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Monitoring of Streambank Stability and Streamside Vegetation in a Livestock Exclosure on the Warm Springs River, Oregon:

Comparison of Ground-Based Surveys with Aerial Photographic Analysis

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MONITORING OF STREAMBANK STABILITY AND STREAMSIDE VEGETATION IN A LIVESTOCK EXCLOSURE ON THE WARM SPRINGS RIVER, OREGON: COMPARISON OF GROUND-BASED SURVEYS WITH AERIAL PHOTOGRAPHIC ANALYSIS

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ABSTRACT

The objective of this monitoring project was to determine the baseline condition for a 960-m long stream reach and its associated streamside zone, which terminates at the confluence with the Deschutes River. This stream reach had been damaged heavily in the February 1996 flood and had also received many years of overuse by livestock grazing. The monitoring project was conducted in July 1997 just after installation of riparian exclosure fencing. Future resurvey of the study area will allow determination of progress made in ecological recovery.

Baseline conditions were determined using a variety of techniques and parameters. Data were collected via aerial photography followed by GIS mapping and analysis and also by ground-based surveys. Primary environmental features surveyed included streamside vegetation, channel morphology, and streambank stability. Vegetation, recorded by color infrared stereo photography, was mapped into a GIS format. Mapped features on aerial photography included trees and shrubs by height class, river margins, topographic elevation to the nearest 0.5 m, fences, roads, locations of permanent iron stakes and benchmarks, cobble areas. Channel morphology was inferred from aerial photography by measurements of wetted width and streambank slope and height.

Ground-based monitoring involved establishing 25 permanent transects spaced at 40-m intervals, starting at the mouth of the Warm Springs River. Along the upstream side of alternate transect lines, starting at the active water edge, four adjacent quadrats of 25 m^2 area (5 x 5 m) were laid out on the north and south sides of the river. For each transect line for which vegetation surveys were made, there was a South A, B, C, and D quadrat and a North A, B, C, and D quadrat. Data collected for each quadrat included vegetative type (tree, shrub, forb, grasses) and species, height class, and cover class and also type of ground cover (e.g., cobble, gravel, sand, soil, ground-layer vegetation). Streambank stability was determined from data collected on height and angle of bank, bank material composition, and vegetative cover. These data were collected for the lower and upper bank and integrated using an index of bank stability developed in this project. Ground-based photography was taken at photopoints on every transect line. Photopoints were located on transect lines generally at 20-m distance from the active water and looking directly toward the stream along the transect line. Another set of photopoints was located on the transect line at each stream margin, looking in the upstream direction.

This monitoring project provided basic baseline data that can be used to establish future environmental trends. However, it also had a significant research and development purpose. After a review of literature on methodology used in assessing streambank stability, a new method was synthesized from past methods that eliminates much of the subjectivity and many logical inconsistencies of past methods. It also avoids labeling streambank stability in the field using the "black and white" stable/unstable dichotomy in favor of collecting more quantitative data that can be interpreted in the office according to any number of conceptual processes for estimating stability characteristics. That is, when stable or unstable are the only data collected in the field for each transect, there is no further ability to re-interpret stability characteristics or to compare baseline condition with future surveys at a fine scale in streambank restoration.

This project also provided a means to explore techniques for rapidly collecting useful data to evaluate vegetation and channel recovery. These data collection efforts were conducted at two spatial scales provided by aerial- and ground-based surveys. It was concluded that significant data on vegetative conditions can be obtained from aerial surveys followed by GIS mapping and analysis. At a scale of

1:6000 a comprehensive analysis of cover by trees and shrubs of several height classes was made for a 20-m wide band on each side of the river. Intensive vegetation analysis was conducted on the ground that could not have been fully duplicated from aerial surveys. Estimates of cover by vegetation type (tree or shrub) and height class were easily estimated by aerial mapping but species diversity was not feasible to infer from aerial techniques used. Tree and shrub cover by height class measured from aerial surveys compared favorably with ground-based analysis when both estimates were determined from the same fixed quadrats. This corroboration attests to the accuracy of aerial estimates. Ground-based vegetation analysis by quadrat provided a representative subsample of the entire streamside band of 20-m width outward from each stream margin as measured by aerial survey. This information was useful in demonstrating the adequacy of quadrats to sample vegetation in the streamside zone. Cover estimates by vegetation type, species, and height class on north and south sides of the river were significantly different from one another. Species composition and height diversity by species indicated a highly disturbed range condition, heavily dominated by exotic invader species and unpalatable native species. Species distribution was highly dependent upon relative elevation of the vegetation above the river water surface.

Ground-based photography was hot-linked to photopoints indicated on GIS vegetation maps. Project files in the GIS permitted displaying orthorectified aerial photography as a background layer to mapped vegetation polygons, quadrats and transect lines, photopoints, contour lines, etc. By this method it was possible to view the vegetation on the aerial photo, see how it was mapped, get information on the height class, and call up the ground-based photo for a particular photopoint to compare with the aerial image or mapped vegetation. The GIS then serves as a means to link data on various spatial scales and provide cross-validation of information at any scale. Past methodology that relied primarily on a few fixed photopoints could not ensure that photos were representative of the entire study area. The linkage of comprehensive aerial imagery and ground-based photography provided a more efficient and effective means to represent a baseline condition.

ACKNOWLEDGEMENTS

Funding for this monitoring project was provided by the Bonneville Power Administration under project number (BPA) 96FC96721. The Columbia River Inter-Tribal Fish Commission (CRITFC) staff worked under a Professional Services Contract with the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO). In addition, much financial support was provided by CRITFC thanks to Phil Roger (CRITFC, Fishery Science Department Manager) to ensure that this project, which proved to be more involved than anticipated as well as a valuable prototype for monitoring, could be seen to completion. The objective of this project was to conduct baseline monitoring of streambank conditions and streamside vegetation subsequent to installation of riparian exclusion fencing to reduce livestock impacts to the lower mile of the Warm Springs River near the mouth. Monitoring conducted by CRITFC was a component of the overall BPA contract to implement this BPA-funded stream restoration project.

Jim Griggs was the CTWSRO Fisheries Program Manager during the initiation of this monitoring project and was instrumental in helping establish this service contract. I also appreciate the support given this project by Charles Calica, Bobby Brunoe, and Terry Luther at the CTWSRO. Patty O'Toole, who assumed the responsibilities as Fishery Program Manager at CTWSRO, also oversaw the majority of the field work. Her assistance in the field as well as in project management was extremely valuable. David Smith, BIA range conservation officer at CTWSRO, generously provided very helpful training in recognition of plants in the study area and also assisted greatly in field work. Very helpful and diligent field work was also provided by Roland Kalama, Rayna Estimo, and Orlando Doney. Marissa Stradley, GIS specialist at CTWSRO, contributed an exceptional amount of work to this project. She imported files from BPA's mapping department into ArcInfo and created all GIS map coverages for resource themes on the river. Much personal effort and expertise was applied by Marissa to get these mapping coverages to conform to my analysis needs. Her advice in using ArcView was invaluable. Eric Brandt, GIS program manager, was instrumental in seeing that our GIS needs were provided under this contract.

Tom Morse was the BPA contracting officer responsible for administering the contract and coordinating aerial photography and mapping products. Jerry Green in the BPA mapping department was helpful in planning aerial flights. Ray Ronald performed all the mapping from stereo aerial photography using the analytical stereoplotter. His expertise and care in mapping were a great benefit. Kim Salarzon edited the map work. Chip Dunham was very helpful in sending mapping files to Warm Springs in formats that could be further manipulated. He and Ray also facilitated other mapping requests.

This project was greatly assisted by excellent work contributed by many dedicated people to whom I am very indebted. Matthew Schwartzberg (CRITFC, Fisheries Scientist) helped develop this monitoring proposal, assisted in field work, and kept the Macintosh computer running smoothly. His problem-solving approach to doing research was always inspirational. Roy Beaty provided many useful suggestions for producing the report and welcome encouragement. Hilary Forrest, CRITFC database programmer, contributed greatly to this project by setting up the structure of the databases. It was always a relief and a fascinating experience to get such competent help in explaining the workings of Access. Brent Campbell and Matt Freid were very helpful in solving several ArcView and MacIntosh problems

It is always humbling to see just how many people's expertise are vitally needed for a project to be successful. It was a great pleasure and experience to work with all these people.

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INTRODUCTION

Study Area

The study area was the approximately 1.6 km (1 mile) long river reach extending from Bennie's Bridge on the Warm Springs River to the river mouth where it enters the Deschutes River. The study area is a sagebrush-rabbitbrush-juniper rangeland that has been heavily disturbed by past livestock grazing and the February 1996 flood event. This last major flood event caused local channel widening and created overflow channels that eroded floodplains and cut into upland sagebrush habitat, thereby leaving some alders and also sagebrush communities as isolated islands or pedestals along the summertime wetted margins of the mainstem. Ground-based vegetation monitoring extended outward 20 m from each stream water surface edge and aerial mapping of vegetation was done outward to 50 m from each channel margin.

This study area is situated within the Warm Springs Indian Reservation at an elevation of approximately 378 m (see BPA contour map). The reservation is 1000 mi^2 in area and lies in the Deschutes River basin east of the Cascade Range. The climate is primarily continental, with some moderating effects of marine air. Maximum temperature range is approximately -38 to 114°F. Mean annual precipitation in the Cascade portion of the Reservation is 120 inches, but the eastern two-thirds of the Reservation has from 5 to 50 inches. However, in the study area itself, the mean annual precipitation range is merely 5-10 inches (Marsh, Helliwell, and Rodgers 1987).

The entire Reservation offers habitat for approximately 20 coniferous tree species, 5 deciduous species, 60 species of shrubs, and 300 species of forbs, grasses, and grass-likes (CTWSRO 1991).

The significance of the Warm Springs River and its watershed to spring chinook production in the Deschutes River basin is very great. Currently, natural spring chinook production is sustained primarily in the Warm Springs River and Shitike Creek. The adult spring chinook run passes Sherars Falls from early May to mid June and reaches spawning grounds (primarily tributaries Beaver Creek and Mill Creek) (see Figure 1). A second peak in the run occurs in late August to early September, but this comprises less than 10% of the run. Spawning occurs from late August to mid-September (NPPC and CBFWA 1990). Restoration of the anadromous fish production potential in the river will involve restoration of riparian vegetation, streamside shade, and channel structure. Although spawning areas are upstream, the quality of the lower river migration corridor is also important. Restoration of riparian cover for purposes of water temperature control is a watershed-wide restoration activity. Improvements to water temperature via riparian restoration in a livestock exclosure may be fairly small when evaluated on a stream reach as short as the study area. However, the potential for the stream to become very wide and shallow by lateral cutting into the floodplain area is great. Increased stream heating is caused when channels are widened, exposing greater surface area, as well as by riparian canopy removal. In addition, maintenance of small W/D ratios and deep pools in the channel is important for providing good migration conditions.

Objectives

The objective of the monitoring project done under the CTWSRO-CRITFC subcontract was to establish an environmental baseline condition for a stream reach on the Warm Springs River that will be useful in interpreting future ecological recovery of this reach after major flood damage and also installation of riparian exclosure fencing.

The environmental features monitored are key physical features of salmon habitat that are heavily dependent upon management of the local riparian zone and floodplain. This monitoring program will provide important baseline information on condition of the streamside vegetation, bank stability, and channel morphology of the 960-m reach of the Warm Springs River immediately upstream from its confluence with the Deschutes River. Stream characteristics that are heavily controlled by upstream stream or watershed management, such as water temperature or channel substrate fine sediment condition were not measured. The lower reaches of the river were severely altered during the February 1996 flood. The effects of this natural flood event were probably made worse by past management impacts to the riparian zone–primarily by grazing. Under exclusion fencing, it is expected that improvements in bank stability, increased vegetation cover, an increase in tree cover relative to ground cover, a narrowing of the channel, and a change in floodplain morphology to redefine channel banks will occur. The value of this monitoring effort will be to (1) establish baseline conditions on key monitoring variables that reflect changes in livestock management, (2) evaluate the ability of vegetation monitoring via aerial photography and mapping to provide reliable baseline data, (3) serve as a tool for visual display of all data, graphics, and photography produced in the study, and (4) field test, critique, and assemble useful and rapid methods for vegetation and bank stability monitoring that can be recommended for more extensive application. This field study, conducted in July 1997, represents baseline conditions for future monitoring of channel bank and riparian recovery from effects of grazing and floods.

Background on Importance of Monitoring Variables

(1) Bank Stability

Livestock grazing along the Warm Springs River is a major source of streambank instability in the lower extent of the river. Cattle destabilize streambanks by removing riparian vegetation that provides deep roots to retain soils. Livestock grazing is a major contributor to loss of bank stability by vegetation removal, bank trampling and calving, leading to loss of bank overhangs, channel widening, and water depth decrease. Riparian trees and shrubs reduce water velocities in floodplains during overbank flow events. Overgrazing can severely affect the age structure and vigor of riparian trees and shrubs, leading to diminished root binding of streambanks and eventual elimination of trees as old ones die and are not replaced.

Maintenance of excellent bank stability conditions is an essential component of providing high quality habitat conditions for salmonids. Monitoring of bank stability for comparison to a standard and to apply adaptive management to riparian zones has various objectives, such as to (a) prevent streambank erosion processes from delivering sediment directly to spawning and rearing areas or to prevent increases in the total sediment load of the stream system that will cause downstream cumulative effects, (b) create conditions favorable for development of undercut banks, (c) protect streambank

deep-rooted vegetation that will stabilize streambank soils and allow development of shade, and (d) maintain width/depth ratios that provide optimal fish habitat conditions for the channel type.

(2) <u>Riparian Vegetation Condition</u>

One of the clearest indications of improvement in stream system condition is from restoration of riparian vegetation. Riparian vegetation, when restored to a late seral ecological condition, will provide critical functions for the stream channel and fish habitat. This riparian condition will provide deep rooted vegetation that will stabilize banks, reduce erosion, produce areas of overhanging bank that will support rearing salmonids. It will also provide shade for temperature control and LWD that stores sediment and creates pools and fish hiding cover. Vegetation that is most effective in providing these functions includes trees, shrubs, sedges, and perennial grasses. Species indicative of overgrazing tend to be frequently non-native species that can spread rapidly on heavily disturbed soils and are generally poor forage for cattle. This creates a downward spiral for rangeland vegetation in which the most palatable forage or browse is also that which creates the best conditions for promoting bank stability and wildlife.

(3) <u>Channel Morphology</u>

Riparian vegetation exerts a strong influence on fish habitat by stabilizing streambanks, contributing large woody debris to the channel, and providing shade, among other functions. Livestock grazing impairs these functions of riparian vegetation by directly removing vegetation, impeding recovery of vegetation, reducing the long-term supply of large woody debris, and breaking down banks. Bank destabilization results in increased channel width, reduced pool frequency and depth, increased water temperature, and increased substrate fine sediment. Because of the obscuring effects of upstream uncontrolled actions in this study design, channel width and cross-sectional morphology of the channel/floodplain zone were evaluated among the aforementioned variables because they are heavily influenced by degradation or restoration in the study area. Remonitoring of these variables after several years of restoration may reveal changes in stream width or cross-sectional morphology of the floodplain zone. Overall floodplain morphology could be evaluated using the topographic contour map by calculating changes in the volume of floodplain material above a fixed datum. For present purposes, sample cross-sections of the floodplain and channel from topography mapping were compared with ground based cross-sections. Changes in pool frequency and depth could also be monitored as an indicator of major channel morphology changes associated with bank stability, LWD, and sediment loads. Pools, however, were not surveyed because large pools were not an apparent feature of this section of the river.

METHODS

Division of Responsibility in Data Collection and Analysis

Establishing the study area layout, collecting and analysis of data on environmental features was accomplished with cooperation among three organizations. The division of responsibilities among these organizations is given in Table 1.

Table 1. The division of responsibilities in monitoring.

Environmental Features	Organization Responsible		
	BPA[1]	**CTWSRO**	**CRITFC**
Study area layout	establish and locate by GPS the permanent benchmarks; contract aerial flight	assist in installing iron re-bar stakes, transect lines, and sample quadrats; GPS all iron stakes	establish iron re-bar stakes on transect lines; number the stakes; layout sample quadrats along transect lines
Bank stability	aerial photo interpretation.		ground estimation of bank stability.
Vegetation cover	mapping from stereo aerial photographs; convert to GIS; create GIS tabular databases assoc. w/polygons	convert all mapped data to GIS coverages; add "buffer" zones (5-m bands) to GIS product to create map coverage; create coverage defining locations of quadrats; intersect vegetation with quadrat and band layers.	analyze GIS data for vegetation cover
			photographic documentation at transects; store digital images on CDs; link images to GIS system

[1] Work done on a separate contract

		assist in ground estimates of vegetation cover on quadrats; guidance and assistance in vegetation identification	ground-based monitoring of vegetation cover and height diversity on quadrats; analysis of all vegetation data; comparison of field- and aerial-based vegetation data.
Channel morphology			analyze and plot channel cross-section showing floodplain morphology from topographic. contour map
			note location of major pools; measure pool depth

Establish Transects and Quadrats

In early June 1997 iron re-bar (3/4" diameter) transect markers were driven into the ground in locations considered to be relatively secure from the effects of scouring by floods. The first permanent stake was driven on the north side of the river near the mouth, opposite the telephone pole located on the south side that holds an osprey nest (Figure 2). From this "0" point marker, other iron transect markers were installed at 40-m intervals up to Bennie's Bridge. Spacing was determined by stretching a tape from one stake to the next in a direction estimated visually to be parallel to the adjacent river channel trend. A total of 25 stakes were driven on the north side, identifying transect lines 0 to 24. Then, with crew members on each side of the river communicating with radios and by raising a 6-m long telescoping stadia rod with a flag on top at each stake, an opposing stake was positioned as close to perpendicular to the local channel trend as could be visually determined. The stakes on the south side of the river were also located at approximately 15 to 20 m from the water edge except in those transects where flood scouring necessitated placing stakes further from the river. Overflow channels cut into the streamside terraces on the south side of the river resulted in creation of several lateral ponds with minimal connection to the mainstem during the summertime flow period. Frequently these lateral ponds were separated from the mainstem by a longitudinal string of alders growing on gravel berms and/or by small remnants of the sagebrush community existing as a small island or an unstable pedestal with a ground surface at a relative elevation of 1.0-1.5 m above the adjoining water surface.

Wooden stakes were driven into the ground near the river along the line sighted between the two iron transect markers with crews on each side of the river helping identify positions of the iron stakes and the correct positioning of wooden stakes. Once wooden stakes were in place and marked with spray paint it was easy for a crew of 1 or 2 to identify each transect line while working on only one side of the river at a time. Given the transect line defined by the iron stakes and each associated wooden

stake, nylon string was reeled out from the water's edge outward along the transect line to a distance of 20 m. Each sample plot was defined as a rectangle with one limb extending 5 m upstream perpendicular to the other limb (the 20-m segment of the transect line). Each sample plot was divided into 4 quadrats of 5 m x 5 m, identified as A,B,C, and D, where A was closest to the river (see Figure 3). The A quadrat also had a sub-quadrat A1, which extended only 1 m upslope and was also 5 m along the river (Figure 3). In situations where this 1-m wide buffer zone fell on a berm within <0.5 m relative elevation above the water surface there sometimes existed typical greenline vegetation (e.g., sedges) covering these surfaces.

Ground-based sampling of vegetation and bank stability was done on approximately every other transect when it became clear that the time spent sampling every transect would become excessive. Photographs were taken on every transect line to provide a fuller documentation of vegetation from the ground perspective.

Positioning of ground-based quadrats was replicated on GIS maps of the study area derived from stereo aerial photographs, again using the transect line and the active water edge as referencing indicators. The majority of quadrats had areas of nearly 25 m^2 but areas ranged from approximately 15 to 45 m^2 because of a few transects having buffer lines distorted by highly irregular stream margins. In the future, automated mapping of quadrats could more accurately reflect ground position and dimensions of quadrats by either smoothing the trace of the stream margins or by manually drawing strongly smoothed lines to provide a less complex line on which to generate buffer lines.

See Figure 4 for the layout of quadrats and transects and the table ALLQUAD in the VegBand2 database. This database table lists quadrats sampled on the ground and their areas as determined by GIS and created in the buffering process. Transect points, transect lines, and photopoints from aerial mapping are shown in Figure 2.

See Appendix 1 (from database WSPlants6: table Photos2) for a tabulation of positions of each iron stake: distance from the stake to the active water edge along each transect line. Appendix 1 also provides data on geographic orientation (based on true north) of transect lines as measured from GIS maps. Sighting from one transect stake to the opposing one on the other bank was frequently difficult because of intervening vegetation. This required five people to accomplish in these instances. This method of aligning people along the line connecting transect markers worked as long as the people stationed between two other people near transect stakes could clearly see at least these two individuals and serve to line up people along the path. Wooden stakes were then driven into the bank near the water's edge along this line to facilitate additional transect line placements and location of quadrats on each bank of the river.

Photographic Documentation

(1) <u>Ground-based Photography</u>

Vegetation was photographed using a 35-mm Canon camera equipped with a wide-angle zoom lens set to 18 mm focal length. Photographs were taken typically at a distance of 20 m from the water's edge along the transect line with the exact center of the viewing frame lined up with the transect line (see Appendix 1 for distances and notes on photos). Crew members held the rod vertically at a typical

distance of 10 m from the active water's edge (i.e., edge of the mainstem, flowing water) and 10 m from the camera lens. The camera was mounted on a tripod for these photos and leveled using a clinometer so that the film plane was vertical. The center point of the camera view window was superimposed on the rod held vertically on the transect line. The intersection of the center of the film frame with the rod, then, should be at a horizontal level equal to that of the camera lens so that angles projected above and below this point outward to the canopy at a distance of 10 m beyond the rod would roughly indicate the height of the vegetation. Transect lines and bank (north or south) were written on a green chalk board in white chalk to document each color transparency. Variation that did occur in positioning of the rod or camera relative to the water's edge generally required using a distance smaller than 10 m between rod and camera because of interference by a fence or a large impenetrable tree occupying the line of sight. Photographs taken on transect lines, sighting toward the stream.

In addition to photographs toward the river along each transect line, color photographs were taken at the water's edge in an upstream direction on both the north and south banks for each transect. This means that for each transect there were four photographs. The camera field of view was great enough so that each photo taken nearly perpendicular to the channel incorporated vegetation from the study segments upstream and downstream of each transect line. It would have been desirable to take all photographs exactly at the permanent iron stakes along the transect lines but it seemed to be more desirable to standardize the distance from the lens to the dominant trees that were typically rooted within 5 m of the stream edge. Ground-based photographs linked to photopoints on the GIS vegetation maps are useful in establishing a visual connection between aerial photography, mapped vegetation on the GIS, and recorded data on vegetation type, height, and cover by quadrat. Whereas conventional monitoring programs may rely exclusively on ground-based photopoints, the monitoring system devised here creates linkages among maps, photos, and data that spans various levels of spatial resolution. Ground-based photos, then, gain additional significance when they can be viewed in relation to the entire landscape. They are also a more immediate validation of the quality of the mapping.

Photographic transparencies and negatives were digitized using a Polaroid slide scanner (SprintScan 35/LE) at a resolution of 1000 dpi. This film scanner delivers digital images at 10 bit/color. Image sizes were approximately 3.3 M stored in .tif format, the preferred format to preserve color information. [Note: images placed on the CD were originally scanned in .bmp format, converted to .jpg (to take advantage of data compression), and finally converted to .tif after it was discovered that ArcView 3.0a would not read .jpg images. Consequently, some information loss was inevitable and film would need to be rescanned as .tif images before attempting any color analysis]. Digital images were linked to the transect lines of the GIS map using the hot link feature, which allows viewing photos of the site simultaneously with the vegetation map. Each image was coded by bank, transect line, and either perpendicular to the stream (T) or upstream (U) orientation. Photos shot perpendicular to the stream along transect lines were loaded into one photopoint theme and those shot in an upstream direction from the stream edge or at other positions on the transect line were loaded into another theme in ArcView. See Appendix 1 for notes on each image. Notes contain information on key taxa visible and the position of the camera lens relative to the rod and the active water edge. Unless otherwise specified in notes, distance between the camera and the rod was 10 m and the distance from the rod to the active water was 10 m. The photo image data was loaded into the WSPlants6 Access database as a table using an Access data form for entering data. Photos were linked to other Access tables so that queries could be performed to identify, for example, any photo containing a certain plant or other feature in the database. The photo database table (converted to .dbf

format) was also linked to the ArcView GIS project file containing photopoints mapped as a photopoint theme.

(2) Aerial Photography

Bonneville Power Administration contracted the aerial photography mission with Bergman Photographic Services, Inc. of Portland, Oregon. CRITFC and Warm Springs staff set up white plastic panels in x-shapes having diagonal limbs of approximately 2 ft on each side of the center point, which marked the location of iron transect stakes. BPA crews established permanent control points monumented with heavy brass markers and flagged these points in the same manner as with the transect markers. The latitude, longitude, and altitude of these markers were measured via GPS using a Oregon's HARN network (High Accuracy Reference Network, a control system that US National Geodetic Survey established for accurate GPS surveys) as known, fixed ground stations. Trimble 4000ssi geodetic receivers were set up at two HARN sites and also at each monument in the study area to receive data from 4 to 8 satellites. The horizontal datum was established using NAD83/91; the vertical datum was obtained from NAVD88. Aerial photography was shot at 1" = 500' (1:6000 scale) using color infrared film. Mapping was done using a Zeiss P1 analytical stereoplotter. Zeiss Phocus software was run on a Vax VMS workstation with the stereoplotter to collect and store mapping data. This software has an advantage in allowing the image of a digitized point to be superimposed stereoscopically on the 3-D image viewed through the optics. Phocus software produced aerotriangulation results. Terramodel was the software used to compute contour lines from the elevation data taken at all sampled points on the ground surface. Topographic breaklines were entered into the DTM file to instruct Terramodel how to create the best contour solutions. The contour product was then examined as it fit visually on the terrain as an error checking procedure. All mapping products (e.g., vegetation polygons, terrain contours, etc.) were stored in Phocus, exported to intermediate files, and then sent to the Warm Springs Tribe's GIS department. These files were then converted by Warm Springs to ArcInfo coverages, which were projected to either State Plane coordinates or UTM Zone 10 coordinates, depending upon the set of files and purpose for analysis. Final GIS .e00 files were sent by modem to CRITFC where they were imported into ArcView 3.0a for analysis.

Warm Springs staff, using its own backpack GPS unit determined the x-y coordinates of all iron stakes driven into the ground to mark transect lines established in the study area. These stakes were flagged with white plastic sheeting to create a target on the ground that was distinctly visible on aerial photos. The x,y and z coordinates of each iron stake were mapped by BPA within the geodetic framework established by the surveyed monuments in the study area. The x,y coordinates taken at the iron stakes by Warm Springs staff were compared with the locations of the same points mapped by BPA using their higher performance equipment to determine level of discrepancy. Of the 50 points surveyed, the discrepancy ranged from 0 to 6.2 m with a mean of 3.0 m. Eighty percent of all points measured by Warm Springs staff varied no more than 4.0 m from the location as determined by BPA. The majority of points appeared to be shifted in space in the same direction. This degree of consistency in results indicates that in future work, GPS systems that do not rely on the highly sophisticated HARN system may be sufficient, especially given that accurate monuments now exist in the study area.

The Zeiss stereoplotter was used with 10-12 x magnification for mapping vegetation and other features. Accuracy in mapping, which depended upon scale of photography, optical capabilities of the instrument, and accuracy in conducting GPS work was ±2.1 cm horizontally and ±9.1 cm vertically.

Bank Stability Evaluation

(1) Review of Problems Inherent in the Method

Bank stability was estimated as a function of bank angle, bank material composition, and vegetative cover of the lower bank and the upper banks. The lower bank is that portion of the channel from the current water line up to the bankfull line. The upper bank is the ground surface above the bankfull line. The upper bank may be a floodplain or terrace surface immediately adjacent to the channel and may make a transition to a steeper sideslope. In other situations the upper bank is actually a steep sideslope starting immediately at the bankfull line.

Floodplain or terrace surfaces on which riparian vegetation has been removed can be subject to erosion of side channels and exaggerated channel migration. Vegetation removal and soil disturbance on steep sideslopes can represent a potential for sediment delivery to the channel. These situations point out the value of recording bank angle, bank material, and vegetation cover on upper bank surfaces. However, because there are so many possible slope segments along a channel transect extending from the bankfull line outward on the floodplain or terraces that can vary in their potential for fluvial erosion should the streamflow impinge on them, it appeared to be more reasonable to record merely the condition of the first 1-m band width at the bankfull line.

In streams having a trapezoidal channel bottom, the water width might be reduced greatly in summer, leaving a wide, relatively low-sloped berm of cobble-to-sand up to a bankfull line. The widened channel form might not rank as unstable because of its low slope and coarse bed material. Because this portion of the channel is generally inundated during higher flows, vegetation does not become established on this surface except near the margins. This channel form might, then, be the result of past instability and has taken a more stable form that, nonetheless is an indicator of poor fish habitat. Overhanging banks appear to be unstable in appearance--that is, the overhanging bank material appears to be precariously situated, but if well covered by deeply rooted vegetation in the upper bank area, the bank is often considered to be stable and to provide excellent fish habitat. Bank stability is an indicator intended to provide an index to the current potential of the bank to erode (contributing sediment to the channel), to lose its existing fish habitat potential, and to lead to increased channel widening (W/D). In cases where the banks are totally broken down by livestock and have assumed a very shallow channel cross-sectional morphology, a high W/D, but are fully covered by grasses, one might conclude that by shifting to a maximally disturbed form that it achieves a form resistant to change (i.e., it can't assume a wider cross-section or lower bank angles). The most likely change in form this channel could undergo would be for vegetation to begin trapping sediment and aggrading banks and for channel narrowing to occur. These examples point out the importance of deep rooted vegetation on the lower as well as upper banks and considering more than merely bank angle when translating indicators to a stability rating.

The bank stability rating described by Platts et al. (1987) is comprised of a 1 to 4 rating scale representing stability values of 0-24, 25-49, 50-74, and 75-100%, respectively. A stable surface is one covered by vegetation in vigorous condition, bedrock, boulders, or rubble. This system is based on rating only that portion of the bank or floodplain along a transect line within 5 ft of the stream margin or to the top of the bank, whichever is larger. Platts et al. (1983) recommended rating only the part of the streambank intercepted by the channel cross-sectional transect because they detected greater observer error associated with rating of entire banks. A difficulty with the Platts et al. (1987) method

is that it can at times include floodplain area above the bankfull line and at other times consider only the channel below the bankfull line, depending upon the proximity of the water's edge to the top of the bank. Also, the "top of the bank" is not an especially precise term. Some channels have steep banks that may rise far beyond bankfull height. Others can have successive smaller banks along a transect line perpendicular to the channel.

The system of bank condition ratings used by the BLM (Myers et al. 1989) emphasizes rating of three conditions: streambank soil alteration, vegetative bank protection, and subsurface water status. The streambank soil alteration rating is based upon the percentage of the bank along the transect line that is receiving stress, is broken down, or eroding; conversely, one would rate the percentage in a natural condition. Banks that had been altered and may have attained a degree of stability are still rated as altered. Alteration is classified as either artificial or natural, and livestock grazing is considered to be artificial. If an artificial alteration cannot be distinguished from a natural one, the alteration is classed as artificial. Artificial plus natural alteration can total no more than 100% altered. A difficulty with this method is in distinguishing types of alteration. In addition, the method uses terms such as stable, altered, stress, and broken down or eroding as all being indicators of the presence of soil alteration. This system leaves it unclear how to deal with a streambank that may have suffered severe erosion in the last flood, leaving a vertical cutbank. This bank may not be broken or slumping but the vertical soil bank can appear to be raveling somewhat. If the upper surface has a sagebrush community on it with 20% shrub cover, 20% cheatgrass, and 60% bare soil, and the vegetation condition and species composition show evidence of overgrazing, the upper bank area could be considered to be altered to some extent. Lack of clarity in the amount of transect line to evaluate (i.e., whether it extends from the water's edge to the bankfull height or beyond to the upper bank area) makes this rating fairly subjective. Is percentage alteration a percentage of the transect line distance that shows evidence of alteration? If so, a gradually sloping cobble berm terminating in a 0.5 m vertical soil bank extending to bankfull height could be predominantly stable in terms of percentage of transect length, but the cutbank portion would indicate a zone of active erosion in high flows. This system, however, offers a useful concept in rating as "altered" those banks that had achieved a degree of stability during an erosion process.

The BLM vegetative bank protection rating system, also a rating of 1 to 4, indicates percentage cover by trees, shrubs, grass, and forbs combined. Cover classes are >90, 70-90, 50-70, and <50%. The problem with this rating is that it recommends consideration of a wide variety of characteristics within each rating value that may not always co-occur. For example, it suggests cover criteria, but introduces confusion in the mixture of trees, shrubs, grass, and forbs present, dispersion of openings, plant vigor and reproduction, root density, and vegetation distribution. While the cover classes appear to be quantitative, the need to consider so many other factors makes the rating much more subjective.

The BLM subsurface water status involves a rating of 1 to 4 of the relative composition of the riparian site by hydrophytic vs. upland plants. This rating system includes consideration of whether either of the two vegetation types are reproducing, advancing in their distribution or are water stressed. These features may not be easily discerned or consistently rated, are probably dependent on when sampling occurred (temporal variation) or may require repeated monitoring to detect. It is unclear where on a transect line the vegetation is examined. Is it from the water's edge to the bankfull line? Is it above the bankfull line? A gradually sloping cobble berm may be classed as stable but near the bankfull line some hydrophytic vegetation may occur. As in the case of the Warm Springs River, this may also be a zone where a row of alders exists. Outward from this bankfull line there might be a transition to a sagebrush shrub-dominated community at >0.5 to 1.0 m above bankfull. This transition is abrupt

where there is a vertical cutbank of 0.5 to 1.0 m and in these locations the alder string does not occur adjacent to the vertical cutbank, possibly because erosion was too severe at these points in creating this channel form. As restoration occurs fine sediments should accumulate along channel margins, below and above the normal bankfull line. As soil quality improves, a greater diversity of hydrophytic plants would be found. Maintenance of these communities also depends upon extremes in flows. This subsurface water status index is intended as an indication of shallow aquifer presence. However, whether or not vegetation is found on a cobble berm, there is a shallow aquifer present. Consequently, use of plant composition and reproduction as an indicator of water status can be meaningful, but the bank morphology, bank materials, and elevation of bank surfaces probably adequately define vegetation potential.

The Timber/Fish/Wildlife (1989) monitoring manual indicates that lower banks are evaluated by the combination of bank material, obstructions and flow deflectors, and bank cutting. Bank material is rated on a scale of 1 to 4 according to percentage of large rock and bedrock. A rating of 1 denotes >65% large angular boulders or bedrock highly resistant to lateral scour. On the other end of the scale, a rating of 4 denotes <20% rock, mostly cobble, gravel, or fine sediment that is easily erodible. Although bank material is significant as a means of bank protection, the percentage of large rock would generally depend highly on stream size and gradient. Consequently, although bank material is probably a good index to stability in a particular stream size and channel type, it may not be adequate alone as a consistent index to stability among different stream sizes and channel types.

Bank cutting in the TFW method is defined as the number of feet/1000 ft of stream having bank cutting. A clear definition for recognizing cutting consistently was not given.

The BLM and TFW methods utilize multiple variable indices to evaluate streambank condition. Likewise, the method of Bauer and Burton (1993) recommends evaluating bank erosion potential as a function of both streambank stability and streambank cover. This method classifies bank erosion class as erosional, vulnerable, and non-erosional. The proportion of the total length of both banks falling into the erosion categories for the entire stream reach is calculated. Evaluation of banks along their lengths rather than along cross-sectional transects is a departure from Platts et al. (1983). Streambanks are unstable if they show any of the following features: breakdown, slumping, fracture, vertical (>80° slope) banks, and eroding. Streambanks are considered to be covered if >50% cover is provided by perennial vegetation, roots, rock or cobble or larger size material, or logs with diameter ≥4 inch. Otherwise, banks are considered to be uncovered.

This evaluation of bank erosion using streambank stability and streambank cover, where each of these two variables has two states (i.e., stable/unstable; covered/uncovered, respectively), yields three categories (erosional, vulnerable, and non-erosional) that are produced by all permutations of the various states. This method is a simplification of the Platts et al. (1983) method and has the advantage that entire streambanks are evaluated for the study reach rather than just a subsample at transects. However, there are some limitations in the method. Obviously, streambanks are not simply stable or unstable and covered or uncovered. But, this simplification may be useful in rapidly evaluating an entire reach. It is unclear how useful this method may be in comparing streams from different regions or streams of different channel type within a region where the streams involved may vary in potential vegetation cover, species composition, form of the dominant vegetation creating streambank root development, and hydrology. The interaction of streambank material and streambank stability is not well defined; also these variables are not independent. Streambank stability indices are based predominantly on visible evidence of erosiveness (breakdown, slumping, and fracture) but it also

includes an index to potential erosivity (bank angle). Bank angle and bank material probably interact within the context of a particular stream environment to define bank erosivity. Stability can be considered to be a tendency for erosivity given various characteristics of the streambank, such as bank materials, bank form (slope, shape), and bank cover. The Bauer and Burton method mixes indices of erosiveness, in which the bank had a change in state, with indices for potential. The first type of index shows the result of the action of livestock or natural hydrological events, for example, on the inherent characteristics of the streambank. If a streambank collapsed, it could be said that the inherent instability of the streambank resulted in a change of state. The collapsed bank took on a more relaxed state that may have increased its stability. The immediate consequence is that there is a great amount of sediment delivery to the channel, which will cause channel substrate sedimentation. A steep bank beyond the angle of repose for the bank materials shows an inherent instability that can lead to bank collapse, resulting in a more stable state. The ability of various bank materials and bank slopes, in combination with various strengths of vegetative rooting and bank heights, should likely define the potential for erosion and be more suitable as indicators of bank conditions.

A clear definition of key terms is essential in understanding any bank stability methodology. Bauer and Burton (1993) defined the streambank as the steeper-sloped sides of the stream channel. This is the portion of the channel between the annual scour line and the bankfull level according to these authors and is most affected by erosion during high water. At least, the method would focus on the typically steep area occupied by the vegetative greenline, which is below the bankfull level. On gravel and sand bars, the bank is typically found above the annual scour line as a steepened area below the perennial vegetation or the sod limit. The difficulty of trying to distinguish vegetation rooted solely in the zone between the annual scour line and the bankfull line (such as in the Bauer and Burton 1993 method) makes it more reasonable to consider all vegetation below the bankfull line and that above the bankfull line but within some defined distance from the channel. Another conceptual difficulty with this methodology is that overhanging banks are considered to be stable. Platts et al. (1987) measure bank angle on overhanging banks as 90 to 180°. This would place the bank angle in the unstable category of Bauer and Burton (1993). In addition, the overhanging bank would certainly not have perennial vegetation growing underneath the overhang, leading to a classification of uncovered. The stability of bank overhangs must depend largely on vegetative cover above the bankfull line, yet the Bauer and Burton (1993) method considers vegetative cover only below the bankfull line. This raises the question of why it is not just as significant what the vegetative cover is above the bankfull line but near the high water channel margin.

The channel stability rating of Pfankuch (1978) (as cited by McDonald et al. 1991) involves rating several indicators each for upper bank, lower bank, and channel bottom. Upper bank rating is formed on sideslope gradient, mass wasting potential, debris jam potential, and vegetative cover. Lower bank rating is a function of channel capacity, bank rock content, obstructions and flow deflectors, bank cutting, and sediment deposition. The TFW method and the Bauer and Burton method emphasize the channel below bankfull. The TFW method considers bank rock content, obstruction and flow deflectors, and bank cutting in common with the Pfankuch method. The Bauer and Burton method shares the bank rock content with the Pfankuch method, but utilizes indices of bank slope angle and vegetative cover for rating the lower bank, which the Pfankuch method used in rating the upper bank.

Streambank stability must be an integration of the stability provided by the lower and the upper bank. That is, if the lower bank is unstable, the upper bank would be undermined. Conversely, if the upper bank has no vegetative cover, is composed of erodible materials, and has a steep slope, high water

conditions or intense rainfall could erode the upper bank despite the protection provided on the lower bank. After all, this is one of the principal reasons for protecting the riparian tree and shrub zone.

The method used in the Warm Springs River monitoring study takes what was considered to be the best elements of the previously mentioned methods. See Appendix 2 for notes on the basic elements of methods for streambank stability ratings previously published. The method recommended here for estimating bank stability is to assess bank angle, bank material, and bank vegetative cover for both the upper bank and lower bank. An advantage of reporting the actual data for each of these variables is that given different criteria for evaluating whether a bank falls in the stable or unstable category, that new designation can be made.

(2) <u>Assigning a Stability Class from Streambank Character Data</u>

Evaluate the lower bank and upper bank at locations where transect lines intersect the banks. Evaluate bank angle, vegetative cover, and bank material on 1 x 5 m plots (the 5-m dimension runs parallel to the bank margin). Record these data on streambank plots (Appendix 3) and calculate vertical descent of slope elements, overall slope, and stability using trigonometric functions on the spreadsheet (see Figure 5).

When the lower bank is evaluated to a defined horizontal distance from the bankfull elevation, bank angle also implies consideration of bank height. A bank element that is 90° and 0.25 m in height was considered to have a bank angle rating of 3; if this slope element had a height of 0.6 m its rating was 1. If the slope elements within the first 1 m of horizontal distance are 27° and 90°, with vertical descents of 0.25 and 0.6 m, respectively, the overall angle from bankfull would be 40° (see Figure 6). Such an angle with a total descent of 0.85 m over 1 m horizontal distance has a rating of 3. In this case, the single 90° slope element's stability rating (1) takes precendence.

A) Lower bank: the lower bank would not be considered unstable by itself unless the total elevation change within the first 1 m horizontal from the bankfull line is ≥1 m.

1) Bank angle

Is the total drop in bank elevation ≥1 m within the 1-m wide survey band?
Yes.

Height of slope element (m)	Bank angle (°)	Bank angle rating
≥1 >1	45-63° 63-90° or overhanging	1 0

No. If the total drop in elevation is < 1 m, find the bank angle rating in the following table. If the drop in elevation of any slope element falls with one of the two classes (0-0.5 or 0.5-1.0), determine its corresponding bank angle and bank angle rating. For example, the total drop in elevation from the bankfull line within 1 m horizontal distance from the bankfull line might be 0.9 m. If one slope

element has an angle of 90° and is 0.6 m in height, its rating would be 1. If its height were 0.25 m, its rating would be 3. The remaining 0.3 m in drop (i.e., 0.9-0.6), if uniformly distributed to 1 m horizontal distance would equate to a bank angle of 17° and its rating would be 5. The stability rating should be the lowest one applied to any slope element or to the overall slope if the distribution of elements is very complex. In this example the total elevation loss is 0.9 m within the first 1 m horizontal distance; if this is distributed uniformly over the 1-m distance, the overall slope is 41° and the rating would be 3. A rating of 1 is the lowest for elements in this zone, so this value is assigned. Bank slope elements with vertical descent <0.25 m are all rated as 5, regardless of angle; evaluate overall slope for all elements combined to determine whether overall bank angle rating is <5.

No.

Slope element vertical height * (m)	Bank angle (°)	Bank angle rating
0.25-0.5	0-11 11-45 45-90	5 4 3
0.5-1.0	27-45 45-63 65-90 or overhanging	3 2 1
* Height of an individual slope element or overall descent (m) in first 1 m horizontal distance from bankfull line		

2) Bank material. Add rating scores together for each of the three cobble size classes. Maximum possible score is 5 (i.e., if total rating score adds to 6, reduce total rating to 5 except when bank material is bedrock).

Bank material	Percentage by area (%)	Bank material rating
large cobble (>25 cm)	5-20 20-40 >40	2 3 4
cobble (12.5-25 cm)	10-20 20-40 >40	1 2 3
gravel (6-12.5 cm)	10-20 20-40 >40	1 1 2
bedrock	100	15

In locations where ground vegetation obscures the bank material composition, it might be necessary to adopt a convention such as using a hand-held rock pick to strike the ground surface in 10 random locations to a depth of 5 cm to determine whether rock is present. The percentage rock could be converted to a rating. In the Warm Springs River, such a process was not needed. The purpose of such classification is to derive an index to resistance to erosion. The effectiveness of this method depends on the correlation of top material layers to subsurface layers. Penetrating the surface to a depth of 5 cm with a pick could be a useful test, but was not employed in current monitoring.

3) Vegetative cover. Add rating scores together for each of the vegetative cover classes. Maximum possible score is 5 (i.e., if total rating score adds to 6, reduce total rating to 5).

Vegetative cover	Percentage cover (%)	Vegetation cover rating
Shrub and tree canopy cover (Add shrub + tree canopy)	75-100 50-75 25-50 10-25 5-10	5 4 3 2 1
Sedge, perennial grass ground cover	75-100 50-75 25-50 10-25	4 3 2 1

B) Upper bank

1) Bank angle

Is the total drop in bank elevation ≥1 m within the 1-m wide survey band or does any slope element have a drop of ≥1 m?

Yes.

Height of slope element (m)	Bank angle (°)	Bank angle rating
≥1 >1	45-63 63-90 or overhanging	1 0

No.

Slope element vertical height * (m)	Bank angle (°)	Bank angle rating
0.25-0.5	0-11 11-45 45-90	5 4 3
0.5-1.0	27-45 45-63 63-90 or overhanging	3 2 1
* Height of an individual slope element or overall descent (m) in first 1 m horizontal distance from bankfull line		

2) Bank material. Add rating scores together for each of the three cobble size classes. Maximum possible score is 5 (i.e., if total rating score adds to 6, reduce total rating to 5, except when bank material is bedrock).

Bank material	Percentage by area (%)	Bank material rating
Large cobble (>25 cm)	5-20 20-40 >40	2 3 4
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gravel (6-12.5 cm)	10-20 20-40 >40	1 1 2
bedrock	100	15

3) Vegetative cover. Add rating scores together for each of the vegetative cover classes. Maximum possible score is 5 (i.e., if total rating score adds to 6, reduce total rating to 5).

Vegetative cover	Percentage cover (%)	Vegetation cover rating
Shrub and tree canopy cover	75-100 50-75 25-50 10-25 5-10	5 4 3 2 1

Sedge, perennial grass ground cover	75-100 50-75 25-50 10-25	4 3 2 1

Summary Table showing components of the streambank stability rating and maximum scores possible:

Geomorphic surface	Component of stability	Cumulative score
Lower bank	a) Bank angle b) Bank material c) Vegetative cover	Max. 5 Max. 5 Max. 5
	Lower bank subtotal (a+b+c)	Max. 15
Upper bank	a) Bank angle b) Bank material c) Vegetative cover	Max. 5 Max. 5 Max. 5
	Upper bank subtotal (a+b+c)	Max. 15
‣Total bank stability score	Upper + lower subtotals	Max. 30
‣Total bank stability rating	(Upper + lower subtotal)/6	Max. 5

Channel Morphology

Stream channel morphology can be evaluated on various dimensions. Channels express morphological development in vertical variation (e.g., longitudinal profile of the channel bottom, stepped profile of the water surface, spatial distribution of primary pools), planar variation (e.g., sinuosity, braiding, side channel, edge development) and cross-sectional variation (constriction vs. expansion sequences, width variation, cross-sectional form). These same sources of channel morphological variation can also be expressed for valley morphology. A fourth source of variation that extends from the channel into the valley is hyporheic development. This variable can be expressed as a cross-sectional index measured from the channel banks to depth in the substrate and outward into the valley, depending upon interstitial connectivity in the substrate materials.

In this monitoring study, longitudinal or cross-sectional stream depth measurements were not made in the wetted channel. However, channel morphology can be assessed in various ways from GIS data collected. Water surface slope was determined from the upper end of the study area to the mouth using measured water surface elevation in each location based on GIS mapping and the instream channel distance along the centerline. Variation in channel width and mean channel width were

measured on the wetted stream channel GIS layer using the measuring tool with the channel width magnified to approximately 30% of screen monitor dimensions on a 20 inch monitor. Stream width was measured starting at the north bank from the point where each transect line crossed the wetted margin. From this point, the shortest distance across the channel was determined. This channel bisector was not always coincident with the transect line because of varying ability originally to locate transect lines at right angles to the channel.

Channel sinuosity was calculated from GIS mapping of the channel by dividing channel length as measured between the center points of the upstream and downstream transects by the straightline distance between these same two points.

Channel cross-sections were produced using the GIS topographical map created from hundreds of ground-surface elevations with a contouring program by BPA. Contour lines were drawn at 0.5-m intervals. With this map the distances from channel wetted margins outward along transect lines on each bank to intersections of the transect line with contour lines were determined using the GIS measuring tool. Elevation and distance from each bank's wetted margin were plotted for sample transects to evaluate the ability to monitor bank morphology from aerial photography.

Vegetation Analysis from Field Surveys

(1) <u>Floristic analysis:</u> <u>species composition, major growth forms, ecotypes</u>

Plant species identification was conducted with expert assistance from David Smith, range conservation specialist of the Warm Springs Tribe. Mr. Smith provided guidance in the field in identification of major plant species (i.e., approximately four occasions with up to approximately 2 h assistance each devoted to plant recognition) and assistance in the office in species classification of specimens collected in the field. The Warm Springs Tribe has a very useful plant key by Helliwell ("Forest plants of the Warm Springs Indian Reservation") that lists the major species found on the reservation within various plant associations. In addition, David Smith provided a checklist of common species on the reservation, although not specifically limited to those in a riparian or lowland area or a sagebrush and juniper rangeland (Appendix 4). With this degree of orientation to the species, I attempted to be as definitive as possible in species identifications with an elementary level ability to recognize riparian and rangeland plants. Although considerable time was spent taking samples from the study area for later identification by specialists, a clarification of most of these identifications will not assist greatly in refining the species lists by quadrat. No plant with significant biomass and very few with significant frequency were overlooked. Keying unknowns to species would provide the most help in developing a master list of species present in the study area for this baseline monitoring investigation. In addition, this would facilitate future monitoring efforts by providing a basic list of species to expect in sampling.

Because I did not have the benefit of extensive experience in keying the species present, continuous help from a specialist, and a complete set of samples for the study area that were all identified to species prior to commencing data collection, it is necessary to describe the degree to which the plant classification as performed should be relied upon. In many cases there were rare species that had low frequency, insignificant biomass, and minor or negligible influence on soil holding (erosion prevention), shading, or streambank stability. These species can be grouped by family, by indicator

status (exotic/native, aggressive invader/rare or infrequent plant, forage quality (excellent/poor)), or by major plant type (tree, shrub, forb, grass), or plant growth form. Also, there were two common species that it later became obvious were being confused (flixweed and tumble mustard). These species are both members of the Brassicaceae with very similar growth forms--tall, biennial herbs with a very diffuse, branching form. Each has long seed pods. The tumble mustard can be distinguished by large, deeply dissected lower leaves, not found on flixweed, and a more stout stem (USDA 1988). Other common species are the sedges and rushes. These will not be distinguished in the analysis, despite attempts in the field to do this to a limited extent. However, they were distinguished by height class.

To make interpretations from data most meaningful and so as not to imply false precision, taxa were lumped where uncertainty in classification warranted it. Groupings that were made were based on similarity in plant form and ecological type. There was little difficulty in consistently identifying all the trees and shrubs in the study area, at least to genus. Willows were not common and were all lumped as *Salix* spp. Many forbs were easily recognizable to species level and especially to genus. Due to the varying degrees to which vegetation was classified, the taxa used as identifiers are listed below according to greatest level of differentiation. Dominant forbs and grasses were, for the most part, reliably distinguished (but confusion between flixweed and tumble mustard was noted, resulting in combining these taxa). Some of the rarer forbs and grasses presented difficulty in classification and were either lumped or simply not emphasized due to their rarity. However, all taxa were accurately and consistently classified by major cover type (tree, shrub, forb, grass) and height class and were consequently included in summaries by cover type.

Taxonomic differentiation recognized in sampling

Taxa identified in ground-based vegetation monitoring on quadrats are listed below according to level of classification considered to be reliable. The following lists make clear the taxonomic level considered to be meaningful, taxa that were noted but may not have been identified consistently throughout the entire study area, and decisions made to lump taxa according to ecological or taxonomic similarity.

Trees

alder
birch
elderberry
juniper

Note: Cottonwood was the only other tree noted in the study area but was not found in sample quadrats. It was limited to one very large tree and numerous seedlings scattered for approximately 30 m around the tree.

Shrubs

bitterbrush chokecherry mockorange mountain mahogany rabbitbrush sagebrush sumac wild rose or rose willow

Note: Although gray and green rabbitbrush were most often easily distinguished, consider them as one taxon because this vegetation was sometimes simply recorded as rabbitbrush.

Forbs

Common taxa with significant contribution to forb biomass and the taxonomic level to which they were consistently identified with confidence:

buckwheat-- combine strict buckwheat, sulphur buckwheat China lettuce common mullein cudweed curly dock gumweed knapweed knotweed-- combine all forms (i.e., erect and prostrate) leguminaceae-- combine all vetches *Lomatium*-- combine Indian celery, *Lomatium* canbyi nightshade plantain-- combine buckhorn and common plantain poison ivy poison hemlock St. John's wort stork's bill teasle thistle-- combine Canadian thistle and other thistles tumble mustard--combine this taxon with flixweed turkey mullein white blossom sweetclover yarrow yellow blossom sweetclover

Uncommon taxa and taxa with insignificant biomass that were identified with confidence in all quadrats to the taxonomic level indicated:

arrow leaf balsam root
big head clover
cockleburr
dandelion
mallow
mint
morningglory
needle leaf navaretia
nettle
salmon colored collumbia
sunflower

Uncommon species and species with insignificant biomass that were identified as present in the study quadrats by David Smith, but may not have been consistently identified in all quadrats:

forget-me-not
hairy fleabane
moth mullein
stick leaf
speedwell
wild onion
wood sage

Grasses

Common taxa with significant contribution to grass/sedge biomass and the taxonomic level to which they were consistently identified with confidence:

bottlebrush squirreltail-- combine with foxtail barley
cheatgrass
Equisetum-- combine all forms of this genus
medusahead
rabbitsfoot grass
rattlesnake grass
sedges-- combine all sedges and rushes other than Equisetum

Uncommon taxa and taxa with insignificant biomass that were identified as present in the study quadrats by David Smith, but may not have been consistently identified in all quadrats:

Canadian wild rye
Kentucky bluegrass-- combine with bluegrass
mutton grass
Thurber's needlegrass

See file plants2.697 for a digital copy of field notes for plant, ground, and geomorphic data. This file was converted to tables in the Access database by eliminating the table structure, converting to comma delimited form, importing to Access, creating various data tables, and specifiying their relationships.

The taxonomic list of common names used in the Access WSPlants6 database was the basis for developing Table 2 to compile scientific names of taxa noted and their ecological characteristics. Reaction of taxa to grazing and their palatability to livestock were also compiled (Table 2). This table allows evaluation of the ecological condition of the rangeland. These data become even more useful when evaluated in relation to cover and size class information by taxa. From the basis of personal experience with this study reach, the dominant species for riparian and upland plant communities can be listed along with their ecological characteristics and indicator value. In the riparian area the most commonly encountered trees were alder and birch. The most common shrubs in this zone were chokecherry, mockorange, wild rose, and willow. Unfortunately, willow was very restricted in distribution in the study area and cottonwood, though found in the study reach, was extremely rare. Among these shrubs, only the willow has good palatability to livestock, while the other shrubs provide forage mostly for wildlife. Heavy past grazing on this study area appears to be most responsible for the marked lack of willows. On the uplands the tree species that was most common was juniper. Among the shrubs, the most common was sagebrush, gray and green rabbitbrush, sumac, bitterbrush, and mountain mahogany. Of these shrubs, the bitterbrush and mountain mahogany have significance as livestock forage, but appear to be fairly uncommon, probably as a result of their preference by livestock as forage. The more dominant shrubs (sage and the rabbitbrush species) have little forage utility.

The forbs and grasses provide dramatic indication of range damage from overgrazing. The most common taxa of forbs found in riparian as well as upland areas were buckwheat, China lettuce, curly dock, fiddlehead, flixweed, knapweed, knotweed, lamb's quarter, Lomatium, hairy mullein, plantain, poison hemlock, St. John's wort, storksbill, thistle, teasle, tumble mustard, turkey mullein, white blossom sweetclover, yellow blossom sweetclover. The most dominant forbs by biomass and cover appeared to be hairy mullein, turkey mullein, poison hemlock, St. John's wort, knapweed, knotweed, thistle, poison hemlock, and the two sweetclovers. Among these most dominant forbs, the knapweed, St. John's wort, hairy mullein, plantain, sweetclover, and tumble mustard at a minimum are exotic invader species. Poison hemlock is highly toxic to livestock and St. John's wort is also toxic. All of these forb taxa are indicators of overgrazing and poor, dry soils and most have poor palatability. The knapweed, flixweed, and tumble mustard are troublesome invader species with poor forage value for livestock or wildlife and crowd out more useful plants. Of these species, the sweetclovers appear to be the most useful as far as forage value, biomass, and ability to improve poor, depleted range soils. The dominant grasses on the upland range area were cheatgrass, medusahead, and foxtail barley. All these species are typical of degraded rangeland. The cheatgrass and medusahead are introduced exotic grasses that are highly invasive and result in severely diminished forage availability on rangelands because they are both suitable for grazing for only a very limited timespan during their annual cycles. Neither contributes significantly to soil binding and erosion prevention. In wet overflow areas and riparian areas the sedges and rushes (especially Equisetum), are the most common taxa. Lush cover by these taxa was present in localities where access by livestock was discouraged naturally by steep lower bank slopes.

