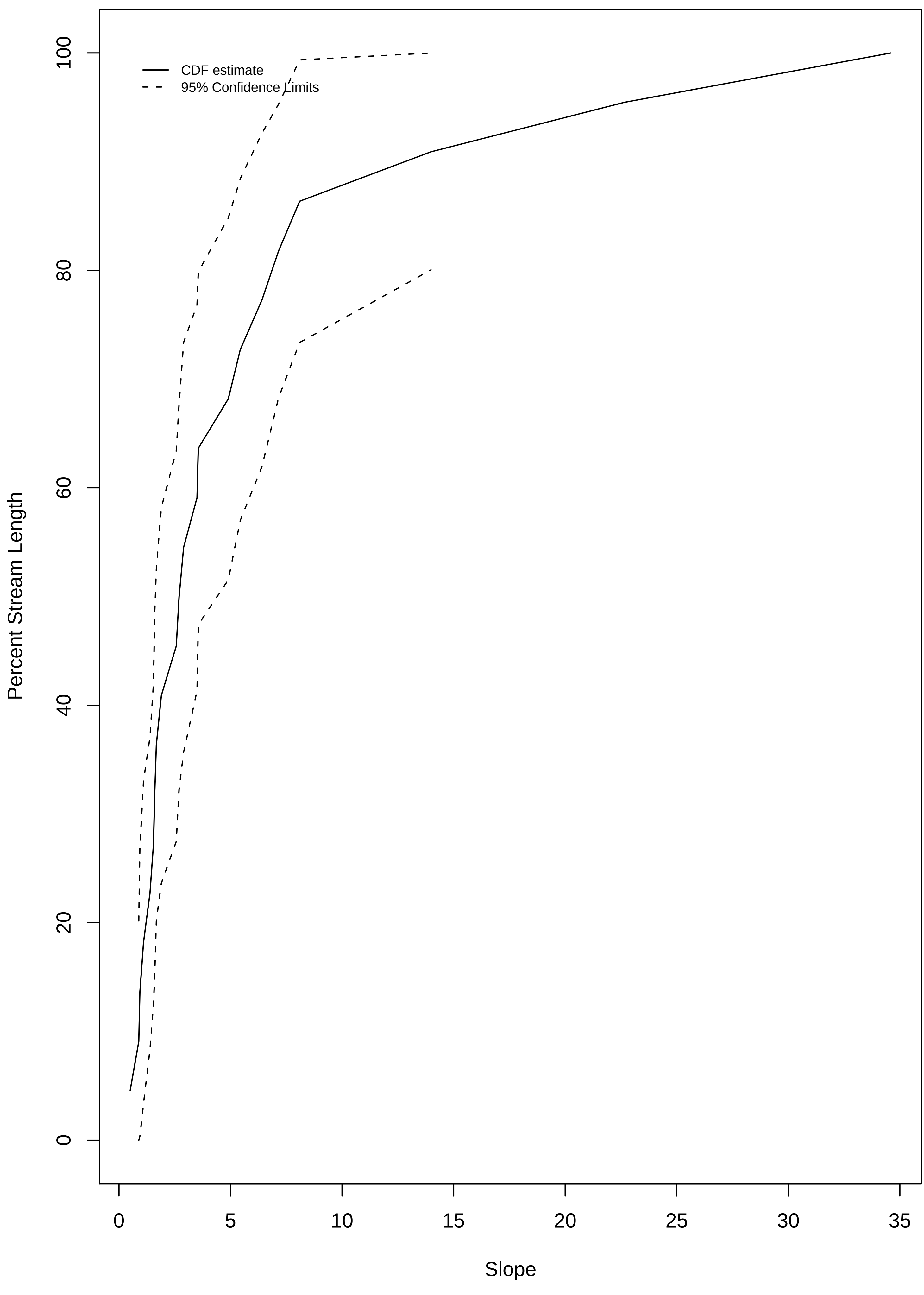

Erodible Reference RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
20
40
60
80
Residual Pool Depth (cm)

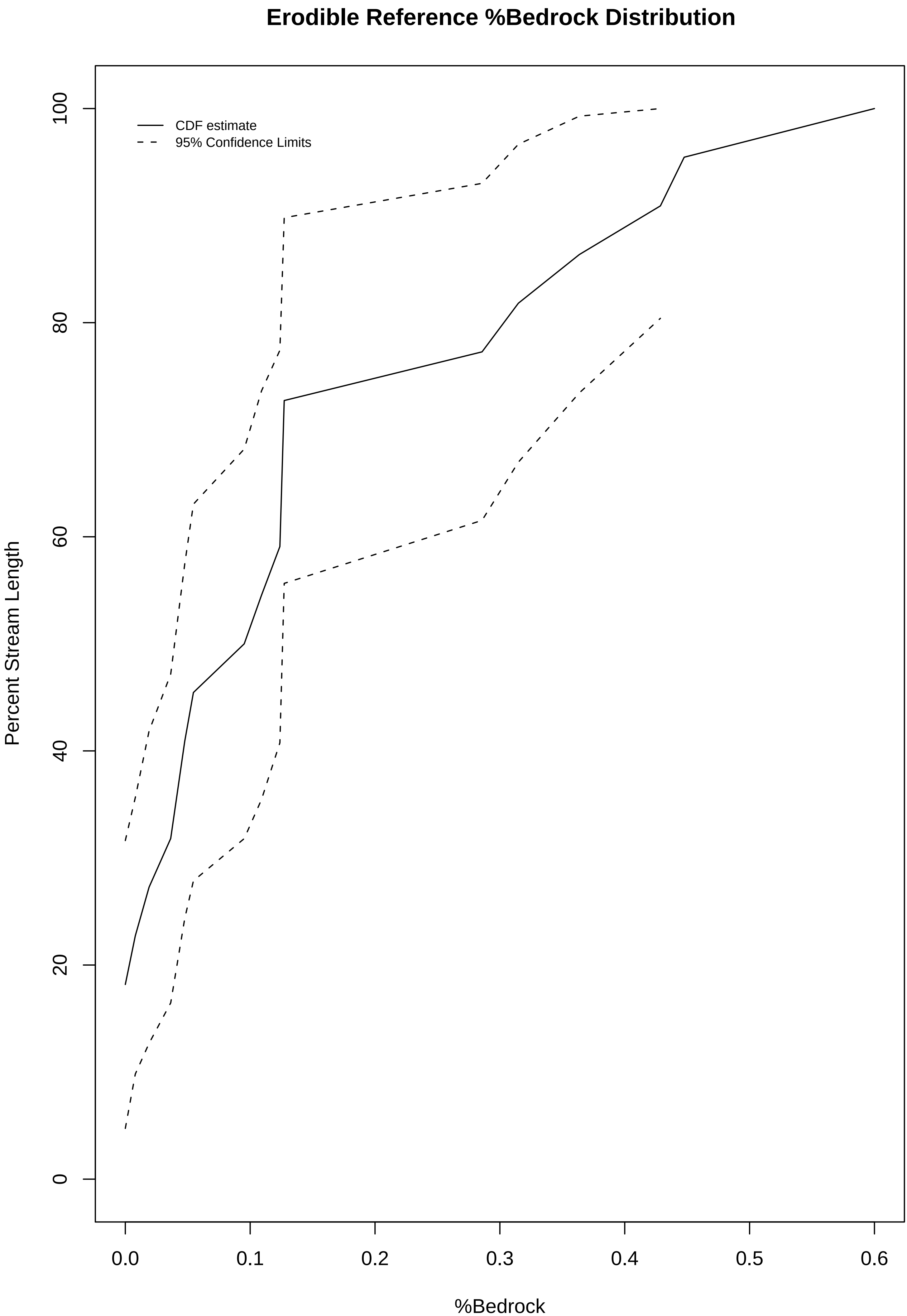

Erodible Reference W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
4
6
8
10
12
14
Bankfull Width to Depth Ratio

Erodible Reference D_GM (mm) Distribution

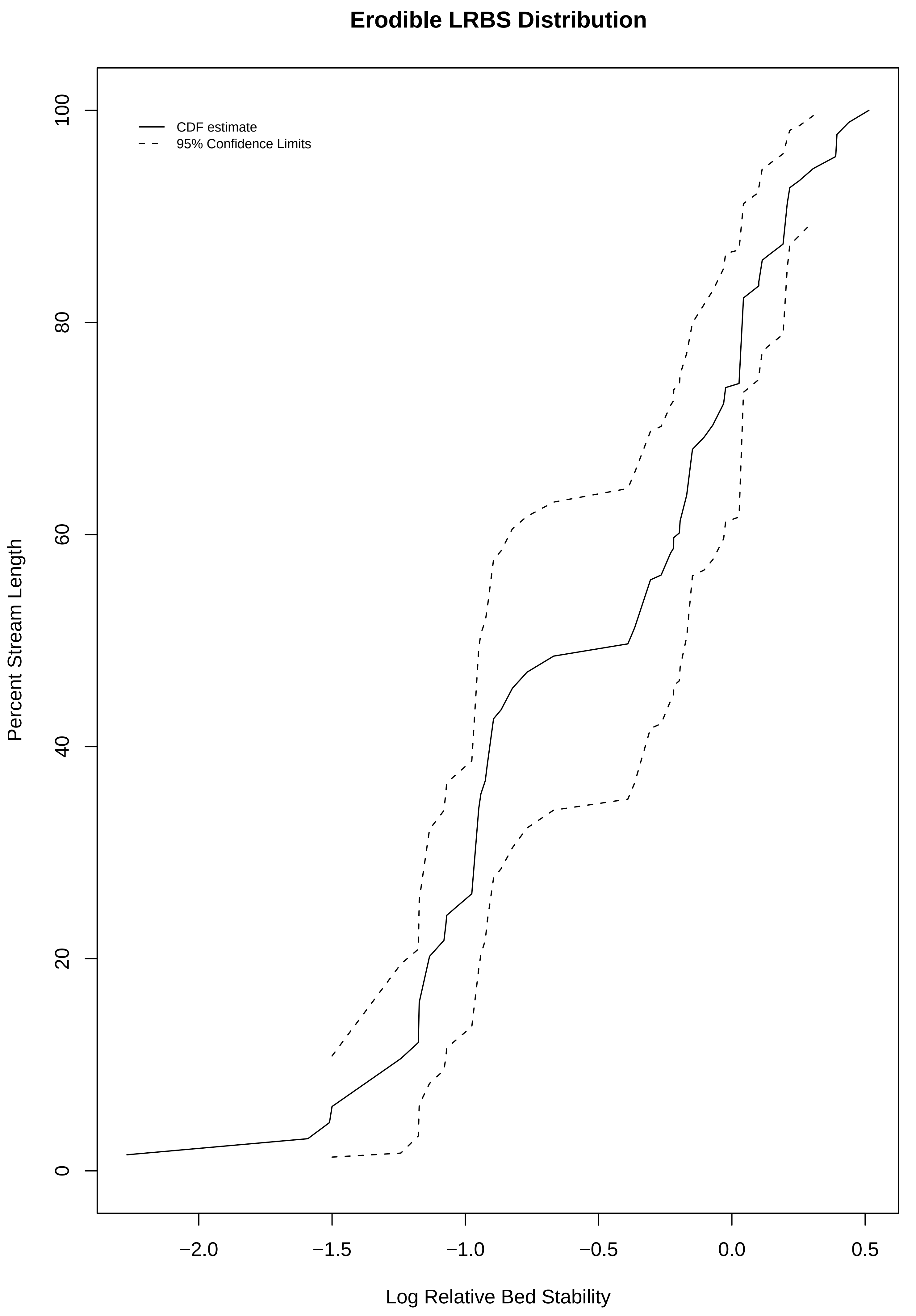


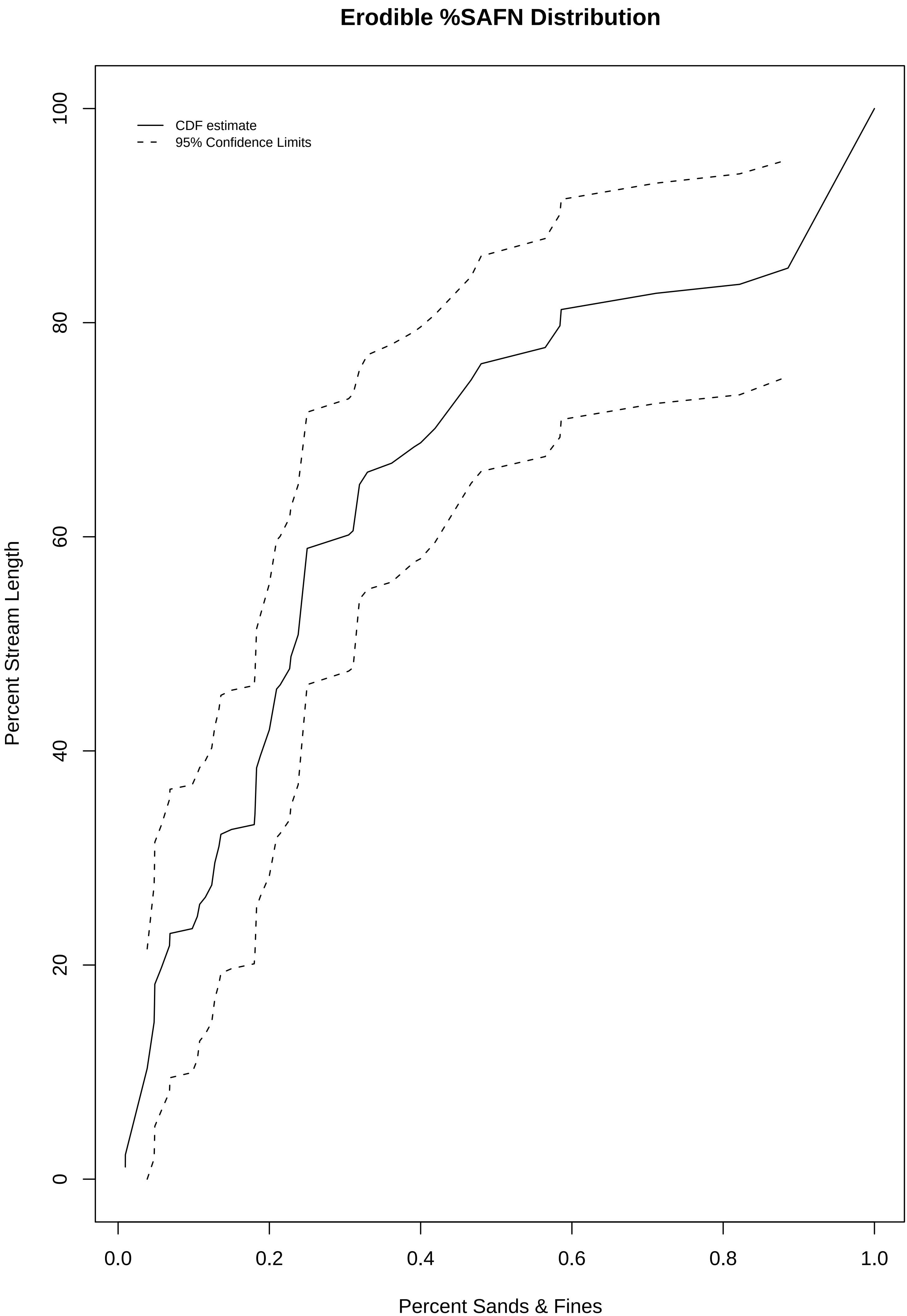
Erodible Reference Slope Distribution

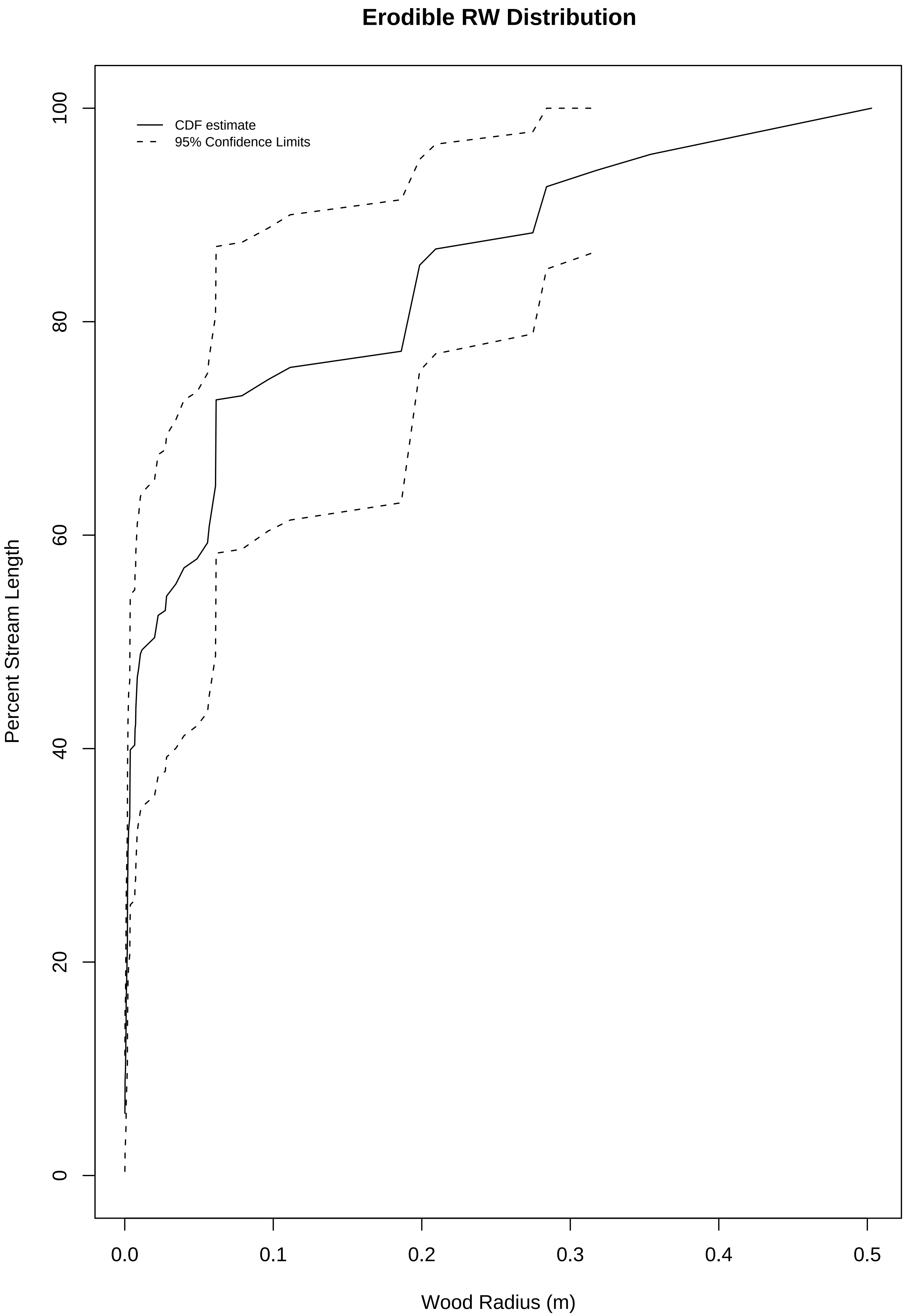




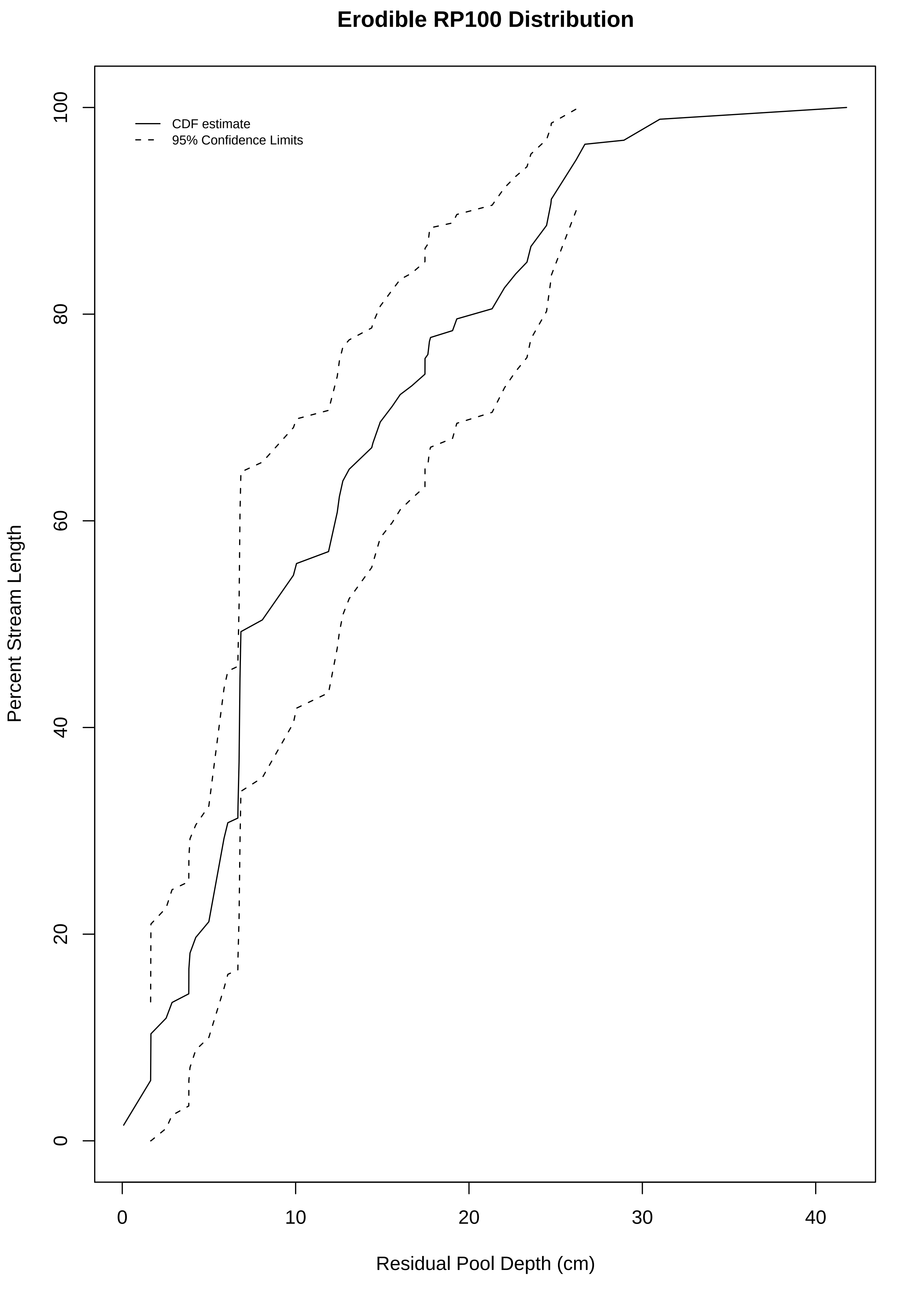
Erodible Reference %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
%Bedrock


Erodible LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−2.0
−1.5
−1.0
−0.5
0.0
0.5
Log Relative Bed Stability

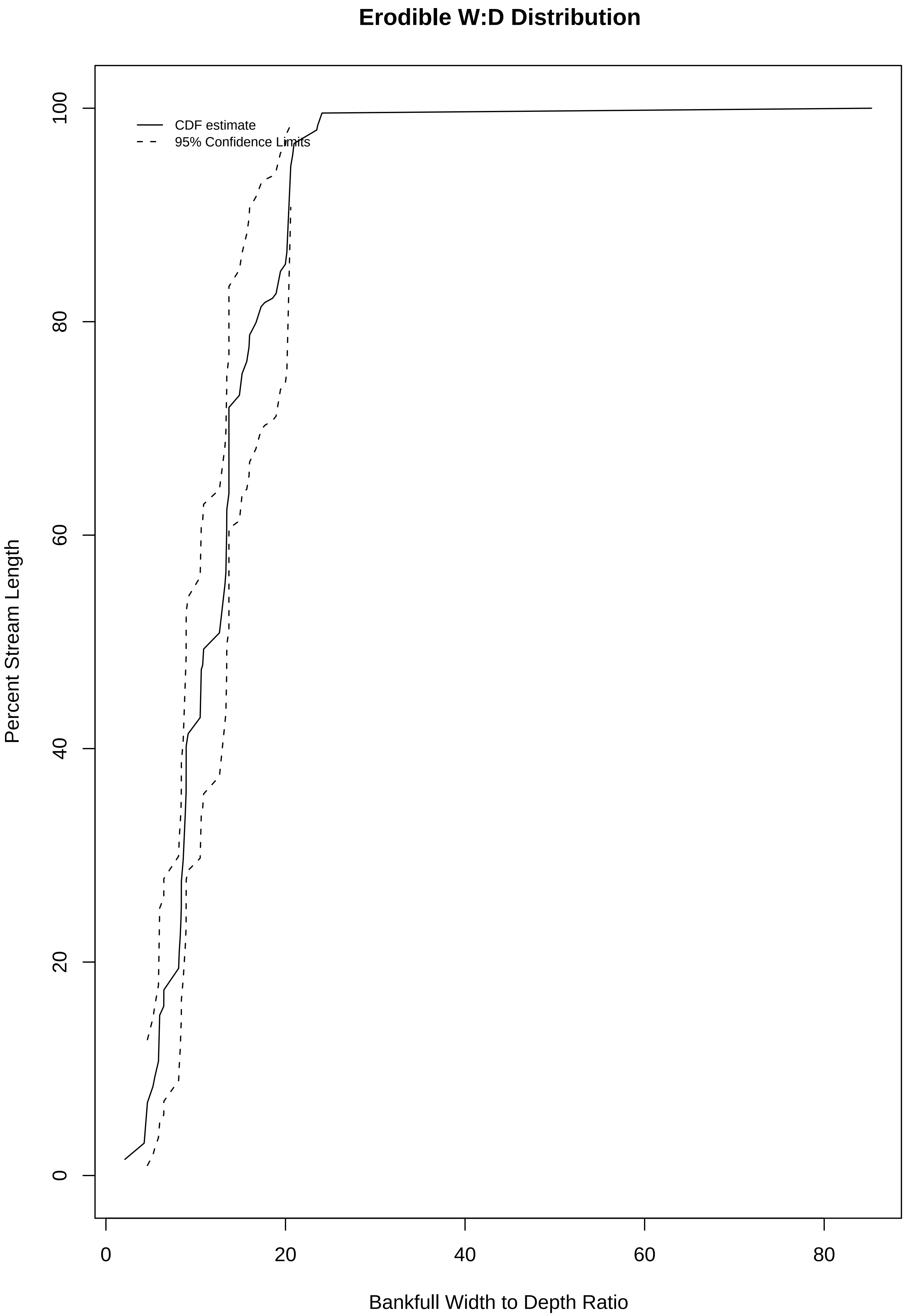

Erodible %SAFN Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
Percent Sands & Fines
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0



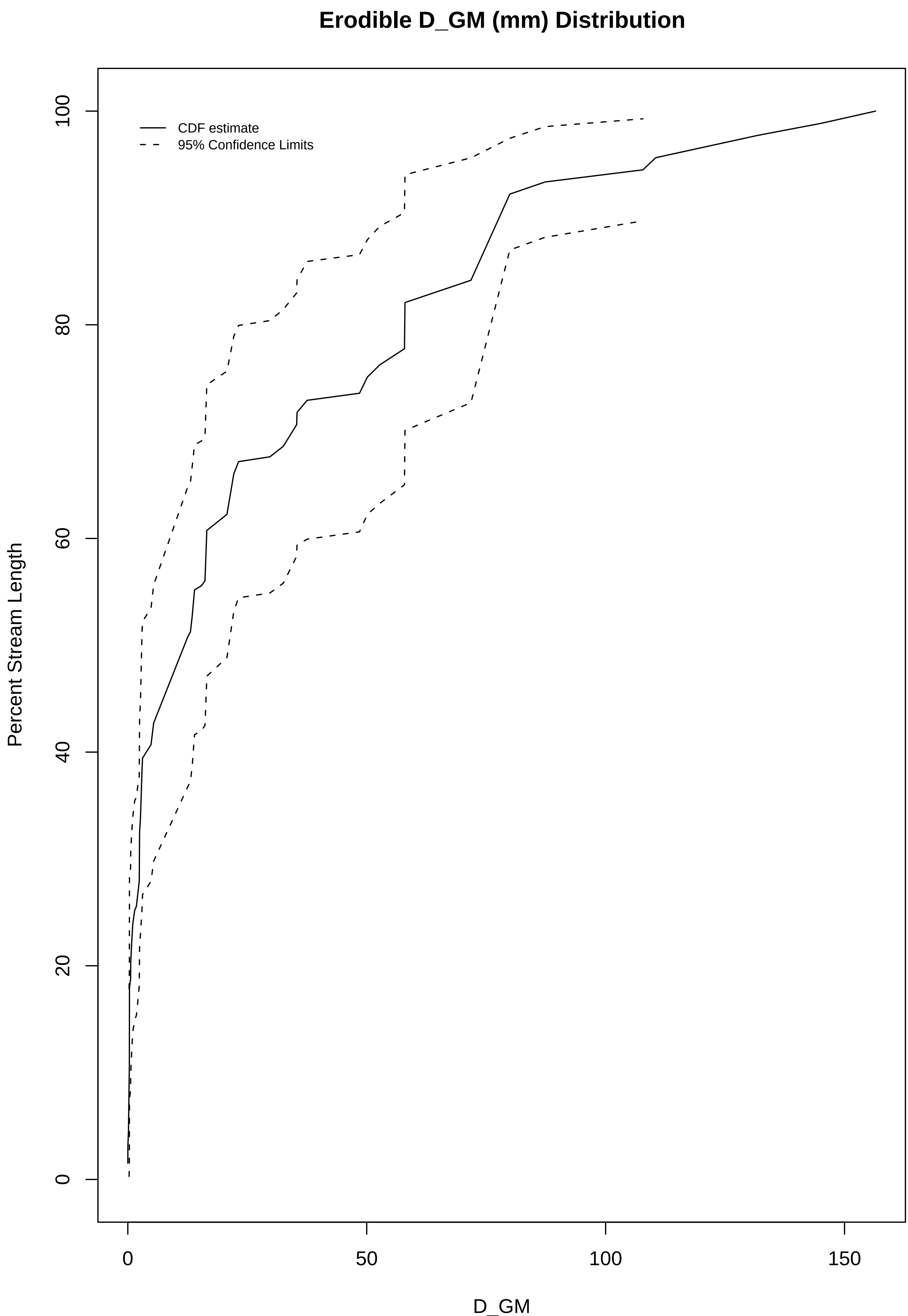
Erodible RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
Wood Radius (m)

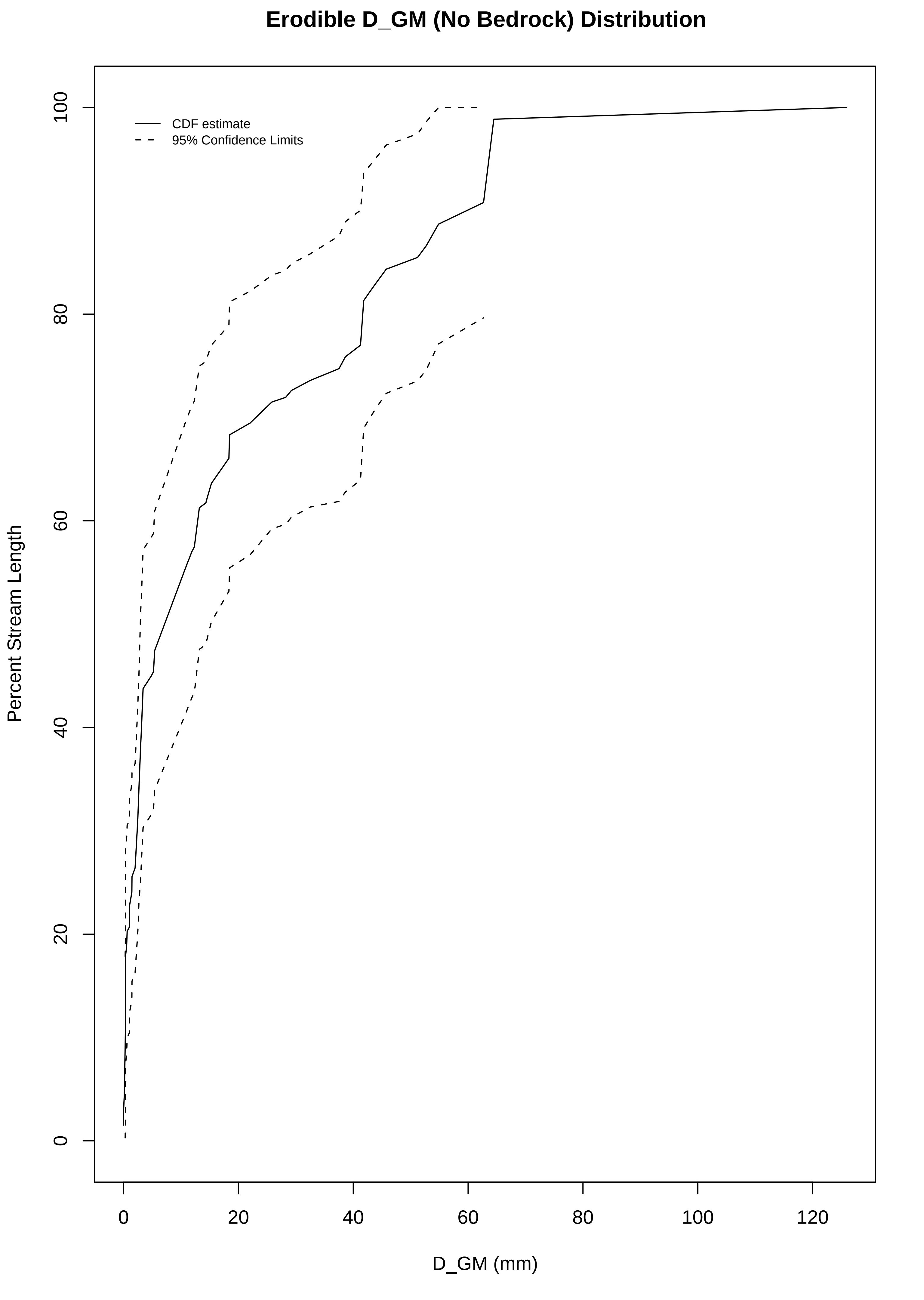


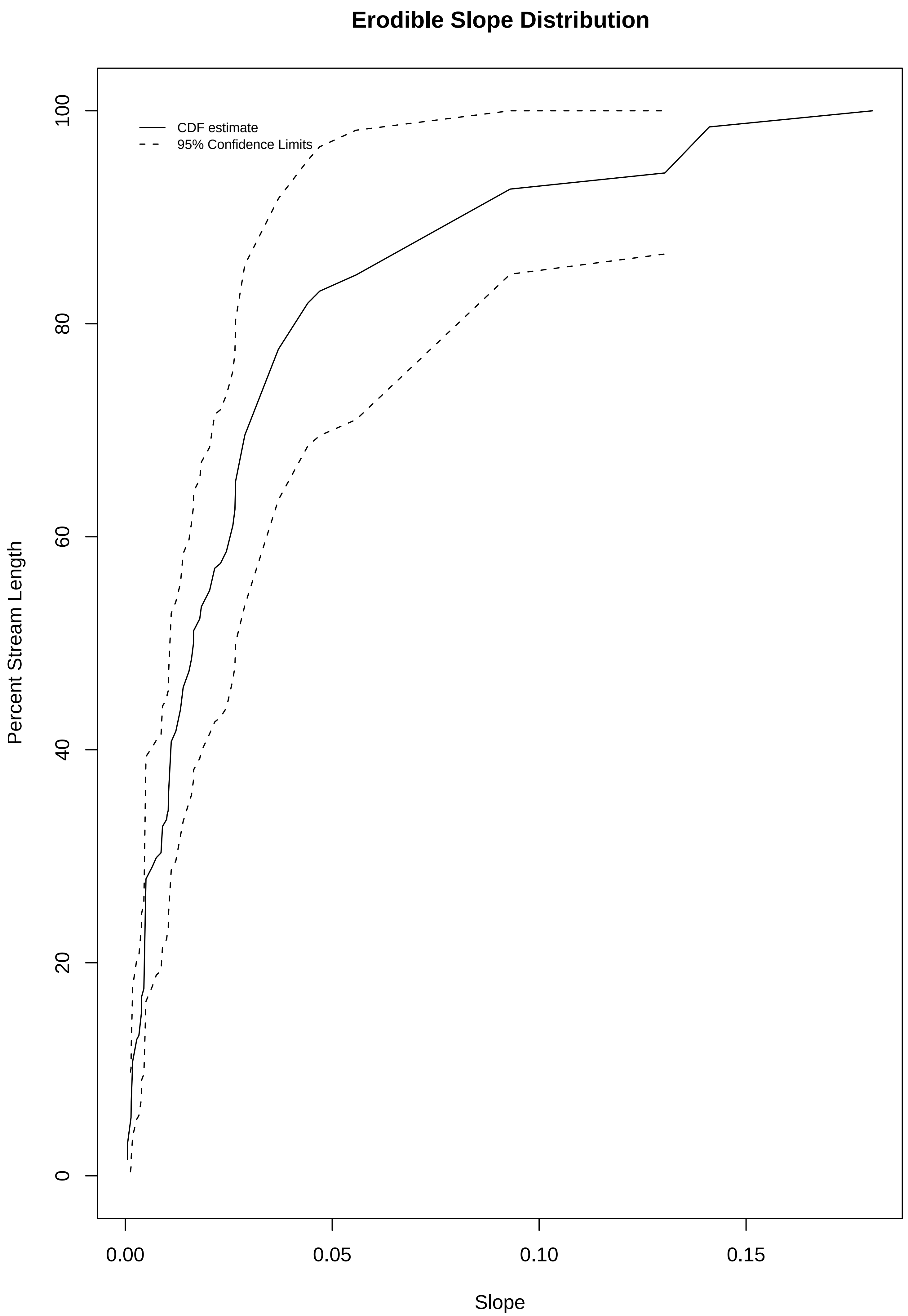
Erodible RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
10
20
30
40
Residual Pool Depth (cm)

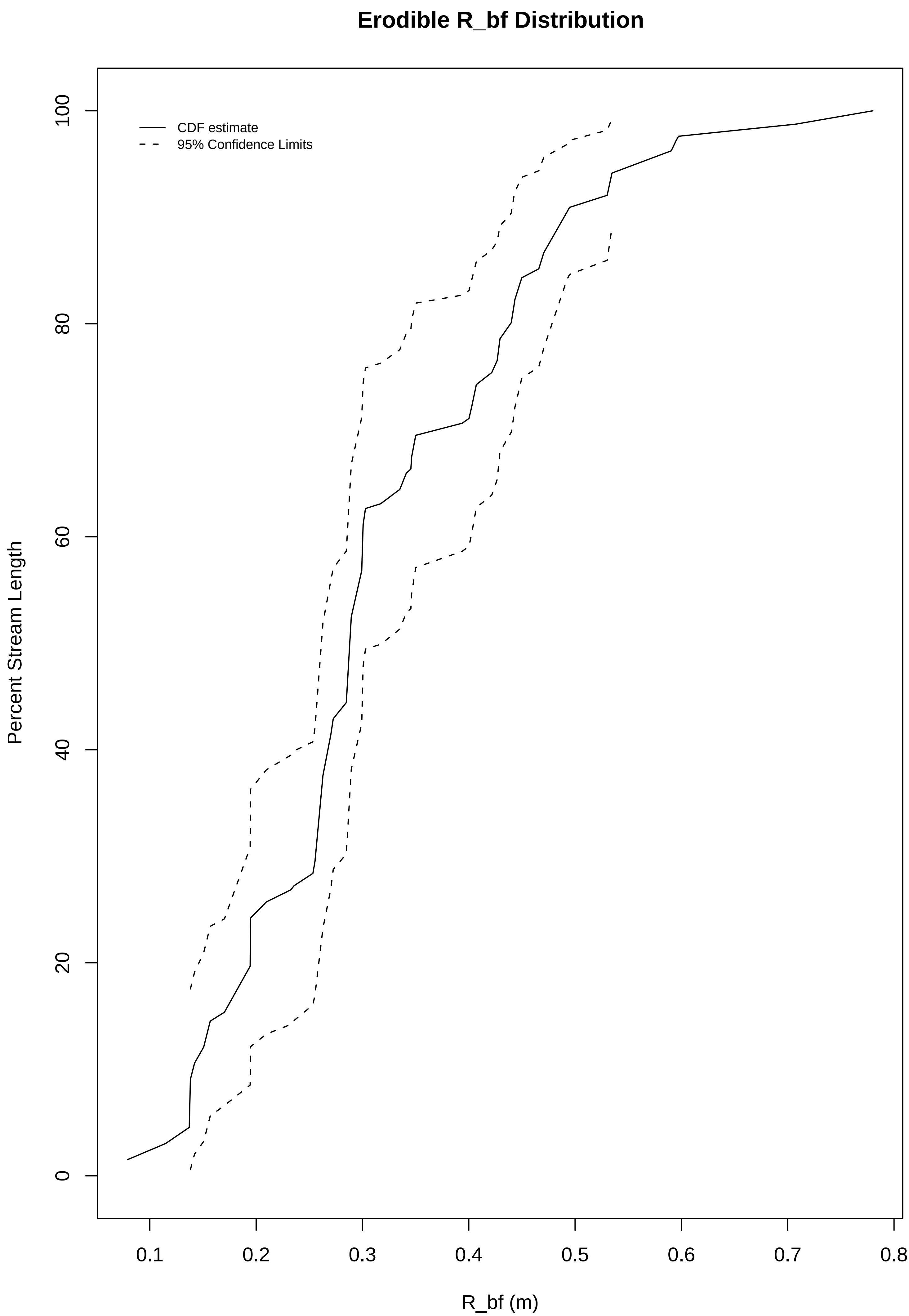


Erodible W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
Bankfull Width to Depth Ratio
0
20
40
60
80
100

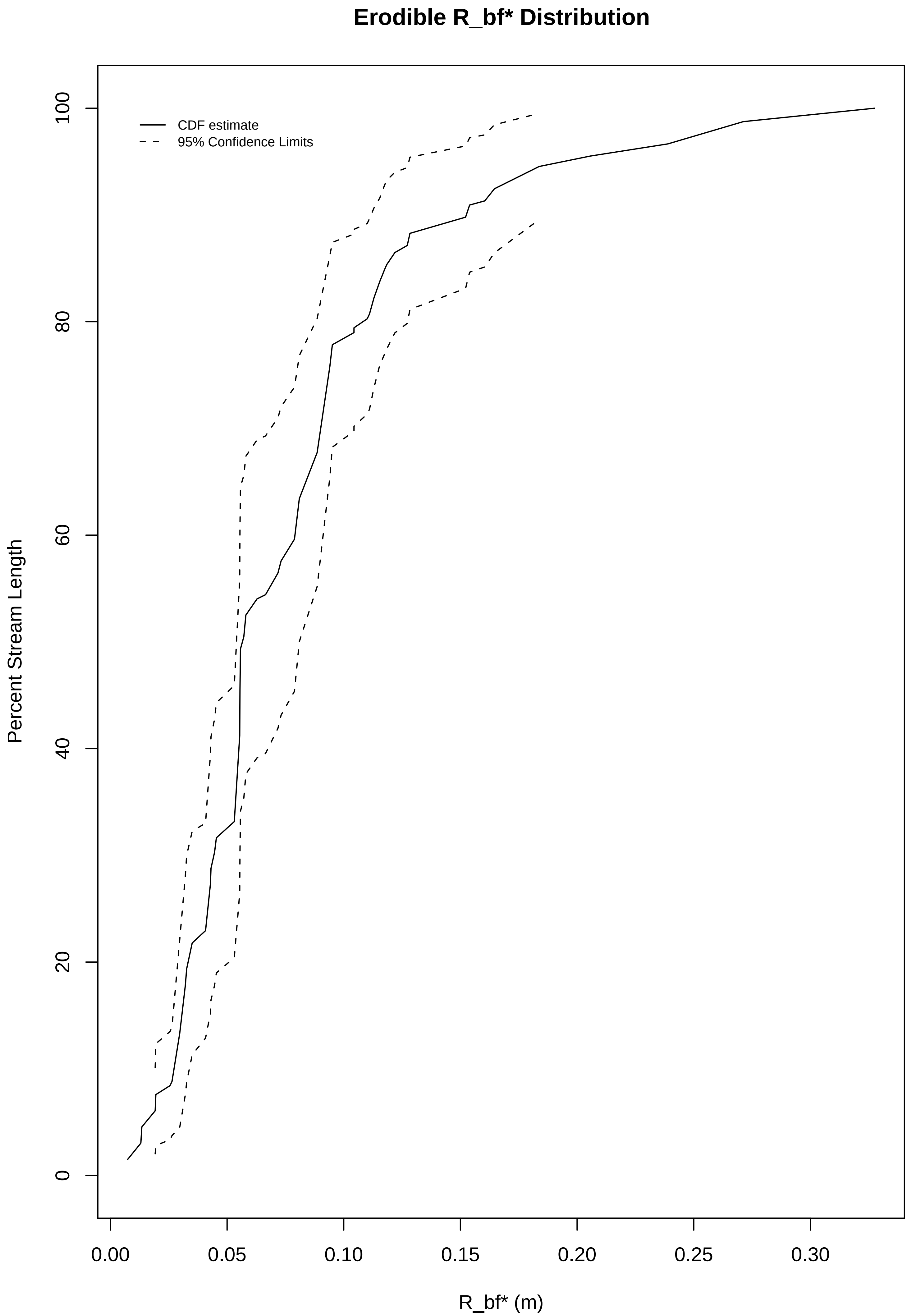

Erodible D_GM (mm) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
50
100
150
D_GM


Erodible D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
20
40
60
80
100
120
D_GM (mm)

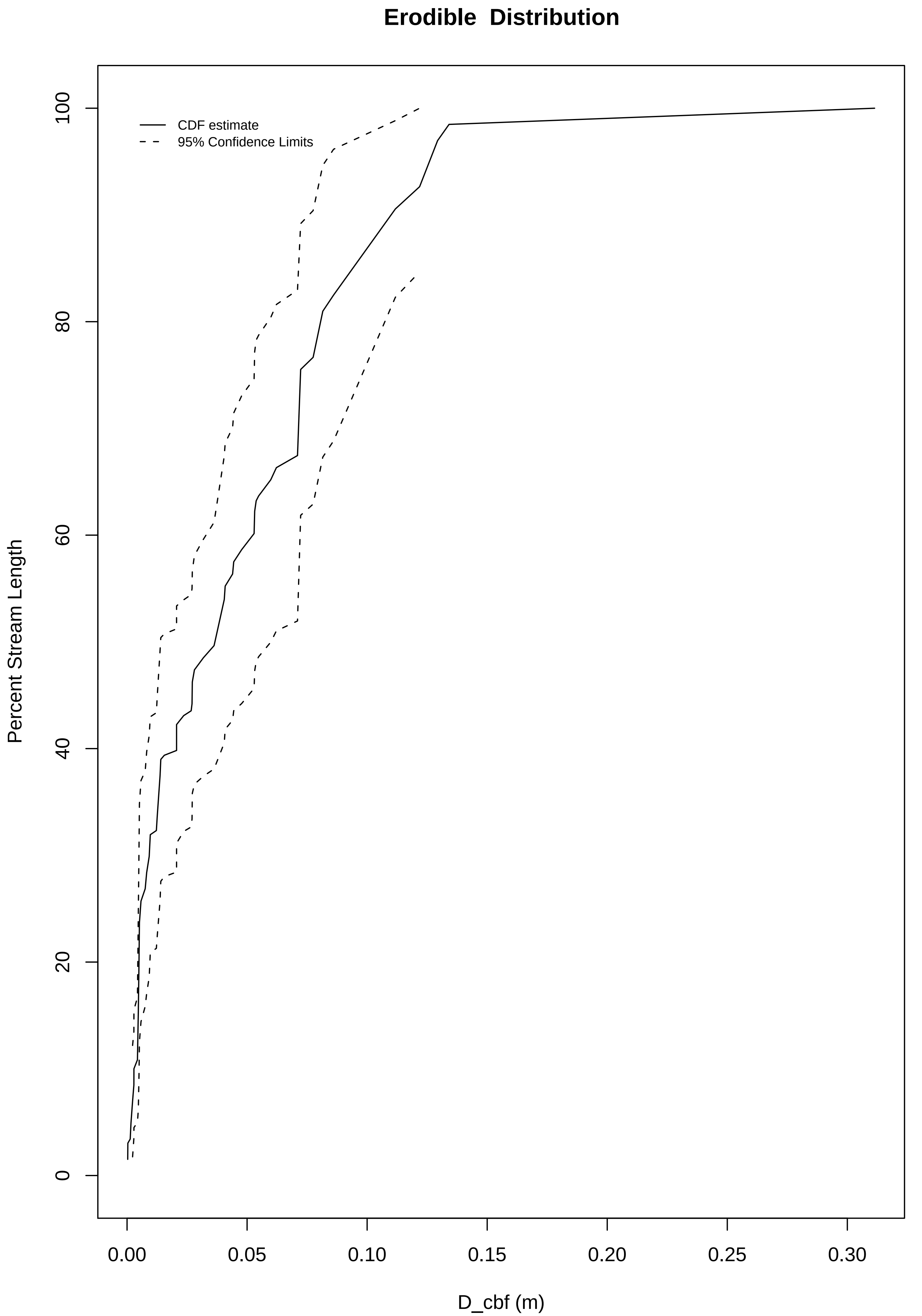

Erodible Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
Slope

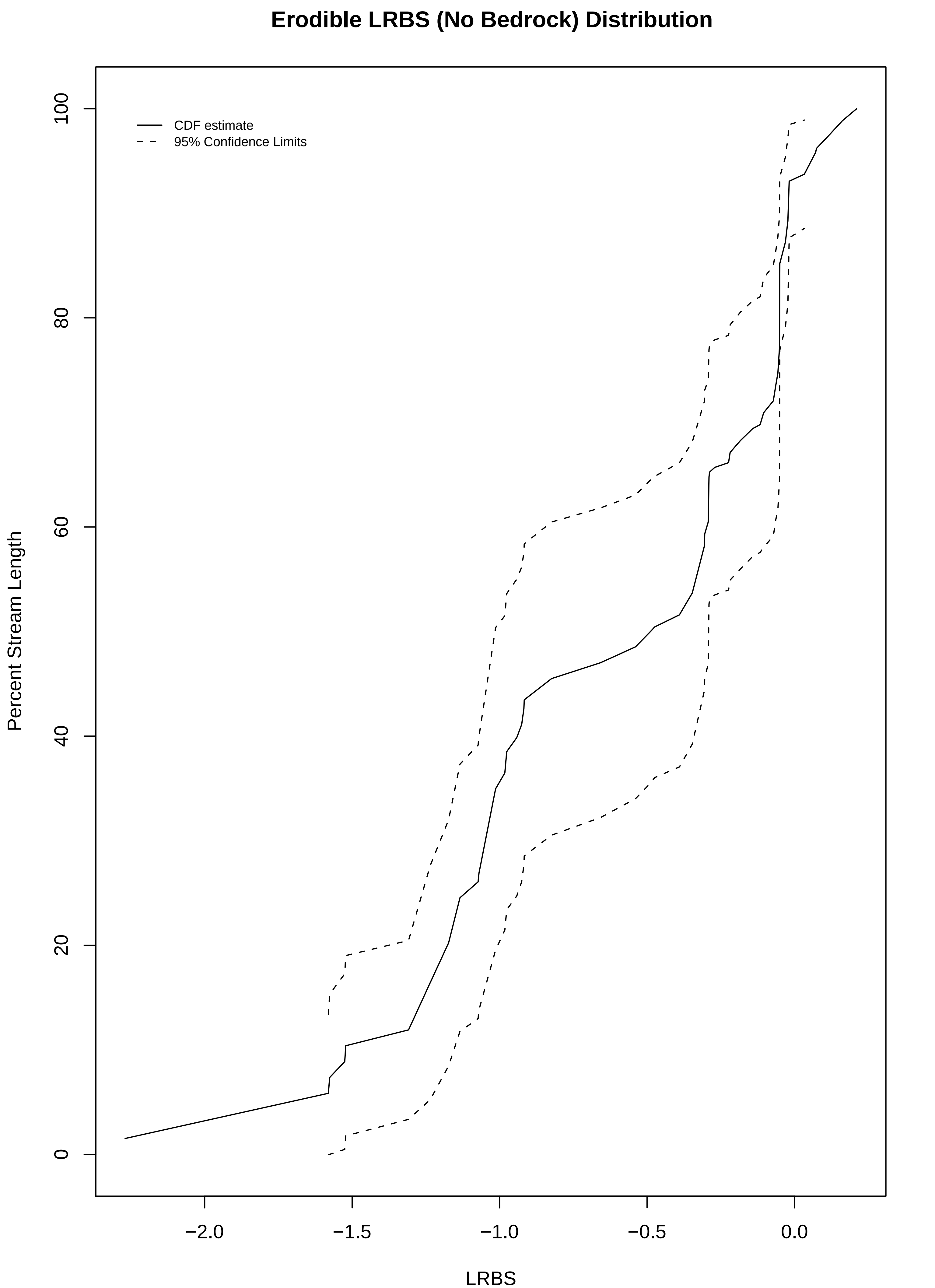


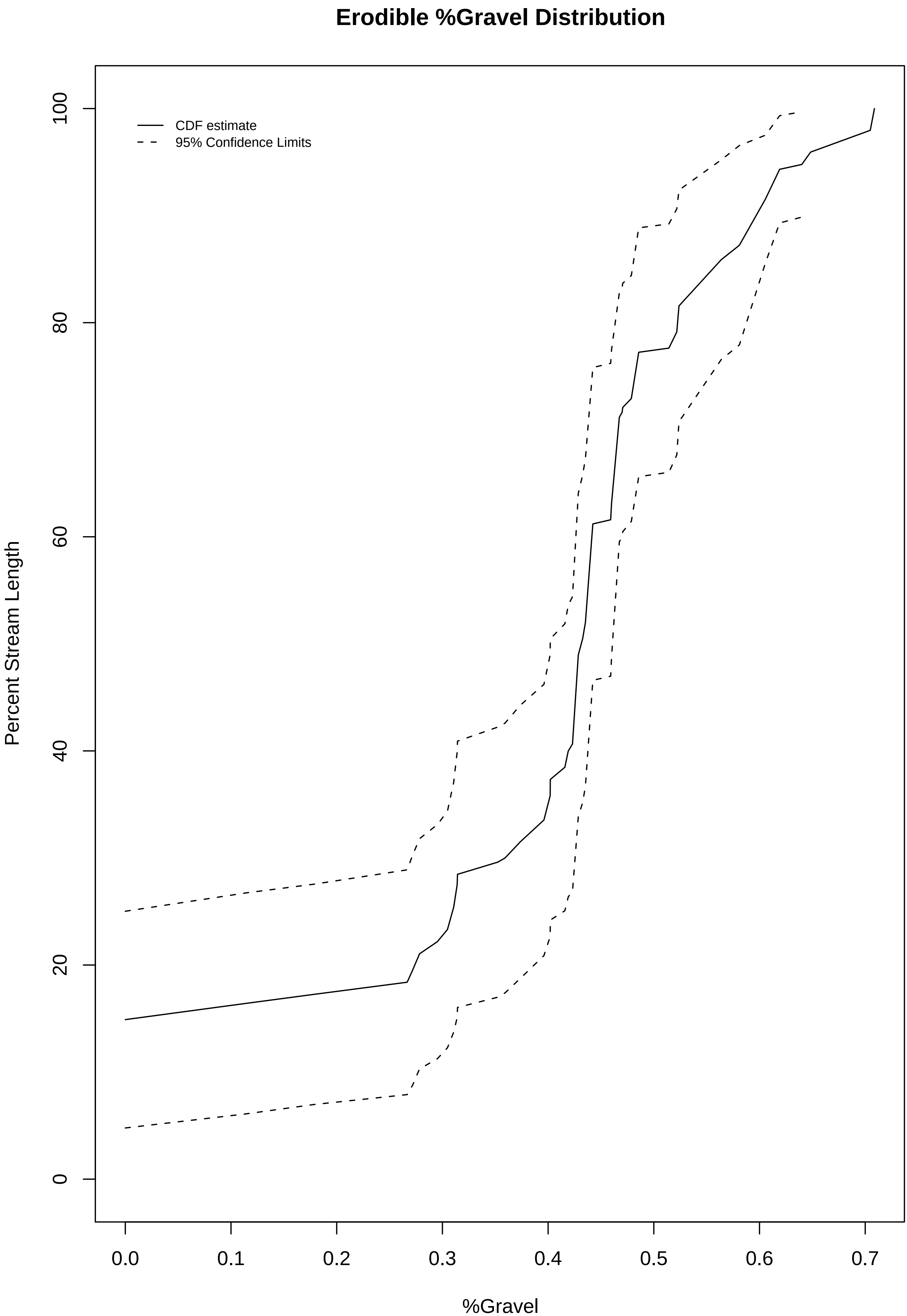
Erodible R_bf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
R_bf (m)



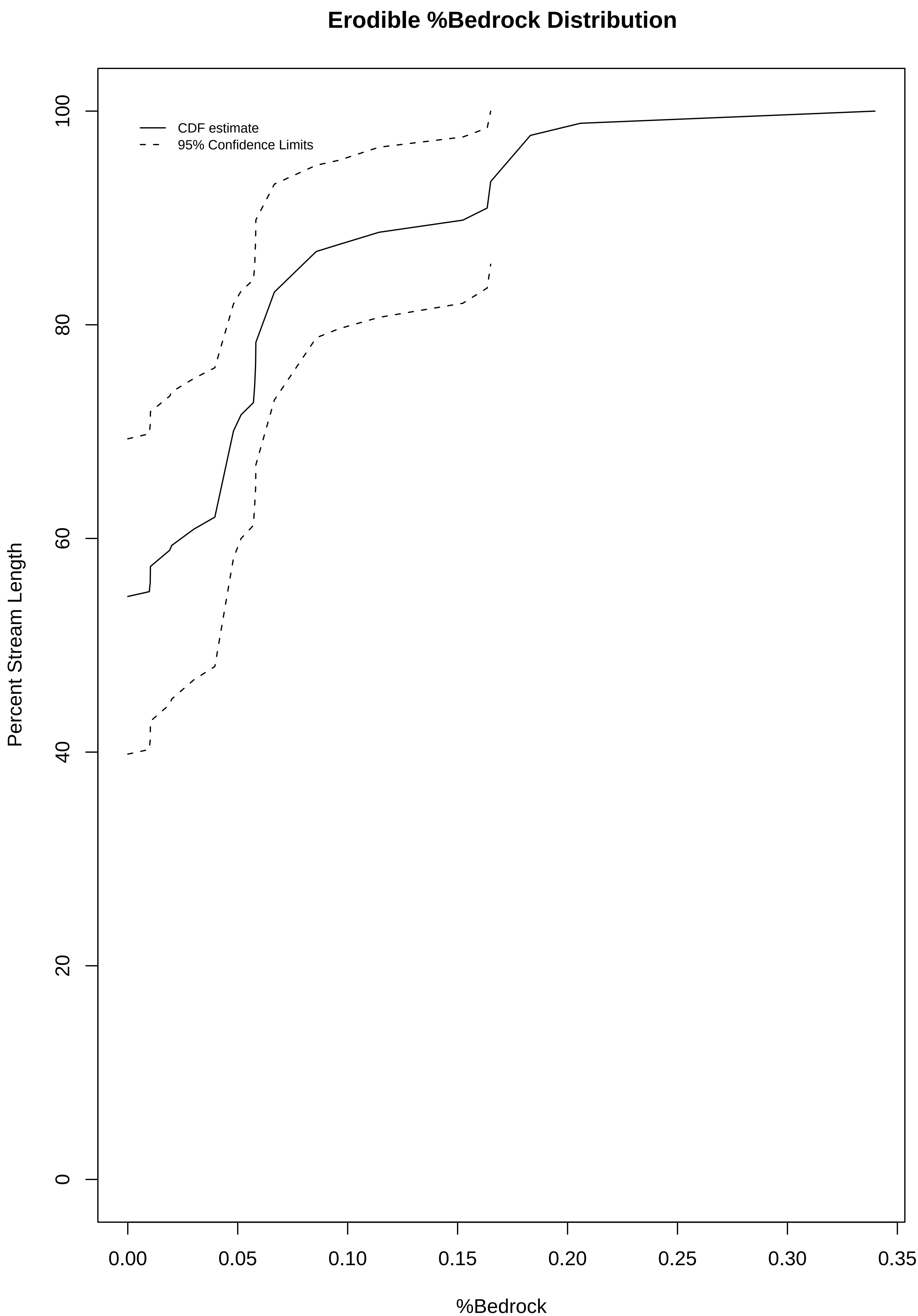
Erodible R_bf* Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
R_bf* (m)


Erodible Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
D_cbf (m)