Table 2. Common and scientific names of taxa observed in quadrats in the Warm Springs River study area and their ecological characteristics.

SpecID	Species Name	Cov Type
1	Alder	*Alnus*
2	Arrow leaf balsam root	*Balsamorhiza sagittata*; important forage plant on spring ranges for livestock and deer and elk; a perennial of the sunflower family; can withstand heavy trampling and grazing but does not aggresively spread; it is sustained by a very deep root system.
3	big head clover	*Trifolium macrocephalum*; has high palatability to cattle, sheep, deer, and elk.
4	Birch	*Betula*
5	Bitterbrush	*Purshia tridentata*;; highly palatable for sheep and cattle; important browse for deer, elk, and antelope; it is an important, high quality forage, especially during spring, fall, and winter; can withstand heavy grazing, but is being eliminated on overgrazed rangeland.
6	bluegrass, Kentucky	*Poa pratensis* (Poaceae)
7	bottlebrush squirreltail	Sitanion hystrix; found in meadows and open woods at low elevations; fair palatability to cattle and sheep in early spring; a perennial bunchgrass, related to foxtail barley; common on dry hills, plains, open woods, and rocky slopes. Both foxtail barley and squirreltail are palatable and can rate as poor to good forage for livestock at young stages but cause damage to animals when mature
8	buckwheat	*Eriogonum* sp.
9	buckwheat - strict	*Eriogonum*
10	buckwheat - sulfur	*Eriogonum*
11	Canadian thistle	*Cirsium arvense* (Asteraceae)
12	Canadian wild rye	Grass
13	cheatgrass	*Bromus tectorum*; an exotic annual or winter annual from the Mediterranean common in disturbed areas; competes with more desirable perennial grasses for moisture; it has a winter to early spring growth period.
14	China lettuce	*Lactuca* (Asteraceae)
15	chokecherry	Prunus virginiana; is poor to fair as forage for cattle and sheep; fairly small amounts of leaves consumed can be lethal to sheep and cows; toxicity decreases late in the season (e.g., by October).
16	cockleburr	*Xanthium* (Asteraceae)
17	cudweed	*Gnaphalium* (Compositae); found on hummocky ground where soil moisture may be high in springtime.
18	curly dock	*Rumex crispus* (Polygonaceae); a tap-rooted perennial; common in disturbed wetlands; seeds are of some use by waterfowl.
19	daisy	Compositae
20	dandelion	*Taraxacum officinale* (Asteraceae)

21	elderberry	*Sambucus* sp. (Caprifoliaceae); deciduous large shrub or small tree; found at low to mid elevations, particularly along streams and roads; common in mixed conifer; good to high palatability in fall to cattle, sheep, deer, and elk. Only one large specimen found in study area and this was dying..
22	elk sedge	*Carex geyeri*
23	Equisetum	Equisetaceae or horsetail family
24	Feces	Ground
25	fireweed	*Epilobium angustifolium* (Onagraceae); Common on burned timberland, wasteland, along streams; found on relatiavely dry sites as well as on moist sites, using gravelly soils to loam; an important forage weed on rangeland; palatability is fair to good for sheep and poor to fair for cattle.
26	flixweed	*Descurainia* sophia (syn. Sophia parviflora, or Sisymbrium sophia) (Brassicaceae); An invader of heavily disturbed and overgrazed sites; an annual or biennial; fair to poor forage for sheep, goats and cattle; does not compete well with annual grasses or weeds in a reduced grazing situation but can provide dense stands of poor quality forage on areas denuded by overgrazing.
27	foxtail barley	*Hordeum jubatum*; a perennial grass; native of North America.; common in wet or alkaline soils, degraded meadows and pastures.
28	Fragaria--buttercup	Forb
29	grasses	Grass
30	gray rabbitbrush	*Chrysothamus nauseosus* (Compositae); a deep-rooted perennial shrub; is found with sagebrush and juniper; often replaces species such as giant wild rye or other desirable forage species on dry rangeland when disturbed or overgrazed; very poor forage value; it is sometimes grazed lightly in late fall during the flowering period.
31	green rabbitbrush	*Chrysothamus viscidiflorus* (Compositae); low elevations in western juniper woodland extending into Ponderosa Pine in open, usually disturbed areas; poor palatability to cattle; fair palatability to sheep, deer, elk.
32	gumweed	*Grindelia* (Compositae); A native plant found in pastures, rangeland, roadsides, and heavily disturbed areas. It is highly drought resistant and unpalatable to livestock.
33	hairy fleabane	Forb
34	moth mullein	*Verbascum blattaria* (Scrophulariaceae); An invader from Europe, occurs along roadsides and waste areas.
35	Indian celery	*Lomatium*
36	juniper	*Juniperus occidentalis occidentalis*
37	Kentucky bluegrass	*Poa pratensis*; a sod-forming perennial grass; can be effective in reducing erosion; is a higly palatable source of forage for livestock, deer and elk. Palatable from spring through summer; resistant to heavy grazing.
38	knapweed	*Centaurea* sp. (Asteraceae); an exotic species from Eurasia; this is a highly invasiv plant that crowds out desirable species on dry rangelands.
39	knapweed (prostrate)	forb

40	knotweed	*Polygonum* (Polygonaceae); found in extremely dry to very wet sites on on poor soils and heavily overgrazed sites lacking perennial cover.; can provide soil erosion protection; low palatability and very poor forage for cattle and horses; fair for sheep and goats.
41	knotweed (common low-growing)	*Polygonum*; an annual;
42	knotweed (erect)	*Polygonum erectum*; 1 to 3 feet tall. An exotic plant from Europe. Thrives in drylands in compacted soils, disturbed areas.
43	knotweed (prostrate)	*Polygonum aviculare*
44	knotweed (sheathed)	forb
45	lambsquarter	*Chenopodium*
46	leguminaceae	American vetch (*Vicia* sp.)
47	Litter/ Duff	ground
48	*Lomatium*	Forb; biscuitroots; found in juniper and sagebrush zones into ponderosa pine and aspen zones on well-drained soils, and dry open slopes; palatability ranges from poor to good for cattle, poor for horses, good for deer and elk.
49	*Lomatium canbyi*	forb
50	mallow	(Malvaceae)
51	medusahead	*Elymus caput-medusae*; an exotic introduced from Eurasia; aggressive winter annual of the semi-arid rangeland on the Pacific Northwest. It can even crowd out cheatgrass; can result in massive (75%) reductions in grazing capacity.
52	milkweed	Western salsify (*Tragopogon dubius* (Asteraceae)); invading plant
53	milky vetch	*Astragalus*
54	mint	Forb
55	mockorange	*Philadelphus lewisii* (Hydrangeaceae); fair palatability to sheep and cattle, highly palatable to deer and elk; not a significant source of forage for livestock; found in moist, alluvial loams to dry, gravelly loams on open hillsides; usually associated with alder, chokecherry, willow on moist sites and bitterbrush, mullein, serviceberry, and ponderosa pine on dry sites.
56	morningglory	Convolvulaceae
57	mountain mahogany	*Cercocarpus* (Rosaceae); palatable by all livestock.
58	mullein	*Verbascum thapsus* a biennial; introduced from Europe; found along rivers, pastures, meadows, on gravelly soils; unpalatable to livestock;
59	mutton grass	*Poa fendleriana*; a perennial bunchgrass; highly palatable and nutritious for livestock, elk, and deer
60	*Myosotis*, forget-me-not	(Boraginaceae); a perennial native forb found in wet areas.
61	needle leaf navaretia	*Navaretia intertexta*; found in moist to relatively dry locations; sparsely distributed, perennial forb.
62	nettle	*Urtica dioica* (Urticaceae); found along streams in moist areas, especially along streams used by livestock.
63	nightshade	*Solanum* (Solanaceae)
64	pink star flower (borage)	Forb

65	plantain - buckhorn	*Plantago lanceolata* (Plantaginaceae); An exotic from Eurasia; found along roadsides and disturbed sites; a commonly occurring weed but widely scattered and not a significant forage species on rangeland..
66	plantain - common	*Plantago major* (Plantaginaceae); An exotic from Eurasia; found along roadsides and disturbed sites; a commonly occurring weed but widely scattered and not a significant forage species on rangeland.
67	poison hemlock	*Conium maculatum*; young shoots are very toxic; roots are extremely toxic to all livestock and basically all mammals.
68	poison ivy	*Toxicodendron radicans*; palatable by sheep, goats, and cattle.
69	rabbitbrush	*Chrysothamnus* (Compositae)
70	rabbitsfoot	*Polypogon monspeliensis* (Poaceae)
71	Western buttercup	*Ranunculus*
72	rattlesnake brome	*Bromus mollis*
73	Rock	Ground
74	Roots	Ground
75	rose	Shrub
76	rye	Grass
77	sagebrush	*Artemisia tridentata*; this species is poor forage for sheep and very poor for livestock in Oregon; it has low palatability because of its bitterness; otherwise it has high nutritional value if eaten; In winter when no other food sources are available it can serve as a useful forage.
78	salmon colored collumbia	*Collumia grandiflo*ra (Polemoniaceae)
79	Sand	Ground
80	sedge	*Carex*
81	Sedge/grass	Grass
82	showy milkweed	Forb; *Tragopogon dubius* or western salsify
83	Soil	Ground
84	St. John'swort	*Hypericum perforatum* (Clusiaceae); A perennial introduced from Europe; found on sandy or gravelly soils; toxic.
85	stick leaf (Agoserus?)	Forb, unknown
86	storksbill	*Erodium cicutarium* (Geraniaceae); An exotic from Europe or Asia; edible by livestock and deer; it is an especially good forage plant, especially in spring; it is found as a widely scattered plant or as extensive clumps; its habit of growing very close to the ground allows it to sustain heavy livestock concentrations; it can spread aggressively on arid land.
88	sumac	*Rhus* (Anacardiaceae);
89	sunflower	*Helianthus*
90	teasle	*Dipsacus* (Dipsacaceae); An exotic from Europe; found in moist sites and disturbed area.
91	thistle	Forb
92	Thurber's needlegrass	Poa thurberiana
93	Total: forbs	Forb
94	Total: grasses	Grass
95	Total: shrubs	Shrub

96	Total: trees	Tree
97	tumble mustard	*Sisymbrium* (Brassicaceae); A native of Europe; is common in rangeland and heavily disturbed areas with exposed mineral soil below elevations of the ponderosa pine. It is an invader of denuded land and provides some degree of soil protection. It is generally of poor palatability but may be fair in early spring when tender.
98	turkey mullein	*Eremocarpus setigerus* (Euphorbiaceae); A native, prostrate annual plant; found on dry sandy soils.
99	unknown forb	Forb
100	unknown tree	Tree
101	vetch	*Vicia* (Fabaceae), pea family
102	white blossom sweetclover	*Melilotus alba*; a very good forage crop, which is best for livestock in the spring; later in the year it becomes more bitter and woody, lessening its palatability; it is very good in improving soil condition and adding humus; a deep taproot improves soil aeration and drainage.
103	wild onion	*Allium*
104	wild rose	*Rosa woodsii*; found in hot, sunny, dry to cool, shaded, moist locations; they are generally scattered in distribution; often found in the vicinity of streambanks or stream margins. Poor to fair forage for cattle; good for sheep, deer and elk.
105	wild strawberry	*Fragaria*
106	willow	*Salix* spp.; an important source of browse on rangeland; it is highly palatable by sheep and less so be cattle (i.e., generally fair for cattle); however, cattle occupying riparian areas make abundant use of willows, especially in late summer when its palatability improves. Damage to willow stands is generally associated with overall degradation of rangeland herbaceous cover.
107	wood sage	Forb, unknown; very small (3" diam); distinctive purple leaves
108	Woody debris	Ground
109	yarrow	*Achillea millefolium*
110	yellow blossom sweetclover	*Melilotus officinalis*; Introduced from Europe and Asia; common along roadsides and disturbed areas. It is sometimes used for soil stabilization and soil improvement. Causes bloat in cattle and produces anticoagulation of blood.
	fiddleneck	Amsinckia (Boraginaceae); native plant, poisonous to livestock; found in N24D quadrat
	puncturevine	Tribulus terrestris (Zygophyllaceae) (Caltrop family); invader from southern Europe, may damage livestock; found in N9 to N24 quadrats.

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(2) Vegetation Frequency

Estimates of vegetation density (number of stems per unit area) appear to be highly desirable for their quantitative nature, but the time required in counting individual stems coupled with the difficulty in counting grass stems, willow shoots, etc., makes the time spent in this pursuit questionable in a monitoring program of this sort (see Mueller-Dombois and Ellenberg 1974). Frequency was calculated from ground-based vegetation surveys as a practical alternative. Frequency identifies the percentage of all sample quadrats that contain the species in question. This index is the frequency percentage (Gleason 1920, as cited by Mueller-Dombois and Ellenberg 1974). Frequency is the most commonly applied descriptive statistic used in North American vegetation studies. Frequency depends upon the size and shape of the quadrat relative to the species richness per unit area and the distribution pattern of each species (e.g., random, contagious). Frequency is not a meaningful indicator of cover because a species with many, small, randomly dispersed individuals can have a high frequency with a low cover.

In transect work in ground-based studies, herbaceous cover is often estimated in small quadrats (e.g., approximately 0.5 x 0.5 m) nested within larger quadrats (e.g., 5 x 20 m) used for shrub or tree canopy cover (see Myers 1989). Permanent quadrats or transects are the best means to follow trends in plant density and cover over a long period of monitoring (Moore and Chapman 1986). Cain and Castro (1959) (as cited by Mueller-Dombois and Ellenberg 1974) suggested using the following quadrat sizes for estimating frequency of these vegetation forms:

moss layer	0.01-0.1 m^2
herb layer	1.0-2.0 m^2
low shrubs and tall herbs	4 m^2
tall shrubs	16 m^2
trees	100 m^2

With the preceding guidelines, quadrats of 5 x 5 m (i.e., 25 m^2) were selected for the shrub layer, 5 x 20 m (i.e., 100 m^2) for the tree layer. It was intended at the outset of monitoring to estimate grass and forb presence and cover on 1 x 1 m (i.e., 1 m^2) nested quadrats spaced at 2-m intervals along the transect and within the 5 x 20 m plot. However, given the sparseness of forb cover in many places in this desert plant community, it seemed to be more suitable to use the standard quadrat dimension for recording forb presence.

(3) Vegetation Cover

Cover is defined as the percentage of the ground occupied by a perpendicular projection of the crown or basal shoot area (Moore and Chapman 1986, Mueller-Dombois and Ellenberg 1974). Although a quantitative technique for cover estimation is less subjective, and therefore more reproducible, visual estimates are often made. Visual estimation of cover is rapid and the problems of subjectivity may be overstated in some of the literature (Kent and Coker 1992). Monitoring of vegetation cover in the Warm Springs River streamside areas was done using a combination of visual estimates and crown-diameter measurement. Crown measurement for shrubs and large forbs was made by placing a PVC rod graduated in units corresponding to areal units (m^2) across the diameter of shrubs, assuming that the shrub canopies were circular. Total area by species of shrub or forb was then determined by summation of individual canopies. Cover for a quadrat did not need to be contributed by species rooted in the quadrat; any canopy cover to the quadrat provided by species in or outside the quadrat

necessitated recording the species and its percentage cover. Direct measurement provided the greatest accuracy in calculating either individual canopy cover or total species canopy cover; but, this more detailed analysis was primarily used as a means to calibrate visual estimates.

The variables describing riparian vegetation that were monitored included canopy cover (ability to provide shade), ground cover (cover by boulders, woody debris, leaves or duff, and ground vegetation, indicated as percentage of the surface area within the streamside area), cover by each of three vegetation layers (ground vegetation, shrub, tree) as an indicator of plant stabilization of the banks and floodplain, and cover by height class and species. The total cover to a vertically stratified plant community may exceed 100% when adding the cover produced by ground vegetation (grasses and forbs), shrubs, and trees. Maximum cover with this method is 300%. Because cover was estimated by cover type (tree, shrub, forb, grass in ground surveys and trees and shrubs in aerial surveys) and height class, the combined information provides an index to vegetation biomass (Mueller-Dombois and Ellenberg 1974). That is, tall trees found with 50% cover on a quadrat would likely contribute more biomass than very short trees with the same cover.

On the basis of the 5 x 5 m quadrats, taxa were listed and were visually classified by height. Height classes were as shown in Table 3.

Table 3. Height classes of trees and shrubs recorded in the field and measured by aerial mapping.

Height Class	Range of Plant Height
1	0-0.1
2	0.1-0.5
3	0.5-1.5
4	1.5-3.0
5	3.0-6.0
6	>6.0 m

The cover was then estimated by taxa and height class. That is, if sagebrush were observed on the quadrat in three height classes (e.g., 3, 4, and 5), the cover for each of these height classes was estimated by a combination of calibrated visual and measurement techniques. For trees and shrubs, cover for each taxon was recorded by height class. When all forbs combined comprised greater than 5% cover in a quadrat, the cover by height class for dominant forbs was recorded; subdominant taxa were merely listed with no height class designation or individual percentage cover. When cover by all forbs combined was less than 5%, the forb taxa were merely listed and an average height class was recorded for the group, giving deference to the taxa comprising the majority of the cover. Cover classes were recorded for each height class for every taxon (Table 4).

Table 4. Percentage cover for cover classes identified visually in field vegetation surveys.

Cover Class	**Range of Cover (%)**	**Midpoints of Cover Classes (%)**
0	0	0
T (trace)	0-1	0.5
1	1-5	2.5
2	5-10	7.5
3	10-25	17.5
4	25-50	37.5
5	50-75	62.5
6	75-95	85
7	95-100	97.5
P	present; <5%	unknown; not essential for analysis

In terms of data input to the database (WSPlants6), recording merely total forb or grass cover for certain quadrats instead of cover by species necessitated having Cover Class assigned to individual species or to Cover Types, respectively. When calculating the total percentage cover by each Cover Type, percentage cover of all individual taxa by cover type was summed, when these percentages were available. In cases where only the total cover was recorded for a given Cover Type (i.e., taxa were listed but no cover by taxon was recorded), this value provided the estimate of total cover. In cases where cover by individual dominant taxa and also total cover for the Cover Type were recorded, total cover for the Cover Type was not calculated by summing the individual taxa cover percentages. Rather, the total cover estimate for the Cover Type estimated visually for the entire group was considered to be more accurate. That is, when calculating a total cover by summing percentages of individual taxa assigned to a cover class, the total is derived by summing the percentages of the mid-points for each cover class. If each taxon was found to have a very small cover percentage slightly greater than 1%, each would be assigned to cover class 1, and the total would be biased by use of the mid-range value to represent the average cover for each cover class. If many rare species in a quadrat had been recorded as trace cover (T), summing the values for the mid-range cover for these species might result in a total far greater than that estimated from the group of taxa as a whole for each cover type. Consequently, total cover by Cover Type was assembled from information in the Species Data and Totals Data tables in the WSPlants6 database, depending on the rules just mentioned (i.e., whether only cover by individual taxa was available, only total cover for the Cover Type, or both).

The cover classes used to record cover by species represent only a slight modification of the Daubenmire cover scale (Daubenmire 1959, 1968, as cited by Mueller-Dombois and Ellenberg 1974). This modification provides a finer breakdown of cover classes for plants with low cover, more adequately suiting the sparse vegetation in the study area.

Composition of the ground itself was recorded using the same cover classes. Ground materials recorded were rock, sand, soil, woody debris, moss, litter/duff, and feces. The categories rock, woody debris, moss, litter/duff, and feces were taken as materials that protect the ground surface from raindrop erosion. Rock in this evaluation was gravel and larger size material. This classification of material was not oriented toward protection from fluvial erosion but toward prevention of surface erosion and ability of plants to inhabit the site.

A review of some literature and additional considerations in devising an efficient vegetative cover monitoring system is given in Appendix 5.

(4) <u>Vegetation Height Diversity</u>

Vegetation was identified at various levels of taxonomic differentiation (see p. 19), depending on ability to recognize the plants and also on time constraints involved in itemizing all rare species, especially rare grasses, sedges, rushes, and forbs. The most basic vegetation classification was into vegetation form classes (i.e., Cover Type in the WSPlants6 database or tree, shrub, forb, and grass). Grasses represented the groups grasses, sedges, rushes). These cover types were further subdivided into taxa, representing species, genus, or ecotype. These taxa were classified by height and percentage cover for each height class. The ground-based vegetation database (WSPlants6) has species name, height class, and cover class data in the Species Data table. The Cover ID variable in this table is linked to the Cover ID variable in the Cover Data table. This allows assigning a Cover Type to each taxon (SpeciesName in the database). This association, then, allows grouping of taxa by Cover Type and by Height Class.

Vegetation Analysis from Aerial Photography

Stereo pairs of color-infrared photographic transparencies (9 x 9") were used in the process of mapping vegetation from the air. Bonneville Power Administration staff (Ray Ronald) mapped the river segment, fences, roads, bridges, topography (ground elevation), and vegetation. Vegetation was classified as tree and shrub; forbs and grasses were not mapped. Vegetation polygons were drawn around tree or shrub patches of a given average height class. Vegetation polygons and other polygonal or linear features were input to a GIS mapping system by the Warm Springs Tribal staff (Marissa Stradley). The GIS system includes maps of the polygonal and line information, representing vegetation and other features of the stream and surrounding terrain. Associated with this map is a database. For example, the vegetation map contains a data table with area of each polygon, cover type for the polygon, and vegetation height. Vegetation was then analyzed at CRITFC from aerial mapping. See Table 5 for a listing of various indices calculated from the data, variables used in sorting data, and contrasts made.

Cover estimates made from GIS mapping of vegetation from the aerial photographic mission were compared to estimates made from ground observations on quadrats.
The purpose of this ground-based estimate was to provide ground-truthing of aerial photo estimates made for the same quadrats. Although ground-based cover estimates have the potential to be more accurate (especially for forbs and grasses) and, at least, to accurately classify vegetation to species, aerial photography and vegetation mapping combined with GIS analysis has several advantages. Among these is the accuracy in cover estimation associated with being able to include the total study

area rather than a subsample (the quadrats sampled only 6.25% of the total area) and having the perspective of seeing nearly a vertical projection of the canopy to the ground. On the other hand, aerial photography and GIS analysis indicate only percentage cover as interpreted from the topmost canopy layer; ground-based methods allow estimates of the cover provided by structural layers that may occur when shrub cover exists beneath tree cover. Ground-truthing the GIS analysis has the purpose of determining to what degree aerial-based estimates can be a valid substitute for the more labor-intensive ground-based analysis. This comparison is needed in terms of cover (%), height class, and cover type differentiation.

Table 5. A guide to the vegetation analyses done on data collected in the field and from aerial photography and GIS mapping.

Analysis Index	**Spatial basis for analysis**	**Vegetation Index**	**Vegetation Class**[e]	**Sorted by**[f]	**Where to find data**[h]
	Ground-based Vegetation Analysis				
1	all quadrats[a]	frequency	indiv. taxa		Total Frequency.xls; AC1: SppFreqbyQuad, FreqSpecies, Total Freq
2	all plots[b]	frequency	indiv. taxa		AC1: SppFreqbyQuad
3	all quadrats	frequency	indiv. taxa	E	AC1: sage2-freq-elev
4 5 6 7 8	indiv. quadrats	cover[c]	indiv. taxa T S F G		AC1: spp-cov-dist; Species Data, Cover Data, Species Names Cov-x-tree-x-Q; Cov-x-covtype-x-Q Cov-x-covtype-x-Q Cov-x-covtype-x-Q Cov-x-covtype-x-Q
9 10 11 12 13	quadrats of a type	mean cover[d]	T S F G T+S+F+G	B B B B B	Tree-Cov-x-ht.xls; SumTreeCov-x-Q; pct-cov-TSFG.xls; NSbyQbyCovT pct-cov-TSFG.xls; NSbyQbyCovT pct-cov-TSFG.xls; NSbyQbyCovT pct-cov-TSFG.xls; NSbyQbyCovT pct-cov-TSFG.xls; NSbyQbyCovT
14 15	quadrats of a type	mean cover	T T+S	B,H B,H	Tree-Cov-x-ht.xls tree-shrub.xls; AC1: AvTree-Shrub-Cov-x-ht-x-Q
16 17 18	quadrat basis	mean cover	indiv. taxa T S	B, E B, E B, E	alder-cov-x-elev.xls; spp-cov-x-elev alder-cov-x-elev.xls; AvShrubCov-x-Elev-A1 alder-cov-x-elev.xls; AvShrubCov-x-Elev-A1

19 20 21	all quadrats combined (or all plots combined)	mean cover	indiv. taxa T S	B B, H B, H	spp-meanCov.xls; AC1: alder-cov-dist treecover.xls treecover.xls
	Aerial-based Vegetation Analysis				
22	quadrats of a type	mean cover	T	B	GISvsField-T.xls, AC2: GIS-field-treecov
23 24	bands[g] of a type	cover	T S	B B	Area-band-polygons.xls Area-band-polygons.xls
25	bands of a type	cover	T+S	B	Area-band-polygons.xls; AC3 database
26	bands of a type	cover	T,S	B,H	Area-band-polygons.xls
27	entire water surface	mean cover	T,S T+S	H	RivCover.xls RivCover.xls
	Contrasts Made between Ground-based and Aerial-based Vegetation Data				
28 29 30	indiv. quadrat vs. indiv. quadrat	cover	T S T+S		GISvsField-T.xls; AC2: GIS-field-treecov GISvsField-S.xls; AC2: GIS-field-ShrubCov-x-Q GISvsField-T.xls; AC2: GIS-Field-TreeShrubCov
31	indiv. quadrat vs. indiv. quadrat	cover	T+S	H	T-S-ht-Quad-GISvsField.xls; AC2: T-S-ht-Quad-GISvsField

Key: a--individual quadrats were identified by bank (north or south), transect number, and quadrat type (A1,A,B,C,D) in the databases. Frequency data were based on the 100 quadrats of type A,B,C, and D that are each of 25m^2 area. A1 is a subset of A and represents only the narrow (1-m wide) streamside zone, which is often the greenline zone when the A1 quadrat is within 0-0.5 m relative elevation to the water surface.

b--plots were comprised of the combined A,B,C, and D quadrats existing on either streambank at transect lines. Plot dimension were 5 x 20 m (100 m^2).

c--percentage cover of vegetation recorded for the entire quadrat; cover is a total for an individual taxon or for a cover type. Cover for a quadrat refers to all height classes combined for the taxon or cover type, but other analyses might consider cover by a particular height class (see page 29).

d--mean percentage cover of vegetation , where vegetation is defined as a particular cover type (T,S.F,G), a species (e.g., alder), or height class by species or type; this may be calculated as the mean for all quadrats of a given type.

e-- vegetation classes include designated individual taxa, or cover types, such as T (tree), S (shrub), F (forb), G (grass), combinations of these, or composite taxa grouped by growth form or ecotype.

f--variables used to sort data. B is bank (North or South), H is height class of vegetation, E is relative elevation (see p. 47). For example, a mean cover could be calculated for a given height class of trees as a cover type or of an individual taxon (e.g., alder) for quadrats that are sorted by bank.

g--bands of a type are band A,B,C, and D. These streamside zones are found running the length of the study area at distances of 0-5, 5-10, 10-15, and 15-20 m from the stream margin and were created on the GIS map using the "buffering" algorithm.

h--figures and data supporting the individual analyses can be found in listed Excel files (having file extension *.xls) and also in Access database tables and queries. Access files include AC1: WSPlants6, AC2: VegAnal2, AC3: Band-data.

Note: Depending upon the objective of a particular analysis, data collected on individual quadrats were examined on the basis of individual quadrats, data collected in the field for an individual quadrat was compared with GIS-based data for the same quadrat, quadrats of a type were examined as a group (and these groupings were further subdivided by sorting by bank or relative quadrat elevation), vegetation within plots as measured in the field or by aerial mapping were examined as a unit, or vegetation mapped from aerial photos into a GIS were examined on the basis of bands of a type. If mean cover was calculated for any sampling unit (e.g., quadrat, plot), the mean was variously examined for individual taxa, cover types, groups of cover types, and the means were sometimes calculated for separate vegetation height classes.

Databases and Spreadsheets

(1) Access Databases

WSPlants6

Field records of vegetation cover and height class by taxa were initially typed into WordPerfect table format. These data were proofed, stripped of table formatting, saved as comma-delimited text, and imported to Access for creation of the WSPlants6 database files. [Note: In future work it is recommended to enter data directly into Access and to create a report format so that the database would create a text-based version of the sample data for easy reading]. The WSPlants6 database contains all ground-based vegetation data taken from quadrat sample sites on transects. This database is composed of several key, linked tables. For many quadrats, forb and grass cover were recorded as a total cover for combined taxa in each cover type. In some cases, cover was also recorded for forbs and grasses as cover per individual taxon. In all cases, tree and shrub cover types had cover expressed as cover by individual taxa. For trees and shrubs and often for forbs and grasses, cover was also recorded by height class of taxa. For forbs and grasses, when total cover was estimated visually for an entire cover type, this estimate was used as the more accurate measure of cover for all component taxa and height classes by taxa. In cases where a total cover estimate was not made for a cover type, total cover by cover type was determined by summing cover by taxa. These data were used to compile the "Cover by Cover Type by Quad" table.

Taxa, cover, and height class data were recorded on quadrats (A,B,C,D) positioned along transects. Each sample quadrat was identified by a unique Location ID, which represents a combination of information: Transect (the transect line number--a number from 0 at the mouth to 24 at the upstream end of the study area), NorthSouth designation (N= north bank; S= south bank), and Quadrat (the A,B,C,D position on the transect line).

Using the linkages created among tables in this database, Cover Class (see Table 4 for codes for percentage cover) can be converted to percentage cover, representing the mid-point of the range for each Cover Class. Total cover by taxon was calculated as the sum of cover for all height classes and total cover by Cover Type (tree, shrub, forb, or grass) was calculated as sum of total cover for all taxa.

Through additional linkages in these key data tables, SpeciesName (i.e., taxon) can be classified as a particular Cover Type. This cross-reference is needed when adding up the cover for all trees, shrubs, forbs, or grasses. In the process of executing a query, a SpeciesName for any quadrat is identified as a particular Cover Type so that the relevant cover percentages can be added.

See Appendix 6 (file Relaton3) for a more detailed documentation of the data tables and queries used in the WSPlants6 database.

VegAnal2 database

The VegAnal2 database contains data on area of vegetation polygons as mapped from aerial photography and classified by cover type (trees, shrubs) and height class. The mapped vegetation in the GIS database was overlaid with the mapped quadrat boundaries. These two map layers were used to create an intersection of the vegetation polygons and the quadrats by subdividing any vegetation polygon cut by any of the quadrat boundaries. This allows a query to return the area value for only that portion of an original entire vegetation polygon that is located within any quadrat.

The GIS map and associated database were queried using ArcView 3.0a GIS program from ESRI[2] to select all quadrat polygons. This was accomplished using the data fields RIVMETER (i.e., 5 = the buffer band from 0 to 5 m from the water's edge) and selecting fields with RIVMETER = 5, 10, 15, or 20; TNUM (i.e., transect number) and selecting fields with TNUM = 0 to 24). After selecting all study quadrats using the parameters just described, other relevant data from the database associated with quadrat polygons were saved as a d-BASEIV database (.dbf) and imported to the Access database (VegAnal2). This table in the database was called ALLQUADS and described the sample quadrats. The entire vegetation database from the GIS (i.e., VEGSHP) was also imported to VegAnal2. Based on the field RT5MBUFF_, which uniquely identified each study quadrat, the vegetation polygon data associated with all study quadrats was extracted to form VEGSHP2 table. A linkage between ALLQUADS and VEGSHP2 was defined using the common field RT5MBUFF_. This variable is a unique identifier for each quadrat polygon. This linkage allows all vegetation data on study quadrats from the GIS vegetation database to be associated with key quadrat information (area, location). Because ground-based vegetation was recorded in quadrats designated by A,B,C, or D, the RIVMETER designations (i.e., 5, 10, 15, 20) were related to their respective ground-based labels.

This database allowed various vegetation statistics to be calculated from the study quadrats based upon aerial photography and GIS mapping. A listing of sample statistics or indices that were calculated from these vegetation data are in Table 5.

In addition, tables were created comparing tree, shrub, or tree+shrub cover (%) by quadrat or by height and quadrat from the aerial mapping (i.e., the GIS data) with the ground-based estimates. These tables were created by importing relevant tables from WSPlants6 (i.e., the field data) into the VegAnal2 database and then executing queries that matched comparable data from the two data sources.

See Appendix 6 (file Relaton3) for a more detailed documentation of the data tables, queries, and definitions of terms used in the VegAnal2 database.

VegBand database

The VegBand database contains information on the tree and shrub cover within the 5-m bands running the length of the study reach on the north and south banks. These bands are 5 m wide and were created by buffering the stream margin in the GIS system. Vegetation polygons were intersected with

[2] Environmental Systems Research Institute, Redlands, CA.

these band lines. The RT5MBUFF_ identifiers for all individual polygons comprising each band on the north and south banks were selected from the RT5MB.dbf file in the GIS database. This data layer and its associated map layer contain key data such as polygon area, RIVMETERS (i.e., distance from the water's edge), BETWEEN (i.e., identifying that the polygon is between two transect lines), and BANK (north or south bank). The RT5MBUFF_ polygon identifiers in each band file provided all the information needed to extract, using database query techniques, vegetation polygon area and height class data for all polygons contained within each entire band.

(2) <u>GIS Maps and Databases</u>

The ArcView GIS database was created at Warm Springs by conversion of the data format used by BPA in mapping. The total GIS database was delivered to CRITFC via internet as .e00 files from CTWSRO. These were then imported into ArcView 3.0a to create various data layers. A set of GIS files is available in UTM Zone 10 projection and are used in the project file WarmSp-Veg.apr. These files provide separate coverages for photopoints for photos shot along transect lines, photopoints for photos directed upstream at streamside, transect points (locations of iron stakes), transect lines, tree and shrub polygons (coded by height class), roads, fence lines, the river polygon, cobbles. In this database, vegetation was not intersected with buffer lines or quadrats. In this project photopoints are hotlinked to photo images. [Note: the photopoint attribute table gives the path to the image file in Macintosh computer format. This would need to be adjusted to PC path formats for viewing photo images on a PC]. Another database is available in which vegetation polygons were intersected with buffer lines and with quadrats (project quad-elev.apr). These coverages are in the state plane coordinate system. Coverages available include the photopoints, river polygon, transect lines, buffer lines and quadrat lines, contour intervals (0.5-m intervals), contour polygons (the area defined between two contour intervals and coded as the elevation for the higher of the two contour lines involved), vegetation, and fences. In this GIS data, all vegetation data are in one database file instead of separate files for each cover type and height class. The VEGSHP data file contains a field called HEIGHT, which provides cover type and height class information combined. For example, a record in the HEIGHT field might indicate "SB 0.1-0.5," meaning shrubs of height class 0.1-0.5. A third file (project stakes.apr) shows the locations of iron stakes as determined by BPA and CTWSRO GPS data, respectively. These data indicate level of accuracy and precision attributable to lower cost backpack type GPS units as compared with very high accuracy units.

(3) <u>Excel Files</u>

Many Access database tables or queries were copied to Excel spreadsheet files so that graphing could be done. In addition, some tables from these Access sources were copied to DeltaGraph on the MacIntosh for graphing. Data transfers to DeltaGraph on the MacIntosh were made from exported .dbf files. In addition, data tables saved in comma-delimited format from Excel spreadsheets or from WordPerfect tables (after table formatting was removed), were also easily imported into DeltaGraph.

Definitions

A description of the analysis of data intended in this study requires first a clarification of definitions.

Study area. The study area was the lower approximately 1.6 km reach of the Warm Springs River downstream of Bennie's Bridge to the mouth where the river enters the Deschutes River and includes a terrestrial area from each stream margin outward to a maximum of 50 m on each side of the river. A 20-m buffer zone on each streambank was studied in ground surveys and a 50-m zone was mapped by aerial survey and GIS mapping.

Permanent transect markers. The iron re-bar stakes that were driven into the ground and numbered with brass tags from 0 to 24 on each side of the river. Stakes were spaced at approximately 40-m intervals on the north side of the river and, given the river curvature and the attempt to position transect lines perpendicularly to the channel, vary more in spacing on the south bank but still average about 40 m.

Transect. The line drawn across the river (perpendicular) between 2 iron stakes and extending in either direction outward from the stream margin to 50 m..

Plot. The 5 x 20 m area defined by the transect line on each side (N, S) of the stream, the stream edge, and a buffer line parallel to the transect line at a distance of 5 m upstream of the transect line.

Quadrat. These subplots (A,B,C,D) were 5 x 5 m and were found on the N and S side on each transect line.

Quadrat type. Types were A,B,C, and D. Quadrat A adjoined the stream edge (i.e., the wetted margin).

Greenline quadrat. Subquadrat A1, which measures 1 x 5 m, was found at the stream edge in quadrat A.

Quadrat relative elevation. The number of meters above the adjacent river surface elevation. Relative elevation of quadrats were calculated to the nearest 0.5 m and was estimated for the center of each quadrat.

Band. The zones running the length of the study area that were 5-m wide. These were created in the GIS system (ARCINFO) by the CTWS using the buffer feature with each stream margin as a starting line.

Cover type. Tree, Shrub, Forb, Grass, Ground (e.g., rock, soil, sand, woody debris, feces, duff).

Cover. The percentage of the ground surface in a quadrat covered by a vertical projection of the canopy on the ground, meant to indicate the percentage interception of raindrops. For most vegetation, the projection of the canopy to the ground was not especially difficult to visualize. Alders, sagebrush, and rabbitbrush, for example, had fairly compact canopy projections. However, extremely diffuse plants such as flixweed or tumble mustard had individual plant canopies that were relatively large but provided a small amount of ground shielding from raindrop impact. Cover by these taxa was adjusted for spindly or diffuse canopies. For canopies such as alder, canopy boundaries were visualized as following major canopy irregularities but variability among trees in canopy thickness, and therefore light interception, was not considered significant enough to require adjusting cover. The same was true for all trees, shrubs and most forbs. If distinctions were ever considered important among tree canopies, for example, in light interception, percentage cover would provide a gross index to solar shielding but other variables needed to estimate light penetration to the ground would include tree species; canopy height (or another better measure of thickness), and leaf area

index. These variables, if correlated with measured direct solar penetration through the canopy, would permit adjusting canopy cover of separate taxa to indicate solar shielding.
Total Canopy cover. The total of cover by Tree, Shrub, Forb, and Grass. Forb and Grass cover represent the ground layer vegetation. Total vegetative cover can be 300% and is comprised of the tree, shrub, and ground layer vegetation.
Total ground layer cover: the sum of ground layer vegetation and ground materials protecting the quadrat from erosion. The ground materials include rock, duff, and woody debris.

RESULTS

Bank Stability and Morphology

Bank stability data were collected for the lower and upper banks for, generally, alternate transects. Information collected for each of these surfaces included the bank angle, bank material, vegetative cover, and signs of instability. The first three variables indicate a potential for instability and signs of instability (cracking, eroding, slumping, collapsing, etc.) indicate visible effects of erosional processes and tendency for sediment delivery to the channel from the bank. Bank angle alone has been taken as an indicator of instability; that is, if bank angle (where the bank is considered to be the channel sideslope below bankfull) is greater than 80°, banks have been deemed unstable (Bauer and Burton 1993). However, it streambank cover and bank materials probably interact to influence whether a given bank angle would be considered unstable. A difficulty with using tree roots as an indicator of bank cover (see Bauer and Burton 1993) is that many trees rooted at streamside do not have exposed root systems--i.e., with roots covering >50% of the ground surface. The most that trees often contribute to bank ground surface cover is cover by basal area. But if canopy cover is dense over the lower bank or upper bank in the vicinity of the bankfull line, one can assume that root density and strength in the bank material provides stability. If canopy cover is 100%, one could probably also assume that as bank material makes a transition from soil to cobble along a sequence of streambank sites, resistance to erosion increases. If vegetative cover is extensive, it seems appropriate to consider banks stable even if bank angle is steep, up to a certain maximum height (possibly 0.5 m). This would be even more true as bank material coarsened.

The Bauer and Burton (1993) method appears to be a modification of the Platts et al. (1987) method with utility and ease of application. Its strengths appear to be in its simplicity. Also, it removes some of the subjectivity from the Platts et al. (1987) method that could lead to variability in estimates. However, there are significant weakness in the Bauer and Burton (1993) method. Their method uses streambank stability and streambank cover as two variables (each binary--i.e., stable/unstable, covered/uncovered, respectively), which taken together in all possible states define whether the bank is non-erosional, vulnerable, or erosional. Streambank stability is rated unstable if there are visible signs of instability (erosiveness) or the bank is mostly uncovered, the bank angle is greater than 80°, and the bank is eroding. The definition of this variable has several problems. Instead of bank stability, this variable should be termed bank angle. The authors take 80° as a threshold between stable and unstable. Although break points are necessary in simple indices, there is no explanation of the physical basis for this. The requirement that the bank be mostly uncovered and to have an angle >80° mixes stability and cover variables within the stability estimate. The requirement that the vertical bank (i.e., angle >80°) be eroding shows the conflicting purposes in the variable--i.e., developing indices to erosion potential (bank angle) vs. listing the various forms of erosion (e.g., slumping). It is also confounding to use forms of erosion to indicate stability, and then to add streambank cover as the final variable to enable classification of the bank as erosional/non-erosional. If the bank is eroding (unstable) it should be termed erosional. It is questionable whether a slumped bank that is fully covered by sedges is merely vulnerable, rather than erosional. Also, if the bank angle is <80°, the bank 60% covered, but eroding, should it be termed non-erosional? This also raises the question of why bank angle and cover are considered at all if it is so unequivocal recognizing an erosional surface from a non-erosional one. It may be true that steep banks often have negligible cover below the

bankfull line, but it is not clear why cover and bank angle must be taken together here to evaluate stability. Does this mean that if a bank angle is >80° but cover is ≥50% that the bank would be vulnerable no matter how high the bank? It is unclear why overhanging banks would not be considered unstable because of their angle. If vegetation cover were considered on an overhanging bank, it would be vegetation above bankfull that would be evaluated. However, the Bauer and Burton (1993) method is restricted to considering the bank below the bankfull line.

Streambank cover in the Bauer and Burton (1993) method is identified as covered or uncovered depending upon various sources of ground cover being present at ≥50%. Perennial vegetation ground cover ≥50% results in a rating of covered. It is unclear whether ground cover represents the grass/sedge group alone. If so, there seems to be a low value given to tree and shrub cover, because these species are assigned cover value only in terms of providing ≥50% root cover. In addition, how could 50% cover by sedges be compared with 100% canopy cover by alder where alder basal area is 5%? Roots or basal area at the surface provide bank protection in the same way that surface cobbles do, but much of the rooting strength is contributed by roots that are not visible in the bank. It seems that a measure of tree or shrub cover is needed that goes beyond the visible root system.

The remaining problem in application of the Bauer and Burton (1993) method is in excluding the upper bank from stability or erosional evaluation. Certainly there is a limit to how far from the channel that bank stability estimates should be made, but the immediate vicinity of the bankfull line should be considered relevant to stability in terms of the combination of bank angle, vegetation cover, and bank materials. If the lower bank is the point of immediate focus of stream erosional energy, the lower bank angle may be steep and the cover negligible. If the steep lower bank is 0.5 m high, and the upper bank angle is low, the slope fully covered by trees, and the bank material is soil, it would seem reasonable to assume that the upper bank vegetation would provide erosion control. On the other hand, if the lower bank is steep, uncovered, and 1.0 m high, but the upper bank is as just stated, the lower bank appears to be a focus of erosion and the ability of riparian vegetation to retain the bank is probably less. If bank material were coarser, the stability should be greater and erosion potential reduced.

The Bauer and Burton (1993) method can probably be applied consistently, but it might merely document sites that are actively eroding. It probably does not meaningfully reflect potential stability and some of its definitions of cover probably give incomparable value to various forms of vegetation cover and negligible emphasis to some key forms of vegetation (trees and shrubs). Although this method has simple binary definitions to stability and to cover, this simplicity may be suitable to extensive stream surveys, provided enough sample points are evaluated. However, the deficiencies of this method led to the following attempt to improve the classes of stability. Because basic data are not typically recorded in using the Bauer and Burton method, post-classification is not possible with this method. However, the method developed in Warm Springs monitoring would allow the Bauer and Burton parameters to be applied to classify but would also permit future refinements in classification to be applied if changes are made in physical thresholds for theoretical models.

Data from the field records on bank slope were entered into an Excel spreadsheet. Data entered were segment length and segment angle (°). For graphical purposes, bank morphology was plotted starting from nominal x-y coordinates of (0,0). Length and angle of segments were converted to successive x-y points using formulas: [starting x coordinate]+ [segment slope length][cos (segment angle)] = next x coordinate; [starting y coordinate] + [segment slope length][sin (segment angle)] = next y coordinate. The series of x-y coordinates calculated by these formulas were then plotted at approximately 1:1 scale

to illustrate bank morphology and to facilitate tabulating stability data (Figure 5). Vertical descent accounted for by individual segments was easily calculated by subtracting y-coordinate values of successive points.

Bank morphology on four representative channel cross-sections was plotted using the 0.5-m contour intervals from the topographic GIS coverage produced by BPA. These cross-sections represent lower and upper banks for north and south sides of the river along transect lines. These cross-sections, plotted for transects 3, 5, 17, and 24, do not show wetted channel bottom morphology but do show channel wetted surface width, and bar and bank morphology. Channel widths for every transect line were measured (Appendix 7). To draw the four cross-sections, distances from the stream margin to the intersection of the transect line with each contour line were measured using the GIS measuring tool. These horizontal distance increments provided the x-coordinates; increments in relative elevation from the water surface, derived from contour intervals, yielded the y-coordinate data.

(1) Evaluation of Streambank Stability

Field data for bank angles and slope lengths, bank materials, composition and vegetation cover are available in Appendix 3 (file bankst.298). Using the rating scheme developed for Warm Springs River monitoring, the bank stability scores and rating for the transects on the Warm Springs River were computed (Table 6).

Table 6. Bank stability scores and rating.

Transect	Lower bank stability score	Upper bank stability score	Total bank stability score	Total bank stability rating
N23	5 + 1 + 4	5 + 2 + 0	10 + 7= 17	2.8
N21	5 + 2 + 0	5 + 1 + 0	7 + 6=13	2.2
N19	3 + 3 + 5	3 + 1 + 3	11 + 7=18	3.0
N17	4 + 3 + 3	4 + 1 + 2	10 + 7=17	2.8
N15	3 + 2 + 3	3 + 0 + 0	8 + 3=11	1.8
N13	4 + 0 + 1	0 + 0 + 0	5 + 0=5	0.8
N11	3 + 1 + 3	4 + 2 + 1	7 + 7=14	2.3
N9	4 + 3 + 0	5 + 0 +0	7 + 5=12	2.0
N7	4 + 2 + 0	5 + 2 + 1	6 + 8=13	2.2
N5	0 + 1 + 0	5 + 0 + 0	1 + 5=6	1.0
N3	3 + 1 + 1	5 + 0 + 1	5 + 6=11	1.8
N1	5 + 0 + 1	5 + 0 + 0	6 + 5=11	1.8
S24	1 + 3 + 1	5 + 0 + 1	5 + 6=11	1.8
S23	5 + 3 + 0	5 + 0 + 1	8 + 6=14	2.3

S21	2 + 1 + 0	5 + 5 + 0	3 + 10=13	2.2
S19	4 + 1 + 0	5 + 0 + 3	5 + 8=13	2.2
S17	4 + 2 + 1	5 + 0 + 0	7 + 5=12	2.0
S16	1 + 0 + 0	5 + 0 + 2	1 + 7=8	1.3
S15	1 + 3 + 0	5 + 0 + 1	4 + 6=10	1.7
S13	2 + 0 + 0	5 + 0 + 2	2 + 7=9	1.5
S11	4 + 0 + 5	5 + 0 + 5	9 + 10=19	3.2
S9	4 + 2 + 5	5 + 0 + 0	11 + 5=16	2.7
S7	4 + 3 + 5	5 + 3 + 5	12 + 13=25	4.2
S5	4 + 5 + 2	4 + 0 + 2	9 + 6=15	2.5
S3	4 + 0 + 1	5 + 0 + 0	5 + 5=10	1.7
S1	2 + 0 + 5	5 + 0 + 3	7 + 8=15	2.5
Mean	3.3+1.6+1.8	4.5+0.7+1.3	6.6 +6.5=13.0	2.2

Field data on bank conditions (Appendix 3) collected on transect lines were summarized in Table 6 by translating lower and upper bank angle, bank material, and vegetative cover into a stability rating. A total of 26 banks were evaluated. The mean stability rating was 2.2 out of a possible 5.0, considering the combination of lower and upper banks. The range in scores was 0.8 to 4.2. Based upon the bank angle variable, the lower banks tended to be less stable than the upper banks. Bank material scores for the lower bank ranged from 0 to 5 (mean 1.6), while those for the upper bank also ranged from 0 to 5 but had a mean of 0.7. The lower bank had seven bank material scores of 0 while the upper bank had 18 scores of 0 out of 26 banks. Upper banks were frequently largely composed of soil and were often nearly level. If the level soil ground surface is well covered by vegetation, a total upper bank stability score of 10 could be achieved (15 maximum). A higher score could only be achieved if the ground surface contained cobbles or bedrock. The bank vegetation rating averaged 1.8 for lower banks and 1.3 for upper banks. Only six of the lower banks evaluated had vegetative scores of 4 or greater while only 2 of the upper banks did. Vegetative cover was probably the most conspicuously lacking element along the streambanks that could contribute significantly to total streambank stability if restored. The Warm Springs River in this study reach has cobble material of a maximum size in the range 25-50 cm, but its substrate is predominantly in lower size fractions. Steep cutbanks in soil or alluvial material were common in eroding bank areas. These banks were typically associated with creation of overflow channels cutting into xeric vegetation areas that were deficient in cover or scour on outside river bends. Wide, gently sloping, bare cobble/gravel bars were also common, as were banks of moderate slope, coarse bank material, and moderate vegetation cover.

A desirable bank situation for the Warm Springs River study reach given the geomorphic setting, could be for the lower bank to have a slope of 20°, bank material of 5, 20, and 20% (in size fractions 25-50, 12.5-25, and 6-12.5 cm, respectively), and ≥90% vegetative cover on average for the lower bank. The upper bank typical ideal situation given the geomorphic setting might be to have a slope of

0-5°, bank material of 0, 0, 10% of the cobble fractions, and ≥90% vegetative cover. These bank stability goals would translate to lower and upper bank scores of 4+4+5 and 5+1+5, or 13+11, respectively. This score translates to a total stability rating of 4.0 Stability could naturally be greater than this score, but it should not be significantly less. Some vertical banks might occur in a natural situation, but using this scoring system, they do not contribute to reducing the stability rating if less than 0.25 m in height. If between 0.25 and 0.5 m in height, they would still receive a score of 3. If the lower bank material were 5, 10, and 10% of the three cobble fractions, respectively, and graded up to the 0.3-m cut slope (soil) at a 20° slope, and there were no lower or upper bank vegetation, the overall stability rating would be low. But if cover were ≥90% on lower and upper banks, and the upper bank had a 5° slope with a soil surface, the stability scores would be 3+4+5 and 5+0+5; the total stability rating would be 3.7. With these considerations one could take ratings of 3.5 to 4.0 as vulnerable, 4.0-5.0 as stable, and 0-2.5 as very degraded. Ratings of 2.5 to 3.5 would be indicate reduced stability. With this stability classification, only 1 of 26 streambanks on the study reach rated a stable classification. There were 20 of 26 streambanks classified as very degraded.

The mean wetted stream width for the study reach was 24.8 m (computed from transect lines in Appendix 7). The range in stream width at the 25 transect lines was 14.4 to 52.3 m. The distance from the center of transect 0 to the center of transect 24 was 920.0 m traveling down the centerline of the channel. The straightline distance between these same two points was 706.1 m. This indicates that the sinuosity calculated for this length of channel is 1.30.

(2) Comparison of Cross-Sections from GIS Mapping vs. Ground Measurement

Bank slope determined from plotting 0.5-m contour increments (Figure 7) against cumulative distance of contour lines from the water margin was generally similar to that measured on the ground (Figures 5 and 8). For bank N3 the overall slope was 29° from the water's edge to 4.5 m distance at which point the slope became 0°. Ground-based measurements indicated a slope of 32° for 5 m horizontal distance to a point where slope declined to 0-10° (assumed 5°). On bank S3 the slope was 25° overall for 2.2 m horizontal distance from topographic map measurements but was 22° on the ground.

For bank N5 there was an 8° overall slope from the water's edge to the upland terrace and the steepest individual slope element was 12°. However, ground-based measurements indicated a 90° slope element of 1.8 m height and a smaller one of 25° and 0.55 m in height. These two slope elements accounted for 2.35 m descent from the upland terrace. The topographic map indicated that the terrace edge was 16.8 m from the stream. This equates to a minimum slope of 8° overall from the terrace edge to the stream, the same value as derived from the GIS system. For bank S5 the GIS map and the ground-based measurement indicated lower bank slopes of 22 and 25°, respectively. However, the GIS map indicated a bank slope of 41° immediately next to the bank. This error from the stream to the first contour line is probably attributable to taking the elevation of the water surface from the elevation assigned to the entire water surface polygon at this transect line. It is possible that the elevation of the water surface was just slightly less than that of the first contour line upslope while the contour line was very close to the water's edge, resulting in a false steep slope estimate for the first contour interval.

Bank S17 had a maximum slope of an individual slope element of 8°, while ground-based measurement resulted in a 15° lower bank slope. Bank N17 had GIS and ground estimates of 26 and 25°, respectively.

Bank S24 had a slope of 40° from the water's edge to the upper terrace (a 1 m height gain within 1.21 m horizontal distance from the water's edge. As measured on the ground this was a 1.1 m height gain within 1.1 m horizontal distance from the water's edge. This overall slope translates to 45°. This represents an excellent correspondence between GIS- and ground-based data in overall slope. However, the lower bank had a 0.6 m descent from a 90° slope element. Such fine-grained topographic features that would result in occasional significant differences in bank stability ratings illustrate that GIS data cannot always be relied upon to produce accurate stability ratings.

Vegetation Monitoring

Vegetation data collected either by ground-based surveys or interpreted from aerial photography and mapped into GIS format were analyzed on the basis of individual quadrats, quadrats of a type, or all quadrats combined. Vegetation indices computed on various areal bases were frequency, cover by individual taxa, cover by cover types, total cover by all cover types. Also, data were variously sorted according to streambank (N,S), relative elevation, and vegetation height class. Because of the large number of combinations of vegetation indices, variables used in sorting data, and areal bases for analysis, unique aspects of analyses were listed in Table 5 as a guide to results.

(1) Vegetation Analysis from Field Surveys

Vegetation frequency

(Analysis index 1). Analysis of vegetation frequency was performed on dominant taxa for the A,B,C, and D quadrats, given that they were all the same size (25 m^2). The sample quadrats were located on the north bank at transects 24, 23, 21, 19, 17, 15, 13, 11, 9, 7, 5, 3, and 1. Of these transects, all had A, B, C, and D quadrats except transects 19 and 17, which had only quadrats A and B. On the south bank, transects were located at 24, 23, 22, 21, 19, 17, 15, 13, 11, 9, 7, 5, and 3. These transects each provided A, B, C, and D quadrats. The total number of quadrats evaluated was 100 (48 on the north bank and 52 on the south). Although the A quadrat was generally at a lower elevation relative to the water than the B, C, or D quadrats because A is next to the active water margin, the fairly equal number of each type of quadrat (26, 26, 24, and 24, respectively) would present a relatively unbiased basis for calculation of frequency. That is, it was expected that this sampling procedure would represent vegetation occurring on the 20-m wide vegetation band on each stream bank.

Species frequency was calculated from the WSPlants6 database from queries. Complete listings of species presence (counts of occurrence) by quadrat are located in the SppFreqbyQuad, FreqSpecies, and TotalFreq queries. An abbreviated summary of frequency is shown in Table 7. A guide to the vegetation indices calculated is found in Table 5, listed according to an assigned "analysis index" number.

Table 7. Frequency of dominant plant taxa.

Species Name	Frequency (%)(based on 25-m^2 plot)
Trees	
alder	36
juniper	4
birch	4
Shrubs	
sagebrush	54
mockorange	23
willow	20
rabbitbrush	20
chokecherry	10
rose	13
mountain mahogany	7
sumac	7
bitterbrush	5
Forbs	
white+yellow blossom sweetclover	72
mullein	50
poison hemlock	42
knotweed	30
buckwheat (all spp.)	25
tumble mustard+flixweed	23
St. John's wort	23
curly dock	23
China lettuce	20
stork's bill	20
lamb's quarter	17
yarrow	13
Lomatium	13
fireweed	12
Equisetum	11
knapweed	11
milkweed	10
cudweed	9
needle leaf navaretia	9
plantain (common and buckhorn)	9
thistle	7
moth mullein	7
turkey mullein	6

Grasses	
cheatgrass	73
rabbitsfoot grass	23
sedge	23
medusahead	19
foxtail barley	13
rattlesnake brome	12
bottlebrush squirreltail	5

(Analysis index 2). Frequency calculations are heavily influenced by the area of the sample unit. The quadrat size for all ground-based vegetation analysis was 25 m^2. Quadrats A,B,C, and D grouped as a sample plot comprise an area of 100 m^2. Calculating frequency of taxa with this larger sample unit provides some indication of the spatial distribution of the taxa. Frequency was computed for taxa that were dominant and others that were rare based on this larger plot size (Table 8).

Table 8. Frequency of vegetation taxa calculated from sample plots having an area of 100 m^2.

Species Name	**Frequency (%) (based on 100-m^2 plot)**
alder	92
juniper	12
sagebrush	85
mountain mahogany	15
rabbitbrush	35
white+yellow blossom sweetclover	81
needle leaf navaretia	27
St. John's wort	50
turkey mullein	15
cheatgrass	92
rabbitsfoot grass	54

By increasing the area of the analysis unit from 25 m^2 to 100 m^2 the calculated frequency of all taxa increased. However, the sample size was still not so large that any species was found on 100% of plots. Alder appeared to be restricted to quadrats near water (Figures 9, 10, 11, 12). This would cause them to be found preferentially in A quadrats. Because the 5 x 20 m (100 m^2) plots were laid out along transect lines and bordered the stream margin, they incorporated a variety of geomorphic surfaces from river bar, true riparian, to dry upland. Many quadrats were entirely freshly worked bar material or overflow channel bottom. Consequently, these quadrats were not likely to contain

perennial species or dryland. The sweetclovers had very little increase in frequency from the quadrat to total plot sample unit because they readily invaded cobble bar areas as well as dry uplands. Cheatgrass had a very similar pattern of distribution. It appears that the 5-m^2 quadrat was a useful size sample unit for monitoring changes in frequency of taxa. However, in subsequent years if the relative elevation of quadrats changes significantly (e.g., the average A and B quadrats are found at significantly greater relative elevations above the river than in previous years), frequency of taxa would change simply due to changing channel and floodplain or terrace cross-sectional structure. To establish trends in frequency on an equal basis between years, it may be necessary to compare frequency of quadrats that fall within certain relative elevation ranges. For example, it may be sufficient to group all quadrats within 0-0.5 m and 0.5-3.0 m relative elevation above the river.

Frequency by relative elevation

(Analysis index 3). An individual quadrat's elevation was determined relative to the elevation of the river at its transect line using information available in the GIS system. Relative elevations were assigned to elevation classes (Table 9).

Table 9. Elevation classes of quadrats.

Relative elevation above the river (m)	**Elevation class**
0	0
0-0.5	1
0.5-1.0	2
1.0-1.5	3
1.5-2.0	4
2.0-3.5	5

Counts of the number of quadrats by elevation class in which a taxon was present were then calculated (Table 10). These counts were only for quadrats A,B,C, and D (A1 was excluded because of its different size) and combined quadrats from the north and south bank.

Table 10. Count of number of quadrats by elevation class having presence of various plant taxa.

Taxon	**Elevation Class**					
	0	**1**	**2**	**3**	**4**	**5**
alder	11	7	10	4	3	1
birch	3	1				
juniper		1		2	1	

sagebrush	4	6	11	11	8	14
rabbitbrush (all taxa)			3	6	2	8
mockorange	7	5	6	3	2	
willow	6	5	4	5		
mountain mahogany	1	2	1	1	3	
bitterbrush				1	1	3
sweetclover (all taxa)	15	17	20	10	8	2
cheatgrass	6	9	21	13	8	16
Quadrat distribution by elevation class	18	19	24	15	8	16

The distribution of alder by elevation indicates a preference for elevations less than 1.0 m above the river level although it was found even within elevation class 5 (2.0-3.5 m relative elevation). Willow had a distribution similar to alder with respect to elevation. Birch was confined to relative elevations less than 0.5 m. Sagebrush frequency was very high in quadrats with elevation class of 3 or greater (i.e., >1.0 m relative elevation); however, it was found at all other elevations, but at far lower frequency. Rabbitbrush frequency was greatest at relative elevations greater than class 3. Sweetclover (white and yellow) was found at all elevation classes. It was found at very high frequency in elevation classes 0-4 but at markedly lower frequency at the highest elevation class. It appeared to be able to rapidly colonize exposed river bar areas and disturbed rangeland but became limited in distribution on the drier portions of the uplands. Cheatgrass had a distribution that also spanned the elevation classes 0-5. However, it had very high frequency at relative elevations of 2-5 and much reduced frequency at the lower relative elevations. In relative elevation classes 4 and 5 its frequency was 100%. That is, of the 16 quadrats at elevation class 4 and 5, all had cheatgrass. In addition, most quadrats in elevation class 2 and 3 also had cheatgrass. Less than half in lower relative elevation classes had cheatgrass. This well illustrates the importance of following trends in frequency of various taxa by sampling on a set of quadrats having comparable relative elevations. Restoration of the streamside zone will involve processes of bank aggradation and channel narrowing in places, which may result in future changes in the distribution of relative elevation of quadrat types.

Cover analysis in the streamside zone

Data collected in ground vegetation surveys can be used to evaluate cover by species or cover type (or groups of cover types) on an individual quadrat basis or on the basis of quadrat type (A,B,C,D). Data may be sorted by bank (north, south), or vegetation height class. In addition to using quadrat type as a basis for determining mean cover, quadrats were also grouped by relative elevation class to allow comparison of mean cover by species or cover type; or species or cover type sorted by vegetation height class. See Table 5 for a guide to the analyses made. The analysis index number is used in the text to identify the types of analyses done. This also gives a guide to the data tables and queries used from the databases.

☐ <u>Individual quadrat data</u>

(Analysis index 4-8). Data on cover by trees, shrubs, forbs, and grasses were collected from ground-based surveys for a total of 100 individual quadrats (A,B,C, D). These data are available in data tables that are part of the WSPlants6.mdb database. These data will have utility after future re-surveys are completed in allowing comparisons from t_1 to t_2 at fixed sites. Initial layout of quadrats was made along fixed transect lines and starting with respect to location of the active water margin. In terms of relocating quadrats in future resurveys, the quadrat placement was relative to the active water edge for July 1997, a feature that could vary in location. Quadrats A,B,C, and D have a specific meaning--i.e., distance from active water. If it later appears desirable to relocate exact original quadrat positions, this could be done with respect to fixed iron stakes. This would allow comparison of identical quadrats between time periods to establish trends from plots fixed in space. However, if the stream channel shifts laterally over time, the location of the water margin would change. This would cause quadrats laid out according to the water margin and the fixed transect line to be located at different positions relative to the water's edge. A shift in the stream channel laterally and especially in vertical position (due to aggradation or downcutting) could result in vegetative shifts in community composition on fixed location plots. It might be necessary to establish trends by examining vegetative condition over time at fixed points as well as at points relative to the stream edge and stream elevation. These vegetative trends can be examined on the basis of changes in cover or height class distribution by individual species, by ecotypes (indicators of overgrazing; exotic species; families), by cover type (tree, shrub, forb, grass), or by groups of cover types (e.g., trees+shrubs).

(Analysis index 4). By taking only A quadrats from all sample locations, the total alder cover for each quadrat was calculated. There were 23 of a total of 26 A quadrats that had alder cover. Alder cover for each quadrat was summed for all observed size classes in field surveys. Total alder cover by quadrat for the 23 quadrats having alders ranged from 0.5 to 85%. The distribution of alder cover by quadrat (Figure 13) revealed that 6 of 23 quadrats had alder cover of ≥25%, and 17 quadrats having alder had alder cover of <25%.

☐ <u>Grouped by quadrat type</u>

When ground-based data on cover by species are grouped by quadrat type (A,B,C,D), mean percentage cover by the various species or cover types can be calculated.

Mean cover by cover type (tree, shrub, forb, grass) can be expressed for quadrats of a type (A,B,C,D), for quadrats of a type differentiated by bank (north, south), and also by vegetation height class. Each of these means of expressing mean cover is reported below.

Trees

(Analysis index 9). Mean percentage cover by trees on the north bank was highest in the A1 quadrat (25%), 17% on A quadrats, and was <2% for all other quadrats (Figure 9). On the south bank mean percentage tree cover followed a similar pattern with highest values near the active water margin (Figure 10). However, mean percentage tree cover was considerably greater on all the south bank quadrats. The south bank A1 quadrats had a mean cover of 61%, A quadrats had 39% mean cover, and the other quadrat types all had <9% cover. The reason for C quadrats having a mean cover as high as 9% can probably be attributed to the more complex near-stream bank morphology. That is, with a high occurrence of summer-dry overflow channels and a broader floodplain on the south side,

alder tended to line the banks of the dry overflow channels as well as the active summer wetted channel.

(Analysis index 14). Mean tree cover (%) sorted by bank, quadrat type, and tree height class indicates that on the north bank, five height classes were represented in A quadrats (Figure 11). However, trees of height class 6 (i.e., >6 m) provided a mean of 15.6% cover on A quadrats. Trees in this height class provided 94% of all tree cover on average for the A quadrats. Tree cover in B quadrats was nearly equally divided between height classes 1 and 3. All the tree cover in C quadrats was contributed by the smallest height class and this accounted for a mean cover of near 0%, while the D quadrats had an average 1.5% cover contributed solely by height class 1.

On the south bank, mean percentage tree cover by height class indicates that for A quadrats all height classes were represented (Figure 12). Height class 6 provided 36% mean cover (i.e., 92% of the total cover provided by trees of all heights in the A quadrats). Height class 6 provided the majority (>80%) of the cover in the other quadrat types (i.e., B,C,D), but in absolute values, trees of height class 6 comprised only 4-8% mean cover.

Shrubs

(Analysis index 10). Shrubs on the north bank had their highest mean cover in the A1 quadrat (15%) (Figure 9). Cover in all other quadrat types ranged from 7-13%. On the south bank the A1 quadrats had the lowest shrub cover (1.5%), while the D quadrats had the highest (13%) (Figure 10). Cover in the other quadrats ranged from 4-5%. Relative elevation of quadrats probably had a great deal to do with shrub distribution. The south bank had many A1 quadrats that were on barren cobble bars, given the high occurrence of bank erosion and widening focused on this side.

Forbs

(Analysis index 11). On the north bank forbs were present with a low mean cover (1.5-2.5%) in all quadrats except the A quadrats, which had a mean of 5.5% (Figure 9). On the south bank forbs had a mean cover that increased steadily from a low in the A1 quadrats (2%) to a high in the D quadrats (10%) (Figure 10).

Grasses

(Analysis index 12). On the north bank grasses accounted for a very low mean cover in all quadrats, ranging from 3-5%. On the south bank grass cover was approximately 17% in the A1 and D quadrats and was 5-11% in the others. The difference between the north and south banks probably reflected a lower grazing impact on the south side.

Trees+shrubs

(Analysis index 15). Trees and shrubs combined are able to provide the most significant deep-rooted vegetation in the streamside zone. By sorting the vegetation by bank and height class and analyzing vegetation data on a quadrat basis, it is possible to evaluate the height class distribution of significant cover for each quadrat. The north and south banks both had the greatest mean tree+shrub cover in height class 6 (Figures 14, 15). Cover by height class 6 tree+shrub vegetation on the south bank A quadrats was more than twice that on the north bank. On the north bank in quadrats B,C, and D, vegetation of height class 3 provided the greatest mean cover (4-7%). On the south bank, vegetation

of height class 6 provided the greatest mean cover in B and C quadrats (4 and 8%, respectively), but on D quadrats this was provided by height class 3 (i.e., 8%).

Trees+shrubs+forbs+grasses

(Analysis index 13). By summing the cover by trees, shrubs, forbs, and grasses and dividing by the number of quadrats per quadrat type and bank, mean vegetation cover by all plants combined was calculated for each quadrat type and differentiated by bank. The A1 and A quadrats were first and second in importance for total vegetation cover for both north and south banks (Figure 16). Vegetation of all height classes was combined in these estimates. South bank quadrat types had greater mean total cover than north bank quadrat types. Mean total cover on B,C, and D quadrat types on the north bank ranged from 13-16%, whereas it was 38% in the A quadrat. South bank B and C quadrats had nearly identical mean total cover (26%), but the D quadrat was 45% and the A quadrat was 55%. Although the A and D quadrats of the south bank had similar mean total cover, it was qualitatively different. The majority of the cover for the A quadrat was provided by trees while on the D quadrats, the majority of the cover was provided by grasses and forbs. The A1 quadrats had significantly greater cover than the A quadrats, indicating that the tree cover was heavily concentrated within the first meter of the water's edge. That is, canopy thickness was very low along the streambanks, even on the south bank which had the greater vegetation cover.

- <u>All quadrats combined</u>

(Analysis index 19). The sum of the total cover of all height classes combined for any individual species for all sample quadrats on the north and the south banks, respectively, divided by 48 or 52 for north or south banks, respectively, yields an estimate of the mean percentage cover within 20 m of the stream margin. The two species that provided significant cover and also rooting within this 20-m streamside zone and which typified the hydric and xeric zones, respectively, were alder and sagebrush. Alder comprised 5 and 11% mean cover on the north and south banks, respectively, in the 20-m wide streamside zone. Sagebrush comprised 3-4% mean cover within this same zone on north and south banks (Figure 17).

Trees

(Analysis index 20). When data from all quadrats were combined and data were sorted by bank and height class, the dominant influence of the greatest height class on mean percentage cover within 20 m of the active water edge was evident. North bank quadrats provided 4.5% mean cover and south bank quadrats 13% mean cover from trees of height class 6 (Figure 18). On the north bank all other height classes provided negligible cover on average. On the south bank quadrats, cover by height class 5 trees was approximately 1%, but all other height classes contributed little cover.

Shrubs

(Analysis index 21). When data from all quadrats were combined and data were sorted by bank and height class, it was evident that for both north and south banks, shrubs of height class 3 provided the greatest mean cover (approximately 4% in each case) (Figure 19). Shrub cover on the north bank quadrats was greater than on the south bank quadrats for each height class. Also, north bank quadrats had a small amount of cover in height class 5; shrubs on the south bank had not attained this height.

☐ <u>Grouped by relative elevation class of quadrats</u>

Individual taxa

(Analysis index 16). Alder and sagebrush typified dominant vegetation of the hydric and xeric zones, respectively. After eliminating the A1 quadrats from analysis, the mean percentage cover by relative elevation above the adjacent stream surface for sample quadrats (A,B,C, and D) for the north and south banks was determined. For example, mean percentage alder cover by relative elevation was calculated as total alder cover for each elevation class divided by the total number of quadrats in each elevation class. On the north bank, alder comprised 9-12% cover in the middle two elevation classes (i.e., 2 and 3) but very low cover in relative elevation classes 0, 1, and 5 (Figure 20). The low alder cover on the quadrats having the highest elevation class is understandable because the occurrence of alder, a species that achieves greatest dominance in wet soil, high above the water table is probably low. The low cover in the two low elevation classes is more difficult to explain. It is possible that these areas were largely cobble bars and more prone to scouring. On the south bank alder provided the greatest cover on quadrats of relative elevation class 3 (i.e., 18%). Mean percentage cover was fairly uniform on the other elevation classes (0,1,2, and 4) ranging from 8 to 11.5%.

(Analysis index 16). Sagebrush provided low mean percentage cover on both north and south banks at relative elevation classes 0 and 1 (Figure 21). On the north bank sagebrush provided approximately 5% mean cover at elevation classes of 3 or greater. On the south bank sagebrush provided 9% cover at elevation class 2 and 7% at elevation class 4. It appears that sagebrush achieves a dominance in the canopy structure at relative elevations of 2 or greater.

Trees

(Analysis index 17). Although the majority of streamside trees was composed of alders, it is useful to examine the mean percentage of total tree cover by relative elevation class. All A,B,C, and D quadrats from north and south banks, respectively, were classified by relative elevation above the nearest stream surface. Mean tree cover was then calculated by dividing total tree cover per relative elevation class of quadrats by the number of quadrats per elevation class. Trees on the north bank provided low cover in elevation class 0 and 1, while it was ≥9% in elevation classes 2 and 3 (Figure 22). Elevation class 5 had extremely low tree cover. Although junipers are capable of tolerating dry soil, they did not assume great significance as alder cover diminished with higher relative elevation above the stream. On the south bank, trees provided a mean percentage cover of >17% in elevation classes 0, 1, and 3. Even in elevation class 4, trees comprised approximately 8% cover. This represented predominantly the influence of alders.

Shrubs

(Analysis index 18). Shrub cover provided a different distribution pattern from trees. The mean percentage cover by total shrubs was generally low in the two lowest elevation classes on both the north and south bank quadrats, but was high on quadrats of elevation classes 2 or greater (Figure 23). Mean total shrub cover was highest on the north bank at elevation class 2 (i.e., 13%) and was approximately 11% on the north bank at elevation class 3 and the south bank at elevation class 4.

(2) Vegetation Analysis from Aerial Photo Interpretation and GIS

Cover analysis in the streamside zone

- Based upon individual quadrats

Trees

(Analysis index 28). There were 100 quadrats sampled in the field and from aerial mapping, 48 on the north bank and 52 on the south bank. Total tree cover was calculated for all quadrats from field data (reported above) and also for the same quadrats from GIS (aerial) mapping of vegetation. Because the method used to draw the 5-m buffer lines sometimes created quadrat boundaries that did not well correspond to those laid out on the ground, the area of quadrats from the GIS analysis varied about the 25-m^2 ideal size. Quadrats were considered acceptable as a comparison to field-based quadrats if their area ranged from 20-30 m^2, they visually appeared to be nearly square, and they had nearly the correct placement on the ground (Figure 4). In correlating GIS with field data, estimates on quadrats N24C, N24D, S23 (all), S19(all), S15(all), S13C, S13D, and S9B were not considered because they varied too much from the ideal. Other quadrats created by the GIS buffering system also did not conform to desired standards (S0(all), S8C, S12D, S16(all), and S18(all)), but these were not surveyed on the ground anyway; consequently, they did not enter into the correlation consideration. Tree cover for the quadrats eliminated from the correlation were not considered to approximate data collected from the corresponding positions on the ground in field work.

After eliminating those quadrats that did not meet size and shape standards, total tree cover estimates of all remaining quadrats from GIS and ground-based analysis were correlated. This produced a correlation coefficient of 0.84. This correlation was based on 83 quadrats. There were 20 quadrats in which GIS analysis indicated tree cover >0%. Correlating the GIS tree cover estimates from these 20 quadrats with that from ground surveys yielded a correlation coefficient of 0.67. It is obvious that the higher correlation coefficient produced by taking the full set of qualifying quadrats (i.e., 83) was attributable to the finding of 0% tree cover in 63 quadrats by GIS methods and approximately the same value on the ground surveys. The fact that a lack of trees was recorded by GIS mapping in quadrats in which trees also were lacking on the ground is significant, just as is a correlation of GIS- and ground-based cover when trees are actually present. It is significant that trees in these instances were not confused with shrubs in photointerpretation.

GIS estimates of total tree cover (all size classes combined) matched field estimates very well for certain quadrats. For example, on N19A, the GIS and field estimates were 69 and 63%, respectively. However, for the S11B quadrat, the GIS and field estimates were 2 and 45%, respectively. This disparity was likely caused by misclassification of vegetation in aerial vegetation mapping. That is, most of the tree cover was classified as shrub cover in GIS mapping. The other possible source of error in comparing GIS and field estimates of tree cover in any quadrat is misalignment of quadrat boundaries. However, the area of the quadrat as mapped on the GIS was 25.4 m^2, very close to the ideal for the ground survey and also appears to be properly placed (Figure 4). The tree+shrub cover for this quadrat was 46% for both GIS and field estimates, indicating that in some instances it was better to lump trees and shrubs when using GIS mapping to get a reliable estimate of cover for vegetation of the deep rooting characteristics that their taxa possess. Quadrat S11B had 7.5% cover provided by elderberry, which was classified on the ground as a tree. Even if the elderberry were classified as a shrub, the tree cover for the quadrat (field estimate) would be reduced to 37.5%

(provided by birch), which is still far greater than 2% (the GIS estimate). This appears to confirm a misclassification of trees as shrubs.

Shrubs

(Analysis index 29). Total shrub cover was calculated for each quadrat of types A,B,C, and D. Of the 100 quadrats evaluated by GIS- and ground-based mapping, some were eliminated because the GIS quadrat boundaries were inadequate in terms of size or shape; this included N24C, N24D, S23 (all), S19(all), S15(all), S13C, S13D, and S9B as previously stated. By including all GIS-based shrub cover estimates for qualifying quadrats (those with 0% shrubs as well as >0% shrub cover), the correlation coefficient between GIS- and field-based estimates was 0.50 (n=83). There were only a few quadrats in which correspondence appeared to be substantially in error (a difference of ≥25 percentage points); this included quadrats N21B, N17A, N5D, N1B, N1D, S24D, S11B, and S11C. However, eliminating these eight quadrats from the correlation increased the correlation coefficient to only 0.56 (n=75).

Trees+shrubs

(Analysis index 30). Tree+shrub cover was calculated for quadrats of types A, B, C, and D. Of the 100 quadrats evaluated by GIS- and ground-based mapping, some were eliminated because the GIS quadrat boundaries were inadequate in terms of size or shape; this included all N24C, N24D, S23 (all), S19(all), S15(all), S13C, S13D, and S9B. Of the quadrats remaining there were a total of 68 that had tree+shrub cover for the GIS-mapped vegetation that was >0%. The correlation of these 68 records with the corresponding tree+shrub data measured on the ground was 0.79. There were an additional 15 quadrats that had 0% tree+shrub cover from GIS mapping. After the corresponding field estimates of tree+shrub cover were added to the Excel file, the correlation coefficient was 0.80 for a total of 83 records. This use of the correlation between tree+shrub cover data derived from the two methods was expected to be less prone to error involved in misclassification of trees as shrubs, or vice versa and therefore produce a higher correlation between GIS and field estimates. The less than perfect correlation could still be attributable to misclassification of forbs as trees or shrubs or also to the inaccuracy in mapping the exact boundaries of quadrats studied on the ground. That this occurred to some degree is evident in the variation about the ideal quadrat size of 5x5 m (i.e., 25 m^2). But as pointed out, misclassification also occurred. In some locations, such as in the vicinity of transect 0S tall forbs were mistaken for shrubs.

(Analysis index 31). Tree+shrub cover (considering only cover of height classes 3, 4, 5, and 6) by quadrat and vegetation height class was compared between the GIS (aerial) analysis and the field-based survey (Figure 24). On N23A the GIS and field estimates were very similar for vegetation of height class 6. On N19A the GIS analysis estimated approximately 70% tree+shrub cover in size class 5 while the ground survey recorded nearly this cover value (62%) as height class 6. Similar cases of having comparable percentage cover estimates but assigned to adjacent height classes was found for N15A, N13B, S11B, S11C, and S3A. It also happened that cover identified by GIS analysis for a single height class in a quadrat was recorded in field surveys to be distributed into two or more height classes. This occurred in N19A, N17A, N15C, N15D, N13C, N11C, N9B, N9D, N3A, N3C, N1D, S13A, S9A, S7A, S7D, S5B, and S3A. The reverse (where cover for a size class estimated in field surveys appeared to be distributed into two or more height classes in GIS estimates) happened far less often. It occurred only in quadrat S22A. There were cases in which tree+shrub cover was recorded in GIS surveys but not in field surveys: quadrats N23B, S22D, S19B, and S7B. There were also cases in

which cover was recorded in field estimates but not GIS-based estimates: quadrats N24A, N24B, N23D, N21D, N19D, S11D, S3C, and S3D.

- ☐ Based upon quadrats of a type

Trees

(Analysis index 22). There were 6 "A" quadrats on the north bank and 10 "A" quadrats on the south bank for which GIS-based tree cover was tabulated as >0%. These data were summed to get total GIS-based estimates of tree cover for all A quadrats on north and south banks, respectively. This value was then divided by 13 (the number of A quadrats on north and south banks, respectively) to derive mean cover by GIS. The mean tree cover for the north A quadrats was 18.4% and that for south bank A quadrats was 25.4% (see GISvsField-T.xls).

- ☐ Based upon vegetation bands of a type

Tree, shrub

(Analysis index 23). Tree and shrub cover data were also evaluated independently for vegetation bands A,B,C, and D for north and south banks (Figure 25). On both north and south banks, tree cover in band A was greater than for the other three vegetation bands. North and south A vegetation bands had 17 and 24% tree cover, respectively. On north bank vegetation bands B,C, and D tree cover ranged from 1-3%. On south bank vegetation bands B,C, and D tree cover ranged from 6-8%.

(Analysis index 24). Shrub cover was least in the A vegetation band on both north and south banks (Figure 25). This probably reflects the dominance of tree cover near the stream. Shrub cover appeared to increase with distance from the stream. Shrub cover on the north bank ranged from 8-12% and on the south bank from 15-18%.

(Analysis index 26). The same data on tree and shrub cover, sorted by bank, were further sorted by height class (Figures 26, 27). For trees, the lowest height class was excluded because it accounted for little cover. On the north bank, the greatest contribution to tree or shrub cover came from trees of the greatest height class (i.e., >6m) (Figure 26). Nearly equal percentages of cover were contributed in the A band from tree height classes 1.5-3.0 m and 3.0-6.0 m and shrub height classes 0.1-0.5 and 0.5-1.5 (i.e., all were approximately 3-4% cover individually). Very little tree cover was present in vegetation bands B,C, or D. A uniform contribution to cover (3-4%) was provided by shrubs of height class 0.1-0.5 in all four vegetation bands. The contribution by shrubs of height class 0.5-1.5 increased steadily from band A (4%) to band D (7%).

On the south bank a very similar pattern in cover by tree and shrub height class was shown (Figure 27). Again, the A band vegetation cover was provided primarily by trees of the greatest height class (i.e., >6m). This accounted for nearly 20% cover in the A band. Next most significant in the A band were shrubs of height class 0.1-0.5 and 0.5-1.5. Trees provided significant cover in all four bands, but ranged from only 4 to 6% in bands B,C, and D. Nearly uniform shrub cover (4-5%) was provided by height class 0.1-0.5. Shrubs of height class 0.5-1.5 provided very significant cover in all bands and it generally increased with distance from the stream. Shrub cover in this height class increased from 4% in the A band to 12% in the C band.

Tree+shrub

(Analysis index 25). Percentage vegetation cover of a cover type (i.e., tree, shrub) was estimated from ground-based surveys on quadrats on north and south banks. Cover data were also mapped using the GIS from aerial photography for trees and shrubs by height class. GIS-mapped cover data for tree and shrub cover was examined according to these same quadrats and also for vegetation bands. The band data provides an estimate of total tree and shrub cover for entire 5-m bands running between transect 0 and transect 24. The A-band was that 5-m band between these transect lines that had the stream margin as one side. The A quadrats were essentially samples of this zone; they were spaced at 40-m intervals. Because approximately every other quadrat was sampled, the quadrat data represented nearly 6.3% of the total band area.

Area of all tree and shrub polygons falling within each band on north and south banks was added and divided by total band area to calculate total percentage cover by trees+shrubs. Tree+shrub cover for the A bands was greater than for the other bands on the north and south banks (Figure 28). Percentage cover was nearly 25% on the north bank and 33% on the south bank. The tree+shrub cover for the bands B,C, and D ranged from 11 to 13% for the north bank and 23-24% for the south bank (Figure 28).

Cover Analysis over the River

- ☐ <u>Trees, shrubs, and trees+shrubs</u>

(Analysis index 27). Canopy cover by trees and shrubs was estimated in the field on quadrats that had the stream margin as the leading edge to quadrat A. However, cover that was vertically projected over the water was not considered in field evaluations. The aerial mapping via GIS allowed separate estimation of tree and shrub cover over the river for individual vegetation height classes. Of the shrub height classes, the 0.5-1.5 m height class provided the greatest percentage cover (0.4%). Trees, however, provided far more significant cover to the entire river surface area. The three greatest height classes (1.5-3.0, 3.0-6.0, and >6.0 m) provided 0.7, 1.6, and 9.6% cover, respectively, over the water surface area based upon GIS mapping (Figure 29). The total river water surface area was 22804.5 m^2 for the channel length between transect 0 and 5 m upstream of transect 24. This total distance down the centerline of the channel was 920.0 + 5.0 = 925.0 m. The wetted stream surface area of the channel between these lines excludes the area of the island that occurs at the upper end of the channel. The total area covered by trees of all height classes was 2725 m^2 and for shrubs was 147 m^2. Tree+shrub cover was 12.6% for the wetted channel area as vertical cover. Quadrat-based estimates made in the field and by aerial mapping indicated that the majority of vegetation cover, and especially tree cover, occurred in the first 5 m from the river's margin. The mean water surface width for the river was 24.8 m as calculated from a mean of 25 width measurements taken perpendicular to the channel initiated at the intersection of transect lines with the north stream edge. Stream water surface width estimated by dividing wetted area by instream channel length down the centerline was 24.65 m.

If the canopy extended as far over the water as it did over band A (i.e., 5 m) on each side of the river, this would mean that 10 m of the mean 24.8 m wetted width would be covered by the vertical projection of trees. If average tree canopy cover directly over the water were approximately the mean cover percentage determined by GIS for the A vegetation band (i.e., 25% cover), the tree cover over the water, weighted for the entire water surface, would be approximately 10%. This value is roughly what was determined by GIS mapping of tree canopies (i.e., 11.95%). Canopy cover to the river was

also provided by tree cover on the one island present. Although the river has become widened considerably by effects of flooding and bank destabilization from grazing, the significance of canopy vertically projected over the river was considerable. A narrowing of the channel that is possible from concerted efforts to protect and restore riparian vegetation would vastly increase canopy closure in the A vegetation band as well as total vertical project of the canopy over the stream. Increased canopy width would result in further improvement in stream shading by increasing canopy density along azimuths to the sun. Addition of cottonwoods to the riparian community would provide exceptionally taller canopy. Conventional wisdom often downplays the importance of stream surface shading by riparian vegetation in large streams but in the case of the Warm Springs River much progress could be made in improving shading by the combination of channel narrowing, bank stabilization by riparian vegetation, addition of cottonwoods, and allowing alders and willows to regenerate.

DISCUSSION

Summary

(1) <u>Streambank Stability</u>

a) A method was developed for making quantitative estimates of streambank stability, incorporating lower and upper bank angle, bank material, and vegetative cover. In the study area, lower banks were less stable on average than upper banks. Vegetation was the factor that seemed to be most limiting in streambank stability.

b) Although the south bank of the study area had the greatest vegetative cover, it also had greater impacts from flooding that occurred in February 1996. The flood flows created several overflow channels where lateral scouring through the sagebrush occurred. This new channel network created a complex set of additional channel banks that are sources of future sediment erosion and transport.

c) The mean stability rating for all 26 bank samples was 2.2 out of a total 5.0. Ratings of individual bank locations ranged from 0.8 to 4.2. This overall rating would be considered to reflect very degraded conditions. This condition is the result of the combined effects of flooding and livestock damage from past unrestricted grazing in the streamside zone. The impacts of cattle to bank condition during the study period (summer 1997) was evident with trampling and excessive ground disturbance in ramps down banks to the water's edge caused in periodic trespass situations. Combined with livestock impacts to banks there was considerable impact to preferred forage such as willow and sedges in locations where these were accessible.

(2) <u>Stream Channel</u>

a) Wetted channel width during July 1997 in the study area ranged from 14.4 to 52.3 m. Mean wetted width was 24.8 m. Distance down the centerline of the channel in the study area was 920.0 m. Straightline distance between points in the center of the channel at the upper and lower extent of the study area was 706.1 m.

b) A comparison was made between GIS-based and ground-based cross-sections at north and south banks on four transect lines selected from the study area. GIS-based cross-sections were derived from contour lines (0.5-m intervals) and spacing along transect lines. Ground-based cross-sections were produced from measurements of angle and slope length of slope elements of the near upper and lower banks. Although any contour generating software can produce contour maps with any specified contour interval, the accuracy of such maps is a function of the accuracy in the original mapping. BPA terrain mapping was of highest quality possible and was limited primarily by the scale of the photos. The analytical stereoplotter and GPS instrumentation were probably among the best available commercially and produced a topographic map capable of representing 0.5-m contour intervals.

GIS-based cross-sectional plots very nearly approximated those constructed from ground-based measurement in many cases. However, some fine-grained topographic features that can be significant in determining a bank stability rating cannot be detected with the GIS mapping. Overall slope angles

though can be represented effectively in the area near the bankfull line. If such technology is used consistently to establish a timetrend, it probably would be a meaningful means of gaining an index to bank stability. This index would be dependent on overall slope and vegetative cover at the bankfull zone as derived from GIS mapping.

(3) Vegetation

Ground-based analysis

□ Frequency

a) The tree, shrub, forb, and grass taxa that occurred in highest frequency was alder, sagebrush, sweetclover, and cheatgrass, respectively.

b) Even when frequency was determined on the basis of 100-m^2 plots, there was no taxon found at 100% frequency. Frequency was dependent on the size of the sample unit. Quadrats of 25 m^2 area yielded frequency estimates that were less than when determined on larger plots. Quadrats were located at varying relative elevations above the river; consequently, they provide varying soil moisture environments as well as probability of being flooded for plants. This also indicates that there is substantial variation within a 100-m^2 plot in its potential to support various taxa. If all taxa had the same relative elevation, frequency would then reflect more exclusively factors such as history of grazing, burning, flooding, colonization, or species competitive interactions.

c) When frequency of taxa were examined with respect to relative elevation above the river, distinct patterns were obvious. Alder tended to be found predominantly at relative elevations of 1.0 m or less, although it occurred at all relative elevations within the 20-m band on each side of the river. Birch had a low frequency of occurrence but was entirely restricted to relative elevations <0.5 m. Willow was found up to 1.5 m relative elevation and at fairly constant frequency at all relative elevation classes up to that level. Rabbitbrush and bitterbrush were restricted to relative elevations above 1.0 m and occurred at highest frequency at the highest elevation class. Sagebrush was more ubiquitous, but still had its greatest frequency at the highest elevation class. Cheatgrass was found in all elevation classes, but was in very high frequency at elevations of 0.5 m and above.

□ Cover

a) Alder cover for individual A quadrats ranged from 0.5 to 85%. Alders occurred in 23 of 26 A quadrats. Of the 23 quadrats having alders, 17 of them had alder cover of <25%.

b) Mean percentage tree cover on north bank A quadrats was 17%; that on south bank A quadrats was 39%.

c) Trees of height >6 m provided mean cover of 16% on A quadrats on the north bank and 36% on the south bank. Trees of height >6 m provided >92% of all tree cover on both north and south bank A quadrats. This indicates the lack of regeneration of trees in the streamside zone. Most of the existing tree cover was found in the greatest height class even though five height classes were present on the north bank and six on the south. It is possible that smaller trees have been prevented in becoming established by intense grazing, flooding, or poor climatic or soil conditions. Soil conditions (e.g., organic matter) and moisture content during summer can be a product of past grazing and fire

history. Trees of height >6 m provided no more than 8% mean cover for any quadrat type of groups B, C, or D.

d) Mean percentage shrub cover was higher (approximately a factor of 2) on the north bank than on the south bank for quadrat types A, B, C, and D. Possibly the greater fluvial erosion on the south bank eliminated shrub production. Also, willow, a water-loving shrub, was not common on south bank quadrats. It is possible that its distribution was a function of past grazing distribution. Of the 20 quadrats (A, B, C, or D) having willow, only 4 were contributed by south bank quadrats. Of the 10 quadrats having choke cherry, only 1 was contributed by south bank quadrats.

e) Mean forb cover was approximately twice as great on south bank quadrat types as on similar quadrat types on the north bank. However, mean forb cover reached a maximum of only 10% on south bank D quadrats.

f) Mean grass cover was approximately 2-3 times greater on south bank quadrat types than on similar quadrat types on the north bank.

g) When tree and shrub cover was combined and sorted by height class, it was found that tree+shrub cover by height class 6 on the south bank was approximately 2 times that on the north bank. In quadrats B, C, and D on the north bank, tree+shrub cover of height class 3 provided the greatest mean cover (4-7%). This height class also provided 8% mean cover on the south bank D quadrats. However, on B and C quadrats, height class 6 provided the dominant cover.

h) Mean total vegetation cover (tree+shrub+forb+grass) was nearly 2 times greater for every quadrat type on the south bank as on the north bank. Mean total vegetation cover was greatest in the A quadrats, but even so was only 55% on the south and 38% on the north quadrats.

i) When grouping all quadrats on each bank individually, alder was found to provide 5% and 11% mean cover on north and south banks, respectively. Sagebrush provided 3-4% mean cover for all quadrats on the north as well as south bank.

j) When grouping all quadrats on each bank individually, trees of height class 6 (i.e., > 6 m tall) provided 5% cover on the north bank and 13% cover on the south bank. The groups of quadrat types (A, B, C, and D) represents a sample of the 20-m wide streamside zone on each streambank.

k) When grouping all quadrats on each bank individually, it was found that on north and south banks, vegetation of height class 3 provided approximately 4% cover. This represents a sample of the 20 m wide streamside zone on each streambank. A small amount of cover was provided on the north bank by shrubs of height class 5, a size class not present on the south bank.

l) Mean alder cover in relative elevation classes 2 and 3 on the north bank ranged from 9-12%, but was very low in other relative elevation classes. On the south bank alder cover reached its greatest mean cover value (18%) at relative elevation class 3, but was 8-11.5% at all other relative elevations.

m) Mean sagebrush cover at relative elevation classes of 3 or greater was 5-9% for north and south banks. South bank quadrats had greater mean sagebrush cover for any relative elevation class. Mean sagebrush cover was low in relative elevation classes 0 and 1.

n) Mean total tree cover on the north bank was low in elevation classes 0 and 1, but was approximately 9% in elevation classes 2 and 3. Mean tree cover was very low in elevation class 5. On the south bank mean total tree cover was >17% in elevation classes 0, 1, and 3, and was approximately 8% in elevation class 4.

o) Mean total shrub cover was low in relative elevation classes 0 and 1 on both north and south banks. Mean total shrub cover reached its highest level in north bank elevation class 2 (13%).

Aerial-based analysis

- <u>Cover</u>

a) There was a high degree of correlation (r=0.84, n=83) between tree cover estimates made using ground-based vs. aerial-based analysis on the basis of quadrats. This correlation was based upon all quadrats meeting requirements for size, shape, and placement in the GIS mapping. It included any quadrat for which GIS analysis produced an estimate of ≥0% tree+shrub cover.

b) There was a moderate degree of correlation (r=0.50, n=83) between ground-based and aerial-based analysis of total shrub cover for quadrats.

c) There was a high degree of correlation (r=0.80, n=83) between tree+shrub cover estimates made using ground-based vs. aerial-based analysis on the basis of quadrats. One might assume that the correlation of tree+shrub cover between ground-based vs. aerial-based cover estimates would be higher than a correlation based on solely tree cover. That is, if some trees were potentially misclassified as shrubs, or vice versa, an estimate of cover for these two cover types together should eliminate this internal misclassification. However, it might be that confusion between trees or shrubs and forbs could also weaken the tree+shrub correlation by the two methods. In any case, there was a strong correlation between estimates made by each technique for trees and trees+shrubs.

d) A comparison of tree+shrub cover estimated by ground- and aerial-based analysis sorted by vegetation height class Tree+shrub cover estimated by ground- and aerial-based analysis was sorted by vegetation height class for individual quadrats. A comparison of these estimates indicated several types of inaccuracies attributable to the aerial approach: i) it was fairly common for vegetation of a height class determined on the ground to be assigned to an adjoining height class when interpreted from aerial photography, ii) cover recorded in multiple height classes on the ground was sometimes lumped into a single height class in GIS mapping, and iii) cover recorded for a quadrat on the ground was not noted at all in GIS mapping. The first two of these inaccuracies are not unexpected. Minor errors in estimating vegetation height on aerial photos could easily result in a shift in assigning height categories. Also, in the process of mapping vegetation polygons, height is recorded not for individual shrubs but as an average for a cluster. It is far easier on the ground to mentally tally small increments of shrub cover in various height classes than to attempt to measure heights of many minute polygons from aerial photography. Mapping assumes making decisions to assign average height classes to clumps of vegetation and establishing a minimum polygon size for which to designate height.

e) Mean tree cover estimated by GIS mapping for the north bank A quadrats was 18% and that for south bank A quadrats was 25%.

f) When evaluating tree cover for entire A vegetation bands using GIS analysis, it was found that north bank A bands had 17% cover and south bank A bands had 24% cover. This result indicates that sampling only A quadrats from the A band yields essentially the same cover estimates for north and south banks as achieved by using the entire band (see (e) above). This may simply indicate that in this study area the spacing of transects and sample quadrats was sufficient to accurately represent the vegetation present. It shows that the distribution of trees was such that the sampling pattern was able to capture the overall cover value.

g) Shrub cover on the north bank was 8-12% and on the south bank was 15-18%, depending upon vegetation band. Shrub cover increased with distance from the stream.

h) Trees of height >6 m contributed the greatest amount of cover in vegetation band A on north and south banks. Trees of this height provided 20% cover on the south bank A band. Shrub cover of height class 0.5-1.5 contributed 4-7% cover on the north bank vegetation bands and 4-12% cover on south bank vegetation bands, generally increasing in cover percentage with distance from the stream.

i) Tree+shrub cover on A band vegetation was approximately 25% on the north bank and 33% on the south bank. For B, C, and D bands tree+shrub cover was 11-13% on the north bank and 23-24% on the south bank.

j) GIS mapping was used to estimate tree and shrub canopy cover that projected vertically above the river water surface. Shrubs of any height class provided negligible cover. However, trees of height classes 1.5-3.0, 3.0-6.0, and >6.0 m provided 0.7, 1.6, and 9.6% cover, respectively, directly over the water surface. Total tree+shrub cover directly over the water was approximately 12.6%. Of this amount nearly 95% was contributed by tree cover of all height classes.

Recommendations

(1) <u>Improvement in Current Work Products</u>

a) Aerial photography was taken at a scale of 1" to 500' or 1:6000. An advantage of this scale was that few photographs were necessary to cover the entire study area. The stream reach flowed in a broad arch. If the study area were to be mapped at a scale of 1:2000, for example, it might be necessary to have two or three flight lines. This would then necessitate taking several photos on multiple flight lines to cover the study area instead of the three photos taken on one flight line at the 1:6000 scale imagery. Setting up stereo images on a analytical stereoplotter prior to creating digital maps requires significant time expenditure. Also, a denser network of ground control points is needed when mapping from stereo photos at higher resolution, causing greater expense and difficulty in tying imagery together in a comprehensive, accurate model. This problem can be overcome by taking a second set of photographs at a smaller scale (or higher altitude) that covers the entire study area. These smaller scale photos can then be used to correct the mapping done from larger scale photos of the same area by correlating identical points on the two photo coverages.

The photos taken with color IR film at 1:6000 appeared to provide too coarse an image to offer much opportunity to differentiate tree or shrub species. However, because the analytical stereoplotter used

by BPA to map vegetation had such good optical properties and could use a magnification of 10-12x vegetation canopies and height of canopies were estimated with sufficient accuracy. Selection of film and photographic scale is a compromise between expense and time spent and the type of analysis possible. It is possible that a scale of 1:3000 would provide a significant improvement in ability to identify and measure vegetation properties but still be of a resolution coarse enough to be economical in terms of cost of photography and mapping.

b) Some errors were noted in classifying vegetation based on discrepancies between ground-based vegetation analysis and aerial mapping. This error involved misidentification of vegetation as trees vs. shrubs. It is probable that trees of the height class >6 m would not be mistaken for shrubs, but at the photo scale of 1:6000 it seems likely that vegetation under 1.5 m height could be easily confused. Because trees and shrubs both provide important rooting properties that retain soil, the other important feature to distinguish them would be height class for their shading characteristics. If monitoring focuses primarily on these benefits of vegetation, the 1:6000 scale might be adequate. However, there were also instances in which tall forbs were mistaken for shrubs. This would argue for using a greater photo scale.

It is recommended in future work that if more reliable distinctions between trees and shrubs are desired that a scale greater than 1:6000 is needed. A scale of 1:2500 represents the highest resolution that would be needed, but something on the order of 1:4000 might be sufficient and a major improvement.

c) This project involved significant contributions at three locations: CRITFC in Portland; Warm Springs Tribe at Warm Springs, Oregon; and BPA in Portland. Communication among workplaces on a project depending on proper sequencing and accuracy at each step is vital. Although significant communication did occur, in retrospect it would have been better for CRITFC staff familiar with the Warm Springs vegetation in the study area to be intimately involved in photointerpretation during the entire process. This may have led to greater classification success. A similar retrospective desire on the GIS mapping done by Warm Springs would be to have recognized earlier that the buffering procedure used to create 5-m vegetation bands and sample quadrats was inadequate in locations where the stream margin was highly convoluted. Any time a significant piece of work is done independently at any worksite there is the potential to overlook opportunities to make adjustments in mid-course. Every project, no matter how well coordinated, involves coming away with learning experiences that give guidance to how to work more efficiently and accurately in the future.

d) Numerous experiences were gained by CRITFC staff in ways to do work more efficiently in the future on tasks it was involved in. Establishing iron stakes on the ground could be done more effectively if aerial photos were available in advance. By plotting the desired locations and orientations of transect lines, a compass could have been used to sight from stakes established at 40-m intervals on one side of the stream to stake locations on the opposite bank. With a greater initial assurance that stakes were located properly, it would have been more effective to attach permanent stake brass numbering tags as stakes were driven. Radio communication between crews working on each side of the stream provided to be essential.

Future work would also benefit from greater time allocated to collecting and identifying plants. This would increase taxonomic reliability of observations. Attempting to make repeat observations on unknown taxa is not feasible when the objective is to rapidly record data on cover and height class by taxon. It may also be reasonable to collect data simply at the level of tree, shrub, forb, and grass on

cover and height class. This resolution does not provide the ecological interpretations on range condition possible with more extensive floristic analysis, but it could indicate major changes in cover, soil retention, shading, and height diversity. Aerial photographic analysis of vegetation at the 1:6000 scale resulted in simply distinctions by tree and shrub cover according to height class. A greater scale might have allowed distinction of certain tree species and possibly allowed separation of sagebrush and rabbitbrush from shrubs such as mockorange, choke cherry, or willow. If the purpose of future monitoring is also to relate vegetation observed on aerial photos with ground-based observation, the tree/shrub/forb/grass designations might be sufficient. An alternative might be to record all species on every other transect on ground surveys but simply tree/shrub/forb/grass on other transects. The purpose in correlating ground and aerial surveys is so that aerial surveys can then be used with confidence to provide a more extensive coverage to the vegetation communities. Aerial mapping is perhaps the best tool for delineating boundaries in plant communities or patches in a single community type having distinct plant densities.

(2) <u>Suggestions for Future Research</u>

a) Try to correlate the aerial cover and height estimates with ground-based estimates of tree+shrub canopy cover density and height diversity. Digital image analysis methodology offers the prospect of distinguishing vegetation types by color classification. There may be a possibility of estimating canopy heights from digital images by application of trigonometric functions and surveying techniques. This could provide a convenient means of documenting riparian condition and doing a quantitative analysis that could be repeated in the future to detect trends. Image analysis could be a far more satisfactory means to determine effectiveness of canopy in shading a stream channel than use of a spherical densiometer. A densiometer assesses occurrence of shading vegetation on a very limited number of points on a spherical grid. Image analysis would permit this analysis for the entire set of pixels captured by the image.

b) If necessary, refine the bank stability method by using a penetrometer or other similar device to probe the banks for cobble material. Banks that have significant ground vegetation cover or layers of fine sediments over coarser material can hide the nature of the bank material, making it difficult to assess potential stability. A fine sediment covering to a large-cobble-bank having a slope of 40° and no vegetation could appear unstable, but would likely be rated differently than a similar bank not having the fine sediment covering. This situation highlights the difficulties in streambank stability estimates. A bank may have conditions lending to potential instability; there could be evidence of current erosion (slumping, raveling, fissure or gully creation); and on the other end of the spectrum the bank could collapse, thereby assuming a more stable slope. In the latter case, revegetation will improve stability over time. The collapsed bank shows the product of potential bank instability, effective erosion processes, and then a potential restoration phase in which vegetation can stabilize the slope and collect additional sediments. As fine sediments accumulate in the surface layer, vegetation must be added so that the stability rating can increase.

c) Explore the use of digital scanning imagery taken from a helicopter for riparian vegetation analysis. The use of ratios of different band frequencies, such as done in satellite imagery, could assist in distinguishing vegetation types.

d) Test the use of a lower cost analytical stereoplotter combined with photography taken in natural color at a greater scale (e.g., 1:4000) for mapping vegetation. Investigate getting training in the use of this equipment to create GIS maps. The primary advantages to this are that the person with the

greatest familiarity with vegetation on the site would also map the vegetation and the lower costs involved in mapping. The disadvantages include time spent becoming trained to produce accurate maps, the time commitment to working on mapping, and the lesser accuracy provided by the less sophisticated equipment. A compromise would be spending at least 20% of the time required for mapping with the expert mapper to assist in vegetation recognition and decision making during the process.

e) In re-mapping vegetation on established transects, consider determining vegetation within the same quadrats as measured originally, despite where the active water's edge is. Such information would say something about vegetation community trends on sites that change in proximity to the active channel. This may or may not be a significant factor. Proximity to the channel could be significant if grazing were ever to occur in the protected area again and it were concentrated in the near-stream area. There may also be an influence at a fixed dryland site from adjacent hydric communities. This might influence the frequency of hydric species invading nearby drier sites.

With this convention it may be possible to use Adobe Photoshop or other digital image processing software to analyze canopy density or cover.

(3) <u>Notes for Future Modification of the Stability Scoring System</u>

A lower bank that is very wide may have an extensive cobble/gravel bar. The lower bank stability scoring system only considers the first 1 m from the bankfull line. Consequently, the composition of the bar substrate and the gradient of the majority of the bar do not influence the stability rating. As far as overall streambed stability, it is influenced by the streambed composition, including bar composition. If the bar has steep slope elements greater than 1 m distant from the bankfull line, they would not contribute to the stability rating. The current streambank erosional forces are focused near the bankfull line. If the lower bank gradient up to bankfull is low (e.g., <11°), a maximum stability score from slope considerations is given. If this slope is low, it would imply that at bankfull flows, the combination of velocity and depth of water results in low streambed tractive force. If there is a steep slope element next to the bankfull line, erosive force can be more significant. If there is an overhanging bank at the stream margin, good fish habitat is created. However, this morphological condition should be considered to be inherently unstable unless heavily covered by deeply rooted vegetation. Greater stability should be implied by 100% cover with trees or shrubs than with sedges/perennial grasses. If the summertime wetted stream margin extends to beneath a bank overhang, the lower bank to evaluate should be the lower surface of the overhang. The bank material would likely be soil, and have no vegetation. This would result in a lower bank score of 0. It is likely that even well vegetated overhanging banks are more unstable than well vegetated, gently sloping, cobbled banks, although they may be far more productive for fish populations. Woody debris in each bank type would enhance production potential and probably also bank protection. Tree or shrub roots would improve stability of the lower bank surface of an overhang. Exposed roots on the overhang might be given some score to express resistance to erosion, in the same way as exposed cobbles, although this would to some extent double count the value of vegetation. For an intact overhang to be present and for it to be covered by vegetation implies that livestock or other ungulates have not caused significant damage. If banks express overhangs with abundant cover but still yield a total stability score of <3.5, some allowance might need to be made for the fish habitat provided. The stability scores in such a case should be evaluated for the entire reach to determine the mean stability. Also, it should be assessed whether more effective cover is able to colonize the overhanging banks, such as trees>shrubs>grasses.

There may be too much information expected from a bank stability rating. That is, good fish habitat arises from a channel with abundant LWD, good water quality, low amounts of fine sediment, bank overhangs, low embeddedness, abundant riparian vegetation and cover. Generally, high bank stability is conducive to good fish habitat. Poor lower and upper bank stability indicates conditions where a channel may potentially or actually be widening, contributing sediment for transport, and due to the frequent lack of vegetation, is also resulting in elevated water temperature. However, not all the potential for erosion and sediment transport can be derived from evaluation of the lower and upper banks. The stream channel itself stores and releases sediment, and lateral, point, or mid-channel bars serve this function. Bars of varying widths, surface gradients, and total volumes may be exposed at low water conditions and indicate the sediment regime for the watershed. For this reason it seems best not to overly confuse the bar area with the lower bank. These features of the channel should be monitored in addition to bank stability and channel substrate condition to follow trends in the sediment regime. The area of exposed cobble bar was mapped using GIS. These data in conjunction with before/after analysis of sediment volumes from topographic contour data would allow analysis of floodplain sediment storage or loss.

(4) Costs of Monitoring

The costs of conducting this monitoring study on 1000 m of the Warm Springs River were divided into work performed by BPA, CRITFC, and the CTWSRO.

Approximate project costs for work performed by BPA were:

GPS work (establish control points, surveying, computations)	20,000
Aerial photography contract	3,300
Mapping, editing of map layers, computations, creation of files	11,000
Total	34,300

The CRITFC budget was apportioned as follows:

Personnel	10,036
Travel	2,385
Supplies and Services	2,300
Indirect	5,594
Total	20,315

Work done by Warm Springs specifically on the aquatic monitoring portion of the total monitoring and evaluation work done on the Warm Springs River was funded at $1000 directed to GIS work.

Original budget estimates by CRITFC for fencing necessary to complete this monitoring were closer to $30,000, but budget limitations imposed in the Fish and Wildlife Program dictated that if CRITFC were to undertake this project, it would have to fund any cost overruns from its own sources. Field work was conducted on June 4-5, 1997, June 17-18, June 25-26, July 2-3, 1997, October 14-15, 1997. In addition, two additional days were devoted prior to these listed field days in doing reconnaissance of the site and discussing the project with CTWSRO staff. Field time totaled 12 working days (96 h minimum field hours). After BPA produced the DXF maps of the site from aerial photos and CTWSRO converted these to GIS format, CRITFC was able to conduct the analysis using ArcView 3.0 and Access database programs. CRITFC also had to create the databases from field data, do all data analyses, and write the monitoring report. This entire office portion of the project probably consumed 5 months (best estimate). This would indicate approximately 870 hours devoted to the data input, analysis, and writing. Total hours spent by CRITFC on field and office work were 966 h. Including fringe and indirect costs, the personnel cost devoted to the work totaled approximately $41,300. Total costs for staff time, including fringe and indirect rates covered in the BPA contract were $13,850, leaving the remainder (i.e., $27,450) to be contributed by CRITFC.

Total costs of the project (i.e., including work done by BPA, CRITFC, and CTWSRO) were approximately $83,000. It is clear that at this cost, detailed monitoring and analysis for extensive lengths of streams in the Columbia River would be prohibitive. However, the purpose of this project was to develop and test methods that have promise in facilitating rapid, reliable monitoring of stream condition. Much of the field and office time spent was devoted to exploring and considering new methods, developing database structures, and devising methods for analysis and data presentation. Future monitoring efforts can likely take advantage of time-saving opportunities in modifying and improving these methods or in conducting similar studies.