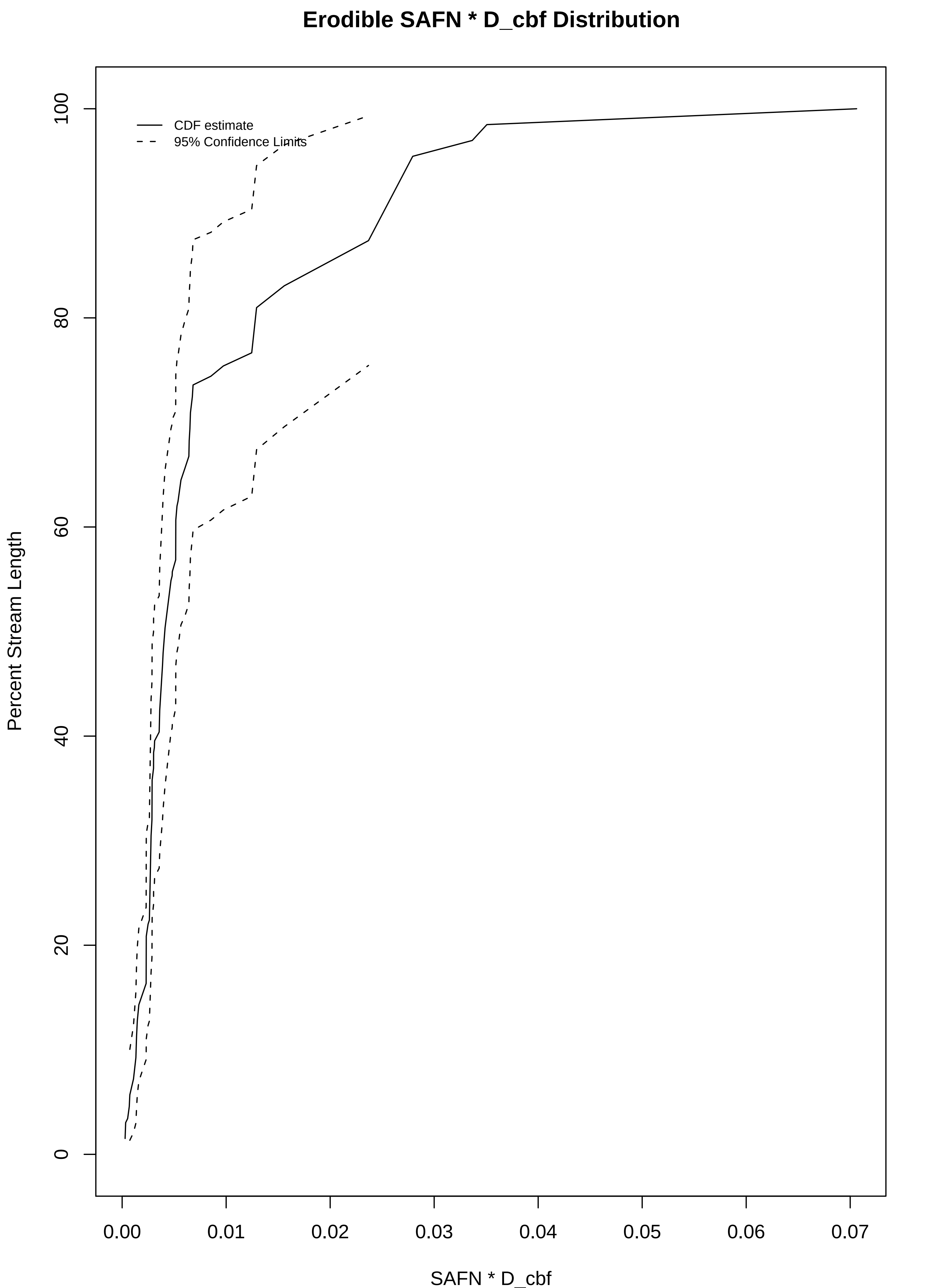

Erodible LRBS (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−2.0
−1.5
−1.0
−0.5
0.0
LRBS



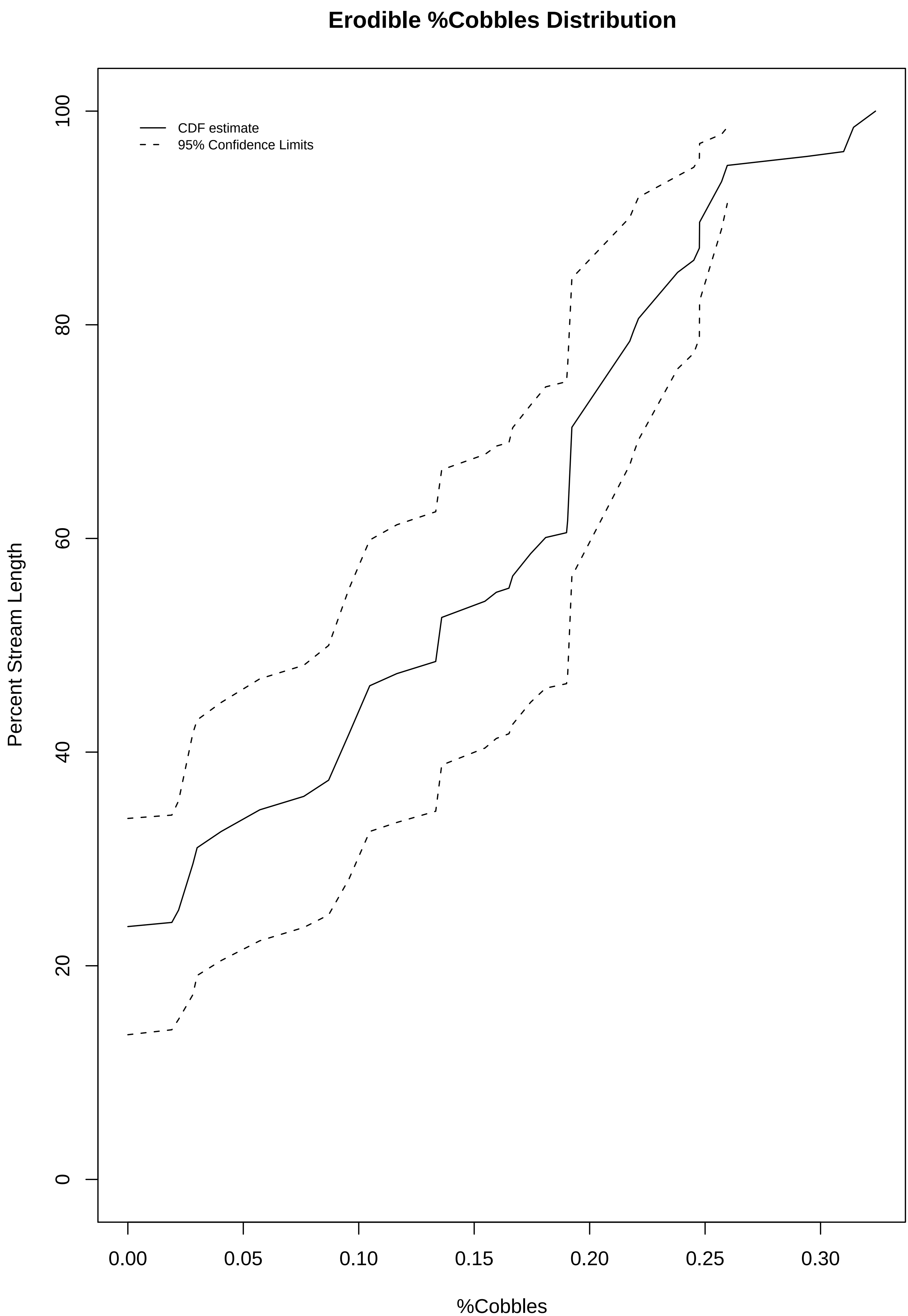
Erodible %Gravel Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
%Gravel
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

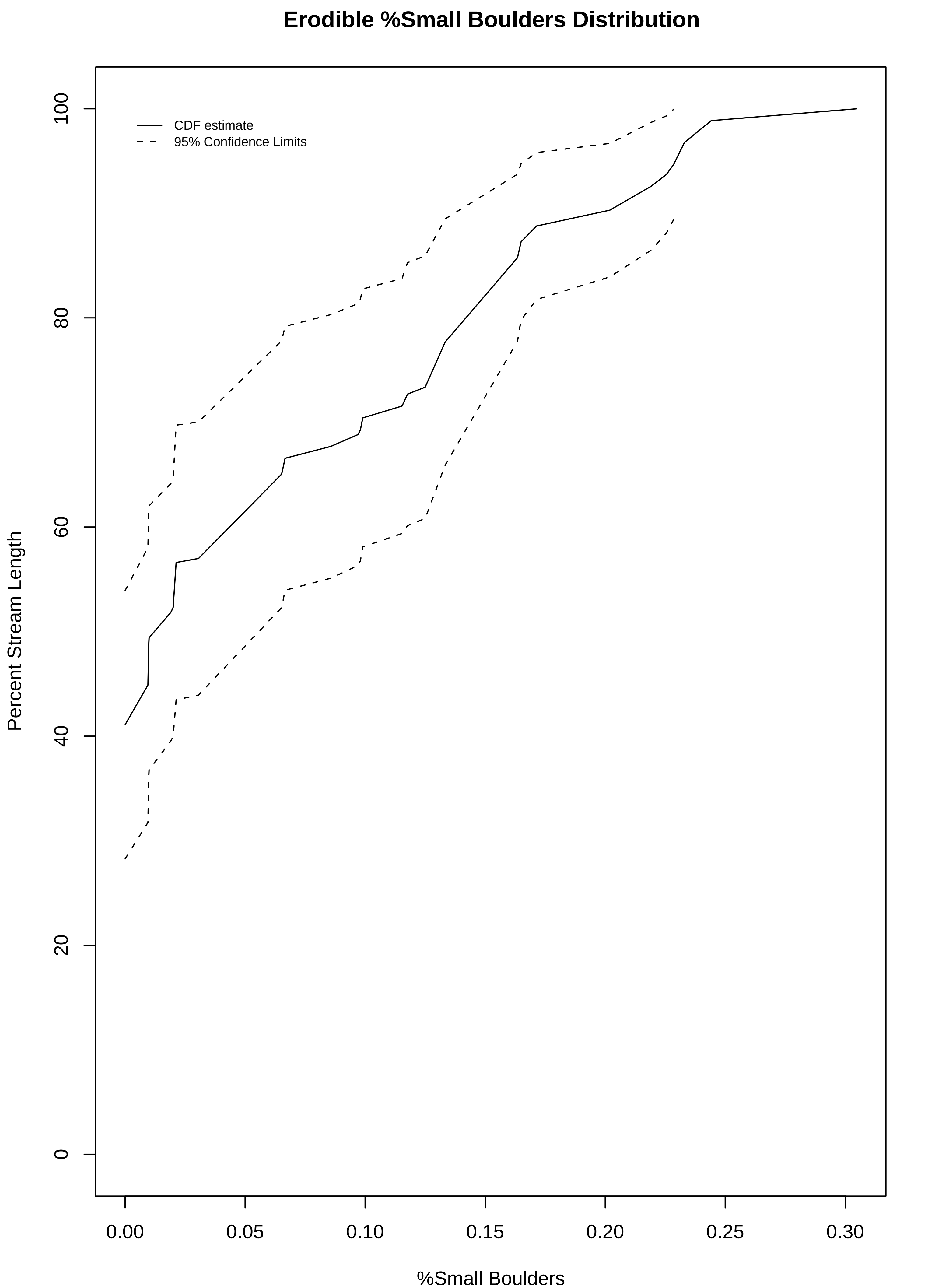


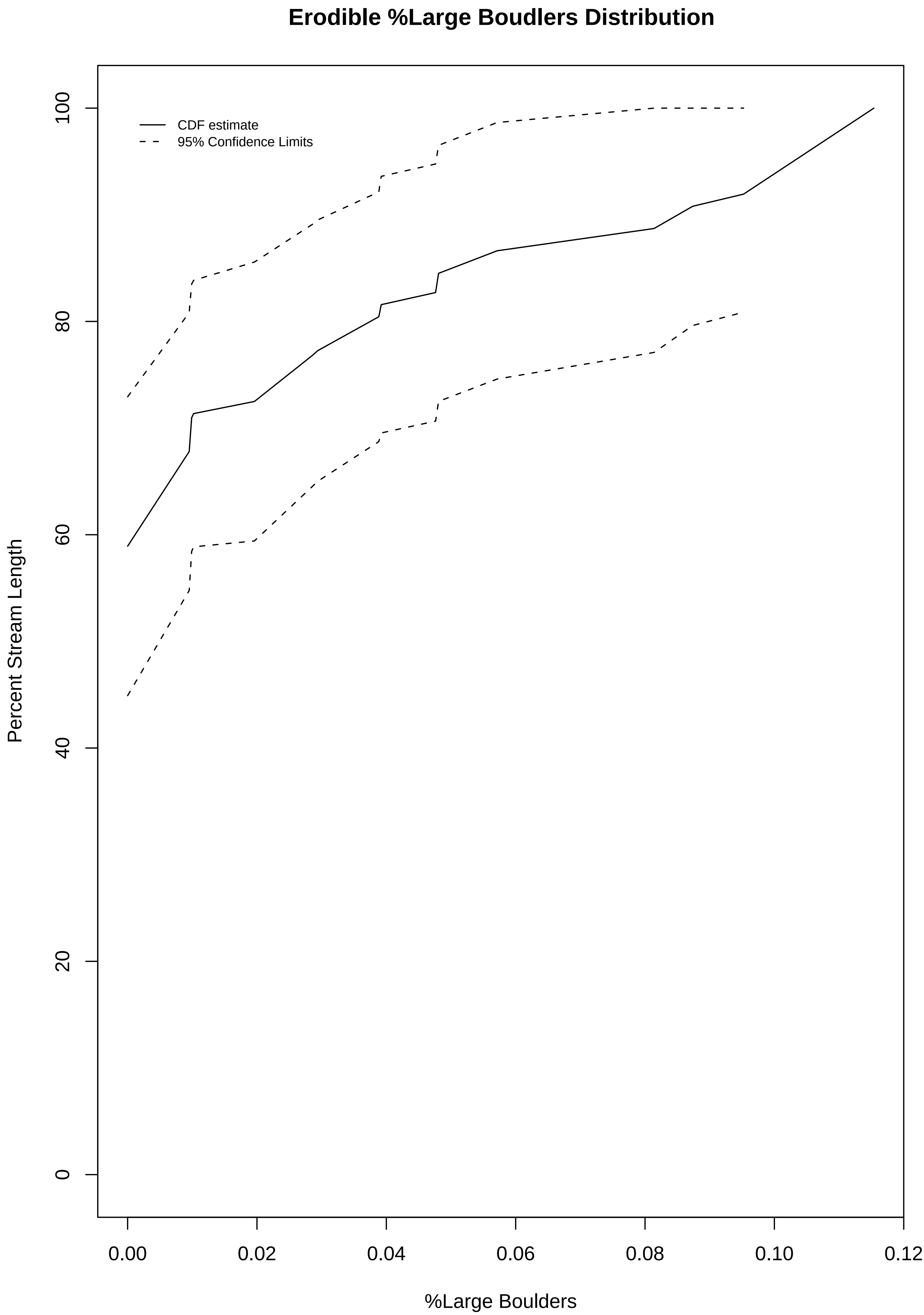
Erodible %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
%Bedrock
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35



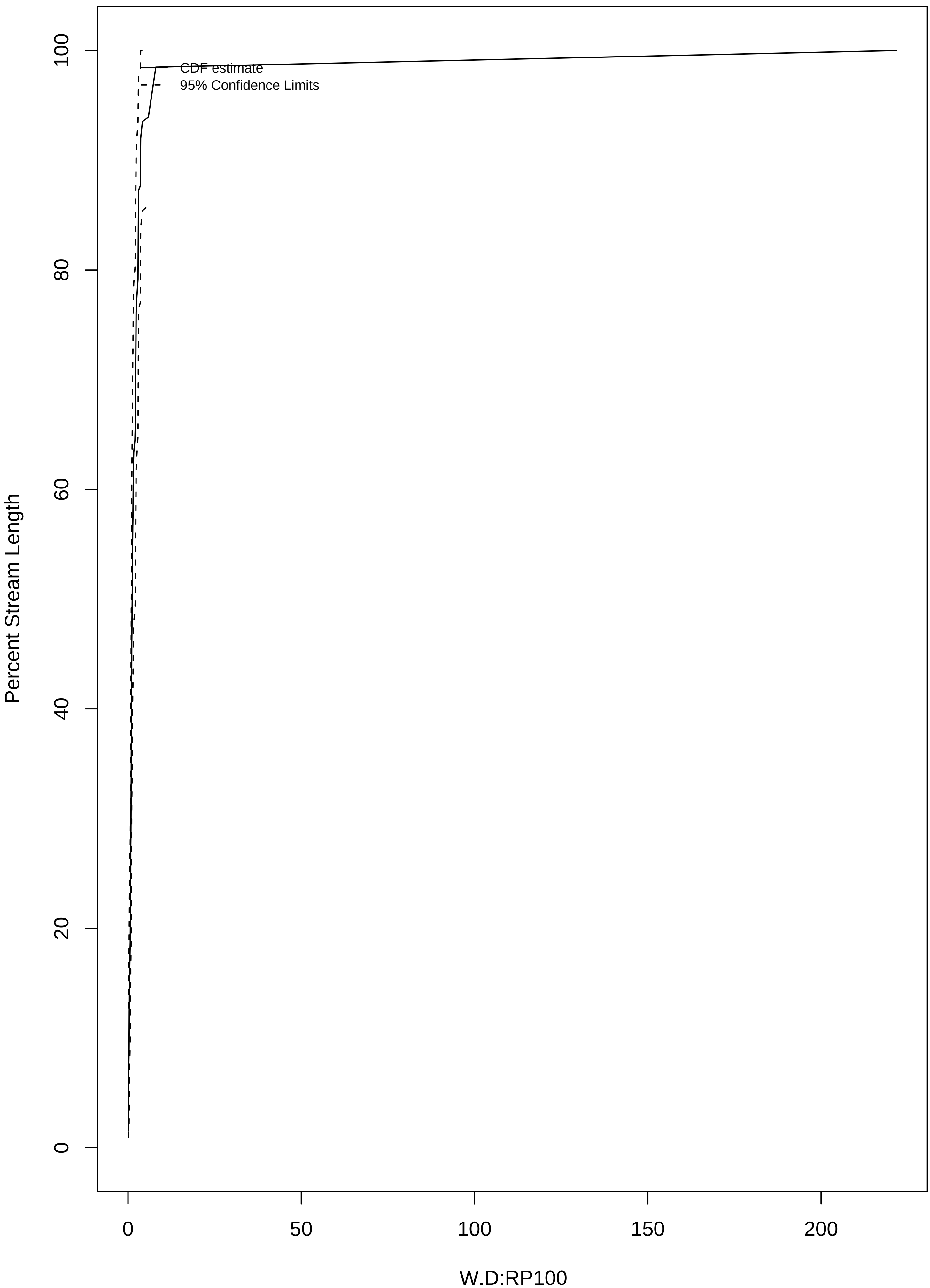
Erodible SAFN * D_cbf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
SAFN * D_cbf

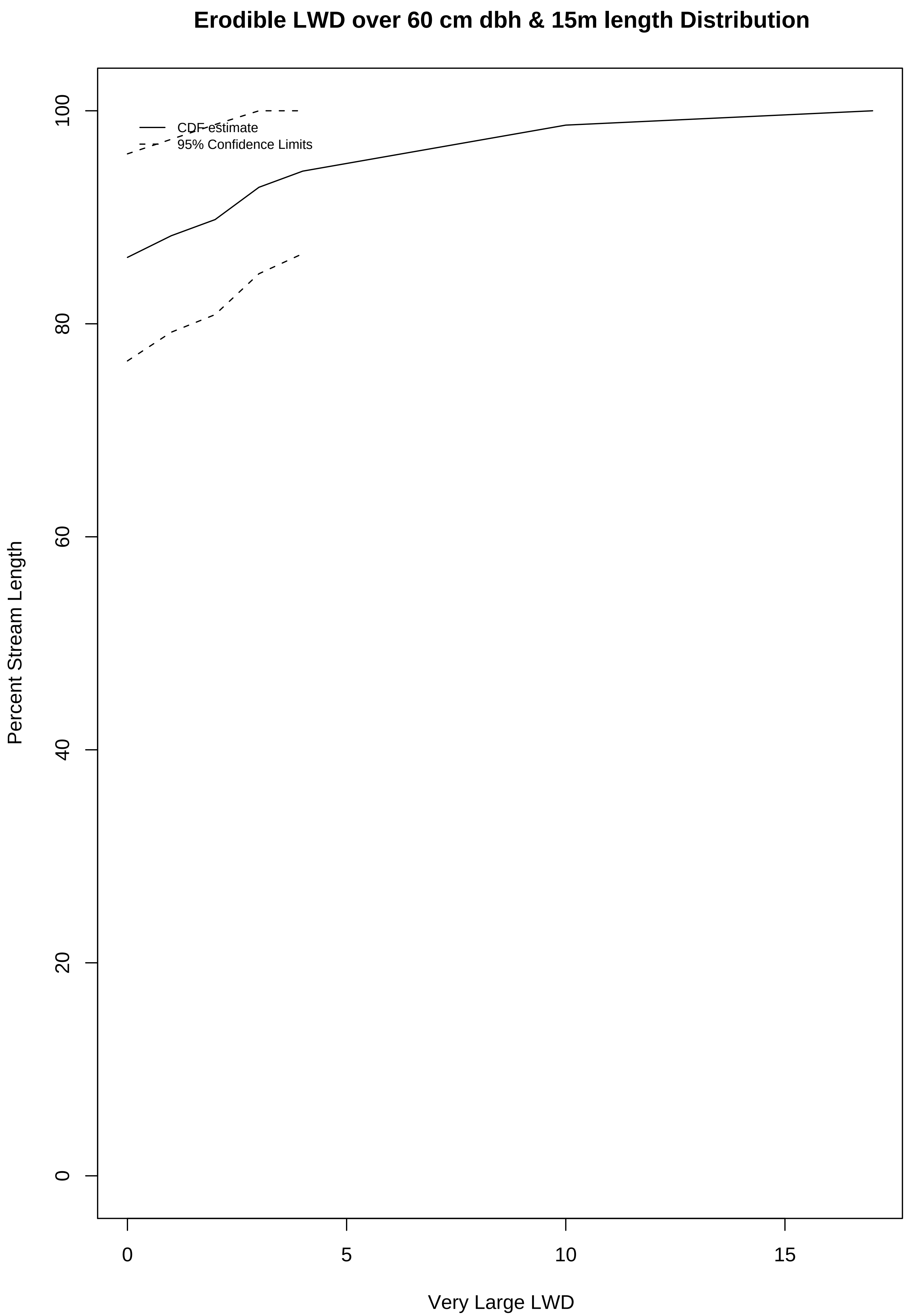

Erodible %Cobbles Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
%Cobbles
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30


Erodible %Small Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
%Small Boulders


Erodible %Large Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
%Large Boulders
0
20
40
60
80
100
0.00
0.02
0.04
0.06
0.08
0.10
0.12

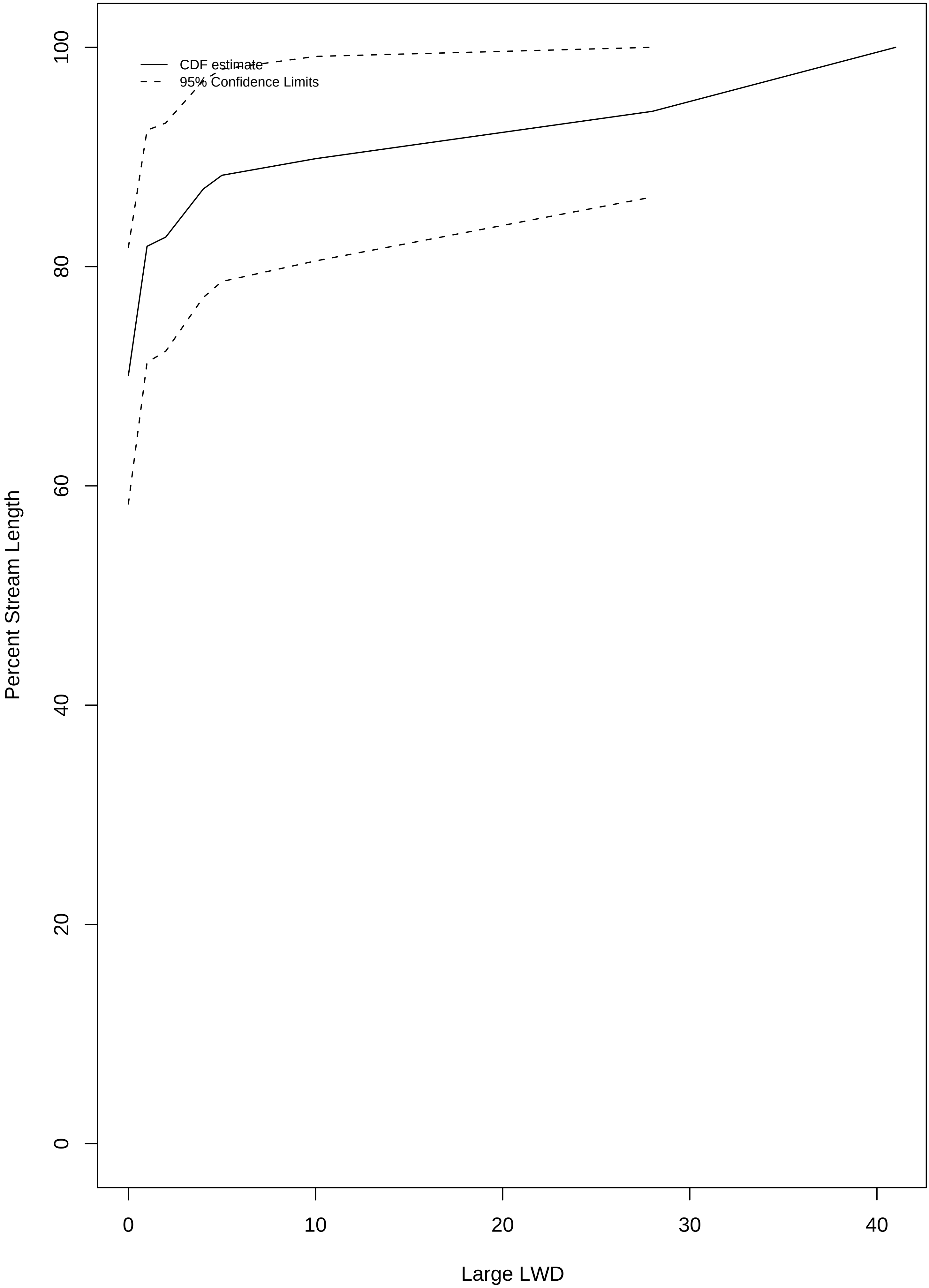
Erodible W.D:RP100 Distribution

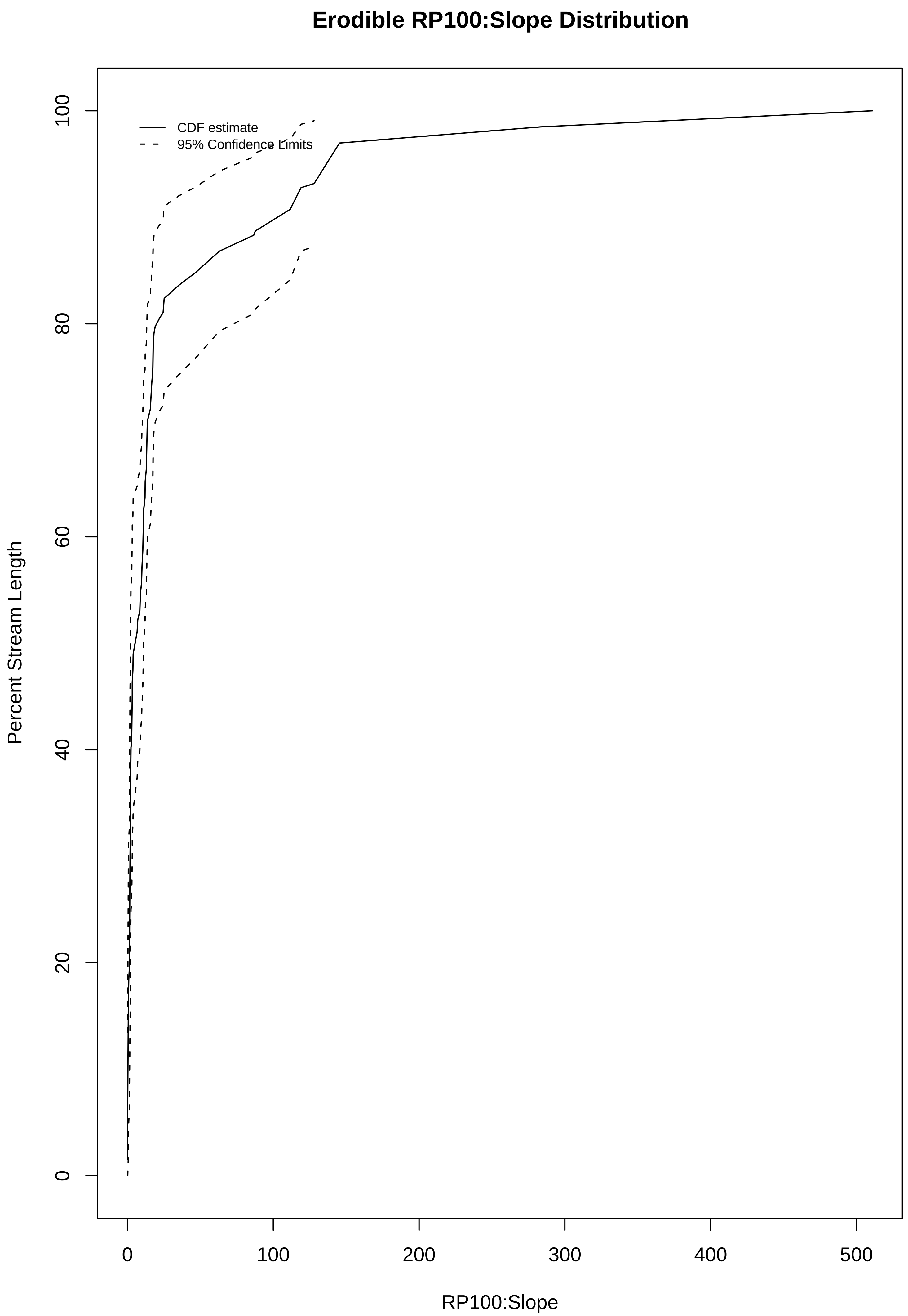


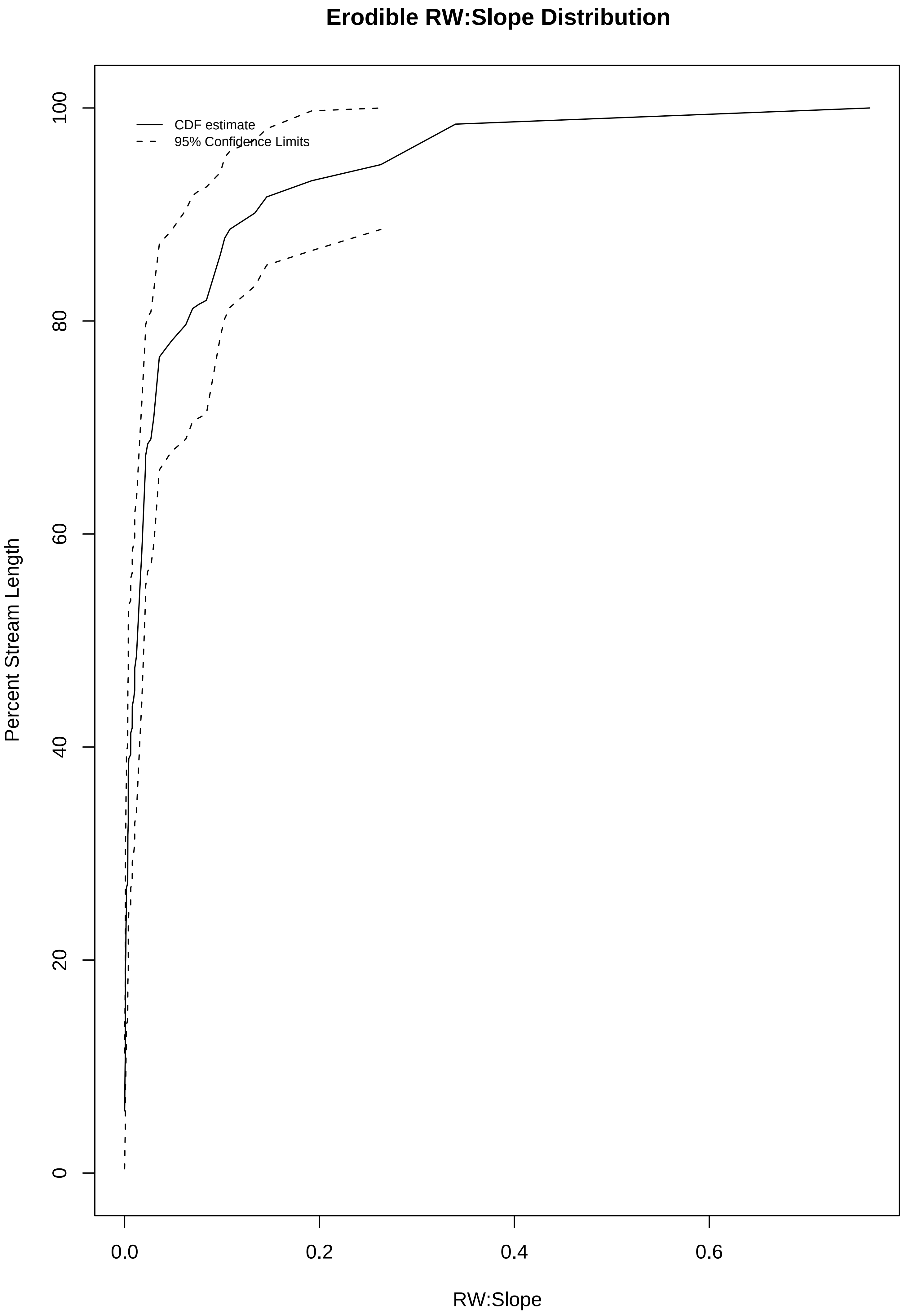


Erodible LWD over 60 cm dbh & 15m length Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
5
10
15
Very Large LWD

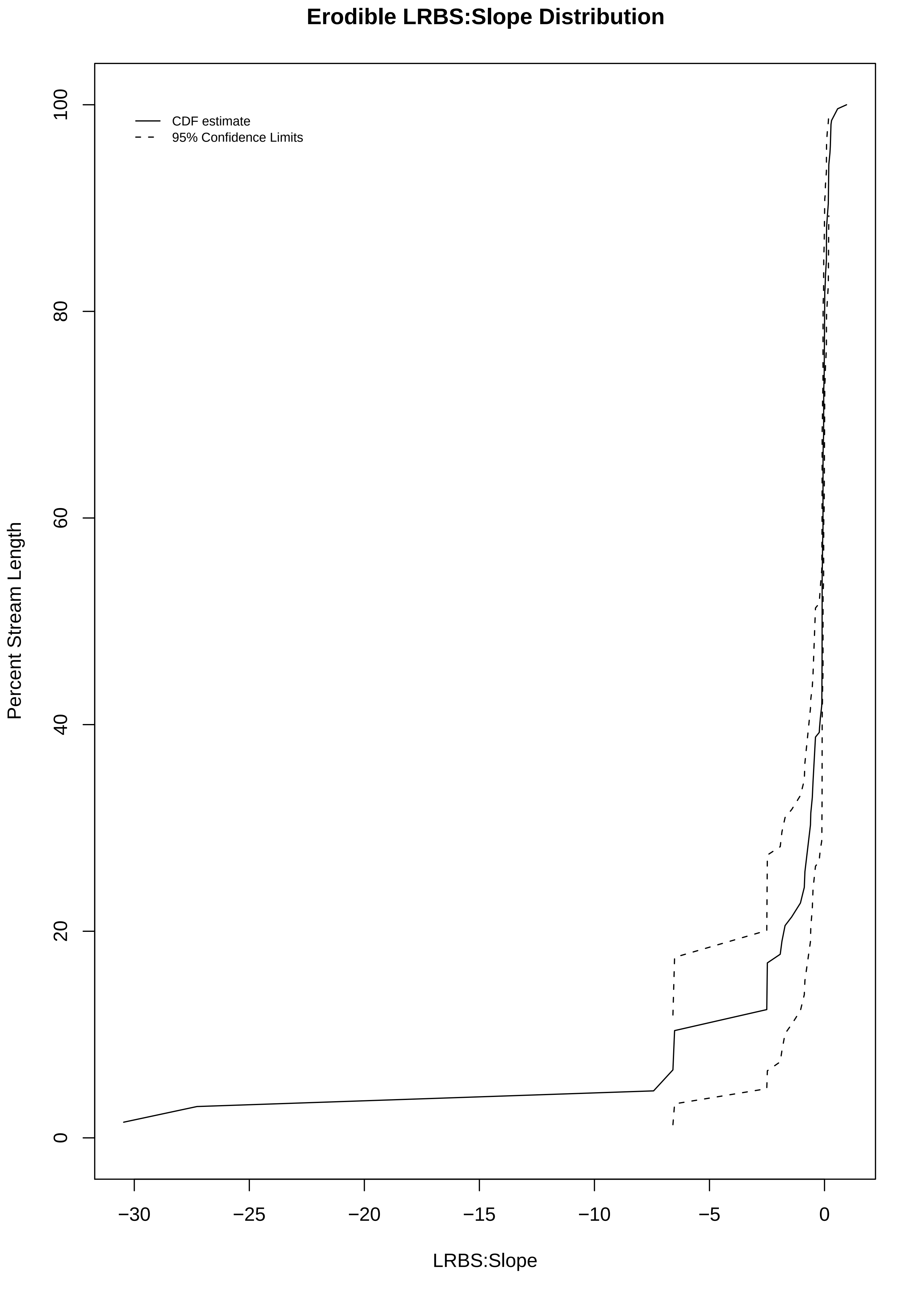
Erodible Erodible LWD over 60 cm dbh Distribution



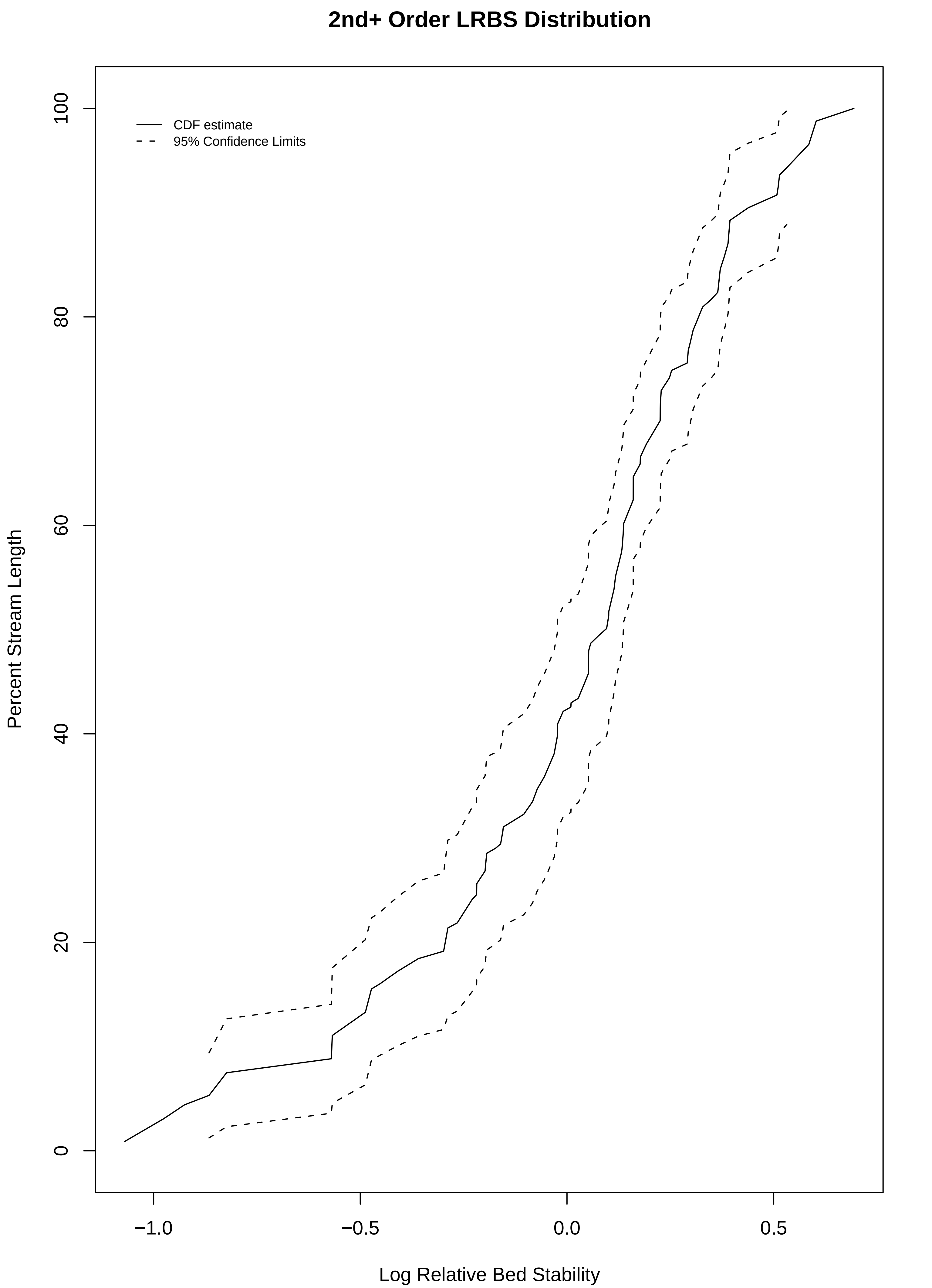

Erodible RP100:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
100
200
300
400
500
RP100:Slope



Erodible RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
RW:Slope

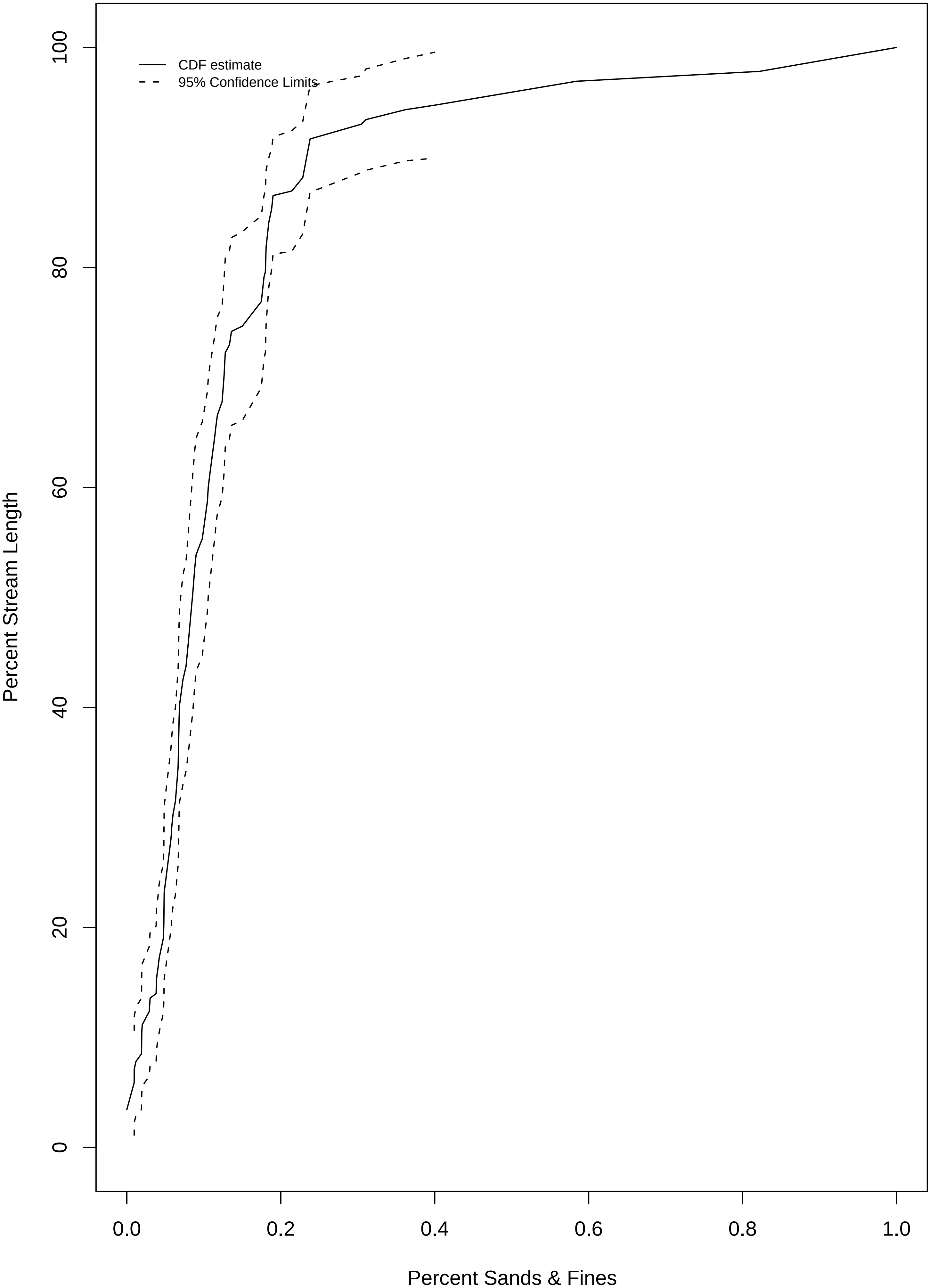


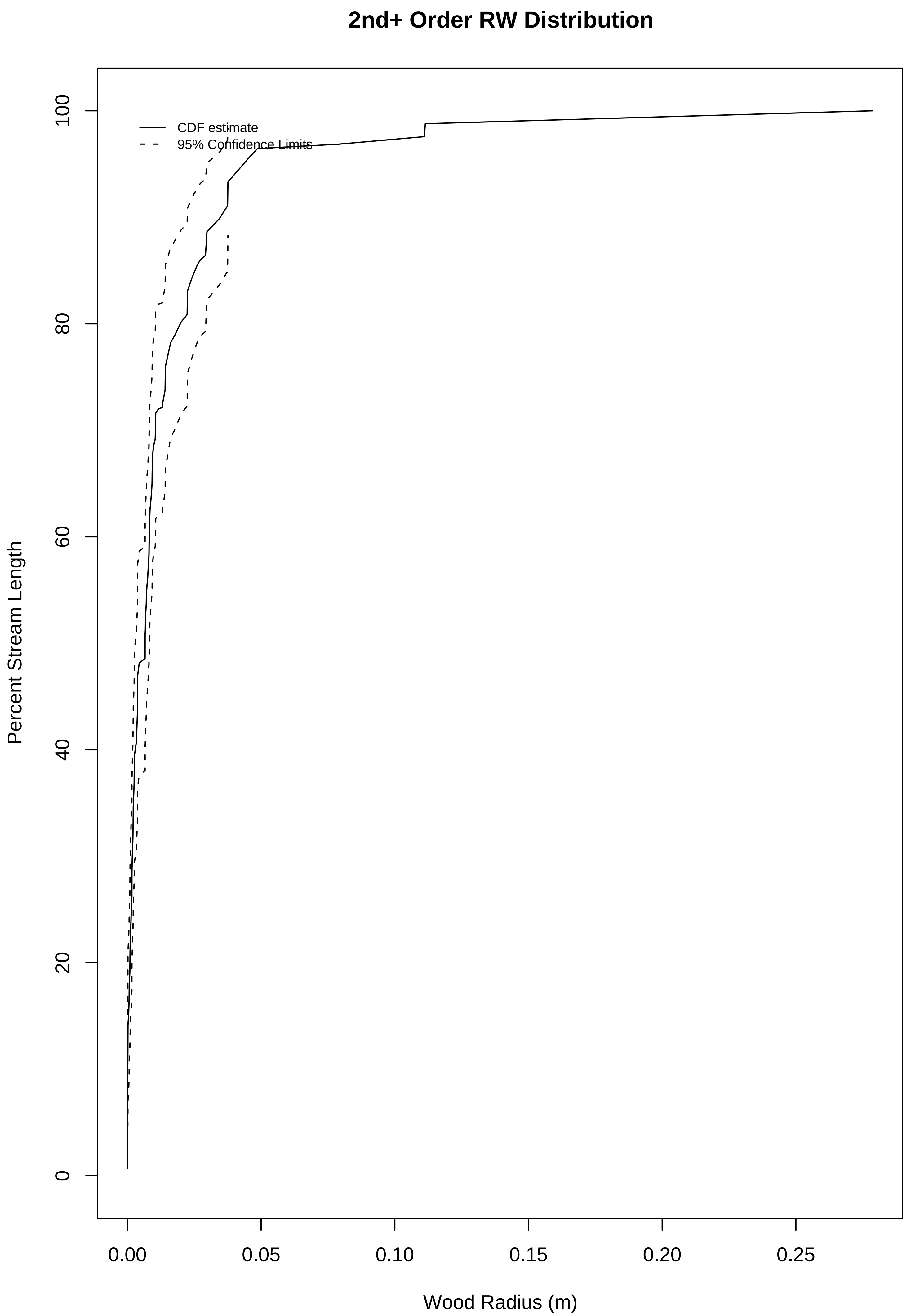
Erodible LRBS:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−30
−25
−20
−15
−10
−5
0
LRBS:Slope



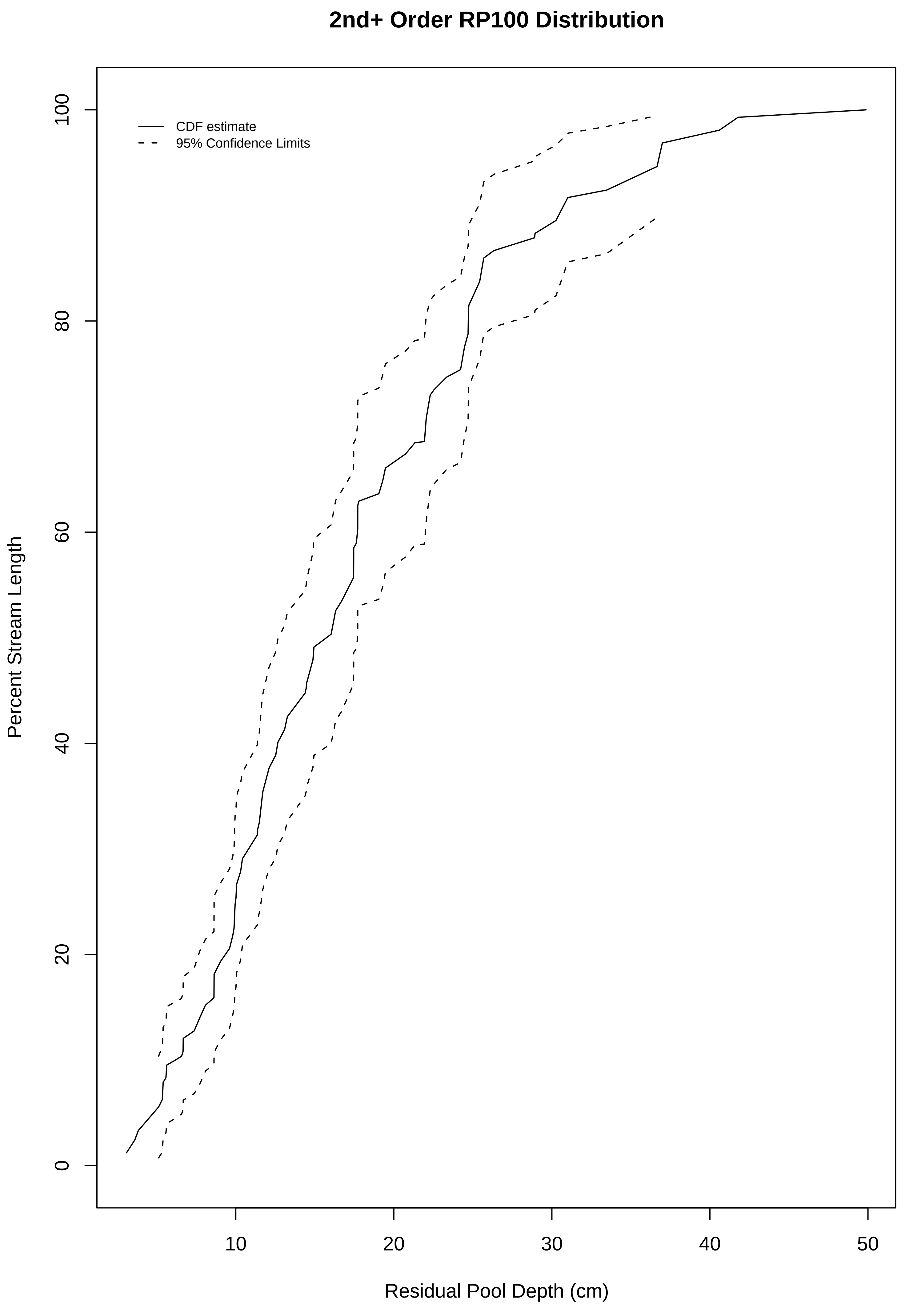
2nd+ Order LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−1.0
−0.5
0.0
0.5
Log Relative Bed Stability

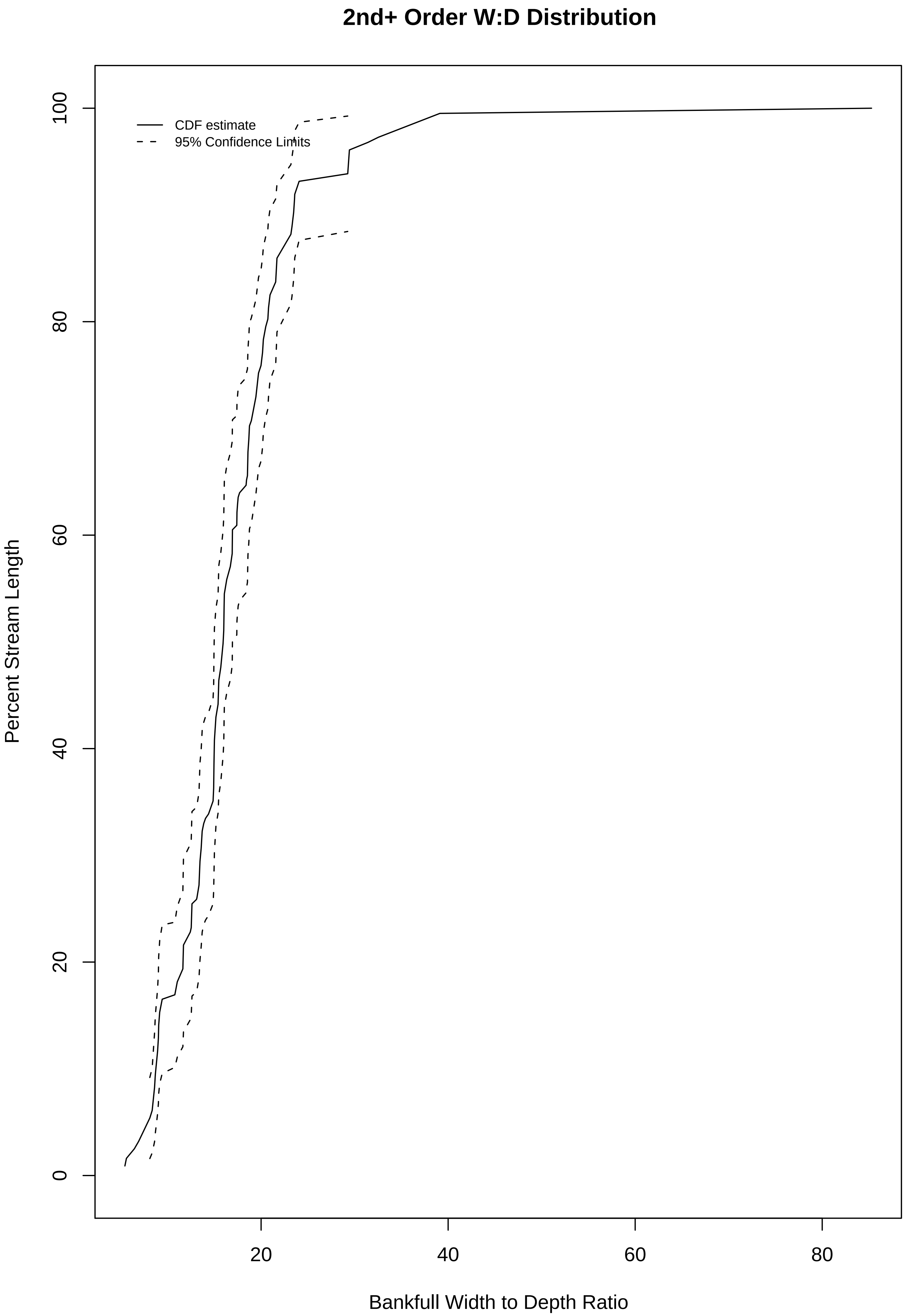
2nd+ Order %SAFN Distribution

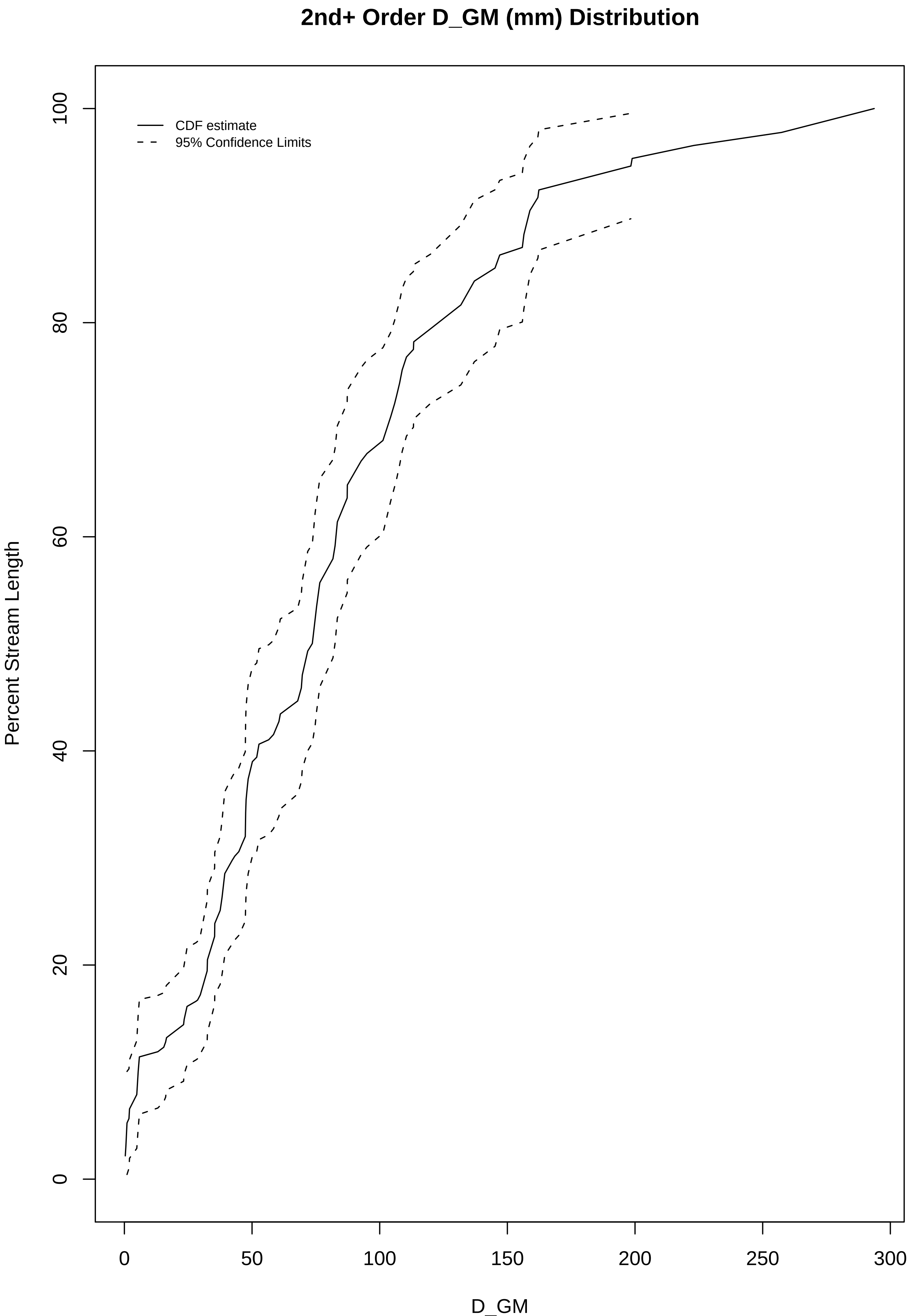


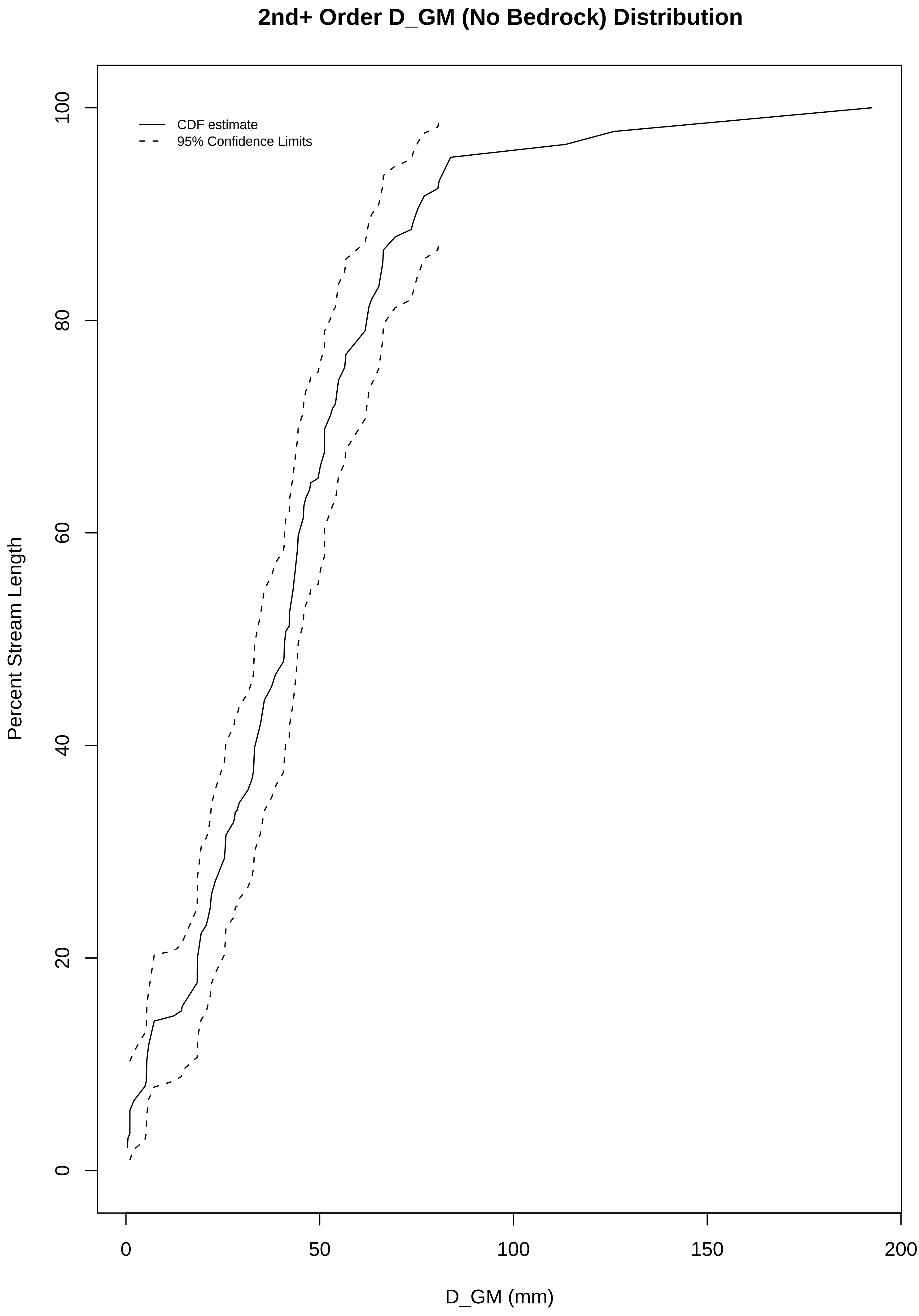


2nd+ Order RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
Wood Radius (m)