FIGURES

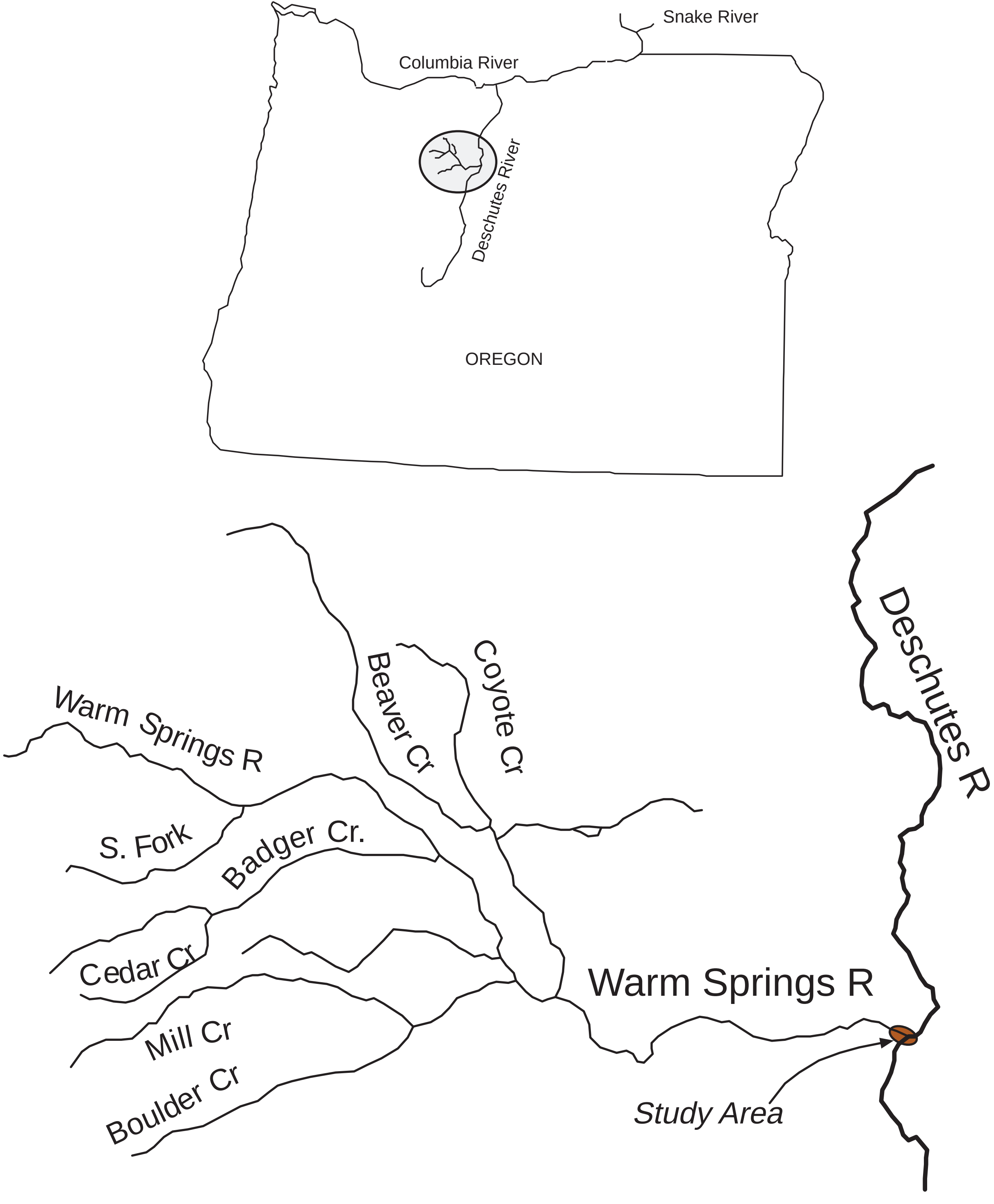


Figure 1. Map of the Warm Springs River and its tributaries

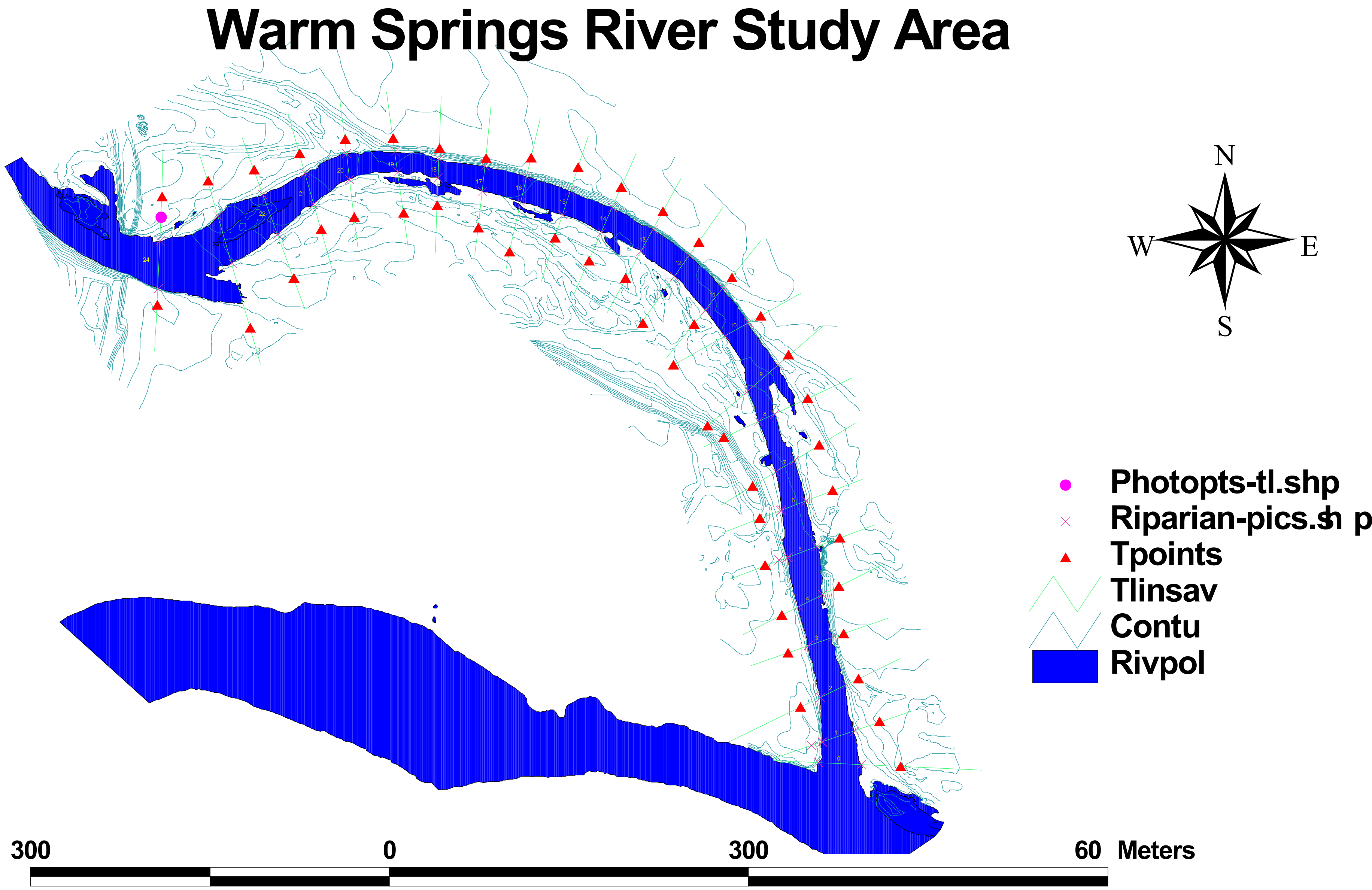


Figure 2. The study area near the mouth of the Warm Springs River,
showing upland and riparian photopoints, transect lines, transect markers, and contour lines (0.5 m).

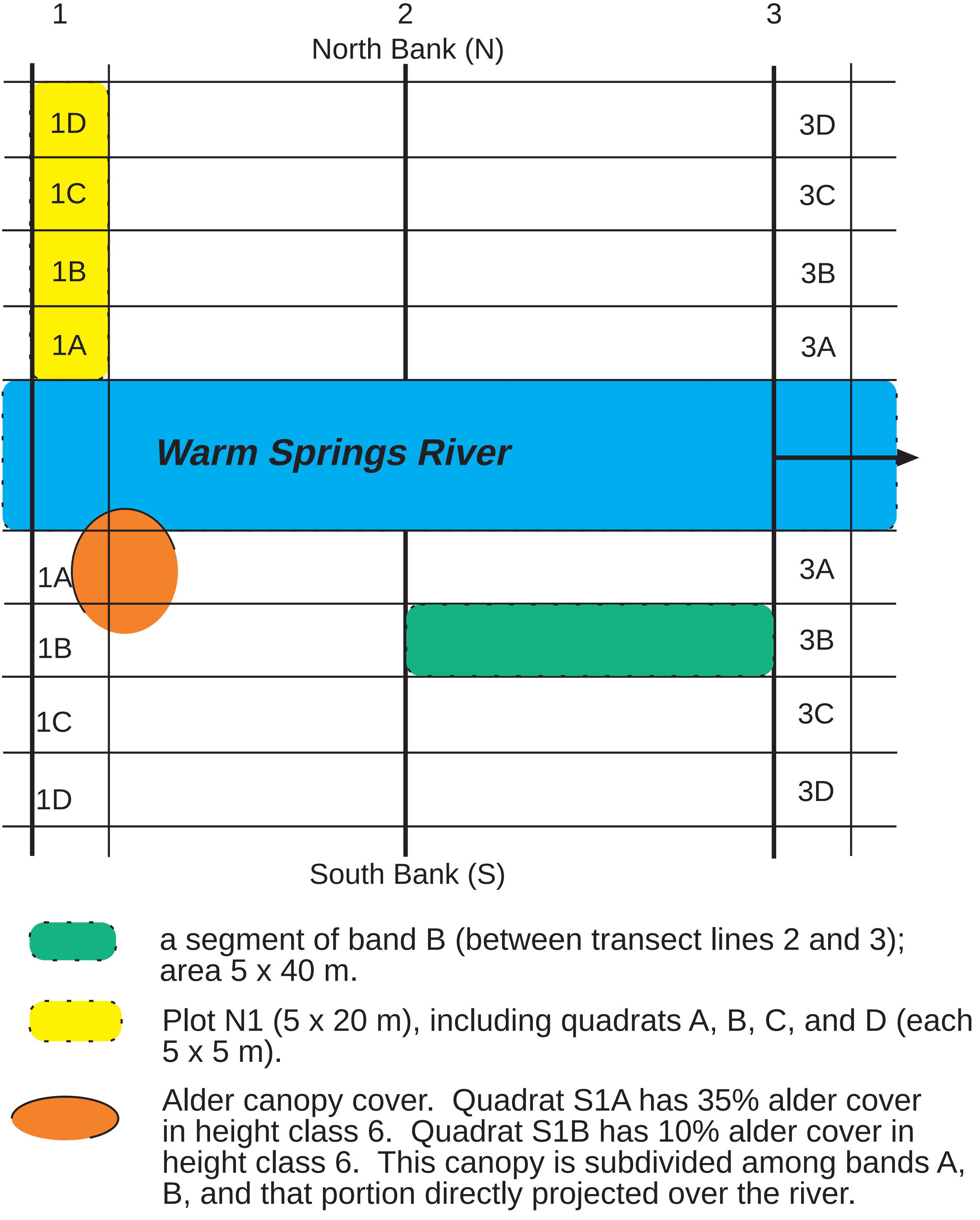


Figure 3. Conceptual diagram of the layout of transects, quadrats, vegetation, and other resources to be mapped.

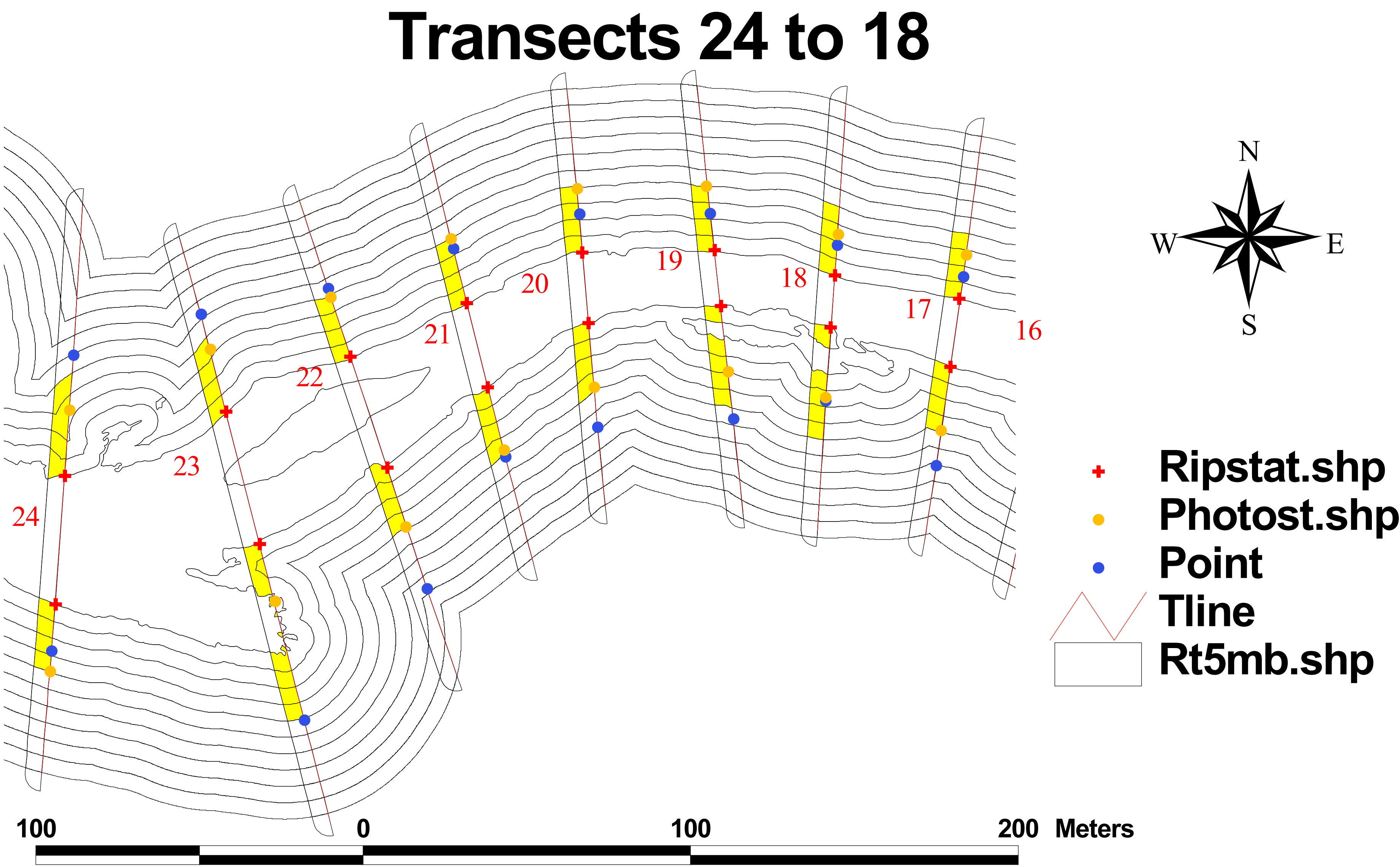
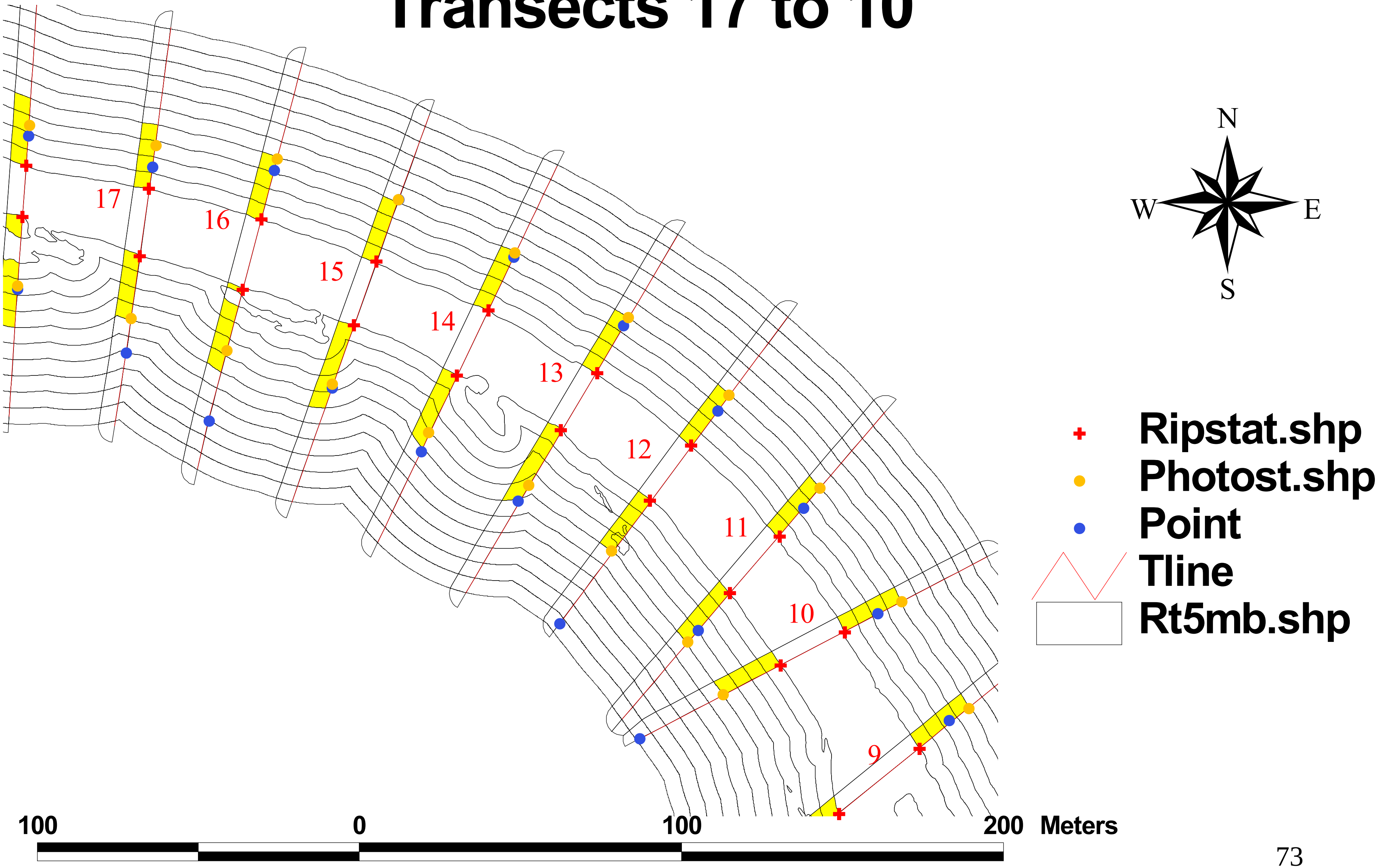
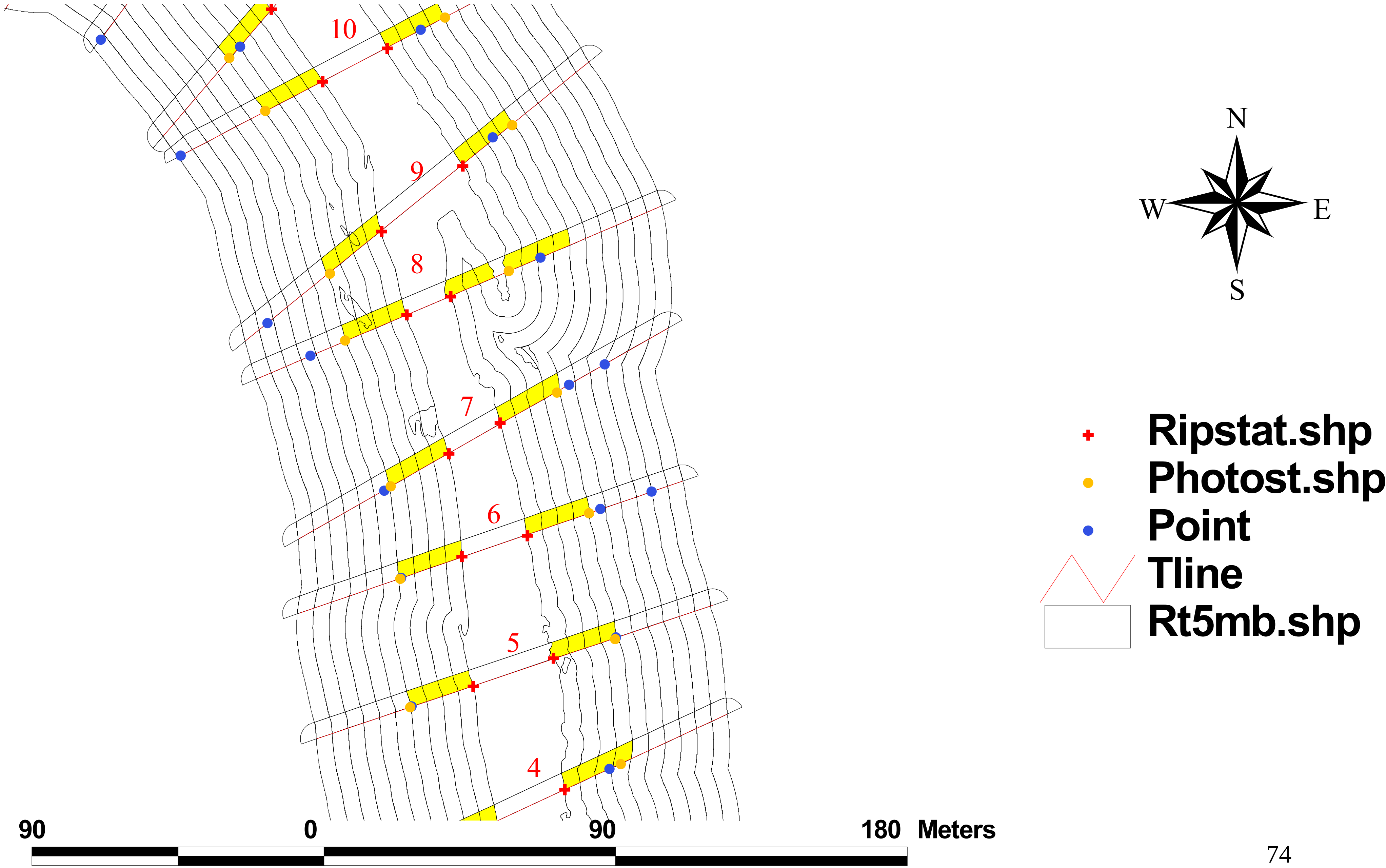


Figure 4. Maps of the study area with transects, transect points (permanent stakes), and photopoints; also showing quadrats as they were created by the buffering process in the GIS.

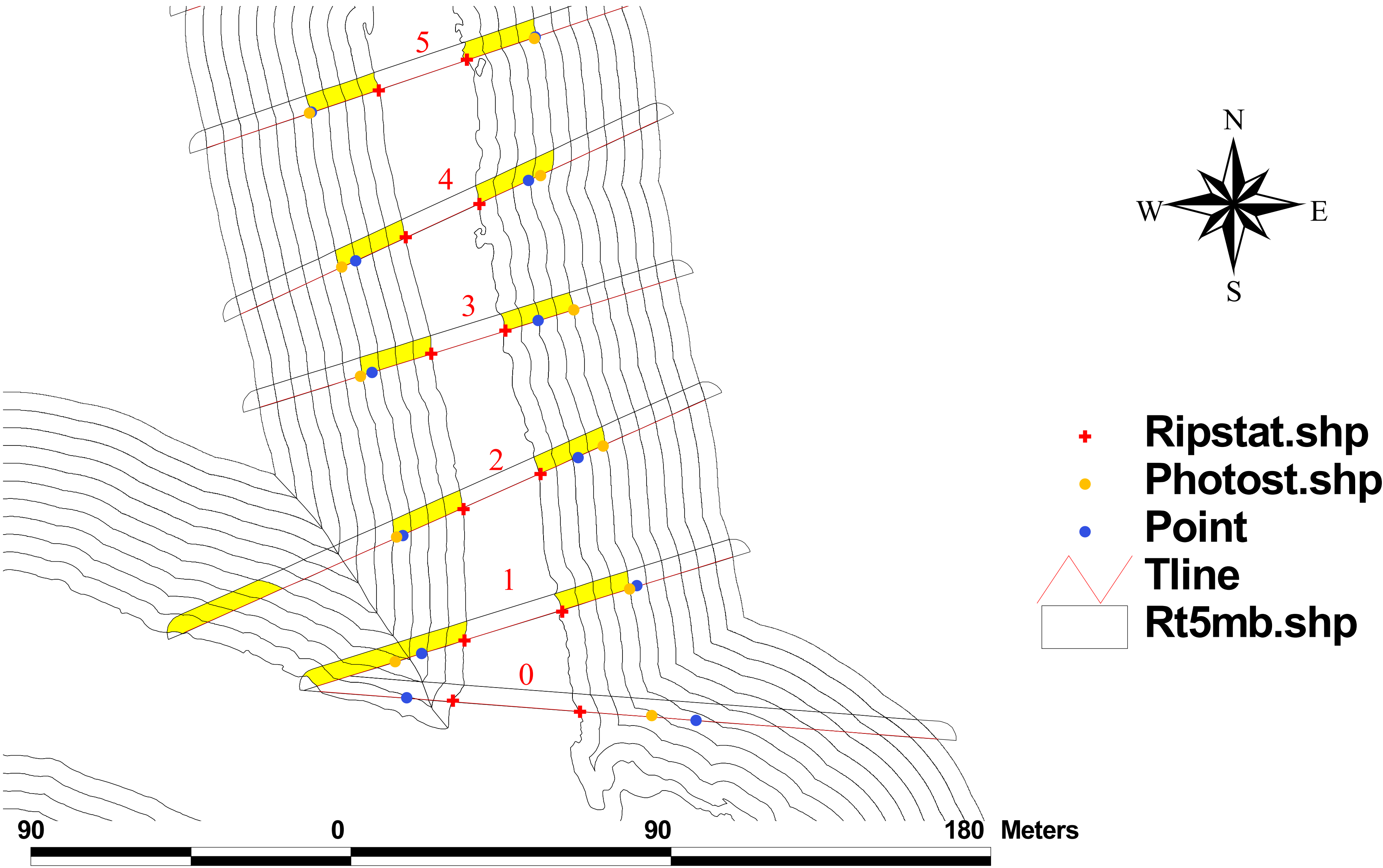
Transects 17 to 10



Transects 9 to 5



Transects 4 to 0



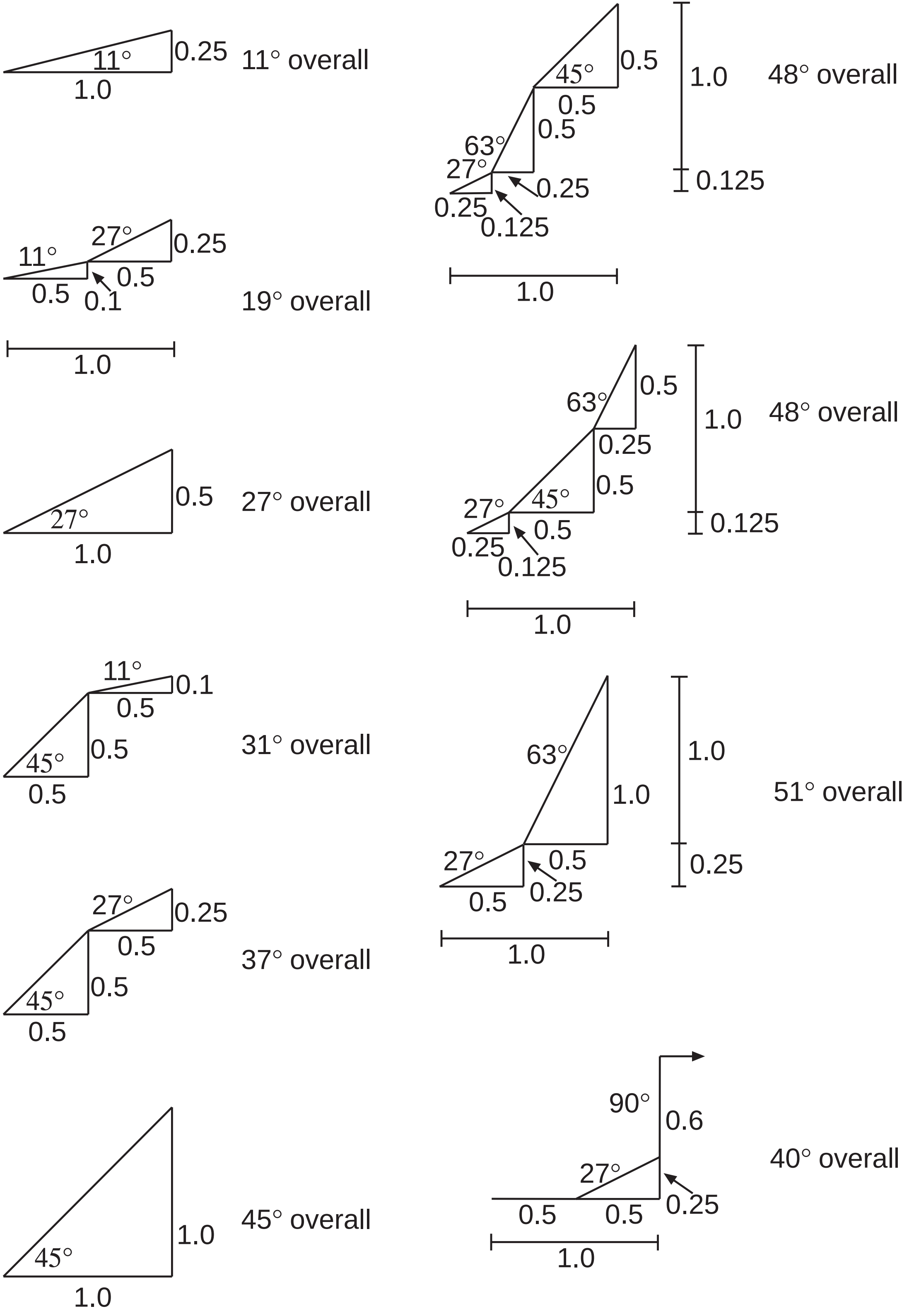
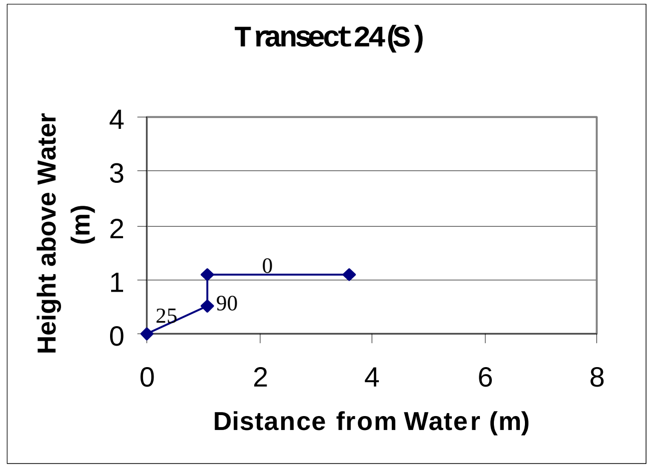
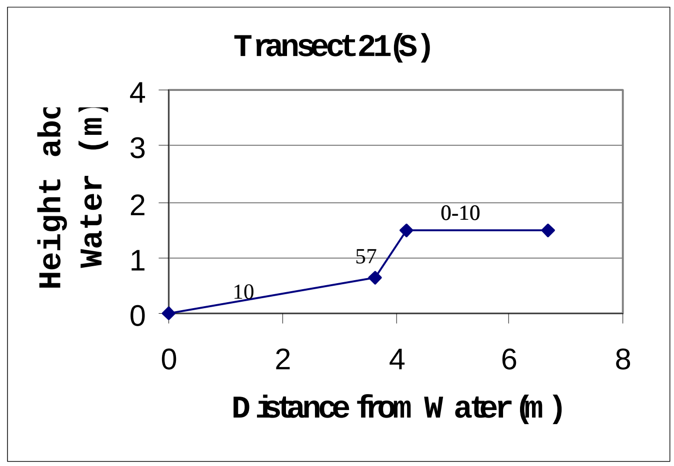


Figure 5. Conceptual streambank slope diagrams used in visualization of different types of lower and upper bank form and overall slope.

Seg. length (m)	Angle deg.	x	y
		0.00	0
1.2	25	1.09	0.51
0.6	90	1.09	1.11
2.5	0	3.59	1.11



Seg. length (m)	Angle deg.	x	y
		0.00	0
3.7	10	3.64	0.64
1.0	57	4.19	1.48
2.5	0	6.69	1.48



Seg. length (m)	Angle deg.	x	y
		0.00	0
3.0	21	2.80	1.08
2.5	5	5.29	1.29

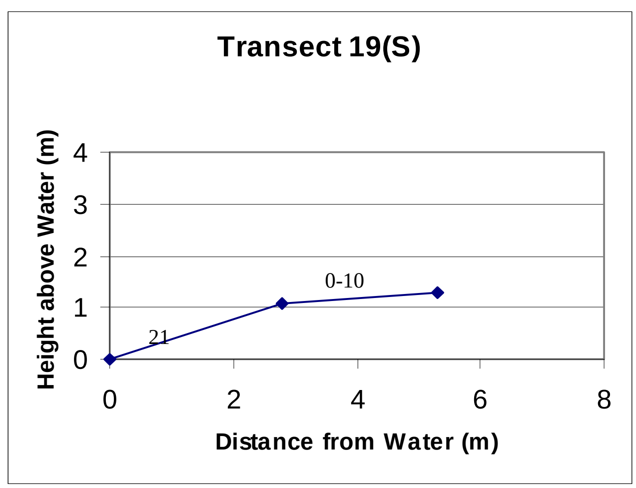
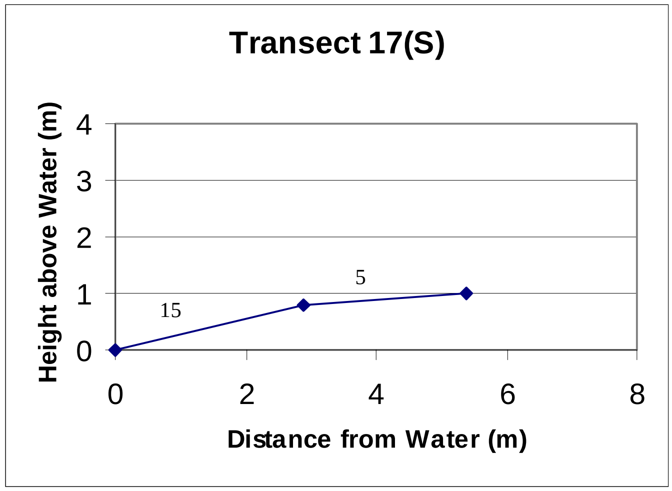
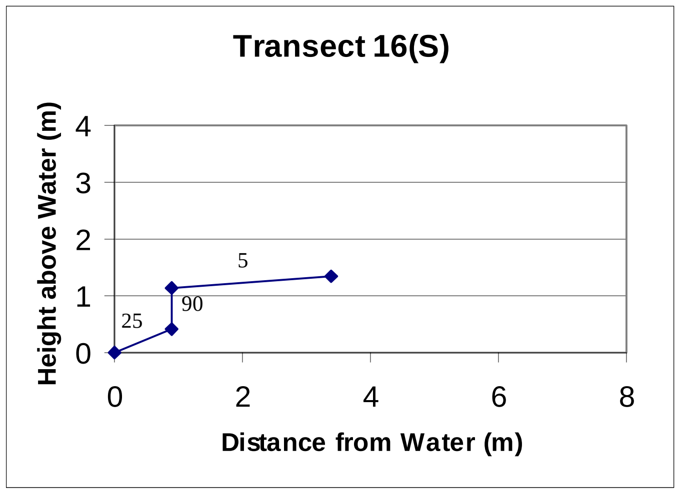


Figure 6. Streambank cross-sections plotted from measurements of angle and length of slope elements using trigonometric functions.

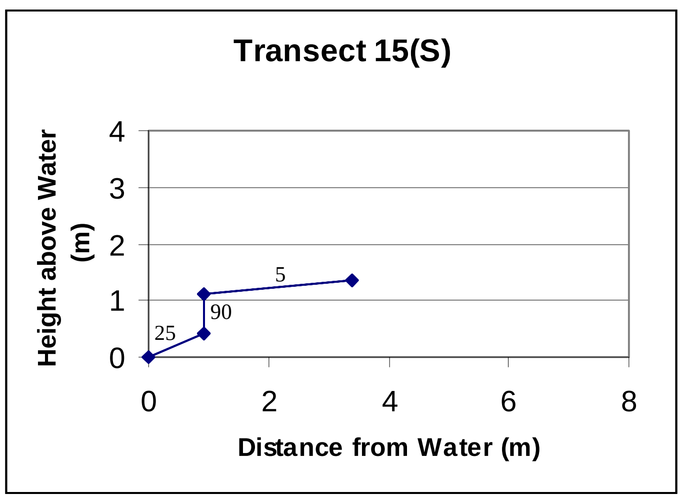
Seg. length (m)	Angle deg.	x	y
		0.00	0
3.0	15	2.90	0.78
2.5	5	5.39	0.99



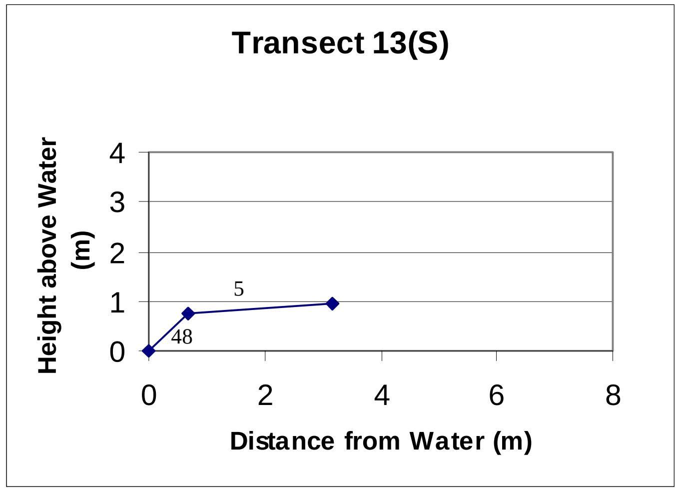
Seg. length (m)	Angle deg.	x	y
		0.00	0
1.0	25	0.91	0.42
0.7	90	0.91	1.12
2.5	5	3.40	1.34



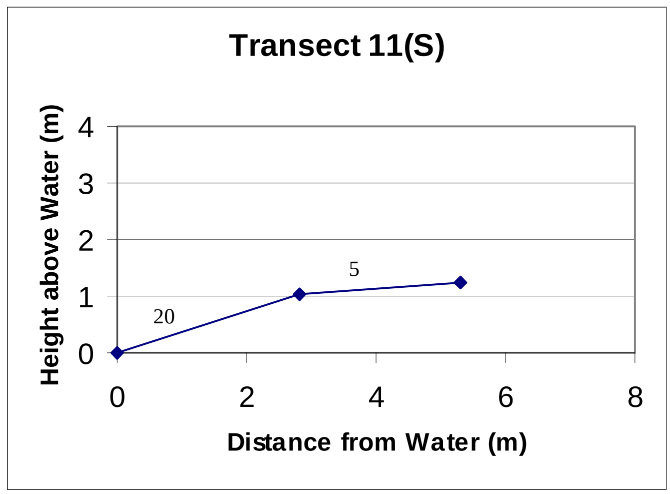
Seg. length (m)	Angle deg.	x	y
		0.00	0
1.0	25	0.91	0.42
0.7	90	0.91	1.12
2.5	5	3.40	1.34



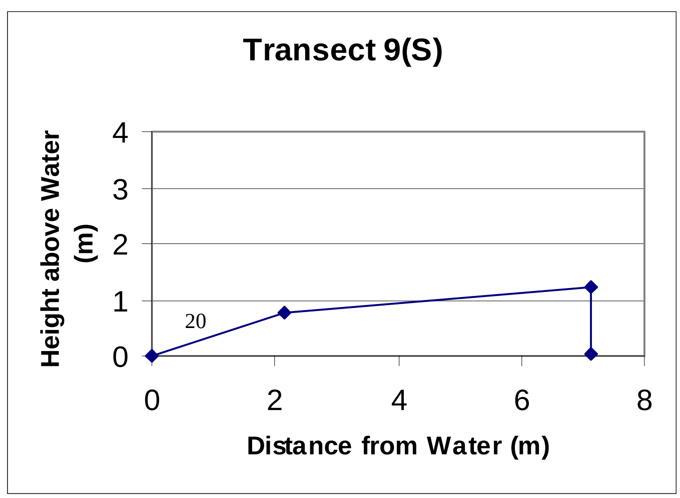
Seg. length (m)	Angle deg.	x	y
		0.00	0
1.0	48	0.67	0.74
2.5	5	3.16	0.96



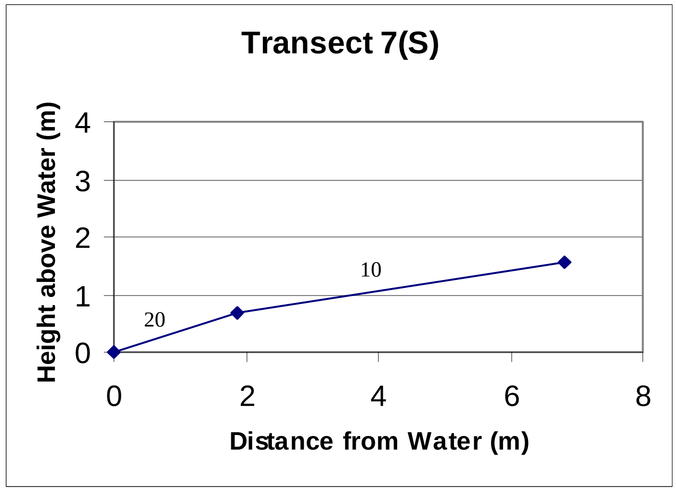
Seg. length (m)	Angle deg.	x	y
		0.00	0
3.0	20	2.82	1.03
2.5	5	5.31	1.24



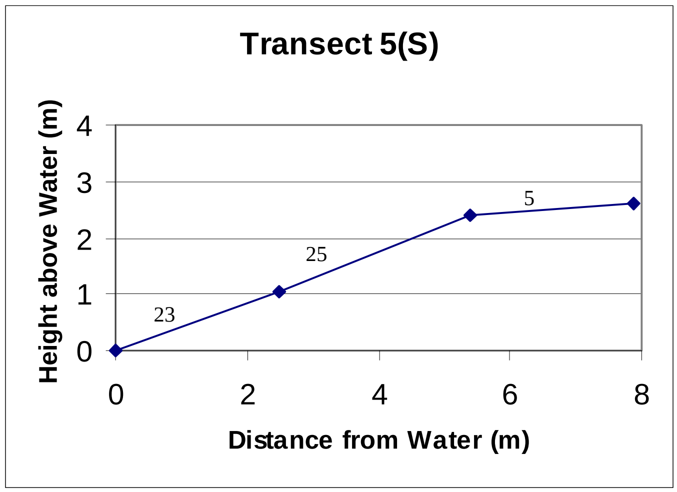
Seg. length (m)	Angle deg.	x	y
		0.00	0
2.3	20	2.16	0.79
5.0	5	7.14	1.22
1.2	-90	7.14	0.02



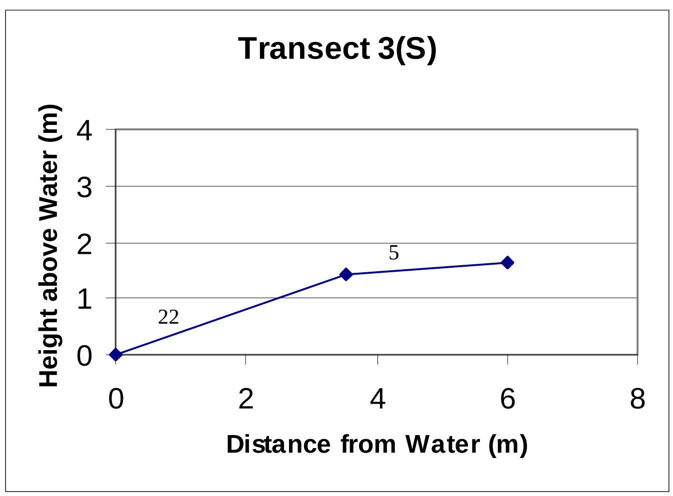
Seg. length (m)	Angle deg.	x	y
		0.00	0
2.0	20	1.88	0.68
5.0	10	6.80	1.55



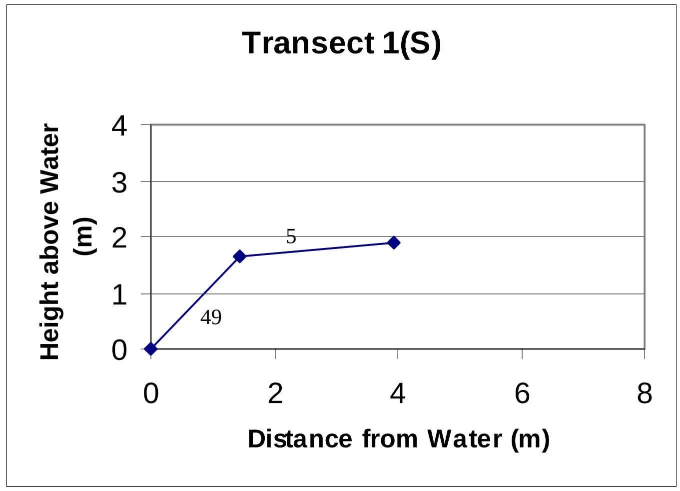
Seg. length (m)	Angle deg.	x	y
		0.00	0
2.7	23	2.49	1.05
3.2	25	5.39	2.41
2.5	5	7.88	2.63



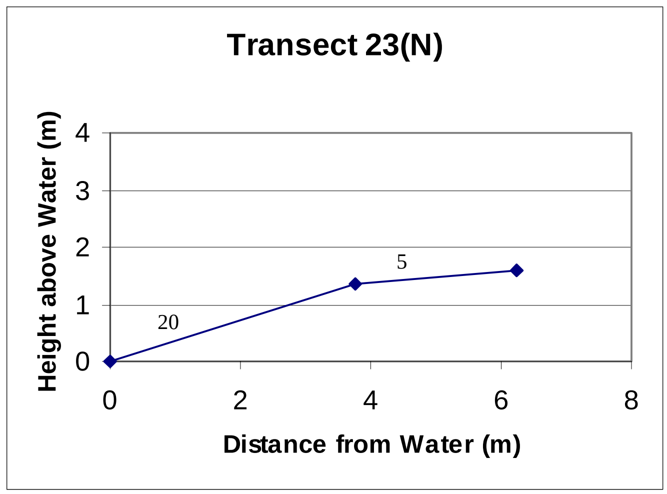
Seg. length (m)	Angle deg.	x	y
		0.00	0
3.8	22	3.52	1.42
2.5	5	6.01	1.64



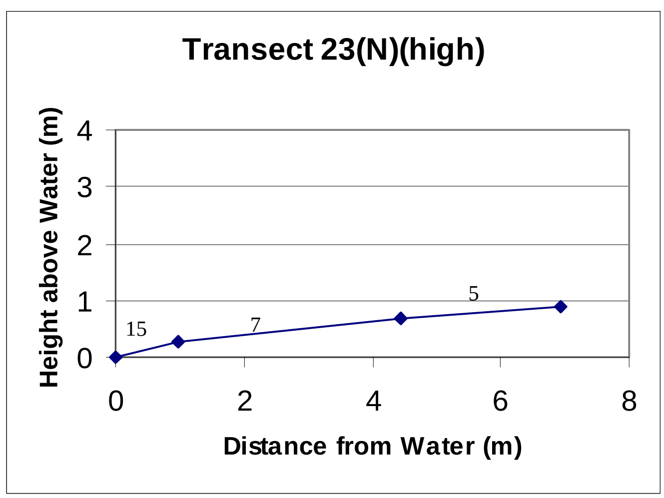
Seg. length (m)	Angle deg.	x	y
		0.00	0
2.2	49	1.44	1.66
2.5	5	3.93	1.88



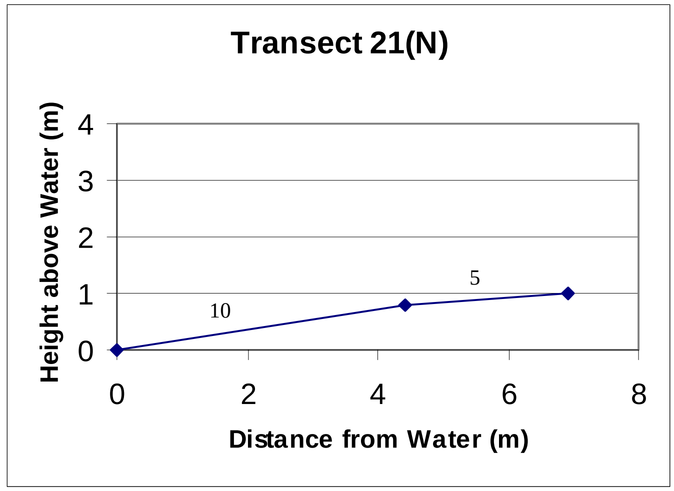
Seg. length (m)	Angle deg.	x	y
		0.00	0
4.0	20	3.76	1.37
2.5	5	6.25	1.59



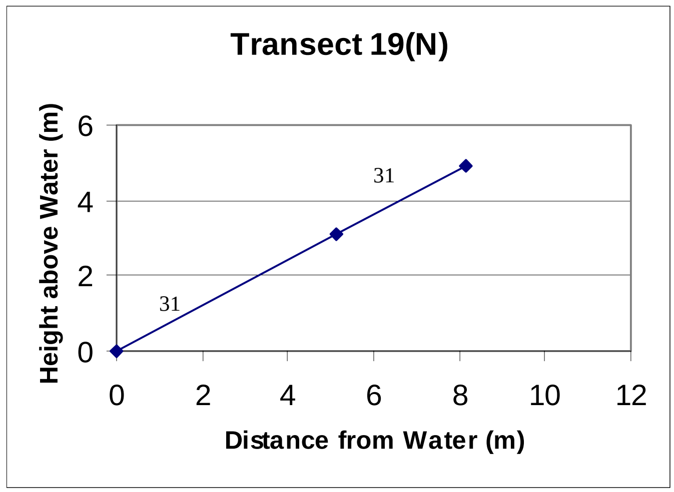
Seg. length (m)	Angle deg.	x	y
		0.00	0
1.0	15	0.97	0.26
3.5	7	4.44	0.69
2.5	5	6.93	0.90



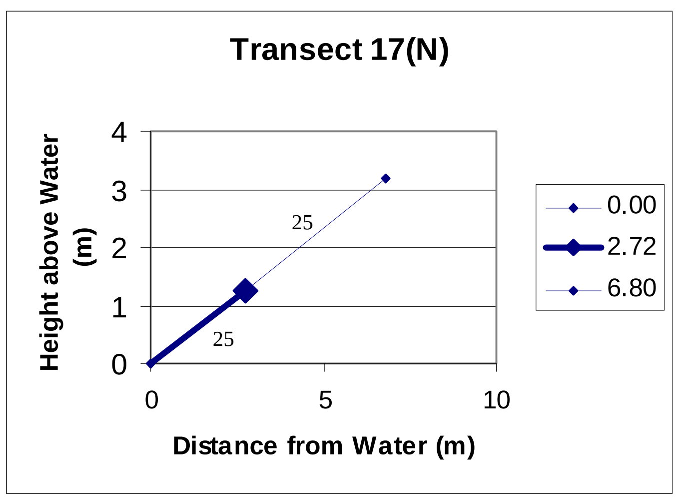
Seg. length (m)	Angle deg.	x	y
		0.00	0
4.5	10	4.43	0.78
2.5	5	6.92	1.00



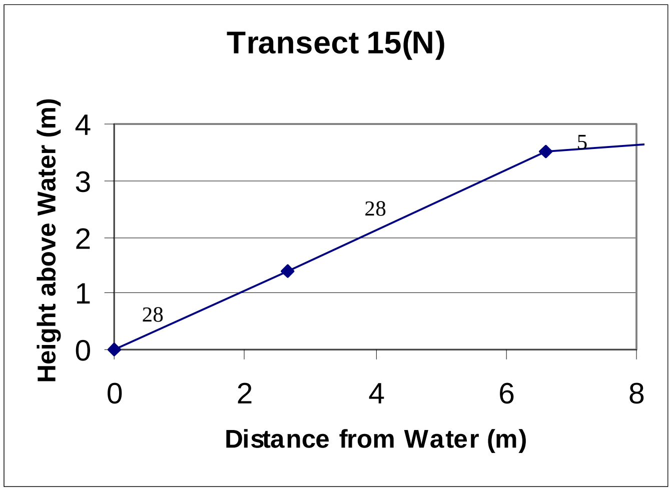
Seg. length (m)	Angle deg.	x	y
		0.00	0
6.0	31	5.14	3.09
3.5	31	8.14	4.89



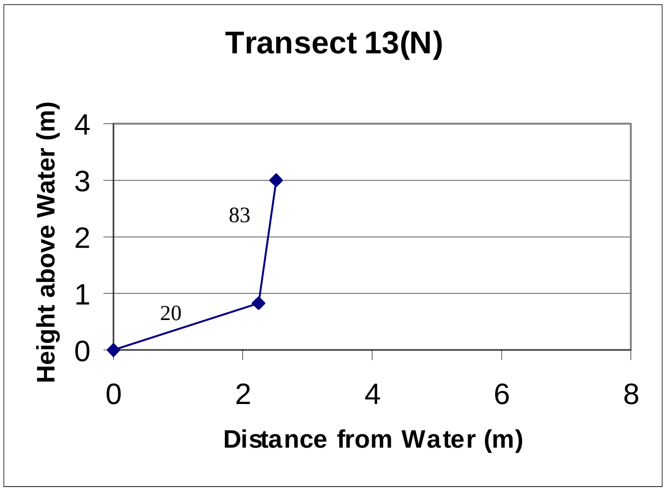
Seg. length (m)	Angle deg.	x	y
		0.00	0
3.0	25	2.72	1.27
4.5	25	6.80	3.17



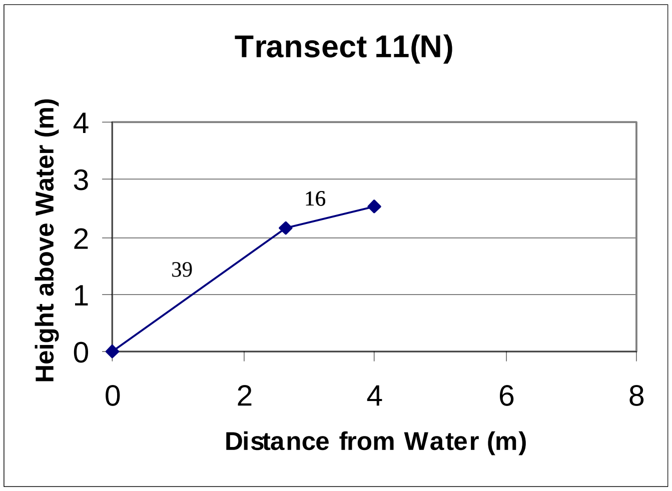
Seg. length (m)	Angle deg.	x	y
		0.00	0
3.0	28	2.65	1.41
4.5	28	6.62	3.52
2.5	5	9.11	3.74



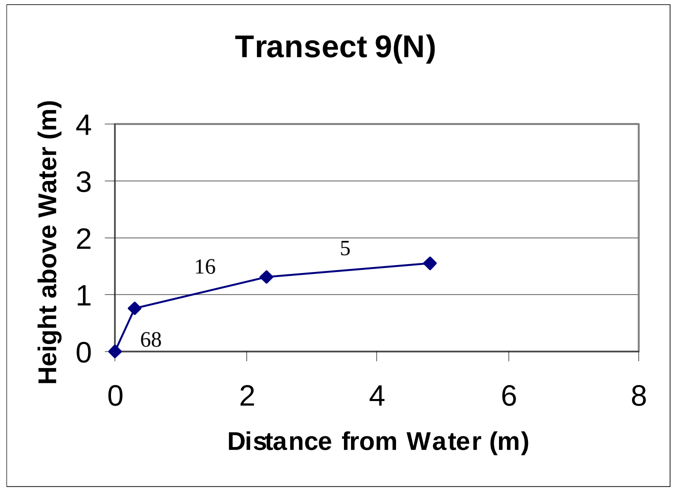
Seg. length (m)	Angle deg.	x	y
		0.00	0
2.4	20	2.26	0.82
2.2	83	2.52	3.00



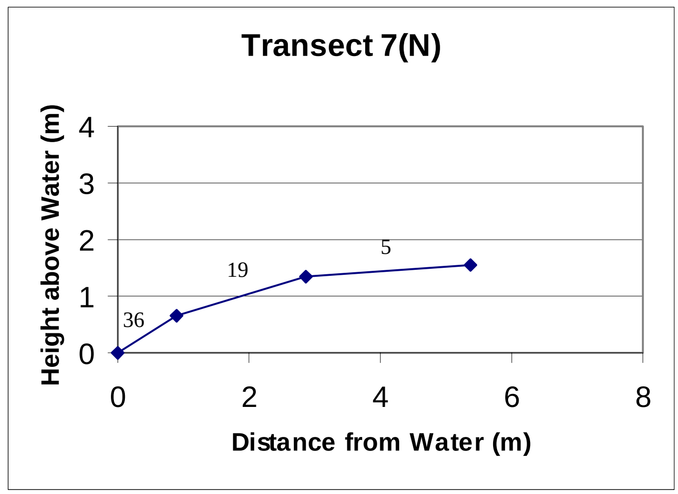
Seg. length (m)	Angle deg.	x	y
		0.00	0
3.4	39	2.64	2.14
1.4	16	3.99	2.53



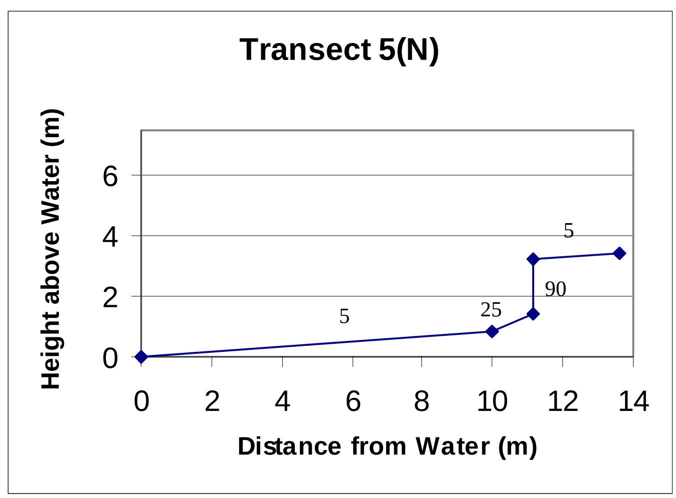
Seg. length (m)	Angle deg.	x	y
		0.00	0
0.8	68	0.30	0.74
2.1	16	2.32	1.32
2.5	5	4.81	1.54



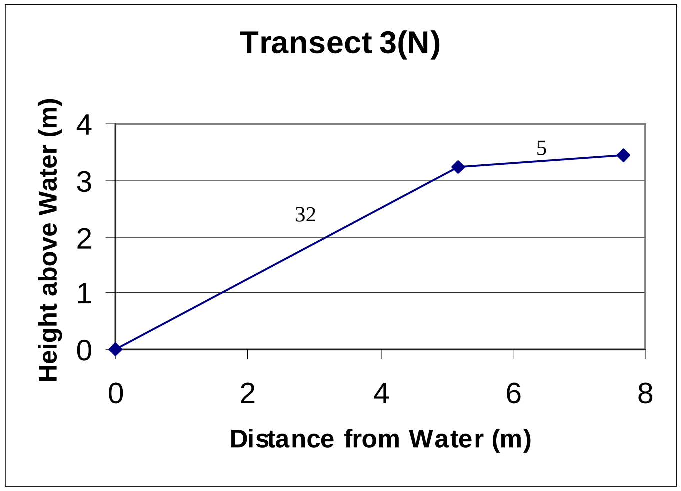
Seg. length (m)	Angle deg.	x	y
		0.00	0
1.1	36	0.89	0.65
2.1	19	2.88	1.33
2.5	5	5.37	1.55