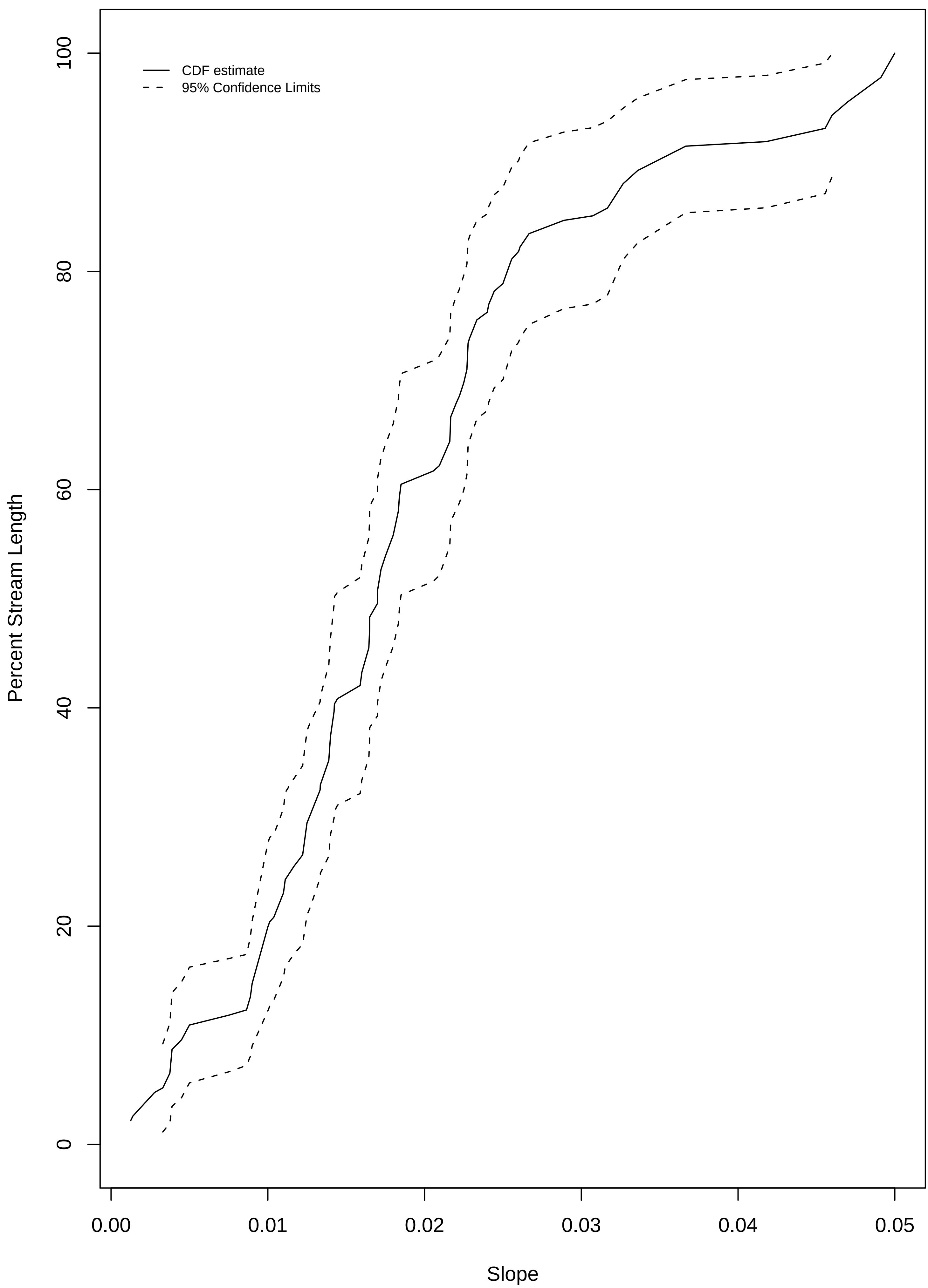

2nd+ Order RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
10
20
30
40
50
Residual Pool Depth (cm)


2nd+ Order W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
20
40
60
80
Bankfull Width to Depth Ratio

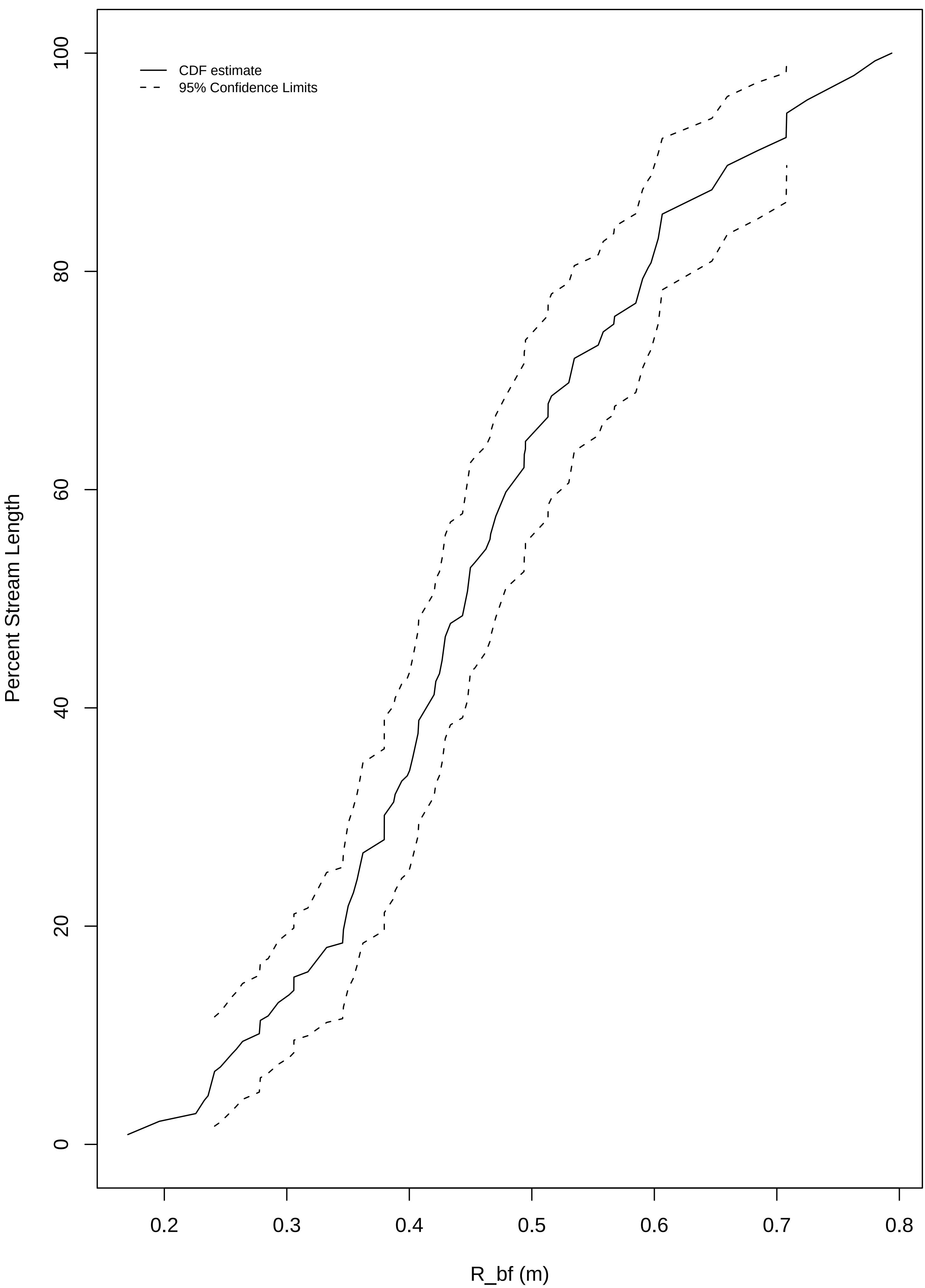

2nd+ Order D_GM (mm) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
50
100
150
200
250
300
D_GM

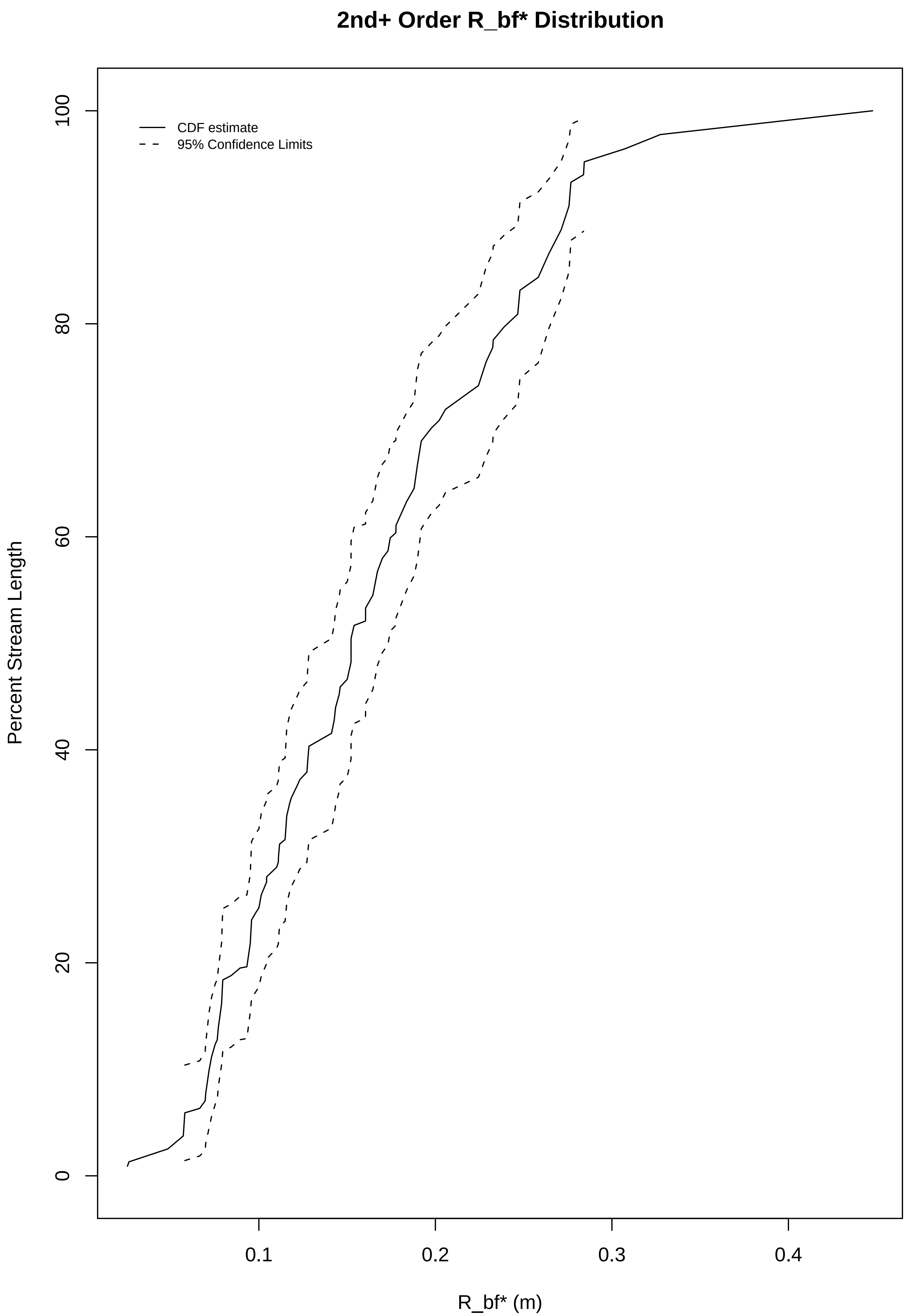

2nd+ Order D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
50
100
150
200
D_GM (mm)

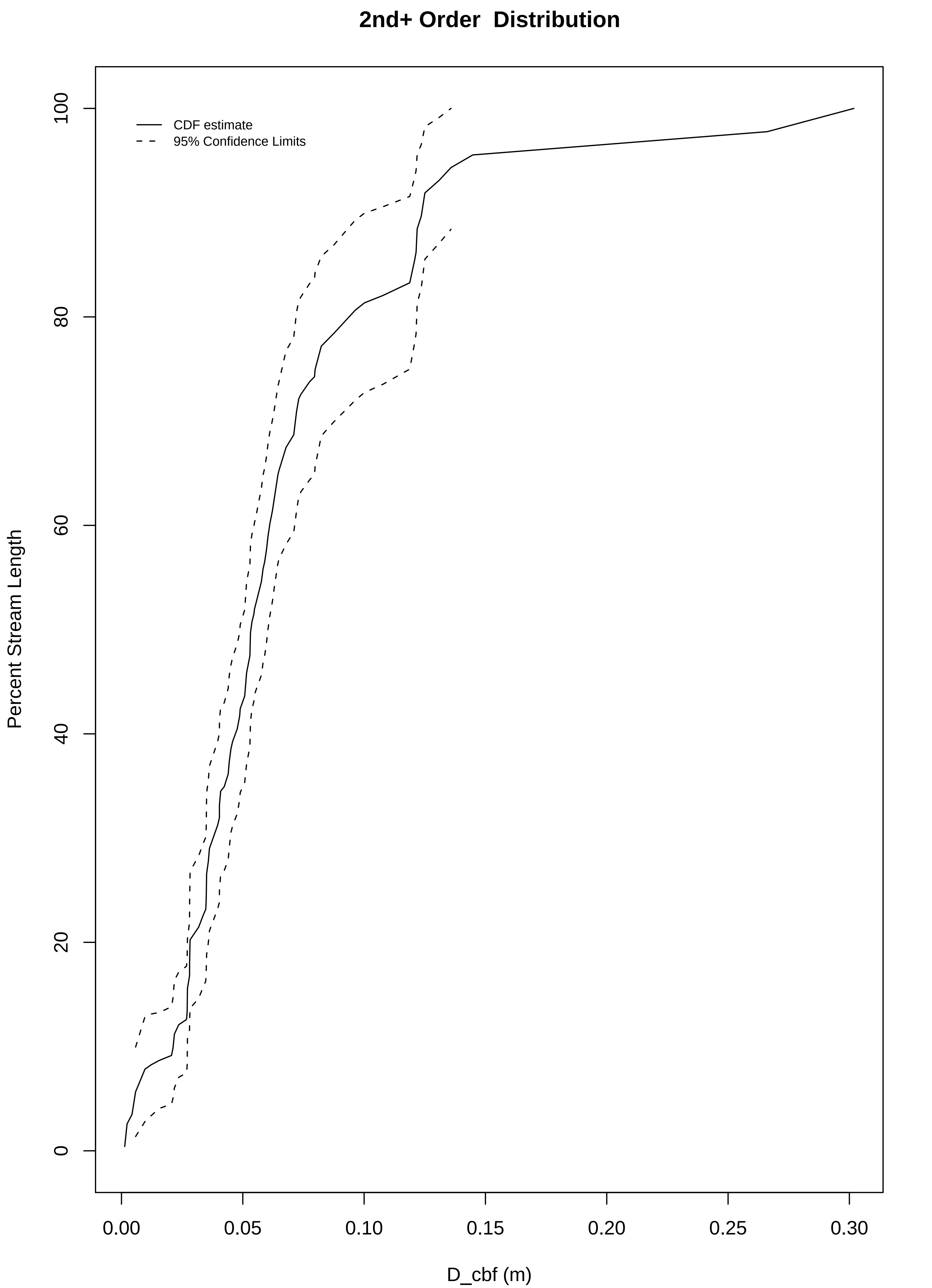
2nd+ Order Slope Distribution

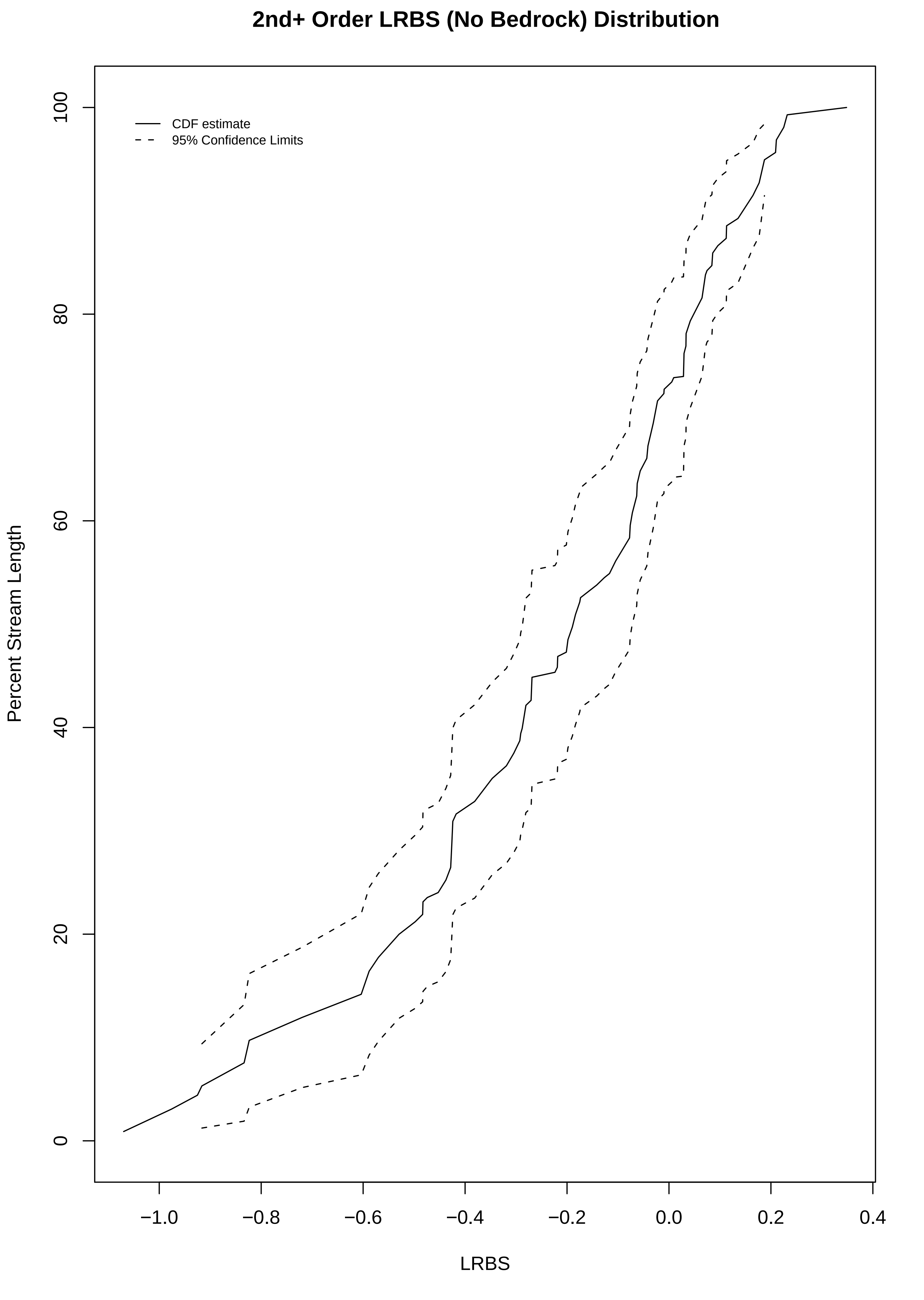


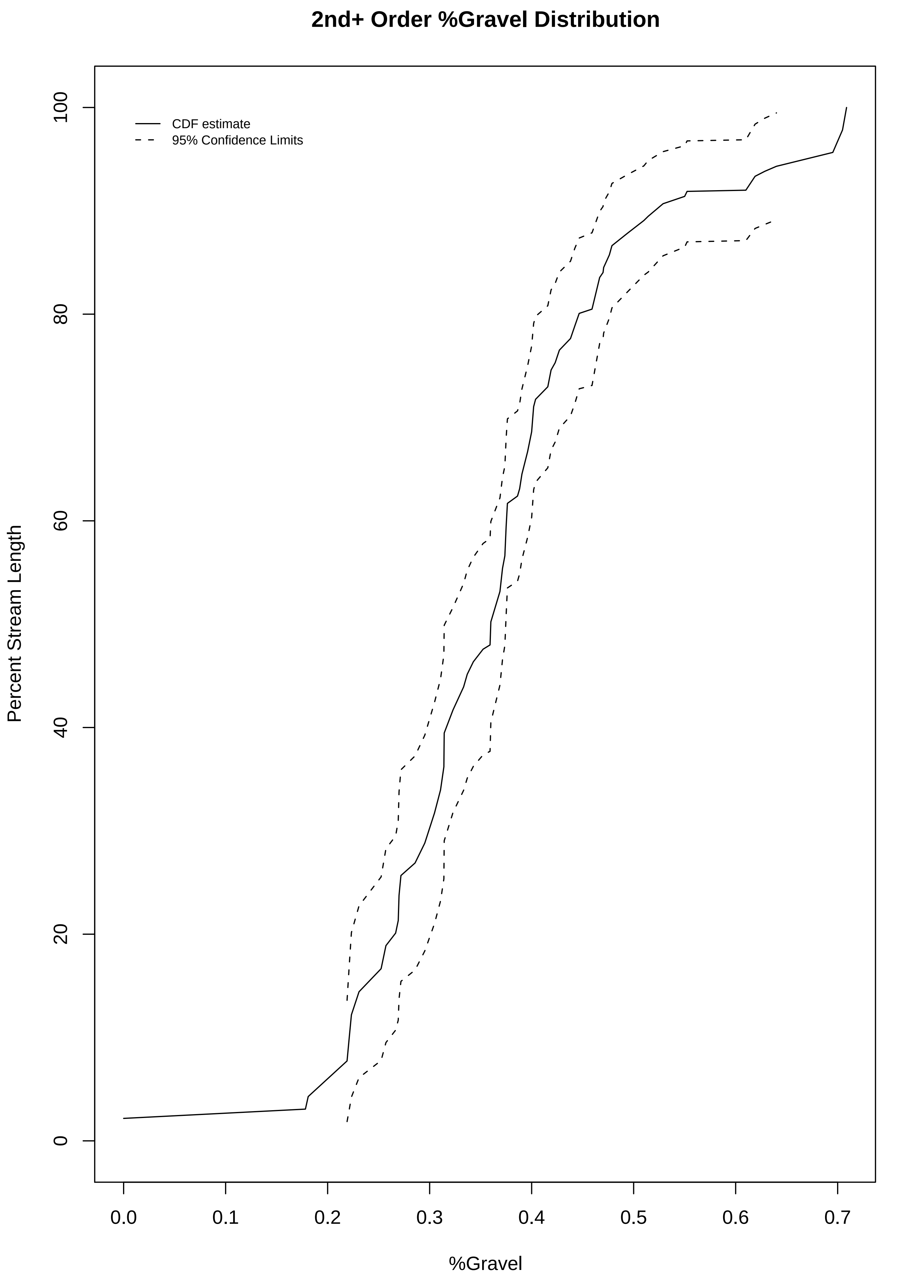
2nd+ Order R_bf Distribution



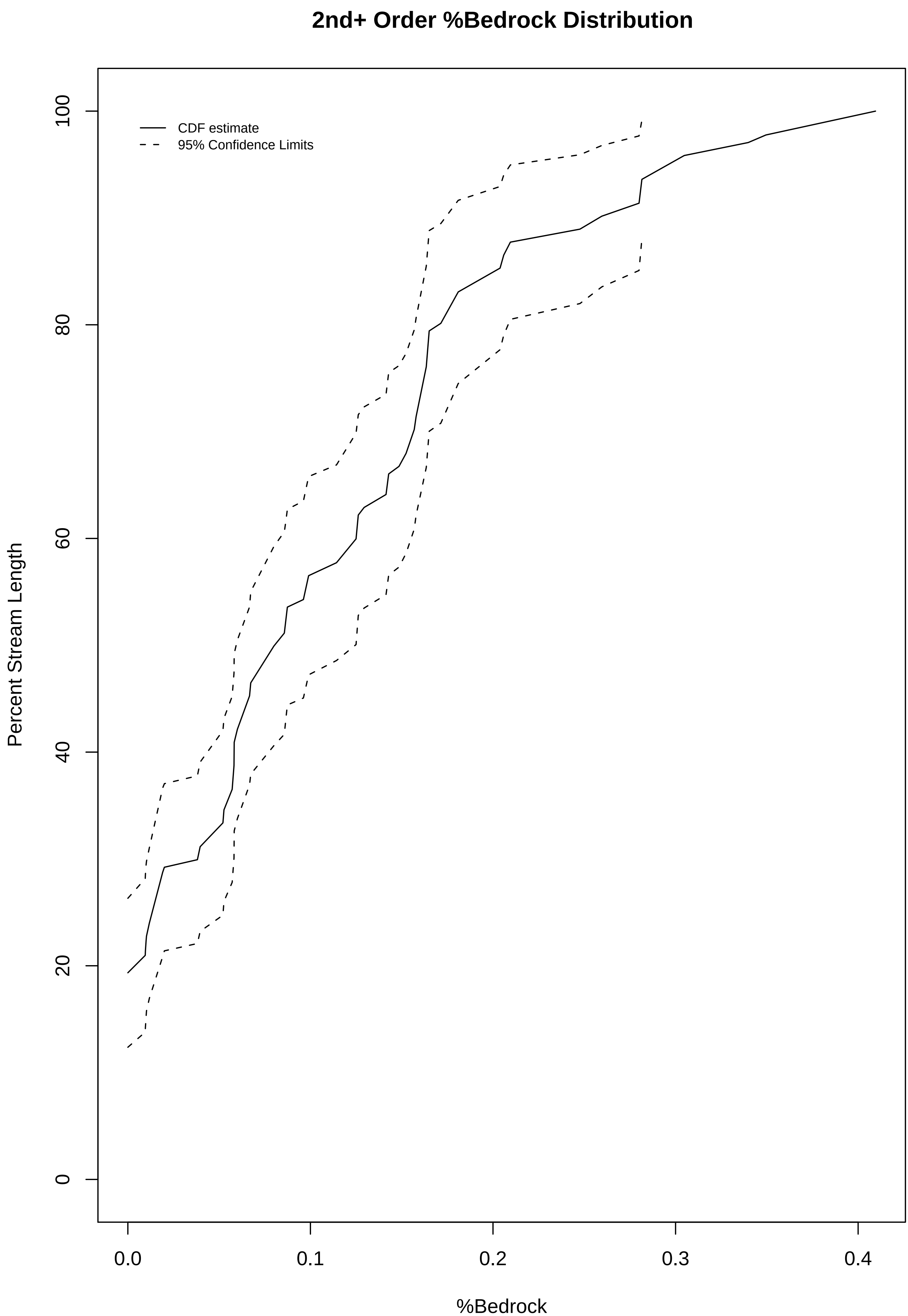

2nd+ Order R_bf* Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
R_bf* (m)

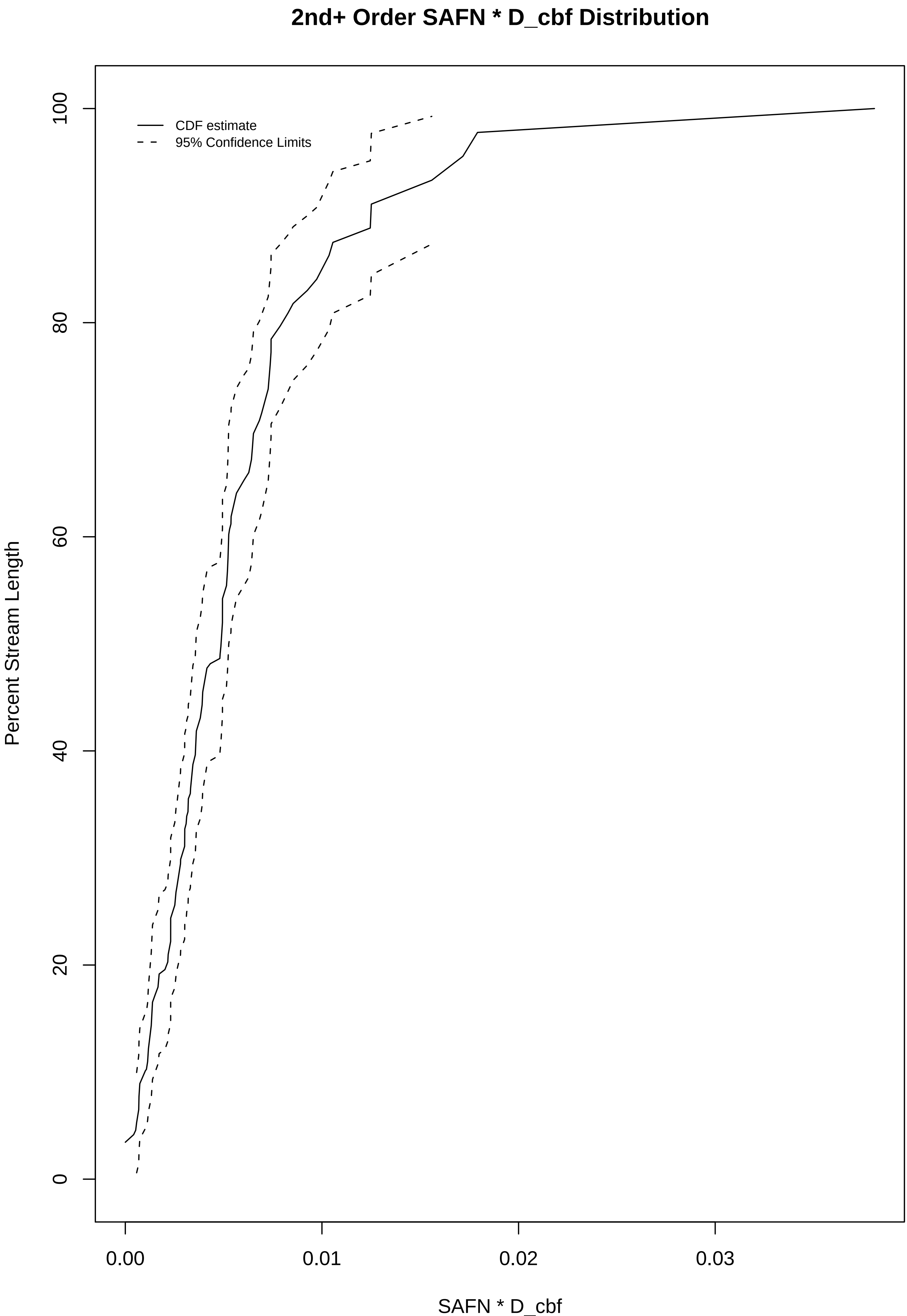

2nd+ Order Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
D_cbf (m)

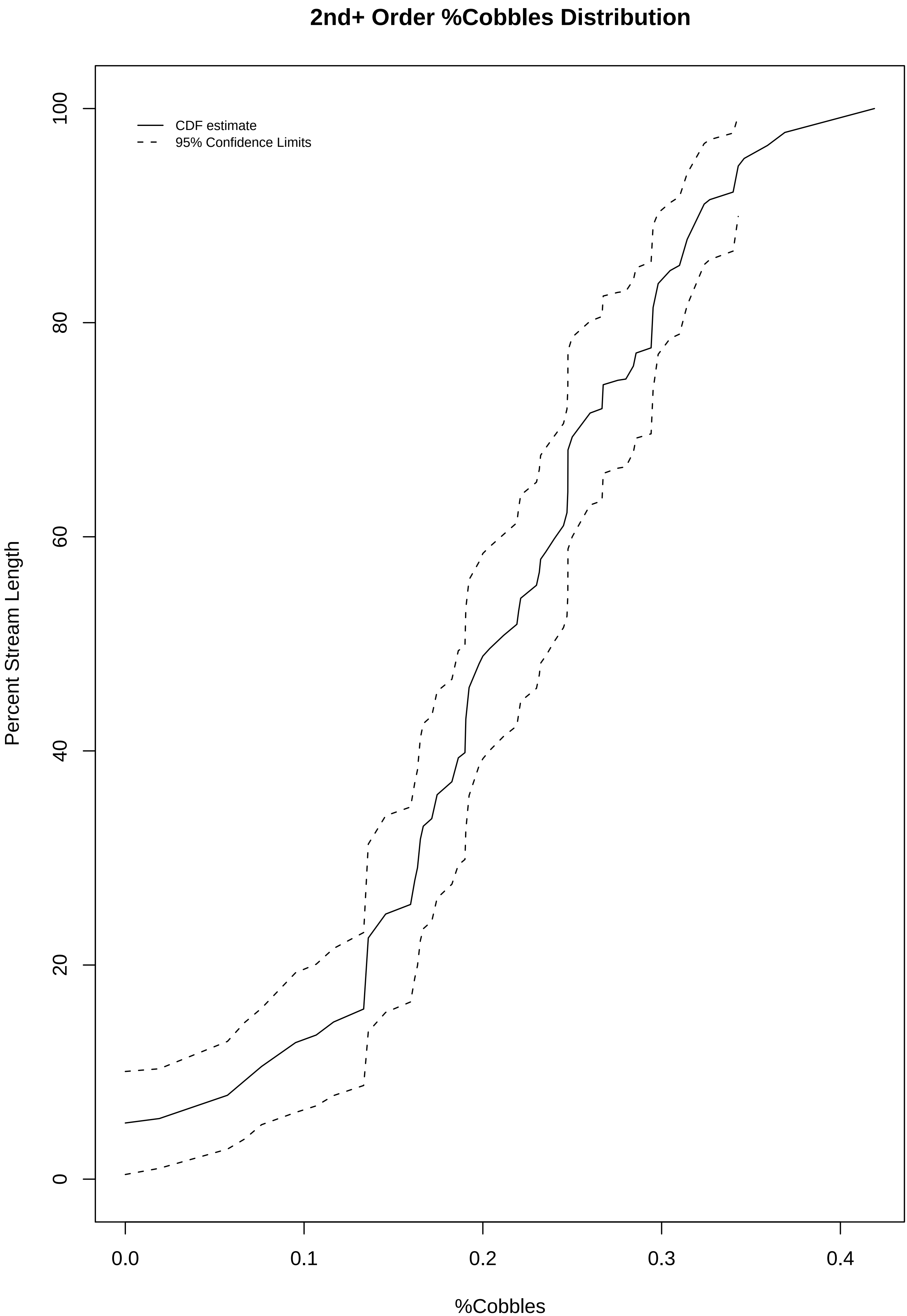

2nd+ Order LRBS (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−1.0
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
LRBS



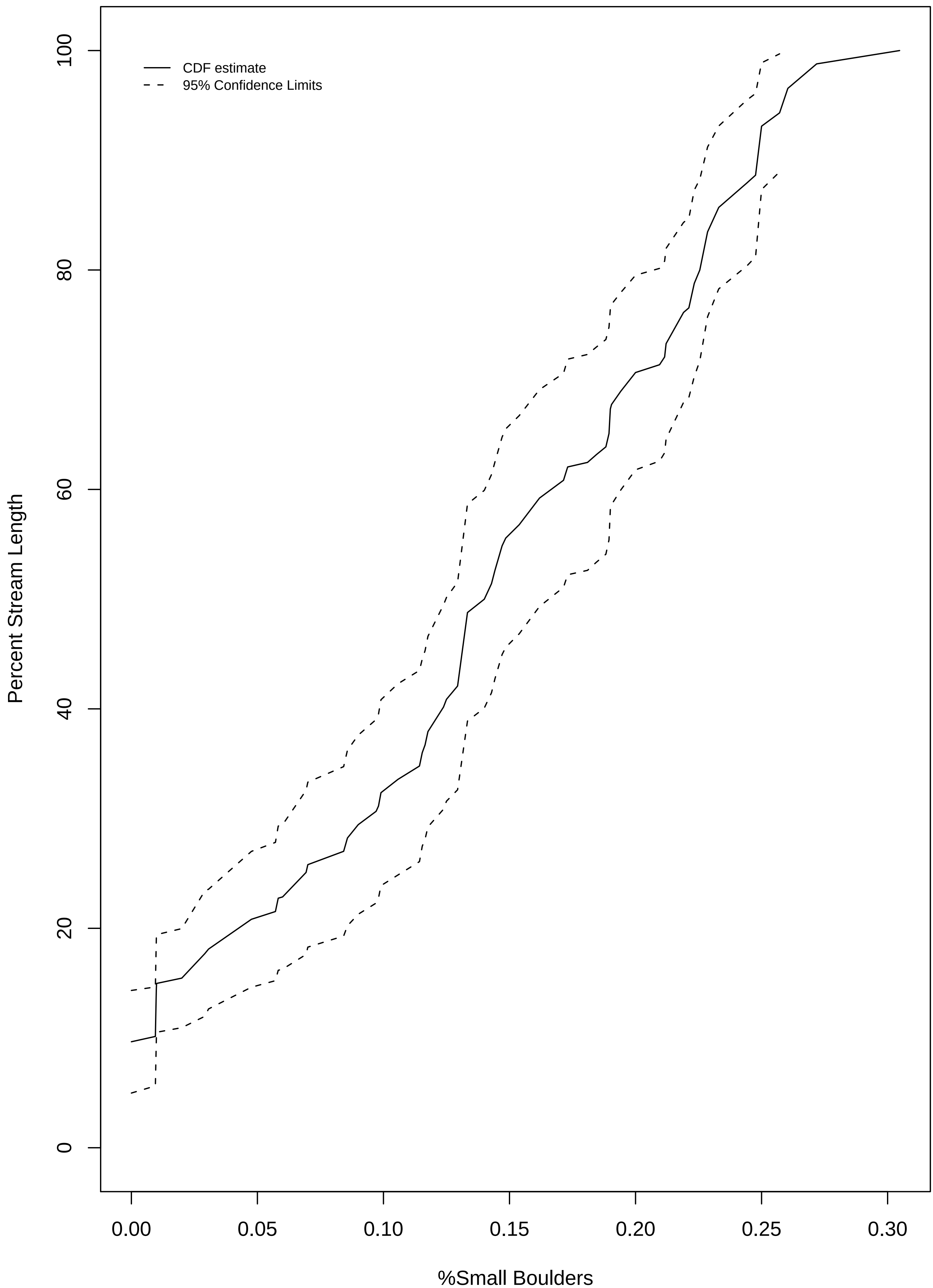
2nd+ Order %Gravel Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
%Gravel
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

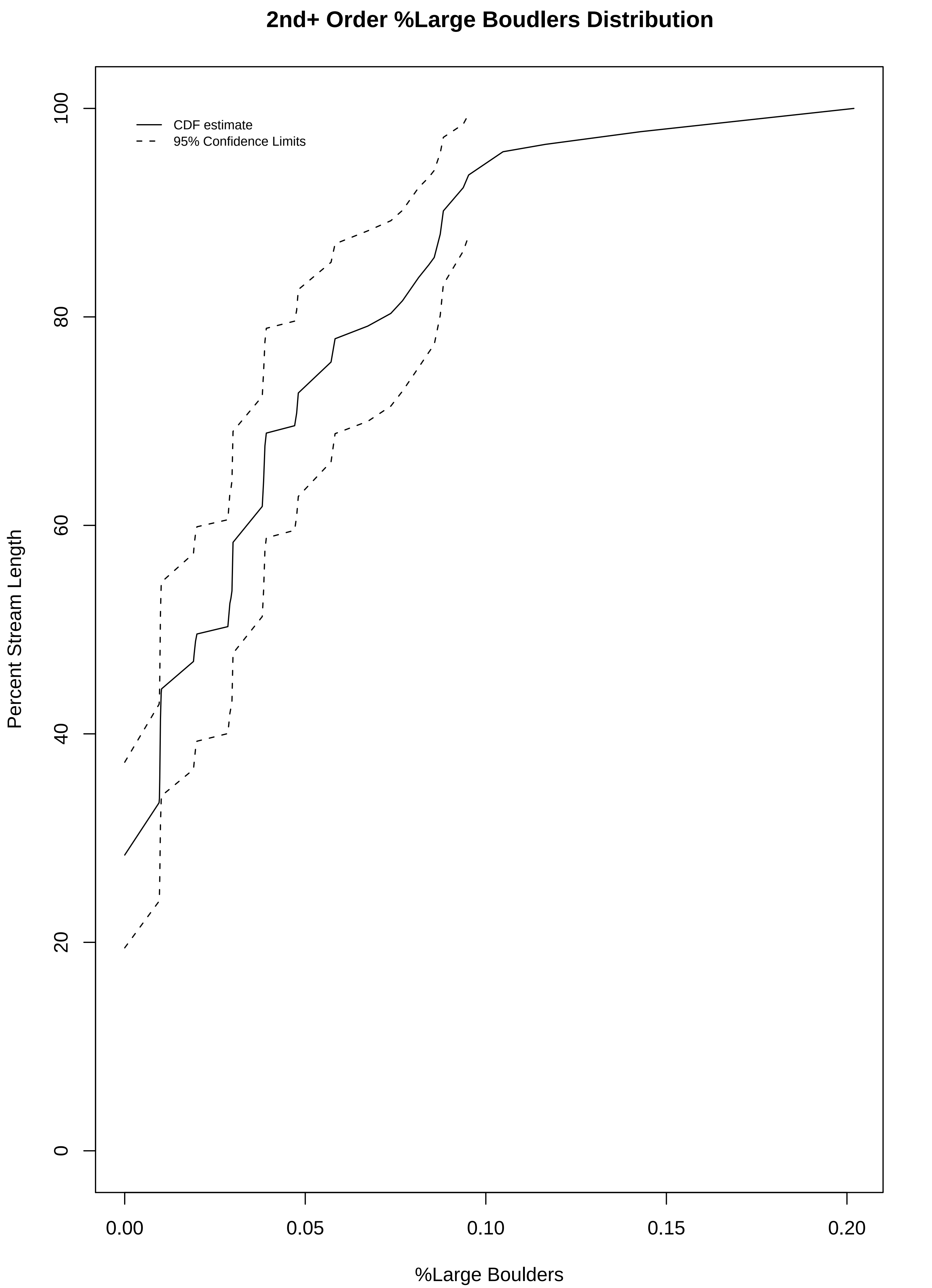

2nd+ Order %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
%Bedrock


2nd+ Order SAFN * D_cbf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.01
0.02
0.03
SAFN * D_cbf

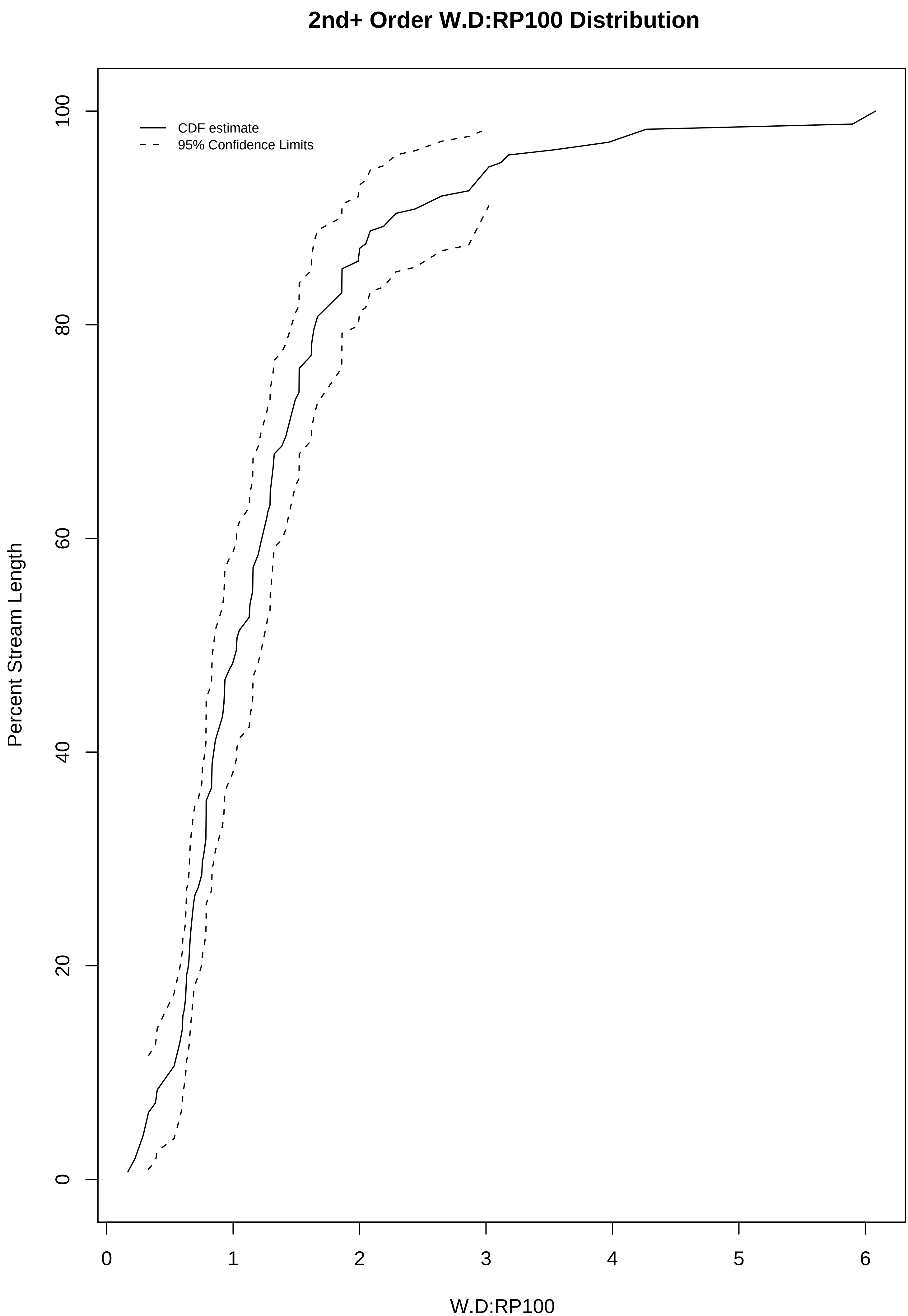

2nd+ Order %Cobbles Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
%Cobbles

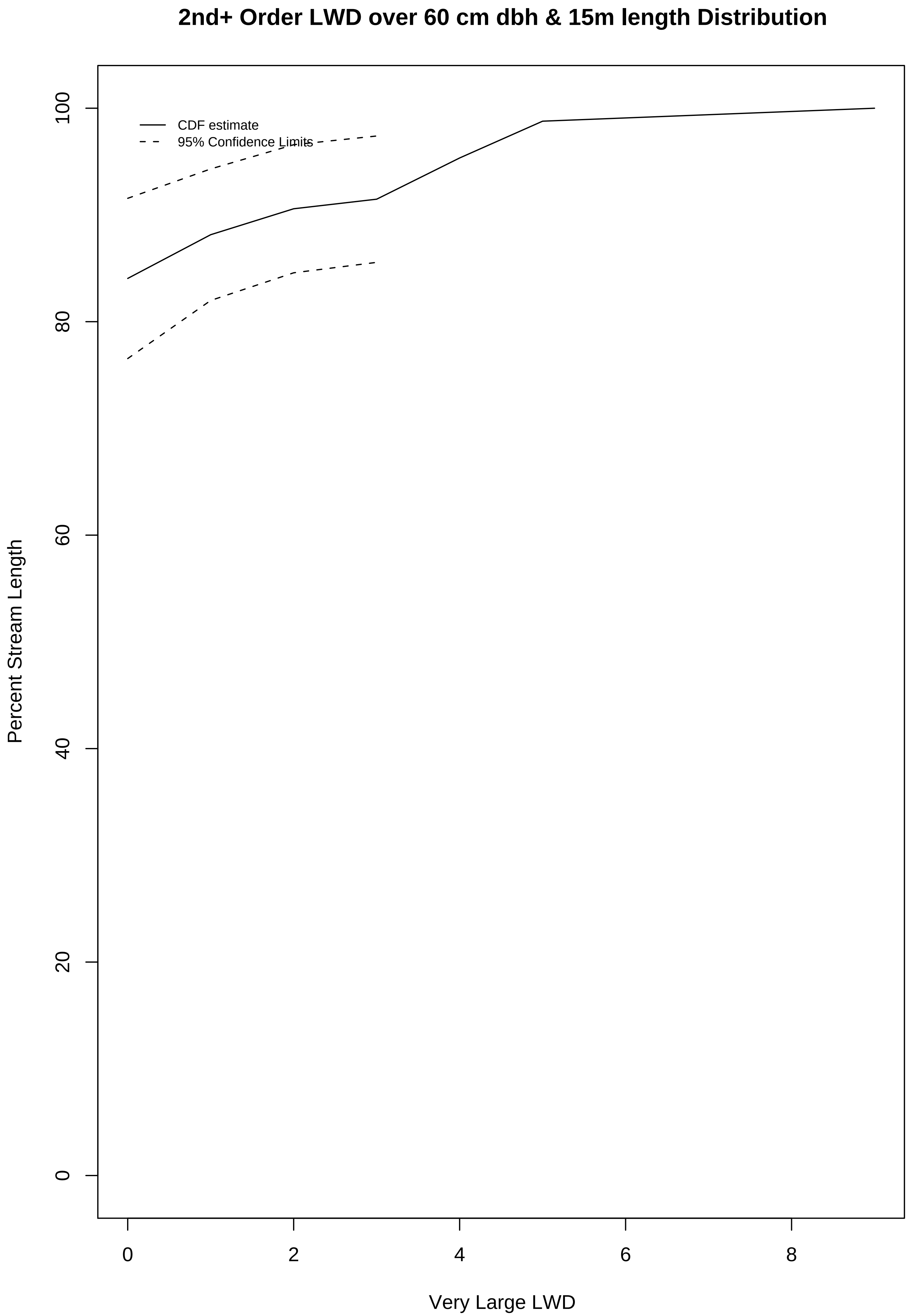
2nd+ Order %Small Boulders Distribution



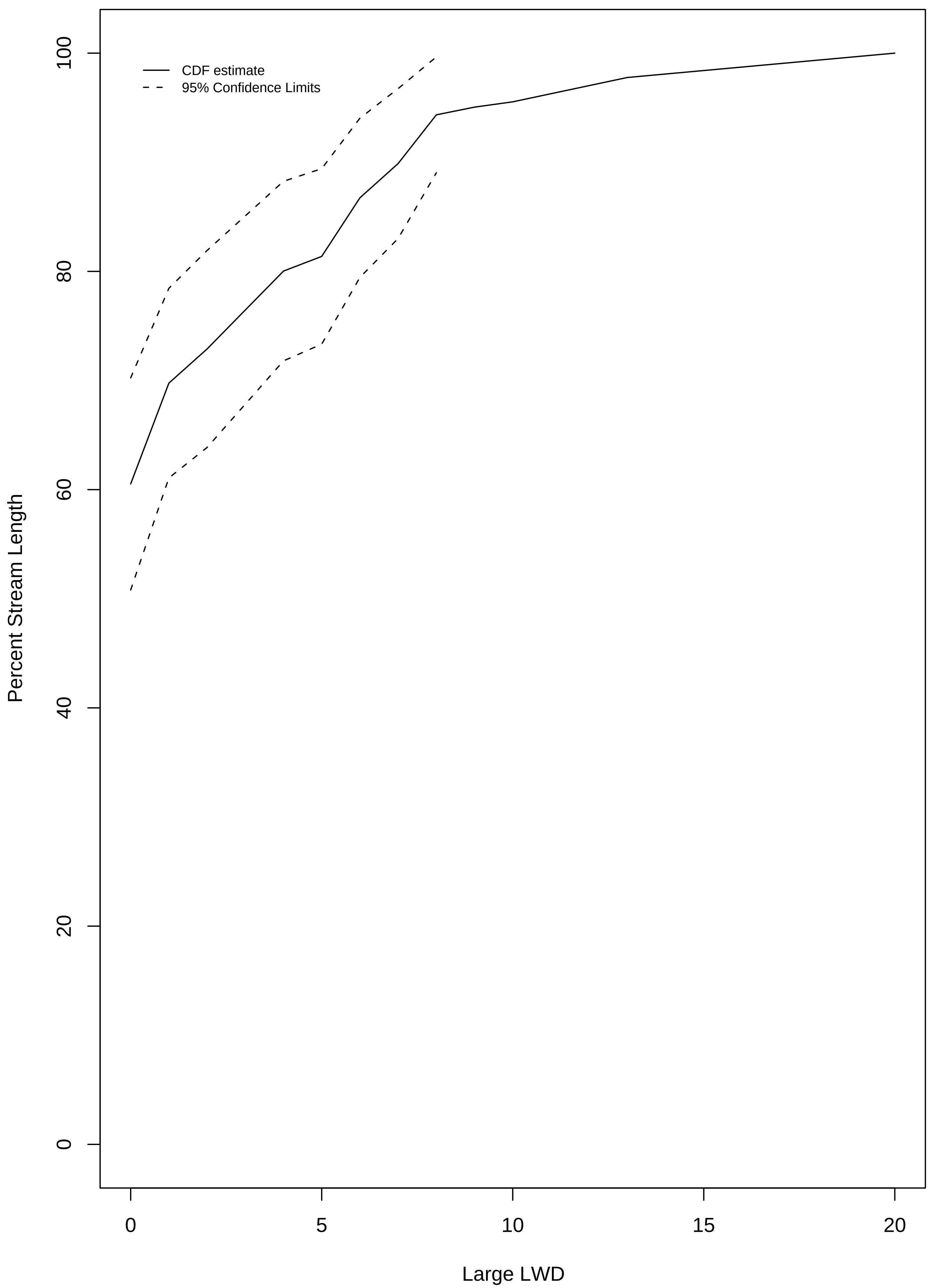


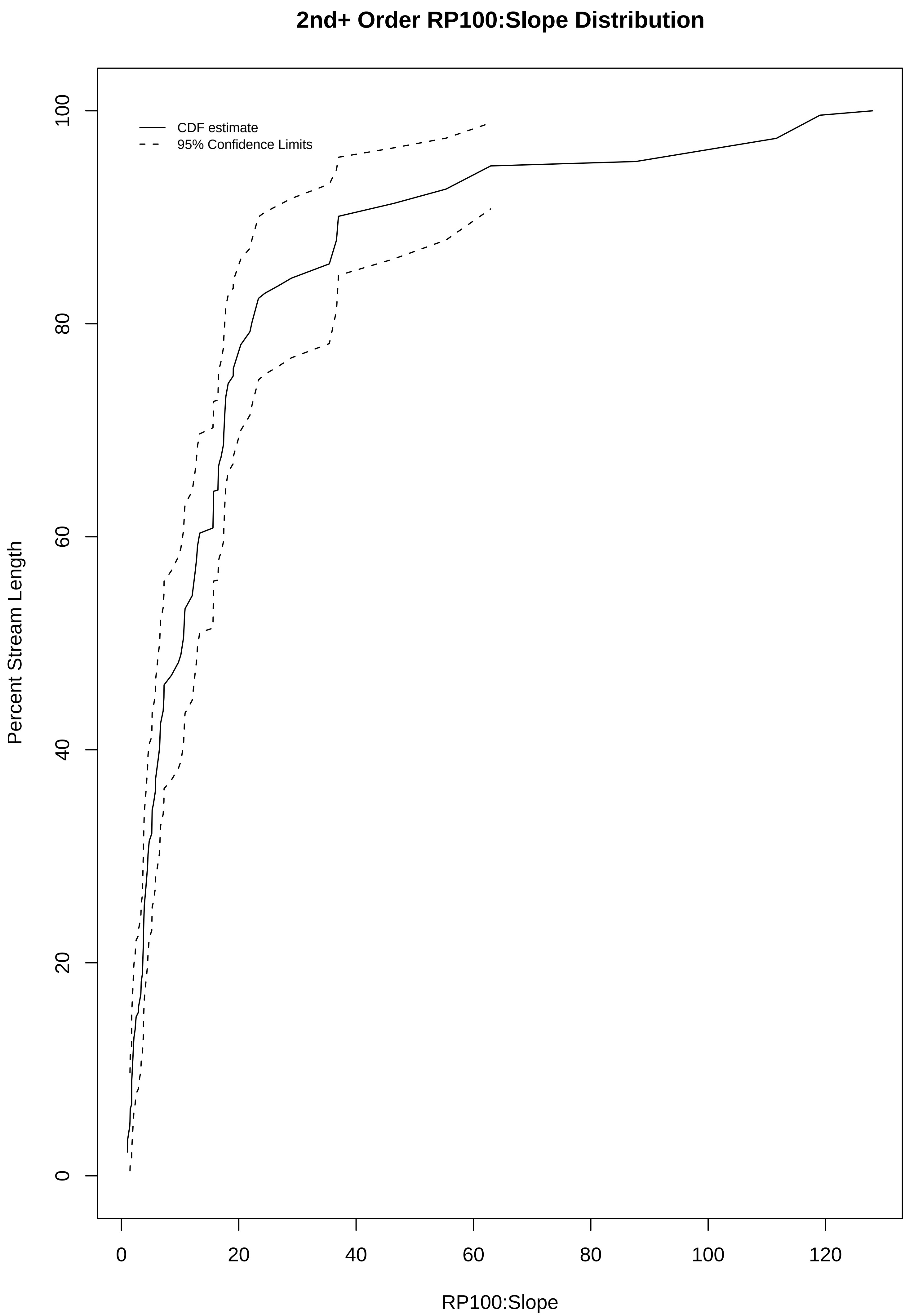
2nd+ Order %Large Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
%Large Boulders

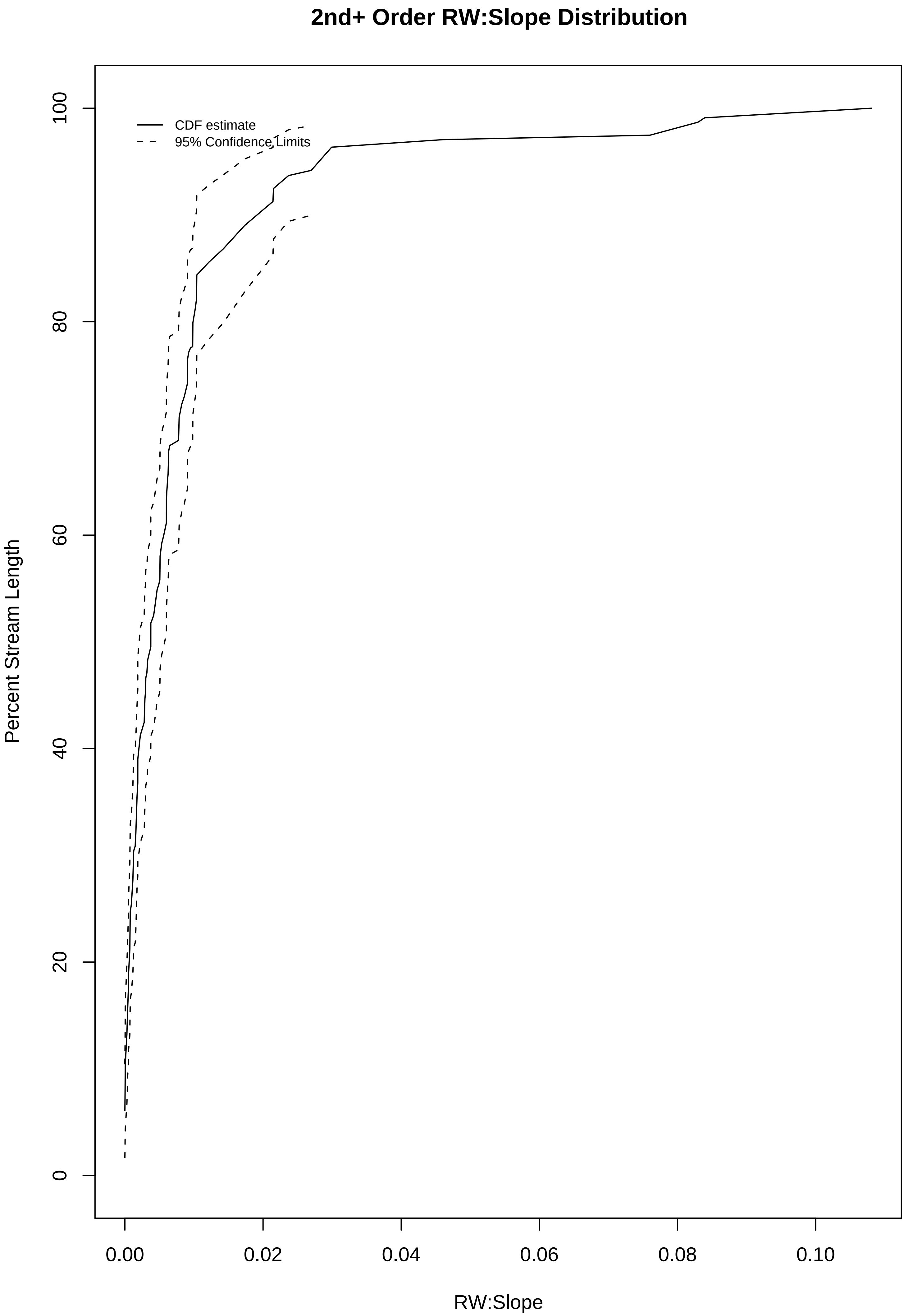

2nd+ Order W.D:RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
1
2
3
4
5
6
W.D:RP100

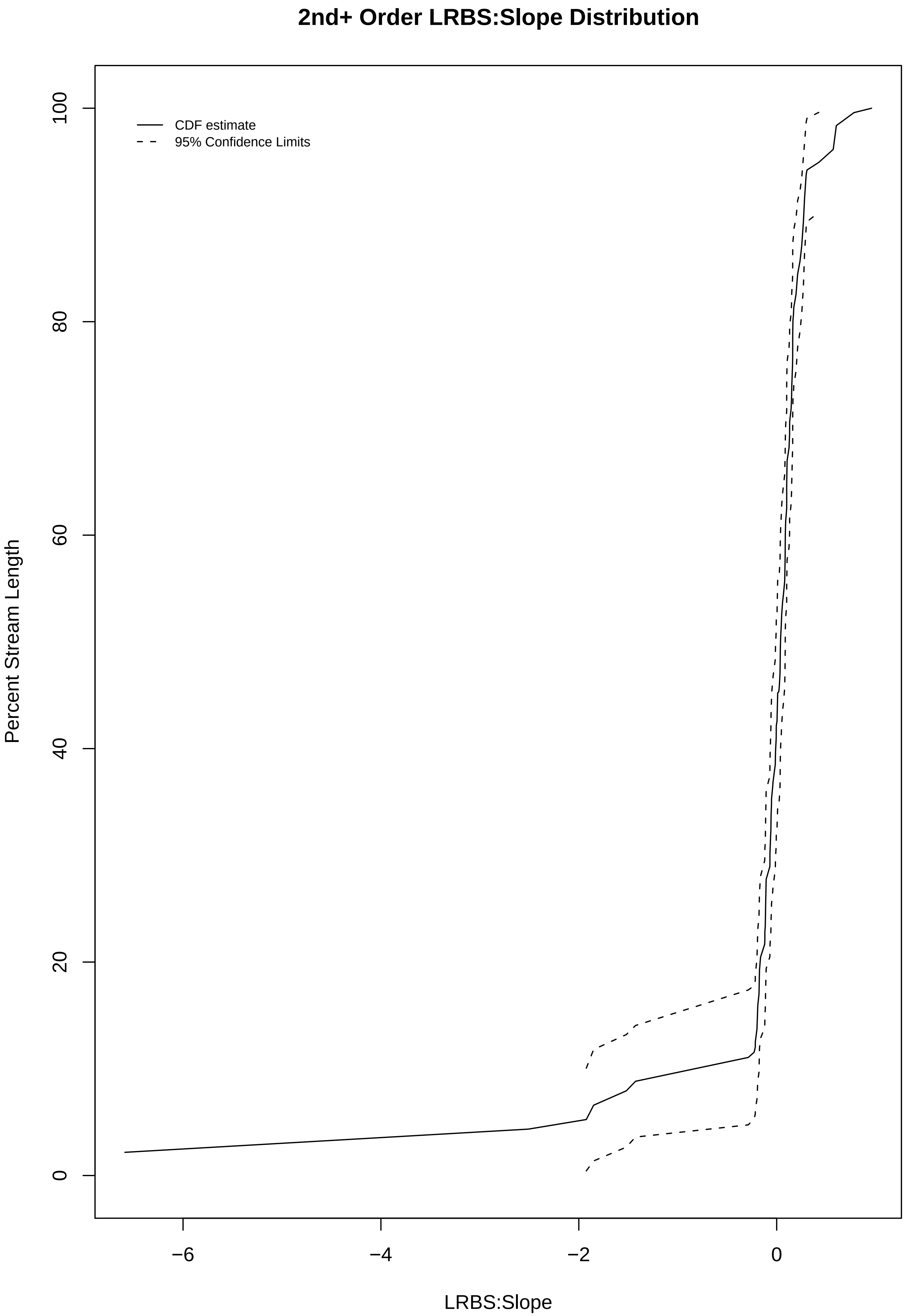

2nd+ Order LWD over 60 cm dbh & 15m length Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
2
4
6
8
Very Large LWD

2nd+ Order 2nd+ Order LWD over 60 cm dbh Distribution

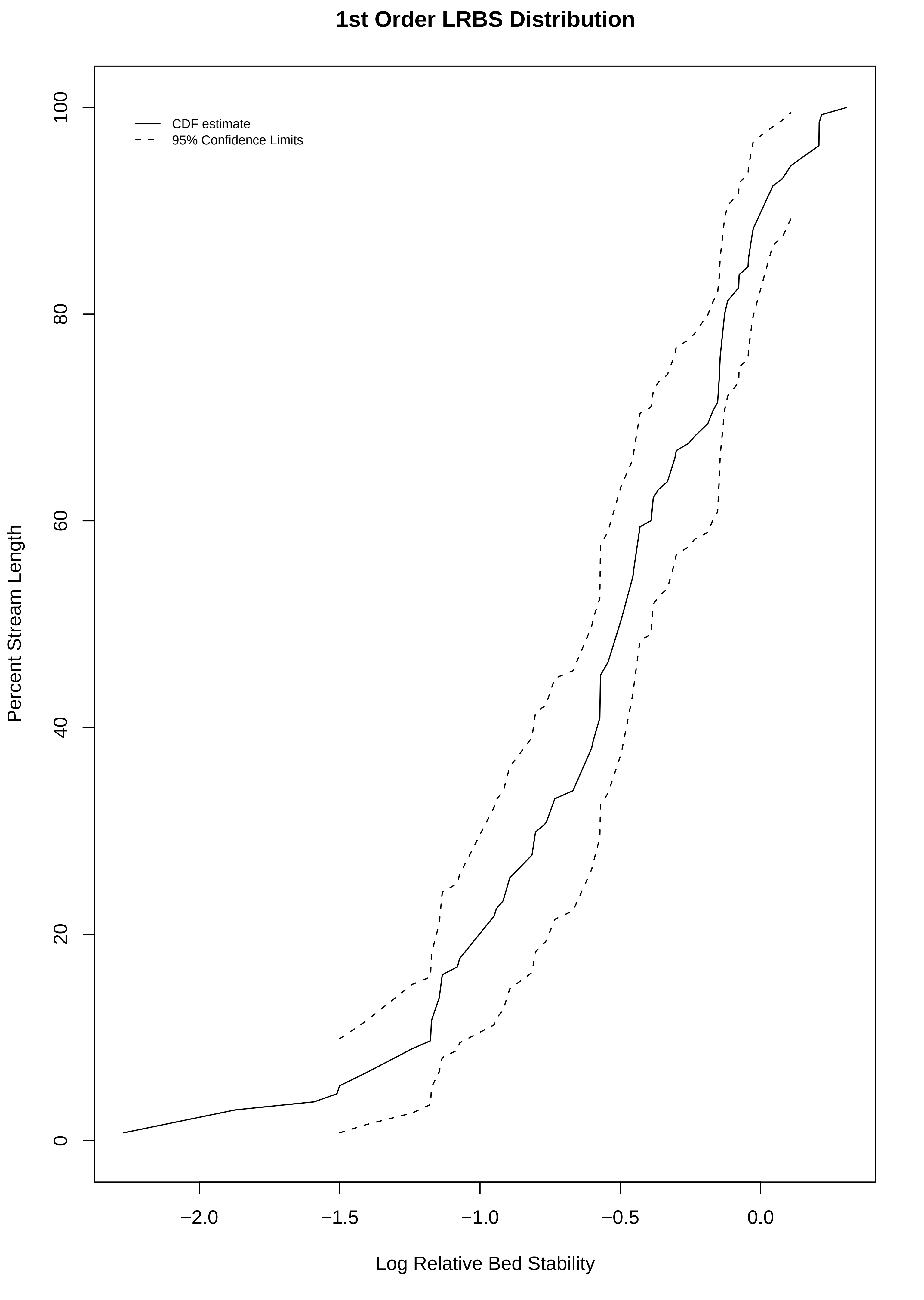



2nd+ Order RP100:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
RP100:Slope
0
20
40
60
80
100
120

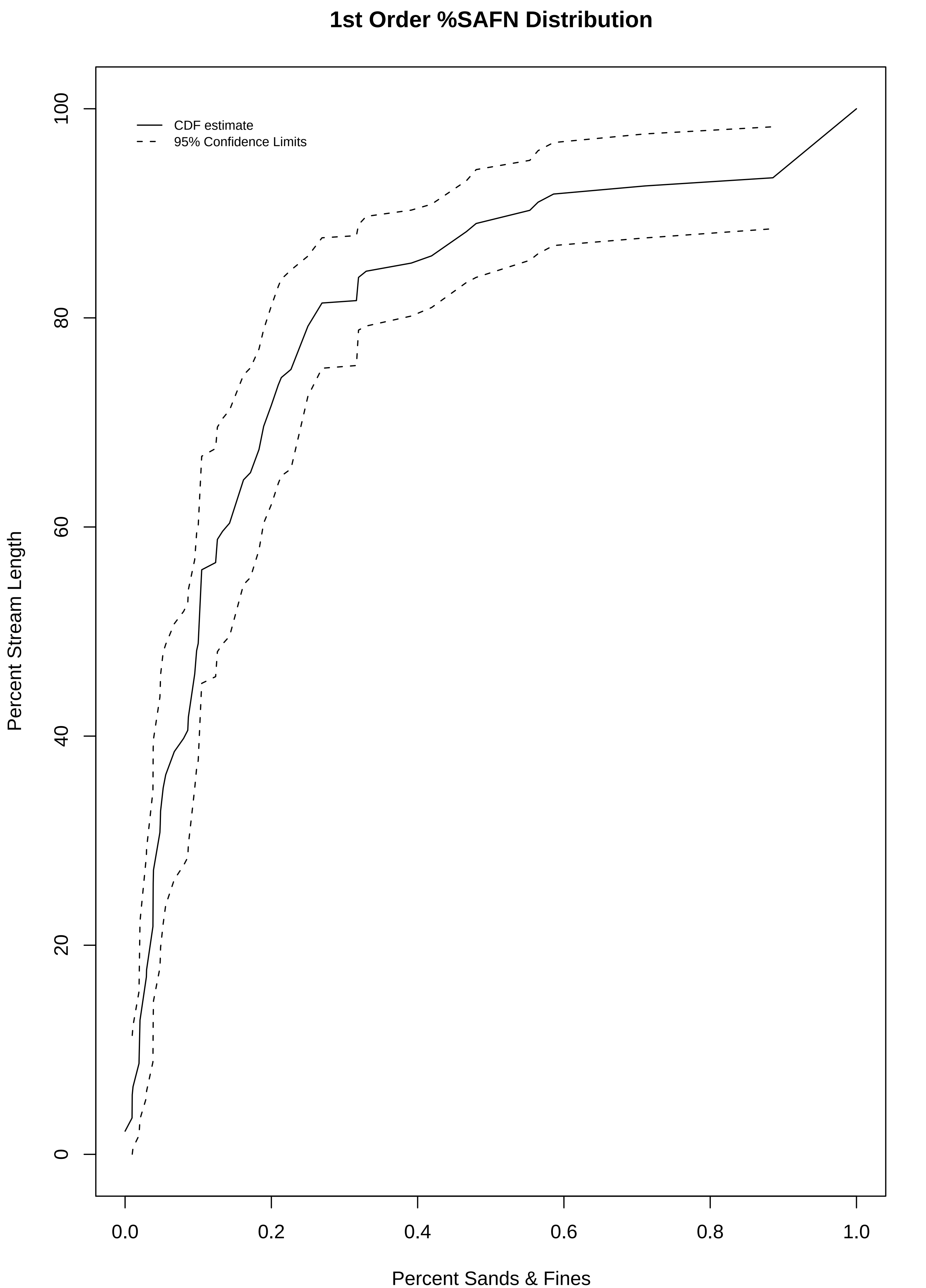

2nd+ Order RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.02
0.04
0.06
0.08
0.10
RW:Slope

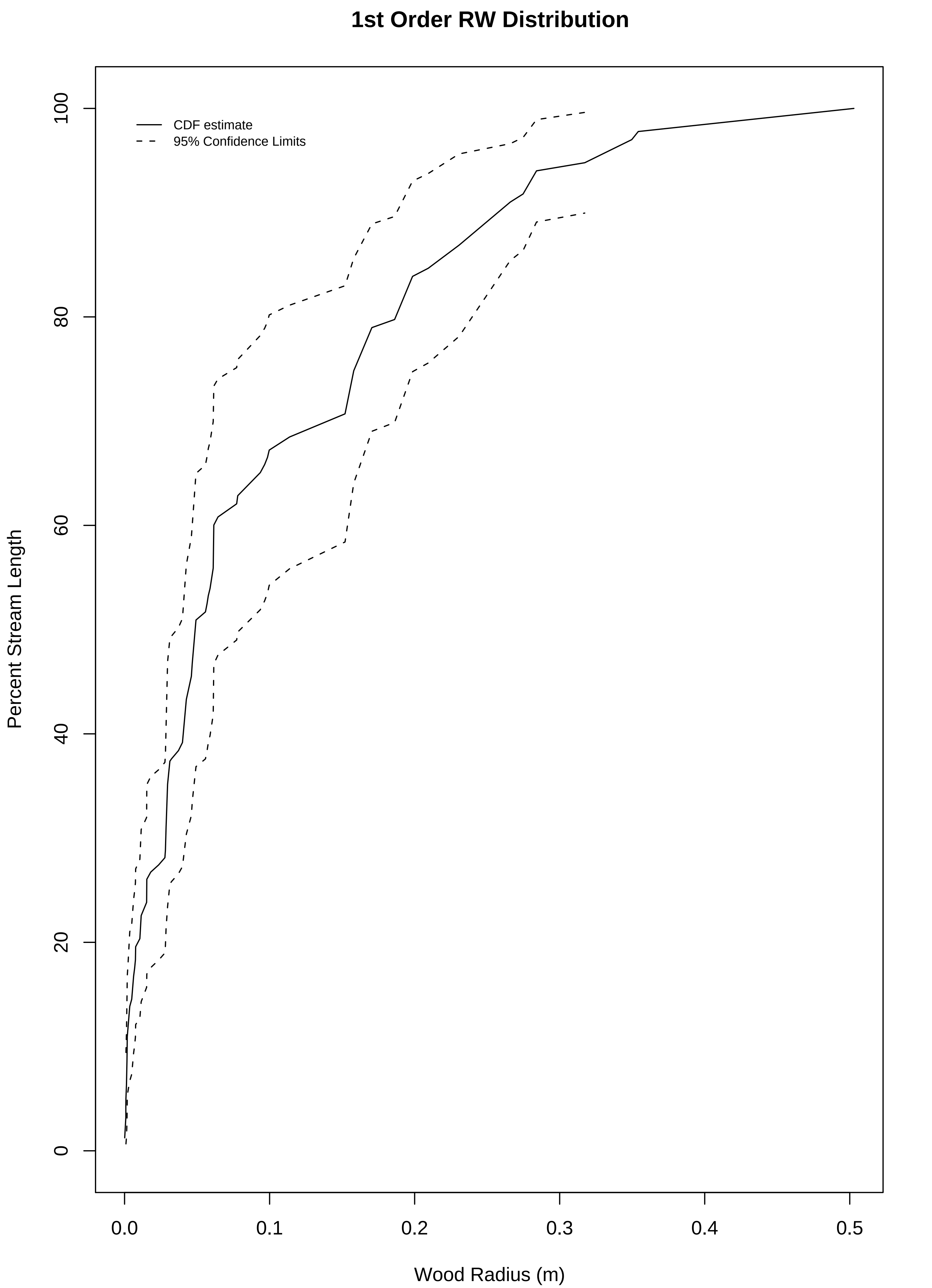


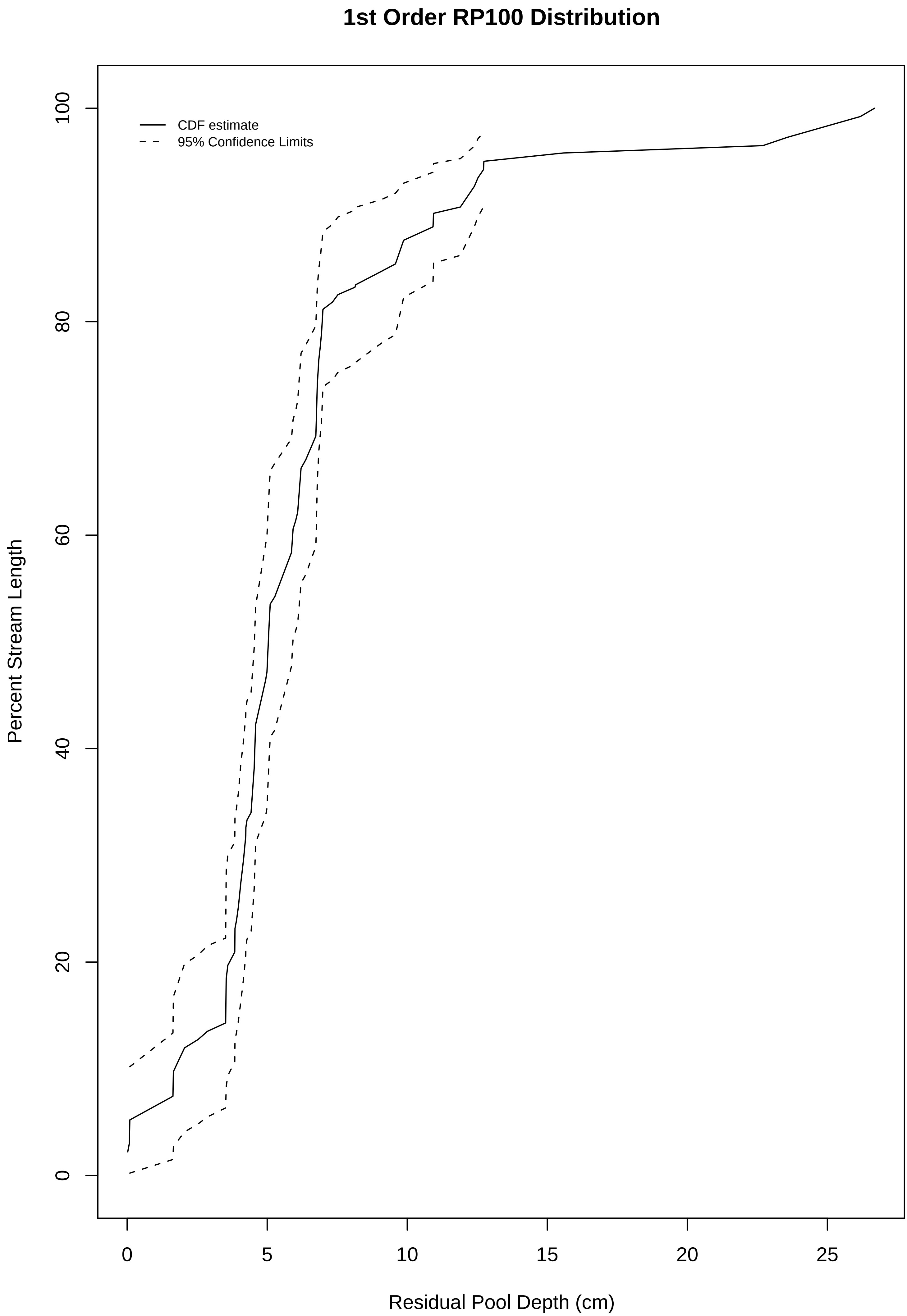
2nd+ Order LRBS:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−6
−4
−2
0
LRBS:Slope

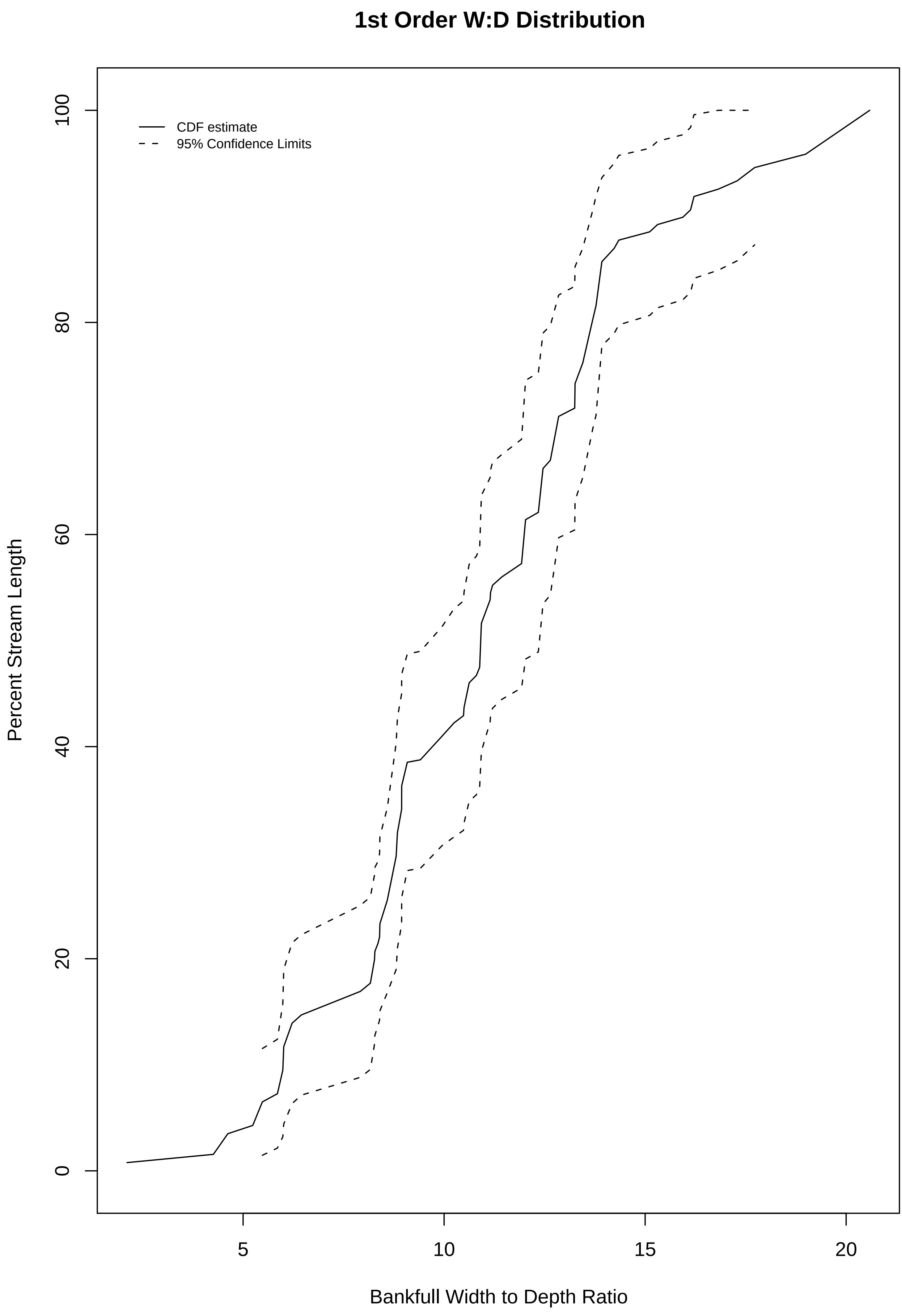


1st Order LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−2.0
−1.5
−1.0
−0.5
0.0
Log Relative Bed Stability

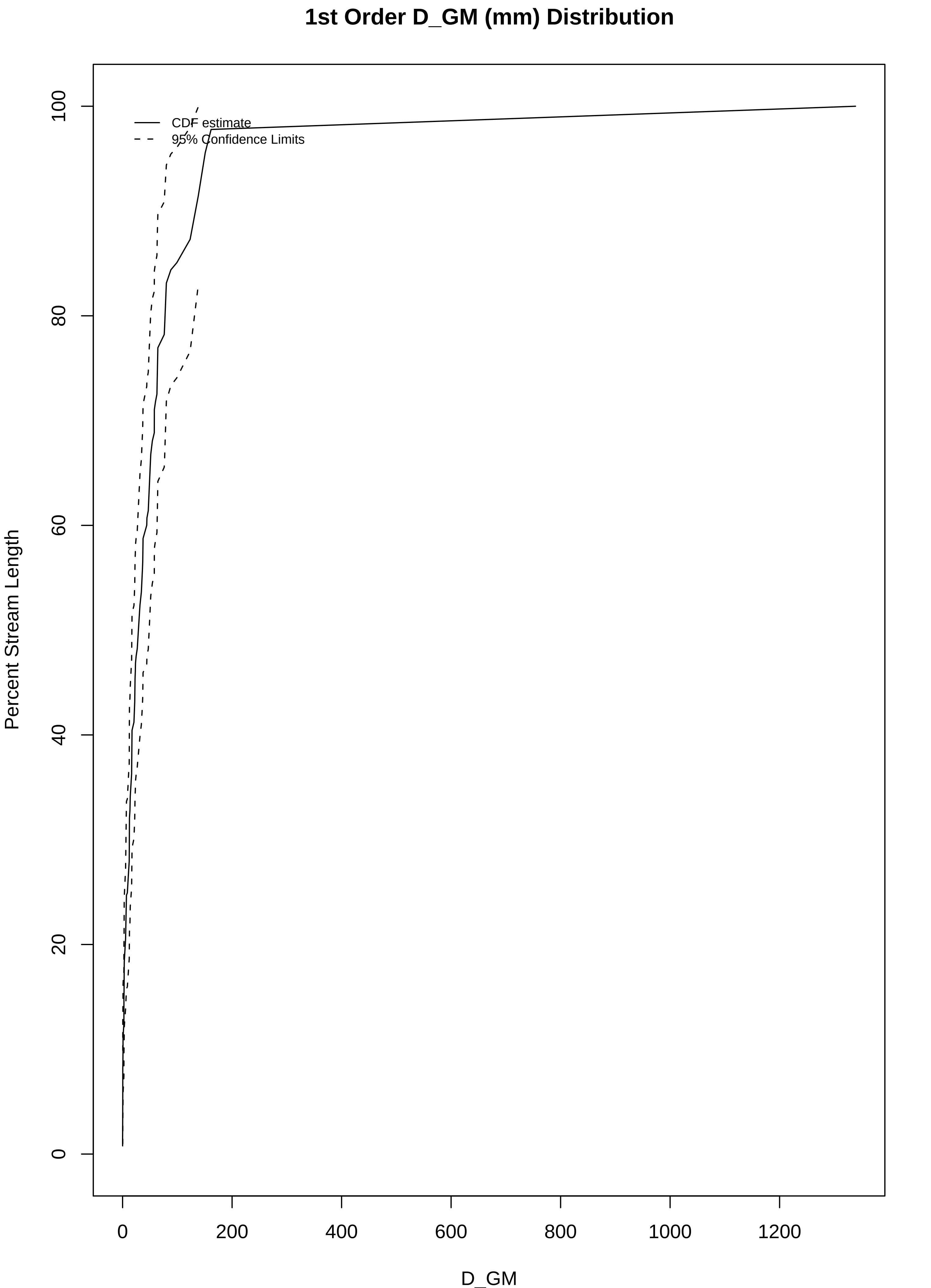

1st Order %SAFN Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
Percent Sands & Fines
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0

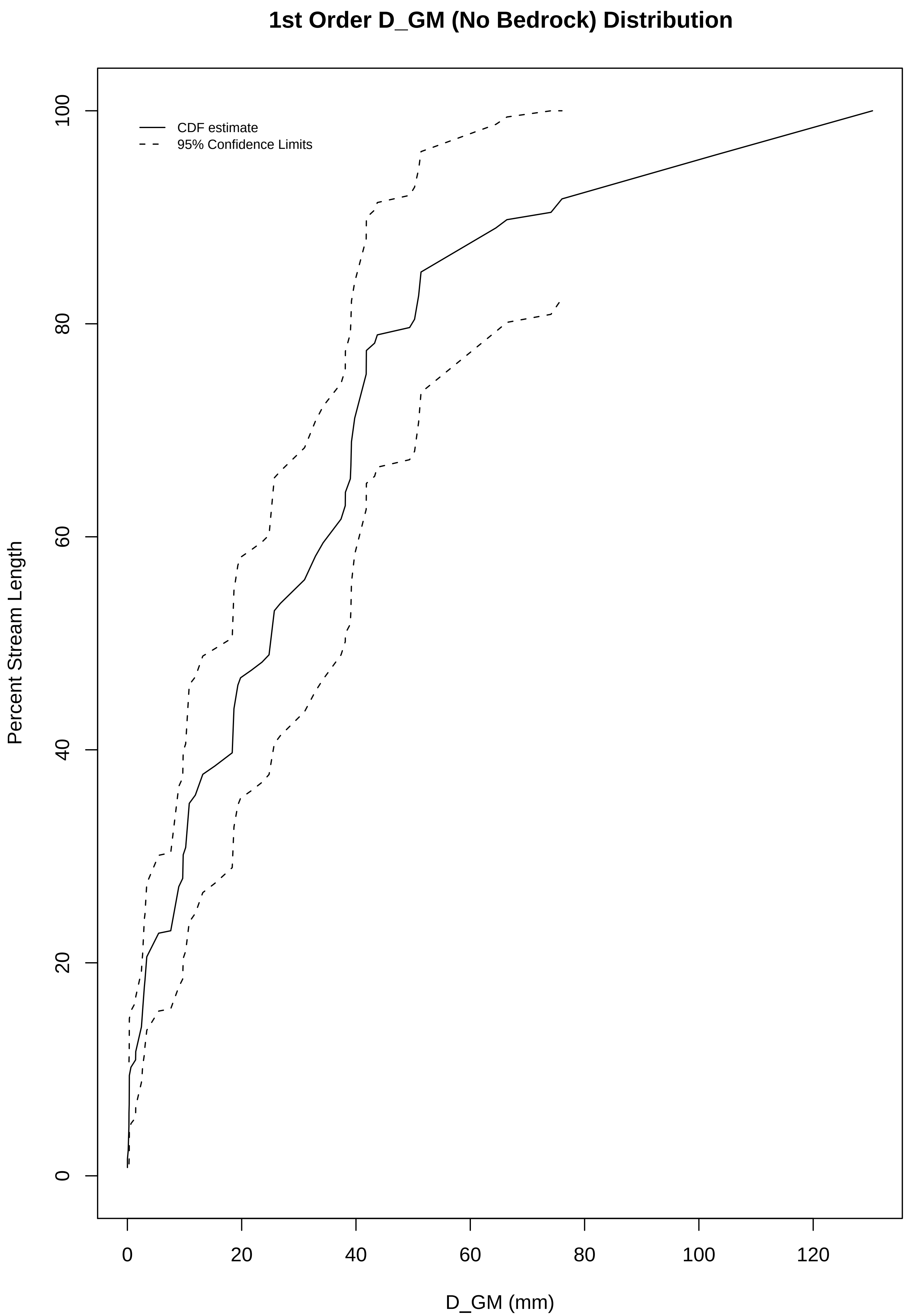

1st Order RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
Wood Radius (m)
0.0
0.1
0.2
0.3
0.4
0.5


1st Order RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
5
10
15
20
25
Residual Pool Depth (cm)

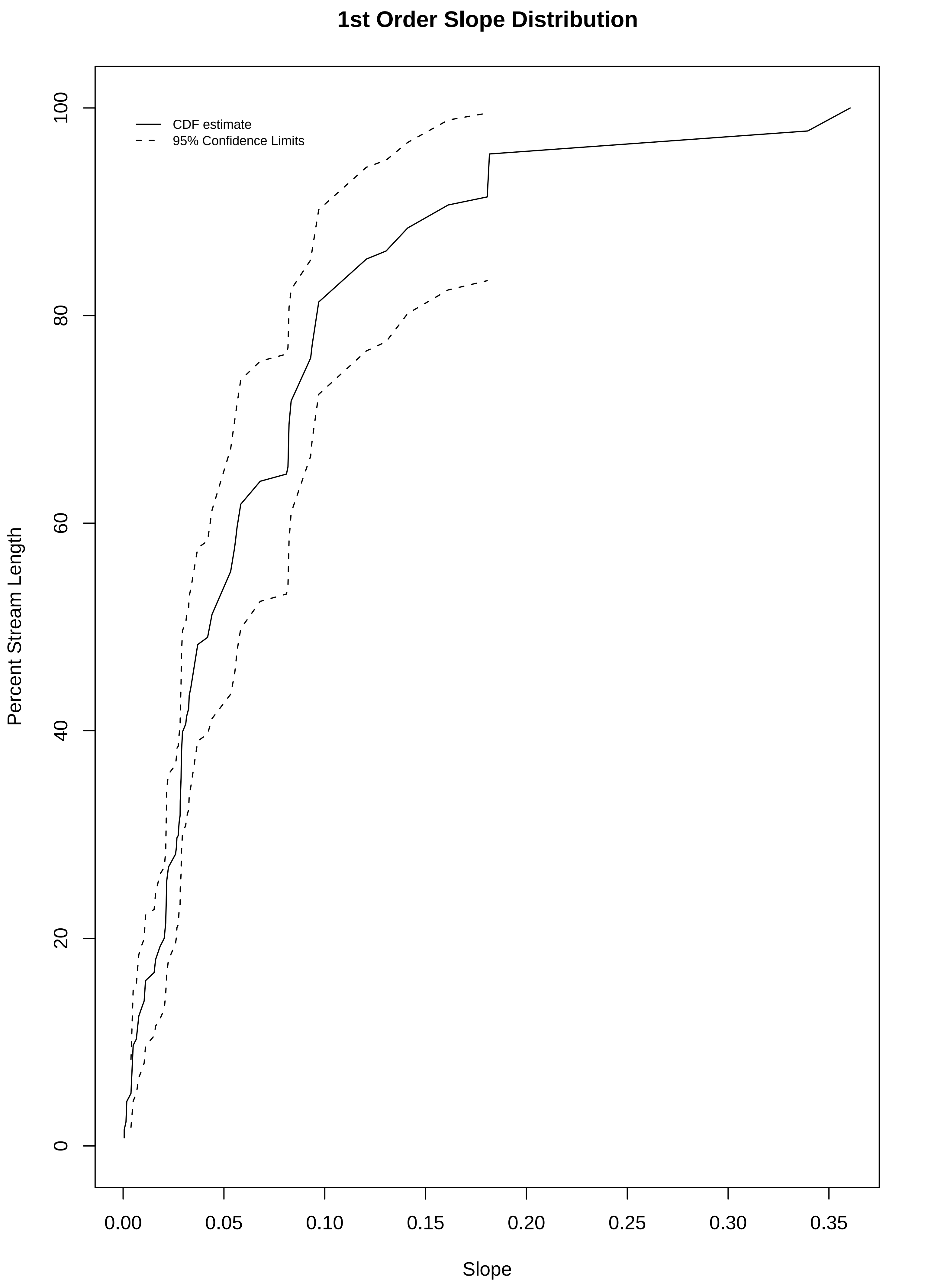


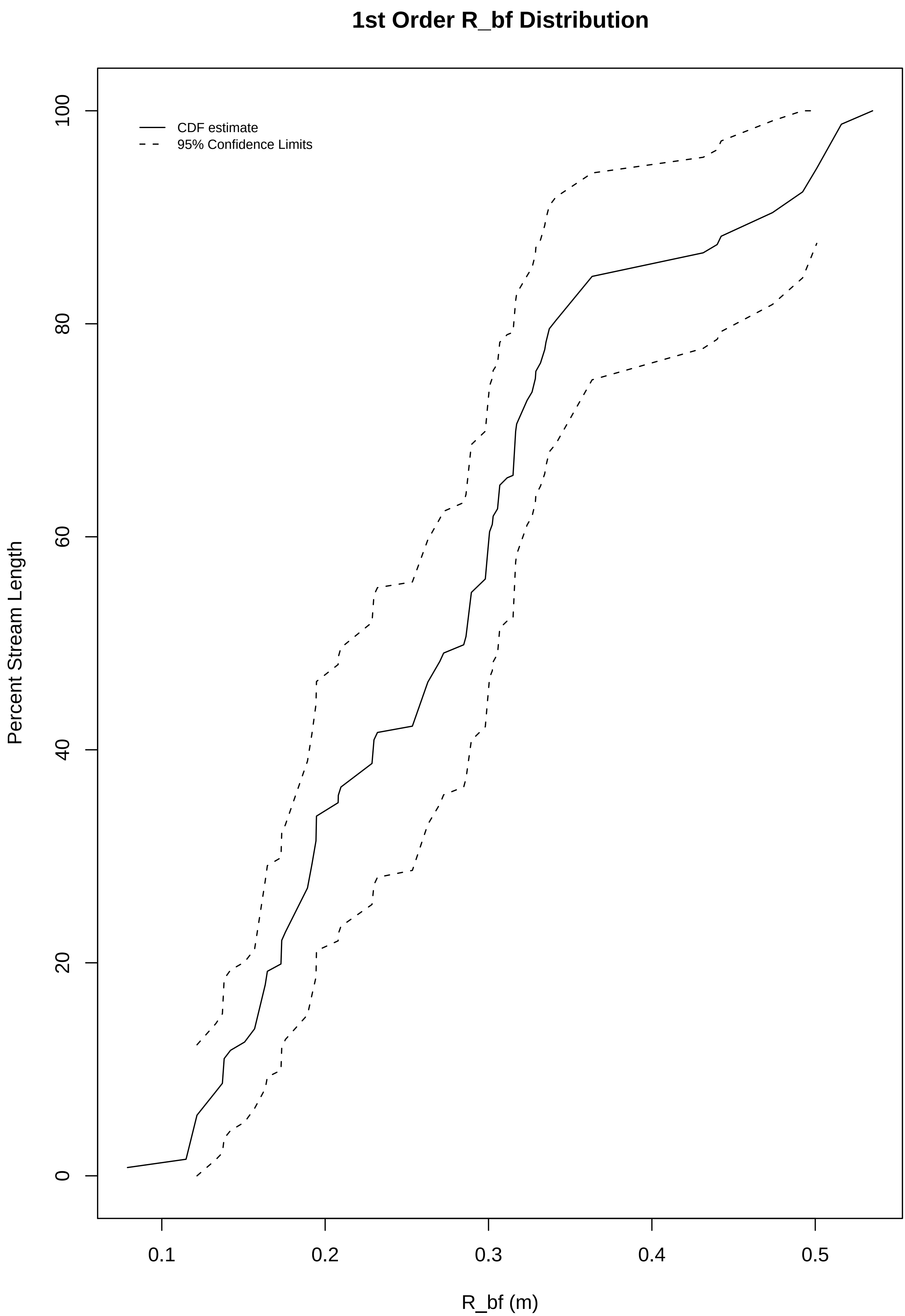
1st Order W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
5
10
15
20
Bankfull Width to Depth Ratio

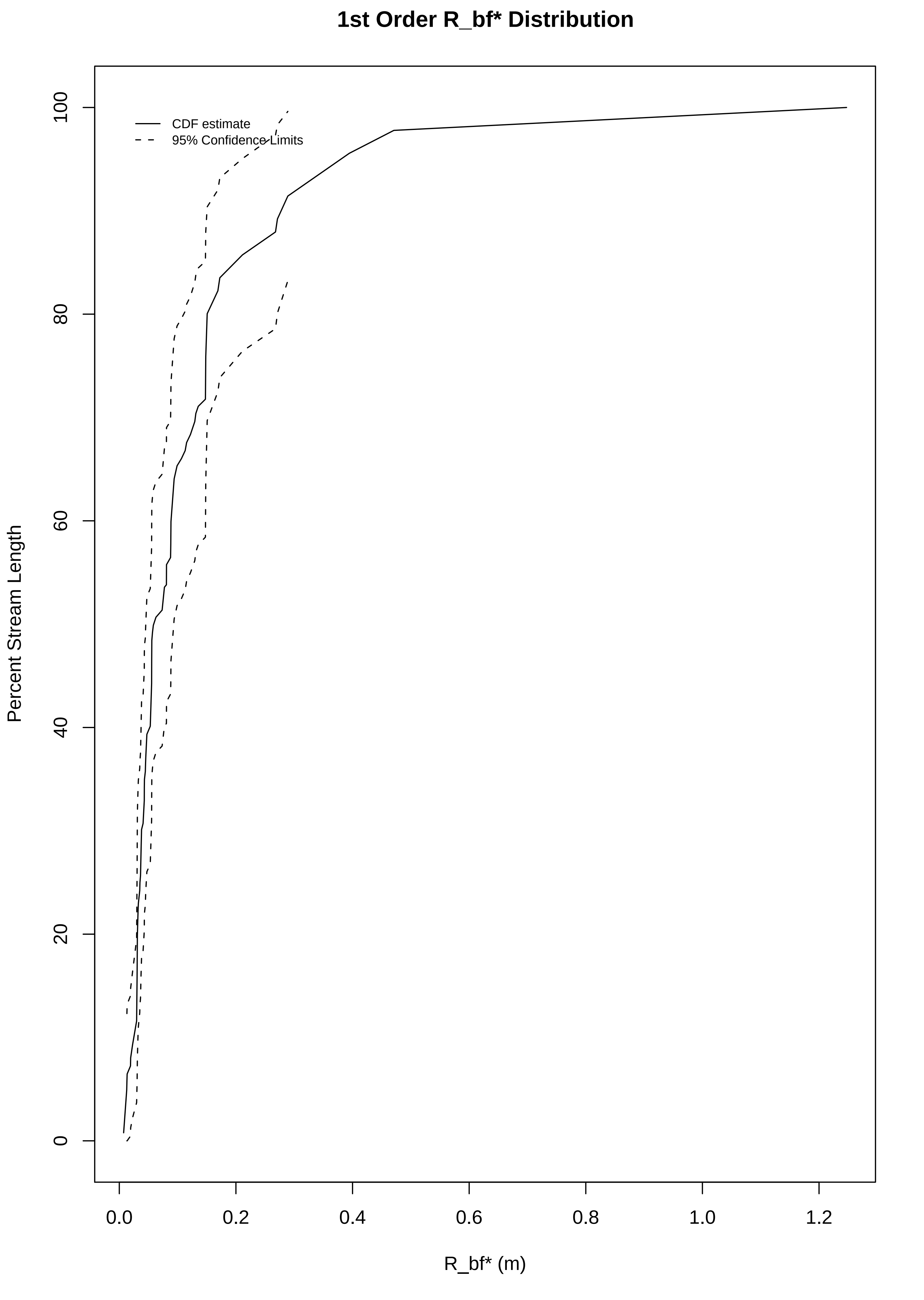

1st Order D_GM (mm) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
200
400
600
800
1000
1200
D_GM

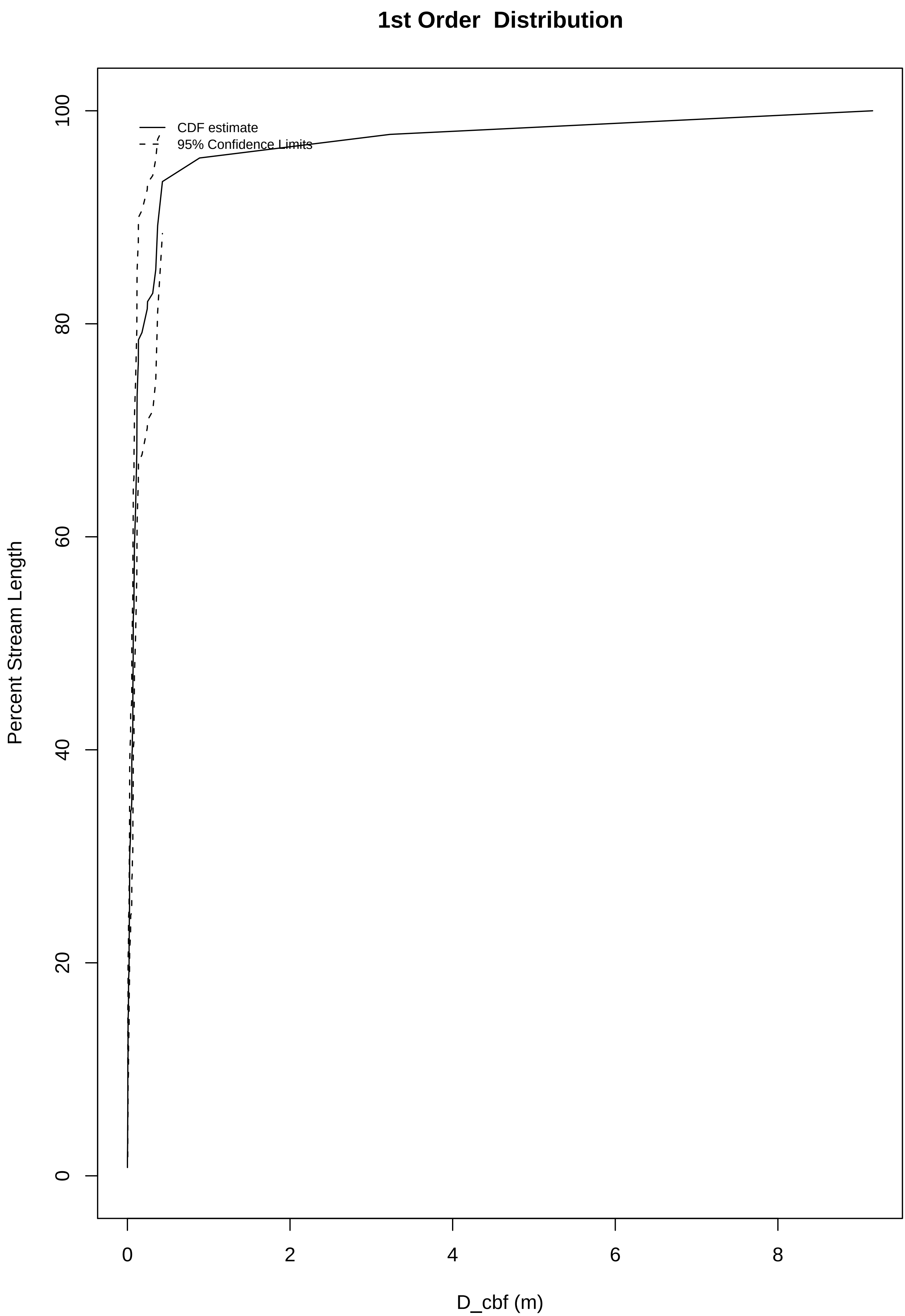


1st Order D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
20
40
60
80
100
120
D_GM (mm)

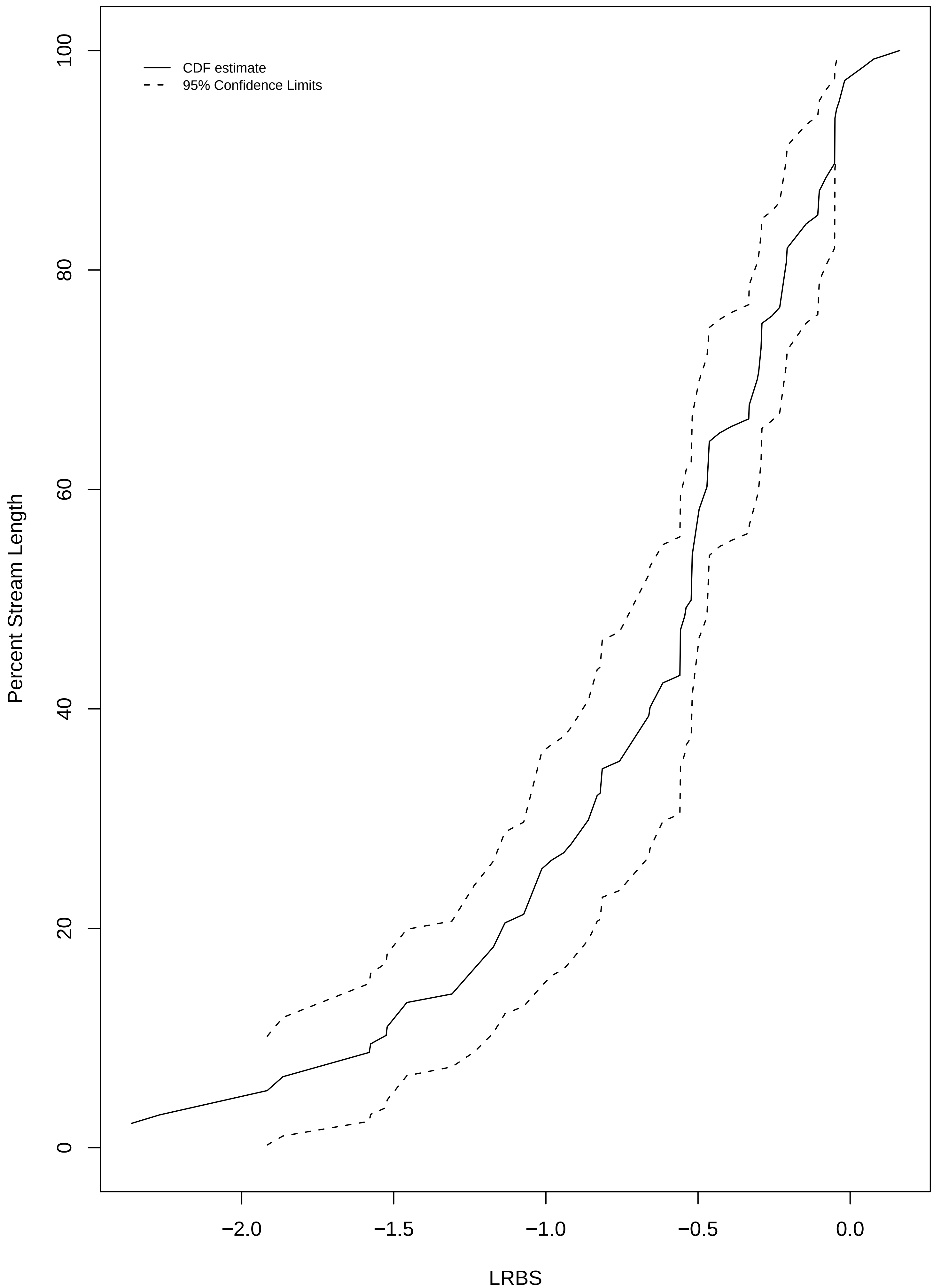

1st Order Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Slope

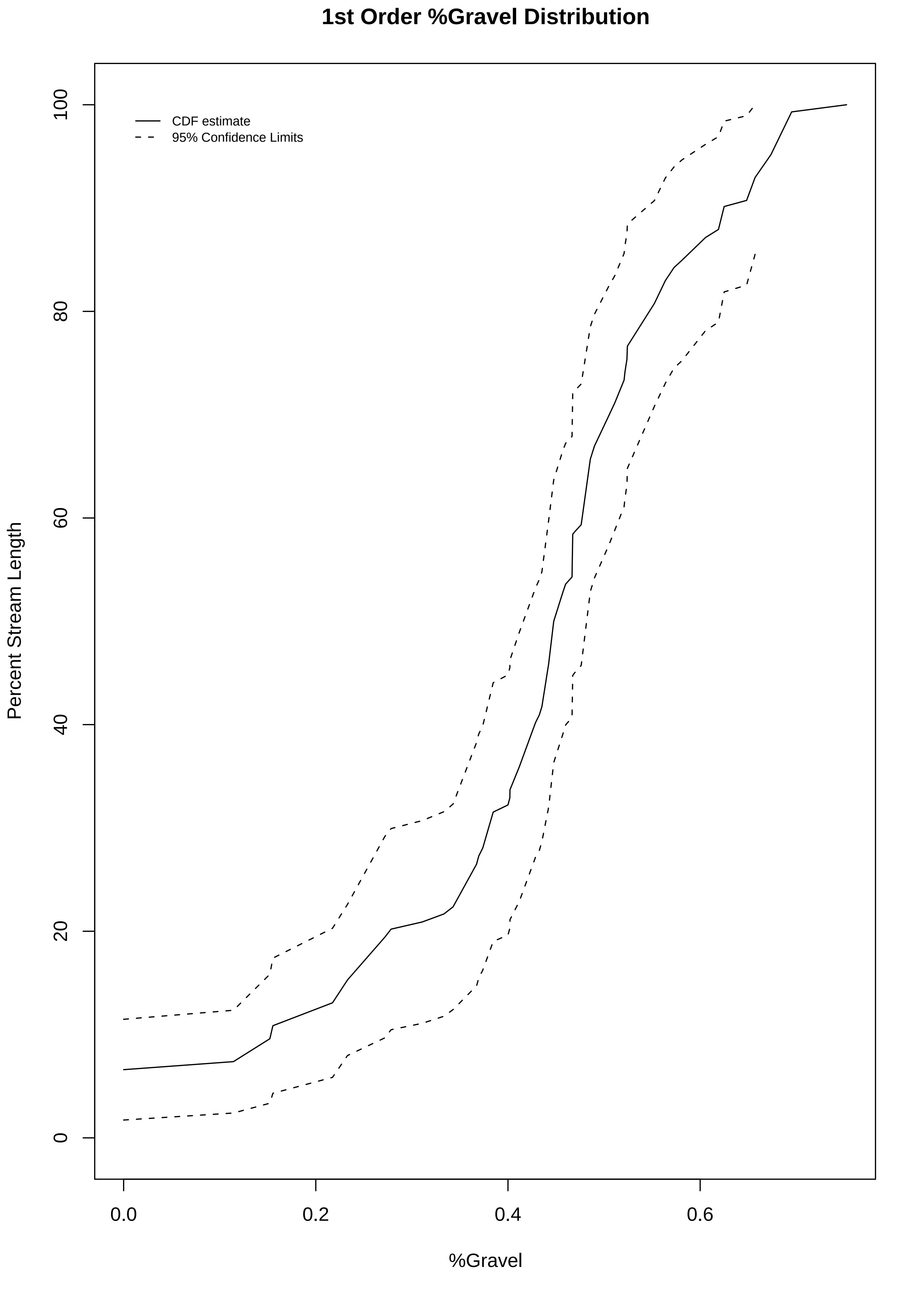

1st Order R_bf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
0.5
R_bf (m)

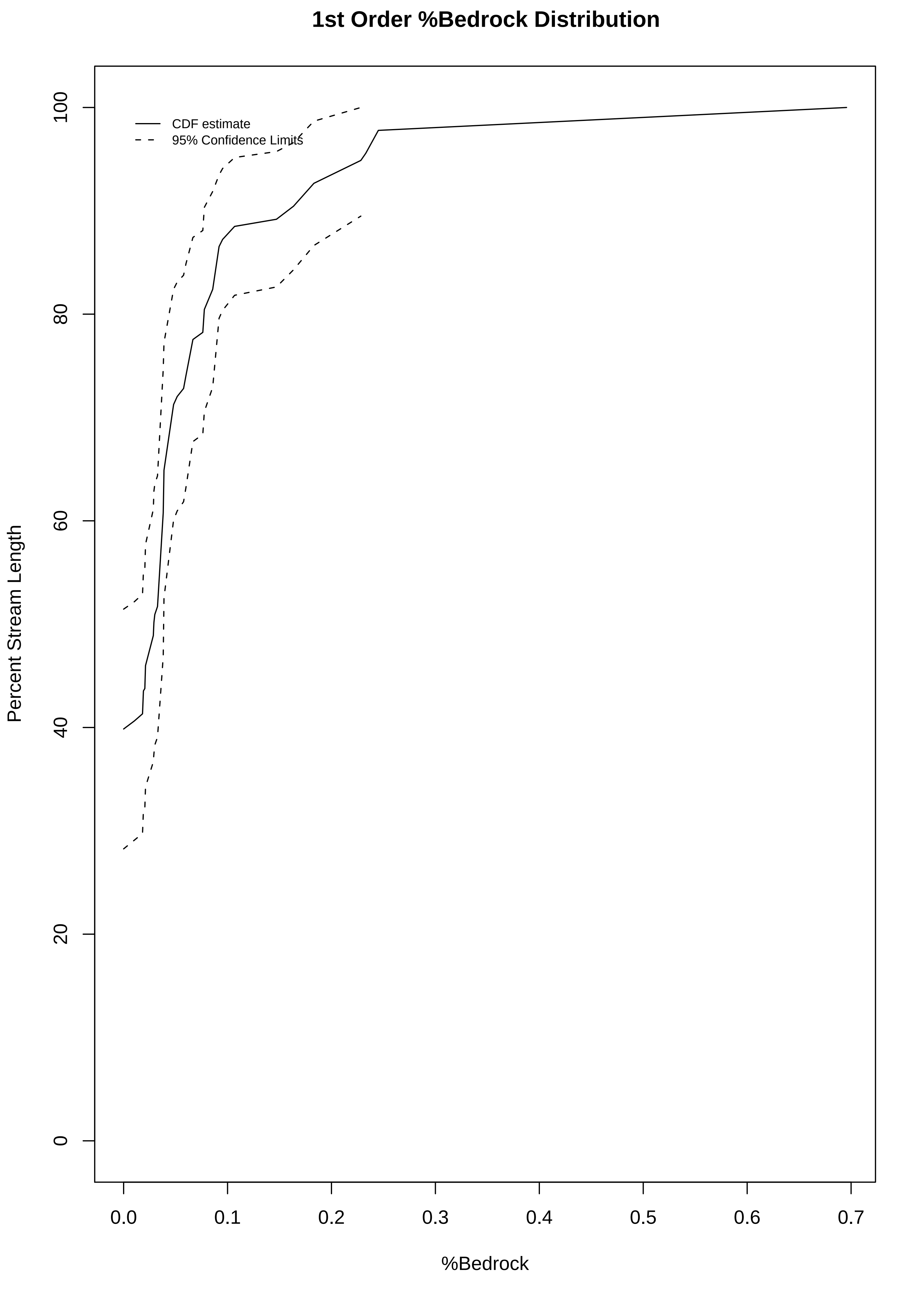

1st Order R_bf* Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8
1.0
1.2
R_bf* (m)


1st Order Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
2
4
6
8
D_cbf (m)

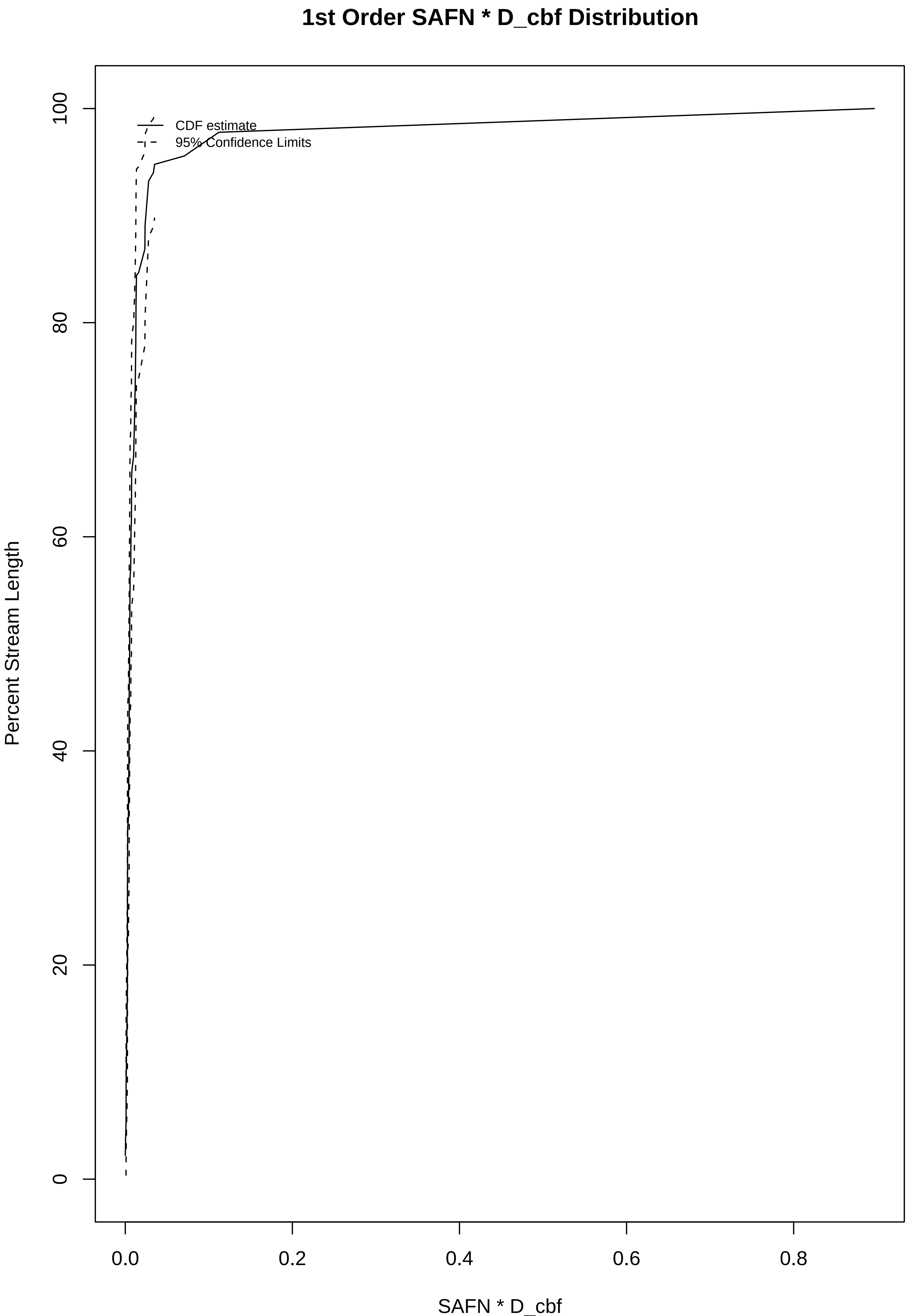
1st Order LRBS (No Bedrock) Distribution