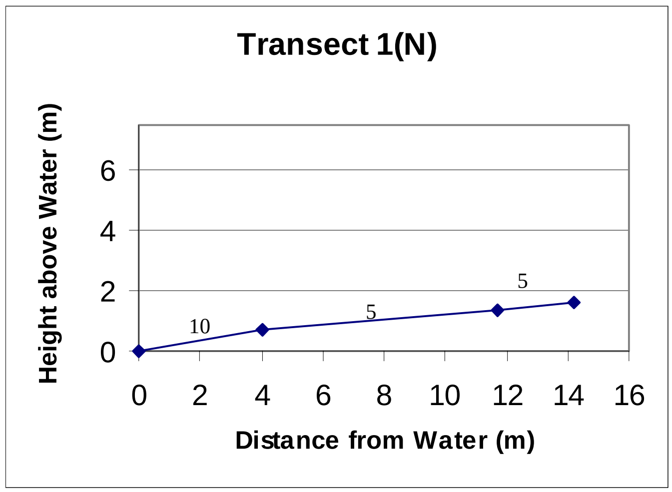
Seg. length (m)	Angle deg.	x	y
		0.00	0
10.0	5	9.96	0.87
1.3	25	11.14	1.42
1.8	90	11.14	3.22
2.5	5	13.63	3.44



Seg. length (m)	Angle deg.	x	y
		0.00	0
6.1	32	5.17	3.23
2.5	5	7.66	3.45



Seg. length (m)	Angle deg.	x	y
		0.00	0
4.1	10	4.04	0.71
7.7	5	11.71	1.38
2.5	5	14.20	1.60



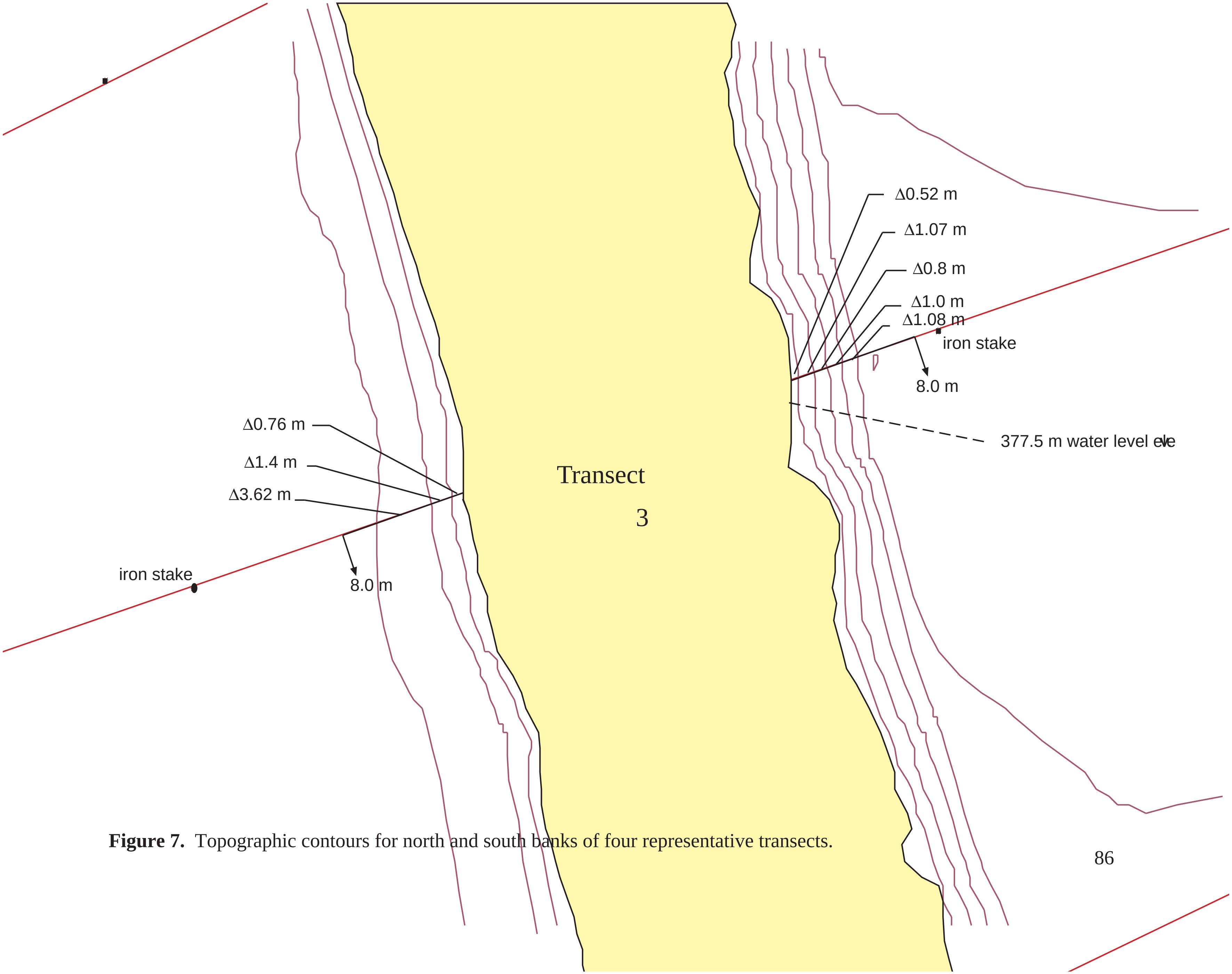
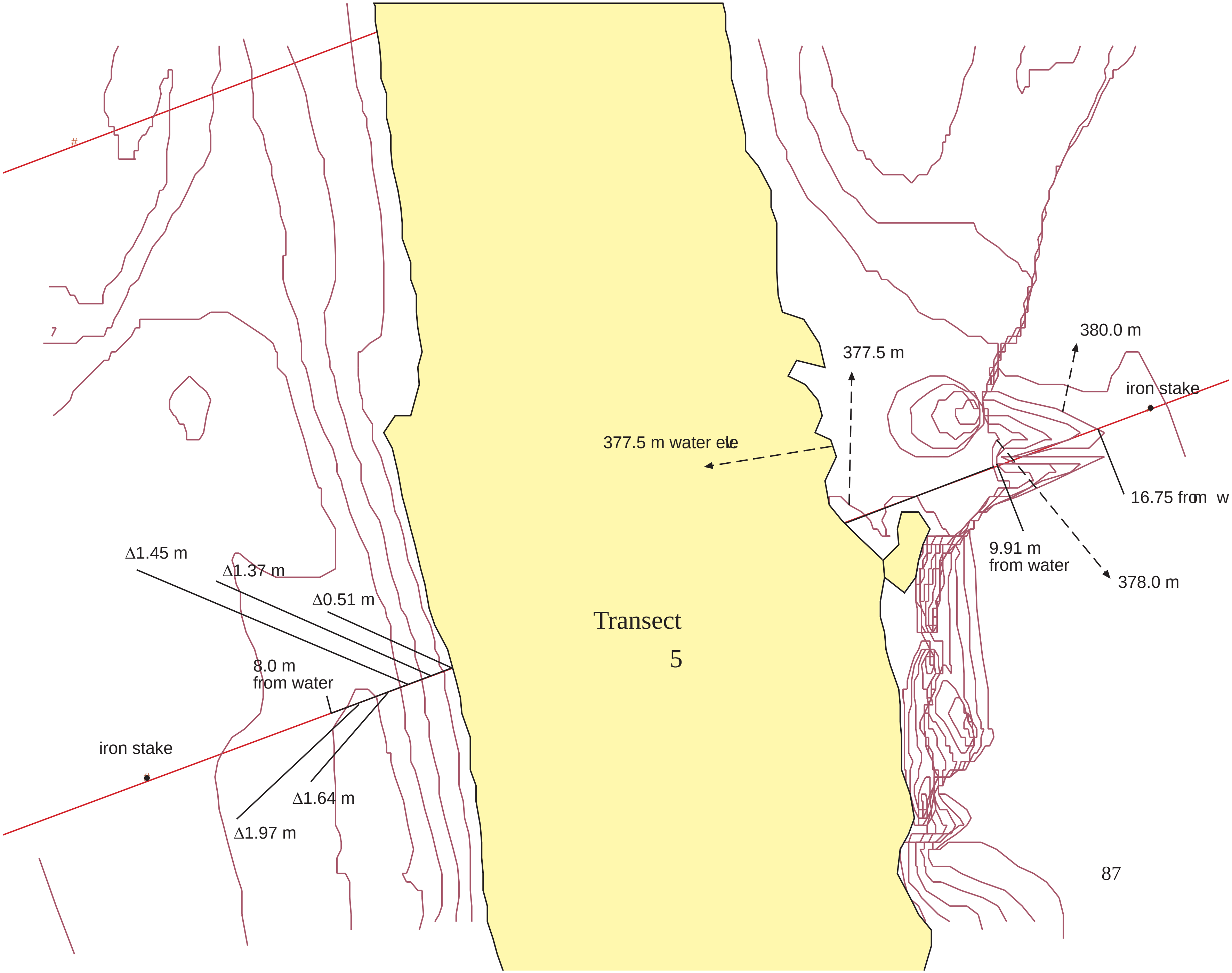
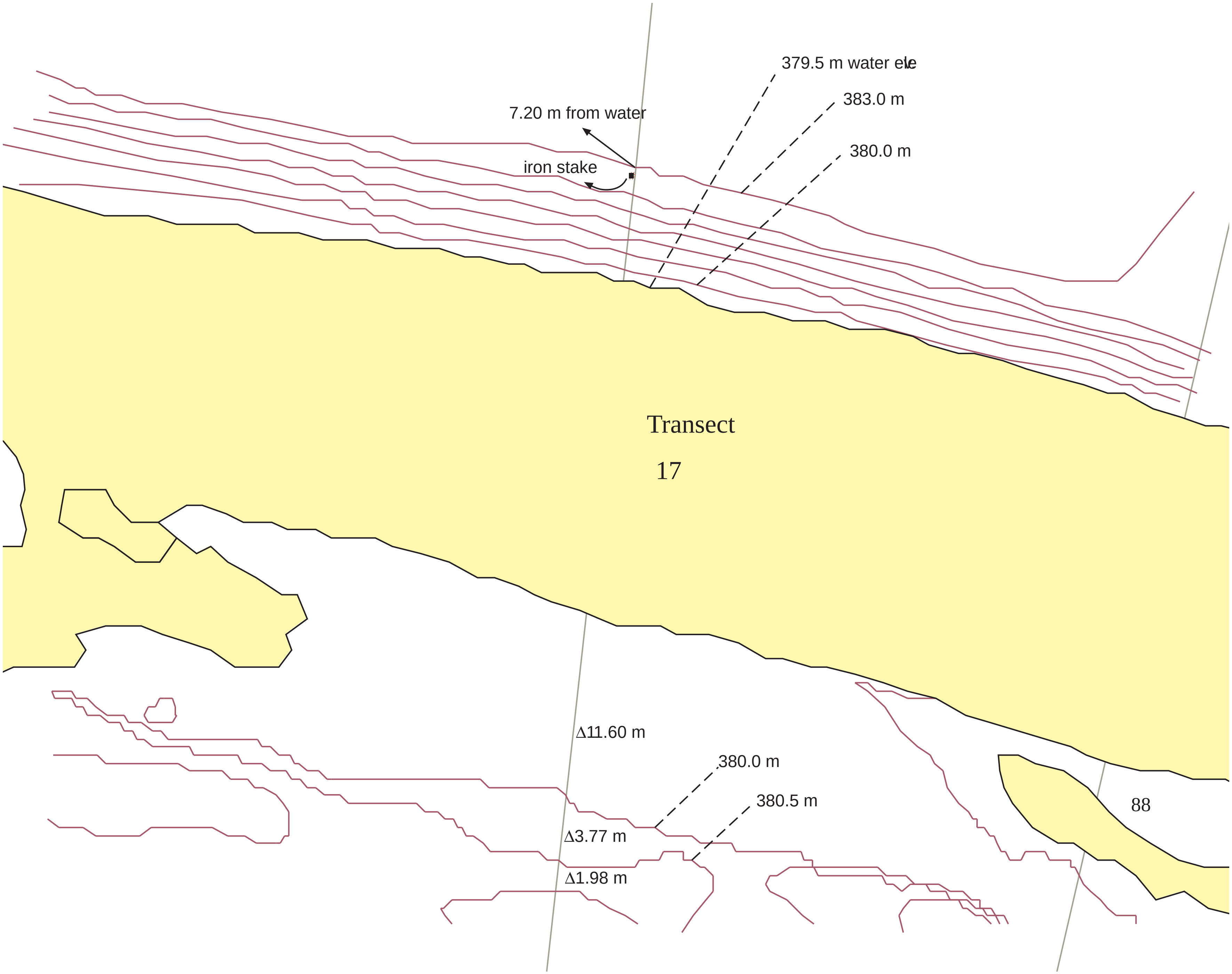


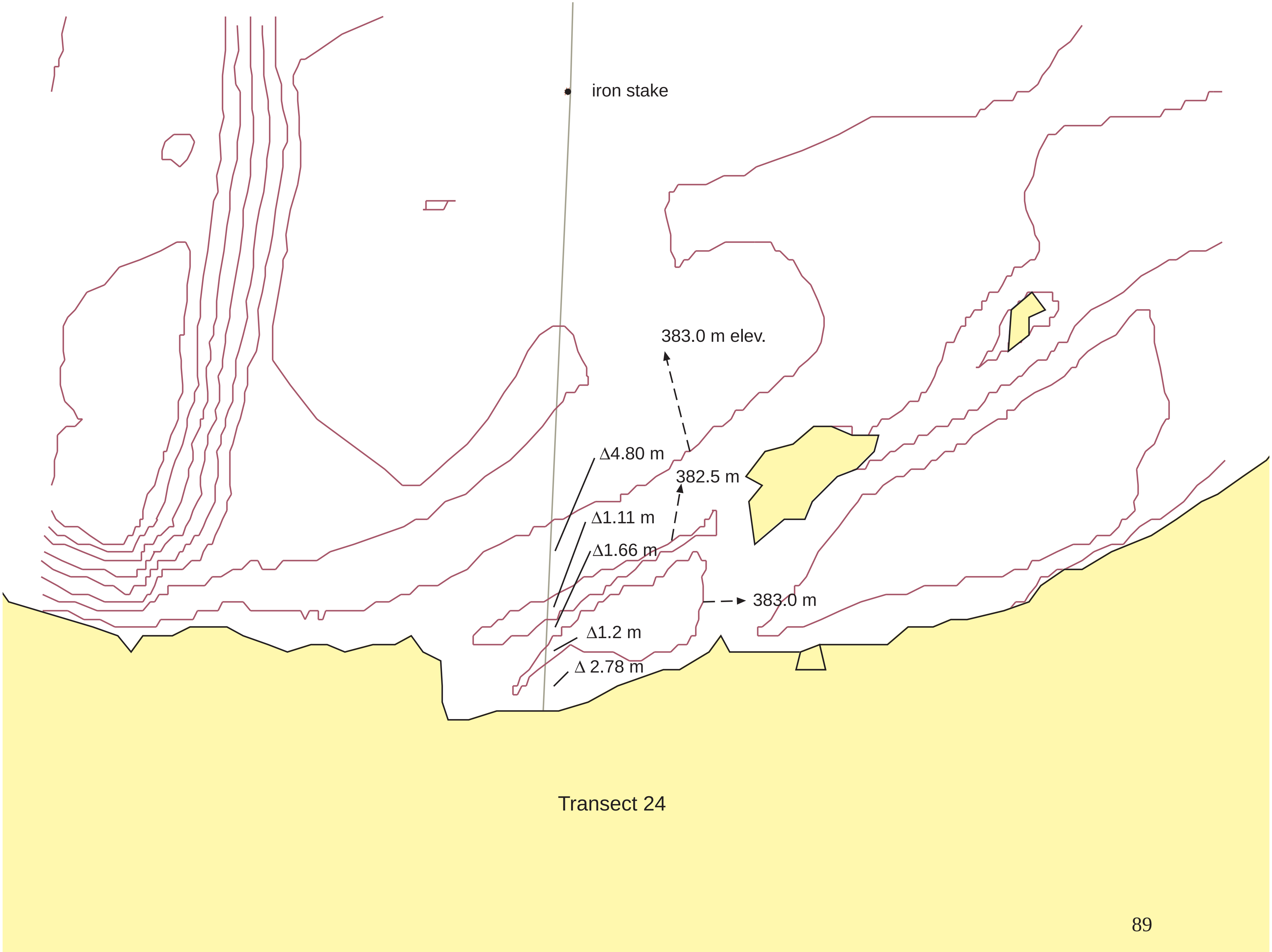
Figure 7. Topographic contours for north and south banks of four representative transects.



380.0 m
377.5 m
iron stake
377.5 m water ele
16.75 from w
9.91 m
from water
378.0 m
Δ1.45 m
Δ1.37 m
Δ0.51 m
Transect
5
8.0 m
from water
iron stake
Δ1.64 m
Δ1.97 m

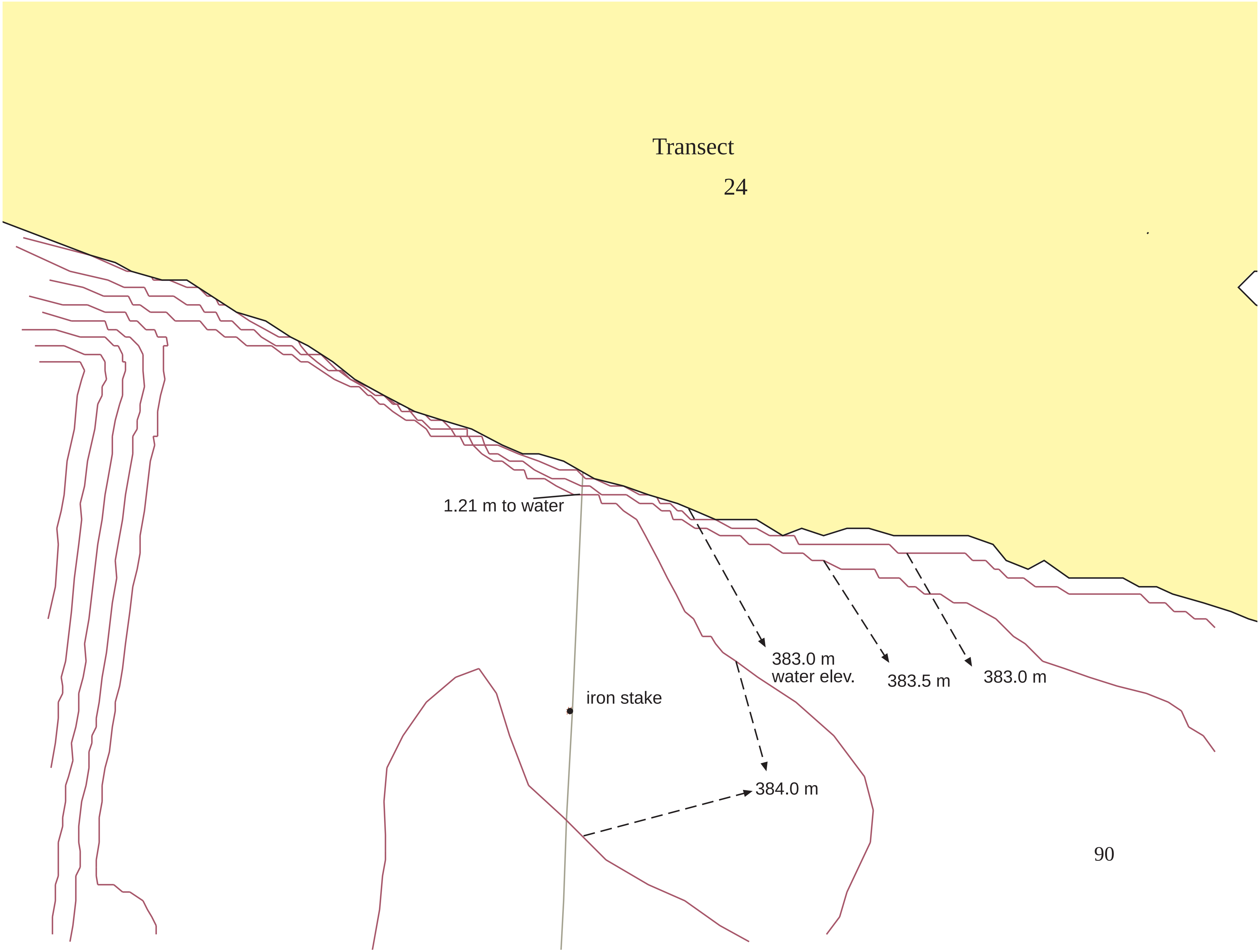


379.5 m water ele
383.0 m
7.20 m from water
380.0 m
iron stake
Transect
17
Δ11.60 m
380.0 m
380.5 m
88
Δ3.77 m
Δ1.98 m

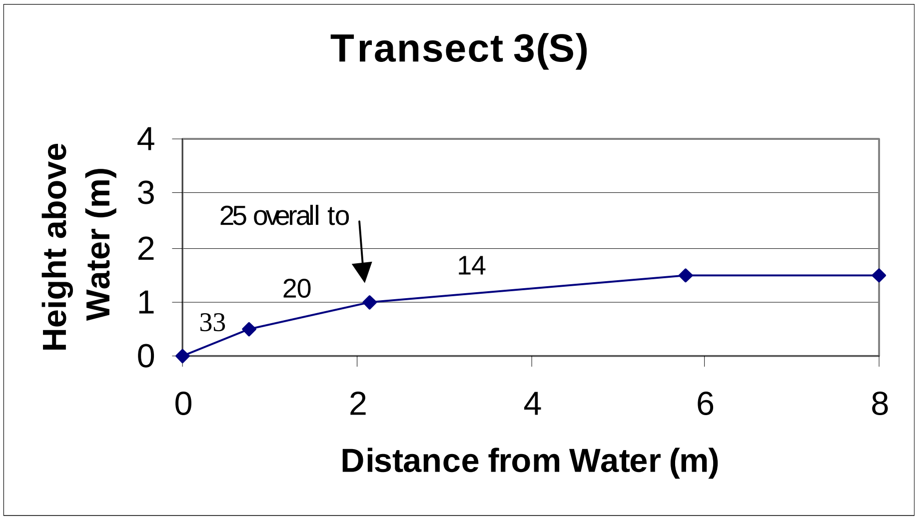


iron stake
383.0 m elev.
Δ4.80 m
382.5 m
Δ1.11 m
Δ1.66 m
383.0 m
Δ1.2 m
Δ 2.78 m

Transect 24


Transect
24
1.21 m to water
383.0 m
water elev.
383.5 m
383.0 m
iron stake
384.0 m
90

Transect 3 South			North		
cont.W	cum.L	Ht. Above water	cont.W	cum.L	Ht. Above water
0	0	0	0	0	0
0.76	0.76	0.5	0.52	0.52	0.5
1.4	2.16	1	1.07	1.59	1
3.62	5.78	1.5	0.8	2.39	1.5
	8	1.5	1	3.39	2
			1.08	4.47	2.5
				8	2.5



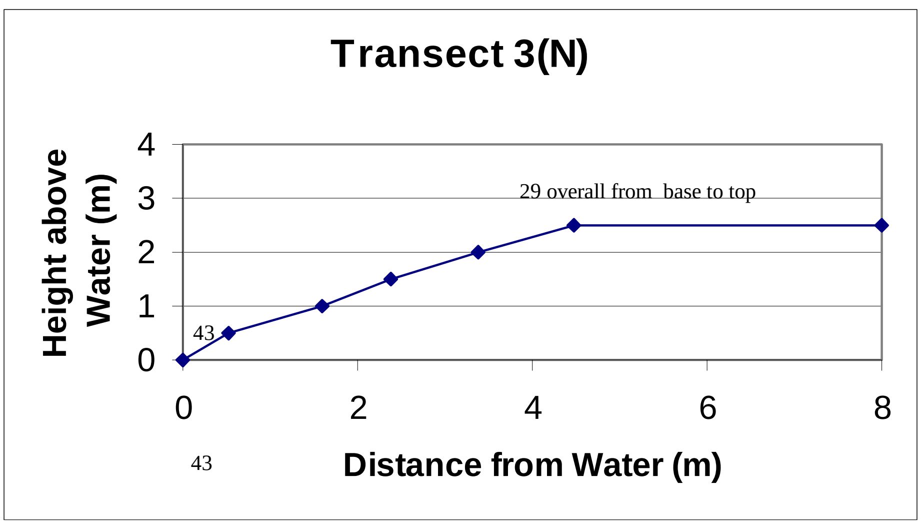
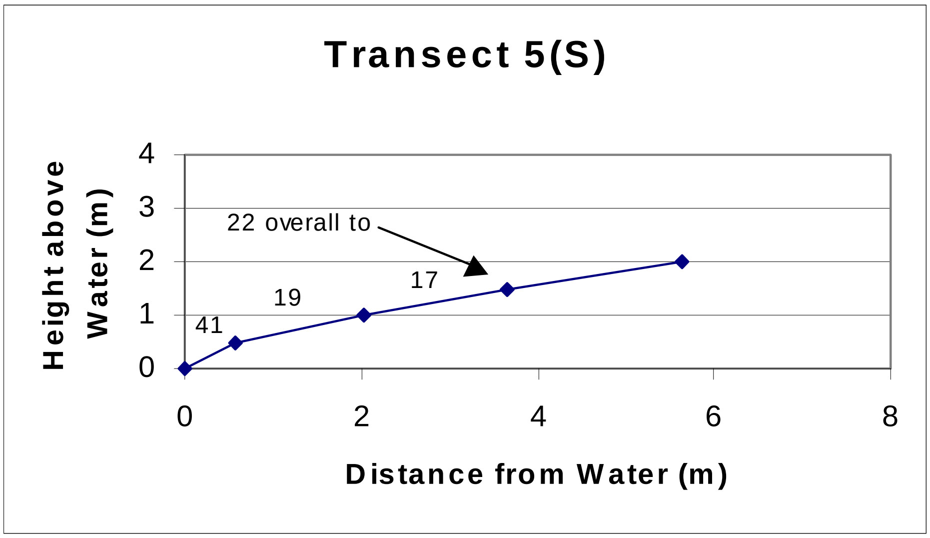
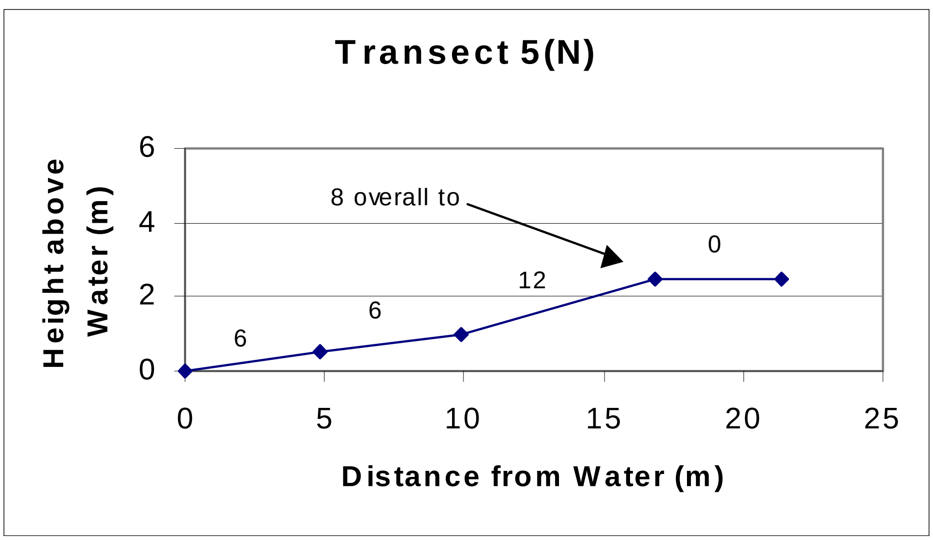


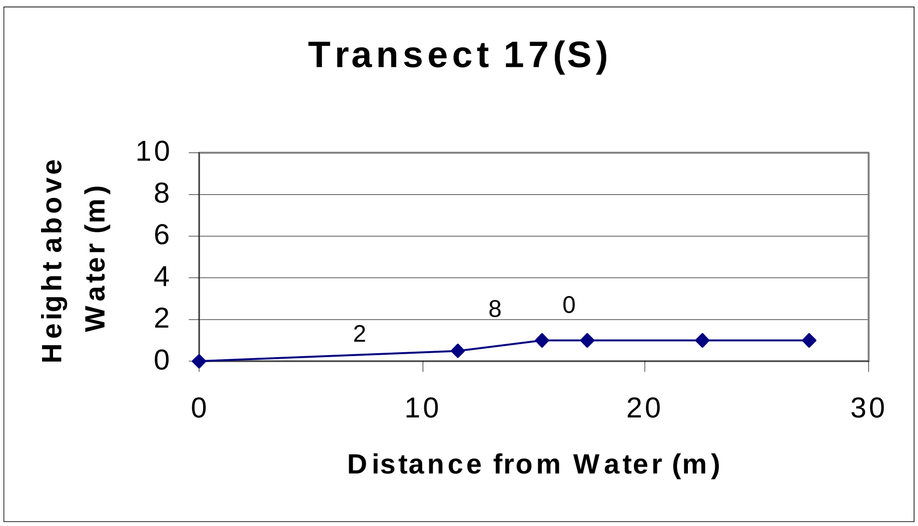
Figure 8. Cross sections plotted from data collected from topographic maps for north and south banks of four representative transects.

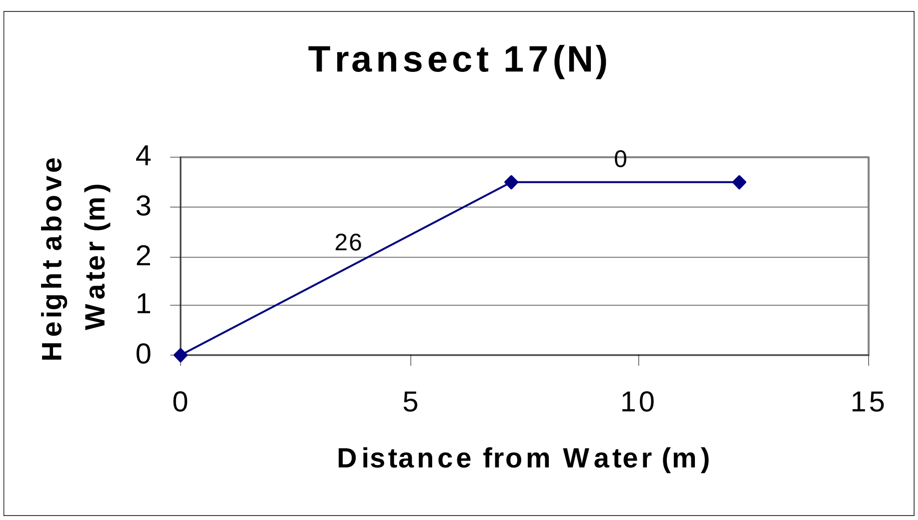
Transcect 5					
South			North		
cont.W	cum.L	Ht. Above water	cont.W	cum.L	Ht. Above water
0	0	0	0	0	0
0.57	0.57	0.5	4.81	4.81	0.5
1.45	2.02	1	5.1	9.91	1
1.64	3.66	1.5	6.92	16.83	2.5
1.97	5.63	2	4.58	21.41	2.5
	8	2			



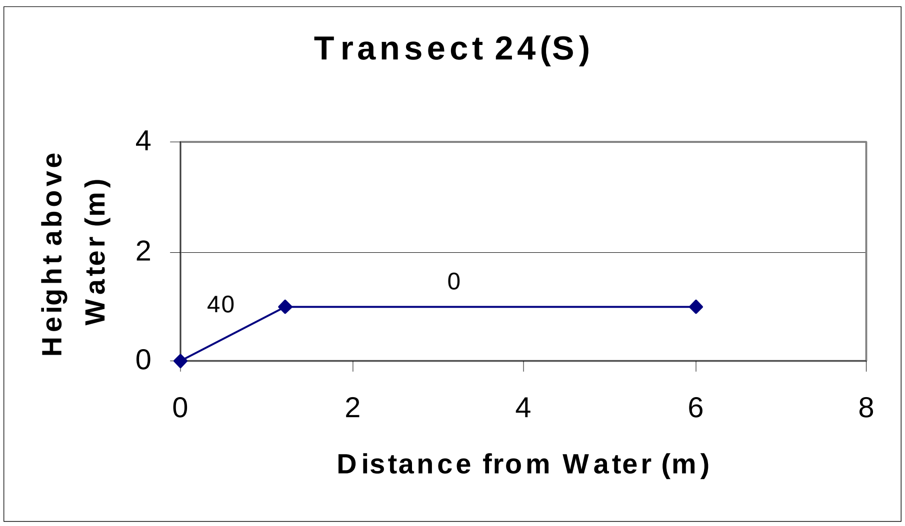


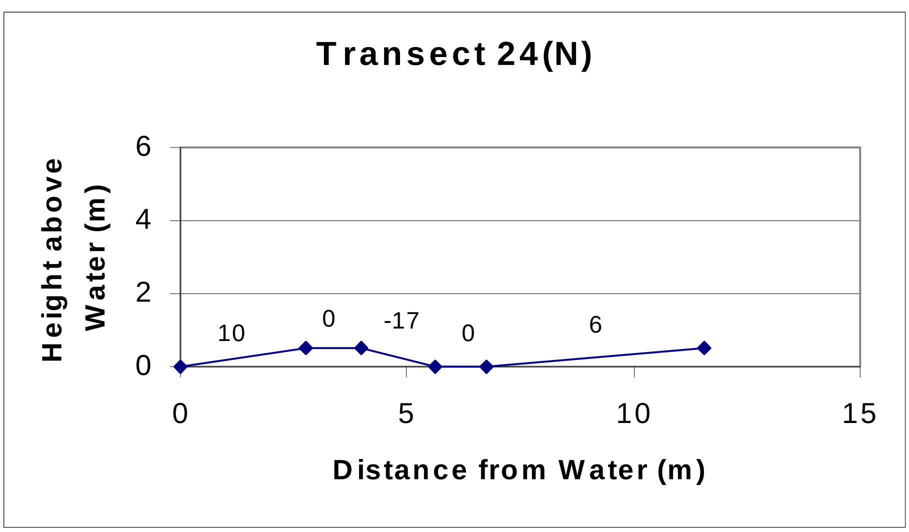
Transect 17						
	South			North		
	cont.W	cum.L	Ht. Above water	cont.W	cum.L	Ht. Above water
	0	0	0	0	0	0
	11.6	11.6	0.5	7.2	7.2	3.5
	3.77	15.37	1	5	12.2	3.5
	1.98	17.35	1			
	5.24	22.59	1			
	4.7	27.29	1			





Transect 24	South			North		
	cont.W	cum.L	Ht. Above water	cont.W	cum.L	Ht. Above water
	0	0	0	0	0	0
	1.21	1.21	1	2.78	2.78	0.5
	6	6	1	1.2	3.98	0.5
				1.66	5.64	0
				1.11	6.75	0
				4.8	11.55	0.5





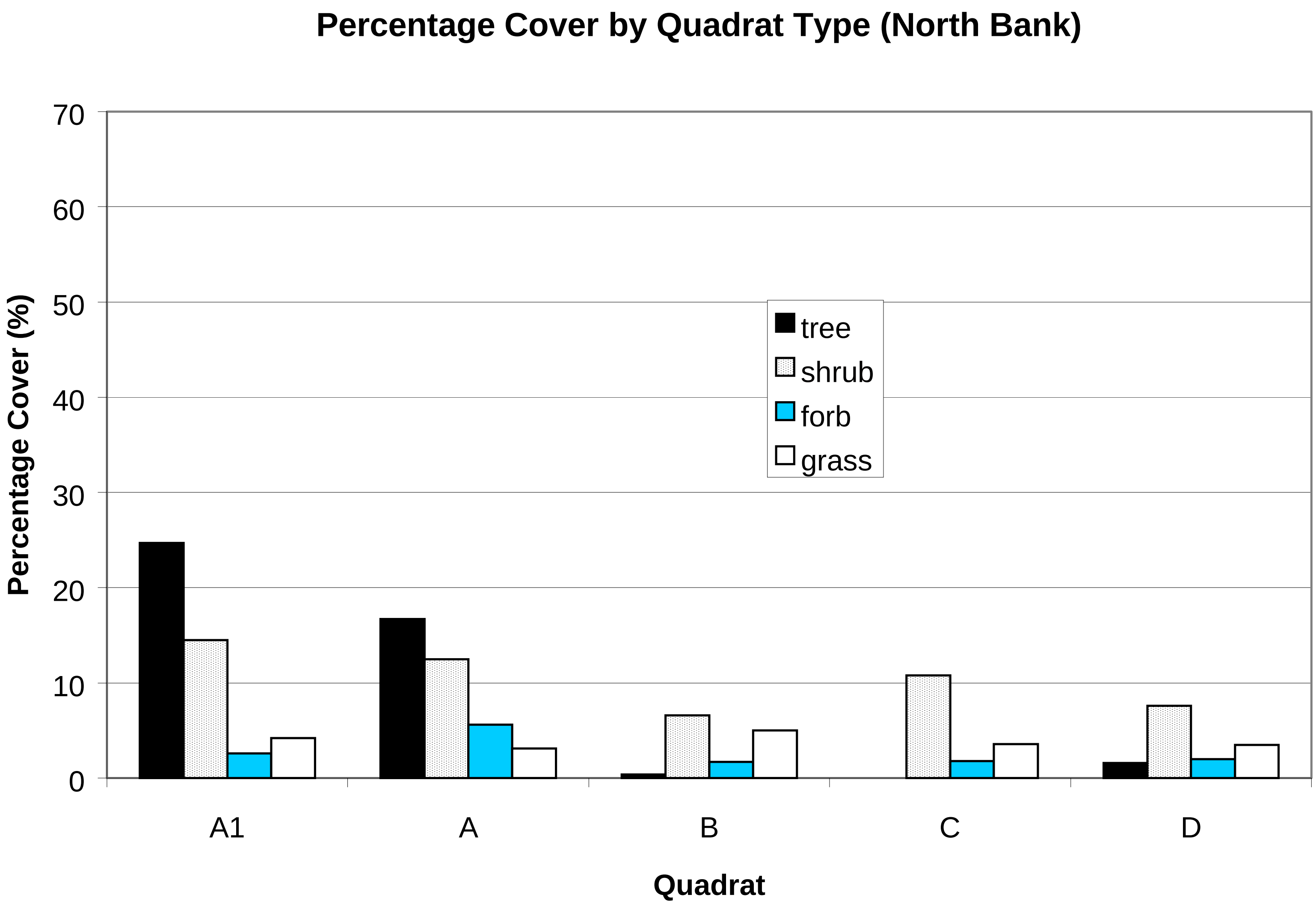


Figure 9. Percentage cover by quadrat type (north bank)

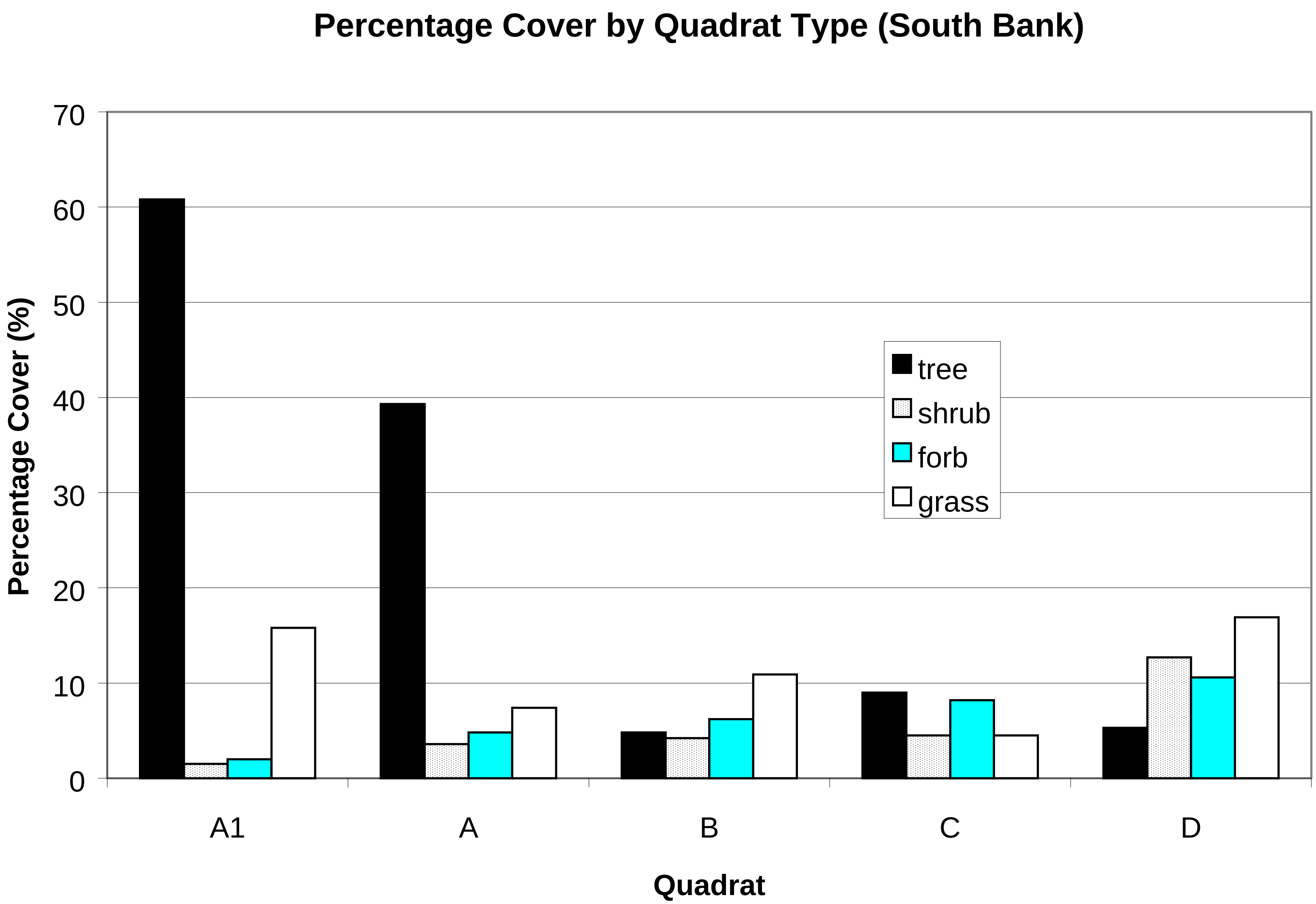
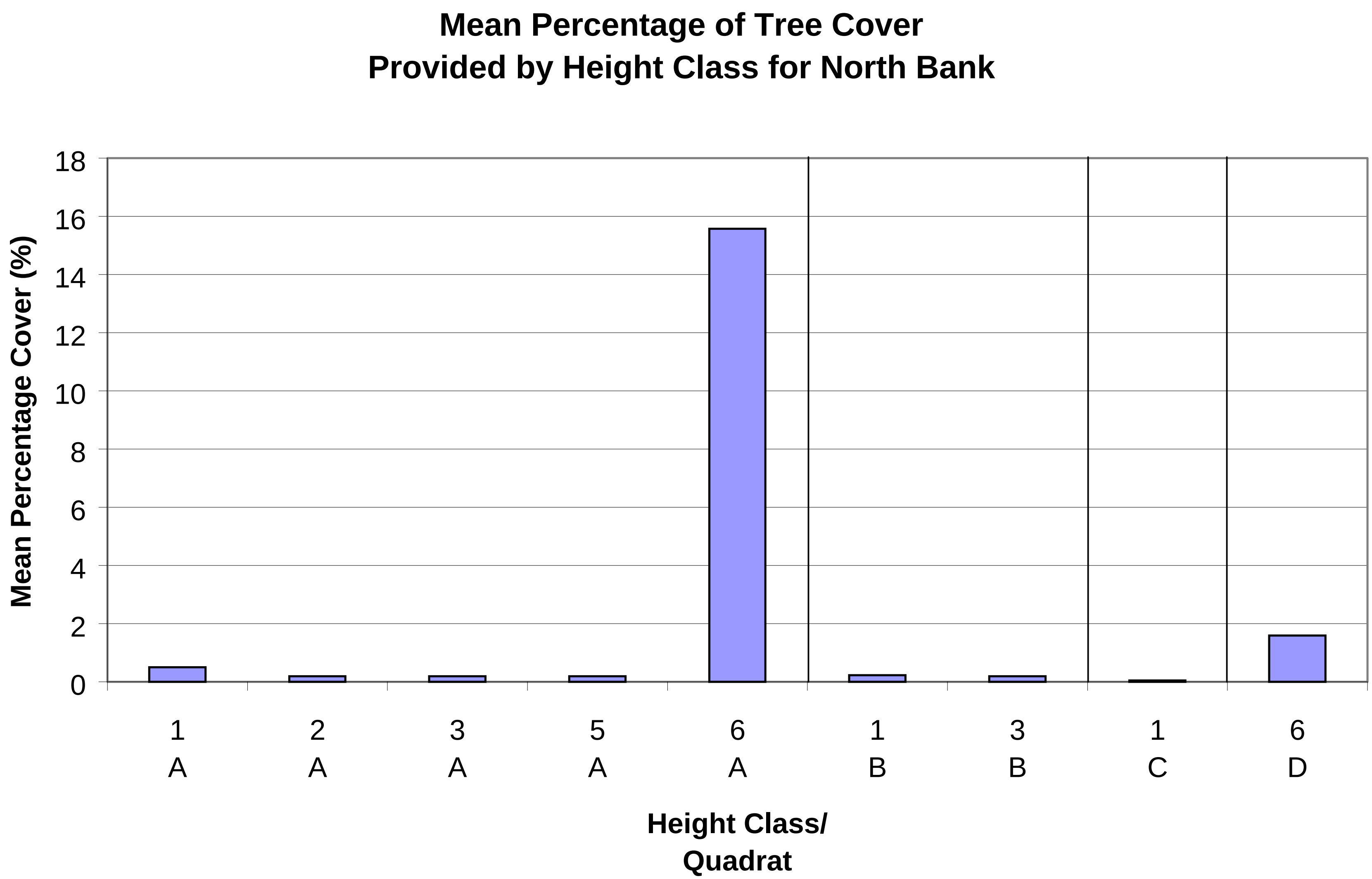


Figure 10. Percentage cover by quadrat type (south bank)



F**igure 11.** Mean percentage of tree cover provided by height class (north bank)

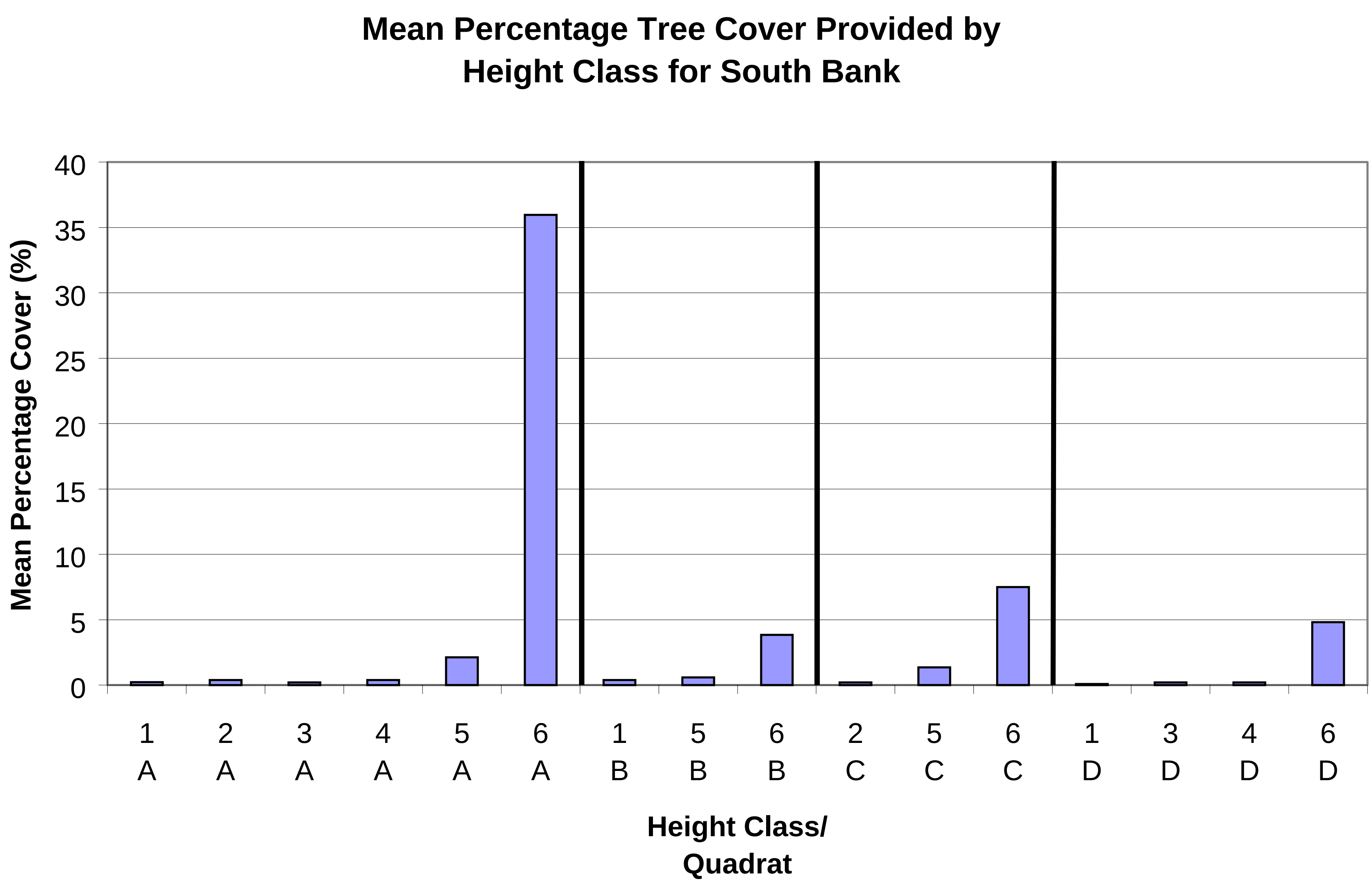


Figure 12. Mean percentage of tree cover provided by height class (south bank)

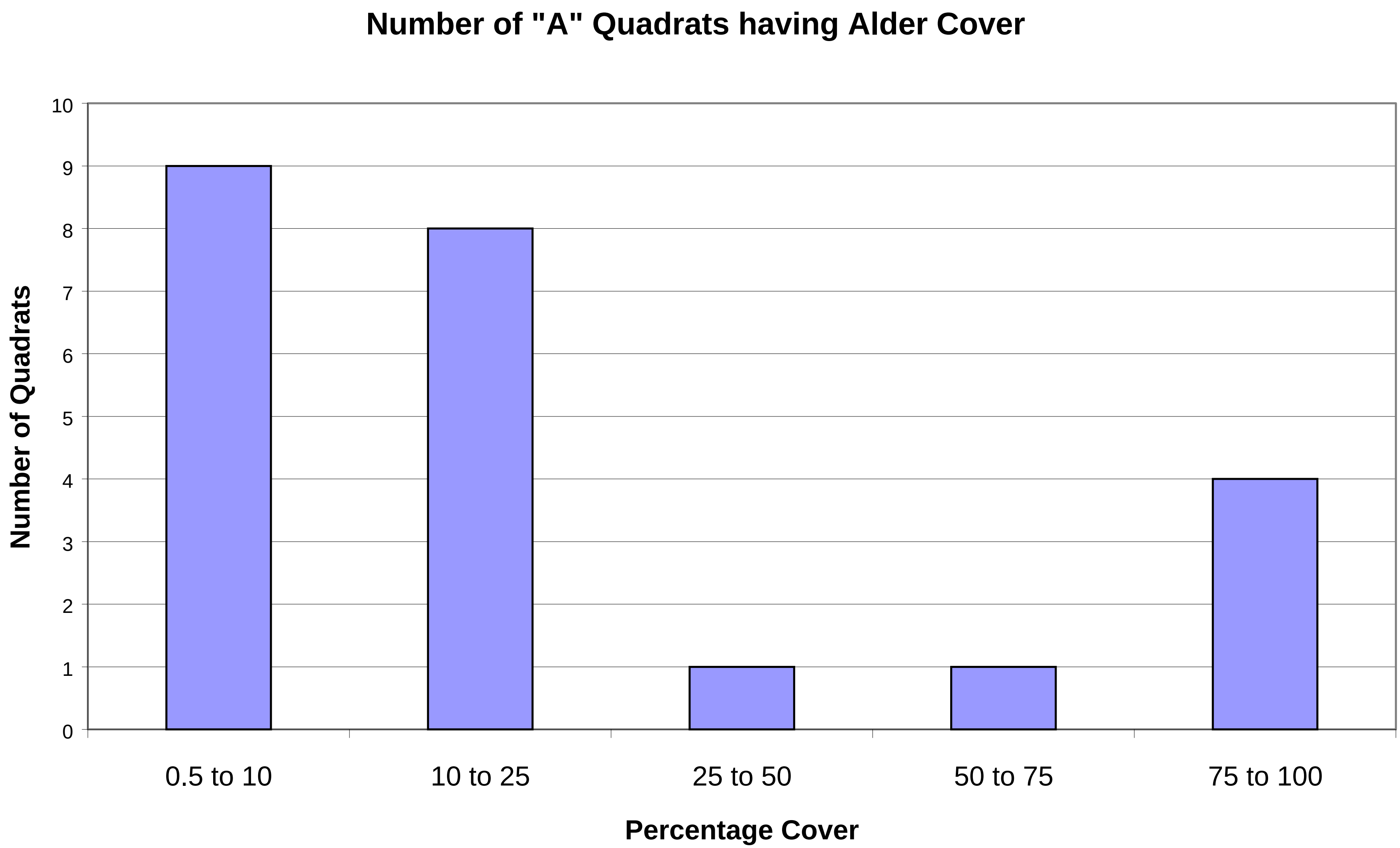


Figure 13. Number of A quadrats having alder cover in five percentage cover categories.

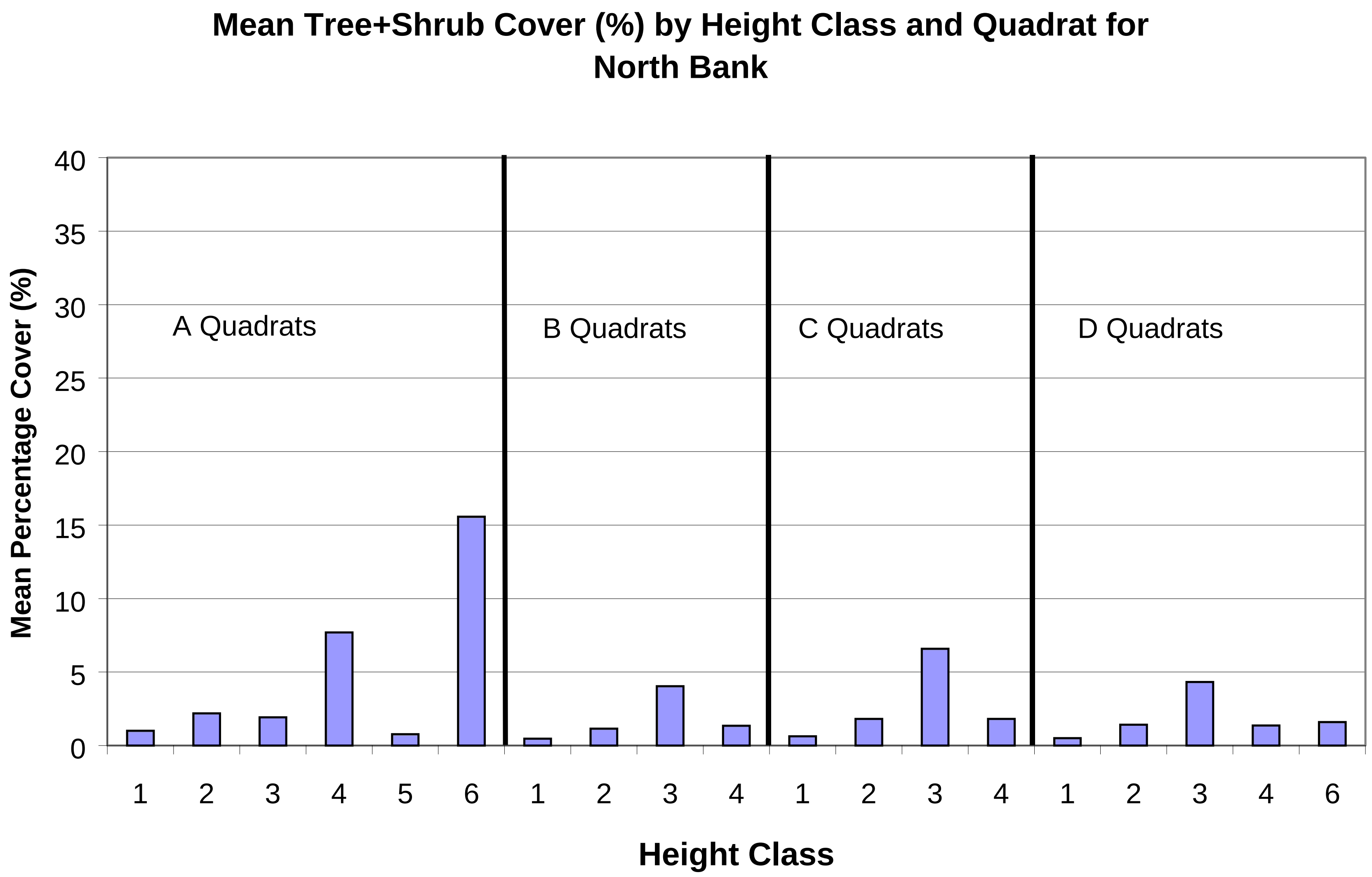


Figure 14. Mean percentage tree+shrub cover by height class and quadrat (north bank).