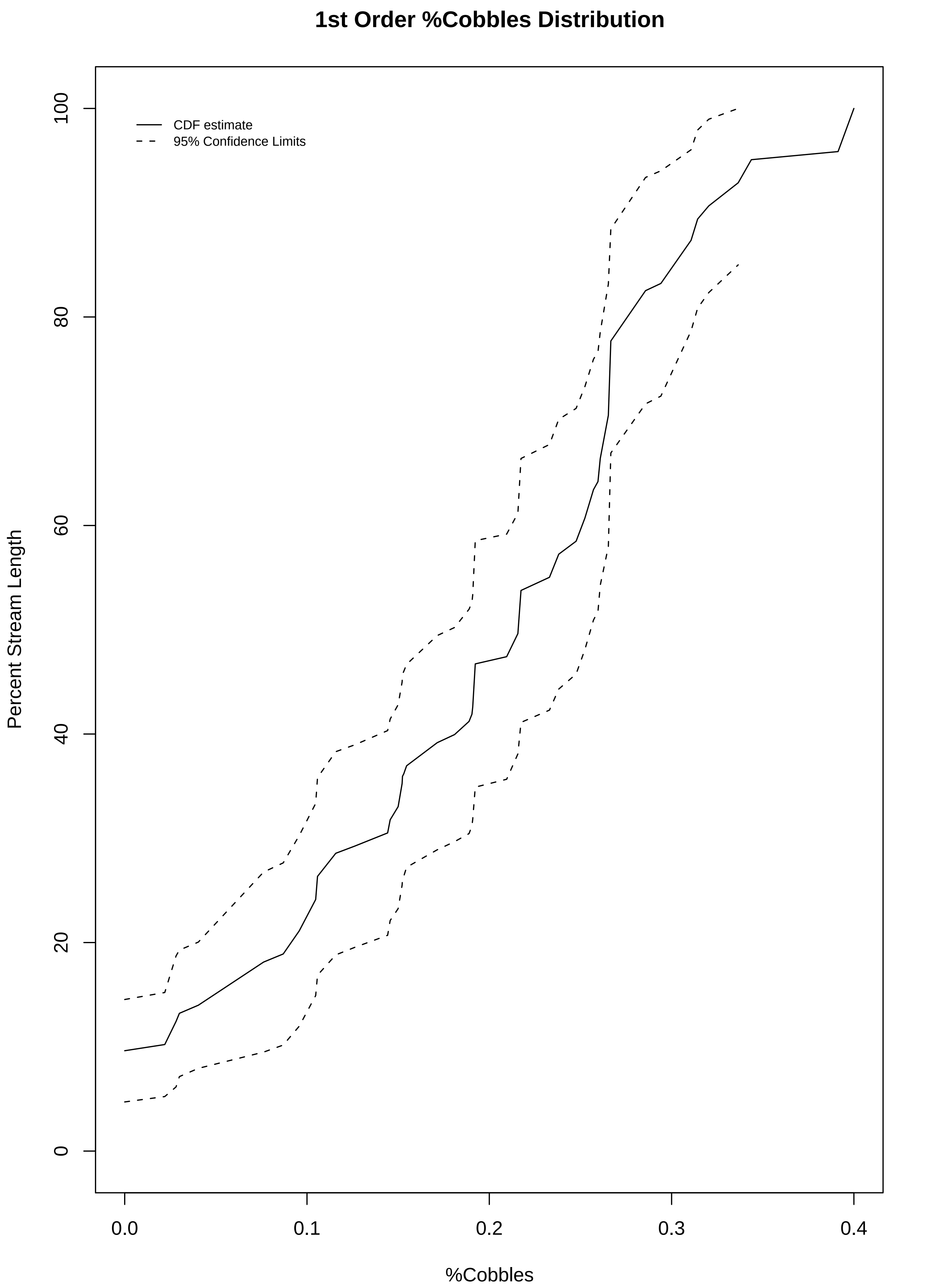

1st Order %Gravel Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
%Gravel

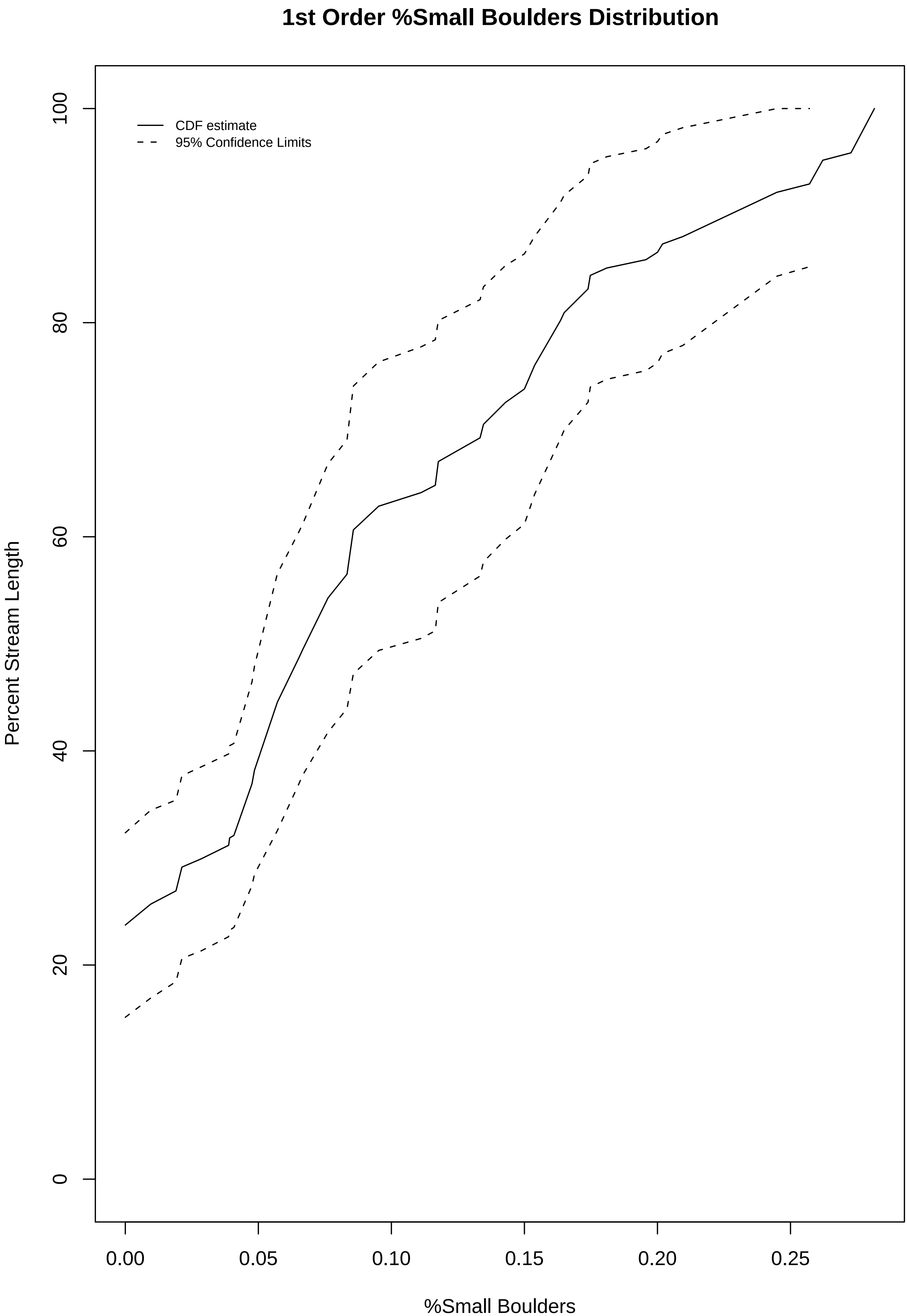


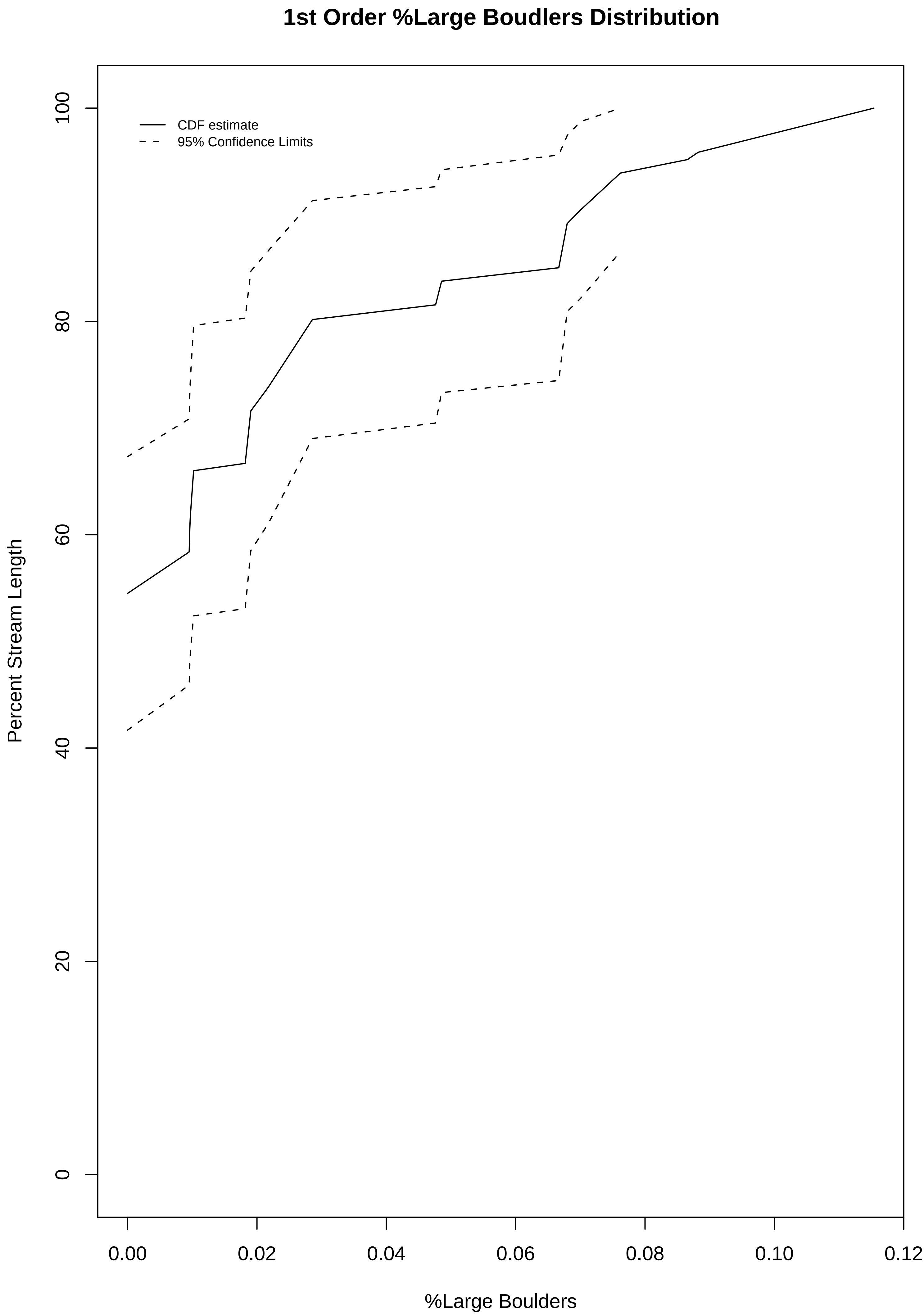
1st Order %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
%Bedrock

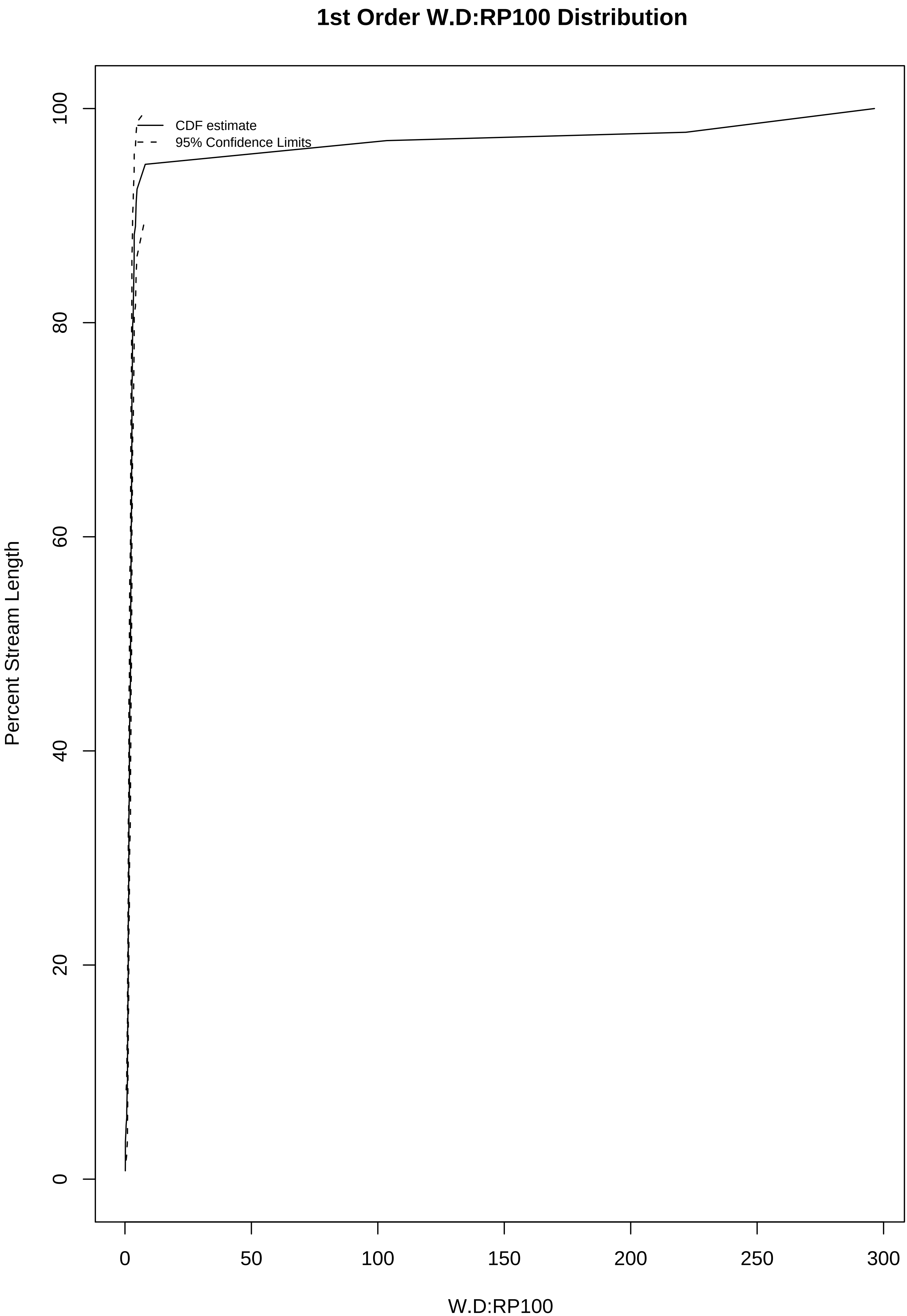


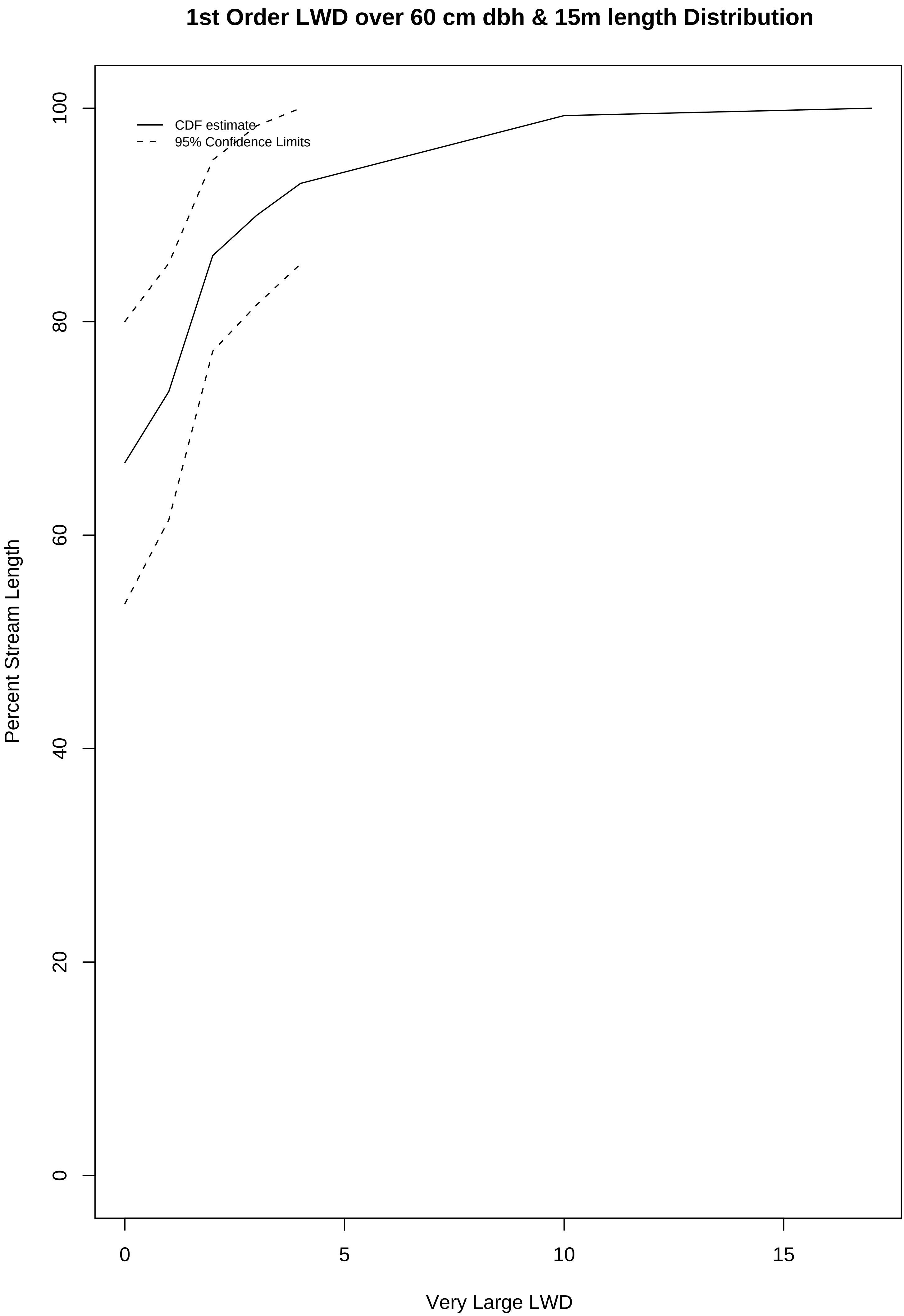
1st Order SAFN * D_cbf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
SAFN * D_cbf
0
20
40
60
80
100
0.0
0.2
0.4
0.6
0.8

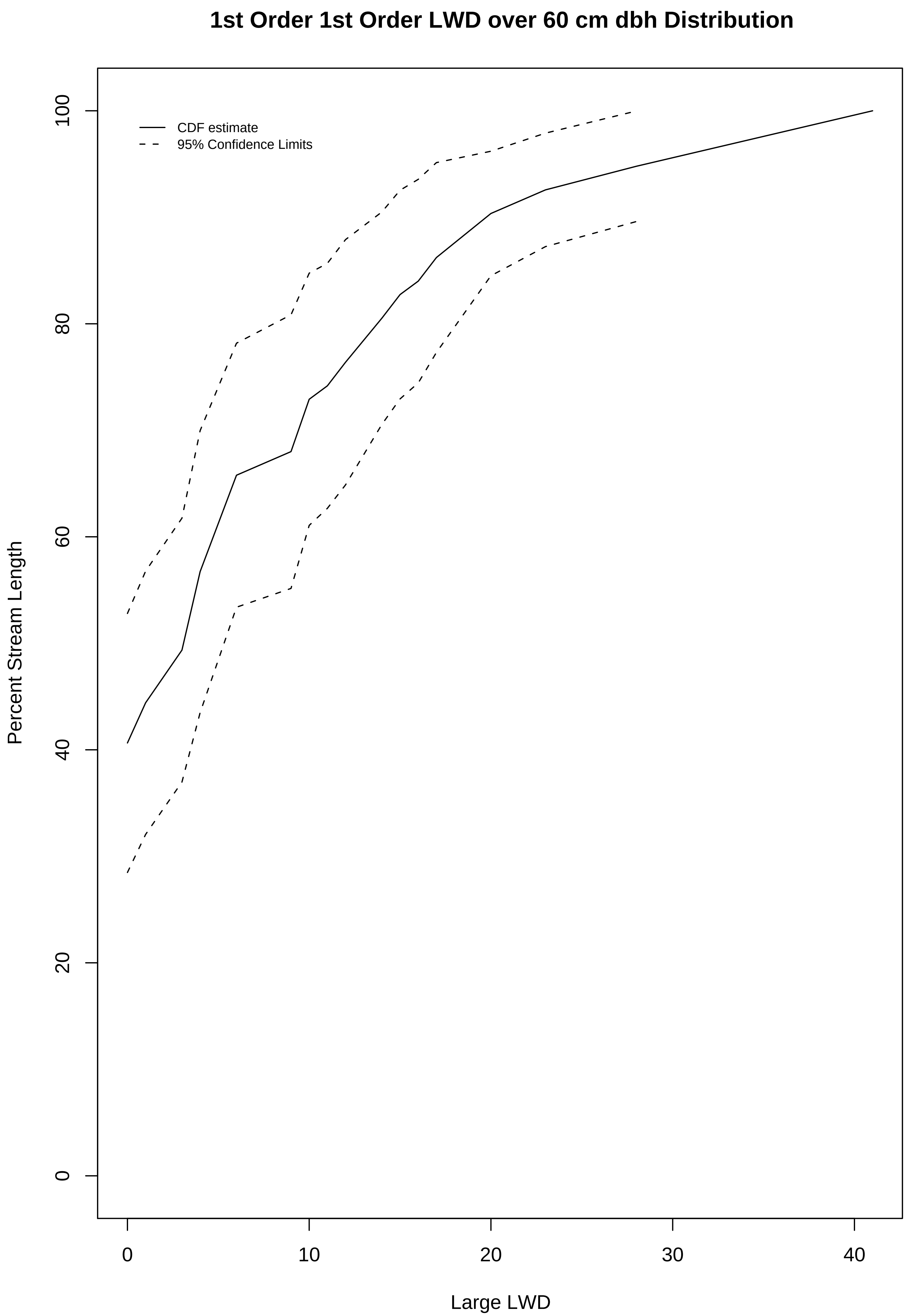

1st Order %Cobbles Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
%Cobbles

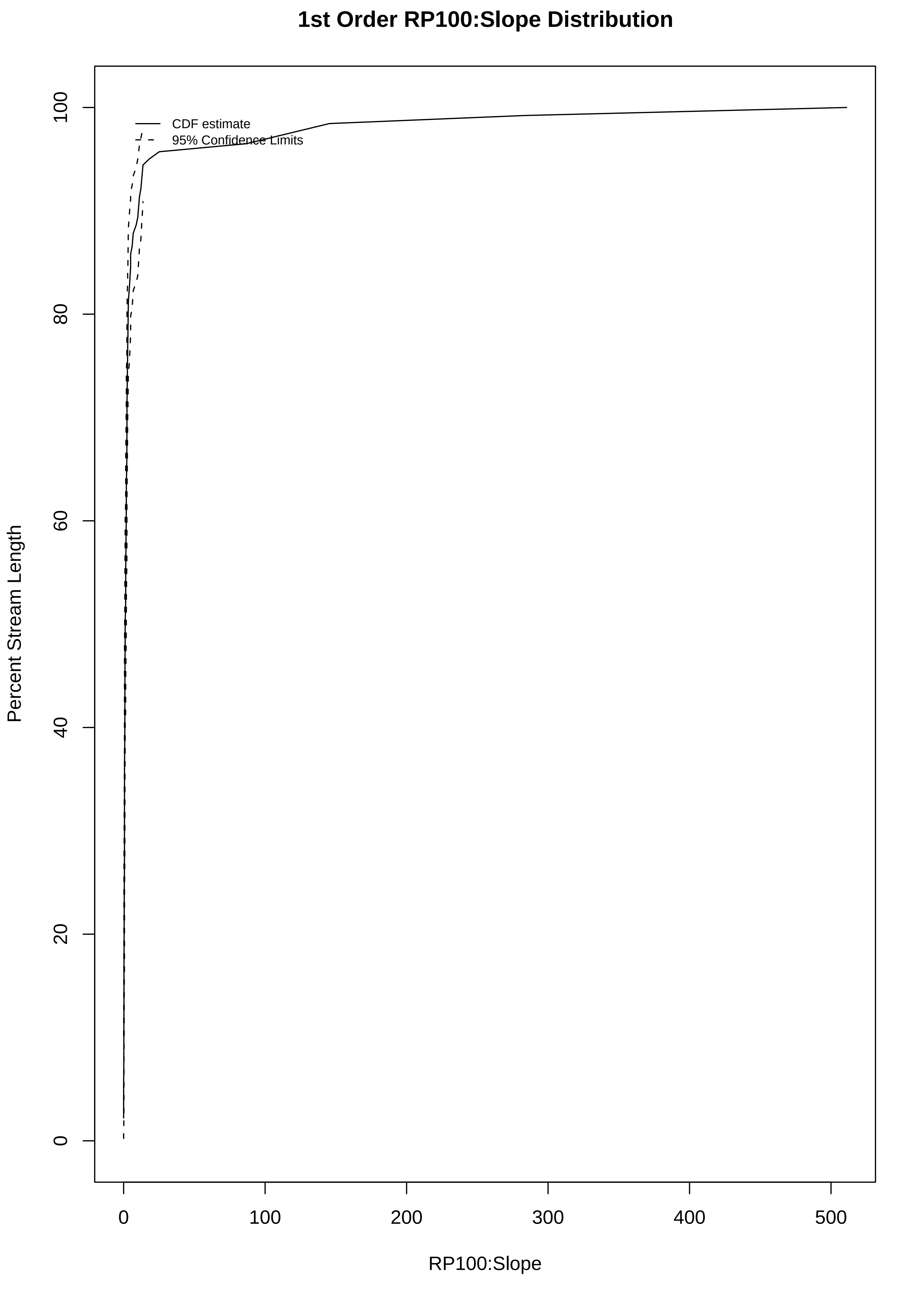

1st Order %Small Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
%Small Boulders

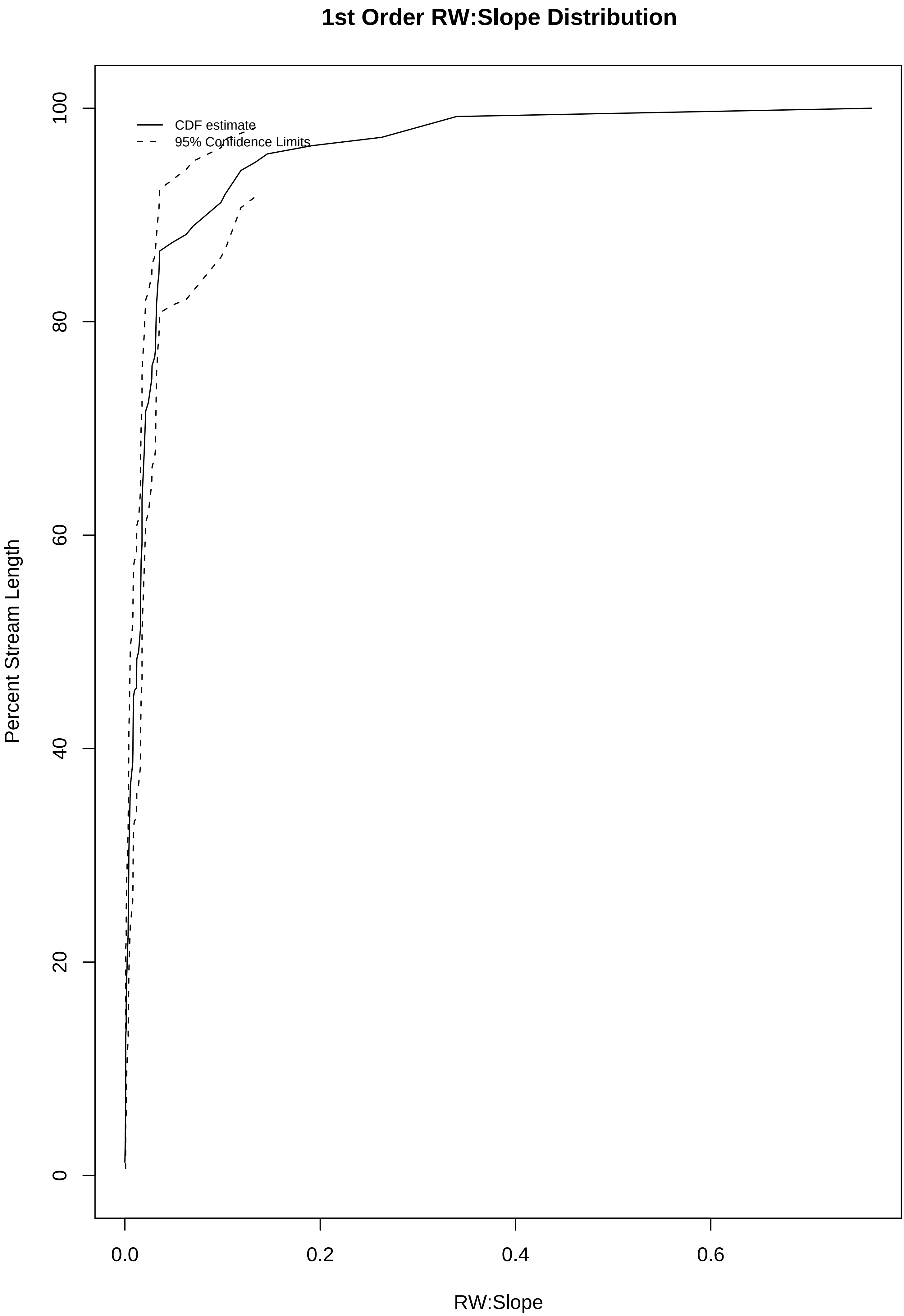

1st Order %Large Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.02
0.04
0.06
0.08
0.10
0.12
%Large Boulders


1st Order W.D:RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
W.D:RP100
0
20
40
60
80
100
0
50
100
150
200
250
300

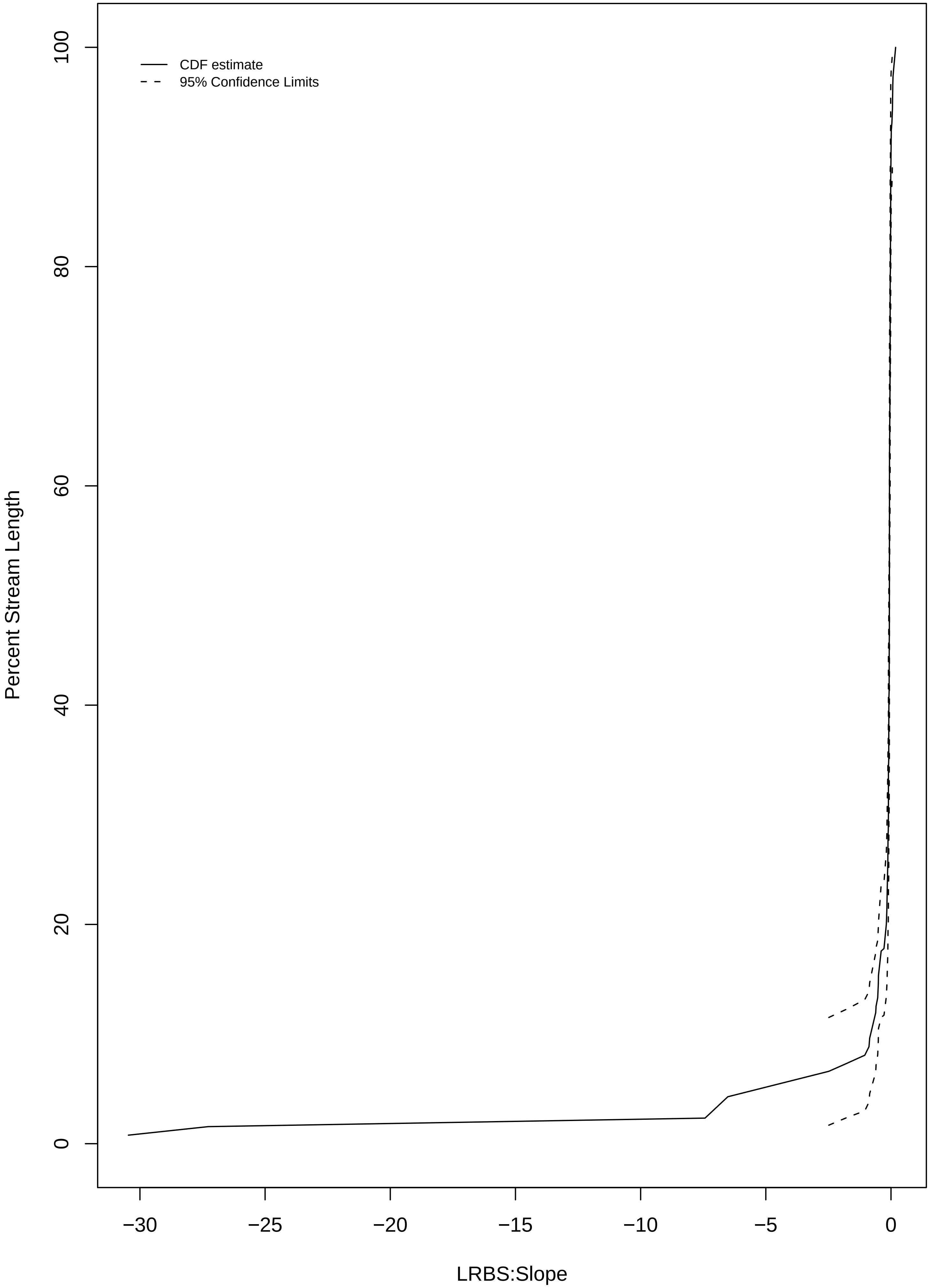

1st Order LWD over 60 cm dbh & 15m length Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
Very Large LWD
0
20
40
60
80
100
0
5
10
15

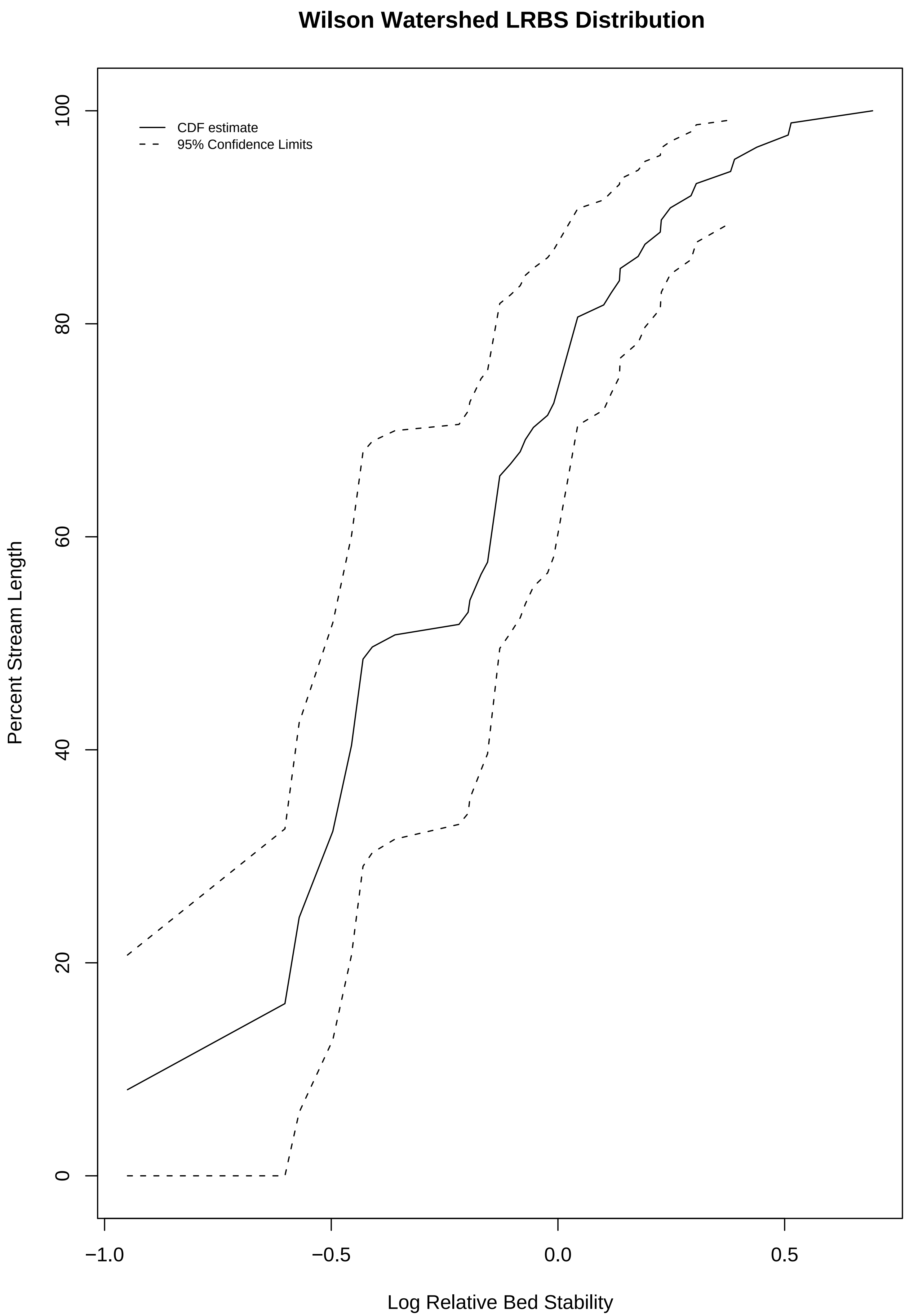

1st Order 1st Order LWD over 60 cm dbh Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
Large LWD
0
10
20
30
40


1st Order RP100:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
RP100:Slope
0
100
200
300
400
500

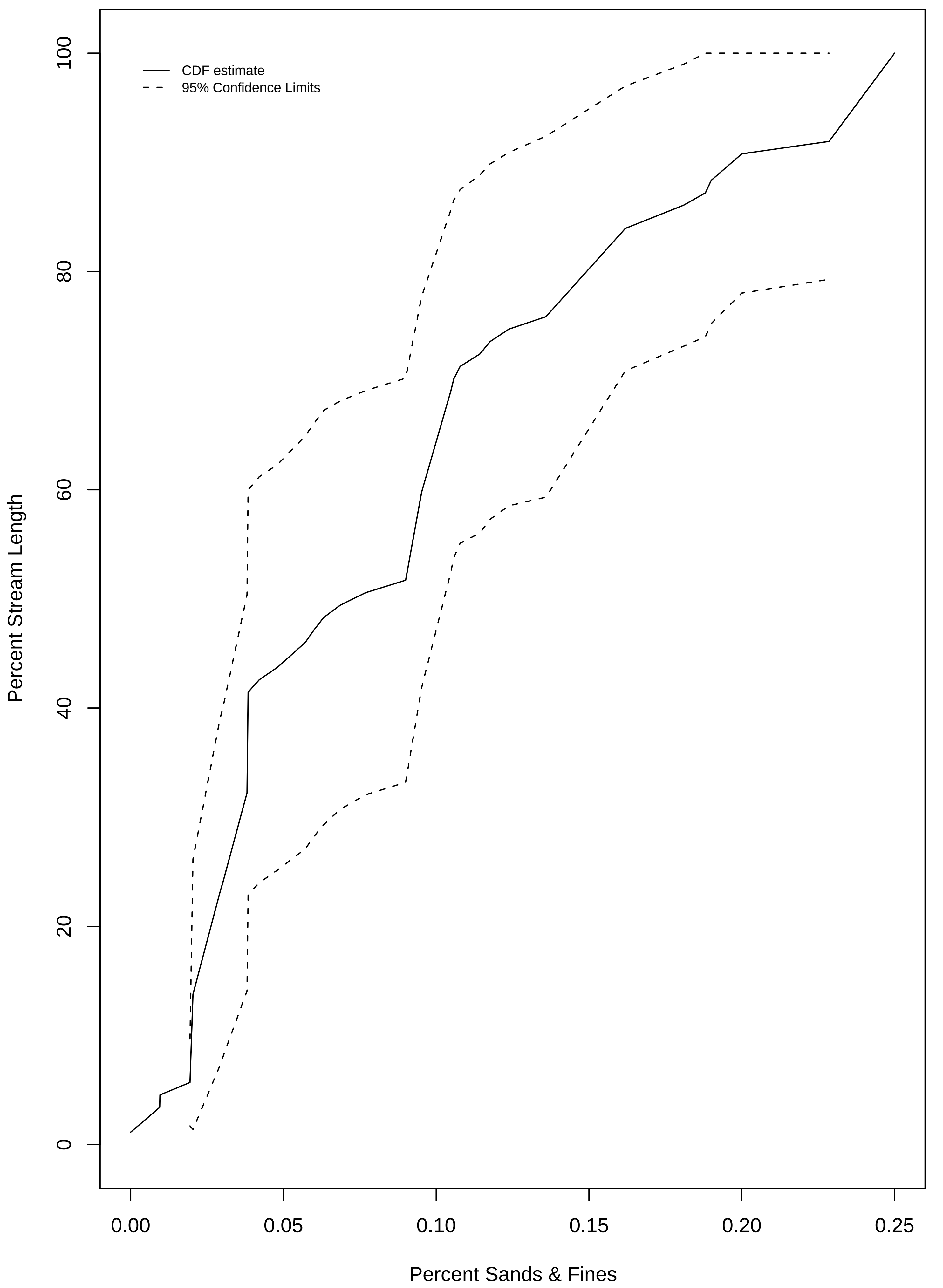

1st Order RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.2
0.4
0.6
RW:Slope

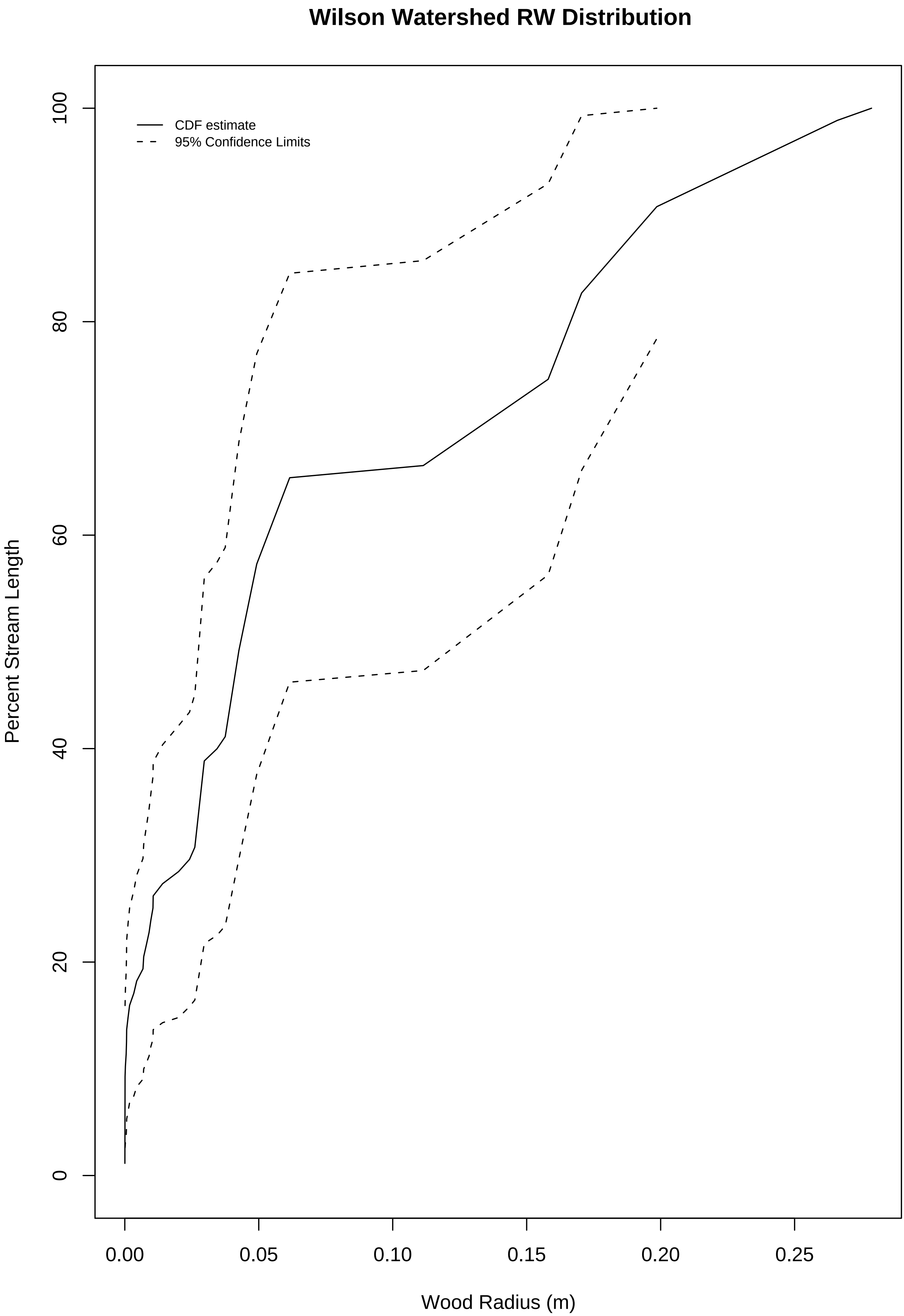
1st Order LRBS:Slope Distribution

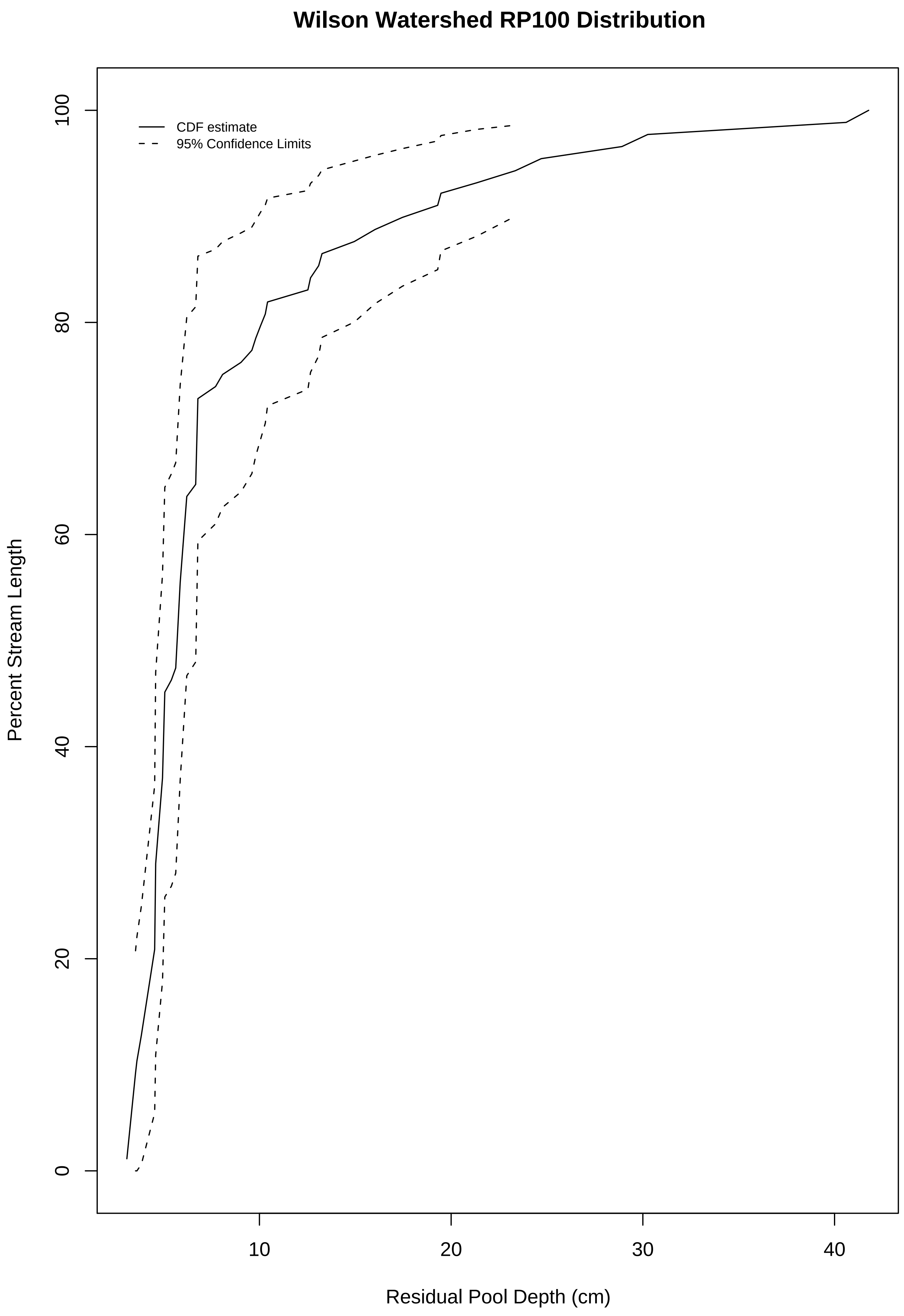


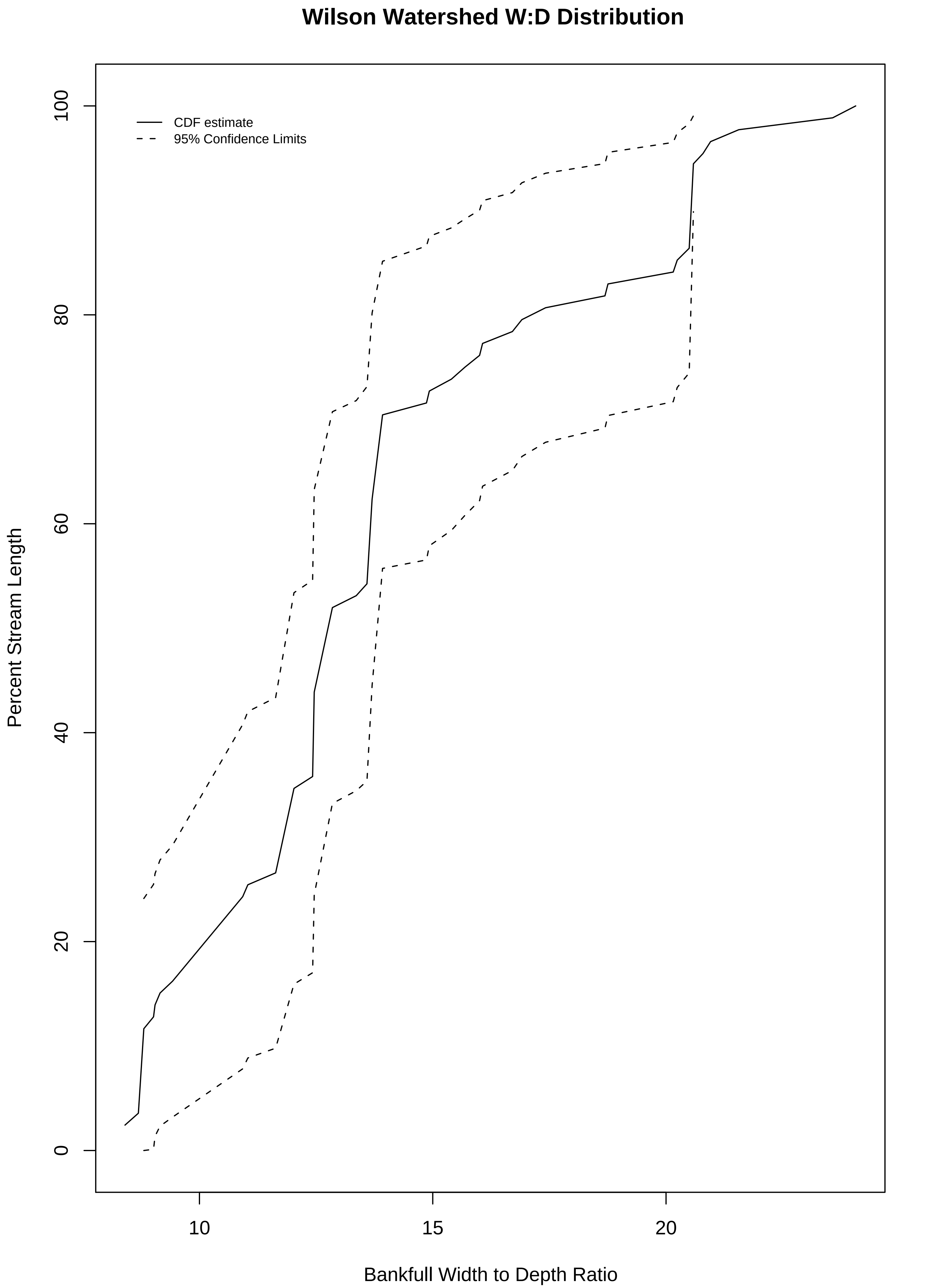

Wilson Watershed LRBS Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−1.0
−0.5
0.0
0.5
Log Relative Bed Stability

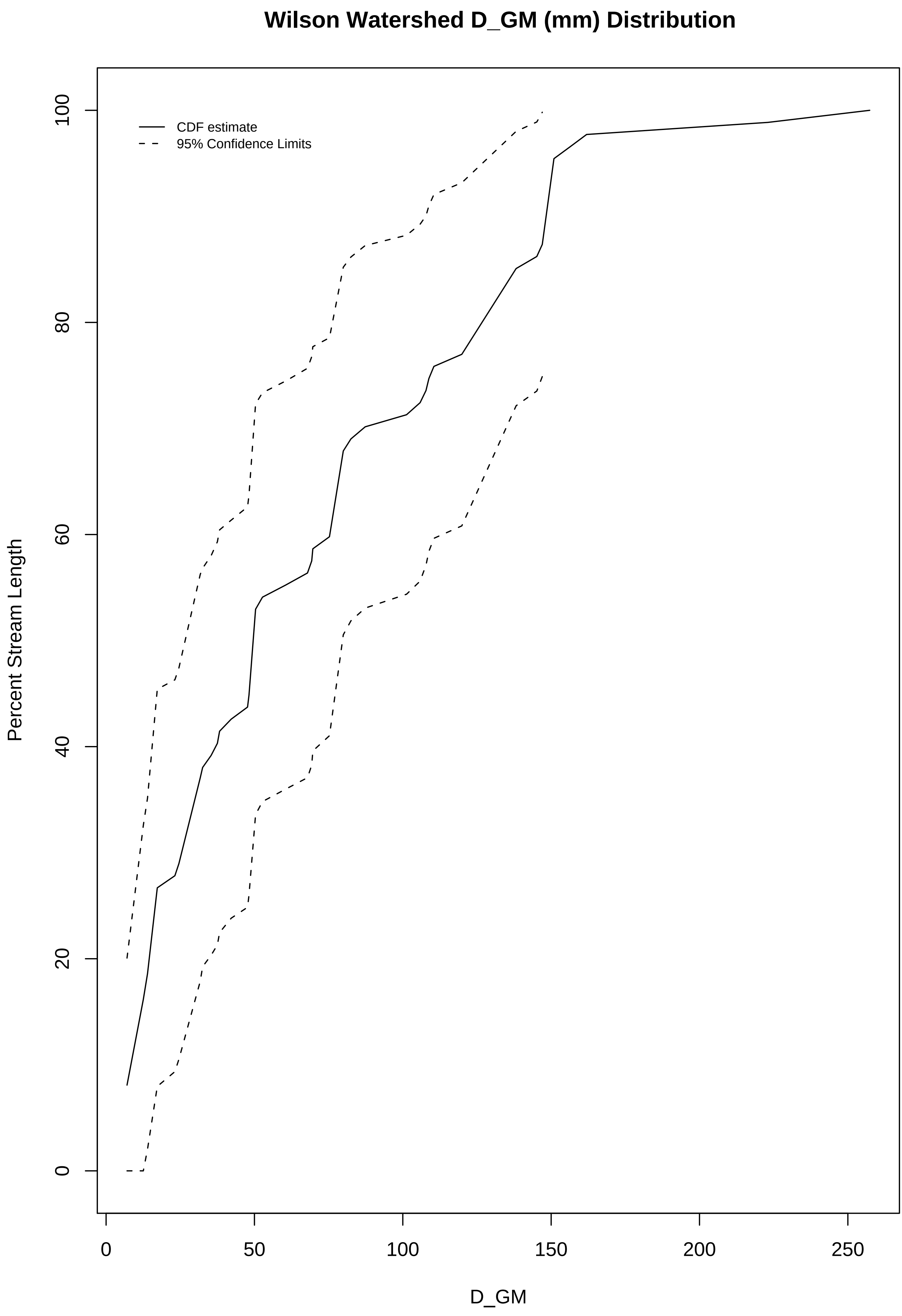
Wilson Watershed %SAFN Distribution

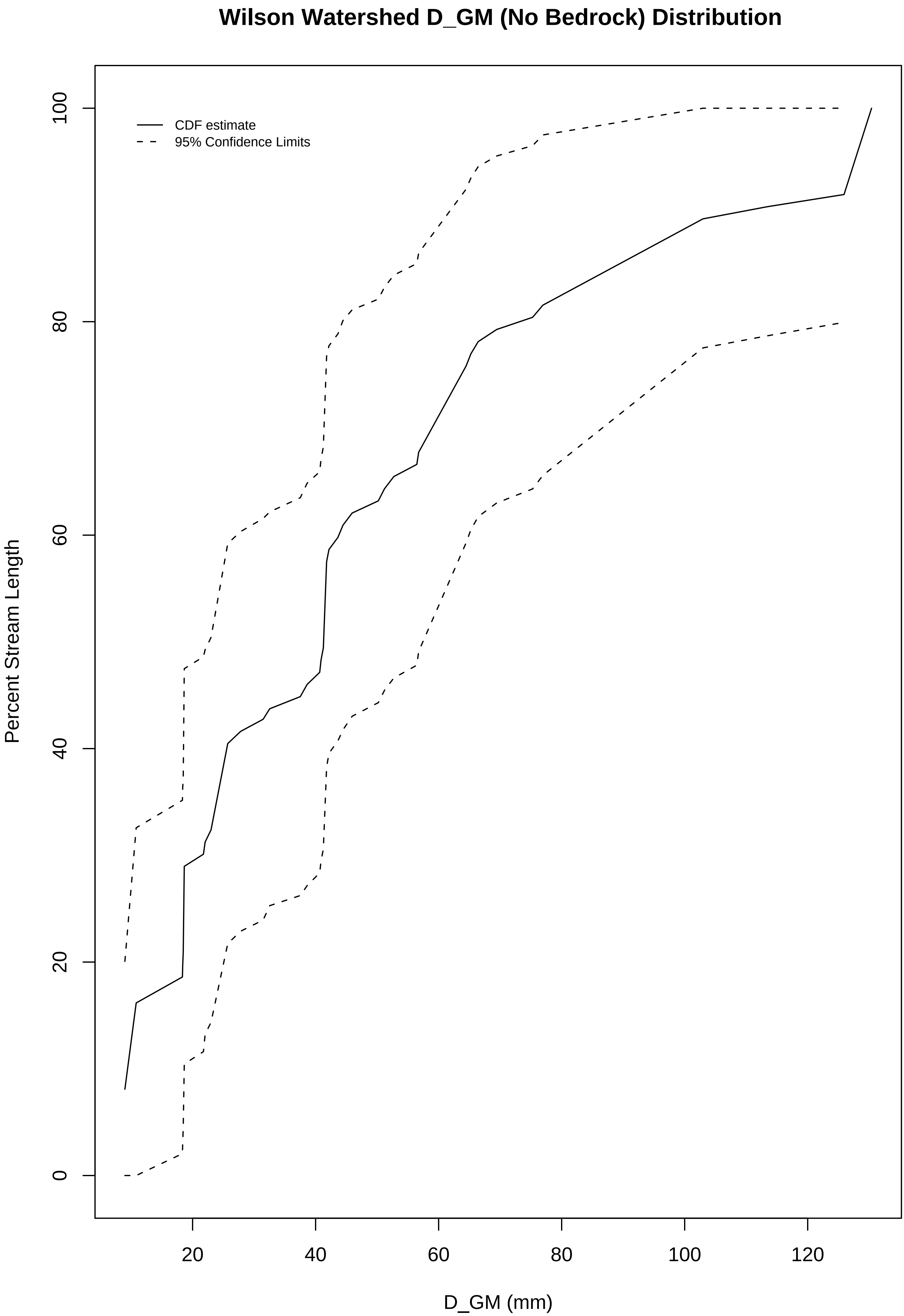



Wilson Watershed RW Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
Wood Radius (m)