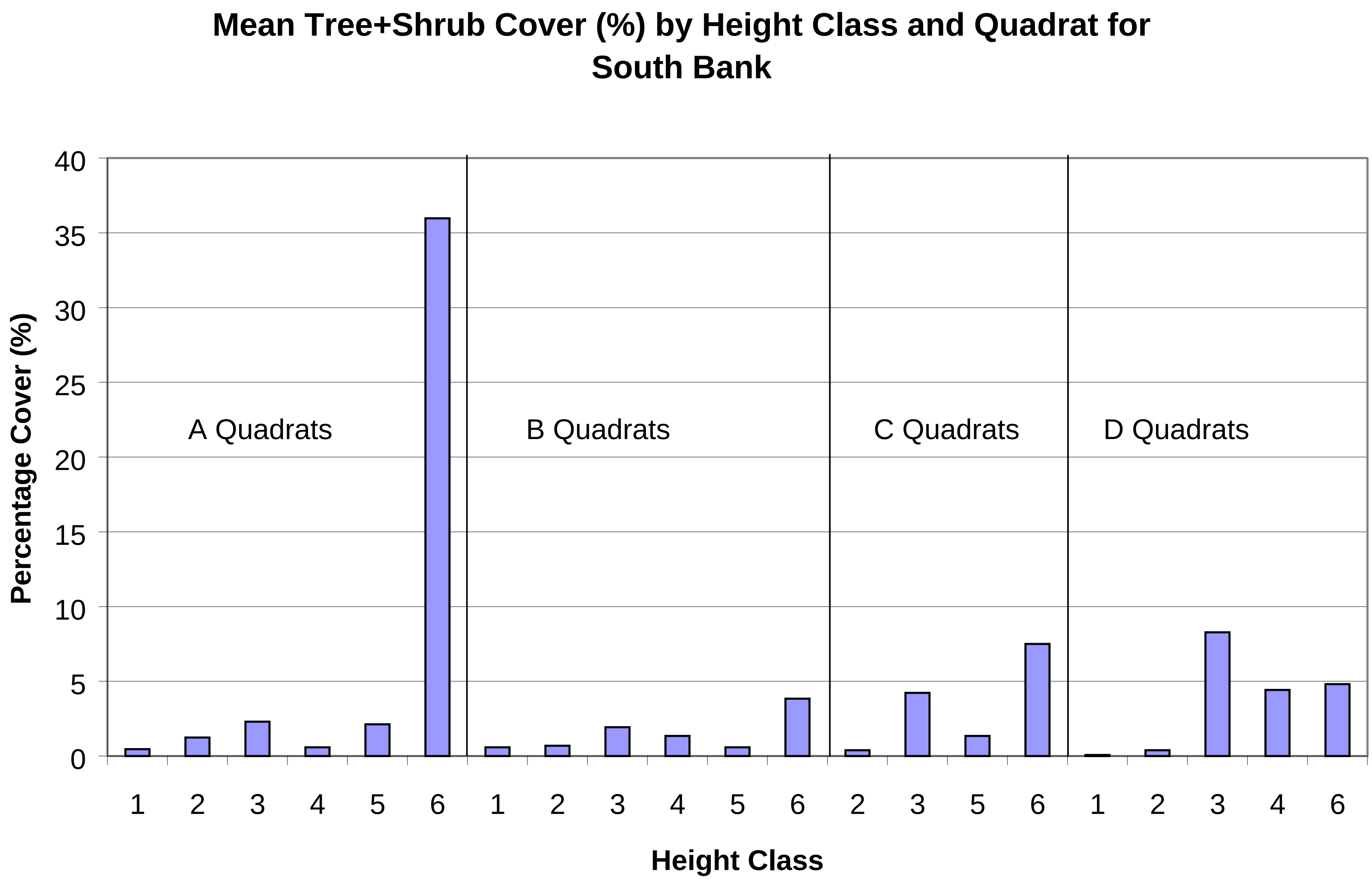


Figure 15. Mean percentage tree+shrub cover by height class and quadrat (south bank).

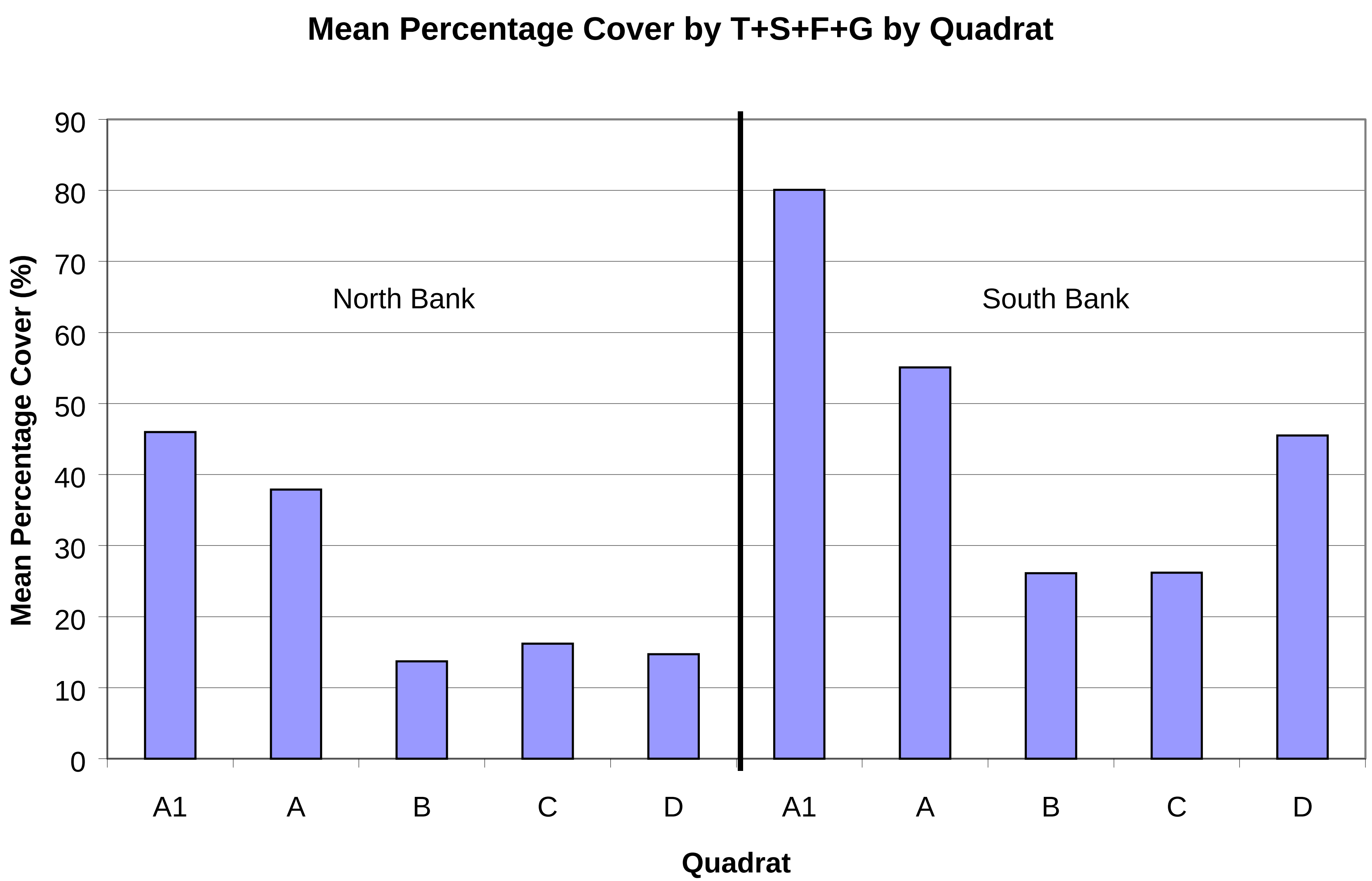


Figure 16. Mean percentage cover by trees+shrubs+forbs+grasses by quadrat type.

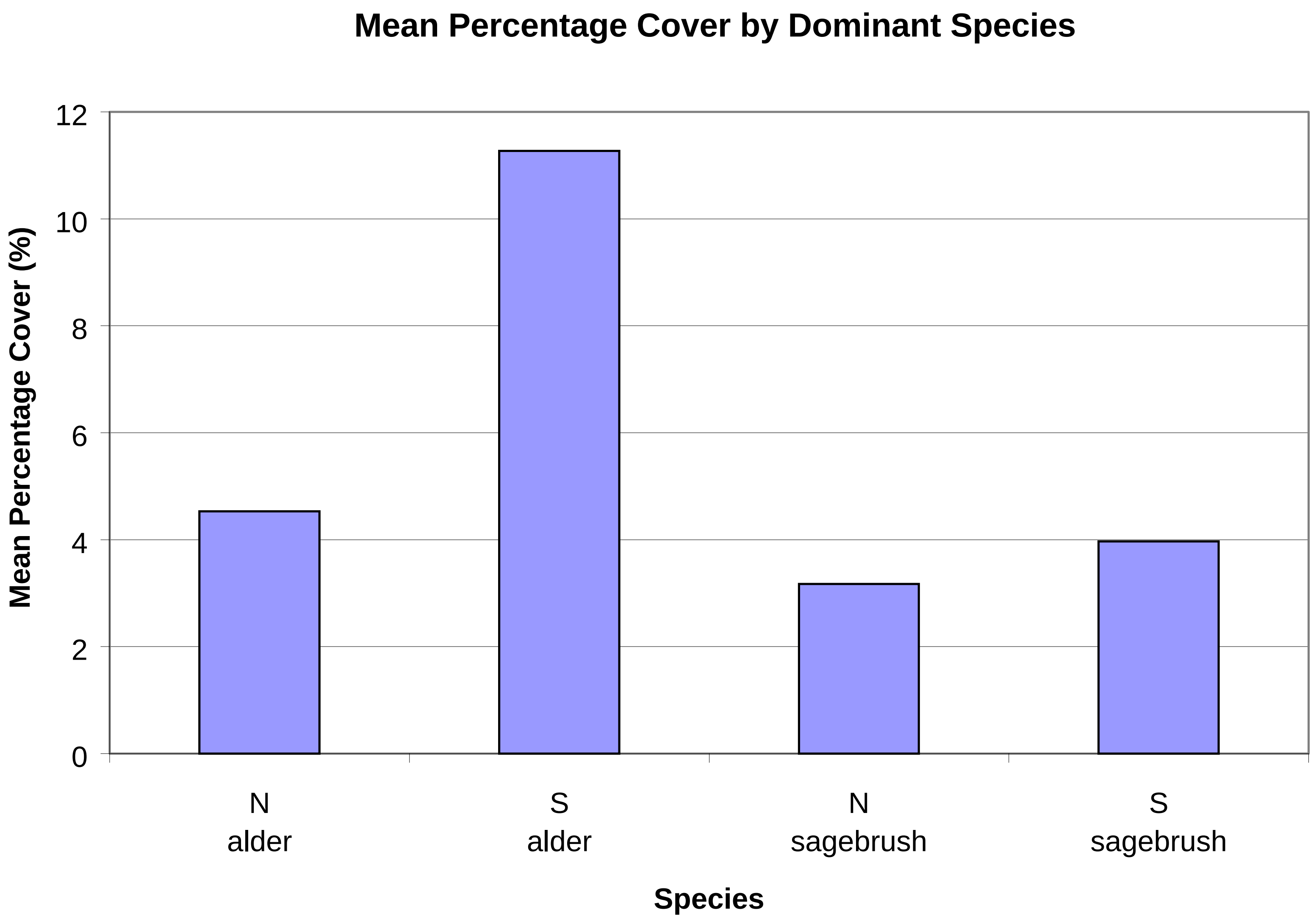


Figure 17. Mean percentage cover by dominant species (alder, sagebrush) on north and south banks.

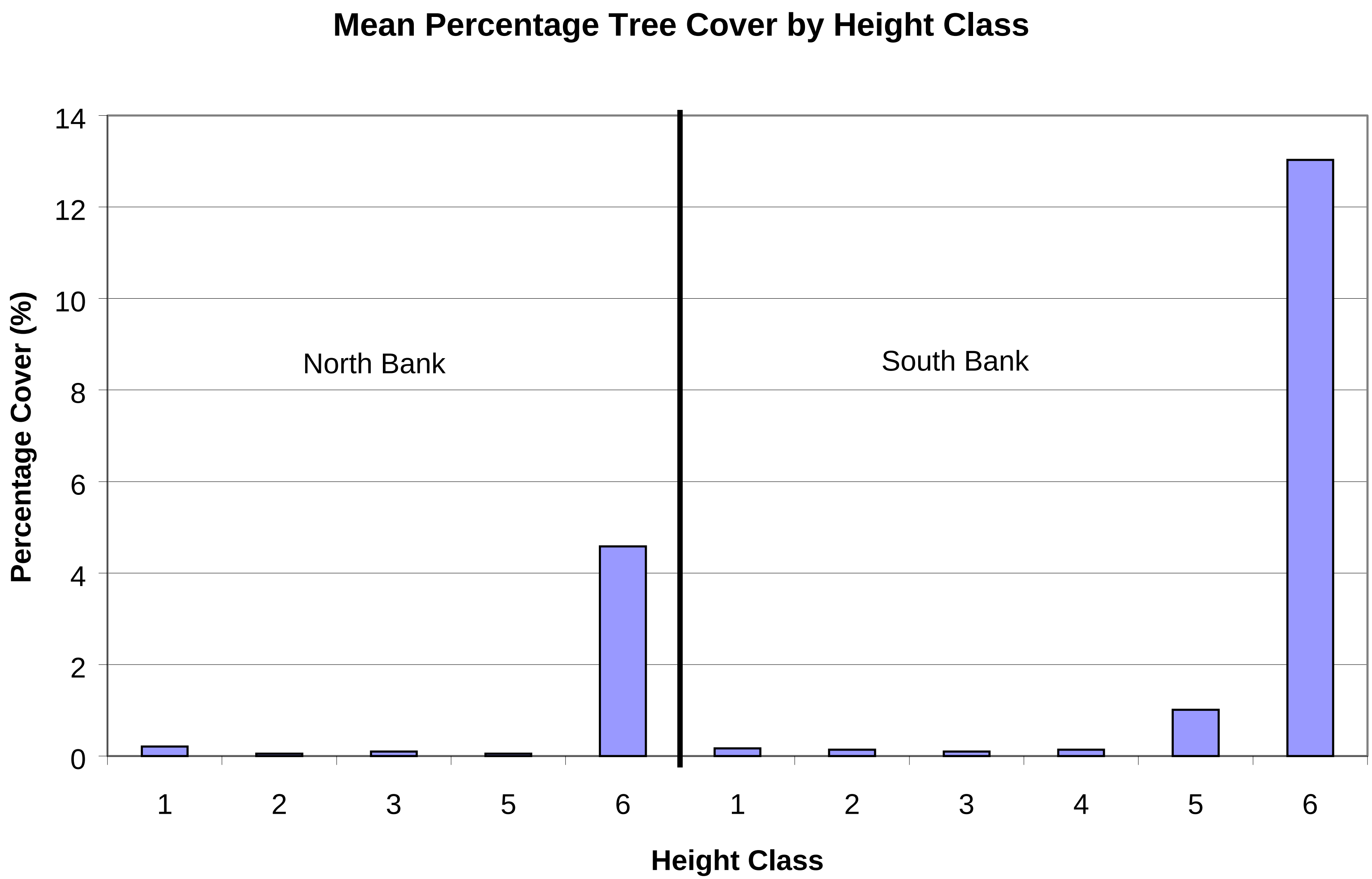


Figure 18. Mean percentage tree cover by height class for north and south banks.

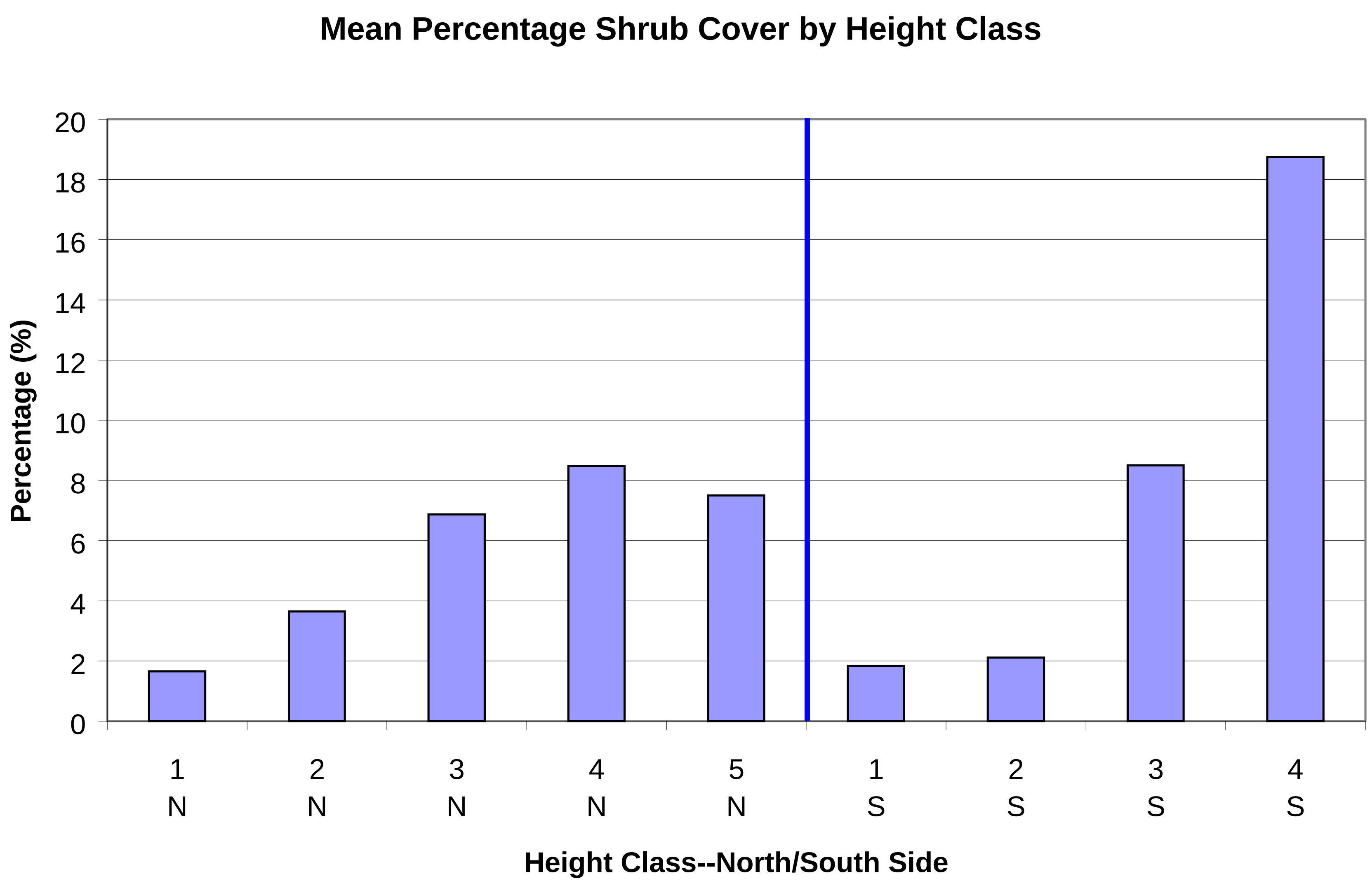


Figure 19. Mean percentage shrub cover by height class for north and south banks.

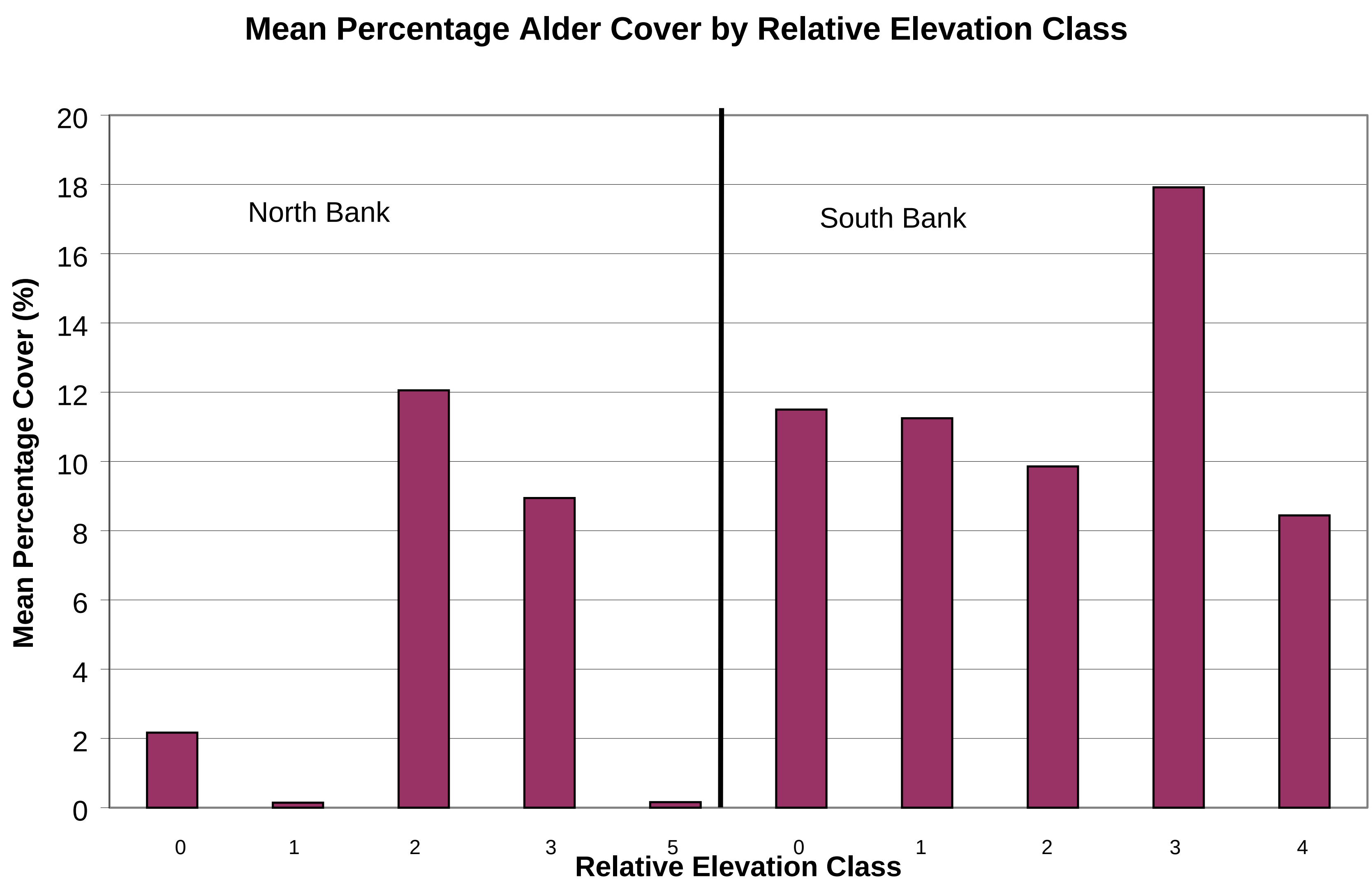


Figure 20. Mean percentage alder cover by relative elevation class for north and south banks.

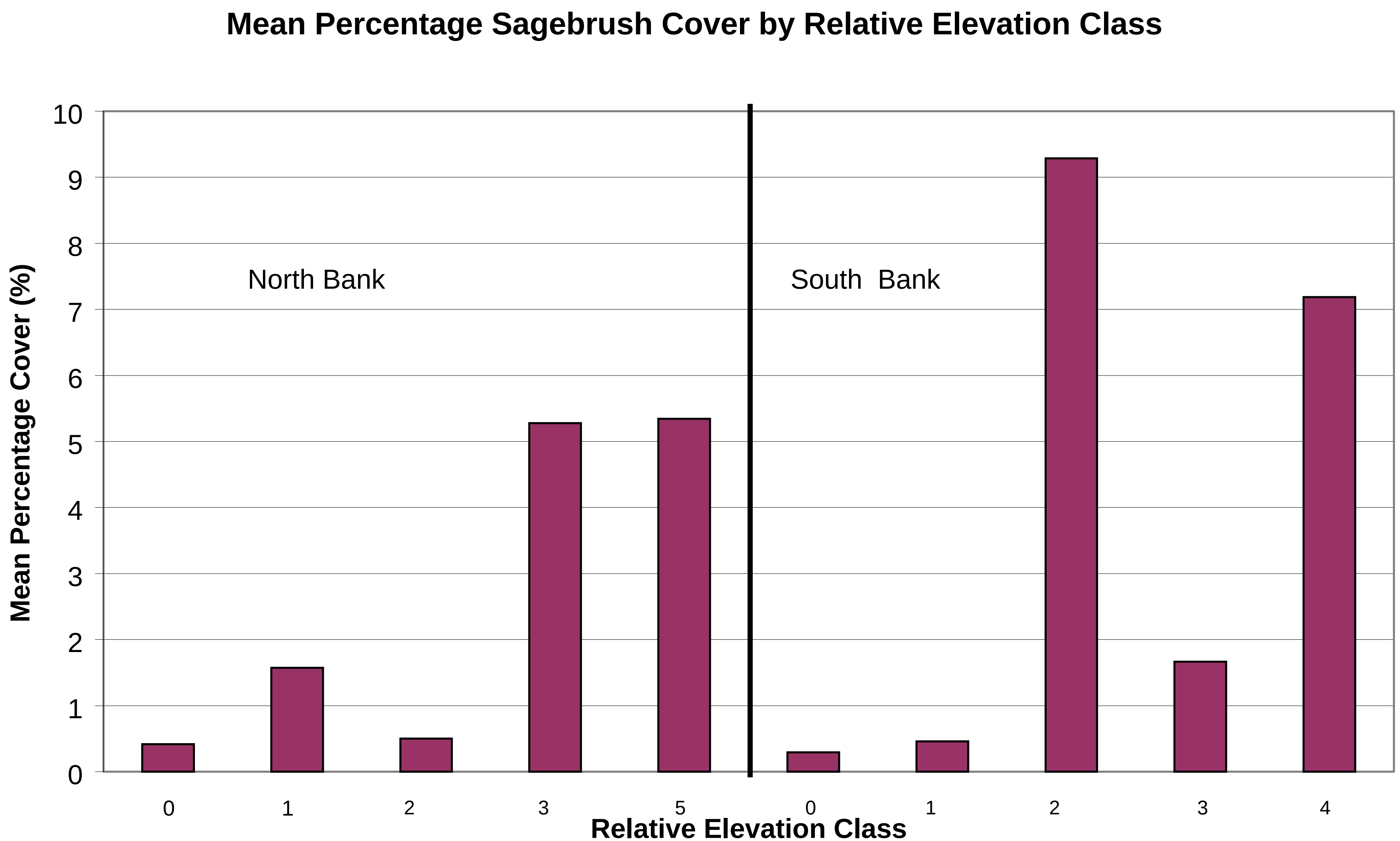


Figure 21. Mean percentage sagebrush cover by relative elevation class for north and south banks.

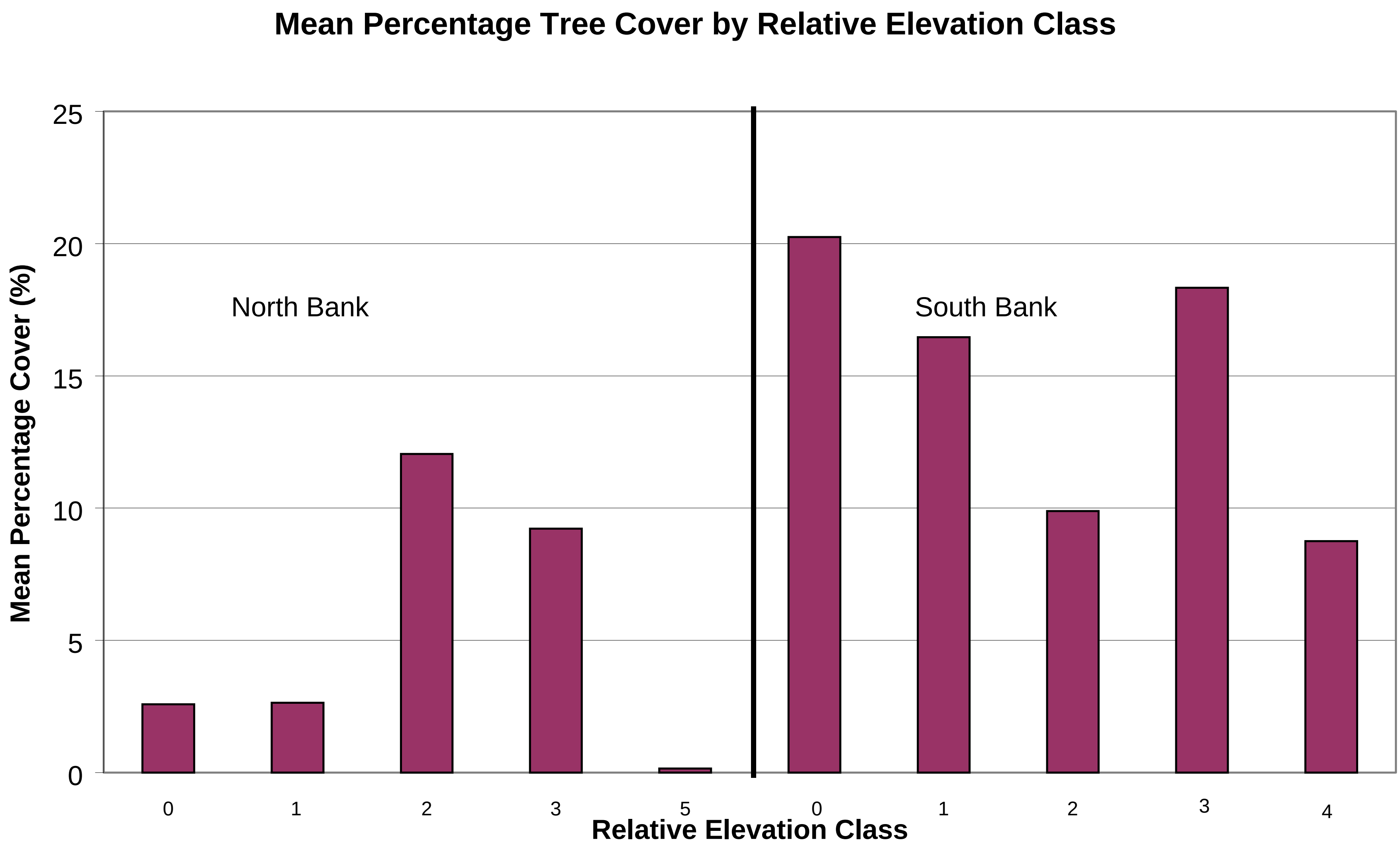


Figure 22. Mean percentage tree cover by relative elevation class for north and south banks.

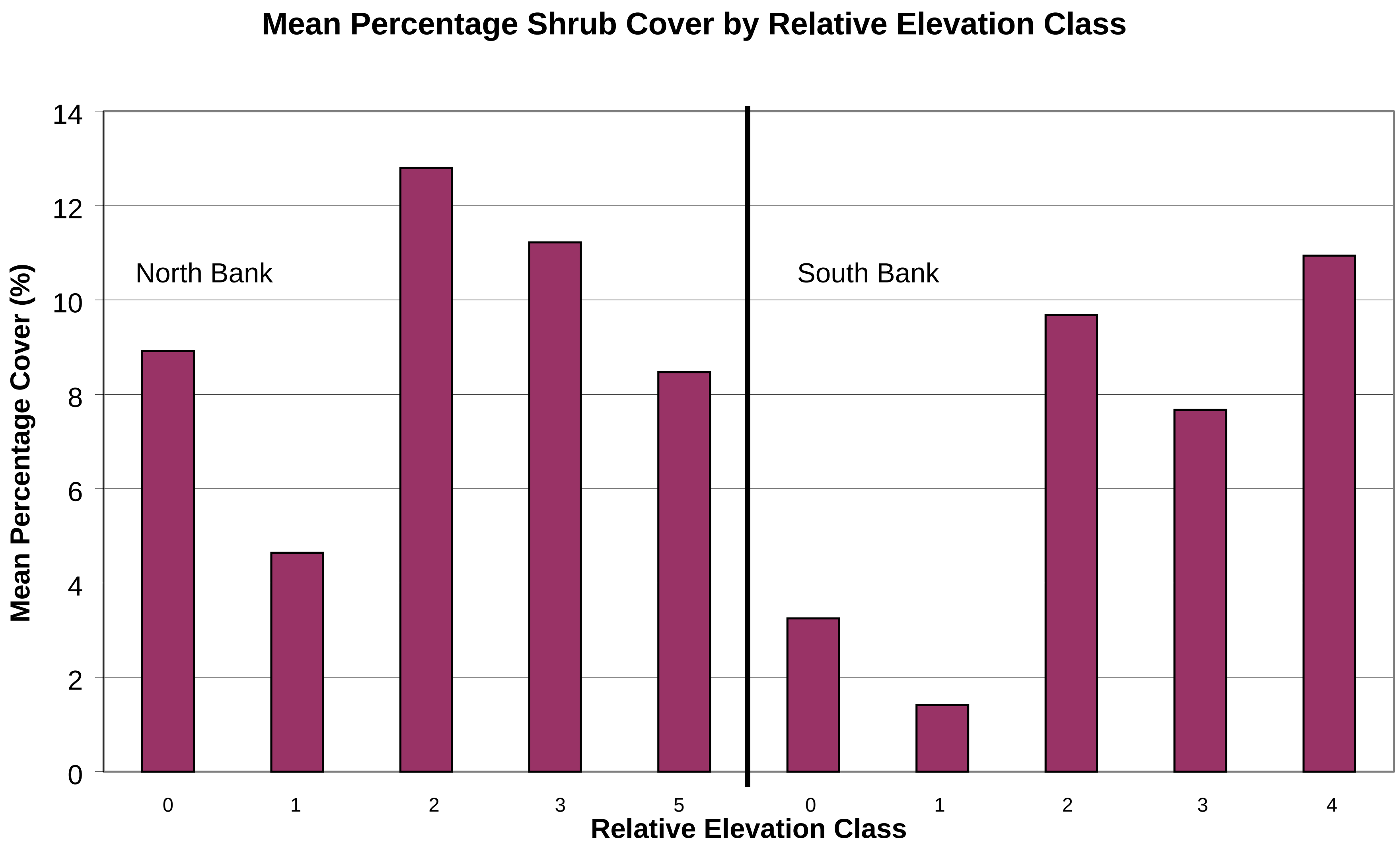


Figure 23. Mean percentage shrub cover by relative elevation class for north and south banks.

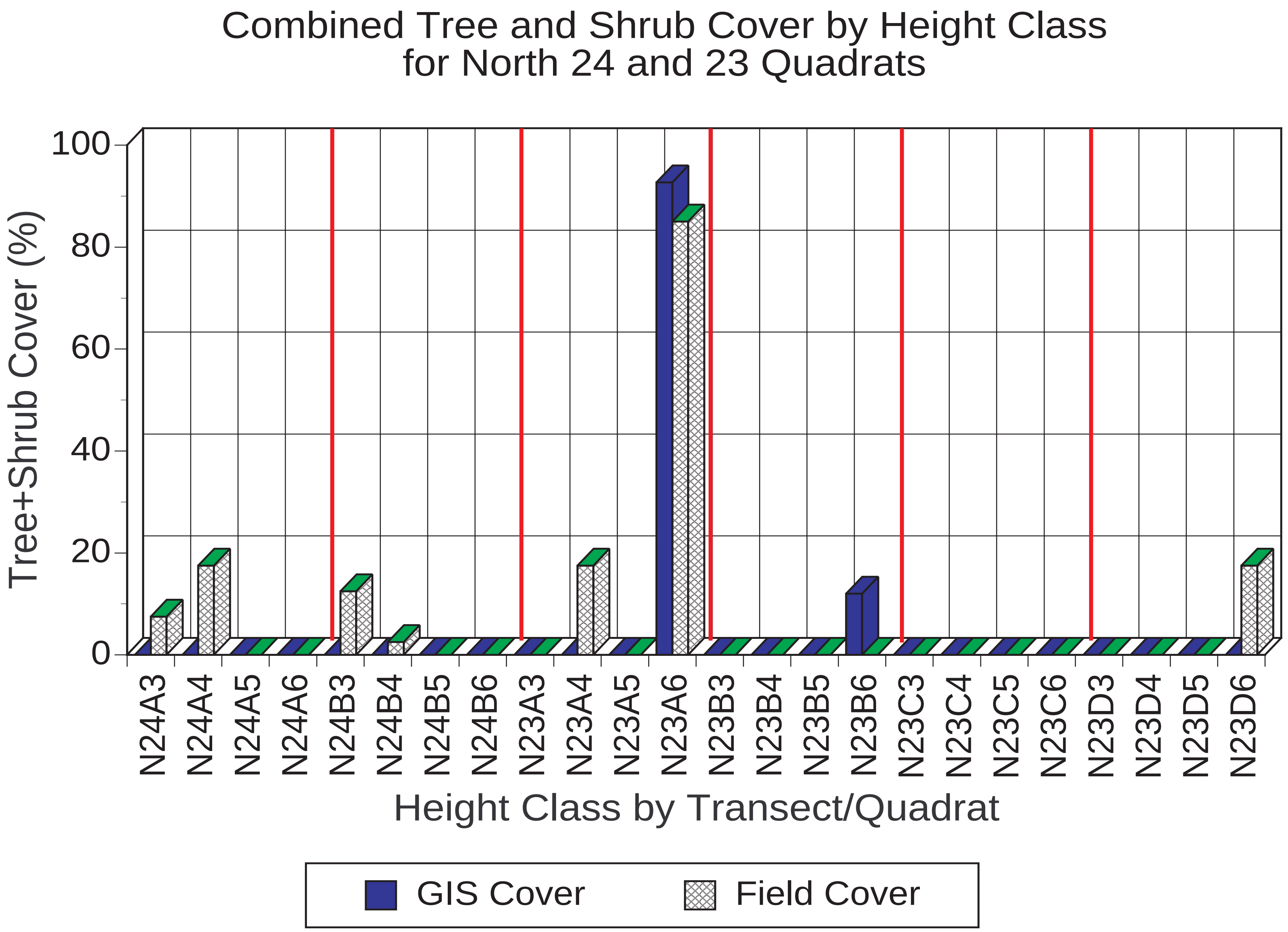
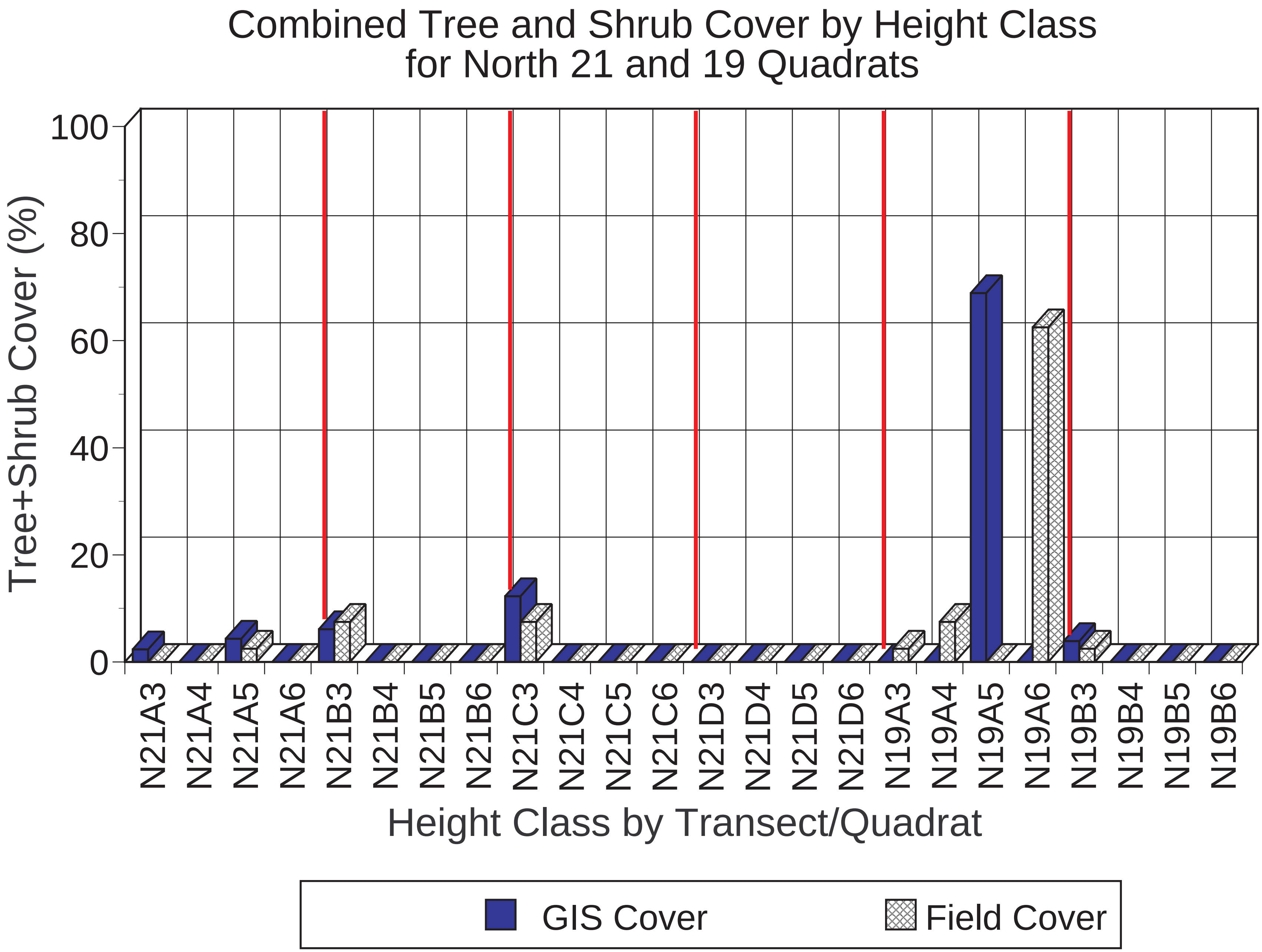
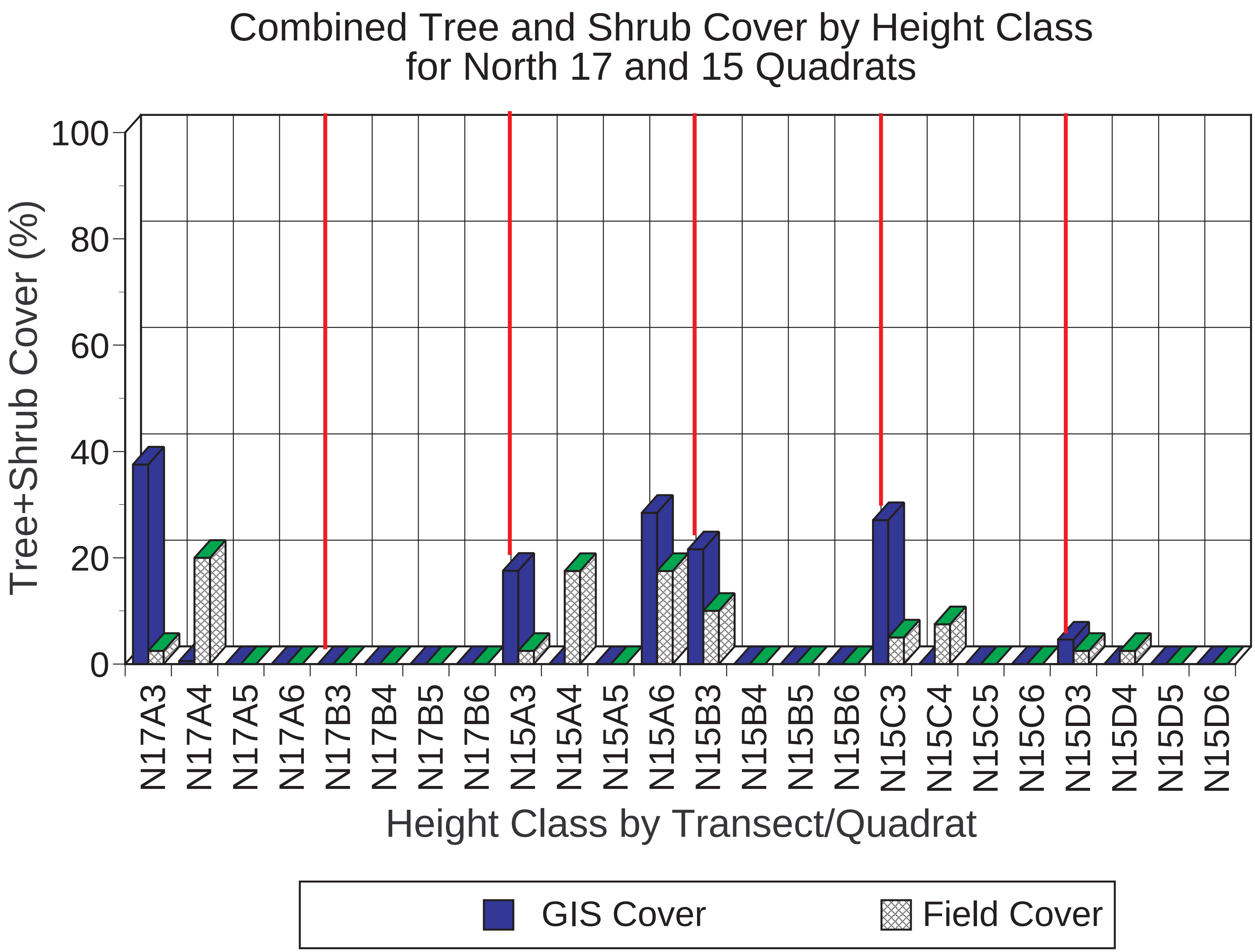
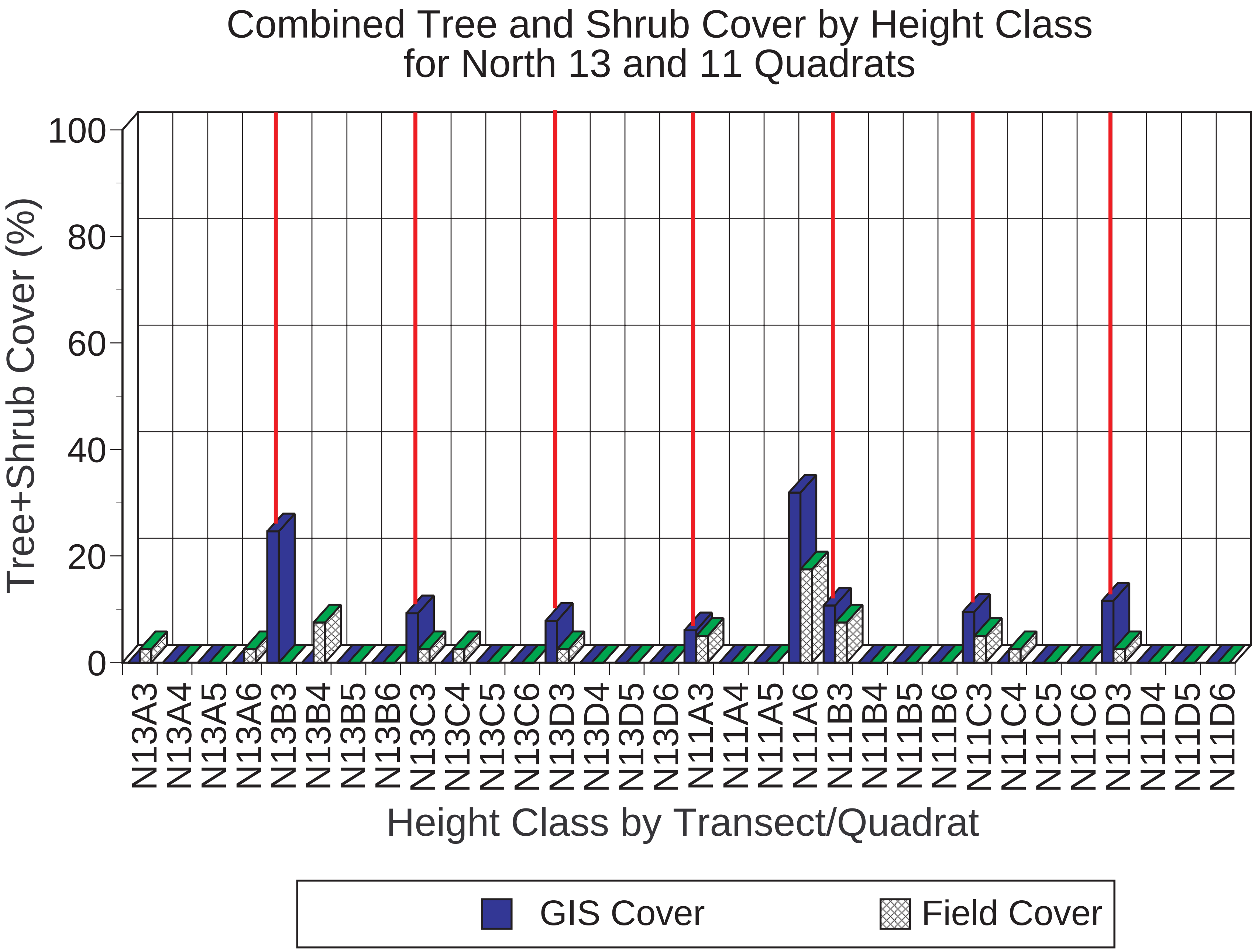
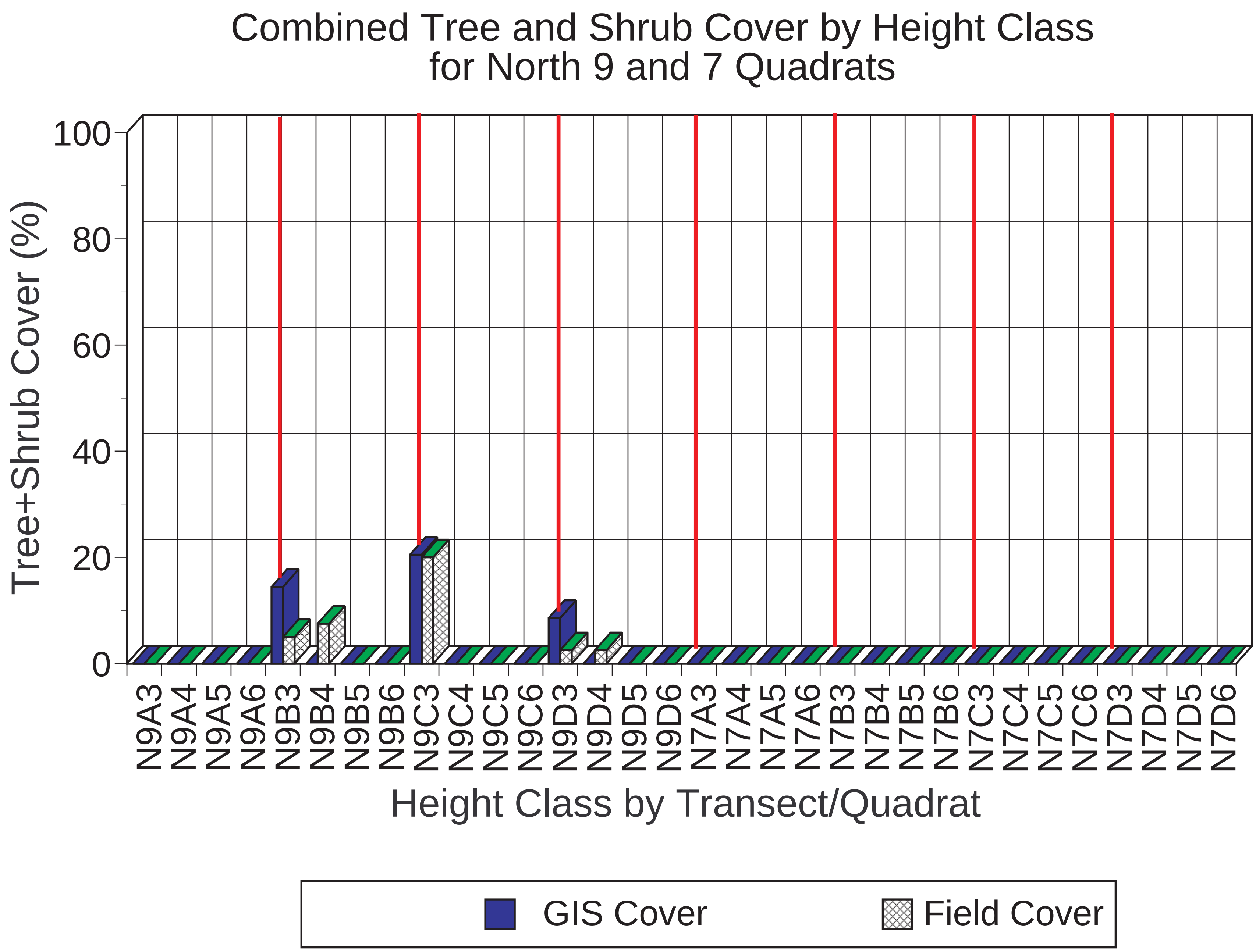


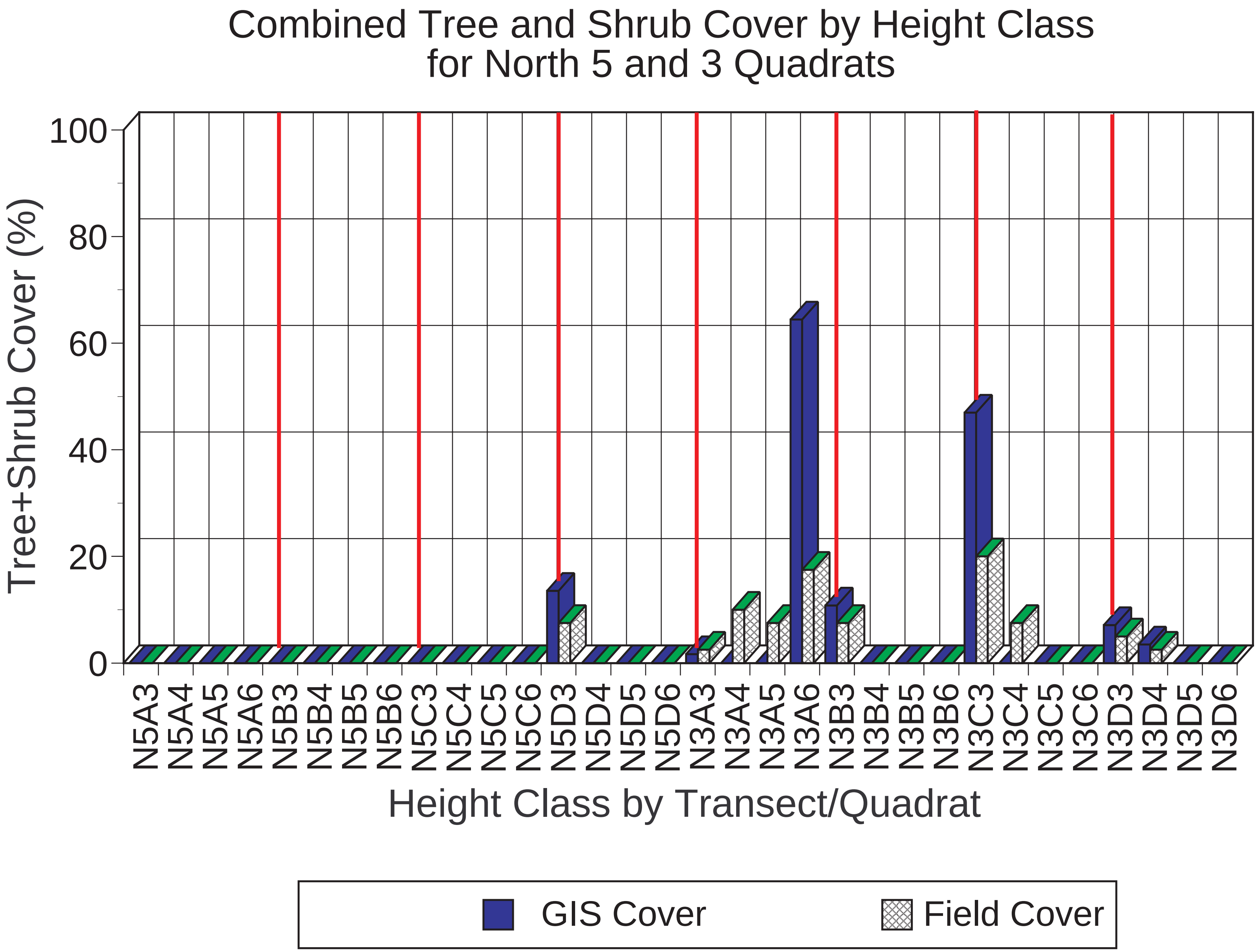
Figure 24. Comparison of tree+shrub cover (considering only cover of height classes 3,4,5, and 6) by quadrat and vegetation height class between the GIS (aerial) analysis and the field-based survey.

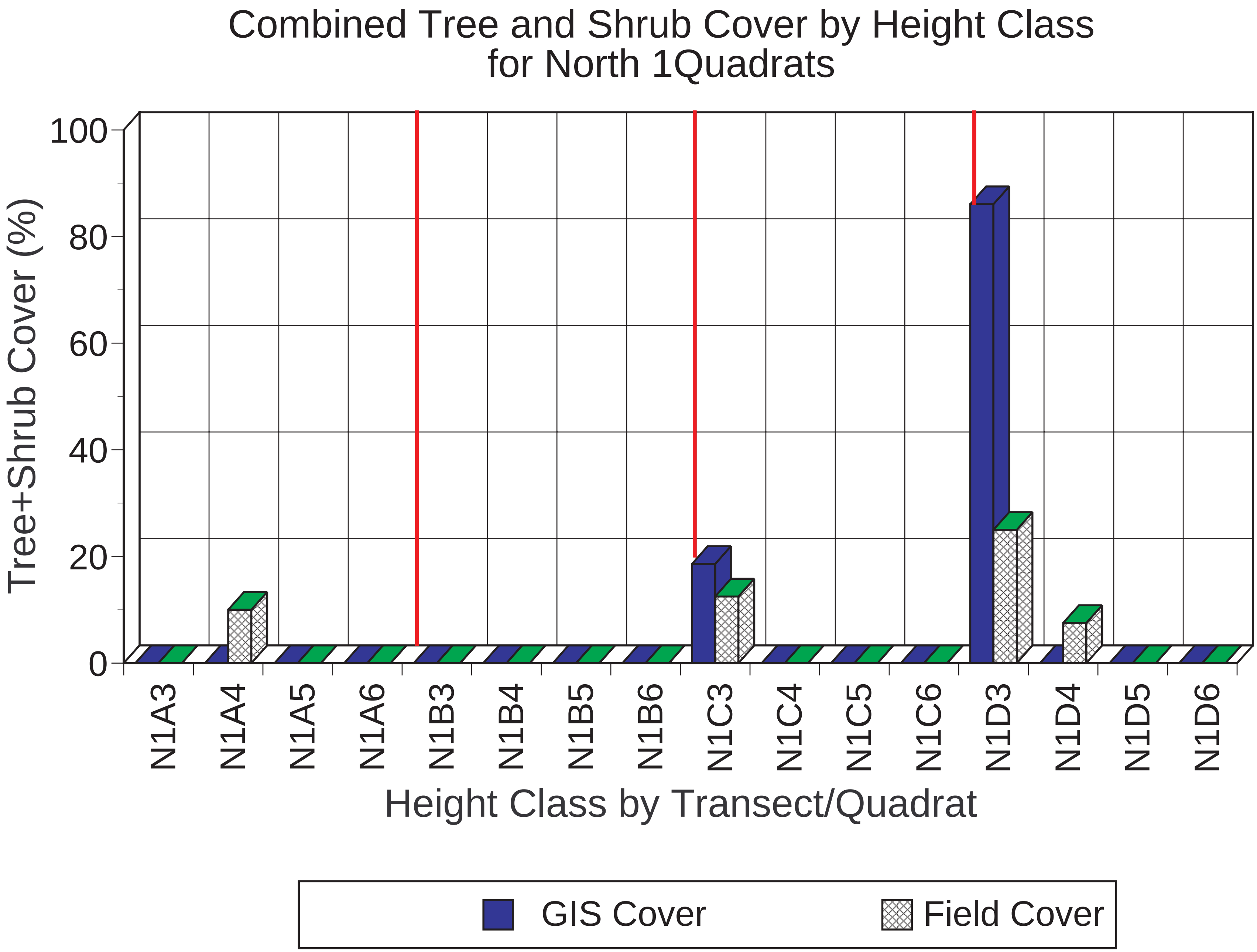

Combined Tree and Shrub Cover by Height Class
for North 21 and 19 Quadrats
Tree+Shrub Cover (%)
100
80
60
40
20
0
N21A3
N21A4
N21A5
N21A6
N21B3
N21B4
N21B5
N21B6
N21C3
N21C4
N21C5
N21C6
N21D3
N21D4
N21D5
N21D6
N19A3
N19A4
N19A5
N19A6
N19B3
N19B4
N19B5
N19B6
Height Class by Transect/Quadrat
GIS Cover
Field Cover


Combined Tree and Shrub Cover by Height Class
for North 17 and 15 Quadrats
Tree+Shrub Cover (%)
0
20
40
60
80
100
N17A3
N17A4
N17A5
N17A6
N17B3
N17B4
N17B5
N17B6
N15A3
N15A4
N15A5
N15A6
N15B3
N15B4
N15B5
N15B6
N15C3
N15C4
N15C5
N15C6
N15D3
N15D4
N15D5
N15D6
Height Class by Transect/Quadrat
GIS Cover
Field Cover


Combined Tree and Shrub Cover by Height Class
for North 13 and 11 Quadrats
Tree+Shrub Cover (%)
0
20
40
60
80
100
N13A3
N13A4
N13A5
N13A6
N13B3
N13B4
N13B5
N13B6
N13C3
N13C4
N13C5
N13C6
N13D3
N13D4
N13D5
N13D6
N11A3
N11A4
N11A5
N11A6
N11B3
N11B4
N11B5
N11B6
N11C3
N11C4
N11C5
N11C6
N11D3
N11D4
N11D5
N11D6
Height Class by Transect/Quadrat
GIS Cover
Field Cover

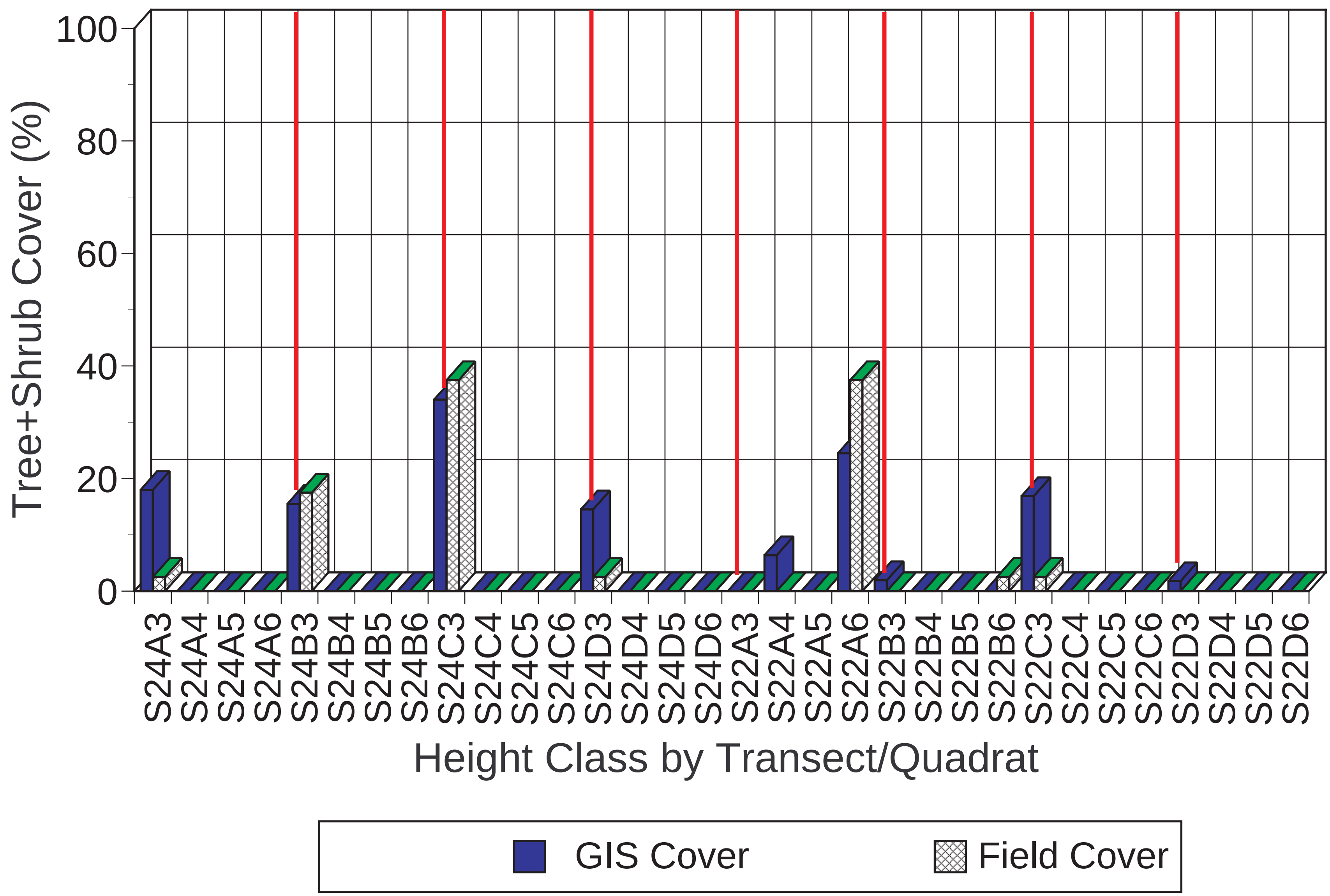

Combined Tree and Shrub Cover by Height Class
for North 9 and 7 Quadrats
Tree+Shrub Cover (%)
0
20
40
60
80
100
N9A3
N9A4
N9A5
N9A6
N9B3
N9B4
N9B5
N9B6
N9C3
N9C4
N9C5
N9C6
N9D3
N9D4
N9D5
N9D6
N7A3
N7A4
N7A5
N7A6
N7B3
N7B4
N7B5
N7B6
N7C3
N7C4
N7C5
N7C6
N7D3
N7D4
N7D5
N7D6
Height Class by Transect/Quadrat
GIS Cover
Field Cover

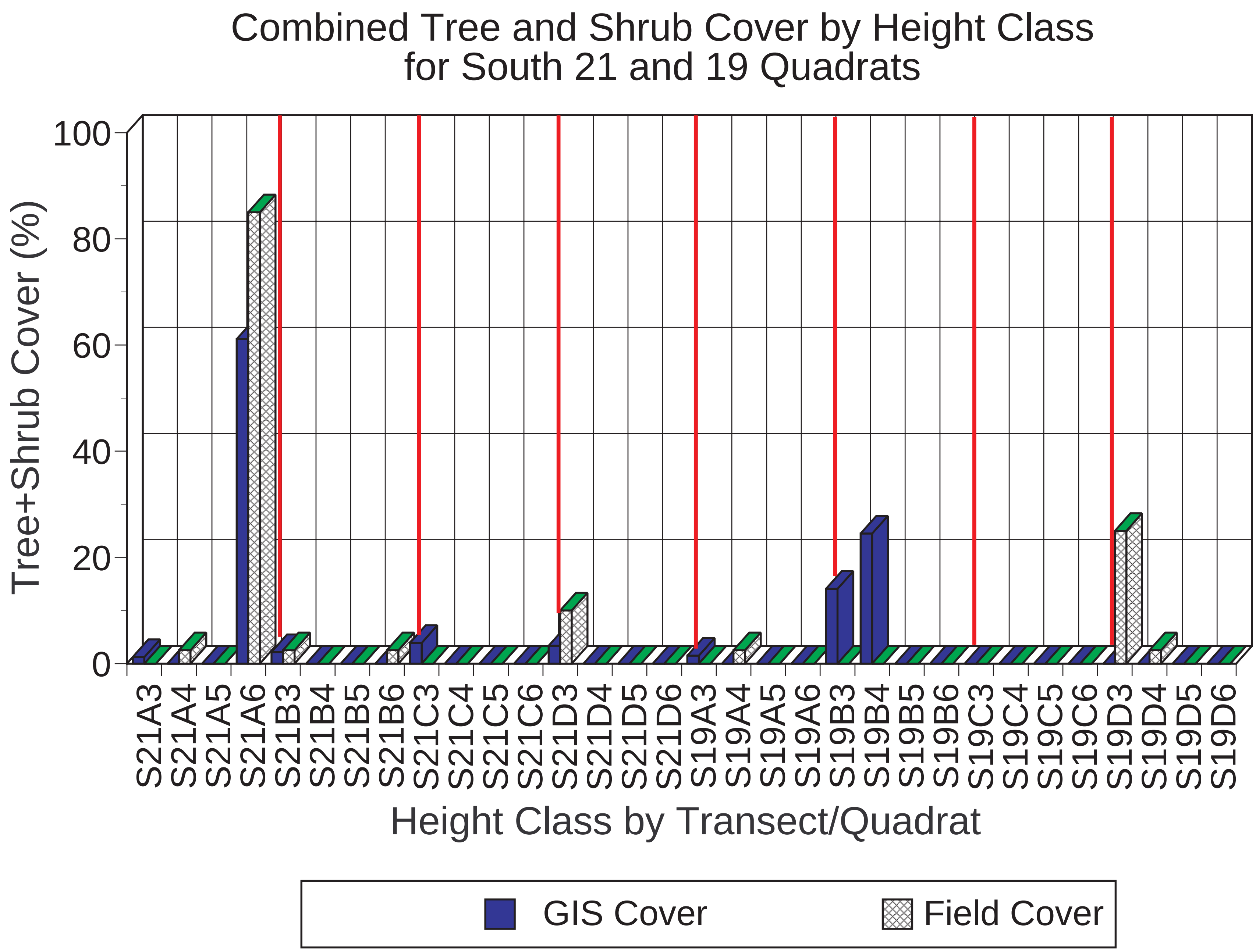

Combined Tree and Shrub Cover by Height Class
for North 5 and 3 Quadrats
Tree+Shrub Cover (%)
0
20
40
60
80
100
N5A3
N5A4
N5A5
N5A6
N5B3
N5B4
N5B5
N5B6
N5C3
N5C4
N5C5
N5C6
N5D3
N5D4
N5D5
N5D6
N3A3
N3A4
N3A5
N3A6
N3B3
N3B4
N3B5
N3B6
N3C3
N3C4
N3C5
N3C6
N3D3
N3D4
N3D5
N3D6
Height Class by Transect/Quadrat
GIS Cover
Field Cover

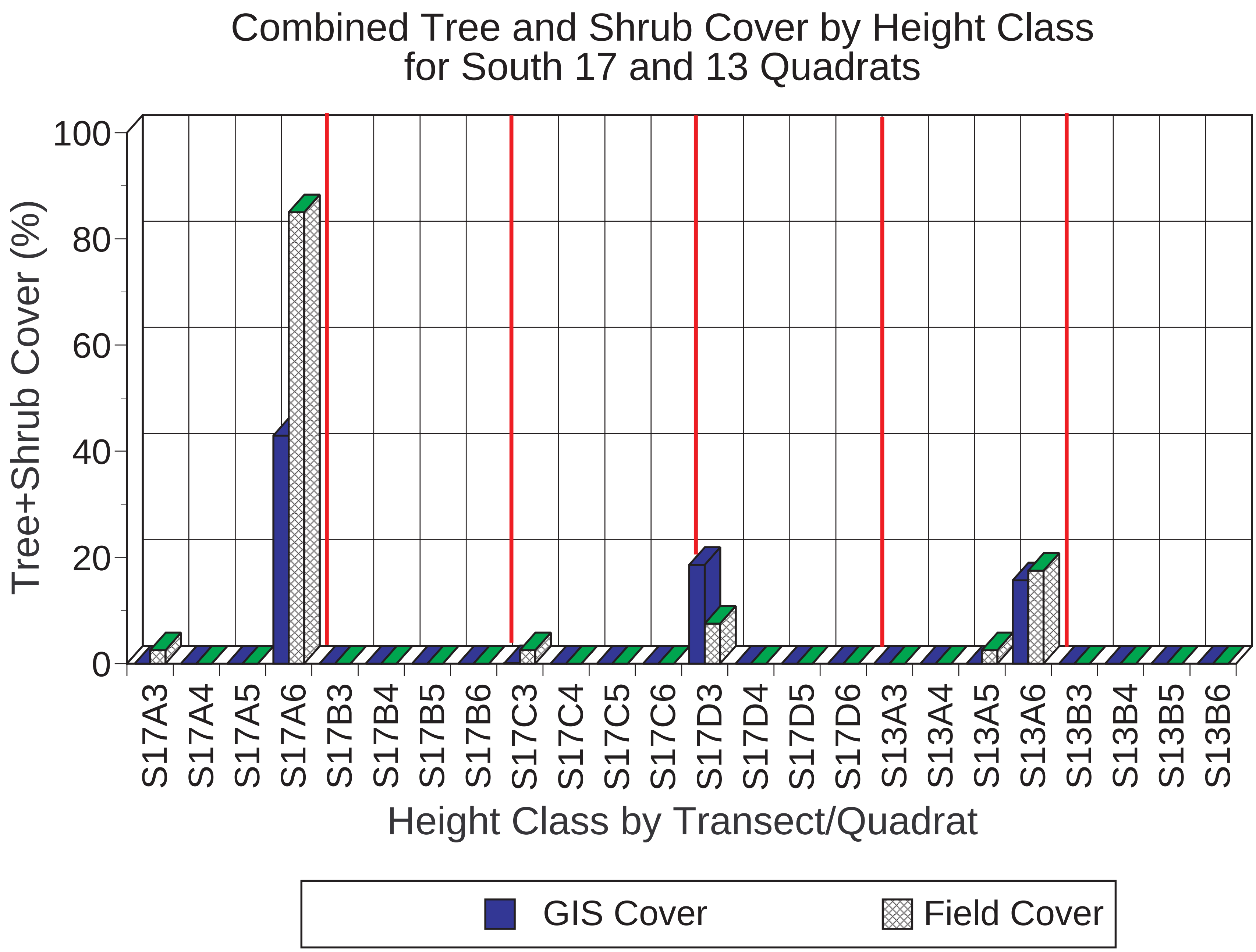


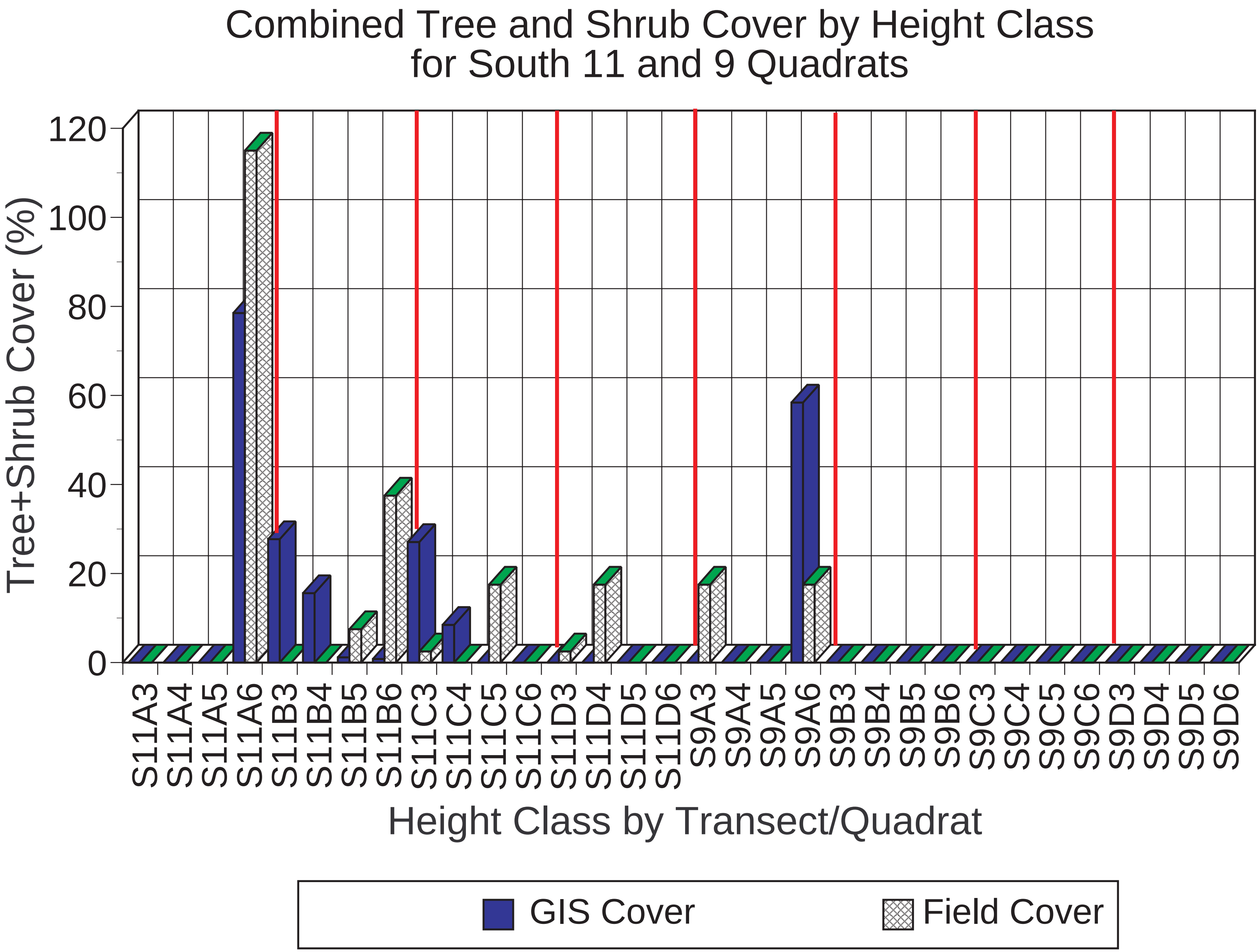
Combined Tree and Shrub Cover by Height Class
for North 1Quadrats
Tree+Shrub Cover (%)
100
80
60
40
20
0
N1A3
N1A4
N1A5
N1A6
N1B3
N1B4
N1B5
N1B6
N1C3
N1C4
N1C5
N1C6
N1D3
N1D4
N1D5
N1D6
Height Class by Transect/Quadrat
GIS Cover
Field Cover

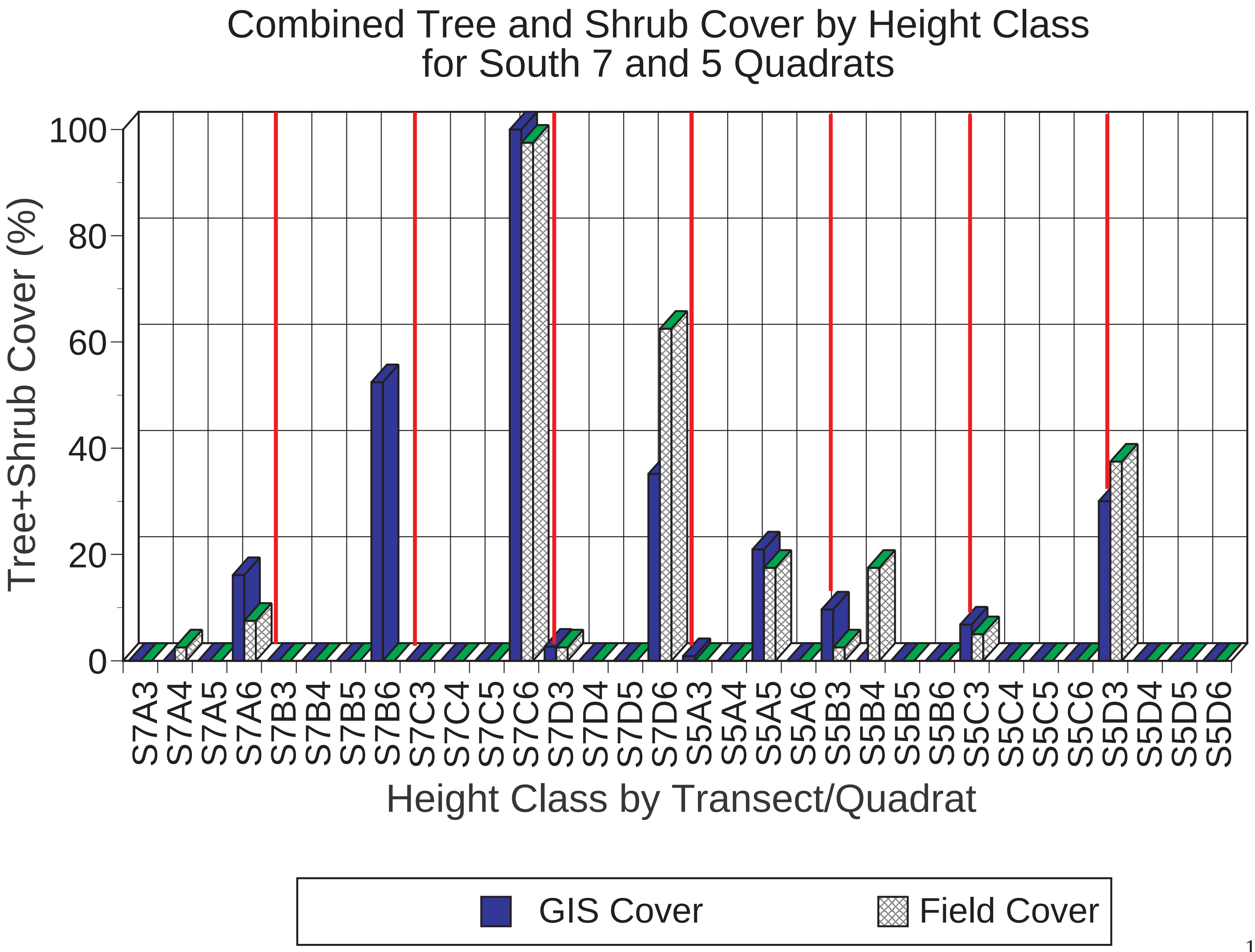
Combined Tree and Shrub Cover by Height Class for South 24 and 22 Quadrats

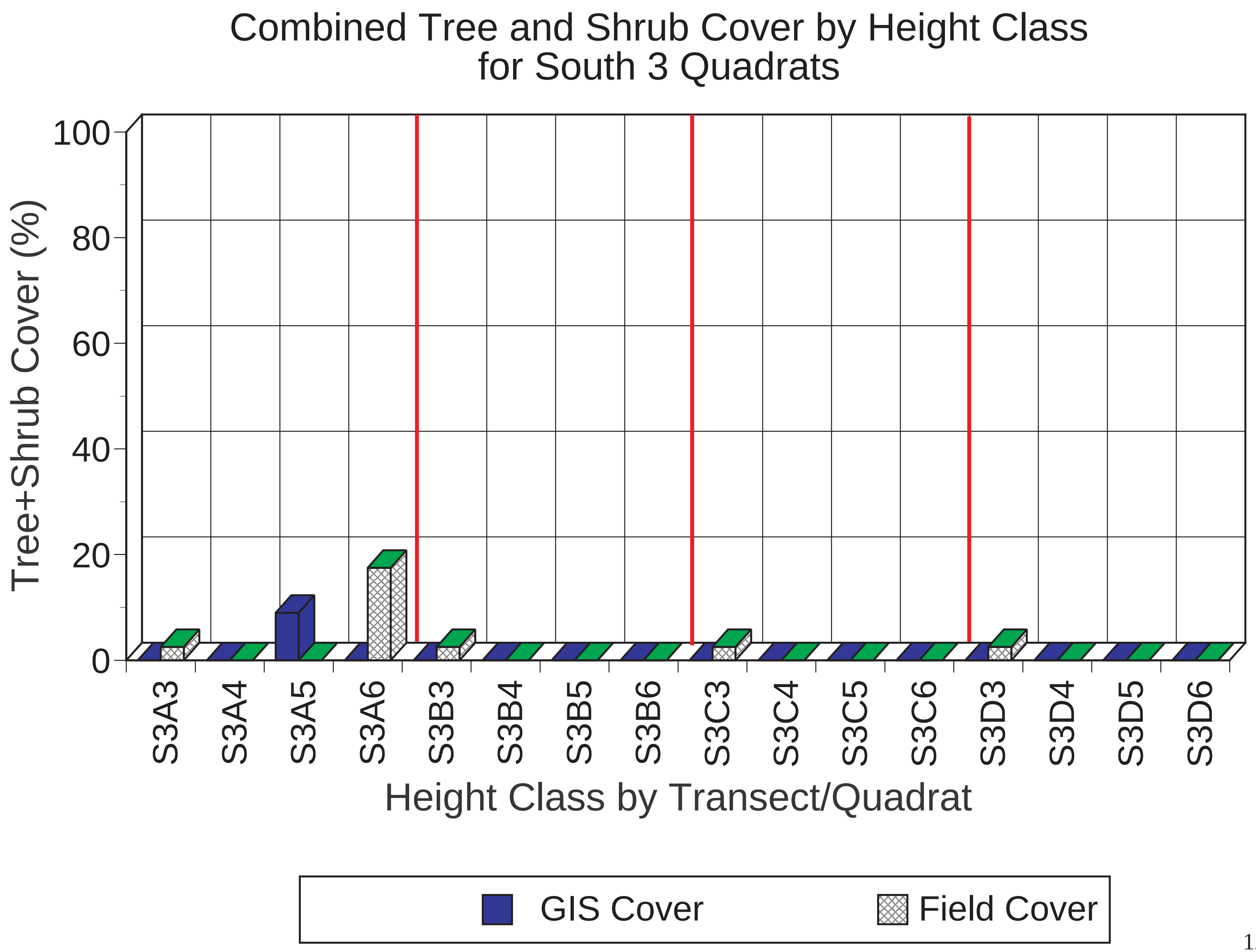



Combined Tree and Shrub Cover by Height Class
for South 21 and 19 Quadrats
Tree+Shrub Cover (%)
0
20
40
60
80
100
S21A3
S21A4
S21A5
S21A6
S21B3
S21B4
S21B5
S21B6
S21C3
S21C4
S21C5
S21C6
S21D3
S21D4
S21D5
S21D6
S19A3
S19A4
S19A5
S19A6
S19B3
S19B4
S19B5
S19B6
S19C3
S19C4
S19C5
S19C6
S19D3
S19D4
S19D5
S19D6
Height Class by Transect/Quadrat
GIS Cover
Field Cover


Combined Tree and Shrub Cover by Height Class
for South 17 and 13 Quadrats
Tree+Shrub Cover (%)
100
80
60
40
20
0
S17A3
S17A4
S17A5
S17A6
S17B3
S17B4
S17B5
S17B6
S17C3
S17C4
S17C5
S17C6
S17D3
S17D4
S17D5
S17D6
S13A3
S13A4
S13A5
S13A6
S13B3
S13B4
S13B5
S13B6
Height Class by Transect/Quadrat
GIS Cover
Field Cover


Combined Tree and Shrub Cover by Height Class
for South 11 and 9 Quadrats
Tree+Shrub Cover (%)
0
20
40
60
80
100
120
S11A3
S11A4
S11A5
S11A6
S11B3
S11B4
S11B5
S11B6
S11C3
S11C4
S11C5
S11C6
S11D3
S11D4
S11D5
S11D6
S9A3
S9A4
S9A5
S9A6
S9B3
S9B4
S9B5
S9B6
S9C3
S9C4
S9C5
S9C6
S9D3
S9D4
S9D5
S9D6
Height Class by Transect/Quadrat
GIS Cover
Field Cover


Combined Tree and Shrub Cover by Height Class
for South 7 and 5 Quadrats
Tree+Shrub Cover (%)
100
80
60
40
20
0
S7A3
S7A4
S7A5
S7A6
S7B3
S7B4
S7B5
S7B6
S7C3
S7C4
S7C5
S7C6
S7D3
S7D4
S7D5
S7D6
S5A3
S5A4
S5A5
S5A6
S5B3
S5B4
S5B5
S5B6
S5C3
S5C4
S5C5
S5C6
S5D3
S5D4
S5D5
S5D6
Height Class by Transect/Quadrat
GIS Cover
Field Cover


Combined Tree and Shrub Cover by Height Class
for South 3 Quadrats
Tree+Shrub Cover (%)
0
20
40
60
80
100
S3A3
S3A4
S3A5
S3A6
S3B3
S3B4
S3B5
S3B6
S3C3
S3C4
S3C5
S3C6
S3D3
S3D4
S3D5
S3D6
Height Class by Transect/Quadrat
GIS Cover
Field Cover

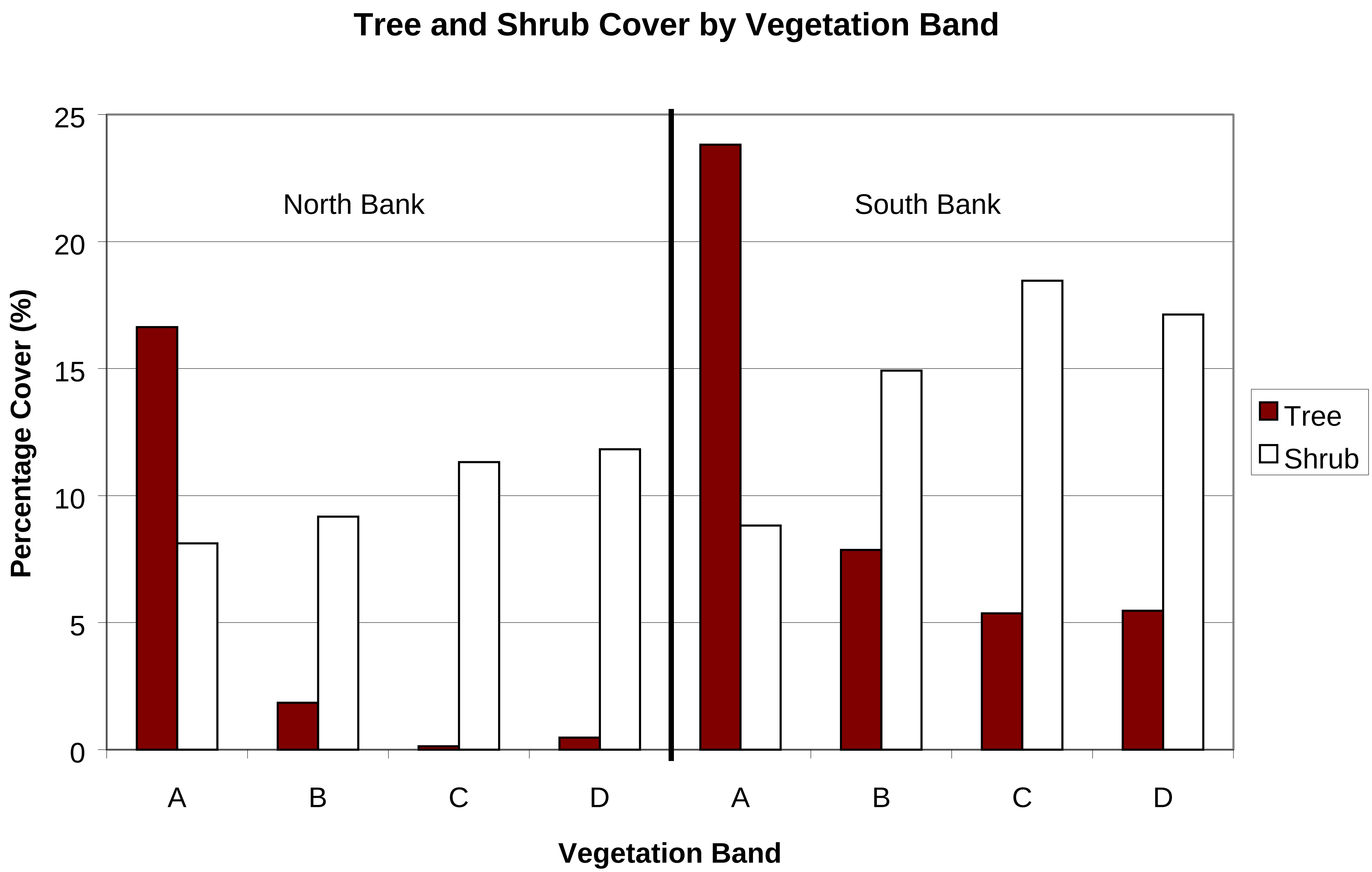


Figure 25. Tree and shrub cover by vegetation bands on north and south banks.

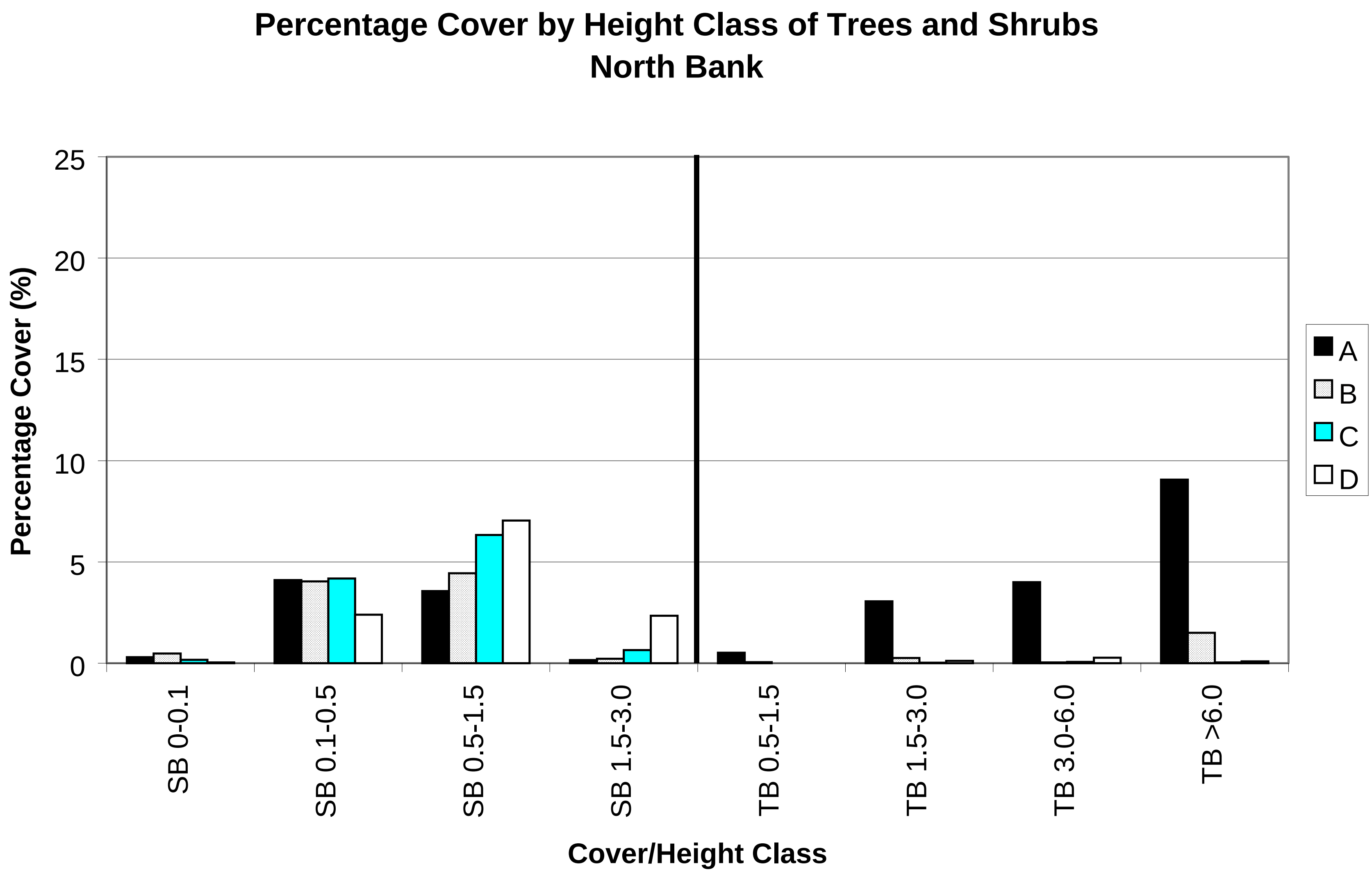


Figure 26. Percentage cover by height class of trees and shrubs (north bank).

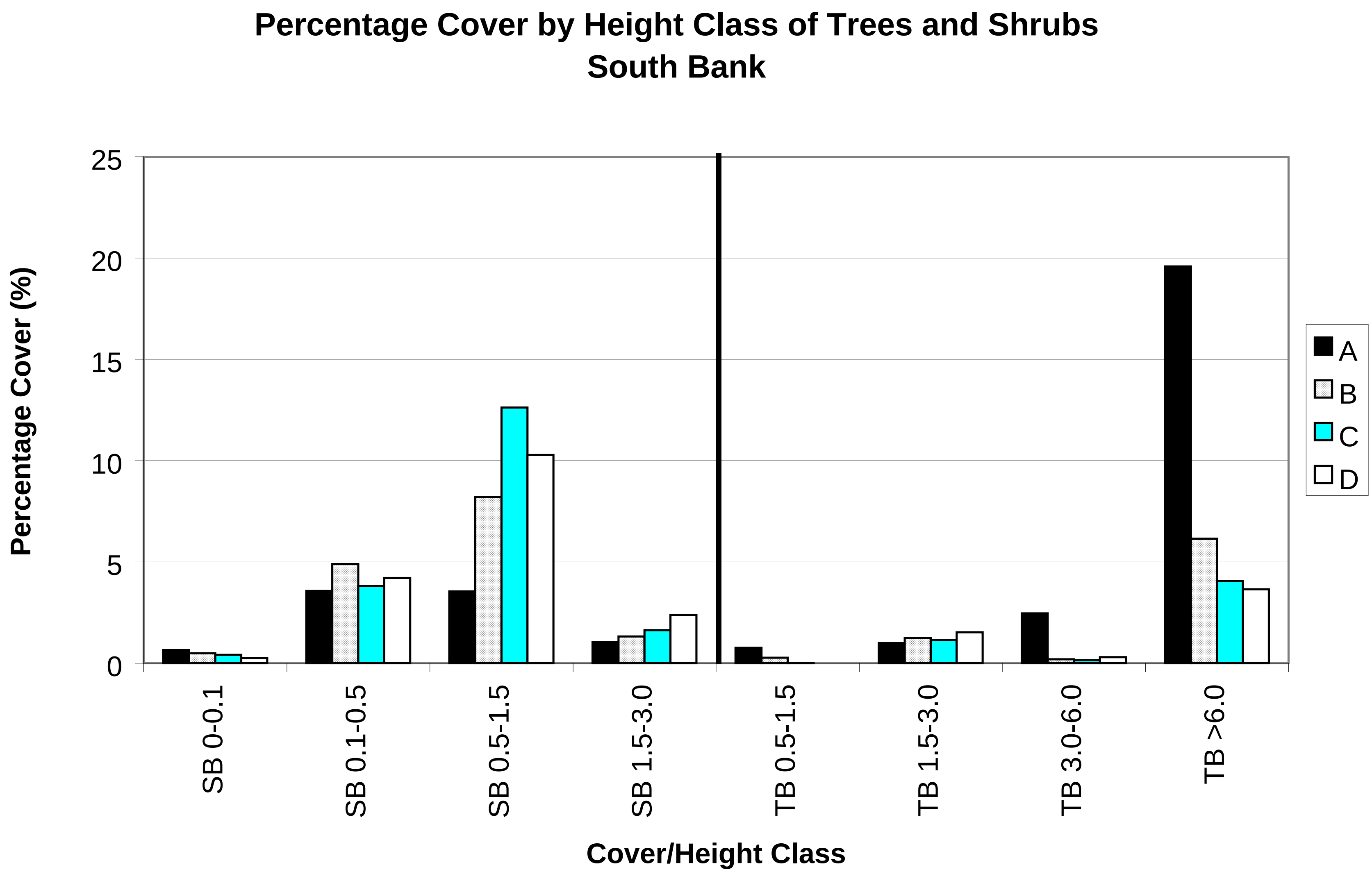


Figure 27. Percentage cover by height class of trees and shrubs (south bank).

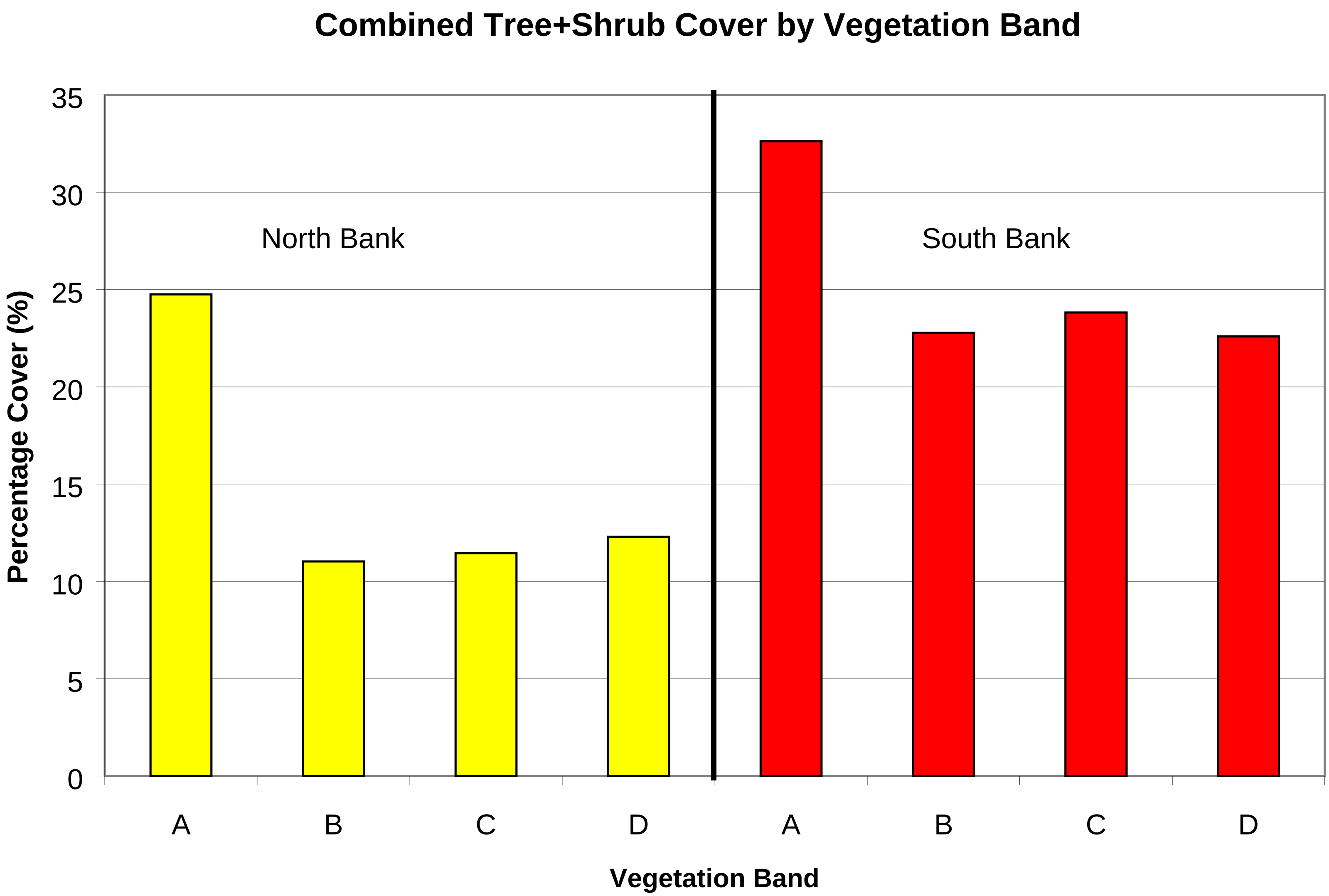


Figure 28. Percentage tree+shrub cover by vegetation band for north and south banks.

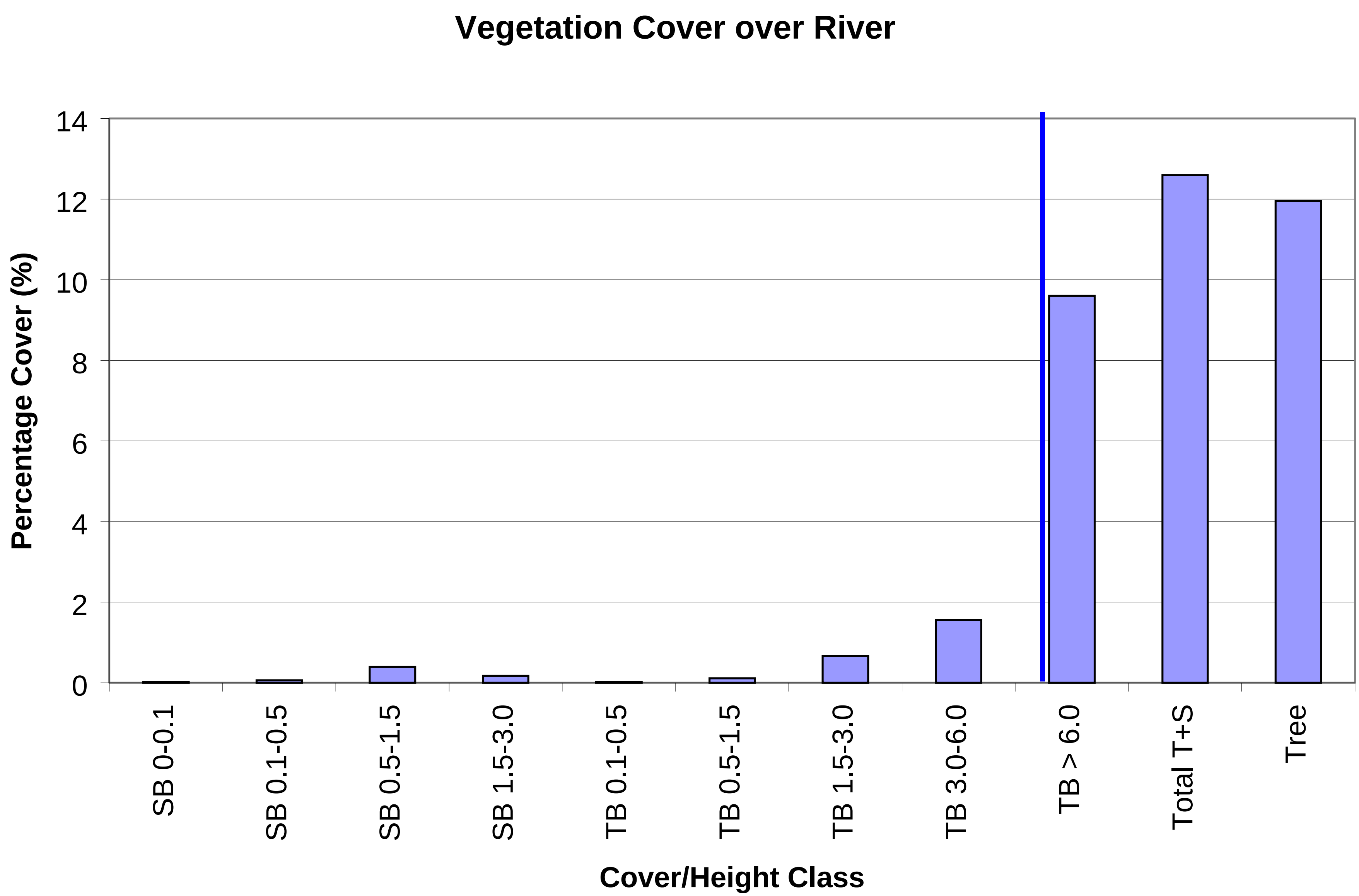


Figure 29. Percentage vegetation (trees, shrubs) cover by height class projected vertically above the river water surface.

APPENDIX 1

Data on Photopoints Established on Transect Lines

The following table was included in Access database WSPlants6.mdb as a portion of the table Photos2. It provides information on the dates of photos in the study area on the Warm Springs River, lens setting for the zoom wide-angle lens, bank and transect number, distance from the iron stake permanent marker to the active water on each bank, distance from the camera lens to the stadium rod held in the foreground as a measuring device, distance from the camera lens to the active water, height of the rod, map orientation (degrees; north = 0°, south = 180°) of the transect line, and general view of the photo (either looking toward the stream along the transect line or looking upstream or downstream at the water's edge).

PhotoID	NSTrans	Date	Camera lens	Stake to water (m)	Photopoint to rod (m)	Photopoint to water (m)	Height of rod	Transect orientation deg. (map)	View
1	N24	08-Jul-97	18 mm	37	10	20	3	2	T
2	N23	08-Jul-97	18 mm	31.1	10	20	3	344	T
3	N22	08-Jul-97	18 mm	22.2	10	20	3	340	T
4	N21	08-Jul-97	18 mm	17.3	10	20	3	344	T
5	N20	08-Jul-97	18 mm	11.8	10	20	3	353	T
6	N19	08-Jul-97	18 mm	11.6	10	20	3	352	T
7	N18	08-Jul-97	18 mm	9.2	2.5	12.5	3	2	T
8	N17	08-Jul-97	18 mm	6.4	3.6	13.6	3	7	T
9	N16	08-Jul-97	18 mm	16.2	10	20	3	13	T
10	N15	08-Jul-97	18 mm	20.9	10	20	3	18	T
11	N14	08-Jul-97	18 mm	18.7	10	20	3	24	T
12	N13	08-Jul-97	18 mm	16.9	10	20	3	29	T
13	N12	08-Jul-97	18 mm	13.7	10	20	3	35	T
14	N11	08-Jul-97	18 mm	11.8	10	20	3	39	T
15	N10	08-Jul-97	18 mm	12	10	20	3	61	T
16	N9	08-Jul-97	18 mm	12.6	10	20	3	59	T
17	N8	08-Jul-97	18 mm	30.4	10	20	3	65	T
18	N7	08-Jul-97	18 mm	24.4	10	20	3	59	T
19	N6	08-Jul-97	18 mm	24	10	20	3	69	T
20	N5	08-Jul-97	18 mm	20.7	10	20	3	70	T
21	N4	08-Jul-97	18 mm	15.4	9.1	19.1	3	63	T
22	N3	08-Jul-97	18 mm	9.9	10	20	3	71	T
23	N2	08-Jul-97	18 mm	11.5	10	20	3	64	T
24	N1	08-Jul-97	18 mm	22.5	10	20	3	71	T
25	N0	08-Jul-97	18 mm	32.7	10	20	3	93	T
26	S24	08-Jul-97	18 mm	14.3	10	20	3	2	T
27	S23	08-Jul-97	18 mm	56.8	10	20	3	344	T
28	S22	08-Jul-97	18 mm	39.9	10	20	3	340	T
29	S21	08-Jul-97	18 mm	22	10	20	3	344	T
30	S20	14-Oct-97	18 mm	32.6	10	20	6	353	T
31	S19	14-Oct-97	18 mm	35	10	20	6	352	T
32	S18	08-Jul-97	18 mm	23	11.6	21.6	4.5	2	T
33	S17	08-Jul-97	18 mm	3.6	10	20	3	7	T
34	S16	08-Jul-97	18 mm	43.2	10	20	6	13	T
35	S15	08-Jul-97	18 mm	20.8	10	20	3	18	T
36	S14	08-Jul-97	18 mm	26.8	10	20	6	24	T

37	S13	08-Jul-97	18 mm	26.1	10	20	6	29	T
38	S12	14-Oct-97	18 mm	47.8	10	20	6	35	T
39	S11	08-Jul-97	18 mm	15.4	10	20	3	39	T
40	S10	08-Jul-97	18 mm	49.7	10	20	6	61	T
41	S9	08-Jul-97	18 mm	45.3	10	20	6	59	T
42	S8	08-Jul-97	18 mm	32.3	10	20	6	65	T
43	S7	08-Jul-97	18 mm	22.8	10	20	6	59	T
44	S6	08-Jul-97	18 mm	20.1	10	20	3	69	T
45	S5	14-Oct-97	18 mm	20.1	10	20	3	70	T
46	S4	08-Jul-97	18 mm	15.6	10	20	6	63	T
47	S3	08-Jul-97	18 mm	17.6	10	20	6	71	T
48	S2	08-Jul-97	18 mm	18.7	10	20	6	64	T
49	S1	08-Jul-97	18 mm	12.5	10	20	3	71	T
50	S0	08-Jul-97	18 mm	12.7	10	20	6	93	T
51	S16	08-Jul-97	18 mm	0	10	13.3	3	0	T
52	S1	08-Jul-97	18 mm	0	10	15	3	0	T
53	N24	09-Jul-97	18 mm	0	0	20	0	0	D
54	N23	09-Jul-97	18 mm	0	0	20	0	0	U
55	N22	09-Jul-97	18 mm	0	0	20	0	0	U
56	N21	09-Jul-97	18 mm	0	0	20	0	0	U
57	N20	09-Jul-97	18 mm	0	0	20	0	0	U
58	N19	09-Jul-97	18 mm	0	0	20	0	0	U
59	N18	09-Jul-97	18 mm	0	0	20	0	0	U
60	N17	09-Jul-97	18 mm	0	0	20	0	0	U
61	N16	09-Jul-97	18 mm	0	0	20	0	0	U
62	N15	09-Jul-97	18 mm	0	0	20	0	0	U
63	N14	09-Jul-97	18 mm	0	0	20	0	0	U
64	N13	09-Jul-97	18 mm	0	0	0	0	0	U
65	N12	09-Jul-97	18 mm	0	0	0	0	0	U
66	N11	09-Jul-97	18 mm	0	0	0	0	0	U
67	N10	09-Jul-97	18 mm	0	0	0	0	0	U
68	N9	09-Jul-97	18 mm	0	0	0	0	0	U
69	N8	09-Jul-97	18 mm	0	0	0	0	0	U
70	N7	09-Jul-97	18 mm	0	0	0	0	0	U
71	N6	09-Jul-97	18 mm	0	0	0	0	0	U
72	N5	09-Jul-97	18 mm	0	0	0	0	0	U
73	N4	09-Jul-97	18 mm	0	0	0	0	0	U
74	N3	09-Jul-97	18 mm	0	0	0	0	0	U
75	N2	09-Jul-97	18 mm	0	0	0	0	0	U
76	N1	09-Jul-97	18 mm	0	0	0	0	0	U
77	N0	09-Jul-97	18 mm	0	0	0	0	0	U
78	S24	09-Jul-97	18 mm	0	0	0	0	0	U
79	S23	09-Jul-97	18 mm	0	0	0	0	0	U
80	S22	09-Jul-97	18 mm	0	0	0	0	0	U
81	S21	09-Jul-97	18 mm	0	0	0	0	0	U
82	S20	09-Jul-97	18 mm	0	0	0	0	0	U

83	S19	09-Jul-97	18 mm	0	0	0	0	0	U
84	S18	09-Jul-97	18 mm	0	0	0	0	0	U
85	S17	09-Jul-97	18 mm	0	0	0	0	0	U
86	S16	09-Jul-97	18 mm	0	0	0	0	0	U
87	S15	09-Jul-97	18 mm	0	0	0	0	0	U
88	S14	09-Jul-97	18 mm	0	0	0	0	0	U
89	S13	09-Jul-97	18 mm	0	0	0	0	0	U
90	S12	09-Jul-97	18 mm	0	0	0	0	0	U
91	S11	09-Jul-97	18 mm	0	0	0	0	0	U
92	S10	09-Jul-97	18 mm	0	0	0	0	0	U
93	S9	09-Jul-97	18 mm	0	0	0	0	0	U
94	S8	09-Jul-97	18 mm	0	0	0	0	0	U
95	S7	09-Jul-97	18 mm	0	0	0	0	0	U
96	S6	09-Jul-97	18 mm	0	0	0	0	0	U
97	S5	09-Jul-97	18 mm	0	0	0	0	0	U
98	S4	09-Jul-97	18 mm	0	0	0	0	0	U
99	S3	09-Jul-97	18 mm	0	0	0	0	0	U
100	S2	09-Jul-97	18 mm	0	0	0	0	0	U
101	S1	09-Jul-97	18 mm	0	0	0	0	0	U
102	S0	09-Jul-97	18 mm	0	0	0	0	0	U
107	S1	14-Oct-97	18 mm	0	0	0	0	0	U
108	S1	14-Oct-97	18 mm	0	0	0	0	0	U
109	S5	17-Oct-97	18 mm	0	0	0	0	0	U
110	S5	17-Oct-97	18 mm	0	0	0	0	0	U

For "View" T signifies perpendicular to stream on transect line
U signifies view looking upstream
D signifies view looking downstream

APPENDIX 2

Review and Evaluation of Bank Stability Methods

Maintenance of excellent bank stability conditions is an essential component of providing high quality habitat conditions for salmonids. The objectives of managing riparian corridors using a bank stability standard are to (1) prevent streambank erosion processes from delivering sediment directly to spawning and rearing areas or to prevent increases in the total sediment load of the stream system that will cause downstream cumulative effects, (2) create conditions favorable for development of undercut banks, (3) protection of streambank deep-rooted vegetation that will stabilize streambank soils and allow development of shade, and (4) foster physical conditions that would maintain or restore width/depth ratios that provide optimal fish habitat conditions for the channel type. Stability is decreased by several major types of land management activities (see Rhodes et al. 1994). Livestock grazing is a major contributor to loss of bank stability by vegetation removal, bank trampling and calving, leading to loss of bank overhangs, channel widening, and water depth decrease. Road building along stream channels tends to remove stabilizing streamside vegetation and oversteepens upper streambanks. Logging of riparian vegetation eliminates much of the effective soil binding capability along streambanks and causes soil compaction and disturbance that frequently lead to surface erosion.