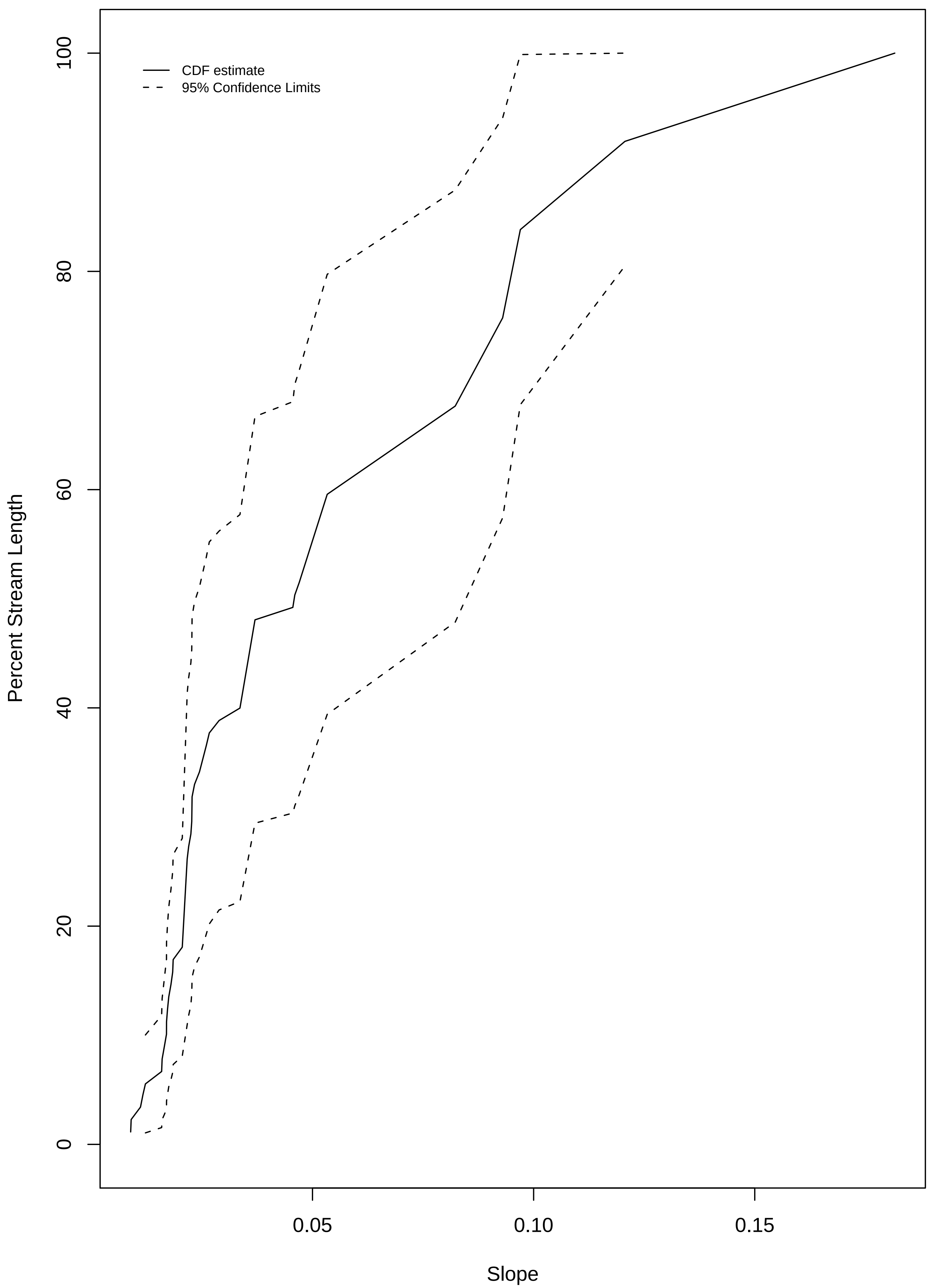

Wilson Watershed RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
10
20
30
40
Residual Pool Depth (cm)

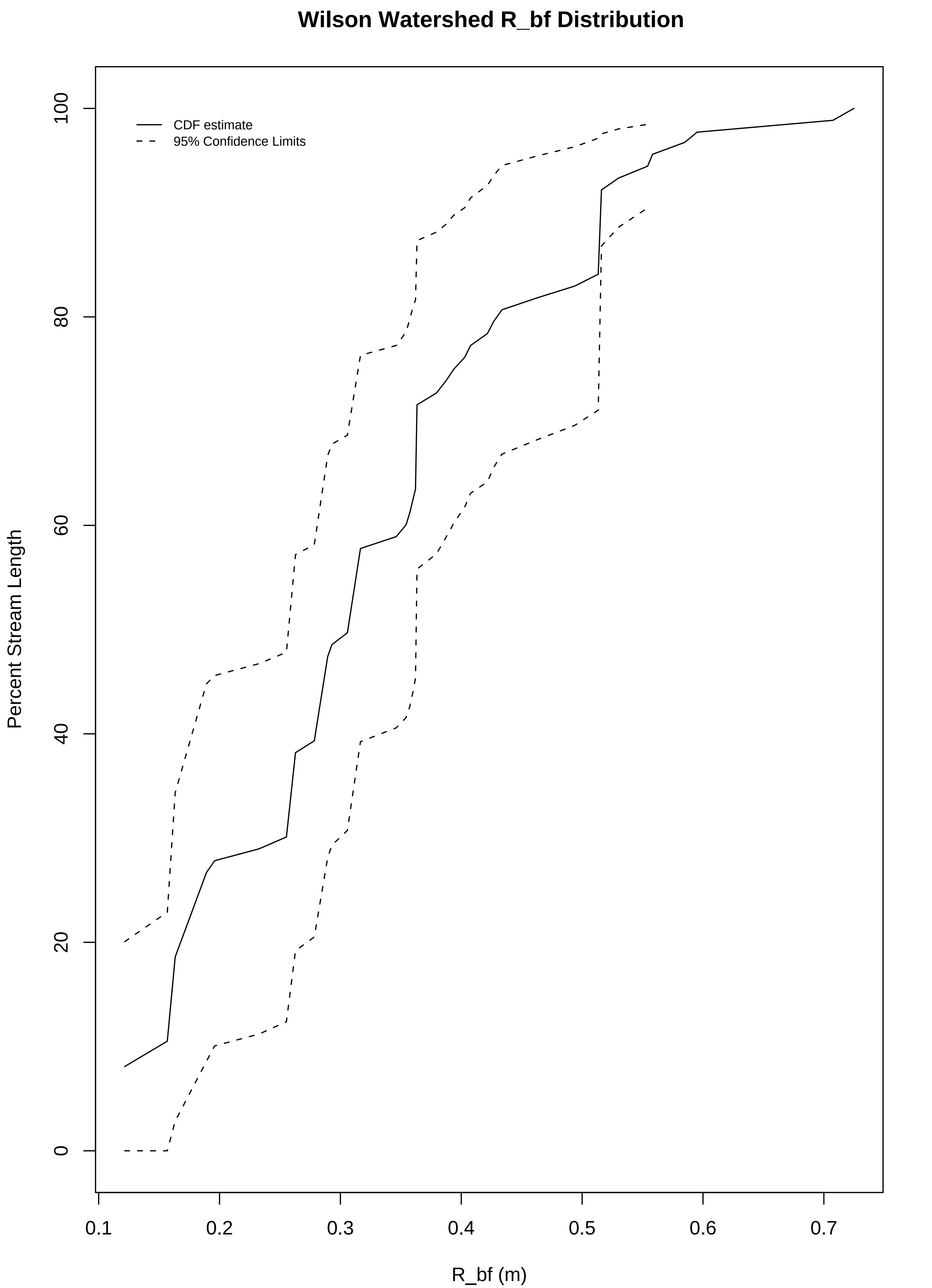

Wilson Watershed W:D Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
10
15
20
Bankfull Width to Depth Ratio

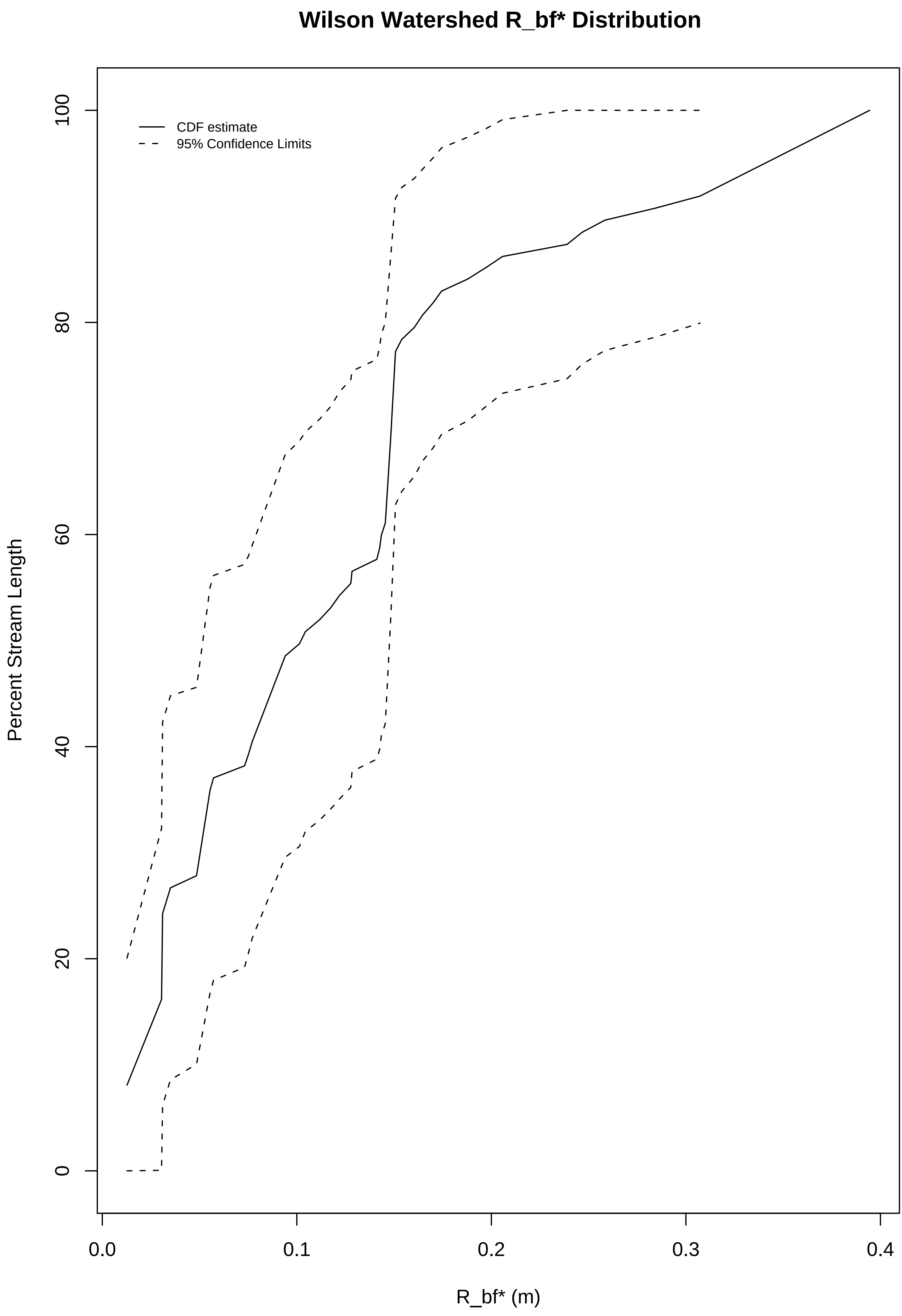

Wilson Watershed D_GM (mm) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
D_GM
0
20
40
60
80
100
0
50
100
150
200
250


Wilson Watershed D_GM (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
20
40
60
80
100
120
D_GM (mm)

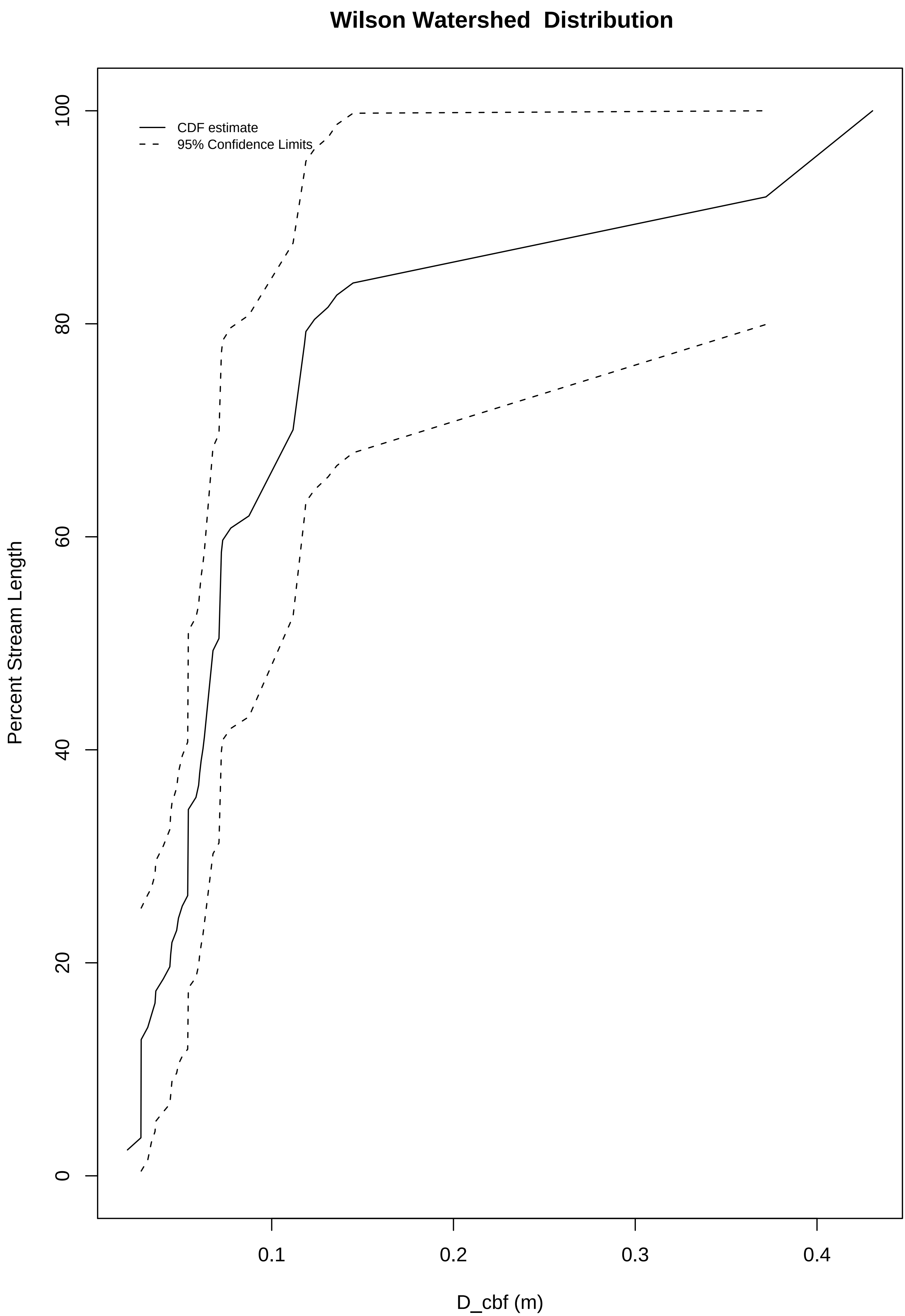
Wilson Watershed Slope Distribution



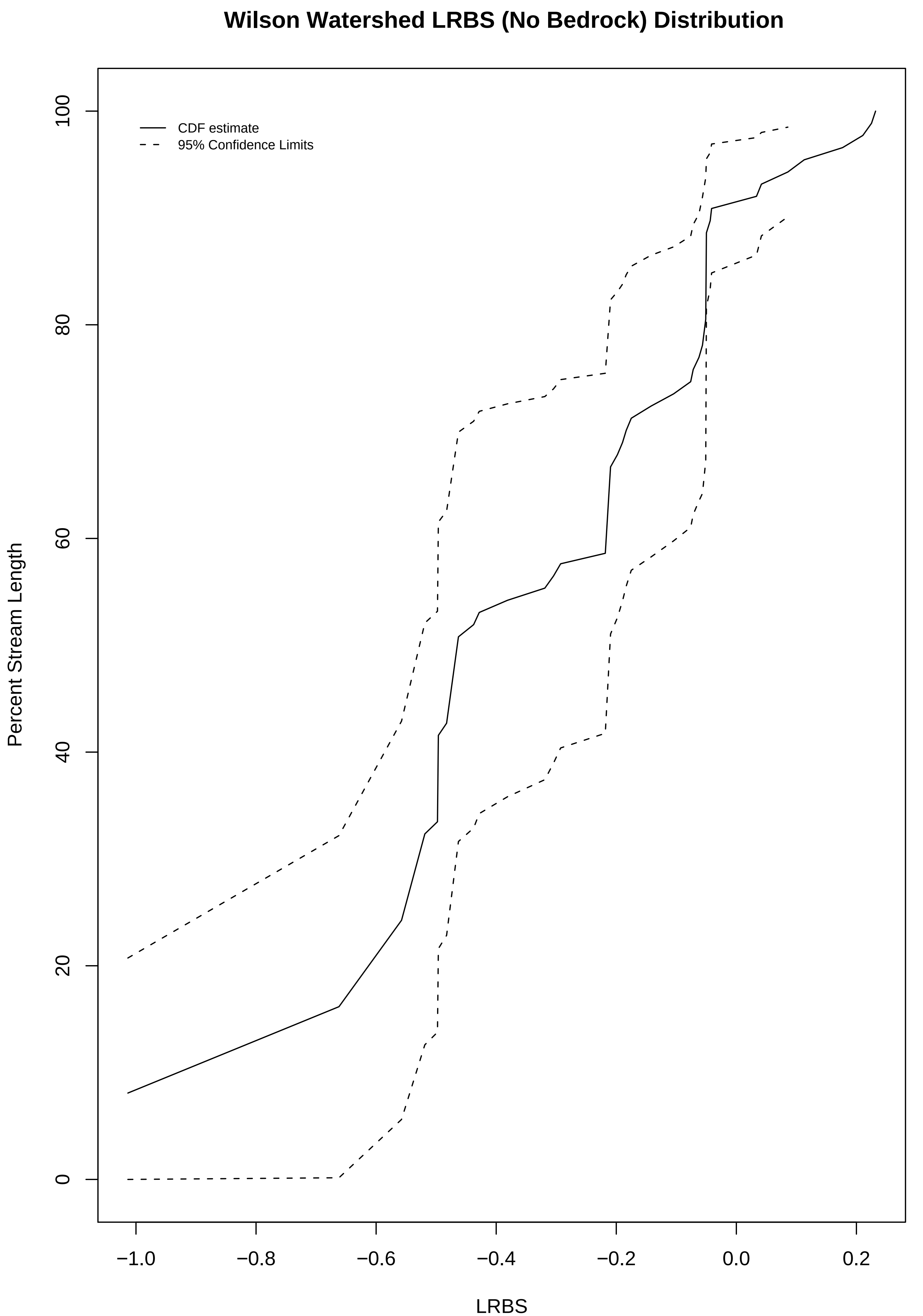

Wilson Watershed R_bf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
R_bf (m)
0
20
40
60
80
100
0.1
0.2
0.3
0.4
0.5
0.6
0.7



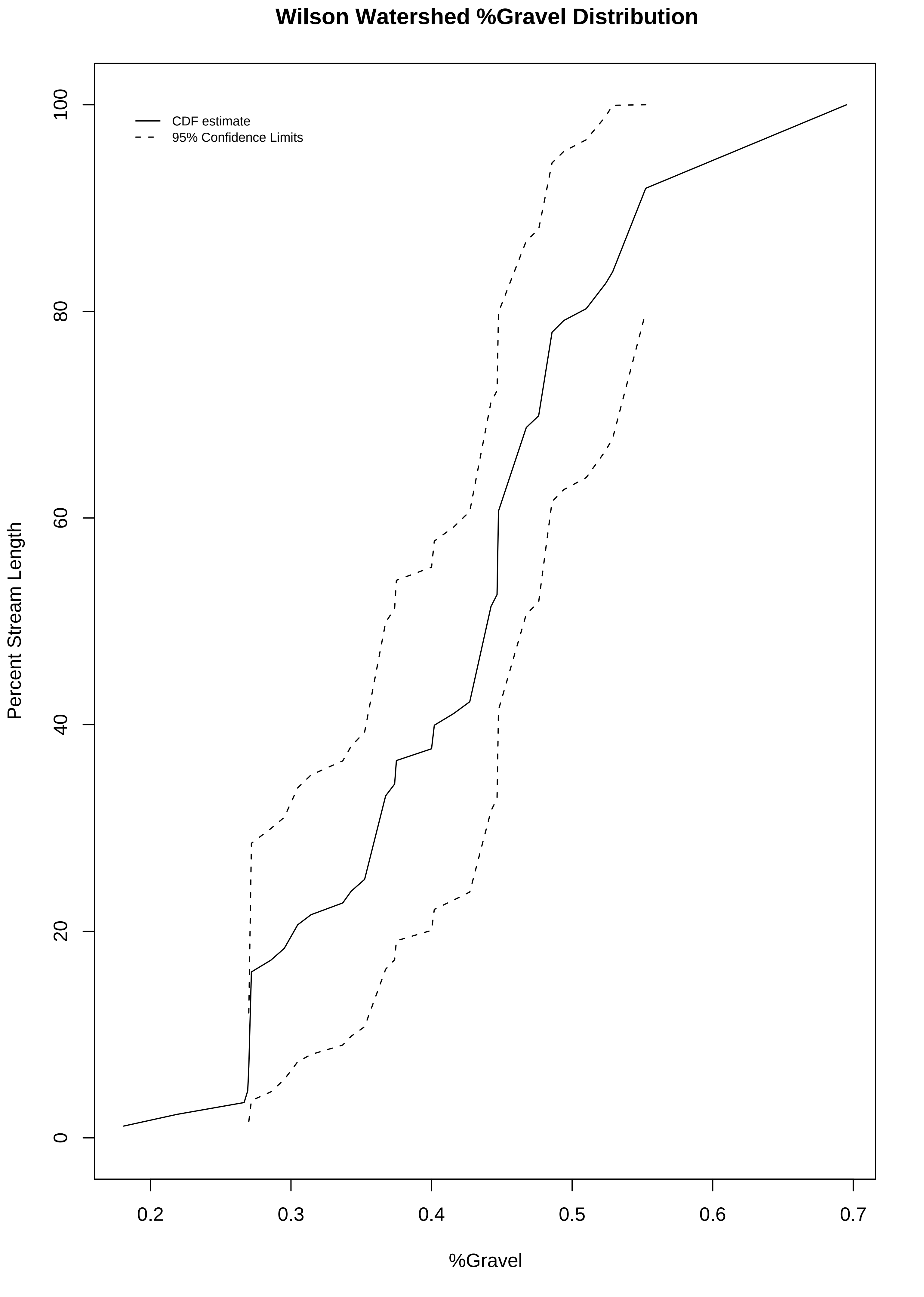
Wilson Watershed R_bf* Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.0
0.1
0.2
0.3
0.4
R_bf* (m)

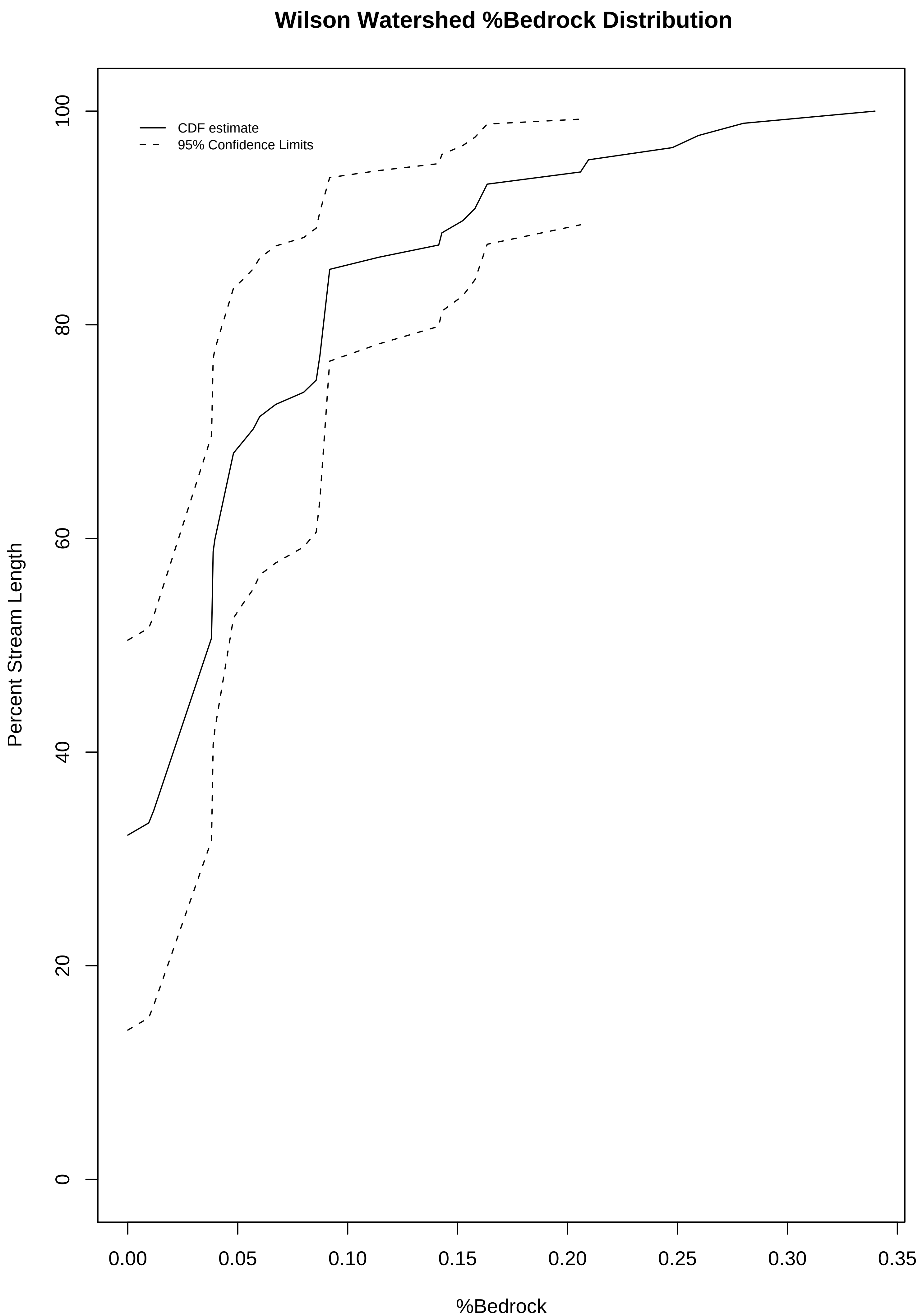


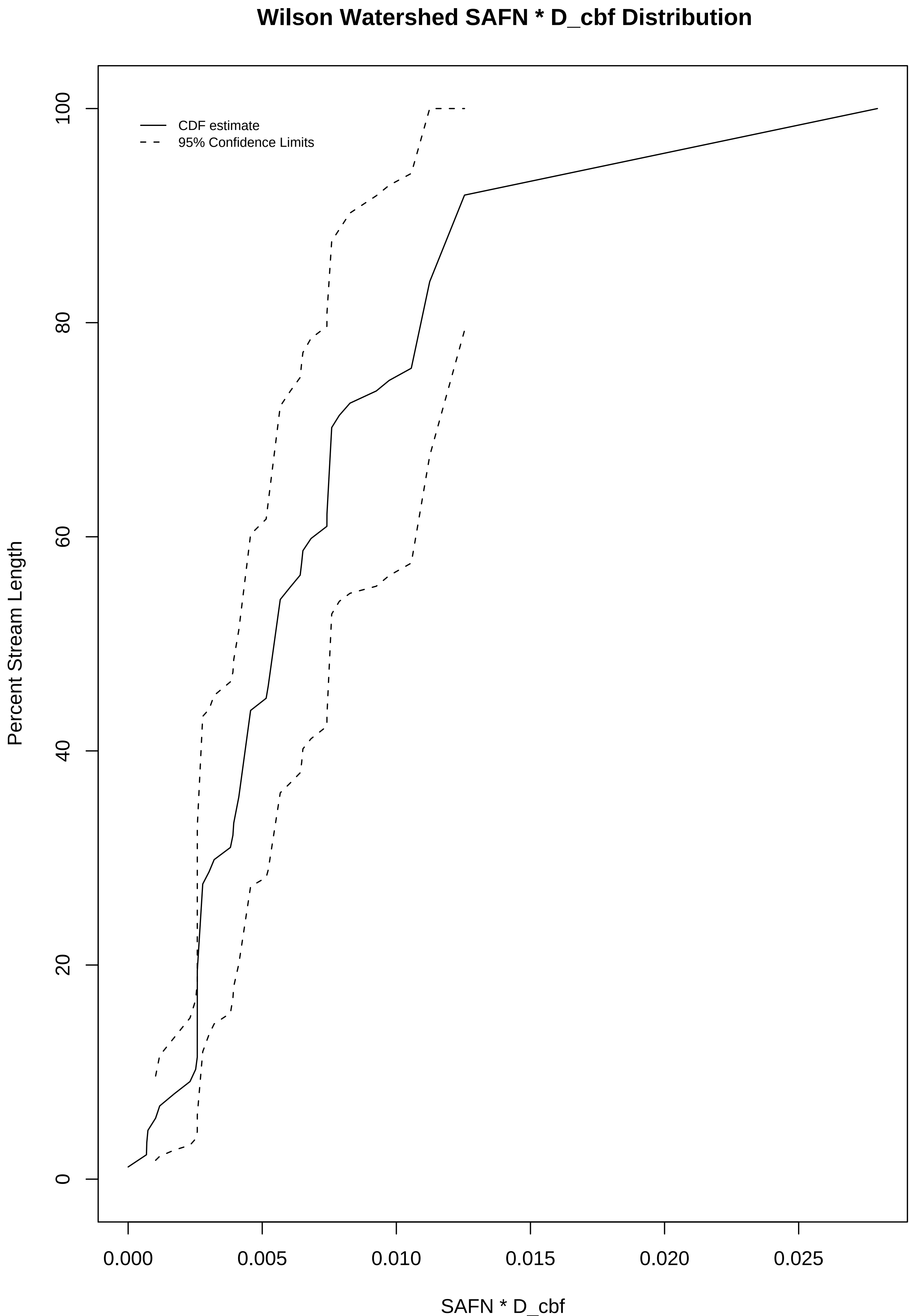
Wilson Watershed Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.1
0.2
0.3
0.4
D_cbf (m)



Wilson Watershed LRBS (No Bedrock) Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−1.0
−0.8
−0.6
−0.4
−0.2
0.0
0.2
LRBS

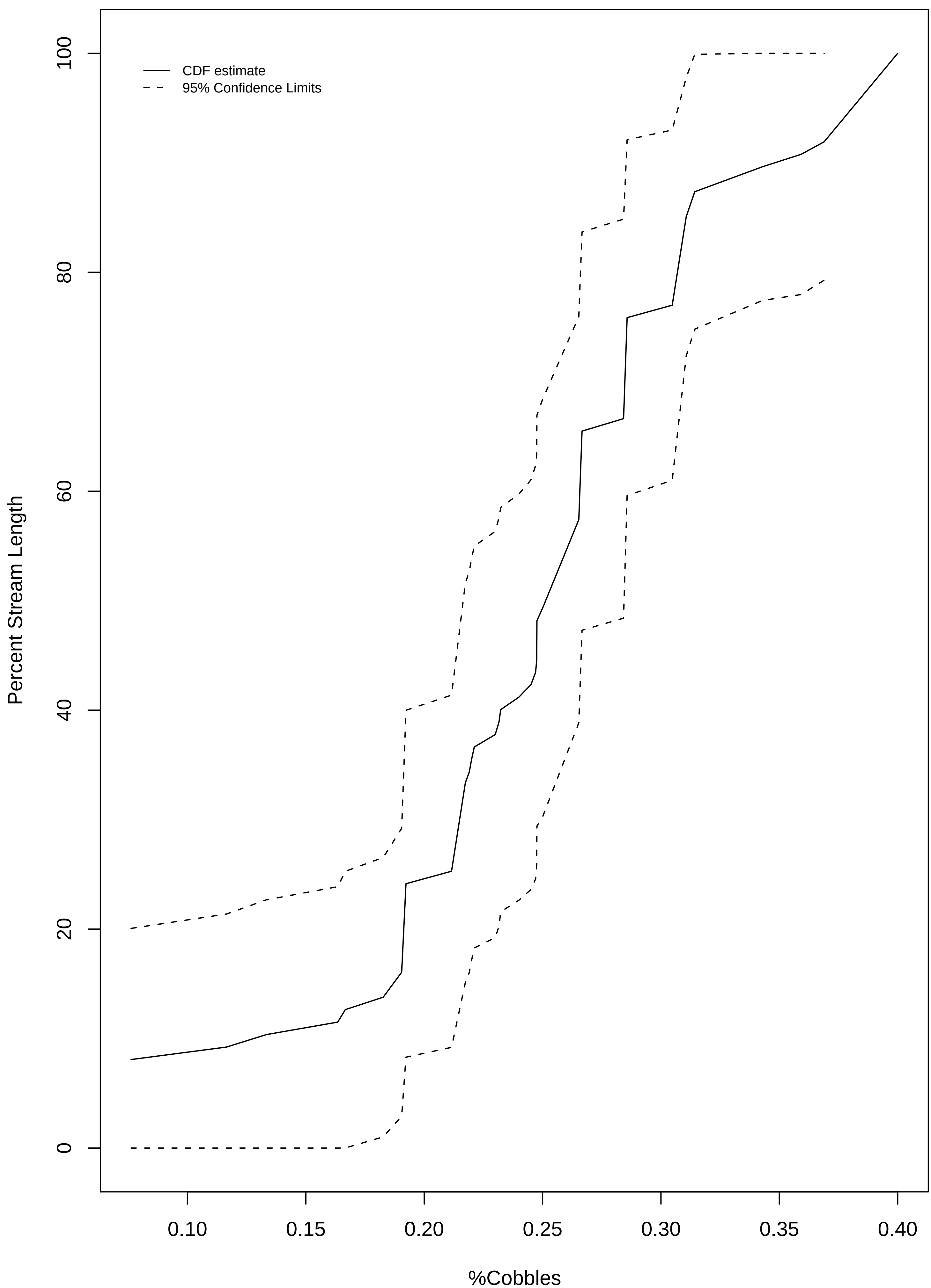

Wilson Watershed %Gravel Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.2
0.3
0.4
0.5
0.6
0.7
%Gravel

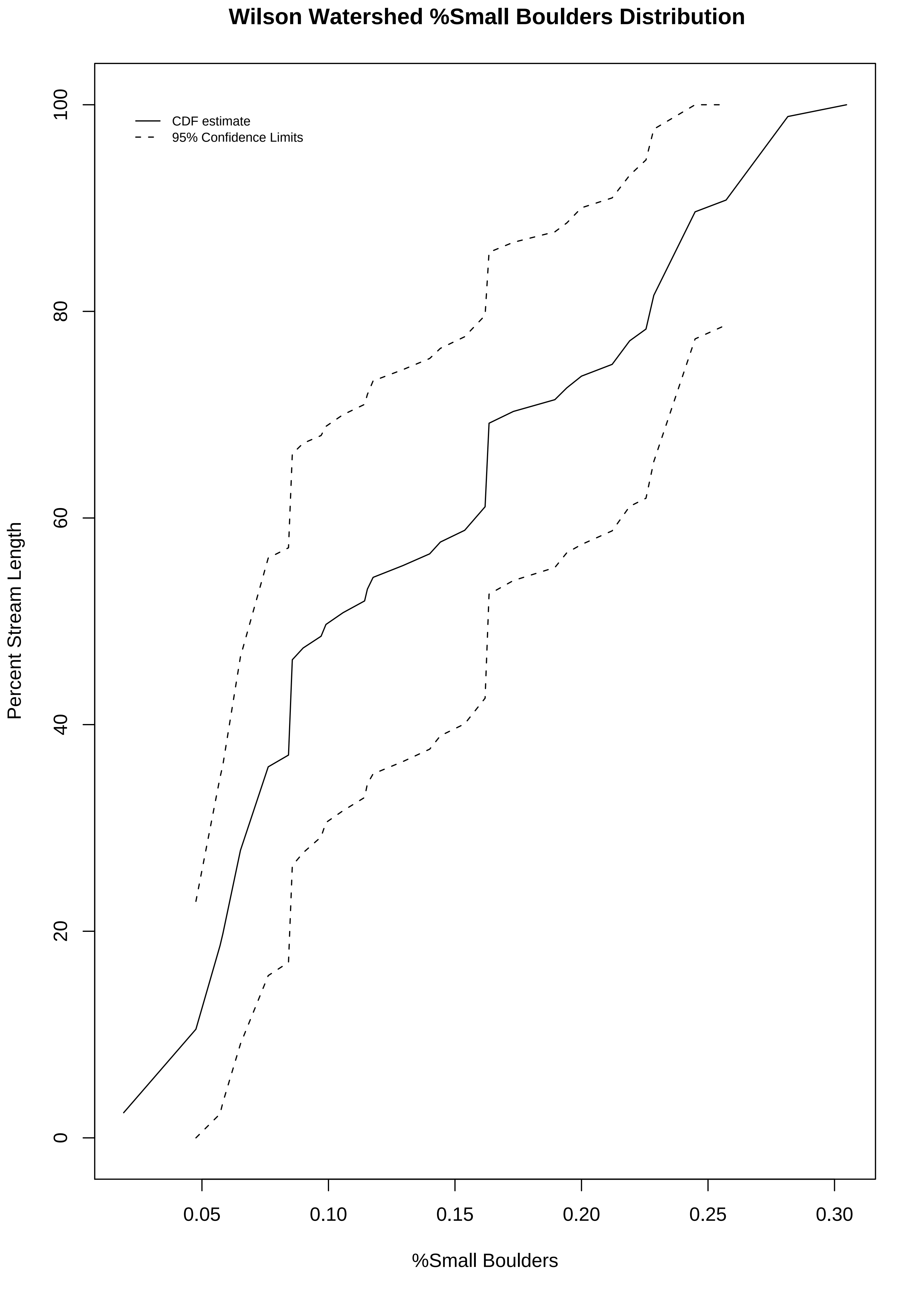

Wilson Watershed %Bedrock Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
%Bedrock

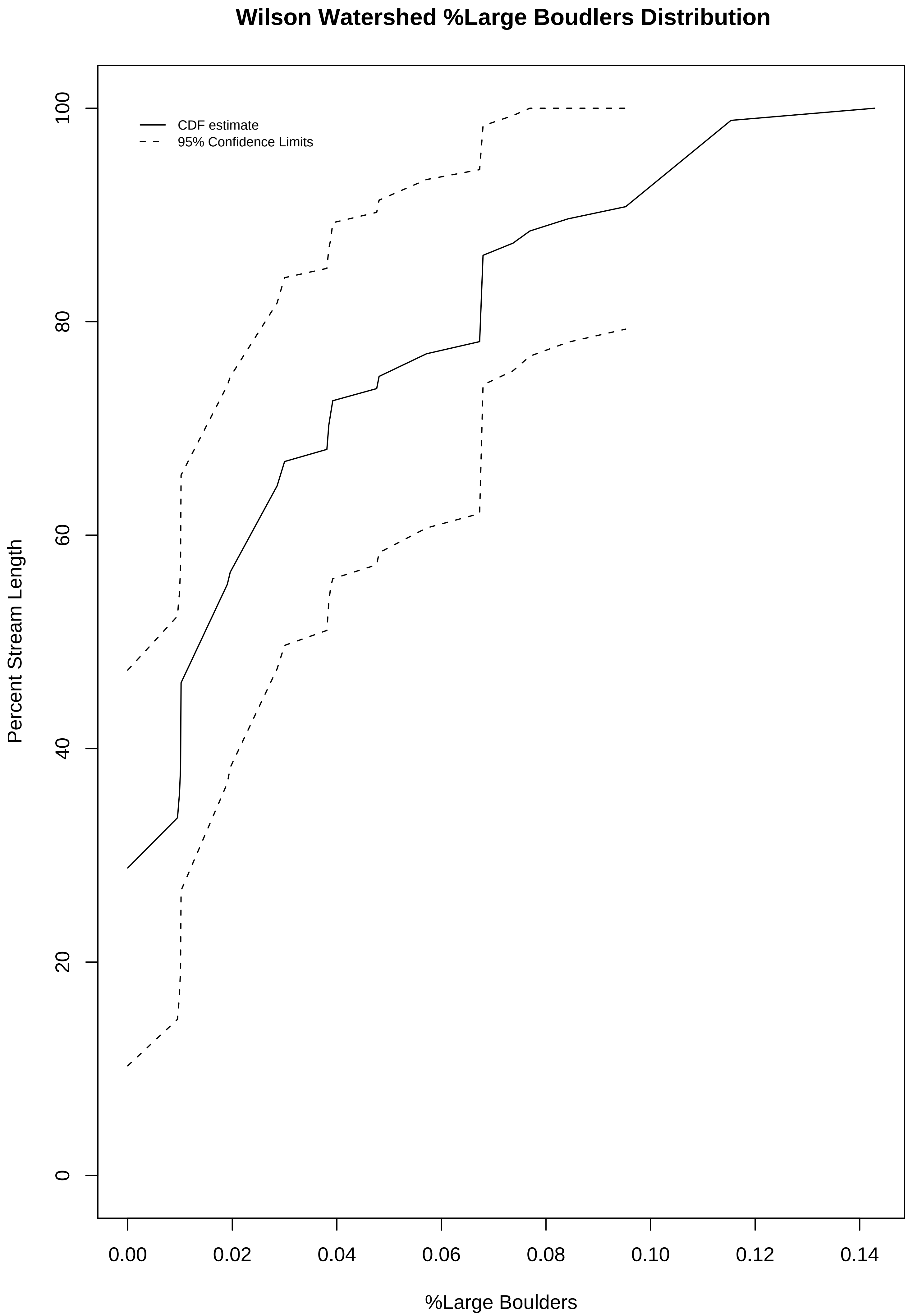


Wilson Watershed SAFN * D_cbf Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.000
0.005
0.010
0.015
0.020
0.025
SAFN * D_cbf

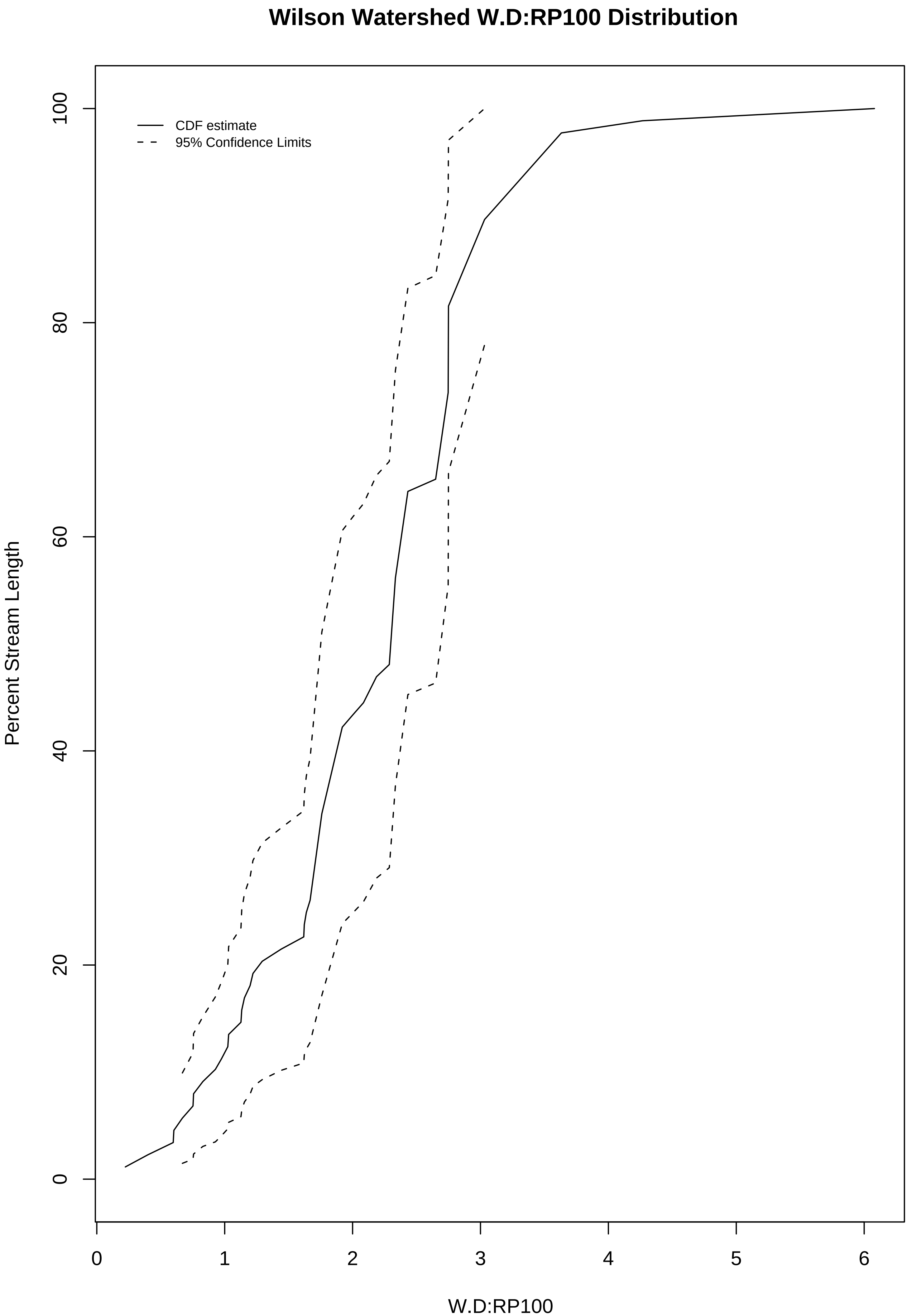
Wilson Watershed %Cobbles Distribution



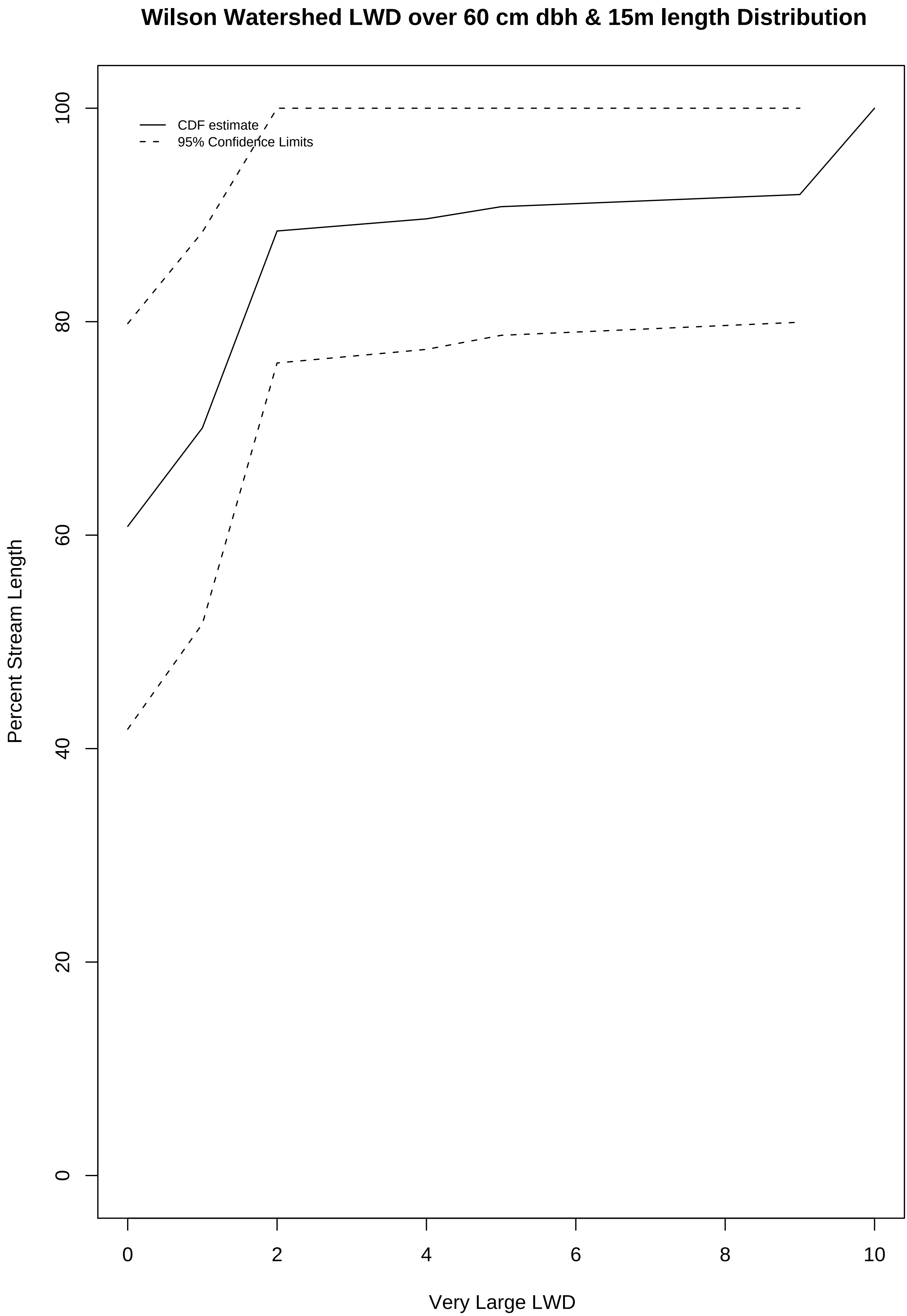

Wilson Watershed %Small Boulders Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.05
0.10
0.15
0.20
0.25
0.30
%Small Boulders



Wilson Watershed %Large Boudlers Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
%Large Boulders

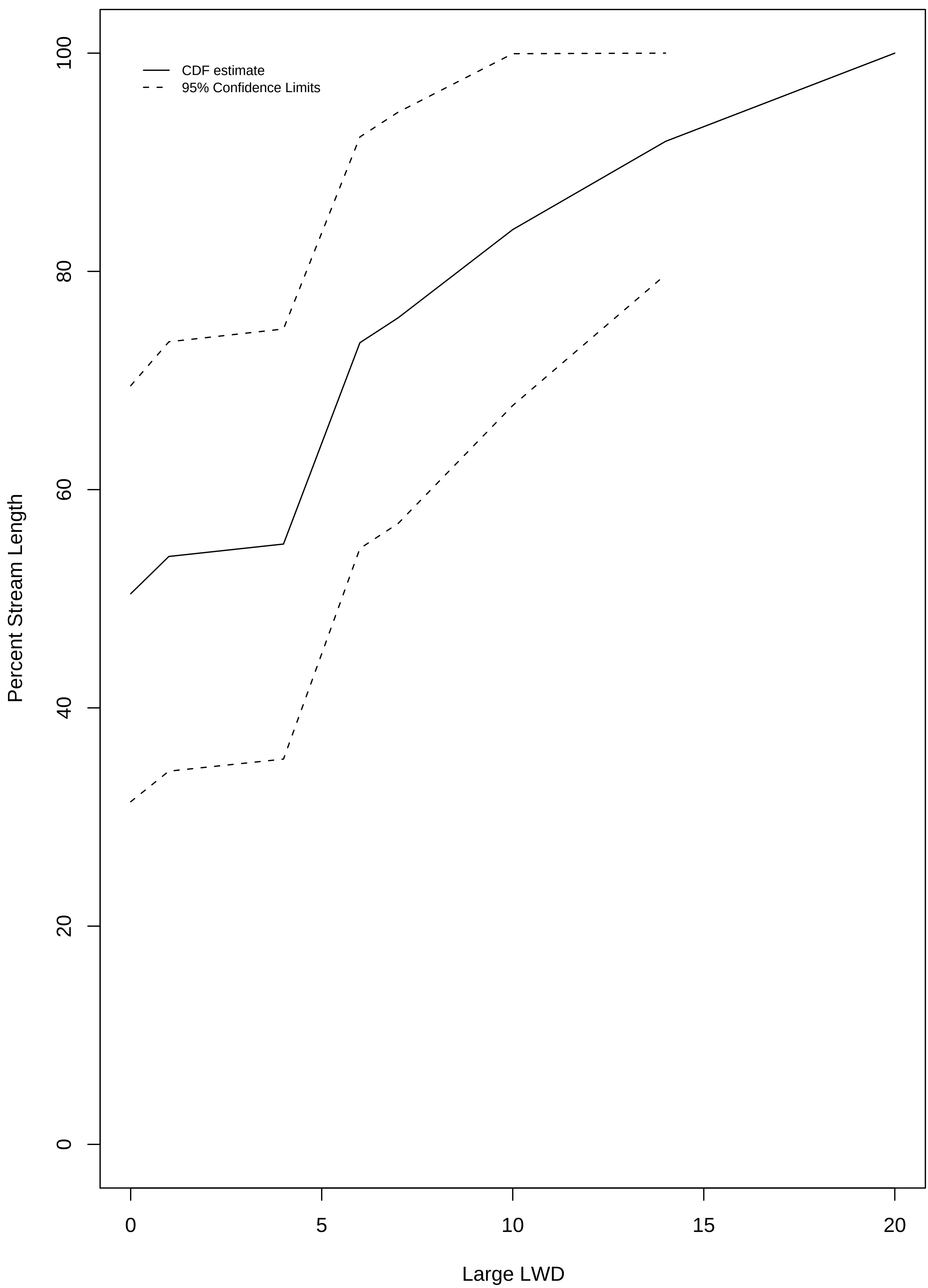


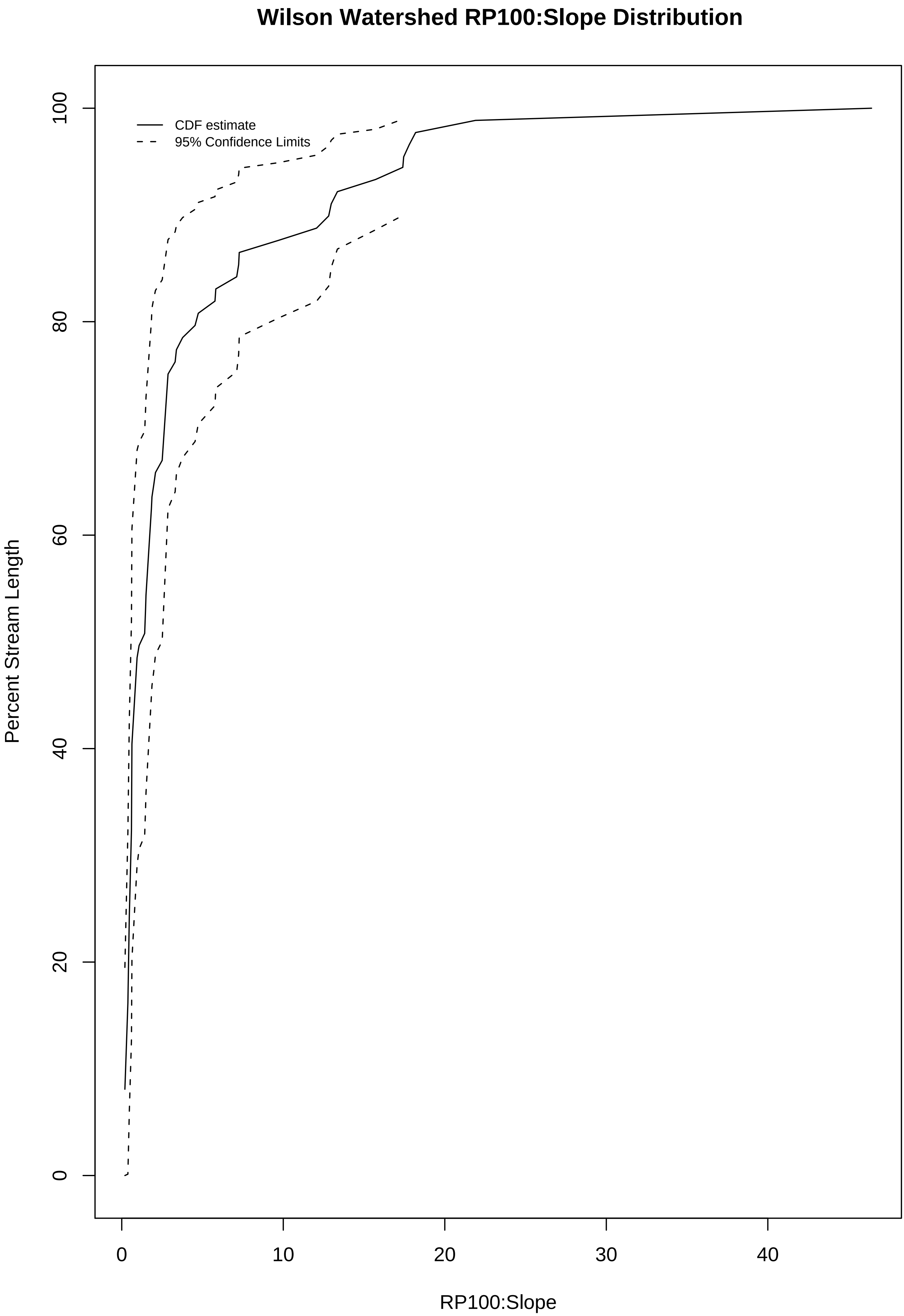
Wilson Watershed W.D:RP100 Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
1
2
3
4
5
6
W.D:RP100



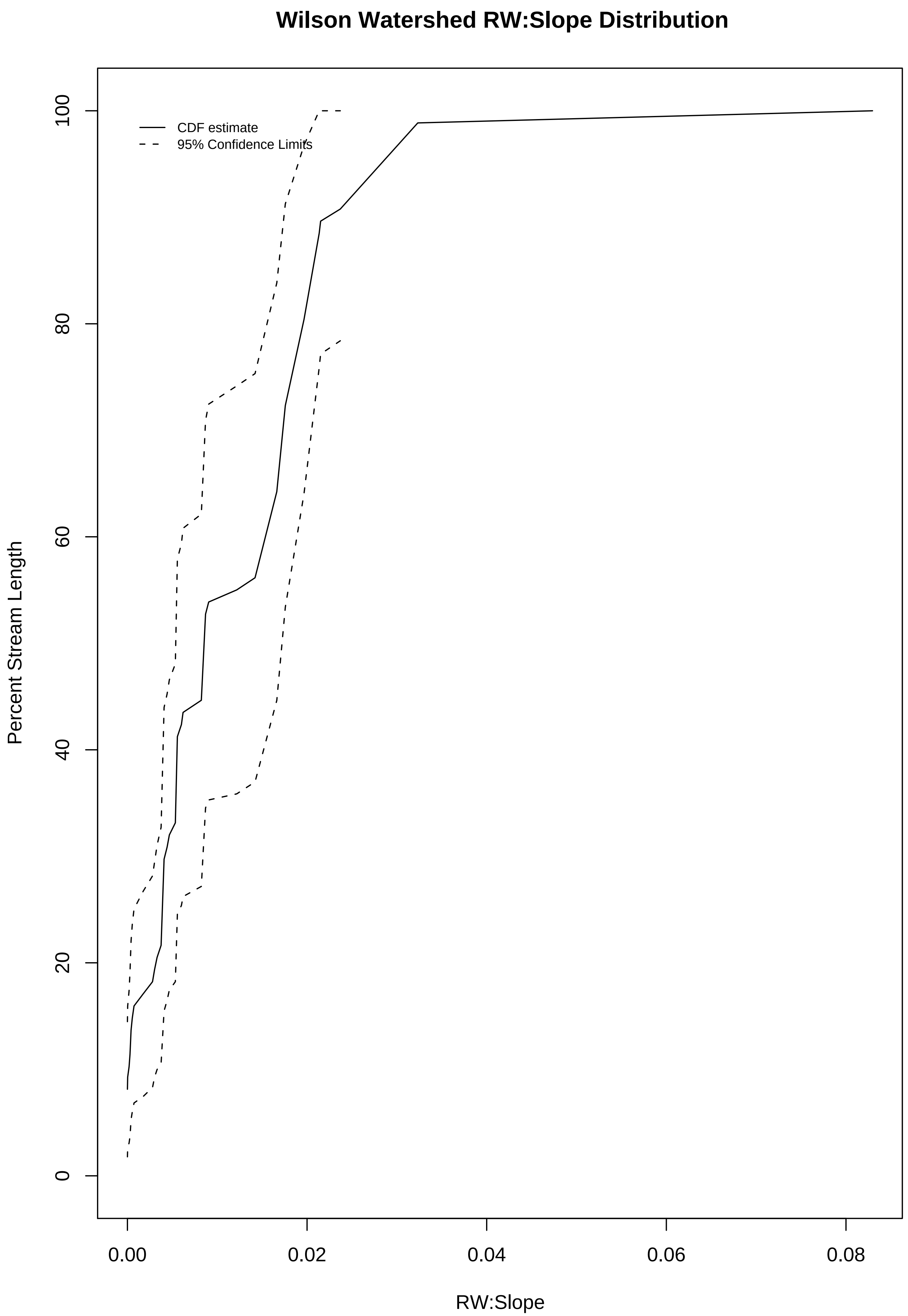
Wilson Watershed LWD over 60 cm dbh & 15m length Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0
2
4
6
8
10
Very Large LWD

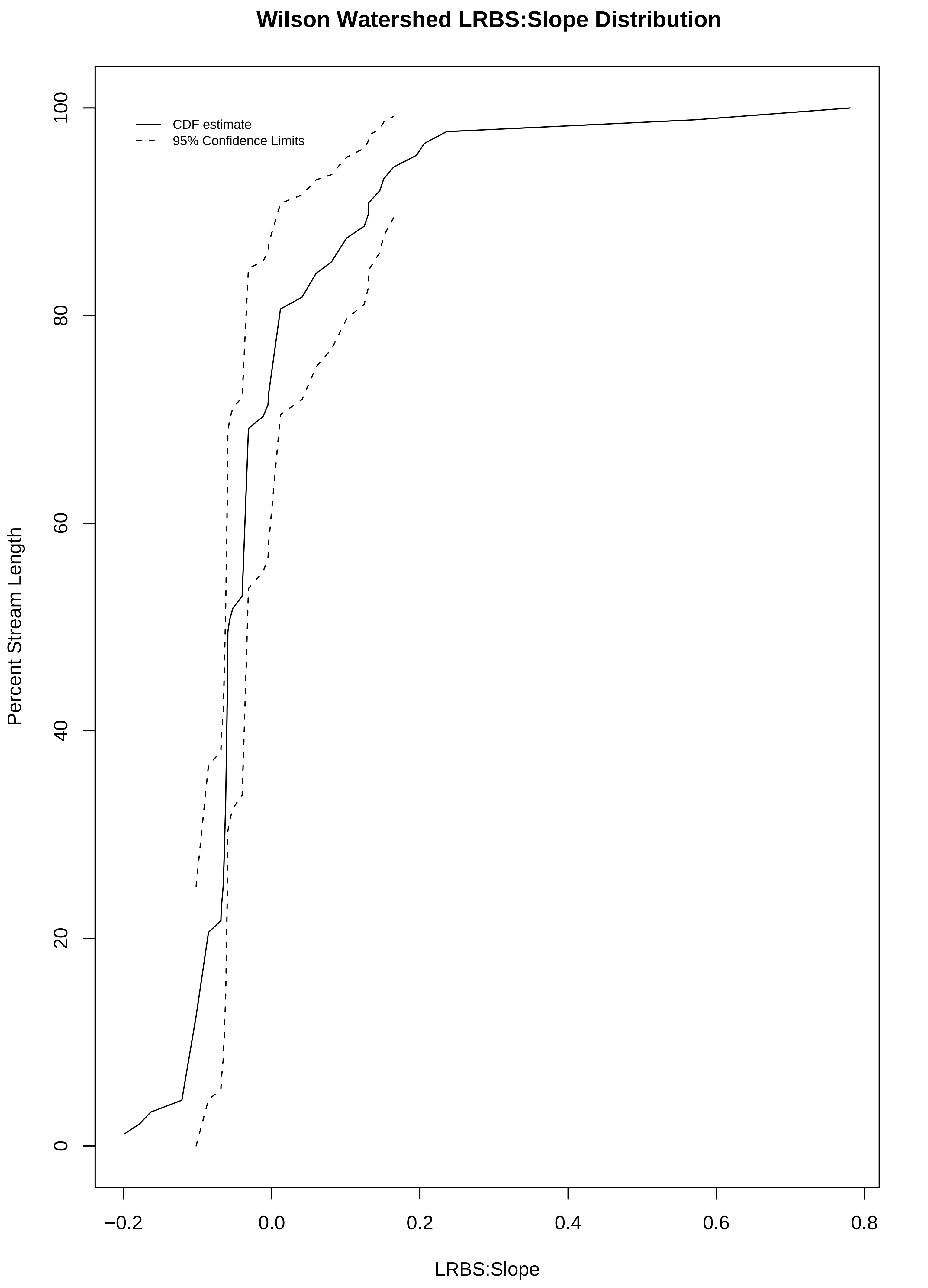
Wilson Watershed Wilson Watershed LWD over 60 cm dbh Distribution





Wilson Watershed RP100:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
RP100:Slope
0
20
40
60
80
100
0
10
20
30
40


Wilson Watershed RW:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
0.00
0.02
0.04
0.06
0.08
RW:Slope


Wilson Watershed LRBS:Slope Distribution
CDF estimate
95% Confidence Limits
Percent Stream Length
0
20
40
60
80
100
−0.2
0.0
0.2
0.4
0.6
0.8
LRBS:Slope

Appendix E - EMAP Section 7

EPA/XXX/X-XX/XXX
April 2001

ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM-SURFACE WATERS:

WESTERN PILOT STUDY FIELD OPERATIONS MANUAL FOR WADEABLE STREAMS

Edited by

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SECTION 7
PHYSICAL HABITAT CHARACTERIZATION (Rev 3/12/01)
(a modification of Kaufmann and Robison, 1998)

Philip R. Kaufmann[1]

In the broad sense, physical habitat in streams includes all those physical attributes that influence or provide sustenance to organisms within the stream. Stream physical habitat varies naturally, as do biological characteristics; thus, expectations differ even in the absence of anthropogenic disturbance. Within a given physiographic-climatic region, stream drainage area and overall stream gradient are likely to be strong natural determinants of many aspects of stream habitat, because of their influence on discharge, flood stage, and stream power (the product of discharge times gradient). Summarizing the habitat results of a workshop conducted by EMAP on stream monitoring design, Kaufmann (1993) identified seven general physical habitat attributes important in influencing stream ecology:

- Channel Dimensions
- Channel Gradient
- Channel Substrate Size and Type
- Habitat Complexity and Cover
- Riparian Vegetation Cover and Structure
- Anthropogenic Alterations
- Channel-Riparian Interaction

All of these attributes may be directly or indirectly altered by anthropogenic activities. Nevertheless, their expected values tend to vary systematically with stream size (drainage area) and overall gradient (as measured from topographic maps). The relationships of specific physical habitat measurements described in this section to these seven attributes are discussed by Kaufmann (1993). Aquatic macrophytes, riparian vegetation, and large woody debris are included in this and other physical habitat assessments because of their

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role in modifying habitat structure and light inputs, even though they are actually biological measures. The field physical habitat measurements from this field habitat characterization are used in the context of water chemistry, temperature, and other data sources (e.g., remote sensing of basin land use and land cover). The combined data analyses will more comprehensively describe additional habitat attributes and larger scales of physical habitat or human disturbance than are evaluated by the field assessment alone. A comprehensive data analysis guide (Kaufmann et al., 1999) discusses the detailed procedures used to calculate metrics related to stream reach and riparian habitat quality from filed data collected using the EMAP field protocols. This guide also discusses the precision associated with these measurements and metrics.