The bank stability estimate does not require distinguishing natural from artificial causes of instability or attempting to infer what historic conditions might have been. The same is the case with other biologically-based standards proposed by CRITFC (CRITFC 1995). The proposed standard for bank stability is based on the assumption that for various types of managed watersheds, 90% bank stability is an anticipated average minimum performance level possible under various natural geomorphic conditions over time and that by maintaining high bank stability, favorable biological conditions will be possible under the normal range of environmental conditions. High channel stability is linked to maintenance of desirable W/D ratios, substrate conditions, and primary pool quantity and quality.

We recommend that bank stability be measured for any stream reach or entire stream network (from the mouth of the stream system upstream to include all first order streams) as the average for left and right sides of the stream. Bank stability is meant to reflect the absence of evidence of factors leading to obvious erosion, regardless of cause. Sediment delivery varies in magnitude depending on the severity of impact to the soil system and the area affected. The streambank can be divided between upper bank and lower bank. The upper bank extends laterally from the stream channel from normal high water to an inflection point where the hillslope begins and could be considered to include the floodplain, low terraces, or a portion of the lower sideslope to the maximum elevation reached by extreme floods. The lower bank extends from normal high water to the water margin during summer flow conditions. Because the lower bank includes frequently submerged portions of the channel that also typically lack vegetation, evidence of impact to streambanks in this zone is not easily discerned.

For ease of monitoring and to eliminate the need to differentiate upper bank from lower hillslope, it is recommended that bank stability impacts be estimated as a band transect, where band width is approximated 1- to 2-m wide. A 1-m horizontal band encompassing an area above bankfull and another below bankfull indicates geomorphologic forces at work at the channel margin. Bank stability is then estimated as a percentage of the length (or area) along the transects lacking evidence of

obvious erosion potential. Sampling of 5-m lengths of these 1-m bands situated on the upstream edge of fixed transect lines is suitable. The streambank is considered stable if it is covered by vegetation (trees, grasses, sedges, rushes, forbs, shrubs). Bank material composition, such as cobbles, also leads to stability. Evidence of broken banks, disturbed soils, bare soil, damaged vegetation, heavily compacted soils indicate erosion potential and lack of stability (vegetative and soil stability). Unstable banks may also be indicated by hillslope slumping (where the hillslope extends directly to the channel) and by jackstrawed or leaning trees along the bank. This monitoring parameter is intended to describe obvious sources of sediment entering the stream currently or potentially entering under very dry or wet conditions. In some cases bank stability is heavily affected by livestock use of stream channels that occurred in the past, leading to loss of steep lower bank angle and channel widening. If subsequent livestock management results in maintenance of shallow rooted grasses on upper banks, protection of the banks from erosion during high flow events will be less than under conditions where the bank is stabilized by deep-rooted vegetation.

(1) Notes on Method of Platts et al. (1987)

Platts, W.S.,C. Armour, G.D. Booth, M. Bryant, J.L. Bufford, P. Cuplin, S. Jensen, G.W. Lienkaemper, G.W. Minshall, S.B. Monsen, R.L. Nelson, J.R. Sedell, and J.S. Tuhy. 1987. Methods for evaluating riparian habitats with applications to management. USDA, Forest Service, Intermountain Research Station, Gen. Tech. Report INT-221.
177 p.

Table 1. Streambank stability as described by Platts et al. (1987).

Rating	Percentage	Description
4	75-100	Over 75% of bank surface is covered by vegetation in vigorous condition or by boulders and rubble. If bank is not covered by vegetation, it is protected by materials that do not allow bank erosion.
3	50-74	Between 50 and 74% of bank surface is covered by vegetation or gravel or larger material. Those areas not covered by vegetation are protected by materials that allow only minor erosion.
2	25-49	Between 25 and 49% of bank surface is covered by vegetation or by gravel or larger material. The area not covered by vegetation is covered by materials that give limited protection.
1	0-24	Less than 25% of the streambank surface is covered by vegetation or by gravel or larger material. That area not covered by vegetation provides little or no control over erosion and the banks are usually eroded each year by high water flows.

This index deals with ability of vegetation and other materials on the bank to resist soil and vegetative erosion from flowing water and ice. Stability is generated by vegetative cover primarily, but also by bedrock, boulder, or rubble. The rated portion of the bank or floodplain includes only that area intercepted by the transect line within 5 ft of the stream or to the top of the bank, whichever is larger.

(2) Notes on Method of Myers (1989)

Myers, L.H. 1989. Riparian area management: inventory and monitoring of riparian areas. Bureau of Land Management, BLM/YA/PT-89/022+1737, Service Center, CO. 89 p.

Table 2. Streambank soil alteration rating.

Rating	Percentage	Description
4	0	Streambanks are stable and not being altered by water flows or animals
	1-25	Streambanks are stable, but are being lightly altered along the transect line. Less than 25% of the streambank is receiving any kind of stress, and if stress is being received, it is very light. Less than 25% of the bank is false*, broken down, or eroding.
3	26-50	Streambanks are receiving only moderate alteration along the transect line. At least 50% of the bank is in a natural stable condition. Less than 50% of the bank is false, broken down, or eroding. False banks are rated as altered. Alteration is rated as natural, artificial, or a combination of the two.
2	51-75	Streambanks have received major alteration along the transect line. less than 50% of the bank is false, broken down, or eroding. A false bank that may have gained some stability and cover is still rated as altered. Alteration is rated as natural, artificial, or a combination of the two.
1	76-100	Streambanks along the transect line are severely altered. Less than 25% of the bank is in a stable condition. Over 75% of the bank is false, broken down, or eroding. A past damaged bank, now classified as a false bank, that has gained some stability and cover is still rated as altered. Alteration is rated as natural, artificial, or a combination of the two.

* False banks are those banks which have been cut back by cattle and are no longer immediately adjacent to the stream.

Artificial alteration is any change obviously produced by exotic force. Trampling by man or livestock, disturbance by bulldozers are examples of artificial changes. Natural and artificial alterations cannot

together account for >100%. It is often difficult to distinguish artificial from natural alterations; when in doubt, count the alteration as natural. If artificial alterations cover already existing natural alterations, only the major type of alteration enters the rating system.

Platts et al. (1983) recommends rating only the part of streambanks intercepted by channel cross-section transects. Rating of entire banks increased observer error.

p. 19. Vegetative bank protection rating was developed by Pfankuch (1975). This scheme assumes a tree/shrub dominance for vegetation vigor and structure. This may need to be modified to account for regional differences. This requires knowledge of site potential. Soil in banks is held in place largely by plant roots. The stem helps reduce velocity of flood flows.

Vegetative bank protection

Rating	Description
4	Excellent: Trees, shrubs, grass, and forbs combined cover more than 90% of the ground. Openings in this nearly complete cover are small and evenly dispersed. A variety of species and age classes are represented. Growth is vigorous and reproduction of species in both the under and overstory is proceeding at a rate to insure continued ground cover conditions. A deep, dense root mat is inferred.
3	Good: Plants cover 70-90% of the ground. Shrub species are more prevalent than trees. Openings in the tree canopy are larger than the space resulting from the loss of a single mature individual. While the growth vigor is generally good for all species, advanced reproduction may be sparse or lacking entirely. A deep root mat is not continuous and more serious erosive incursions can occur in the openings.
2	Fair: Plant cover ranges from 50-70%. Lack of vigor is evident in some individuals and/or species. Seedling reproduction is nil. This condition ranked fair, based mostly on the percent of the area not covered by vegetation with a deep root mat potential and less on the kind of plants that make up the overstory.
1	Poor: Less than 50% of the ground is covered. Trees are essentially absent. Shrubs largely exist in scattered clumps. Growth and reproduction are generally poor. Root mats are discontinuous and shallow.

Table 3. Subsurface water status.

Rating	Description
4	Riparian site vegetation composition dominated by hydrophytic plants; reproduction evident. Little or no encroachment of upland plants (plants intolerant to prolonged saturated soil). Upland plants limited largely to the riparian/upland interface.
3	Riparian site vegetation composition dominated by hydrophytic plants. Some evidence of hydrophytic species decline and corresponding increase in upland plants, with upland species advancing from the riparian/upland interface.
2	Riparian site vegetation composition a roughly equal mix of hydrophytic and upland plant species. Upland species reproducing; little or no reproduction of hydrophytes. Water stress may be apparent in hydrophytic plants.
1	Riparian site vegetation composition dominated by upland species, with some extending to stream channel edge. Hydrophytic species mostly scattered clumps. In extreme cases, hydrophytic species may be totally lacking. Former aquifer presence may be indicated only by isolated hydrophytic remnants such as Salix stumps, etc.

Subsurface water status is an indication of status of hydrophytic plants as an indication of shallow aquifer status. A list of hydrophytic plants are provided by the Wetland Ecology Group (USDI 1986) for various regions. For a Northwest regional report, contact Porter B. Reed, Jr., Wetland Ecology Group, USFWS, Monroe Building, Suite 101, 9720 Executive Center Drive, St. Petersburg, FL 33702, 813-893-3867.

When channel incision or lateral erosion occurs, the recharge function is impaired and the site aquifer level is lowered, becoming less available to hydrophytic plants. In extreme, upland plant species which are intolerant of saturated soils may dominate former riparian sites. Adverse grazing practices reduce the vigor of palatable plants, which reduces riparian site stability, contributing to channel incision or lateral erosion and loss of aquifer recharge/discharge function.

Myers (1989) recommends taking the mean of the ratings for (1) streambank soil alteration, (2) vegetative bank protection, and (3) subsurface water status.

(3) Notes on Method of Schuett-Hames et al. (1994)

Schuett-Hames, D., A. Pleus, L. Bullchild, and S. Hall (eds.). 1994. Ambient monitoring program manual. Timber-Fish-Wildlife, TFW-AM9-94-001. Produced by Northwest Indian Fisheries Commission, Olympia, Washington.

The **TFW manual** on monitoring indicates that lower banks are evaluated by (1) bank material, (2) obstruction, flow deflectors, and (3) bank cutting.

Table 4. Streambank material rating.
:

Rating	Description
1	65% or more large angular boulders or bedrock highly resistant to lateral scour
2	40-65% rock, a mixture of large and small, angular and rounded boulders, such as colluvial deposits
3	20-40% rock, mostly small boulders or cobble, loosely packed and easily detached, such as glacial till or alluvial deposition
4	<20% rock, mostly cobble, gravel, or fine sediment easily erodible material such as fine alluvial or lacustrine deposits, loess, or residuum.

Bank cutting is identified as number of feet/1000 ft of stream that has cutting.
The stream bottom is evaluated for signs of deposition or scour. Also, rating the abundance of vegetation on rocks.

(4) Notes on method of Bauer and Burton (1993)

Bauer, S.B. and T.A. Burton. 1993. Monitoring protocols to evaluate water quality effects of grazing management on western rangeland streams. EPA 910/R-93-017. USEPA, Water Division, Region 10, Seattle, WA.

p. 97. Streambank stability:

Banks are unstable if they show indications of any of the following features:

1) Breakdown. Obvious blocks of bank broken away and lying adjacent to the bank breakage.
2) Slumping or false bank. Bank has obviously slipped down, cracks may or may not be obvious, but the slump feature is obvious.
3) Fracture. A crack is visibly obvious on the bank indicating that the block of bank is about to slump or move into the stream.
4) Vertical and eroding. The bank is mostly uncovered as defined below and the bank angle is steeper than 80 degrees from the horizontal.

Otherwise, banks are stable.

Streambank cover:

Banks are covered if they show any of the following features:

1) Perennial vegetation ground cover is >50%.
2) Roots of vegetation cover more than 50% of the bank. Deeply rooted plants such as willows and sedges provide such root cover.
3) ≥50% of the bank surfaces are protected by rocks of cobble size or larger.
4) ≥50% of the bank surfaces are protected by logs of ≥4 inch diameter.

Otherwise, banks are considered uncovered.

Undercut bank: An undercut bank is that bank which has been cut by the stream so that a protrusion of the upper portion of the bank overhangs the water surface.

Overhanging vegetation. That bank with vegetation which protrudes over the water surface. Vegetation is within 12 inches vertically above the water surface.

Streambank stability is estimated using a simplified modification of Platts, Megahan, and Minshall (1983, p. 13) to allow measurement in a more objective fashion. The lengths of banks on both sides of the stream throughout the linear distance of the representative reach are measured and proportioned into four stability classes as follows:

1) Mostly covered and stable (non-erosional). Streambanks are **>50% covered**. Streambanks are **stable.** Banks associated with gravel bars having perennial vegetation above the scour line are in this category.

2) Mostly covered and unstable (vulnerable). Streambanks are **>50% covered**. Streambanks are **unstable**.   This is typical in meadows where banks are false, slumping occurs, yet vegetative cover is abundant.

3) Mostly uncovered and stable (vulnerable). Streambanks are **<50% covered**. Streambanks are **stable**. Uncovered, stable banks are typical of streamsides trampled by cattle. Banks may be flattened (slumping and breakdown do not occur), but vegetative cover is reduced or eliminated.

4) Mostly uncovered and unstable (erosional). Streambanks are **<50% covered**. Streambanks are **unstable**.   Streambanks are bare and eroding and include all banks mostly uncovered which are at a steep angle to the water surface.

Streambank is that part of the channel that would be most susceptible to erosion during high water events if vegetation were removed. It represents the steeper-sloped sides of the stream channel.

Bank cover is generally viewed at the vegetative greenline located below the bankfull level but above any natural undercutting bank scour (above the scour line). Using a measuring tape, measuring rod, or wheel, record the length of streambank on both sides of the stream in the representative reach represented by each of the stability classes.

Perennial vegetation grows mostly above the streambed eroded during the annual flood. Below this scour line, erosion is mostly a natural phenomenon. Banks form above the scour line where vegetation, roots, rocks, and other forms of resistance counter the flow energy.

On gravel and sand bars, the bank is often defined by the limit of sod or perennial vegetation, or by an indentation in the bar (local steepened area) just above the scour line.

		Streambank Stability	
Streambank Cover		Stable	Unstable
	Mostly Covered	*non-erosional*	*vulnerable*
	Mostly Uncovered	*vulnerable*	*erosional*

(5) Notes on Method of Pfankuch (1978) (as cited by McDonald et al. (1991)

Table 5. Parameters in the streambank rating system.

Upper bank	Sideslope gradient Mass wasting potential Debris jam potential Vegetative cover
Lower bank	Channel capacity Bank rock content Obstructions and flow deflectors Bank cutting Sediment deposition
Channel bottom	Angularity of bed particles Brightness of bed particles Consolidation of bed particles Stability and size of bed particles Amount of scour and deposition Aquatic vegetation

(6) Conclusions based upon review of the literature on bank stability

Bank stability should be rated as a combination:

lower bank angle

lower bank material
lower bank vegetative cover (sedges)

upper bank angle
upper bank material
upper bank vegetative cover (tree, shrub, forb/grass)

For example, an overhanging bank with lower bank of soil, upper bank with heavily grazed perennial grasses could be unstable. The same bank with dense grass cover might be stable. Same bank with trees and shrubs might be more stable.

A lower bank with cobbles on a gradual slope to BF (bankfull) might be stable. If there is a steep cobble/soil bank to BF line, this might be less stable. If the upper bank is heavily vegetated, this could stabilize the lower cutbank face.

APPENDIX 3

Field Data on Streambank Condition Used to Calculate Stability

Data collected October 14, 1997 by Dale McCullough

Bank Stability

Data to record:

1) Lower bank
   a) angle
      1) undercut (u)
      2) 80 °-vertical
      3) 45-80°
      4) 10-45°
      5) 0-10°

      Make diagram of bank morphology. Record slope angle (degrees) and slope distance for each slope segment. Start at bottom of lower bank and proceed away from channel. These classes of bank angle were envisioned as useful at initiation of the monitoring; this was then abandoned in favor of simply recording angles of slope elements as measured by Suunto Tandem compass and clinometer.

   b) material--% by category
      0) large cobble >25 cm
      1) cobble 12.5-25 cm
      2) small cobble 6-12.5 cm
      3) gravel 2-6 cm
      4) sand 0.1-2 cm
      5) soil

   c) vegetative cover as % roots, forbs, perennial grass, sedge, willow
      1) 75-100
      2) 50-75
      3) 25-50
      4) 10-25
      5) 5-10
      6) 0-5

   d) signs of instability

2) Upper bank
   a) angle
   b) material
   c) vegetative cover
   d) signs of instability

Transect S24	
Lower Bank	
a) angle	actual: 1.2 m, 25° 0.6 m, 90° net: 1.9m, 40°
b) material	1) 25 2) 20 3) 30 4) - 5) 25
c) vegetative cover	<5
d) signs of instability	loose rock and soil
Upper Bank	
a) angle	0°
b) material (% by category)	1) 1 2) 2 3) 5 4) - 5) 92
c) vegetative cover (%)	5-10
d) signs of instability	surface looks heavily trampled

Transect S23	
Lower Bank	
a) angle	0-10°; very wide cobble bar
b) material	1) 35 2) 35 3) 25 4) - 5) 5
c) vegetative cover	alder cover only next to stream; within 4 m of water; no shrub cover; majority of bar (~70 m wide) has 0-5% cover.
d) signs of instability	stable large cobble
Upper Bank	
a) angle	0-10°; grades imperceptibly onto upland at 70 m from water
b) material (% by category)	1) 2) 3) 4) 5) 100
c) vegetative cover (%)	5-10
d) signs of instability	much bare soil, heavy disturbance

Transect S21	
Lower Bank	
a) angle	3.7 m, 10° 1 m, 57°
b) material	1) 5 2) 20 3) 30 4) 30 5) 15
c) vegetative cover	0-5
d) signs of instability	stable cobble; alders are at stream edge
Upper Bank	
a) angle	0-10°
b) material (% by category)	0) 5 1) 25 2) 35 3) 25 4) - 5) 10
c) vegetative cover (%)	0-5
d) signs of instability	cobbled floodplain from past floods; poor vegetation condition, mostly cheatgrass

Transect S19	
Lower Bank	
a) angle	3.0 m, 21°,
b) material	1) 0 2) 20 3) 25 4) 35 5) 20
c) vegetative cover	0-5
d) signs of instability	cobble and sand bank; fairly stable
Upper Bank	
a) angle	0-10°
b) material (% by category)	1) 2) 3) 4) 5) 100
c) vegetative cover (%)	40% shrub/forb
d) signs of instability	ground cover poor; just cheatgrass

Transect S17	
Lower Bank	
a) angle	3.0m, 15°
b) material	0) 0 1) 10 2) 15 3) 20 4) - 5) 55
c) vegetative cover	5
d) signs of instability	gentle slope but easily erodible; minimum vegetation cover by sage, rabbitbrush
Upper Bank	
a) angle	0-10°
b) material (% by category)	1) 2) 3) 4) 5) 1m wide soil island; overflow channel on R side; steep eroded soil face
c) vegetative cover (%)	0-5% cover; sage
d) signs of instability	easily erodible

Transect S16	
Lower Bank	
a) angle	1 m, 25° 0.7 m, 90°
b) material	1) 2) 3) 4) 5) 100
c) vegetative cover	none
d) signs of instability	easily erodible soil vertical face
Upper Bank	
a) angle	0-10°
b) material (% by category)	1) 2) 3) 4) 5) 100
c) vegetative cover (%)	15
d) signs of instability	cheatgrass, bare soil, sage

Transect S15	
Lower Bank	
a) angle	1.0 m, 25° 0.7 m, 90°
b) material	0) 1 1) 30 2) 30 3) 30 4) 9 5) -
c) vegetative cover	none, easily erodible soil, vertical face. Sparse tree cover at stream edge lining edge of cobble bar. Birch at S15, within 5 m dstr of transect line, rose at base of tree
d) signs of instability	S15-S16 all looks the same
Upper Bank	
a) angle	0-10°
b) material (% by category)	1) 2) 3) 4) 5) 100
c) vegetative cover (%)	5-10 shrub cover is sage, rabbitbrush, forb, poison hemlock
d) signs of instability	cheatgrass, bare soil

Transect S13	
Lower Bank	
a) angle	1 m, 48°
b) material	1) 2) 3) 5 4) 5) 95
c) vegetative cover	0-5 mostly mullein
d) signs of instability	sloughing, bank breakdown, easily eroded soil, damage by cattle
Upper Bank	
a) angle	0-10°
b) material (% by category)	1) 2) 3) 4) 5) 100
c) vegetative cover (%)	20% by sage, tumble mustard, white blossom sweetclover, poison hemlock, mullein, buckwheat; ground layer cheatgrass
d) signs of instability	stomped by cattle, most forbs are dead and dry, sage is old and large where present

Transect S11	
Lower Bank	
a) angle	3 m, 20°
b) material	1) 0 2) 0 3) 0 4) 5 5) 95
c) vegetative cover	100% canopy cover by alders >6 m;
d) signs of instability	No shrub cover, forb/grass 0-5%. Large trees stabilize soil/sand bank
Upper Bank	
a) angle	0-10°
b) material (% by category)	1) 0 2) 0 3) 0 4) 1 5) 99
c) vegetative cover (%)	alder and birch canopy for 2.5 x 5 m plot is 90% but provides no protection to ground. No trees rooted on upper bank. Total veg. cover 1% by rabbitbrush, mock orange.
d) signs of instability	loose sand and gravel

Transect S9	
Lower Bank	
a) angle	2.3 m, 20°
b) material	1) 15 2) 25 3) 30 4) 30 5) -
c) vegetative cover	alder 100% canopy cover; woody debris 30%
d) signs of instability	stable bank
Upper Bank	
a) angle	3-5 m wide remnant bank, 0-10° surface, overflow channel cut on outer side of this remnant.
b) material (% by category)	1) 5 2) 5 3) 5 4) 89 5) -
c) vegetative cover (%)	loose sand surface with very little vegetation; No trees rooted on upper bank. Shrub cover 0-5% mockorange; white blossom sweetclover, no grass.
d) signs of instability	loose sand

Transect S7	
Lower Bank	
a) angle	2 m, 20°
b) material	0) 1 1) 30 2) 35 3) 25 4) 9 5) -
c) vegetative cover	100% alder; alders >6 m ht) Ground cover 1% by roots.
d) signs of instability	heavily armored bank, good tree cover
Upper Bank	
a) angle	5 m, 10°
b) material (% by category)	0) 1 1) 30 2) 35 3) 25 4) 9 5) -
c) vegetative cover (%)	100% alder canopy; ground cover 2% by tree stems, mockorange, poison hemlock.
d) signs of instability	heavily shaded, large alders create shade, little ground cover but good stability by cobble

Transect S5		
Lower Bank		
a) angle	2.7, 23° 3.2, 25°	
b) material	1) 2 2) 3 3) 1 4) - 5) 94 lower portion	1) 10 2) 25 3) 25 4) - 5) 40 upper portion
c) vegetative cover	74% by sedge, 6% by rock on lower portion of slope. Ground is 94% sedge, 6% rock.	20% alder canopy on upper portion of lower bank, 5% cover by mullein, thistle, tumble mustard, 5% alder not rooted on upper portion.
d) signs of instability	grazed but stable area	
Upper Bank		
a) angle	0-10°	
b) material (% by category)	1) 2) 3) 4) 100 5)	
c) vegetative cover (%)	20% mockorange	
d) signs of instability	ground is predominantly bare soil disturbed by cattle	

Transect S3	
Lower Bank	
a) angle	3.8 m, 22°
b) material	0) 1 1) 5 2) 5 3) 39 4) - 5) 50
c) vegetative cover	10% alder (not rooted on plot) 0-5% sedge 0-5 forb total ground cover 0-5%
d) signs of instability	soil banks broken down and eroding; good alder cover upstream of plot
Upper Bank	
a) angle	0-10°
b) material (% by category)	1) 2) 3) 4) 5) 100
c) vegetative cover (%)	no veg. cover only cheatgrass (sparse)
d) signs of instability	cobbled terrace, sparse vegetation, disturbed surface

Transect S1	
Lower Bank	
a) angle	2.2 m, 49°
b) material	1) 2) 3) 4) 5) 100
c) vegetative cover	60% alder 20% sedge 20% forb total ground cover 40%
d) signs of instability	bank sloughing in places; cattle prints in sedge area, 50% cropping of sedge bulk
Upper Bank	
a) angle	0-10°
b) material (% by category)	1) 2) 3) 4) 5) 100
c) vegetative cover (%)	40% cover by knapweed and poison hemlock; remainder is foxtail barley
d) signs of instability	trampled vegegation by cattle in places; trail carved to water just downstream of transect; heavy bank damage on trail.

Transect N23		
Lower Bank		
a) angle	4.0 m, 20° (bank at lower flow) cobbled overflow channel on outer side of streamside berm, width?	1.0 m, 15° (bank at higher flow) 3.5 m, 7°
b) material	0) 0 1) 5 2) 10 3) 25 4) 60 5) - low flow bank	
c) vegetative cover	60% by alder	
d) signs of instability	good cover by vegetation and debris	
Upper Bank		
a) angle	0-10°	
b) material (% by category)	0) 0 1) 15 2) 20 3) - 4) - 5) 65 for lower bank on outer channel margin;	0) 1 1) 2 2) 20 3) 30 4) 10 5) 37 upper bank at outer channel margin
c) vegetative cover (%)	0-5 shrub 5 woody debris	
d) signs of instability	heavy soil disturbance by cattle; poor vegetation cover, stubble surface	

Transect N21	
Lower Bank	
a) angle	4.5 m, 10°
b) material	1) 20 2) 40 3) 25 4) 15 5) -
c) vegetative cover	2% shrub/tree on whole lower bank surface; 5 m length
d) signs of instability	cobbled area stable
Upper Bank	
a) angle	0-10°
b) material (% by category)	1) 5 2) 30 3) 20 4) - 5) 45
c) vegetative cover (%)	5% cover--sumac, mt. mahogany, misc. forbs, juniper
d) signs of instability	very little ground cover by vegetation; cobbled area provides stability.

Transect N19	
Lower Bank	
a) angle	6 m, 31°
b) material	1) 25 2) 35 3) 25 4) 15 5) -
c) vegetative cover	100% alder cover; 5% choke cherry, mock orange, sedge
d) signs of instability	well stabilized by cobble, even though steep
Upper Bank	
a) angle	3.5 m, 31°
b) material (% by category)	1) 2 2) 25 3) 20 4) - 5) 53
c) vegetative cover (%)	50% alder cover, not rooted in plot 1% sage, 1% forbs or grass
d) signs of instability	??

Transect N17	
Lower Bank	
a) angle	3 m, 25°
b) material	1) 40 2) 35 3) 5 4) 19 5) -
c) vegetative cover	50% cover by mockorange, rose, poison ivy, choke cherry, sedge
d) signs of instability	heavy rock protects slope; fair veg. cover; large sedges at stream edge (when ungrazed are approx. 70cm tall); in this plot, approx. 85% of biomass of these sedge clumps was removed by grazing.
Upper Bank	
a) angle	4.5 m, 25°
b) material (% by category)	1) 5 2) 20 3) 20 4) - 5) 54
c) vegetative cover (%)	15% poison ivy, choke cherry, misc. forbs
d) signs of instability	steep slope, bank damage by cattle, surface disturbance.

Transect N15	
Lower Bank	
a) angle	3 m, 28°
b) material	0) 2 1) 15 2) 30 3) 30 4) 10 5) 13
c) vegetative cover	40% cover mockorange, alder, sedge
d) signs of instability	cattle trails on slope into water
Upper Bank	
a) angle	4.5 m, 28°; 0-10° debris floated 3 m upslope from current water surface level
b) material (% by category)	0) 0 1) 5 2) 5 3) 15 4) 15 5) 60
c) vegetative cover (%)	5% cover by rabbitbrush, sage
d) signs of instability	cattle loosened soil surface, cheatgrass sparse

Transect N13	
Lower Bank	
a) angle	2.4 m, 20°
b) material	1) 2 2) 5 3) 15 4) 15 5) 63
c) vegetative cover	5% cover by choke cherry, sedge, misc. forbs
d) signs of instability	poor veg. cover; exposed soil
Upper Bank	
a) angle	2.2 m, 83°
b) material (% by category)	0) 0 1) 5 2) 15 3) 10 4) - 5) 70
c) vegetative cover (%)	1% forb
d) signs of instability	unstable steep face

Transect N11	
Lower Bank	
a) angle	3.4 m, 39°
b) material	0) 1 1) 20 2) 40 3) 20 4) 19 5) -
c) vegetative cover	30% alder; not rooted on plot; 5% total ground veg. cover--forb, sedge, rooted alder sapling
d) signs of instability	fairly stable; lower bank--poor veg. cover; slightly small size cobble than average for plot
Upper Bank	
a) angle	1.4 m, 16°
b) material (% by category)	1) 10 2) 10 3) - 4) - 5) 80
c) vegetative cover (%)	no veg. on face; upper slope 0-10° has 5% sage cover; forb 1%
d) signs of instability	

Transect N9	
Lower Bank	
a) angle	0.8 m, 68° 2.1 m, 16° net slope is 2.6 m, 30°
b) material	0) 1 1) 25 2) 20 3) 10 4) 10 5) 34
c) vegetative cover	1% sedge
d) signs of instability	very unstable
Upper Bank	
a) angle	0-10°
b) material (% by category)	1) 1 2) 1 3) 1 4) - 5) 97
c) vegetative cover (%)	1% forb cover, turkey mullein
d) signs of instability	very unstable; churned by cattle, bare soil

Transect N7	
Lower Bank	
a) angle	1.1 m, 36° 2.1 m, 19°
b) material	1) 10 2) 30 3) 30 4) 10 5) 20
c) vegetative cover	5% turkey mullein
d) signs of instability	very unstable
Upper Bank	
a) angle	0-10°
b) material (% by category)	1) 10 2) 35 3) 30 4) 20 5) 5
c) vegetative cover (%)	10% sage, rabbitbrush
d) signs of instability	floodplain is cobbled; disturbed by floods to some degree;

<table>
<tr><th colspan="3">Transect N5</th></tr>
<tr><th colspan="3">Lower Bank</th></tr>
<tr><td>a) angle</td><td colspan="2">10 m, 0-10°
1.3 m, 25°
1.8 m, 90°</td></tr>
<tr><td>b) material</td><td colspan="2">1) 5
2) 10
3) 5
4) -
5) 80</td></tr>
<tr><td>c) vegetative cover</td><td colspan="2">no vegetation on face</td></tr>
<tr><td>d) signs of instability</td><td colspan="2">very unstable</td></tr>
<tr><th colspan="3">Upper Bank</th></tr>
<tr><td>a) angle</td><td colspan="2">upper bank starts at some unknown level on vertical face--possibly at top because of floated debris on upper terrace surface; upper terrace is 0-10°</td></tr>
<tr><td>b) material (% by category)</td><td>1) -
2) -
3) -
4) -
5) 100
for vertical face;</td><td>1) -
2) -
3) -
4) -
5) 100
for upper terrace surface</td></tr>
<tr><td>c) vegetative cover (%)</td><td>none;</td><td>1% sage and miscellaneous forbs</td></tr>
<tr><td>d) signs of instability</td><td>unstable;</td><td>5% woody floated debris on upper terrace surface</td></tr>
</table>

Transect N3	
Lower Bank	
a) angle	6.1 m, 32° high water reached most of the way up the bank; debris is 2.2 m high in trees along river
b) material	1) 5 2) 10 3) 5 4) - 5) 80
c) vegetative cover	4 large dead alders would have provided 80% cover, but no longer any leaf cover; ground cover is 5% by shrub, sedge, forb; 10% root mass by dead alders
d) signs of instability	unstable, much bare soil exposed; heavy cattle soil disturbance
Upper Bank	
a) angle	0-10°
b) material (% by category)	1) 0 2) 1 3) 1 4) - 5) 98
c) vegetative cover (%)	5% rabbitbrush
d) signs of instability	moderately heavy soil disturbance by cattle; cheatgrass; debris floated onto upper surface

Transect N1	
Lower Bank	
a) angle	4.2 m, 10°
b) material	1) 5 2) 5 3) 3 4) 3 5) 84
c) vegetative cover	10% willow, mock orange, alder seedlings, sedge
d) signs of instability	very unstable soil
Upper Bank	
a) angle	7.7 m, 5° floodplain area 0-10°
b) material (% by category)	1) 0 2) 5 3) 2 4) - 5) 93
c) vegetative cover (%)	2% forb
d) signs of instability	heavily disturbed area due to pickup truck travel to fishing area near river mouth

APPENDIX 4

Warm Springs Reservation Vegetation Species Checklist

The following table was provided by David Smith, BIA range conservation officer working at the CTWSRO. This table indicates commonly found species on the Warm Springs Indian Reservation, although all these species are not found within the current study area.

Trees	
Alnus	white alder
Abies grandis	grand fir
Juniperus occidentalis	western juniper
Libocedrus decurrens	incense cedar
Pinus ponderosa	ponderosa pine

Shrubs	
Arctostaphylos patula	manzanita
Artemisia dracunculus	herbaceous sagebrush
Alnus incana	alder
Artemisia tridentata tridentata	basin big sagebrush
Artemisia tridentata wyomingensis	Wyoming big sagebrush
Berberis repens	Oregon grape
Chrysothamnus nauseosus	gray rabbitbrush
Chrysothamnus viscidiflorus	green rabbitbrush
Comandra unbellata	bastard toadflax
Crataegus douglasii	black hawthorn
Lonicera involuerata	honeysuckle
Purshia tridentata	bitterbrush
Rosa sp.	wild rose
Ribes cereum	currant
Salix sp.	willow
Spiraea betulifolia	birch-leaf spirea
Symphoricarpos albus	common snowberry
Tetradymia canescens	horsebrush

Forbs	
Achillea millefolium	yarrow
Agoseris sp.	mountain dandelion
Allium sp.	wild onion

Forbs (cont.)	
Amsinckia sp.	fiddleneck
Anemone oregana	Oregon anemone
Anaphalis margaritacea	pearly everlasting
Antennaria rosea	pussytoes
Apocynum androsaemifolium	dogbane
Aster sp.	aster
Astragalus	milkvetch locoweed
Astragalus conjunctus	stiff milkvetch
Balsamorhiza sagittata	arrowleaf balsamroot
Balsamorhiza serrata	toothed balsamroot
Blepharipappus scaber	blepharipappus
Brodiaea hyacinthina	hyacinth blodiaea
Calochortus macrocarpus	Sego lilly
Calochortus sp.	mariposa
Castillija sp.	Indian paintbrush
Chenopodium album	pigweed
Cirsium arvense	Canadia thistle
Cirsium undulatum	wury-leaf thistle
Collinsia parviflora	blue-eyed mary
Collomia grandiflora	Collomia
Convolvulus arvensis	field bindweed
Cordylanthus ramosus	bushy bird beak
Crepis acuminata	hawksbeard
Descurainia pinnata	tansy mustard
Epilobium sp.	annual epilobium
Erigeron	fleabane
Erigeron filifolius	fleabane
Eriogonum douglasii	wild buckwheat

Eriogonum heracleoides	wild buckwheat
E. microtheca	wild buckwheat
Eriogonum sp.	wild buckwheat
E. phaerocephalum	wild buckwheat
Eriogonum strictum	wild buckwheat
Eriogonum umbellatum	wild buckwheat
Eriophyllum lanatum	Oregon sunshine
Erodium cicutarium	fillarie
Euphorbia glyptosperma	spurge
Balium boreale	bedstraw
Grindelia squarrosa	gumweed
Helianthus cusickii	Cusick's sunflower
Hypericum perforatum	Klamath weed
Idahoa scapigera	scalepod
Lactuca serriola	prickly lettuce
Linum lewisii	western blue flax
Lithospermum ruderale	stonecrop
Lomatium nudicaule	wild celery
Lomatium sp.	Lomatium
Lotus douglasii	Douglas lotus
Lotus purshianus	American lotus
Lupinus sericeus	silky lupine
Lupinus sp.	lapine
Machaeranthera canescens	hoary aster
Madia exigua	tarweed
Microsteris gracilis	tall microsteris
Orthocarpus	owl clover
Osmorhiza sp.	sweet cicely
Penstemon sp.	penstemon
Phoenicaulis cheiranthoides	daggerpod
Polygonum douglasii	Douglas' knotweed
Polygonum paryii	Parry's knotweed
Potentialla glandulosa	sticky cinquefoil
Prunella vulgaris	self heal
Pterospora andromedea	pine drops
Phacelia heterophylla	phacelia
Phlox sp.	Phlox
Ranunculus sp.	buttercup
Sanguisorba occidentalis	annual burnet
Sisymbrium altissimum	tumbleweed
Taraxacum officianale	dandelion
Trifolium macrocephalum	bighead clover
Trifolium repens	white clover
Tragopogon major	milkweed
Veratrum californicum	false hellebore
Viola sp.	violet
Wyethia amplexicaulis	mule's ears
Zigadenus sp.	death camas
Grasses	
Agropyron cristatum	crested wheatgrass
Agropyron spicatum	bluebranch wheatgrass
Agrostis exarata	spike bentgrass
Agrostis sp.	bentgrass
Bromus carinatus	mountain brome
Bromus mollis	soft chess
Bromus tectorum	cheatgrass
Carex microptera	ovalhead sedge
Carex sp.	sedge
Danthonia california	California oatgrass
Danthonia unispicata	one-spike oatgrass
Deschampsia danthonioides	annual hairgrass
Elymus cinereus	giant wildrye
Elymus glaucus	blue wildrye
Festuca idahoensis	Idaho fescue

Festuca pacifica	six-weeks fescue	
Juncus balticus	Baltic rush	
Koelena nitida	prairie junegrass	
Melica subulata	Alaska oniongrass	
Poa compressa	flat-stem bluegrass	
Poa pratensis	Kentucky bluegrass	
Poa secunda	Sandberg's bluegrass	
Poa sp.	Bluegrass	
Poa thurberiana	Thurber's needlegrass	
Sitanion hystrix	Bottlebrush squirreltail	
Stipa comata	needle and thread	
Stipa occidentalis	Western needlegrass	
Tainiatherum caput-medusae	Medusahead	
Triticum aestivum	wheat	

APPENDIX 5

Review and Notes on Literature on Vegetative Cover

Cover is defined as the percentage of the ground occupied by a perpendicular projection of the vegetation (Moore and Chapman 1986). For tree cover the mean canopy diameter for trees of various height classes can be used to calculate total canopy coverage by species. In addition, cover on plots of known dimension can be estimated visually. The total cover to a vertically stratified plant community may exceed 100%. Although a quantitative technique for cover estimation is less subjective and therefore more reproducible, visual estimates are often made. Visual estimation of cover is rapid and the problems of subjectivity may be overstated in some of the literature (Kent and Coker 1992). Visual estimates of cover were made on quadrats of sizes selected to match the plant forms identified (i.e., tree, shrub, forb, grasses). Cover was also measured from GIS mapping from aerial photographic interpretation of major plant forms. Ground-based estimates were correlated with GIS-based map estimates. Photographs were also taken on the ground at each transect line. Photopoints on each transect line were located at a distance of 20 m from the active water on each bank and looking toward the river. Digital scans of these images could be used to further evaluate the ability to estimate cover from side views of the streamside canopy or to correlate measures of canopy density with GIS cover estimates..

The following notes on cover estimation are for the purpose of giving some perspective to selection of the ocular technique used in the Warm Springs surveys. Although other techniques are available, it appears to be doubtful that they would be preferable. For example, more quantitative techniques tend to be very labor intensive. Although they might provide accurate estimates on small plots, extrapolation to large streamside zones will be frequently invalid unless many sites are surveyed. Techniques based on aerial or satellite surveys provide broad geographic coverage, but can suffer from inability to highlight the streamside zone from the general rangeland.

Other methods employed for evaluating riparian vegetation include measures of cover, density, and height class diversity. Cover can be estimated over the streamside zone or shading measured over the stream, accounting for solar angle and season. Vegetation can be analyzed by canopy density or gaps, lending itself to estimation by line of sight methods through canopy, light penetration measurement, or digital canopy analysis.

Estimates of canopy cover by height category and growth form (tree, shrub, herbaceous) are frequently made in riparian vegetation evaluation (Myers 1989). Height classes recommended by Meyers (1989) were 0-0.08 m, 0.08-0.6 m, 0.6-1.5 m, 1.5-3 m, 3-8 m, and 8+ m. It is also useful for management purposes to distinguish cover for specific vegetation taxa of interest, such as willows, cottonwood, alder, pine, juniper, sagebrush, rushes, sedges, etc.

Canopy cover (not differentiated by species or plant form) is frequently measured quantitatively by use of a spherical densiometer or a solar pathfinder. The spherical densiometer (model B, see Platts et al. 1987) is used to estimate canopy density. This instrument is placed at a height of 12 inches above the stream near the right and left banks and in the middle of the stream, oriented in a downstream and then an upstream direction. The percentage of the 17 intersection points on the grid of the concave

mirror that are surrounded by vegetation when viewing the mirror is an index of canopy density. The overall density is calculated by averaging the readings from all positions on the transect. The solar pathfinder is an instrument used to gain an index to the interception of light by the vegetation canopy and surrounding topography. After placing the instrument above the stream surface, oriented relative to true south, the reflection of the horizon line (line separating the tree tops or topography from the sky) is traced on the pathfinder's graph paper. This special graph allows one to integrate the solar input possible under a cloudless sky for any day of the year. A drawback to use of the pathfinder is that density of the canopy (gaps in the canopy) is not accounted for in tracing the horizon line. Also, in many situations canopy will obscure topography that may shade the channel. This shading may be more significant than the shading by vegetation. The densiometer does estimate the continuity of the canopy but doesn't allow one to estimate the cover in different months as the sun's elevation changes. For either method to evaluate streamside vegetation recovery and trends in cover, the measurements would need to be taken at sampling locations on the banks rather than in the stream.

A method likely to be very successful in providing the information captured by both the pathfinder and the densiometer is use of a digital camera with a wide angle lens. The digital camera can be oriented south at a known elevation to the canopy from various points on a channel transect. The Kodak DC50 digital camera, for example, comes with a 37 mm to 111 mm focal length lens and provides reasonably high resolution images of 756 x 504 pixels. The built-in data storage (1 MB) allows 7 images of highest quality to be stored. At lower resolution 22 images can be stored. The camera plus software for enhancing photos costs $950 at Camera World Co. Storage cards of 5-MB size (cost $340) can be inserted into the camera to hold additional images. Data can be downloaded to a computer from the cards or from the camera directly. Analysis might consist of differentiating sky or clouds from vegetation, branches, or topographic features on the basis of color. A spherical densiometer samples only 17 points for any placement. The digital camera provides the opportunity to query all pixels below the line defined by the solar path. This method does not account for the number of layers of leaves that provide light filtering for each pixel; only a light meter would provide this capability. It would, however, increase the ability to objectively and accurately assess total light input and canopy density, to make this assessment rapidly, and to create a permanent photographic documentation of the riparian zone condition.

When working with herbaceous vegetation, cover pin frames or frames of cross-wires are conveniently used to quantitatively estimate the percentage of intersections with ground vegetation (Moore and Chapman 1986). A set of cross-wires suspended over a mirror aimed skyward could be employed to make similar estimates of the overhead canopy cover. An alternative to this procedure would be to use a digital camera with a fish-eye lens aimed vertically upward to capture the canopy cover. A cheaper alternative is to use a conventional camera with wide angle or fish eye lens to photograph the canopy and to scan the resulting negatives. Loading the image onto a computer could allow software to statistically sample pixels to distinguish those that contain leaves and branches from those that contain sky. Heisler (1983) used a photographic technique with grid intersections to determine canopy visual density and found a high degree of correlation with pyranometer readings through the canopy. Other similar procedures were presented by Frazer et al.(1997).

In addition to estimation of cover by height class and vegetation form (tree, shrub, forb, grass), estimation of the density of woody species that exceed 1 cm basal diameter is a useful method. For willows, discrimination of effects of grazing can be made by observing stem diameter frequencies between 0.1 and 3.5+ cm (Myers 1989). Myers (1987)(as cited by Myers 1989) counted willow stems in classes of 0.5 cm intervals. To eliminate some of the time consuming aspects of this analysis, it

could be efficient not to count stems < 1 cm diameter. For coniferous species it would be more reasonable to count stem densities in fewer classes (e.g., 1-5 cm, 5-10 cm, 10-20, 20-40 cm, 40-60 cm, and 60+ cm).

A rapid, useful companion to estimation of tree density is a plotless method, the nearest individual method. This method requires measuring the distances to *n* nearest individuals of each species of interest from randomly selected locations (see Mueller-Dombois and Ellenberg 1974, as cited by Kent and Coker 1992). These starting locations can be randomly drawn from a line parallel to and at a fixed distance (e.g., 2 m) from the channel margin. Computation of tree density is:

$$\text{Mean area} = (\text{mean distance to nearest n individuals of a species})^2$$

$$\text{Tree density for a species} = (\text{mean area}/2)^{0.5}$$

This method, however, may not adequately distinguish the extent of riparian recovery. That is, as the riparian zone increases in width with full protection there may be little change in mean distance to nearest individuals, assuming that a 1-m wide zone of riparian vegetation has the same tree density as when the riparian zone expands to a 10-m width. If the vegetation is stratified in these two cases, one would be evaluating a plant community of 1-m width in one case and 10-m width in the other. The simplicity and reproducibility of this method make it desirable for vegetation analysis. However, the potential for error when sampling near the boundaries of the vegetation zone require further consideration in its use.

At the same randomly drawn points along the stream margin or on each of the transect lines, vegetation structure can be evaluated using a profile board (Myers 1989). A convenient modification of the equipment described by Myers would be to use a 7-m long telescoping fiberglass stadia rod as the profile board. The technique requires standing the rod vertically at randomly selected locations and viewing the rod at a distance of 15 m from a randomly selected direction. The percentage of each meter length of the rod that is visible through the foliage represents the visible canopy density. Because canopy density of a rod placed at the stream margin as seen from the center of the stream does not reflect canopy density that functions as shade, this technique would appear to be most useful as a structure index when the rod is viewed from a distance of 15 m upstream or downstream of the randomly selected point. For purposes of estimating shade cover, it would probably be even more effective to measure structure using the rod by viewing a vertical rod placed at the stream margin on each transect line from a position of 15-m distance on the transect line itself. These data, in addition to total tree height in the riparian zone, channel orientation, and canopy gap, would be useful in predicting solar input to the stream.

Satellite imagery analysis is another method that could be useful to evaluate rangeland condition and trends. If resolution can be adjusted so that area covered by a pixel is relatively small on the ground, streamside or riparian vegetation condition could be differentiated from general rangeland. The CTWS has Landsat TM coverage for the entire reservation from 1993 and also SPOT panchromatic imagery from September 1995. Resolution of Landsat TM is approximately 30 m and that of SPOT is 10 m. Landsat TM imagery is multispectral and can be used to calculate amount of vegetation cover. These estimates correlate highly with ground-based cover estimates (Foran and Pickup 1984, as cited by Pickup et al. 1994). Pickup et al. (1994) recommends use of the PD54 index based upon Landsat MSS data. This index effectively discriminates soil and vegetation cover using available bands. He also recommends detecting vegetation from an MSS scene taken during the dry season to represent the

permanent vegetation rather than more transitory herbaceous vegetation that responds quickly to precipitation but then dies away.

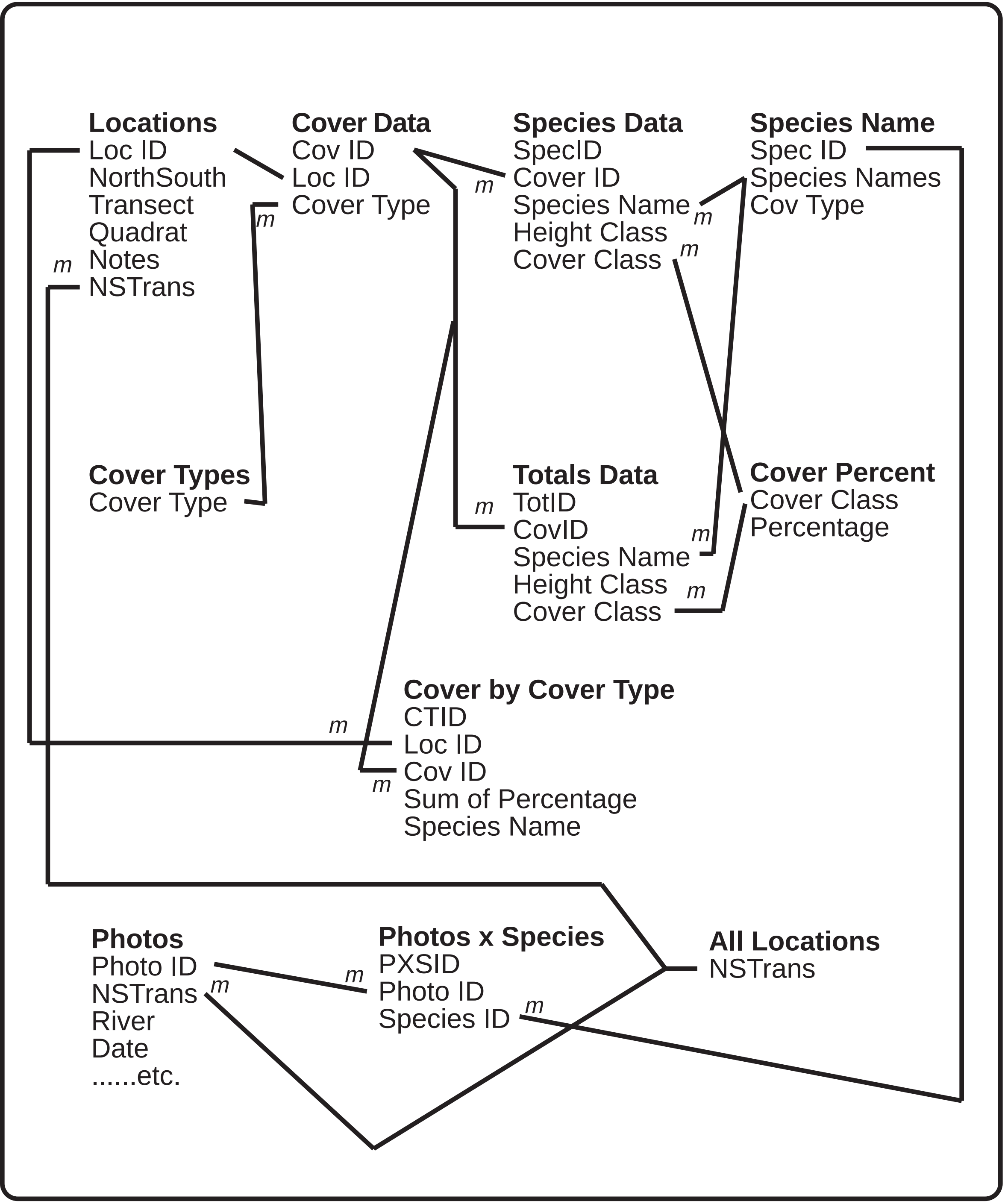
Range condition can be assessed using the WPAC method (wet period average cover)(Pickup et al. 1994) from Landsat data. By this method the vegetation cover detected after a period of the most effective precipitation during the growth period leads to a maximum temporary vegetative cover. A large, above average rainfall in one year leading to a large growth response will also contribute to a large growth response in succeeding years of average precipitation. Cover at any time consists of response by a combination of ephemeral, perennial, and tree/shrub vegetation. Degraded rangeland will not have as great a response to precipitation events an undegraded or well managed rangeland. Comparison of the maximum cover on upland and riparian land for grazed and ungrazed lands would indicate the effect of grazing or reduction in grazing intensity.

Another suggested method is to assess resilience (the RM method of Pickup et al. 1994) of rangelands (both uplands and riparian areas in grazed and also ungrazed reference watersheds). This method requires following the trend in satellite imagery of rangeland through the growing season as precipitation events occur and grazing effects accumulate.

APPENDIX 6

Documentation on Databases Used in Data Compilation and Analysis

The documentation of Access databases (WSPlants6.mdb, VegAnal2.mdb, and Band-data.mdb) can be found in WordPerfect 5.2 file "relaton3." This file is on file at the Columbia River Inter-Tribal Fish Commission and will be placed on the CD that will store all documents, databases, GIS project files, and scanned photos. Linkages among the various data tables in the WSPlants6.mdb database, showing the one-to-many relationships, are depicted in Figure 30.



In all one-to-many relationships, **m** indicates the many side of the relationship.

Figure 30. Relationships among the key tables in the WSPlants6

APPENDIX 7

Channel Widths Measured at Transect Lines

Data were taken by measuring minimum wetted surface width from GIS map
Stream width was measured using the measuring tool on GIS.

Start at the point where the transect line intersects
the north river margin and measure shortest distance to opposite stream margin.

File RivCover.xls

Transect No.	**Min. water width (m)**		
0	36.41	main	side
1	27.00		
2	23.19		
3	20.55		
4	22.33		
5	26.00		
6	20.50		
7	17.84		
8	14.42		
9	29.11		
10	22.16		
11	22.63		
12	20.95		
13	20.71		
14	21.95		
15	20.53		
16	21.95		
17	20.85		
18	23.73	15.90	7.83
19	20.68	16.25	4.43
20	20.83		
21	23.76		
22	32.40		
23	52.31	39.63	12.68
24	36.41		
	619.20	total width	
	24.77	mean width (m)	

Distance from center of transect 0 to center of transect 24 is 919.95m

Area of the channel between transect 0 and 5 m upstream of transect 24 is 22804.5 m2

Mean channel width for this 925 m channel length is 22805/925 = 24.65 m

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