These procedures are intended for evaluating physical habitat in wadeable streams. The EMAP field procedures are most efficiently applied during low flow conditions and during times when terrestrial vegetation is active, but may be applied during other seasons and higher flows except as limited by safety considerations. This collection of procedures is designed for monitoring applications where robust, quantitative descriptions of reach-scale habitat are desired, but time is limited. The qualitative nature of the habitat quality rank scores produced by many currently available rapid habitat assessment methods (e.g., those described in Section 14) have not been demonstrated, as yet, to meet the objectives of EMAP, where more quantitative assessment is needed for site classification, trend interpretation, and analysis of possible causes of biotic impairment.

The habitat characterization protocol developed for EMAP differs from other rapid habitat assessment approaches (e.g., Plafkin et al., 1989; Rankin, 1995) by employing a randomized, systematic spatial sampling design that minimizes bias in the placement and positioning of measurements. Measures are taken over defined channel areas and these sampling areas or points are placed systematically at spacings that are proportional to baseflow channel width. This systematic sampling design scales the sampling reach length and resolution in proportion to stream size. It also allows statistical and series analyses of the data that are not possible under other designs. We strive to make the protocol objective and repeatable by using easily learned, repeatable measures of physical habitat in place of estimation techniques wherever possible. Where estimation is employed, we direct the sampling team to estimate attributes that are otherwise measurable, rather than estimating the quality or importance of the attribute to the biota or its importance as an indicator of disturbance. We have included the more traditional visual classification of channel unit scale habitat types because they have been useful in past studies and enhance comparability with other work.

The time commitment to gain repeatability and precision is greater than that required for more qualitative methods. The additional substrate measurements (pebble count of 105 vs 55 particles) adds 20 to 30 minutes to the protocol described by Kaufmann and Robison (1998). In our field trials, two people typically complete the specified channel, riparian, and discharge measurements in about 3.5 hours of field time (see Section 2, Table 2-1). However, the time required can vary considerably with channel characteristics. On streams up to about 4 meters wide with sparse woody debris, measurements can be completed in about two hours. The current protocol, requiring 21 wetted width measurements, will require less than 4.5 hours for a well-practiced crew of two, even in large (>10 m wide), complex streams with abundant woody debris and deep water.

The procedures are employed on a sampling reach length 40 times its low flow wetted width, as described in Section 4. Measurement points are systematically placed to statistically represent the entire reach. Stream depth and wetted width are measured at very tightly spaced intervals, whereas channel cross-section profiles, substrate, bank characteristics and riparian vegetation structure are measured at larger spacings. Woody debris is tallied along the full length of the sampling reach, and discharge is measured at one location (see Section 6). The tightly spaced depth and width measures allow calculation of indices of channel structural complexity, objective classification of channel units such as pools, and quantification of residual pool depth, pool volume, and total stream volume.

For EMAP-WP, there several modifications to various procedures previously published for EMAP-SW by Kaufmann and Robison (1998). These are summarized in Table 7-1. Four procedures (substrate particle size, instream fish cover, human influence, and thalweg habitat classification) are modified slightly from previous versions., The increase in the number of particles to be included in the systematic pebble count (from 55 particles to 105) increases the precision of substrate characterizations such as %fines. To obtain the additional particles, 10 “supplemental” cross-sections are located mid-way between successive “regular” transects. Procedures for locating and estimating the size of particles on each cross-section remain unchanged, for “regular” and “supplemental” cross-sections, except that only the substrate size class and the wetted width data are recorded at the 10 supplemental cross-sections. Logistically, the supplemental substrate cross-section procedures are accomplished as part of the thalweg profile that is undertaken between regular transects (Section 7.4.1). However, the details of the actual measurements and observations are described in Section 7.5.2. The instream fish cover (Section 7.5.6) and human influence procedures (Section 7.5.7) now include additional or modified features.

TABLE 7-1. SUMMARY OF PHYSICAL HABITAT PROTOCOL CHANGES FOR THE EMAP-SW WESTERN PILOT STUDY

Modifications from Kaufmann and Robison (1998):

11. Substrate: The systematic pebble count is augmented from 55 particles (5 particles in each of 11 cross-sections) to 105 particles (5 particles in each of 21 cross-sections). Ten additional cross-sections are located mid-way between each regular transects. Only the substrate size class and the wetted width data are recorded at each supplemental cross-section.

12. Instream Fish Cover: Fish concealment features now include in-channel live trees or roots. In ephemeral streams these are assessed within the bankfull channel.

13. Human Influence: The human influence category "Pavement" is modified to include cleared barren areas and renamed "Pavement/cleared lot."

14. Riparian "Legacy" Trees and Invasive Alien Plants: New protocol to obtain information on the size and proximity of large, old riparian trees and on the occurrence of non-native invasive tree, shrub and grass species.

15. Channel Constraint: New protocol to classify the general degree of geomorphic channel constraint. This is an overall assessment of reach characteristics that is done after completing the thalweg profile and other measurements at the 11 Cross-section Transects.

16. Debris torrents: New protocol to identify evidence of major floods or debris torrents (lahars). This is an overall assessment for the reach as a whole, and is done after completing the other measurements.

Modifications from Year 2000 Western Pilot Study Activities:

1. Dry Streams: Physical habitat data are no longer collected at streams reaches that are completely dry at the time of the field visit.

2. Off-Channel Backwater Habitat: The thalweg habitat classification now includes the tallying of presence/absence of off-channel backwater habitats, (e.g., sloughs, alcoves, backwater pools). If a backwater pool dominates the main channel habitat, PB is also entered as the channel unit classification code, as in previous versions of this field protocol.

3. Riparian "Legacy" Trees and Invasive Alien Plants: Additional details regarding these procedures is included. Target species of non-native invasive tree, shrub and grass species is modified for some areas of the western U.S.

4. Channel Constraint: Additional detail regarding procedure is included; the number of constraint classes is reduced

In ephemeral streams, fish cover is assessed within the bankfull channel. The thalweg habitat classification (Section 7.4.1) now includes the tallying of presence/absence of off-channel backwater habitats, (e.g., sloughs, alcoves, backwater pools). Backwater pools are included in this tally, but if they are the dominant channel habitat classification, they are also identified by a channel unit classification, as in previous versions of this field protocol.

Three new procedures are included for EMAP-WP. The first (Section 7.5.8) is added to provide additional data on the size and proximity of large, old riparian trees and on the occurrence of non-native invasive tree, shrub and grass species. The second (Section 7.6.1), is added to classify the general degree of geomorphic channel constraint. This is an overall assessment of reach characteristics that is done after completing the thalweg profile and other measurements at the 11 cross-section Transects. Finally, a procedure is added (Section 7.6.2) to identify evidence of major floods or debris torrents (lahars). This is an overall assessment for the reach as a whole, and is done after completing the other measurements. The field form and procedures for assessing debris torrent evidence have been applied in Oregon and Washington research and R-EMAP surveys since 1994.

7.1 COMPONENTS OF THE HABITAT CHARACTERIZATION

There are five different components of the EMAP physical habitat characterization (Table 7-2), including stream discharge, which is described in Section 6. Measurements for the remaining four components are recorded on 11 copies of a two-sided field form, plus separate forms for recording slope and bearing measurements, recording observations concerning riparian legacy (large) trees and alien invasive plants, assessing the degree of channel constraint, and recording evidence of debris torrents or recent major flooding. The **thalweg profile** is a longitudinal survey of depth, habitat class, presence of soft/small sediment deposits, and off-channel habitat at 100 equally spaced intervals (150 in streams less than 2.5 m wide) along the centerline between the two ends of the sampling reach. "Thalweg" refers to the flow path of the deepest water in a stream channel. Wetted width is measured and substrate size is evaluated at 21 equally spaced cross-sections (at 11 regular Transects A through K plus 10 supplemental cross-sections spaced midway between each of these). Data for the second component, the **woody debris tally**, are recorded for each of 10 segments of stream located between the 11 regular transects. The third component, the **channel and riparian characterization**, includes measures and/or visual estimates of channel dimensions, substrate, fish cover, bank characteristics, riparian vegetation

TABLE 7-2. COMPONENTS OF PHYSICAL HABITAT CHARACTERIZATION

Component	Description
Thalweg Profile: (Section 7.4.1)	• Measure maximum depth, classify habitat and pool-forming features, check presence of backwaters, side channels and deposits of soft, small sediment at 10-15 equally spaced intervals between each of 11 channel cross-section transects (100 or 150 individual measurements along entire reach). • Measure wetted width and evaluate substrate size classes at 11 regular channel cross-section transects and midway between them (21 width measurements and substrate cross-sections).
Woody Debris Tally: (Section 7.4.2)	• Between each of the channel cross sections, tally large woody debris numbers within and above the bankfull channel according to length and diameter classes (10 separate tallies).
Channel and Riparian Characterization: (Section 7.5)	• At 11 cross-section transects (21 for substrate size) placed at equal intervals along reach length: - <u>Measure</u>: channel cross section dimensions, bank height, bank undercut distance, bank angle, slope and compass bearing (backsight), and riparian canopy density (densiometer). - <u>Visually Estimate</u>[a]: substrate size class and embeddedness; areal cover class and type (e.g., woody trees) of riparian vegetation in Canopy, Mid-Layer and Ground Cover; areal cover class of fish concealment features, aquatic macrophytes and filamentous algae. - <u>Observe & Record</u>[a]: Presence and proximity of human disturbances and large trees; presence of alien plants
Assessment of Channel Constraint, Debris Torrents, and Major Floods (Section 7.6)	• After completing Thalweg and Transect measurements and observations, identify features causing channel constraint, estimate the percentage of constrained channel margin for the whole reach, and estimate the ratio of bankfull/valley width. Check evidence of recent major floods and debris torrent scour or deposition.
Discharge: (see Section 6)	• In medium and large streams (defined in Section 6) measure water depth and velocity at 0.6 depth at 15 to 20 equally spaced intervals across one carefully chosen channel cross-section. • In very small streams, measure discharge by timing the filling of a bucket or timing the passage of a neutral buoyant object through a segment whose cross-sectional area has been estimated.

[a] Substrate size class is estimated for a total of 105 particles taken at 5 equally-spaced points along each of 21 cross-sections. Depth is measured and embeddedness estimated for the 55 particles located along the 11 regular transects A through K. Cross-sections are defined by laying the surveyor's rod or tape to span the wetted channel. Woody debris is tallied over the distance between each cross-section and the next cross-section upstream. Riparian vegetation and human disturbances are observed 5m upstream and 5m downstream from the cross section transect. They extend shoreward 10m from left and right banks. Fish cover types, aquatic macrophytes, and algae are observed within the channel 5m upstream and 5m downstream from the cross section stations. These boundaries for visual observations are estimated by eye.

structure, presence of large (legacy) riparian trees, non-native (alien) riparian plants, and evidence of human disturbances. These data are obtained at each of the 11 equally-spaced transects established within the sampling reach. In addition, measurements of the stream slope and compass bearing between stations are obtained, providing information necessary for calculating reach gradient, residual pool volume, and channel sinuosity. The fourth component, **assessment of channel constraint, debris torrents, and major floods**, is an overall assessment of these characteristics for the whole reach, and is undertaken after the other components are completed.

7.2 HABITAT SAMPLING LOCATIONS WITHIN THE SAMPLING REACH

Measurements are made at two scales of resolution along the length of the reach; the results are later aggregated and expressed for the entire reach, a third level of resolution. Figure 7-1 illustrates the locations within the sampling reach where data for the different components of the physical habitat characterization are obtained. We assess habitat over stream reach lengths that are approximately 40 times their average wetted width at baseflow, but not less than 150 m long. This allows us to adjust the sample reach length to accommodate varying sizes of streams (see Section 2). Many of the channel and riparian features are characterized on 11 cross-sections and pairs of riparian plots spaced at 4 channel-width intervals (i.e., **Transect spacing = 1/10th the total reach length**). The thalweg profile measurements must be spaced evenly over the entire sampling reach. In addition, they must be sufficiently close together that they do not "miss" deep areas and habitat units that are in a size range of about ⅓ to ½ of the average channel width. Follow these guidelines for choosing the interval between thalweg profile measurements:

- **Channel Width < 2.5 m — interval = 1.0 m**
- **Channel Width 2.5-3.5 m — interval = 1.5 m**
- **Channel Width > 3.5 m — interval = 0.01 × (reach length)**

Following these guidelines, you will make 150 evenly spaced thalweg profile measurements in the smallest category of streams, 15 between each detailed channel cross section. In all of the larger stream sizes, you will make 100 measurements, 10 between each cross section. <u>We specify width measurements only at the 11 regular transect cross-sections and 10 supplemental cross-sections at the thalweg measurement points midway between each pair of regular transects (a total of 21 wetted widths). If more resolution is desired, width measurements may be made at all 100 or 150 thalweg profile locations. In contrast with a</u>

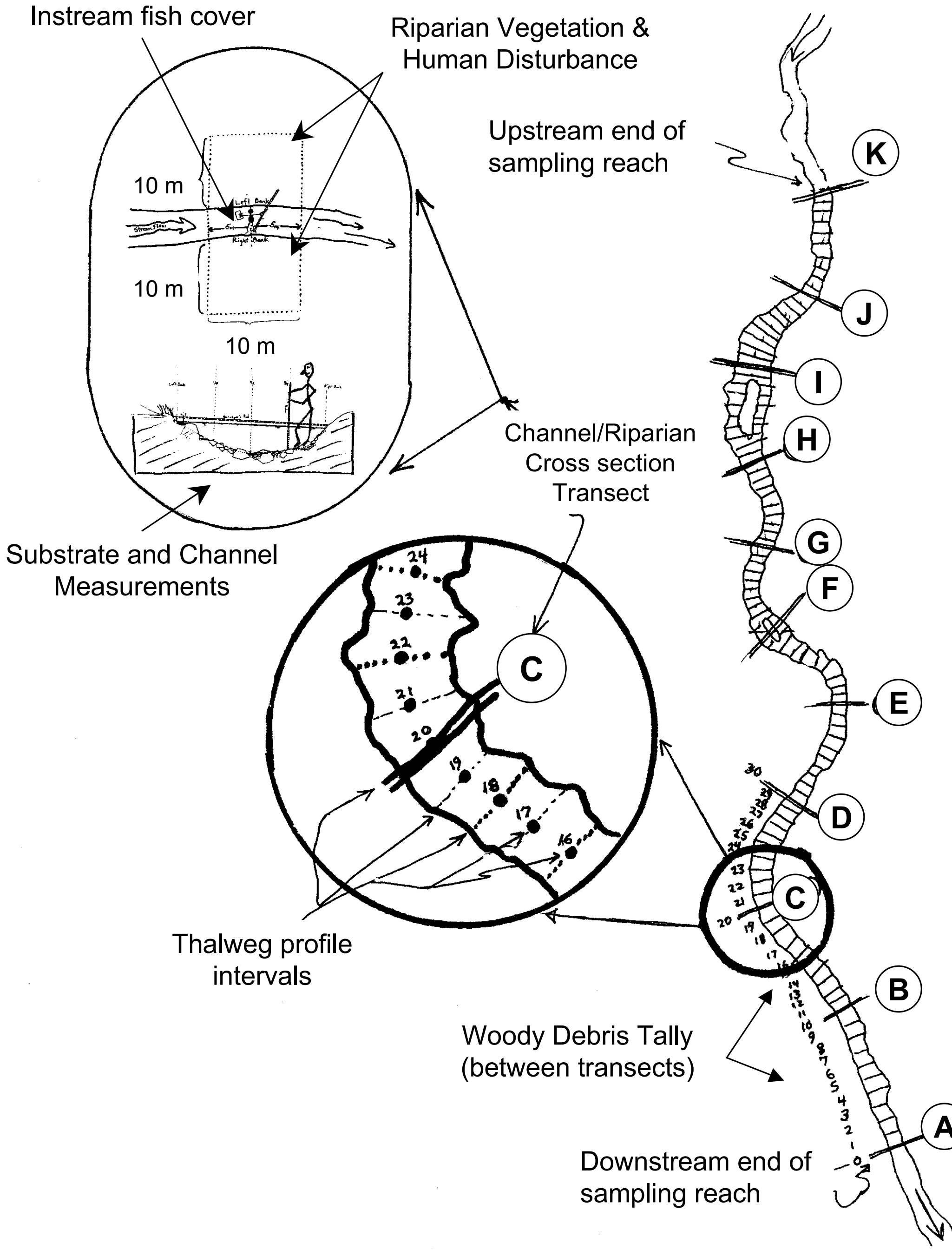
Instream fish cover
Riparian Vegetation & Human Disturbance
10 m
10 m
10 m
Substrate and Channel Measurements
Channel/Riparian Cross section Transect
Upstream end of sampling reach
K
J
I
H
G
F
E
D
C
B
A
Thalweg profile intervals
Woody Debris Tally (between transects)
Downstream end of sampling reach

Figure 7-1. Sampling reach layout for physical habitat measurements (plan view).

previous publication of these methods (Kaufmann and Robison, 1998), where substrate particles are evaluated at 5 cross-section locations at 11 transects, we specify substrate measurements at the 10 supplemental cross-sections in addition to those at the 11 regular transects, for a systematic "pebble count" of 105 (rather than 55) particles.

7.3 LOGISTICS AND WORK FLOW

The five components (Table 7-2) of the habitat characterization are organized into four grouped activities:

1. Thalweg Profile and Large Woody Debris Tally (Section 7.4). Two people (the "geomorphs") proceed upstream from the downstream end of the sampling reach (see Figure 7-1) making observations and measurements at the chosen increment spacing. One person is in the channel making width and depth measurements, and determining whether soft/small sediment deposits are present under his/her staff. The other person records these measurements, classifies the channel habitat, records presence/absence of side channels and off-channel habitats (e.g. backwater pools, sloughs, alcoves), and tallies large woody debris. Each time this team reaches a flag marking a new cross-section transect, they start filling out a new copy of the Thalweg Profile and Woody Debris Form. They interrupt the thalweg profile and woody debris tallying activities to complete data collection at each cross-section transect as it comes. When the crew member in the water makes a width measurement at channel locations midway between regular transects (i.e., A, B,...K), s/he also locates and estimates the size class of the substrate articles on the left channel margin and at positions 25%, 50%, 75%, and 100% of the distance across the wetted channel. Procedures for this substrate tally are the same as for those at regular cross-sections, but data are recorded on the Thalweg Profile side of the field form.

2. Channel/Riparian Cross-Sections (Section 7.5). One person proceeds with the channel cross-section dimension, substrate, bank, and canopy cover measurements. The second person records those measurements on the Channel/ Riparian Cross-section Form while making visual estimates of riparian vegetation structure, instream fish cover, and human disturbance specified on that form. They also make observations to complete the Riparian "Legacy" Tree and Invasive "Alien" Plant field form. Slope and bearing are determined together by backsiting to the previous transect. Intermediate flagging (of a different color)

may have to be used if the stream is extremely brushy, sinuous, or steep to the point that you cannot site for slope and bearing measures between two adjacent transects. (Note that the crews could tally woody debris while doing the back-sight, rather than during the thalweg profile measurements.)

3. Channel Constraint and Torrent Evidence (Section 7.6). After completing observations and measurements along the thalweg and at all 11 transects, the field crew completes the overall reach assessments of channel constraint and evidence of debris torrents and major floods.

4. Discharge (Section 6). Discharge measurements are made after collecting the chemistry sample. They are done at a chosen optimal cross section (but not necessarily at a transect) near the X-site. However, do not use the electromagnetic current meter close to where electrofishing is taking place. Furthermore, if a lot of channel disruption is necessary and sediment must be stirred up, wait on this activity until all chemical and biological sampling has been completed.

7.4 THALWEG PROFILE AND LARGE WOODY DEBRIS MEASUREMENTS

7.4.1 Thalweg Profile

"Thalweg" refers to the flow path of the deepest water in a stream channel. The thalweg profile is a longitudinal survey of maximum depth and several other selected characteristics at 100 or 150 equally spaced points along the centerline of the stream between the two ends of the stream reach. Data from the thalweg profile allows calculation of indices of residual pool volume, stream size, channel complexity, and the relative proportions of habitat types such as riffles and pools. The EMAP-SW habitat assessment modifies traditional methods by proceeding upstream in the middle of the channel, rather than along the thalweg itself (though each thalweg depth measurement is taken at the deepest point at each incremental position). One field person walks upstream (wearing felt-soled waders) carrying a fiberglass telescoping (1.5 to 7.5 m) surveyor's rod and a 1-m metric ruler (or a calibrated rod or pole, such as a ski pole). A second person on the bank or in the stream carries a clipboard with 11 copies of the field data form.

The procedure for obtaining thalweg profile measurements is presented in Table 7-3. Record data on the Thalweg Profile and Woody Debris Data Form as shown in Figure 7-2. Use the surveyor's rod and a metric ruler or calibrated rod or pole to make the required

TABLE 7-3. THALWEG PROFILE PROCEDURE

1. Determine the interval between measurement stations based on the wetted width used to determine the length of the sampling reach.

   For widths < 2.5 m, establish stations every 1 m.
   For widths between 2.5 and 3.5 m, establish stations every 1.5 m
   For widths > 3.5 m, establish stations at increments equal to 0.01 times the sampling reach length.

2. Complete the header information on the Thalweg Profile and Woody Debris Form, noting the transect pair (downstream to upstream). Record the interval distance determined in Step 1 in the “INCREMENT” field on the field data form.

   NOTE: If a side channel is present, and contains between 16 and 49% of the total flow, establish secondary cross-section transects as necessary. Use separate field data forms to record data for the side channel, designating each secondary transect by checking both “X” and the associated primary transect letter (e.g., XA, XB, etc.). Collect all channel and riparian cross-section measurements from the side channel.

3. Begin at the downstream end (station “0") of the first transect (Transect “A”).

4. Measure the wetted width if you are at station “0", station “5" (if the stream width defining the reach length is $ 2.5 m), or station “7" (if the stream width defining the reach length is < 2.5 m). Wetted width is measured across and over mid-channel bars and boulders. Record the width on the field data form to the nearest 0.1 m for widths up to about 3 meters, and to the nearest 5% for widths > 3 m. This is 0.2 m for widths of 4 to 6 m, 0.3 m for widths of 7 to 8 m, and 0.5 m for widths of 9 or 10 m, and so on. For dry and intermittent streams, where no water is in the channel, record zeros for wetted width.

   NOTE: If a mid-channel bar is present at a station where wetted width is measured, measure the bar width and record it on the field data form.

5. At station 5 or 7 (see above) classify the substrate particle size at the tip of your depth measuring rod at the left wetted margin and at positions 25%, 50%, 75%, and 100% of the distance across the wetted width of the stream. This procedure is identical to the substrate size evaluation procedure described for regular channel cross-sections A through K, except that for these mid-way supplemental cross-sections, substrate size is entered on the Thalweg Profile side of the field form.

6. At each thalweg profile station, use a meter ruler or a calibrated pole or rod to locate the deepest point (the “thalweg”), which may not always be located at mid-channel. Measure the thalweg depth to the nearest cm, and record it on the thalweg profile form. Read the depth on the side of the ruler, rod, or pole to avoid inaccuracies due to the wave formed by the rod in moving water.

   NOTE: For dry and intermittent streams, where no water is in the channel, record zeros for depth.

(continued)

TABLE 7-3 (Continued)

NOTE: **At stations where the thalweg is too deep to measure directly**, stand in shallower water and extend the surveyor's rod or calibrated rod or pole at an angle to reach the thalweg. Determine the rod angle by resting the clinometer on the upper surface of the rod and reading the angle on the external scale of the clinometer. Leave the depth reading for the station blank, and record a "U" flag. Record the water level on the rod and the rod angle in the comments section of the field data form. For even deeper depths, it is possible to use the same procedure with a taut string as the measuring device. Tie a weight to one end of a length of string or fishing line, and then toss the weight into the deepest channel location. Draw the string up tight and measure the length of the line that is under water. Measure the string angle with the clinometer exactly as done for the surveyor's rod.

7. At the point where the thalweg depth is determined, observe whether unconsolidated, loose ("soft") deposits of small diameter ($\leq$16mm), sediments are present directly beneath your ruler, rod, or pole. Soft/small sediments are defined here as fine gravel, sand, silt, clay or muck readily apparent by "feeling" the bottom with the staff. Record presence or absence in the "SOFT/SMALL SEDIMENT" field on the field data form. Note: A thin coating of fine sediment or silty algae coating the surface of cobbles should not be considered soft/small sediment for this assessment. However, fine sediment coatings should be identified in the comments section of the field form when determining substrate size and type.

8. Determine the channel unit code and pool forming element codes for the station. Record these on the field data form using the standard codes provided. For dry and intermittent streams, where no water is in the channel, record habitat type as dry channel (DR).

9. If the station cross-section intersects a mid-channel bar, Indicate the presence of the bar in the "BAR WIDTH" field on the field data form.

10. Record the presence or absence of a side channel at the station's cross-section in the "SIDE CHANNEL" field on the field data form.

11. Record the presence or absence of quiescent off-channel aquatic habitats, including sloughs, alcoves and backwater pools in the "Backwater" column of the field form.

12. Proceed upstream to the next station, and repeat Steps 4 through 11.

13. Repeat Steps 4 through 12 until you reach the next transect. At this point complete Channel/Riparian measurements at the new transect (Section 7.5). Then prepare a new Thalweg Profile and Woody Debris Form and repeat Steps 2 through 12 for each of the reach segments, until you reach the upstream end of the sampling reach (Transect "K").

PHAB: THALWEG PROFILE & WOODY DEBRIS FORM STREAMS

Reviewed by (initial): DP

SITE ID: WXXP99-9999 DATE: 07 / 01 / 2001 TRANSEST: ☐ A-B ☒ B-C ☐ C-D ☐ D-E ☐ E-F ☐ F-G ☐ G-H ☐ H-I ☐ I-J ☐ J-K

THALWEG PROFILE — For Transect A-B ONLY: Increment (m) X.X: ____ Total Reach Length (m): ____

STATION	THALWEG DEPTH (cm) (XXX)	WETTED WIDTH (m) (XXX.X)	BAR WIDTH[1] Present	BAR WIDTH[1] XX.X	SOFT /SMALL SEDIMENT	CHANNEL UNIT CODE	POOL FORM CODE	SIDE CHANNEL	BACK WATER	FLAG	COMMENTS
0	14	3.6	(Y) N	0.8	Y (N)	RI	N	Y (N)	Y (N)		
1	13		(Y) N		Y (N)	RI	N	Y (N)	Y (N)		
2	27		(Y) N		Y (N)	RI	N	Y (N)	Y (N)		
3	46		(Y) N		Y (N)	PT	F	Y (N)	Y (N)		
4	40		(Y) N		Y (N)	PT	F	Y (N)	Y (N)		
*5	35	3.2	(Y) N		Y (N)	PT	F	Y (N)	(Y) N		
6	34		(Y) N		(Y) N	PT	F	Y (N)	(Y) N		
*7	47		Y (N)		(Y) N	PT	F	Y (N)	Y (N)		
8	53		Y (N)		(Y) N	PT	F	Y (N)	Y (N)		
9	57		Y (N)		(Y) N	PT	F	(Y) N	Y (N)	F1	SIDE CHANNEL CONVERGENCE
10			Y N		Y N			Y N	Y N		
11			Y N		Y N			Y N	Y N		
12			Y N		Y N			Y N	Y N		
13			Y N		Y N			Y N	Y N		
14			Y N		Y N			Y N	Y N		

SUBSTRATE

Station (5 or 7)	LFT	LCTR	CTR	RCTR	RGT	FLAG
*5	SA	SA	GF	SA	FN	

FLAG	COMMENTS

LARGE WOODY DEBRIS (≥10 cm small end diameter; ≥ 1.5 m length) — CHECK IF ALL UNMARKED BOXES ARE ZERO ☐ — FLAG ____

DIAMETER LARGE END	PIECES ALL/PART IN BANKFULL CHANNEL Length 1.5-5m	5-15m	>15m	PIECES BRIDGE ABOVE BANKFULL CHANNEL Length 1.5-5m	5-15m	>15m
0.1-<0.3 m	6	4	0	0	0	0
0.3-0.6 m	0	0	0	2	0	0
0.6-0.8 m	0	0	0	0	0	0
>0.8 m	0	0	0	0	1	0

SUBSTRATE SIZE CLASS CODES	POOL FORM CODES	CHANNEL UNIT CODES
RS = BEDROCK (SMOOTH) - (LARGER THAN A CAR) RR = BEDROCK (ROUGH) - (LARGER THAN A CAR) BL = BOULDER (250 TO 4000 mm) - BASKETBALL TO CAR) CB = COBBLE (64 TO 250 mm) - (TENNIS BALL TO BASKETBALL) GC = COARSE GRAVEL (16 TO 64 mm) - (MARBLE TO TENNIS BALL) GF = FINE GRAVEL (2 TO 16 mm) - (LADYBUG TO MARBLE) SA = SAND (0.06 TO 2 mm) - (GRITTY - UP TO LADYBUG SIZE) FN = SILT/ CLAY / MUCK - (NOT GRITTY) HP = HARDPAN - (FIRM, CONSOLIDATED FINE SUBSTRATE) WD = WOOD - (ANY SIZE) OT = OTHER (COMMENT ON OTHER SIDE)	N = Not a pool W = Large Woody Debris R = Rootwad B = Boulder or Bedrock F = Unknown, fluvial COMBINATIONS: eg. WR, BR, WRB	PP = Pool, Plunge PT = Pool, Trench PL = Pool, Lateral Scour PB = Pool, Backwater PD = Pool, Impoundment GL = Glide RI = Riffle RA = Rapid CA = Cascade FA = Falls DR = Dry Channel

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Flag Codes: K = no measurement made; U = suspect measurement; F1, F2, ect. = flags assigned by each field crew. Explain all flags in comments. 1 = Measure Bar Width at Station 0 and Mid-Station (5 or 7).

03/26/2001 2001 Phab Thalweg Stream

Figure 7-2. Thalweg Profile and Woody Debris Form.

depth and width measurements, and to measure off the distance between measurement points as you proceed upstream. Ideally, every tenth thalweg measurement will bring you within one increment spacing from the flag marking a new cross-section profile. The flag will have been set previously by carefully taping along the channel, making the same bends that you do while measuring the thalweg profile (refer to Figure 7-1). However, you may still need to make minor adjustments to align each 10th measurement to be one thalweg increment short of the cross section. In streams with average widths smaller than 2.5m, you will be making thalweg measurements at 1-meter increments. Because the minimum reach length is set at 150 meters, there will be 15 measurements between each cross section. Use the 5 extra lines on the thalweg profile portion of the data form (Figure 7-2) to record these measurements.

It is very important that thalweg depths are obtained from all measurement points. Missing depths at the ends of the sampling reach (e.g., due to the stream flowing into or out of a culvert or under a large pile of debris) can be tolerated, but those occurring in the middle of the sampling reach are more difficult to deal with. Flag these missing measurements using a “K” code and explain the reason for the missing measurements in the comments section of the field data form. At points where a direct depth measurement cannot be obtained, make your best estimate of the depth, record it on the field form, and flag the value using a “U” code (for suspect measurement), explaining that it is an estimated value in the comments section of the field data form. **Where the thalweg points are too deep for wading**, measure the depth by extending the surveyor’s rod at an angle to reach the thalweg point. Record the water level on the rod, and the rod angle, as determined using the external scale on the clinometer (vertical = 90°). This procedure can also be done with a taut string or fishing line (see Table 7-3). In analyzing this data we calculate the thalweg depth as the length of rod (or string) under water multiplied by the trigonometric *sin* of the rod angle. (For example, if 3 meters of the rod are under water when the rod held at 30 degrees (*sin*=0.5), the actual thalweg depth is 6 meters.) These calculations are done after field forms are returned for data analysis. On the field form, crews are required only to record the wetted length of the rod under the water, a “U” code in the flag field, and a comment to the right saying “depth taken at an angle of xx degrees.”

At every thalweg measurement increment, determine by sight or feel whether deposits of soft/small sediment is present on the channel bottom. These particles are defined as substrate equal to or smaller than fine gravel (# 16 mm diameter). These **soft/small sediments are NOT the same as “Fines”** described when determining the substrate particle sizes at the cross-section transects (Section 7.5.2). For the thalweg profile, determine if soft/small sediment deposits are readily obvious by feeling the bottom with your boot, the surveyor's rod, or the calibrated rod or pole. (Note that **a very thin coating of silt or algae on cobble bottom substrate does not qualify as "soft/small" sediment** for this purpose.)

Wetted width is measured at each transect (station 0), and midway between transects (station 5 for larger streams having 100 measurement points, or station 7 for smaller streams having 150 measurement points). The wetted width boundary is the point at which substrate particles are no longer surrounded by free water. Substrate size is estimated for 5 particles evenly spaced across each midway cross-section using procedures identical to those described for substrate at regular cross-sections (Section 7.5.2), but at the supplemental cross-sections, only the size class (not the distance and depth) data are recorded in spaces provided on the Thalweg Profile side of the field form.

While recording the width and depth measurements and the presence of soft/small sediments, the second person chooses and records the habitat class and the pool forming element codes (Table 7-4) applicable to each of the 100 (or 150) measurement points along the length of the reach. These channel unit habitat classifications and pool-forming elements are modified from those of Bisson et al. (1982) and Frissell et al. (1986). The resulting database of traditional visual habitat classifications will provide a bridge of common understanding with other studies. Channel unit scale habitat classifications are to be made at the thalweg of the cross section. The habitat unit itself must meet a minimum size criteria in addition to the qualitative criteria listed in Table 7-4. Before being considered large enough to be identified as a channel-unit scale habitat feature, the unit should be at least as long as the channel is wide. For instance, if there is a small deep (pool-like) area at the thalweg within a large riffle area, don't record it as a pool unless it occupies an area about as wide or long as the channel is wide. If a backwater pool dominates the channel, record "PB" as the dominant habitat unit class. If the backwater is a pool that does not dominate the main channel, or if it is an off-channel alcove or slough, circle "Y" to indicate presence of a backwater in the "Backwater" column of the field form, but classify the main channel habitat unit type according to characteristics of the main channel.

Mid-channel bars, islands, and side channels pose some problems for the sampler conducting a thalweg profile and necessitate some guidance. Bars are defined here as

TABLE 7-4. CHANNEL UNIT AND POOL FORMING ELEMENT CATEGORIES

Channel Unit Habitat Classes[a]

Class (Code)	Description
Pools:	Still water, low velocity, smooth, glassy surface, usually deep compared to other parts of the channel:
Plunge Pool (PP)	Pool at base of plunging cascade or falls.
Trench Pool (PT)	Pool-like trench in the center of the stream
Lateral Scour Pool (PL)	Pool scoured along a bank.
Backwater Pool (PB)	Pool separated from main flow off the side of the channel.
Impoundment Pool (PD)	Pool formed by impoundment above dam or constriction.
Pool (P)	Pool (unspecified type).
Glide (GL)	Water moving slowly, with a smooth, unbroken surface. Low turbulence.
Riffle (RI)	Water moving, with small ripples, waves and eddies -- waves not breaking, surface tension not broken. Sound: "babbling", "gurgling".
Rapid (RA)	Water movement rapid and turbulent, surface with intermittent whitewater with breaking waves. Sound: continuous rushing, but not as loud as cascade.
Cascade (CA)	Water movement rapid and very turbulent over steep channel bottom. Most of the water surface is broken in short, irregular plunges, mostly whitewater. Sound: roaring.
Falls (FA)	Free falling water over a vertical or near vertical drop into plunge, water turbulent and white over high falls. Sound: from splash to roar.
Dry Channel (DR)	No water in the channel

(continued)

[a] Note that in order for a channel habitat unit to be distinguished, it must be at least as wide or long as the channel is wide.

TABLE 7-4 (Continued)

Categories of Pool-forming Elements[b]

Code	Category
N	Not Applicable, Habitat Unit is not a pool
W	Large Woody Debris.
R	Rootwad
B	Boulder or Bedrock
F	Unknown cause (unseen fluvial processes)
WR, RW, RBW	Combinations
OT	Other (describe in the comments section of field form)

[b] Remember that most pools are formed at high flows, so you may need to look at features, such as large woody debris, that are dry at baseflow, but still within the bankfull channel.

mid-channel features below the bankfull flow mark that are dry during baseflow conditions (see Section 7.5.3 for the definition of bankfull channel). Islands are mid-channel features that are dry even when the stream is experiencing a bankfull flow. Both bars and islands cause the stream to split into side channels. When a mid-channel bar is encountered along the thalweg profile, it is noted on the field form and the active channel is considered to include the bar. Therefore, the wetted width is measured as the distance between wetted left and right banks. It is measured across and over mid-channel bars and boulders. If mid-channel bars are present, record the bar width in the space provided.

If a mid-channel feature is as high as the surrounding flood plain, it is considered an island. Treat side channels resulting from islands different from mid-channel bars. Handle the ensuing side channel based on visual estimates of the percent of total flow within the side channel as follows:

Less than 15%	Indicate the presence of a side channel on the field data form.
16 to 49%	Indicate the presence of a side channel on the field data form. Establish a secondary transect across the side channel designated as “X” plus the primary transect letter; (e.g., XA), by checking boxes for both “X” and the appropriate transect letter (e.g., A through K) on a separate copy of the field data form. Complete the detailed channel and riparian cross-section measurements for the side channel on this form.

When a side channel occurs due to an island, reflect its presence with continuous entries in the “Side Channel” field on the Thalweg Profile and Woody Debris Form (Figure 7-2). In addition, note the points of divergence and confluence of the side channel in the comments section of the thalweg profile form. Begin entries at the point where the side channel converges with the main channel; note the side channel presence continuously until the upstream point where it diverges. When doing width measures with a side channel separated by an island, include only the width of the main channel in the measures at the time and then measure the side channel width separately.

For dry and intermittent streams, where no water is in the channel at a thalweg station, record zeros for depth and wetted width. Record the habitat type as dry channel (DR).

7.4.2 Large Woody Debris Tally

Methods for large woody debris (LWD) measurement are a simplified adaptation of those described by Robison and Beschta (1990). This component of the EMAP physical habitat characterization allows quantitative estimates of the number, size, total volume and distribution of wood within the stream reach. LWD is defined here as woody material with a small end diameter of at least 10 cm (4 in.) and a length of at least 1.5 m (5 ft.).

The procedure for tallying LWD is presented in Table 7-5. The tally includes all pieces of LWD that are at least partially in the baseflow channel, the "active channel" (flood channel up to bankfull stage), or spanning above the active channel (Figure 7-3). The active (or "bankfull") channel is defined as the channel that is filled by moderate sized flood events that typically recur every one to two years. LWD in the active channel is tallied over the entire length of the reach, including the area between the channel cross-section transects. As in the thalweg profile, LWD measurements in the LWD piece is tallied in only one box. Pieces of LWD that are not at least partially within Zones 1, 2, or 3 are not tallied.

For each LWD piece, first visually estimate its length and its large and small end diameters in order to place it in one of the diameter and length categories. The diameter class on the field form (Figure 7-2) refers to the large end diameter. Sometimes LWD is not cylindrical, so it has no clear "diameter". In these cases visually estimate what the diameter would be for a piece of wood with a circular cross section that would have the same volume. When evaluating length, include only the part of the LWD piece that has a diameter greater than 10 cm (4 in). Count each of the LWD pieces as one tally entry and include the whole piece when assessing dimensions, even if part of it is in Zone 4 (outside of the bankfull channel). For both the Zone 1-2 wood and the Zone 3 LWD, the field form (Figure 7-2) provides 12 entry boxes for tallying debris pieces visually estimated within three length and four diameter class combinations. Each LWD piece is tallied in only one box. There are 12 size classes for wood at least partially in Zones 1 and 2, and 12 for wood partially within Zone 3. Wood that is not at least partially within those zones is not tallied.

7.5 CHANNEL AND RIPARIAN MEASUREMENTS AT CROSS-SECTION TRANSECTS

7.5.1 Slope and Bearing

The slope, or gradient, of the stream reach is useful in three different ways. First, the overall stream gradient is one of the major stream classification variables, giving an

TABLE 7-5. PROCEDURE FOR TALLYING LARGE WOODY DEBRIS

Note: Tally pieces of large woody debris (LWD) within each segment of stream at the same time the thalweg profile is being determined. Include all pieces whose large end is located within the segment in the tally.

1. Scan the stream segment between the two cross-section transects where thalweg profile measurements are being made.

2. Tally all LWD pieces within the segment that are at least partially within the bankfull channel. Determine if a piece is LWD (**small end diameter $10 cm [4 in.]; length $1.5 m [5 ft.]**)

3. For each piece of LWD, determine the class **based on the diameter of the large end** (0.1 m to < 0.3 m, 0.3 m to <0.6 m, 0.6 m to <0.8 m, or >0.8 m, and the class based on the length of the piece (1.5m to <5.0m, 5m to <15m, or >15m).

    - If the piece is not cylindrical, visually estimate what the diameter would be for a piece of wood with circular cross section that would have the same volume.
    - When estimating length, include only the part of the LWD piece that has a diameter greater than 10 cm (4 in)

4. Place a tally mark in the appropriate diameter × length class tally box in the "PIECES ALL/ PART IN BANKFULL CHANNEL" section of the Thalweg Profile and Woody Debris Form.

5. Tally all LWD pieces within the segment that are not actually within the bankfull channel, but are at least partially spanning (bridging) the bankfull channel. For each piece, determine the class based on the diameter of the **large end** (0.1 m to < 0.3 m, 0.3 m to <0.6 m, 0.6 m to <0.8 m, or >0.8 m), and the class based on the length of the piece (1.5 m to <5.0 m, 5 m to <15 m, or >15 m).

6. Place a tally mark for each piece in the appropriate diameter × length class tally box in the "PIECES BRIDGE ABOVE BANKFULL CHANNEL" section of the Thalweg Profile and Woody Debris Form.

7. After all pieces within the segment have been tallied, write the total number of pieces for each diameter × length class in the small box at the lower right-hand corner of each tally box.

8. Repeat Steps 1 through 7 for the next stream segment, using a new Thalweg Profile and Woody Debris Form.

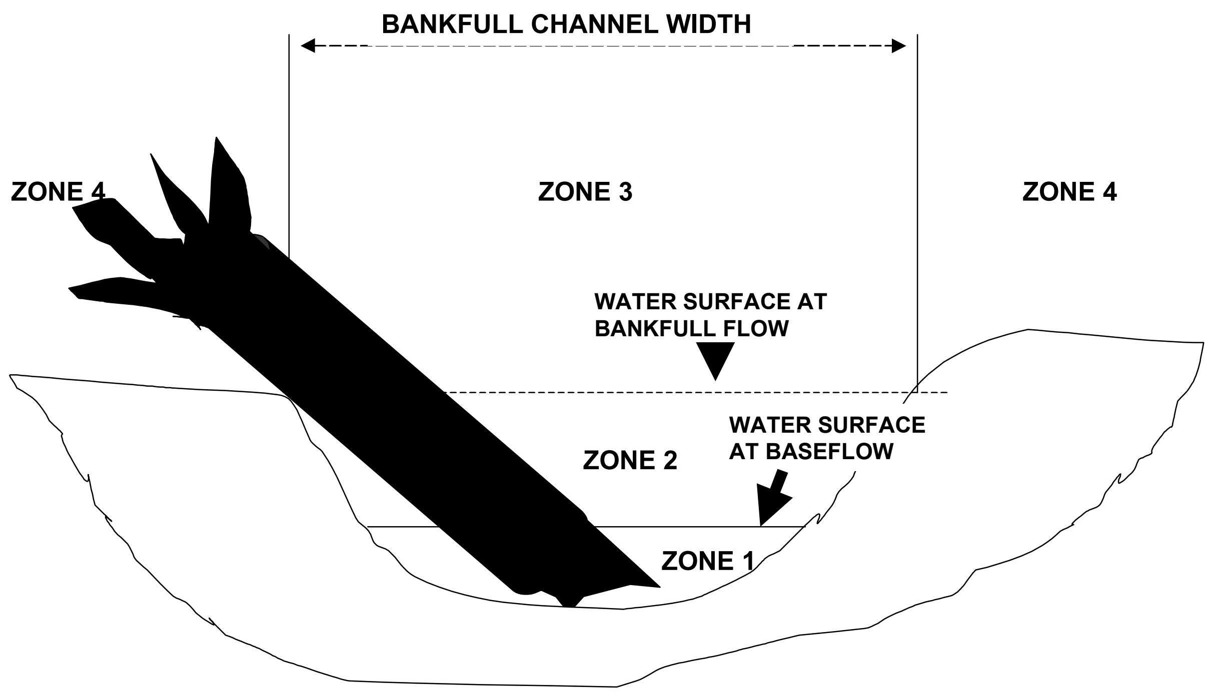


Figure 7-3. Large woody debris influence zones (modified from Robison and Beschta, 1990)

indication of potential water velocities and stream power, which are in turn important controls on aquatic habitat and sediment transport within the reach. Second, the spatial variability of stream gradient is a measure of habitat complexity, as reflected in the diversity of water velocities and sediment sizes within the stream reach. Lastly, using methods described by Stack (1989) and Robison and Kaufmann (1994), the water surface slope will allow us to compute residual pool depths and volumes from the multiple depth and width measurements taken in the thalweg profile (Section 7.4.1). Compass bearings between cross section stations, along with the distance between stations, will allow us to estimate the sinuosity of the channel (ratio of the length of the reach divided by the straight line distance between the two reach ends).

Measure slope and bearing by "backsighting" downstream between transects (e.g., transect “B” to “A”, “C” to “B”, etc.) as shown in Figure 7-4. To measure the slope and bearing between adjacent stations, use a clinometer, bearing compass, tripod, tripod extension, and flagging, following the procedure presented in Table 7-6. Record slope and bearing data on the Slope and Bearing Form as shown in Figure 7-5.

Slope can also be measured by two people, each having a pole that is marked at the same height. Alternatively, the second person can be “flagged” at the eye level of the person doing the backsiting. Be sure that you mark your eye level on the other person or on a separate pole beforehand while standing on level ground. Site to **your eye level** when backsiting on your co-worker. **Particularly in streams with slopes less than 3%, we recommend that field crews use poles marked at exactly the same height for sighting slope. When two poles are used, site from the mark on one pole to the mark on the other. Also, be sure that the second person is standing (or holding the marked pole) at the water’s edge or in the same depth of water as you are.** The intent is to get a measure of the **water surface slope**, which may not necessarily be the same as the bottom slope.

The clinometer reads both percent slope and degrees of the slope angle; be careful to read and record percent slope. Percent slope is the scale on the right-hand side as you look through most clinometers. If using an Abney Level, insure that you are reading the scale marked “PERCENT.” With the clinometer or the Abney level, verify this by comparing the two scales. Percent slope is always a higher number than degrees of slope angle (e.g., 100% slope=45° angle). For slopes > 2%, read the clinometer to the nearest 0.5%. For slopes < 2%, read to the nearest 0.25%. If the clinometer reading is 0%, but water is

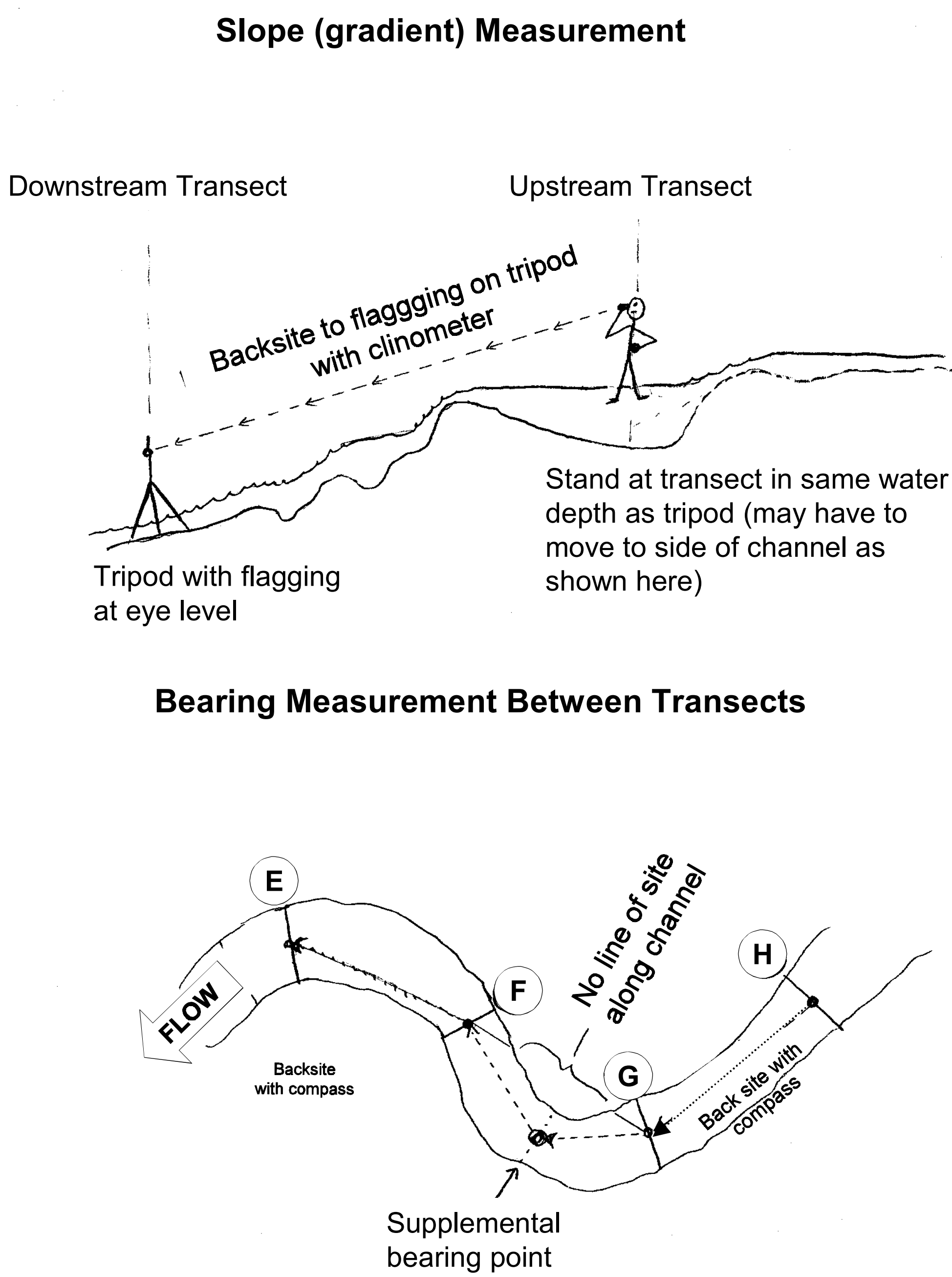


Figure 7-4. Channel slope and bearing measurements.

TABLE 7-6. PROCEDURE FOR OBTAINING SLOPE AND BEARING DATA

1. Stand in the center of the channel at the downstream cross-section transect. Determine if you can see the center of the channel at the next cross-section transect upstream without sighting across land (i.e., do not "short-circuit" a meander bend). If not, you will have to take supplementary slope and bearing measurements.

2. Set up the tripod in shallow water or at the water's edge at the downstream cross-section transect (or at a supplemental point). Standing tall in a position with your feet as near as possible to the water surface elevation, set the tripod extension and mark it with a piece of flagging at your eye level. Remember the depth of water in which you are standing when you adjust the flagging to eye level.

   - On gradually sloped streams, it is advisable to use two people, each holding a pole marked with flagging at the same height on both poles.

3. Walk upstream to the next cross-section transect. Find a place to stand at the upstream transect (or at a supplemental point) that is at the same depth as where you stood at the downstream transect when you set up the eye-level flagging.

   - If you have determined in Step 1 that supplemental measurements are required for this segment, walk upstream to the furthest point where you can still see the center of the channel at the downstream cross-section transect from the center of the channel. Mark this location with a different color flagging than that marking the cross-section transects.

4. With the clinometer, site back downstream on your flagging at the downstream transect (or at the supplementary point). Read and record the **percent** slope in the "MAIN" section on the Slope and Bearing Form. Record the "PROPORTION" as 100%.

   - If two people are involved, place the base of each pole at the water level (or at the same depth at each transect). Then site with the clinometer (or Abney level) from the flagged height on upstream pole to the flagged height on the downstream pole.

   - If you are backsiting from a supplemental point, record the slope (%) and proportion (%) of the stream segment that is included in the measurement in the appropriate "SUPPLEMENTAL" section of the Slope and Bearing Form.

5. Stand in the middle of the channel at upstream transect (or at a supplemental point), and site back with your compass to the middle of the channel at the downstream transect (or at a supplemental point). Record the bearing (degrees) in the "MAIN" section of the Slope and Bearing Form.

   - If you are backsiting from a supplemental point, record the bearing in the appropriate "SUPPLEMENTAL" section of the Slope and Bearing Form.

6. Retrieve the tripod from the downstream cross section station (or from the supplemental point) and set it up at the next upstream transect (or at a supplemental point) as described in Step 2.

7. When you get to each new cross-section transect (or to a supplementary point), backsight on the previous transect (or the supplementary point), repeat Steps 2 through 6 above.

PHab: SLOPE AND BEARING FORM - STREAMS

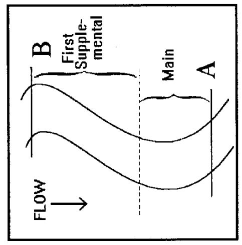
Reviewed by (initial): [illegible]

SITE ID: WXXP99-9999

DATE: 07/01/2001

TRANSECT	MAIN SLOPE XX.X %	MAIN BEARING 0-359	MAIN PROPORTION %	FIRST SUPPLEMENTAL SLOPE XX.X %	FIRST SUPPLEMENTAL BEARING 0-359	FIRST SUPPLEMENTAL PROPORTION %	SECOND SUPPLEMENTAL SLOPE XX.X %	SECOND SUPPLEMENTAL BEARING 0-359	SECOND SUPPLEMENTAL PROPORTION %	FLAG
A ← B	3.5	203	50	4.5	226	50	.			
B ← C	2.0	218	40	2.0	203	30	2.0	230	30	
C ← D	1.0	164	100	.			.			
D ← E	3.0	179	100	.			.			
E ← F	1.0	193	100	.			.			
F ← G	2.0	211	100	.			.			
G ← H	4.5	177	25	3.0	163	75	.			
H ← I	3.0	176	100	.			.			
I ← J	0.1	189	100	.			.			F1
J ← K	0.0	189	100	.			.			F2

FLAG	COMMENT
F1	CLINOMETER READING = 0, BUT PERCEPTIBLE FLOW
F2	CLINOMETER READING = 0, NO PERCEPTIBLE FLOW



Flag codes: K = Sample not collected; U = Suspect sample; F1, F2, etc. = misc. flag assigned by field crew. Explain all flags in comment sections.

03/26/2001 2001 Phab Slope

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Figure 7-5. Slope and Bearing Form.

moving, record the slope as 0.1%. If the clinometer reading is 0% and water is not moving, record the slope as 0%.

For bearing measurements, it does not matter whether or not you adjust your compass bearings for magnetic declination, but **it is important that you are consistent in the use of magnetic or true bearings** throughout all the measurements you make on a given reach. Note in the comments section of the Slope and Bearing Form which type of bearings you are taking. Also, guard against recording "reciprocal" bearings (erroneous bearings 180 degrees from what they should be). The best way to do this is to know where the primary (cardinal) directions are in the field: (north [0 degrees], east [90 degrees], south [180 degrees], and west [270 degrees]), and insure that your bearings "make sense."

As stated earlier, it may be necessary to set up intermediate (“supplementary”) slope and bearing points between a pair of cross-section transects if you do not have direct line-of-site along (and within) the channel between stations (see Figure 7-4). This can happen if brush is too heavy, or if there are sharp slope breaks or tight meander bends. If you would have to sight across land to measure slope or bearing between two transects, then you need to make supplementary measurements (i.e., do not “short-circuit” a meander bend). Mark these intermediate station locations with a different color of plastic flagging than used for the cross-section transects to avoid confusion. Record these supplemental slope and bearing measurements, along with the proportion of the stream segment between transects included in each supplemental measurement, in the appropriate sections of the Slope and Bearing Form (Figure 7-5). Note that the main slope and bearing observations are always downstream of supplemental observations. Similarly, first supplemental observations are always downstream of second supplemental observations.

7.5.2 Substrate Size and Channel Dimensions

Substrate size is one of the most important determinants of habitat character for fish and macroinvertebrates in streams. Along with bedform (e.g., riffles and pools), substrate influences the hydraulic roughness and consequently the range of water velocities in the channel. It also influences the size range of interstices that provide living space and cover for macroinvertebrates, salamanders, and sculpins. Substrate characteristics are often sensitive indicators of the effects of human activities on streams. Decreases in the mean substrate size and increases in the percentage of fine sediments, for example, may destabilize channels and indicate changes in the rates of upland erosion and sediment supply (Dietrich et al, 1989; Wilcock, 1998).

In the EMAP protocol, substrate size and embeddedness are evaluated at each of the 11 cross-section transects (refer to Figure 7-1) using a combination of methods adapted from those described by Wolman (1954), Bain et al. (1985), Platts et al. (1983), and Plafkin et al. (1989). Substrate size is evaluated also at 10 additional cross-sections located mid-way between each of the 11 regular transects (A-K). The basis of the protocol is a systematic selection of 5 substrate particles from each of 21 cross-section transects (Figure 7-6). In the process of measuring substrate particle sizes at each channel cross section, you also measure the wetted width of the channel and the water depth at each substrate sample point (at the 10 midway cross-sections, only substrate size and wetted width are recorded). If the wetted channel is split by a mid-channel bar (see Section 7.4.1), the five substrate points are centered between the wetted width boundaries regardless of the mid-channel bar in between. Consequently, substrate particles selected in some cross-sections may be "high and dry". For cross-sections with dry channels, make measurements across the unvegetated portion of the channel.

The distance you record to the right bank is the same as the wetted channel width. (NOTE: this is the same value that is also recorded under "BANK MEASUREMENTS" on the same form [Section 7.5.3]). The substrate sampling points along the cross-section are located at 0, 25, 50, 75, and 100 percent of the measured wetted width, with the first and last points located at the water's edge just within the left and right banks.

The procedure for obtaining substrate measurements is described in Table 7-7. Record these measurements on the Channel/Riparian Cross-section side of the field form, as shown in Figure 7-7. For the supplemental cross-sections midway between regular transects, record substrate size and wetted width data on the Thalweg Profile side of the field form. To minimize bias in selecting a substrate particle for size classification, it is important to concentrate on correct placement of the measuring stick along the cross-section, and to select the particle right at the bottom of the stick (not, for example, a more noticeable large particle that is just to the side of the stick). Classify the particle into one of the size classes listed on the field data form (Figure 7-7) based on the middle dimension of its length, width, and depth. This “median” dimension determines the sieve size through which the particle can pass. Always distinguish “hardpan” from “fines”, coding hardpan as

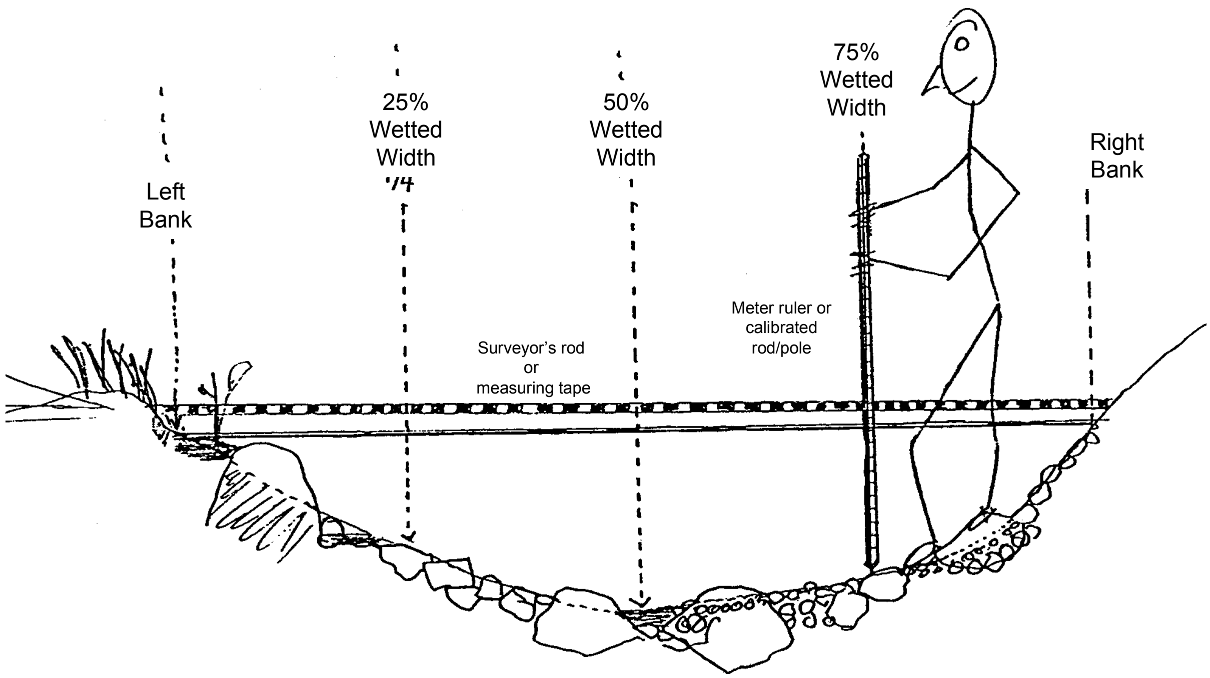

Figure 7-6. Substrate sampling cross-section.

"HP". Similarly, always distinguish concrete or asphalt from bedrock; denote these artificial substrates as "other" ("OT") and describe them in the comments section of the field data form. Code and describe other artificial substrates (including metal, tires, car bodies, etc.) in the same manner. When you record the size class as "OT" (other), assign an "F"-series flag on the field data form (Figure 7-7) and describe the substrate type in the comments section of the field form, as shown in Figure 7-2.

At substrate sampling locations on the 11 regular transects (A-K), examine particles larger than sand for surface stains, markings, and algal coatings to estimate embeddedness of all particles in the 10 cm diameter circle around the substrate sampling point. Embeddedness is the fraction of a particle's surface that is surrounded by (embedded in) sand or finer sediments on the stream bottom. By definition, the embeddedness of sand,

TABLE 7-7. SUBSTRATE MEASUREMENT PROCEDURE

1. Fill in the header information on page 1 of a Channel/Riparian Cross-section Form. Indicate the cross-section transect. At the transect, extend the surveyor's rod across the channel perpendicular to the flow, with the "zero" end at the left bank (facing downstream). If the channel is too wide for the rod, stretch the metric tape in the same manner.

2. Divide the wetted channel width channel by 4 to locate substrate measurement points on the cross-section. In the "DISTLB" fields of the form, record the distances corresponding to 0% (LFT), 25% (LCTR), 50% (CTR), 75% (RCTR), and 100% (RGT) of the measured wetted width. Record these distances at Transects A-K., but just the wetted width at midway cross-sections.

3. Place your sharp-ended meter stick or calibrated pole at the "LFT" location (0 m). Measure the depth and record it on the field data form. (Cross-section depths are measured only at regular transects A-K, not at the 10 midway cross-sections).

   - Depth entries at the left and right banks may be 0 (zero) if the banks are gradual.
   - If the bank is nearly vertical, let the base of the measuring stick fall to the bottom, rather than holding it suspended at the water surface.

4. Pick up the substrate particle that is at the base of the meter stick (unless it is bedrock or boulder), and visually <u>estimate its particle size</u>, according to the following table. Classify the particle according to its "median" diameter (the middle dimension of its length, width, and depth). Record the size class code on the field data form. (Cross-section side of form for Transects A-K; special entry boxes on Thalweg Profile side of form for midway cross-sections.)

Code	Size Class	Size Range (mm)	Description
RS	Bedrock (Smooth)	>4000	Smooth surface rock bigger than a car
RR	Bedrock (Rough)	>4000	Rough surface rock bigger than a car
HP	Hardpan		Firm, consolidated fine substrate
BL	Boulders	>250 to 4000	Basketball to car size
CB	Cobbles	>64 to 250	Tennis ball to basketball size
GC	Gravel (Coarse)	>16 to 64	Marble to tennis ball size
GF	Gravel (Fine)	> 2 to 16	Ladybug to marble size
SA	Sand	>0.06 to 2	Smaller than ladybug size, but visible as particles - gritty between fingers
FN	Fines	<0.06	Silt Clay Muck (not gritty between fingers)
WD	Wood	Regardless of Size	Wood & other organic particles
OT	Other	Regardless of Size	Concrete, metal, tires, car bodies etc. (describe in comments)

5. Evaluate substrate embeddedness as follows at 11 transects A-K. For particles larger than sand, examine the surface for stains, markings, and algae. Estimate the average percentage embeddedness of particles in the 10 cm circle around the measuring rod. Record this value on the field data form. By definition, sand and fines are embedded 100 percent; bedrock and hardpan are embedded 0 percent.

6. Move successively to the next location along the cross section. Repeat steps 4 through 6 at each location. Repeat Steps 1 through 6 at each new cross section transect.

PHab: CHANNEL/RIPARIAN CROSS-SECTION FORM - STREAMS

Reviewed by (Initials): DP

SITE ID: NXXP99-9999 DATE: 07/01/2001 TRANSECT: ☐ A ☒ B ☐ C ☐ D ☐ E ☐ F ☐ G ☐ H ☐ I ☐ J ☐ K X-tra Side Channel ☐

SUBSTRATE CROSS-SECTIONAL INFORMATION

	Dist LB XX.XX m	Depth XXX cm	Size Class Code	Embed. 0-100%	Flag
Left	0.00	0	SA	100	
LCtr	1.38	10	SA	100	F1
Ctr	2.75	17	OT	0	
RCtr	4.13	14	FN	100	
Right	5.50	0	GF	60	

SUBSTRATE SIZE CLASS CODES	Embed. (%)
RS = Bedrock (Smooth) - (Larger than a car)	0
RR = Bedrock (Rough) - (Larger than a car)	0
BL = Boulder (250 to 4000 mm) - (Basketball to car)	
CB = Cobble (64 to 250 mm) - (Tennis ball to Basketball)	
GC = Coarse Gravel (16 to 64 mm) - (Marble to Tennis ball)	
GF = Fine Gravel (2 to 16 mm) - (Ladybug to marble)	
SA = Sand (0.06 to 2 mm) - (Gritty - up to Ladybug size)	100
FN = Silt / Clay / Muck - (Not Gritty)	100
HP = Hardpan - (Firm, Consolidated Fine Substrate)	0
WD = Wood - (Any Size)	
OT = Other (Write comment below)	

FISH COVER/ OTHER

0 = Absent (0%)
1 = Sparse (<10%)
2 = Moderate (10-40%)
3 = Heavy (40-75%)
4 = Very Heavy (>75%)
(circle one)

	Cover in Channel	Flag
Filamentous Algae	0 (1) 2 3 4	
Macrophytes	(0) 1 2 3 4	
Woody Debris >0.3 m (BIG)	0 (1) 2 3 4	
Brush/Woody Debris <0.3 m (SMALL)	0 (1) 2 3 4	
Live Trees or Roots	(0) 1 2 3 4	
Overhanging Veg. =<1 m of Surface	0 1 (2) 3 4	
Undercut Banks	(0) 1 2 3 4	
Boulders	(0) 1 2 3 4	
Artificial Structures	(0) 1 2 3 4	

VISUAL RIPARIAN ESTIMATES

0 = Absent (0%)
1 = Sparse (<10%)
2 = Moderate (10-40%)
3 = Heavy (40-75%)
4 = Very Heavy (>75%)

D = Deciduous
C = Coniferous
E = Broadleaf Evergreen
M = Mixed
N = None

RIPARIAN VEGETATION COVER	Left Bank	Right Bank	Flag
Canopy (>5 m high)			
Vegetation Type	(D) C E M N	(D) C E M N	
BIG Trees (Trunk >0.3 m DBH)	0 1 (2) 3 4	0 (1) 2 3 4	
SMALL Trees (Trunk <0.3 m DBH)	0 (1) 2 3 4	0 (1) 2 3 4	
Understory (0.5 to 5 m high)			
Vegetation Type	(D) C E M N	D C E M (N)	
Woody Shrubs & Saplings	0 (1) 2 3 4	(0) 1 2 3 4	
Non-Woody Herbs, Grasses, & Forbs	0 (1) 2 3 4	(0) 1 2 3 4	
Ground Cover (<0.5 m high)			
Woody Shrubs & Saplings	(0) 1 2 3 4	(0) 1 2 3 4	
Non-Woody Herbs, Grasses and Forbs	0 1 2 3 (4)	0 1 2 3 (4)	
Barren, Bare Dirt or Duff	0 1 (2) 3 4	0 1 (2) 3 4	

0 = Not Present P = >10 m C = Within 10 m B = On Bank

HUMAN INFLUENCE	Left Bank	Right Bank	Flag
Wall/Dike/Revetment /Riprap/Dam	(0) P C B	(0) P C B	
Buildings	(0) P C B	(0) P C B	
Pavement/Cleared Lot	(0) P C B	(0) P C B	
Road/Railroad	(0) P C B	(0) P C B	
Pipes (Inlet/Outlet)	(0) P C B	0 (P) C B	
Landfill/Trash	(0) P C B	(0) P C B	
Park/Lawn	(0) P C B	(0) P C B	
Row Crops	(0) P C B	(0) P C B	
Pasture/Range/Hay Field	0 P C (B)	0 P (C) B	F2
Logging Operations	(0) P C B	(0) P C B	
Mining Activity	(0) P C B	(0) P C B	

BANK MEASUREMENTS

	Bank Angle 0 - 360	Undercut Dist. (m)	Flag
Left	40	0	
Right	75	0	

		Flag
Wetted Width XXX.X m	5.5	
Bar Width XX.X m	3.5	
Bankfull Width XXX.X m	5.7	
Bankfull Height XX.X m	0.3	
Incised Height XX.X m	0.9	

CANOPY COVER MEASUREMENTS

DENSIOMETER (0-17Max)

		Flag			Flag
CenUp	8		CenR	12	
CenL	10		Left	14	
CenDwn	4		Right	7	

Flag codes: K = Sample not collected; U = Suspect sample; F1, F2, etc. = misc. flag assigned by field crew. Explain all flags in comment sections.

Flag	Comments
F1	OTHER = GRASS
F2	CATTLE TRACKS NOTED ON LEFT BANK AT STREAM MARGIN

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Figure 7-7. Channel/Riparian Cross-section Form.

silt, clay, and muck is 100 percent, and the embeddedness of hardpan and bedrock is 0 percent.

7.5.3 Bank Characteristics

The procedure for obtaining bank and channel dimension measurements is presented in Table 7-8. Data are recorded in the “Bank Measurements” section of the Channel/Riparian Cross-section Form as shown in Figure 7-7. Bank angle and bank undercut distance are determined on the left and right banks at each cross section transect. Other features include the wetted width of the channel (as determined in Section 7.5.2), the width of exposed mid-channel bars of gravel or sand, estimated incision height, and the estimated height and width of the channel at bankfull stage as described in Table 7-8. The “bankfull” or “active” channel is defined as the channel that is filled by moderate-sized flood events that typically occur every one or two years. Such flows do not generally overtop the channel banks to inundate the valley floodplain, and are believed to control channel dimensions in most streams.

If the channel is not greatly incised, bankfull channel height and incision height will be the same. However, if the channel is incised greatly, the bankfull level will be below the level of the first terrace of the valley floodplain, making bankfull channel height smaller than incision height (Figure 7-8). You may need to look for evidence of recent flows (within about one year) to distinguish bankfull and incision heights. In cases where the channel is cutting a valley sideslope and has oversteepened and destabilized that slope, the bare "cutbank" is not necessarily an indication of recent incision. Examine both banks to more accurately determine channel downcutting.

Spotting the level of bankfull flow during baseflow conditions requires judgement and practice; even then it remains somewhat subjective. In many cases there is an obvious slope break that differentiates the channel from a relatively flat floodplain terrace higher than the channel. Because scouring and inundation from bankfull flows are often frequent enough to inhibit the growth of terrestrial vegetation, the bankfull channel may be evident by a transition from exposed stream sediments to terrestrial vegetation. Similarly, it may be identified by noting moss growth on rocks along the banks. Bankfull flow level may also be seen by the presence of drift material caught on overhanging vegetation. However, in years with large floods, this material may be much higher than other bankfull indicators. In these cases, record the lower value, flag it, and also record the height of drift material in the comments section of the field data form.

TABLE 7-8. PROCEDURE FOR MEASURING BANK CHARACTERISTICS

1. To measure bank angle, lay the surveyor's rod or your meter ruler down against the left bank (determined as you face downstream), with one end at the water's edge. Lay the clinometer on the rod, read the bank angle in degrees from the external scale on the clinometer. Record the angle in the field for the left bank in the "BANK MEASUREMENT" section of the Channel/ Riparian Cross-section Form.

   - A vertical bank is 90 degrees; undercut banks have angles >90 degrees approaching 180 degrees, and more gradually sloped banks have angles <90 degrees. To measure bank angles >90 degrees, turn the clinometer (which only reads 0 to 90 degrees) over and subtract the angle reading from 180 degrees.

2. If the bank is undercut, measure the horizontal distance of the undercutting to the nearest 0.01 m. Record the distance on the field data form. The undercut distance is the distance from the water's edge out to the point where a vertical plumb line from the bank would hit the water's surface.

   - Measure submerged undercuts by thrusting the rod into the undercut and reading the length of the rod that is hidden by the undercutting.

3. Repeat Steps 1 and 2 on the right bank.

4. Hold the surveyor's rod vertical, with its base planted at the water's edge. Using the surveyor's rod as a guide while examining both banks, estimate (by eye) the channel incision as the height up from the water surface to elevation of the first terrace of the valley floodplain (Note this is at or above the bankfull channel height). Record this value in the "INCISED HEIGHT" field of the bank measurement section on the field data form.

5. Still holding the surveyor's rod as a guide, examine both banks to estimate and record the height of bankfull flow above the present water level. Look for evidence on one or both banks such as:

   - An obvious slope break that differentiates the channel from a relatively flat floodplain terrace higher than the channel.
   - A transition from exposed stream sediments to terrestrial vegetation.
   - Moss growth on rocks along the banks.
   - Presence of drift material caught on overhanging vegetation.
   - transition from flood- and scour-tolerant vegetation to that which is relatively intolerant of these conditions.

6. Record the wetted width value determined when locating substrate sampling points in the "WETTED WIDTH" field in the bank measurement section of the field data form. Also determine the bankfull channel width and the width of exposed mid-channel bars (if present). Record these values in the "BANK MEASUREMENT" section of the field data form.

7. Repeat Steps 1 through 6 at each cross-section transect. Record data for each transect on a separate field data form.

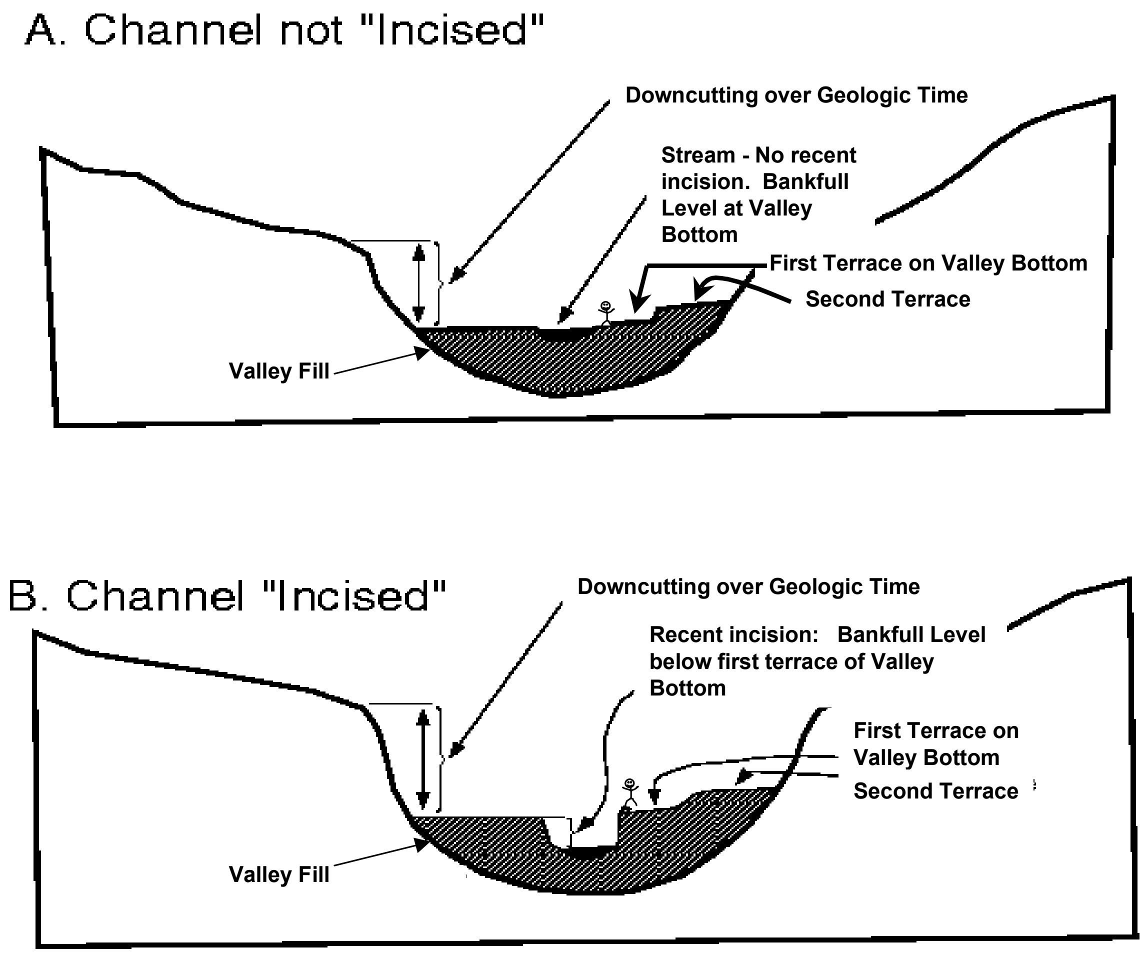


Figure 7-8. Schematic showing bankfull channel and incision for channels. (A) not recently incised, and (B) recently incised into valley bottom. Note level of bankfull stage relative to elevation of first terrace on valley bottom (Stick figure included for scale).

7.5.4 Canopy Cover Measurements

Riparian canopy cover over a stream is important not only in its role in moderating stream temperatures through shading, but also as an indicator of conditions that control bank stability and the potential for inputs of coarse and fine particulate organic material. Organic inputs from riparian vegetation become food for stream organisms and structure to create and maintain complex channel habitat.

Canopy cover over the stream is determined at each of the 11 cross-section transects. A Convex Spherical Densiometer (model B) is used (Lemmon, 1957). The densiometer must be taped exactly as shown in Figure 7-9 to limit the number of square grid intersections to 17. Densiometer readings can range from 0 (no canopy cover) to 17 (maximum canopy cover). Six measurements are obtained at each cross-section transect (four measurements in four directions at mid-channel and one at each bank). The mid-channel measurements are used to estimate canopy cover over the channel. The two bank measurements complement your visual estimates of vegetation structure and cover within the riparian zone itself (Section 7.5.5), and are particularly important in wide streams, where riparian canopy may not be detected by the densiometer when standing midstream.

The procedure for obtaining canopy cover data is presented in Table 7-9. Densiometer measurements are taken at 0.3 m (1 ft) above the water surface, rather than at waist level, to (1) avoid errors because people differ in height; (2) avoid errors from standing in water of varying depths; and (3) include low overhanging vegetation more consistently in the estimates of cover. Hold the densiometer level (using the bubble level) 0.3 m above the water surface with your face reflected just below the apex of the taped "V", as shown in Figure 7-9. Concentrate on the 17 points of grid intersection on the densiometer that lie within the taped "V". If the reflection of a tree or high branch or leaf overlies any of the intersection points, that particular intersection is counted as having cover. For each of the six measurement points, record the number of intersection points (maximum=17) that have vegetation covering them in the "Canopy Cover Measurement" section of the Channel/ Riparian Cross-section Form as shown in (Figure 7-7).

7.5.5 Riparian Vegetation Structure

The previous section (7.5.4) described methods for quantifying the cover of canopy over the stream channel. The following visual estimation procedures supplement those measurements with a semi-quantitative evaluation of the type and amount of various types

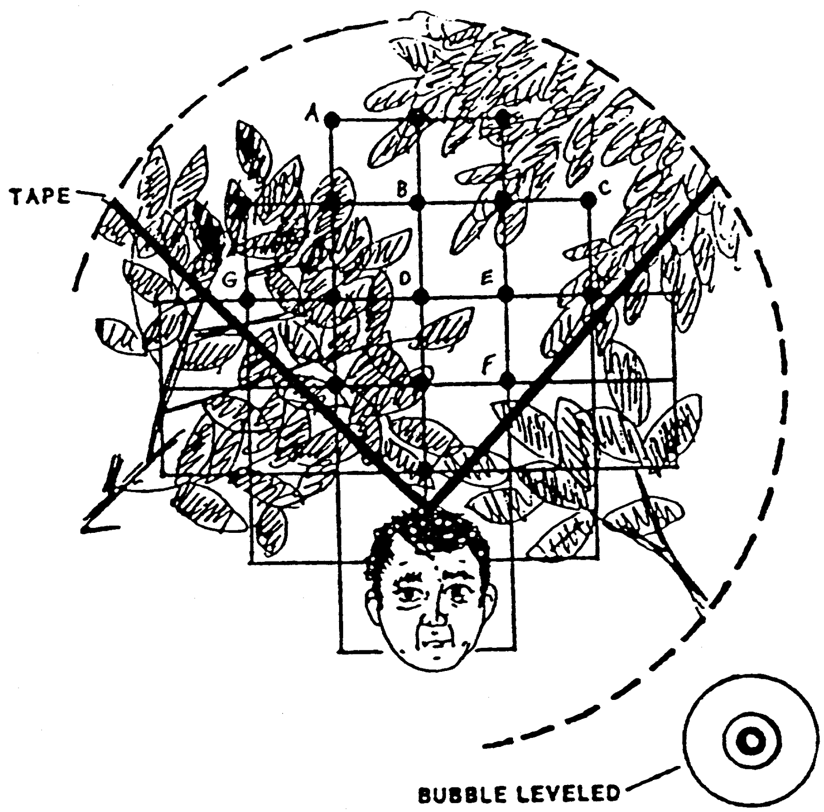


Figure 7-9. Schematic of modified convex spherical canopy densiometer (From Mulvey et al., 1992). In this example, 10 of the 17 intersections show canopy cover, giving a densiometer reading of 10. Note proper positioning with the bubble leveled and face reflected at the apex of the "V."

TABLE 7-9. PROCEDURE FOR CANOPY COVER MEASUREMENTS

1. At each cross-section transect, stand in the stream at mid-channel and face upstream.

2. Hold the densiometer 0.3 m (1 ft) above the surface of the stream. Hold the densiometer level using the bubble level. Move the densiometer in front of you so your face is just below the apex of the taped “V”.

3. Count the number of grid intersection points within the “V” that are covered by either a tree, a leaf, or a high branch. Record the value (0 to 17) in the “CENUP” field of the canopy cover measurement section of the Channel/Riparian Cross-section and Thalweg Profile Form.

4. Face toward the left bank (left as you face downstream). Repeat Steps 2 and 3, recording the value in the “CENL” field of the field data form.

5. Repeat Steps 2 and 3 facing downstream, and again while facing the right bank (right as you look downstream). Record the values in the “CENDWN” and “CENR” fields of the field data form.

6. Repeat Steps 2 and 3 again, this time facing the bank while standing first at the left bank, then the right bank. Record the values in the “LFT” and “RGT” fields of the field data form.

7. Repeat Steps 1 through 6 at each cross-section transect. Record data for each transect on a separate field data form.

of riparian vegetation. These data are used to evaluate the health and level of disturbance of the stream corridor. They also provide an indication of the present and future potential for various types of organic inputs and shading.

Riparian vegetation observations apply to the riparian area upstream 5 meters and downstream 5 meters from each of the 11 cross-section transects (refer to Figure 7-1). They include the visible area from the stream back a distance of 10m (-30 ft) shoreward from both the left and right banks, creating a 10 m × 10 m riparian plot on each side of the stream (Figure 7-10). The riparian plot dimensions are estimated, not measured. On steeply sloping channel margins, the 10 m × 10 m plot boundaries are defined as if they were projected down from an aerial view. If the wetted channel is split by a mid-channel bar, the bank and riparian measurements are made at each side of the channel, not the bar.

Table 7-10 presents the procedure for characterizing riparian vegetation structure and composition. Figure 7-7 illustrates how measurement data are recorded in the "VISUAL RIPARIAN ESTIMATES" section of the Channel/Riparian Cross-section Form. Conceptually divide the riparian vegetation into three layers: a CANOPY LAYER (> 5 m high), an UNDERSTORY (0.5 to 5 m high), and a GROUND COVER layer (< 0.5 m high). Note that several vegetation types (e.g., grasses or woody shrubs) can potentially occur in more than one layer. Similarly note that some things other than vegetation are possible entries for the "Ground Cover" layer (e.g., barren ground).

Before estimating the areal coverage of the vegetation layers, record the type of vegetation (Deciduous, Coniferous, broadleaf Evergreen, Mixed, or None) in each of the two taller layers (Canopy and Understory). Consider the layer "Mixed" if more than 10% of the areal coverage is made up of the alternate vegetation type.

Estimate the areal cover separately in each of the three vegetation layers. Note that the areal cover can be thought of as the amount of shadow cast by a particular layer alone when the sun is directly overhead. The maximum cover in each layer is 100%, so the sum of the areal covers for the combined three layers could add up to 300%. The four areal cover classes are "absent", "sparse" (<10%), "moderate" (10 to 40%), "heavy" (40 to 75%), and "very heavy" (>75%). These cover classes and their corresponding codes are shown on the field data form (Figure 7-7). When rating vegetation cover types, mixtures of two or more subdominant classes might all be given sparse ("1") moderate ("2") or heavy ("3") ratings. One very heavy cover class with no clear subdominant class might be rated "4"

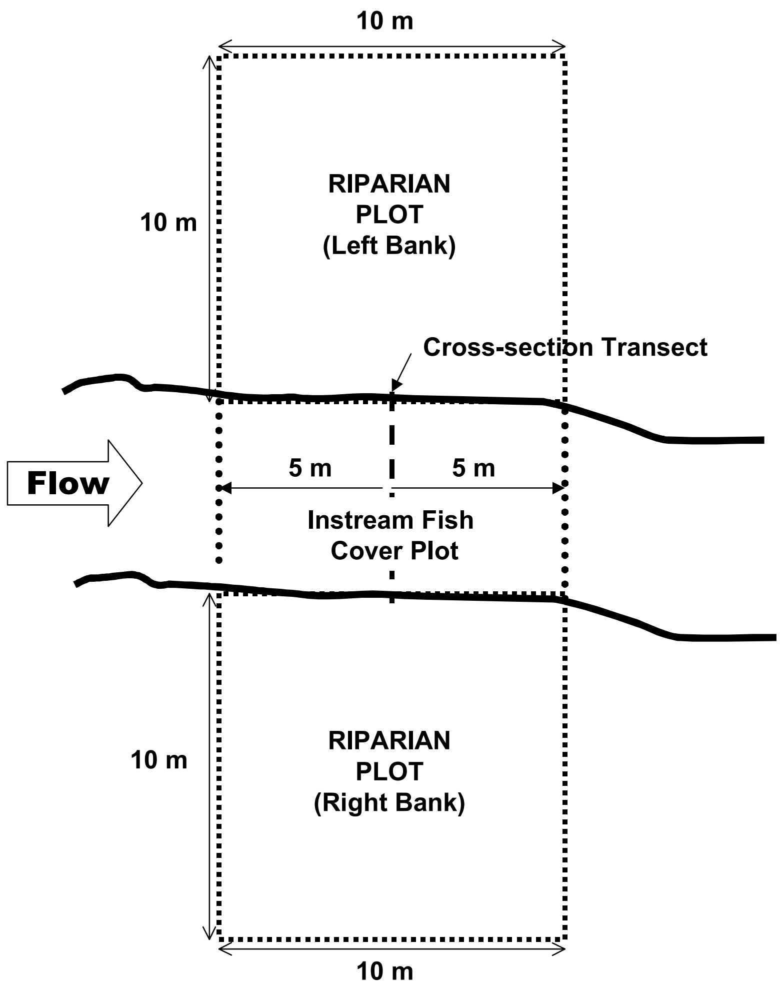


Figure 7-10. Boundaries for visual estimation of riparian vegetation, fish cover, and human influences.

TABLE 7-10. PROCEDURE FOR CHARACTERIZING RIPARIAN VEGETATION STRUCTURE

1. Standing in mid-channel at a cross-section transect, estimate a 5 m distance upstream and downstream (10 m total length).

2. Facing the left bank (left as you face downstream), estimate a distance of 10 m back into the riparian vegetation.

   On steeply-sloping channel margins, estimate the distance into the riparian zone as if it were projected down from an aerial view.

3. Within this 10 m × 10 m area, conceptually divide the riparian vegetation into three layers: a CANOPY LAYER (>5m high), an UNDERSTORY (0.5 to 5 m high), and a GROUND COVER layer (<0.5 m high).

4. Within this 10 m × 10 m area, determine the dominant vegetation type for the CANOPY LAYER (vegetation > 5 m high) as either <u>D</u>eciduous, <u>C</u>oniferous, broadleaf <u>E</u>vergreen, <u>M</u>ixed, or <u>N</u>one. Consider the layer "Mixed" if more than 10% of the areal coverage is made up of the alternate vegetation type. Indicate the appropriate vegetation type in the “VISUAL RIPARIAN ESTIMATES” section of the Channel/Riparian Cross-section Form.

5. Determine separately the areal cover class of large trees (> 0.3 m [1 ft] diameter at breast height [DBH]) and small trees (< 0.3 m DBH) within the canopy layer. Estimate areal cover as the amount of shadow that would be cast by a particular layer alone if the sun were directly overhead. Record the appropriate cover class on the field data form ("0"=absent: zero cover, "1"=sparse: <10%, "2"=moderate: 10-40%, "3"=heavy: 40-75%, or "4"=very heavy: >75%).

6. Look at the UNDERSTORY layer (vegetation between 0.5 and 5 m high). Determine the dominant vegetation type for the understory layer as described in Step 4 for the canopy layer.

7. Determine the areal cover class for woody shrubs and saplings separately from non-woody vegetation within the understory, as described in Step 5 for the canopy layer.

8. Look at the GROUND COVER layer (vegetation < 0.5 m high). Determine the areal cover class for woody shrubs and seedlings, non-woody vegetation, and the amount of bare ground present as described in Step 5 for large canopy trees.

9. Repeat Steps 1 through 8 for the right bank.

10. Repeat Steps 1 through 9 for all cross-section transects, using a separate field data form for each transect.

with all the remaining classes rated as either moderate ("2"), sparse ("1") or absent ("0"). Two heavy classes with 40-75% cover can both be rated "3".

7.5.6 Instream Fish Cover, Algae, and Aquatic Macrophytes

This portion of the EMAP physical habitat protocol is a visual estimation procedure that semi-quantitatively evaluates the type and amount of important types of cover for fish and macroinvertebrates. Alone and in combination with other metrics, this information is used to assess habitat complexity, fish cover, and channel disturbance.

The procedure to estimate the types and amounts of instream fish cover is outlined in Table 7-11. Data are recorded in the “Fish Cover/Other” section of the Channel /Riparian Cross-section Form as shown in Figure 7-7. Estimate the areal cover of all of the fish cover and other listed features that are in the water and on the banks 5 meters upstream and downstream of the cross-section (see Figure 7-10). The areal cover classes of fish concealment and other features are the same as those described for riparian vegetation (Section 7.5.5).

The entry “Filamentous algae” refers to long streaming algae that often occur in slow moving waters. “Aquatic macrophytes” are water-loving plants, including mosses, in the stream that could provide cover for fish or macroinvertebrates. If the stream channel contains live wetland grasses, include these as macrophytes. “Woody debris” are the larger pieces of wood that can influence cover and stream morphology (i.e., those pieces that would be included in the large woody debris tally [Section 7.4]). “Brush/woody debris” refers to smaller wood pieces that primarily affect cover but not morphology. “Live Trees or Roots” are living trees that are within the channel -- estimate the areal cover provided by the parts of these trees or roots that are inundated. For ephemeral channels, estimate the proportional cover of these trees that is inundated during bankfull flows. “Overhanging vegetation” includes tree branches, brush, twigs, or other small debris that is not in the water but is close to the stream (within 1 m of the surface) and provides potential cover. “Boulders” are typically basketball- to car-sized particles. “Artificial structures” include those designed for fish habitat enhancement, as well as in-channel structures discarded (e.g., cars or tires) or purposefully placed for diversion, impoundment, channel stabilization, or other purposes.

TABLE 7-11. PROCEDURE FOR ESTIMATING INSTREAM FISH COVER

1. Standing mid-channel at a cross-section transect, estimate a 5m distance upstream and downstream (10 m total length).

2. Examine the water and the banks within the 10-m segment of stream for the following features and types of fish cover: filamentous algae, aquatic macrophytes, large woody debris, brush and small woody debris, in-channel live trees or roots, overhanging vegetation, undercut banks, boulders, and artificial structures.

3. For each cover type, estimate the areal cover. Record the appropriate cover class in the "FISH COVER/OTHER" section of the Channel/Riparian Cross-section Form:

   "0"=absent: zero cover,
   "1"=sparse: <10%,
   "2"=moderate: 10-40%,
   "3"=heavy: 40-75%, or
   "4"=very heavy: >75%).

4. Repeat Steps 1 through 3 at each cross-section transect, recording data from each transect on a separate field data form.

7.5.7 Human Influence

The field evaluation of the presence and proximity of various important types of human land use activities in the stream riparian area is used in combination with mapped watershed land use information to assess the potential degree of disturbance of the sample stream reaches.

For the left and right banks at each of the 11 detailed Channel and Riparian Cross-Sections, evaluate the presence/absence and the proximity of 11 categories of human influences with the procedure outlined in Table 7-12. Relate your observations and proximity evaluations to the stream and riparian area within 5 m upstream and 5 m downstream from the station (Figure 7-10). Four proximity classes are used: In the stream or on the bank within 5 m upstream or downstream of the cross-section transect, present within the 10 m × 10 m riparian plot but not in the stream or on the bank, present outside of the riparian plot, and absent. Record data on the Channel/Riparian Cross-section Form as shown in Figure 7-7. If a disturbance is within more than one proximity class, record the one that is closest to the stream (e.g., “C” takes precedence over “P”).

A particular influence may be observed outside of more than one riparian observation plot (e.g., at both transects “D” and “E”). Record it as present at every transect where you can see it without having to site through another transect or its 10 m × 10 m riparian plot.

7.5.8 Riparian “Legacy” Trees and Invasive Alien Plants

The Riparian “Legacy” Tree protocol contributes to the assessment of “old growth” characteristics of riparian vegetation, and aids the determination of possible historic conditions and the potential for riparian tree growth. Follow the procedures presented in Table 7-13 to locate a legacy tree associated with each transect. Note that only one tree is identified at each transect. and that at transect K, look upstream a distance of 4 channel widths. Record the type of tree, and, if possible, the taxonomic group (using the list provided in Table 7-13). Record this information, along with the estimated height, diameter at breast height (dbh), and distance from the wetted margin of the stream on the left hand column of the field form for Riparian “Legacy” Trees and Invasive Alien Plants (Figure 7-11).

TABLE 7-12. PROCEDURE FOR ESTIMATING HUMAN INFLUENCE

1. Standing mid-channel at a cross-section transect, look toward the left bank (left when facing downstream), and estimate a 5 m distance upstream and downstream (10 m total length). Also, estimate a distance of 10 m back into the riparian zone to define a riparian plot area.

2. Examine the channel, bank and riparian plot area adjacent to the defined stream segment for the following human influences: (1) walls, dikes, revetments, riprap, and dams; (2) buildings; (3) pavement/cleared lot (e.g.,paved, gravelled, dirt parking lot, foundation); (4) roads or railroads, (5) inlet or outlet pipes; (6) landfills or trash (e.g., cans, bottles, trash heaps); (7) parks or maintained lawns; (8) row crops; (9) pastures, rangeland, hay fields, or evidence of livestock; (10) logging; and (11) mining (including gravel mining).

3. For each type of influence, determine if it is present and what its proximity is to the stream and riparian plot area. Consider human disturbance items as present if you can see them from the cross-section transect. Do not include them if you have to site through another transect or its 10 m ×10 m riparian plot.

4. For each type of influence, record the appropriate proximity class in the "HUMAN INFLUENCE" part of the "VISUAL RIPARIAN ESTIMATES" section of the Channel/Riparian Cross-section Form. Proximity classes are:

   B ("Bank") — Present within the defined 10 m stream segment and located in the stream or on the stream bank.
   C ("Close") — Present within the 10 × 10 m riparian plot area, but away from the bank.
   P ("Present") — Present, but outside the riparian plot area.
   O ("Absent") — Not present within or adjacent to the10 m stream segment or the riparian plot area at the transect

5. Repeat Steps 1 through 4 for the right bank.

6. Repeat Steps 1 through 5 for each cross-section transect, recording data for each transect on a separate field form.

TABLE 7-13. PROCEDURE FOR IDENTIFYING RIPARIAN LEGACY TREES AND ALIEN INVASIVE PLANT SPECIES

Legacy Trees:

- Beginning at Transect A, look upstream. Search both sides of the stream upstream to the next transect. Locate the largest riparian tree visible within 50m (or as far as you can see, if less) from the wetted bank.

- Classify this tree as deciduous, coniferous, or broadleaf evergreen (classify western larch as coniferous). Identify, if possible, the species or the taxonomic group of this tree from the list below.

1. Acacia/Mesquite
2. Alder/Birch
3. Ash
4. Cedar/Cypress/Sequoia
5. Fir (including Douglas Fir, Hemlock)
6. Juniper
7. Maple/Boxelder
8. Oak
9. Pine
10. Poplar/Cottonwood
11. Snag (Dead Tree of Any Species)
12. Spruce
13. Sycamore
14. Willow
15. Unknown or Other Broadleaf Evergreen
16. Unknown or Other Conifer
17. Unknown or Other Deciduous

NOTE: If the largest tree is a dead “snag”, enter “Snag” as the taxonomic group.

- Estimate the height of the legacy tree, its diameter at breast height (dbh) and its distance from the wetted margin of the stream. Enter this information on the left hand column of the Riparian “Legacy” Trees and Invasive Alien Plants field form.

(Continued)

TABLE 7-13 (Continued)

<u>Alien Invasive Plants</u>:

- Examine the 10m x 10m riparian plots on both banks for the presence of alien plant species. Look for those species from the following table that are listed as “target” species for your State.

Name to Check on Form	Common Name	Binomial: Genus species	CA	OR	WA	ID	ND	SD	WY	CO	AZ	UT	MT	NV
Can This	Canada Thistle	*Cirsium arvense*	X	X	X	X	X	X	X	X			X	
G Reed	Giant Reed	*Arundo donax*	X								X	X		X
Hblack	Himalayan Blackberry	*Rubus discolor*	X	X	X	X								
Spurge	Leafy Spurge	*Euphorbia esula*					X	X	X	X			X	
M This	Musk Thistle	*Carduus nutans*	X	X	X	X	X	X	X	X			X	
EngIvy	English Ivy	*Hedera helix*	X	X	X	X	X	X	X	X	X	X	X	X
RCGrass	Reed Canarygrass	*Phalaris arundinacea*	X	X	X	X								
Rus Ol	Russian-olive	*Elaeagnus angustifolia*	X				X	X	X	X	X	X	X	X
SaltCed	Salt Cedar	*Tamarix spp.*	X				X	X	X	X	X	X	X	X
ChGrass	Cheatgrass	*Bromus tectorum*	X	X	X	X	X	X	X	X	X	X	X	X
Teasel	Teasel	*Dipsacus fullonum*	X	X	X					X			X	
C Burd	Common Burdock	*Arctium minus*	X	X	X	X	X	X	X	X	X	X	X	X

X On the list for this state
(shaded) Not on the list for this state

- Record the presence of any species listed for your State within the plot on either the left or right bank by marking the appropriate box(es) on the right hand column of the Riparian “Legacy” Trees and Invasive Alien Plants field form. If none of the species listed for your state is present in either of the plots at a given transect check the box labeled “None” for this transect.

- Repeat Steps 1 through 5 for each remaining transect (B through K). At transect “K”, look upstream a distance of 4 channel widths) when locating the legacy tree.

RIPARIAN "LEGACY" TREES AND INVASIVE ALIEN PLANTS

Reviewed by (initial): DP

22977

SITE ID: WXXP99-9999 DATE: 07/01/2001

Tran	LARGEST LEGACY TREE VISIBLE FROM THIS STATION						ALIEN PLANT SPECIES PRESENT IN LEFT AND RIGHT RIPARIAN PLOTS	
	Trees not Visible	DBH (m)	Height (m)	Dist. from wetted margin (m)	Type	Taxonomic Category	Check all that are present	
A	☐	☐ 0-0.1 ☐ .75-2 ☒ .1-.3 ☐ >2 ☐ .3-.75	☒ <5 ☐ 5-15 ☐ 15-30 ☐ >30	10	☒ Deciduous ☐ Coniferous ☐ Broadleaf Evergreen	POPLAR/COTTONWOOD	☒ NONE	☐ RC Grass ☐ Salt Ced ☐ Hblack ☐ G Reed ☐ Engl Ivy ☐ CanThis ☐ Teasel ☐ C Burd ☐ Ch Grass ☐ M This ☐ Spurge ☐ Rus Ol
B	☐	☐ 0-0.1 ☐ .75-2 ☐ .1-.3 ☐ >2 ☒ .3-.75	☐ <5 ☒ 5-15 ☐ 15-30 ☐ >30	15	☒ Deciduous ☐ Coniferous ☐ Broadleaf Evergreen	SNAG	☒ NONE	☐ RC Grass ☐ Salt Ced ☐ Hblack ☐ G Reed ☐ Engl Ivy ☐ CanThis ☐ Teasel ☐ C Burd ☐ Ch Grass ☐ M This ☐ Spurge ☐ Rus Ol
C	☐	☐ 0-0.1 ☒ .75-2 ☐ .1-.3 ☐ >2 ☐ .3-.75	☐ <5 ☐ 5-15 ☒ 15-30 ☐ >30	5	☒ Deciduous ☐ Coniferous ☐ Broadleaf Evergreen	POPLAR/COTTONWOOD	☐ NONE	☐ RC Grass ☐ Salt Ced ☐ Hblack ☐ G Reed ☐ Engl Ivy ☒ CanThis ☐ Teasel ☐ C Burd ☒ Ch Grass ☐ M This ☒ Spurge ☐ Rus Ol

INSTRUCTIONS

Legacy trees are defined as the largest tree within your search area, which is as far as you can see, but within maximum limits as follows:

Wadeable Streams: Confine search to no more than 50 m from left and right bank and extending upstream to next transect (for 'K' look upstream 4 channel widths)

Non-wadeable Rivers: Confine search to no more than 100 m from left and right bank and extending both upstream and downstream as far as you can see confidently.

Alien Plants: Confine search to riparian plots on left and right bank

Wadeable Streams: 10 m x 10 m

Non-wadeable Rivers: 10 m x 20 m

Not all aliens are to be identified in all states. See Field Manual and Plant Identification Guide.

TAXONOMIC CATEGORIES

Acacia/Mesquite
Alder/Birch
Ash
Maple/Boxelder
Oak
Poplar/Cottonwood
Sycamore
Willow
Unknown or Other Deciduous

Cedar/Cypress/Sequoia
Fir (including Douglas fir and hemlock)
Juniper
Pine
Spruce
Unknown or Other Conifer

Unknown or Other Broadleaf Evergreen

Snag (Dead tree of any species)

ALIEN SPECIES

RC Grass	Reed canarygrass	*Phalaris arundinacea*
Engl Ivy	English ivy	*Hedera helix*
ChGrass	Cheat grass	*Bromus tectorum*
Salt Ced	Salt Cedar	*Tamarix spp.*
Can This	Canada thistle	*Cirsium arvense*
M This	Musk thistle	*Carduus nutans*
Hblack	Himalayan blackberry	*Rubus discolor*
Teasel	Teasel	*Dipsacus fullonum*
Spurge	Leafy spurge	*Euphobia esula*
G Reed	Giant reed	*Arundo donax*
C Burd	Common burdock	*Arctim minus*
Rus Ol	Russian-olive	*Elaeagnus angustifolia*

COMMENTS

Transects D to K continued on other side

03/26/2001 2001 Riparian Legacy Trees

Figure 7-11. Riparian "Legacy" Tree and Invasive Alien Plant Form (Page 1).

A trend of increasing concern along streams in many parts of the Western U.S. is the invasion of alien (non-native) tree, shrub, and grass species. A list of "target" invasive species has been prepared for each individual State, and is summarized as part of the procedure presented in Table 7-13. At each transect, the presence of listed invasive plant species within the 10 m x 10 m riparian plots on either bank is recorded on the Riparian "Legacy" Trees and Invasive Alien Plants field form (Figure 7-11). Note that the list of target plants varies from State to State. Record only the presence of plants which are targets in your state, even though you may observe other alien species in stream reaches within your state. Record an observation for each transect, even if none of the species listed for your state is present.

7.6 CHANNEL CONSTRAINT, DEBRIS TORRENTS, AND RECENT FLOODS

7.6.1 Channel Constraint

Whether natural or the result of human activities, the presence of immovable or difficult-to-move river margins constrains the degree to which the stream can form its own channel and banks through scour and deposition. The degree of channel constraint can strongly influence the quantity and quality of habitat for aquatic organisms. Constraint also influences the type and degree of stream channel adjustment to anthropogenic alterations in flow and sediment supply, or to direct channel manipulations (e.g., dredging, revetment, impoundment). To assess overall reach channel constraint, we have modified methods used by Oregon Department of Fish and Wildlife in their Aquatic Inventories (Moore et al., 1993).

After completing the thalweg profile and littoral-riparian measurements and observations, envision the stream at bankfull flow and evaluate the degree, extent and type of channel constraint, using the procedures presented in Table 7-14. Record data on the Channel Constraint Assessment Form (Figure 7-12). First, classify the stream reach channel pattern as predominantly a **single** channel, an **anastomosing** channel, or a **braided** channel.

- **Anastomosing channels have relatively long major and minor channels** branching and rejoining in a complex network.

TABLE 7-14. PROCEDURES FOR ASSESSING CHANNEL CONSTRAINT

NOTE: These activities are conducted after completing the thalweg profile and littoral-riparian measurements and observations, and represent an evaluation of the entire stream reach.

Channel Constraint: Determine the degree, extent, and type of channel constraint is based on envisioning the stream at **bankfull flow**.

- Classify the stream reach channel pattern as predominantly a **single** channel, an **anastomosing** channel, or a **braided** channel.

  Anastomosing channels have relatively long major and minor channels branching and rejoining in a complex network.

  Braided channels also have multiple branching and rejoining channels, but these sub-channels are generally smaller, shorter, and more numerous, often with no obvious dominant channel.

- After classifying channel pattern, determine whether the channel is constrained within a narrow valley, constrained by local features within a broad valley, unconstrained and free to move about within a broad floodplain, or free to move about, but within a relatively narrow valley floor.

- Then examine the channel to ascertain the bank and valley features that constrain the stream. Entry choices for the type of constraining features are bedrock, hillslopes, terraces/alluvial fans, and human land use (e.g., road, dike, landfill, rip-rap, etc.).

- Based on your determinations from Steps 1 through 3, select and record one of the constraint classes shown on the Channel Constraint Form.

- Estimate the percent of the channel margin in contact with constraining features (for unconstrained channels, this is 0%). Record this value on the Channel Constraint Form.

- Finally, estimate the "typical" bankfull channel width, and visually estimate the average width of the valley floor. Record these values on the Channel Constraint Form.

  NOTE: To aid in this estimate, you may wish to refer to the individual transect assessments of incision and constraint that were recorded on the Channel/Riparian Cross-Section Forms.

  NOTE: If the valley is wider than you can directly estimate, record the distance you can see and mark the box on the field form.

CHANNEL CONSTRAINT AND FIELD CHEMISTRY - STREAMS/RIVERS

Reviewed by (initial): SP

SITE ID: WXXP99-9999 DATE: 07/01/2001

IN SITU MEASUREMENTS		Station ID: (Assume X-site unless marked)
		Comments
STREAM/RIVER DO mg/l: (optional)	5.3	
STREAM RIVER TEMP. (°C):	20.5	
TIME OF DAY:	11:25	

CHANNEL CONSTRAINT

CHANNEL PATTERN (Check One)

- ☒ **One channel**
- ☐ **Anastomosing (complex) channel** - (Relatively long major and minor channels branching and rejoining.)
- ☐ **Braided channel** - (Multiple short channels branching and rejoining - mainly one channel broken up by numerous mid-channel bars.)

CHANNEL CONSTRAINT (Check One)

- ☐ **Channel very constrained in V-shaped valley** (i.e. it is very unlikely to spread out over valley or erode a new channel during flood)
- ☐ **Channel is in Broad Valley** but channel movement by erosion during floods is **constrained by Incision** (Flood flows do not commonly spread over valley floor or into multiple channels.)
- ☐ **Channel is in Narrow Valley but is not very constrained**, but limited in movement by relatively narrow valley floor (< ~10 x bankfull width)
- ☒ **Channel is Unconstrained in Broad Valley** (i.e. during flood it can fill off-channel areas and side channels, spread out over flood plain, or easily cut new channels by erosion)

CONSTRAINING FEATURES (Check One)

- ☐ **Bedrock** (i.e. channel is a bedrock-dominated gorge)
- ☐ **Hillslope** (i.e. channel constrained in narrow V-shaped valley)
- ☐ **Terrace** (i.e. channel is constrained by its own incision into river/stream gravel/soil deposits)
- ☐ **Human Bank Alterations** (i.e. constrained by rip-rap, landfill, dike, road, etc.)
- ☒ **No constraining features**

Percent of channel length with margin in contact with constraining feature: 0 % (0-100%) --->

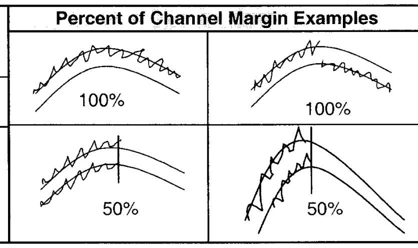
Bankfull width: 6 (m)

Valley width (Visual Estimated Average): 2000 (m)

Note: Be sure to include distances between both sides of valley border for valley width.

If you cannot see the valley borders, record the distance you can see and mark this box. ☒

Percent of Channel Margin Examples



Comments: VALLEY WIDTH > 2000 meters

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03/26/2001 2001 Chan Con/Fld Chem

Figure 7-12. Channel Constraint and Field Chemistry Form, showing data for channel constraint.

- **<u>Braided channels also have multiple branching and rejoining channels</u>**, but these sub-channels are generally smaller, shorter, and more numerous, often with no obvious dominant channel.

After classifying channel pattern, determine whether the channel is constrained within a narrow valley, constrained by local features within a broad valley, unconstrained and free to move about within a broad floodplain, or free to move about, but within a relatively narrow valley floor. Then examine the channel to ascertain the bank and valley features that constrain the stream. Entry choices for the type of constraining features are bedrock, hillslopes, terraces/alluvial fans , and human land use (e.g., road, dike, landfill, riprap, etc.). Estimate the percent of the channel margin in contact with constraining features (for unconstrained channels, this is 0%). To aid in this estimate, you may wish to refer to the individual transect assessments of incision and constraint. Finally, estimate the “typical” bankfull channel width and visually estimate the average width of the valley floor. If you cannot directly estimate the valley width (e.g., it is further than you can see, or if your view is blocked by vegetation), record the distance you can see and mark the appropriate box on the field form.

7.6.2 Debris Torrents and Recent Major Floods

Major floods are those that substantially overtop the banks of streams and occur with an average frequency of less than once every 5 years. Major floods may scour away or damage riparian vegetation on banks and gravel bars that are not frequently inundated. They typically cause movement of large woody debris, transport of bedload sediment, and changes in the streambed and banks through scouring and deposition. While they may kill aquatic organisms and temporarily suppress their populations, floods are an important natural resetting mechanism that maintains habitat volume, clean substrates, and riparian productivity.

Debris torrents, or lahars, differ from “conventional” floods in that they are flood waves of higher magnitude and shorter duration, and their flow is comprised of a dense mixture of water and debris. Their high flows of dense material exert tremendous scouring forces on streambeds. For example, in the Pacific Northwest, debris torrent flood waves can exceed 5 meters deep in small streams normally 3 meters wide and 15 cm deep. These torrents move boulders in excess of 1m diameter and logs >1m diameter and >10m long. In temperate regions, debris torrents occur primarily in steep drainages and are relatively infrequent, occurring typically less than once in several centuries. They are usually set into motion by the sudden release of large volumes of water upon the breaching of a natural or human-constructed impoundment, a process often initiated by mass hillslope failures (landslides) during high intensity rainfall or snowmelt. Debris torrents course downstream until the slope of the stream channel can no longer keep their viscous sediment suspension in motion (typically <3% for small streams); at this point, they “set up”, depositing large amounts of sediment, boulders, logs, and whatever else they were transporting. Upstream, the “torrent track” is severely scoured, often reduced in channel complexity and devoid of near-bank riparian vegetation. As with floods, the massive disruption of the stream channel and its biota are transient, and these intense, infrequent events will often lead to high-quality complex habitat within years or decades, as long as natural delivery of large wood and sediment from riparian and upland areas remains intact.

In arid areas with high runoff potential, debris torrents can occur in conjunction with flash flooding from extremely high intensity rainfall. They may be nearly annual events in some steep ephemeral channels where drainage area is sufficient to guarantee isolated thunderstorms somewhere within their boundaries, but small enough that the effect of such storms is not dampened out by the portion of the watershed not receiving rainfall during a given storm.

Because they may alter habitat and biota substantially, infrequent major floods and torrents can confuse the interpretation of measurements of stream biota and habitat in regional surveys and monitoring programs. Therefore, it is important to determine if a debris torrent or major flood has occurred within the recent past. After completing the Thalweg Profile and Channel/Riparian measurements and observations, examine the stream channel along the entire sample reach, including its substrate, banks, and riparian corridor, checking the presence of features described on the Torrent Evidence Assessment Form (Figure 7-13). It may be advantageous to look at the channel upstream and downstream of the actual sample reach to look for areas of torrent scour and massive deposition to answer some of the questions on the field form. For example, you may more clearly recognize the sample reach as a torrent deposition area if you find extensive channel scouring upstream. Conversely, you may more clearly recognize the sample reach as a torrent scour reach if you see massive deposits of sediment, logs, and other debris downstream.

Reviewed by (Initials): DP

TORRENT EVIDENCE ASSESSMENT FORM - STREAMS

SITE ID: WXXP99-9999 DATE: 07/01/2001

TORRENT EVIDENCE	
Please X any of the following that are evident.	
EVIDENCE OF TORRENT SCOURING:	
☐	01 - Stream channel has a recently devegetated corridor two or more times the width of the low flow channel. This corridor lacks riparian vegetation with possible exception of fireweed, even-aged alder or cottonwood seedlings, grasses, or other herbaceous plants.
☐	02 - Stream substrate cobbles or large gravel particles are NOT IMBRICATED. (Imbricated means that they lie with flat sides horizontal and that they are stacked like roof shingles – imagine the upstream direction as the top of the "roof.") In a torrent scour or deposition channel, the stones are laying in unorganized patterns, lying "every which way." In addition many of the substrate particles are angular (not "water-worn.")
☐	03 - Channel has little evidence of pool-riffle structure. (For example, could you ride a mountain bike down the channel?)
☐	04 - The stream channel is scoured down to bedrock.
☐	05 - There are gravel or cobble berms (little levees) above bankfull level.
☐	06 - Downstream of the scoured reach (possibly several miles), there are massive deposits of sediment, logs, and other debris.
☐	07 - Riparian trees have fresh bark scars at many points along the stream at seemingly unbelievable heights above the channel bed.
☐	08 - Riparian trees have fallen into the channel as a result of scouring near their roots.
EVIDENCE OF TORRENT DEPOSITS:	
☐	09 - There are massive deposits of sediment, logs, and other debris in the reach. They may contain wood and boulders that, in your judgement, could not have been moved by the stream at even extreme flood stage.
☐	10 - If the stream has begun to erode newly laid deposits, it is evident that these deposits are "MATRIX SUPPORTED." This means that the large particles, like boulders and cobbles, are often not touching each other, but have silt, sand, and other fine particles between them (their weight is supported by these fine particles – in contrast to a normal stream deposit, where fines, if present, normally "fill-in" the interstices between coarser particles.)
NO EVIDENCE:	
☒	11 - No evidence of torrent scouring or torrent deposits.

COMMENTS

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Figure 7-13. Torrent Evidence Assessment Form.

7.7 EQUIPMENT AND SUPPLIES

Figure 7-14 lists the equipment and supplies required to conduct all the activities described for characterizing physical habitat. This checklist is similar to the checklist presented in Appendix A, which is used at the base location (Section 3) to ensure that all of the required equipment is brought to the stream. Use this checklist to ensure that equipment and supplies are organized and available at the stream site in order to conduct the activities efficiently.

7.8 LITERATURE CITED

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EQUIPMENT AND SUPPLIES FOR PHYSICAL HABITAT

QTY.	Item	
1	Surveyor's telescoping leveling rod (round profile, metric scale, 7.5m extended)	
1	50-m fiberglass measuring tape & reel	
1	Hip chain (metric) for measuring reach lengths (Optional)	
1	Clinometer (or Abney level) with percent and degree scales.	
1	Lightweight telescoping camera tripod (necessary only if slope measurements are being determined by one person)	
2	½-inch diameter PVC pipe, 2-3 m long: Two of these, each marked at the same height (for use in slope determinations involving two persons)	
1	Meter stick. Alternatively, a short (1-2 m) rod or pole (e.g., a ski pole) with cm markings for thalweg measurements, or the PVC pipe described for slope determinations can be marked in cm and used.	
1 roll ea.	Colored surveyor's plastic flagging (2 colors)	
1	Convex spherical canopy densiometer (Lemmon Mod.B), modified with taped "V"	
1	Bearing compass (Backpacking type)	
1 or 2	Fisherman's vest with lots of pockets and snap fittings. Used at least by person conducting the in-channel measurements to hold the various measurement equipment (densiometer, clinometer, compass, etc.). Useful for both team members involved with physical habitat characterization.	
2 pair	Chest waders with felt-soled boots for safety and speed if waders are the neoprene "stocking" type. Hip waders can be used in shallower streams.	
	Covered clipboards (lightweight, with strap or lanyard to hang around neck)	
	Soft (#2) lead pencils (mechanical are acceptable)	
11 plus extras	Channel/Riparian Cross-section & Thalweg Profile and Woody Forms	
1 plus extras	Slope and Bearing Form; Riparian Legacy Tree and Invasive Alien Plant Form; Channel Constraint Assessment Form; Torrent Evidence Form.	
1 copy	Field operations and methods manual	
1 set	Laminated sheets of procedure tables and/or quick reference guides for physical habitat characterization	

Figure 7-14. Checklist of equipment and supplies for physical habitat.

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NOTES