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Using cottonwoods as indicators of past floods along a gravel-bedded stream

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USING COTTONWOODS AS INDICATORS OF PAST FLOODS ALONG A GRAVEL-BEDDED STREAM

By

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Using Cottonwoods as Indicators of Past Floods on a Gravel-Bedded Stream.

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Research was conducted along Dupuyer Creek to see if valley cross-sections and associated cottonwood ages and locations could be used to identify and date abandoned channels on Theodore Roosevelt Memorial Ranch, Montana. Plains cottonwoods regenerate by seed only in the aftermath of flooding. Thus they can be cored and their ages determined to date floods that allowed their regeneration. The dendrochronological and spatial data from the cottonwoods and cross sections were then combined with aerial photographs in a geographical information system (GIS). In ungaged watersheds such techniques may be useful in determining past floodplain dynamics as well as geomorphic trends. This study showed how even-aged cottonwood stands can be used to identify abandoned channels and floodplain conversion to terrace. The research suggests that large-scale geomorphic change has occurred episodically over the past century.

ACKNOWLEDGEMENTS

The Boone and Crockett Wildlife Conservation provided the generous financial support for this project, as well as an outstanding location to do research. Donald F. Potts extended a wonderful opportunity for a relative neophyte to become a hydrologist, and for that I am grateful. Andrew L. Sheldon was a careful critic whose interest in useful research is a continual inspiration. John J. Donahue questioned my methods and direction so persistently that something worthwhile actually became of this project! Helen Y. Smith provided invaluable technical support in tree-coring and analysis. Peter M. Semen, an old friend from undergraduate school, assisted me during the bulk of the field work in exchange for food, beer, and a ticket to the rodeo; I think his price has risen considerably since then! My parents, Mara L. and William E. Watson, have continually supported me both morally as well as financially throughout my varied academic pursuits, never questioning my reasons—no son is luckier than I. Jennifer A. Newland provided me with the essential criticism, encouragement and day-to-day moral support without which I could not have succeeded.

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INTRODUCTION

Large floods, such as those of 1964 and 1975, have had a tremendous impact on streams along the Northern Rocky Mountain Front (Boner *et al.*, 1967; Johnson *et al.*, 1976). New channels were incised, downcutting and scour occurred, and vast quantities of riparian vegetation were removed. Much of the area has been slow to recover, and examination of the currently active floodplains shows little accumulation of fine sediments from lesser floods. Heavily scoured areas remain paved with gravels, cobbles and even boulders. This will certainly influence the future migration and development of channels.

Aerial photographs taken prior to 1964 show well-vegetated creek bottoms, far less disturbed than after. But the earliest photos also show abandoned channels and a healing landscape in 1937, suggesting that flood damage had been rather extensive before the time of image acquisition, and possibly before the turn of the century.

Today abandoned channels furrow the creek bottoms and terraces jut above the active floodplains. Not all of these features are remnants of the '64 and '75 floods. In fact some may have been abandoned for as long as 80 years or more, as evidenced by time series comparison of aerial photos. But can these features be identified as abandoned channel segments? When were they last active? Research (Everitt, 1968) suggests that plains cottonwood (*Populus deltoides*) can serve as an indicator of past flood events. The present study is an attempt to identify abandoned channel segments and date their activity using the dendrochonology of associated cottonwoods.

LITERATURE REVIEW

Cottonwood Ecology

Recruitment of plains cottonwood (*Populus deltoides*) has been linked to flood processes (Read, 1958; Everitt, 1968; Bradley *et al.*, 1986; Everitt, 1995). Everitt (1968), showed that *P. deltoides* galleries are created on point bars in stream channels when flood stages greater than the bankfull flood coincide with cottonwood recruitment (late spring--early summer). He also found that primarily seed-generated *P. deltoides*, rather than as clones, form the riparian canopies. Read (1958) found that cottonwoods require disturbed sand or coarse soil, initial absence of competition from other species, and full sunlight with abundant and stable supply of groundwater near the surface for seed regeneration. This suggests that determination of the age of canopy cottonwoods can tell the age of the alluvial deposits on which they grow (Merigliano, 1996).

Rood *et al.* (1994) offered a dissenting view which suggested cottonwoods may reproduce just as effectively via asexual means. This study focused strictly on numbers of "small" cottonwoods recruited, which did not account for later senescence. Their work also did not focus on *P. deltoides*. Just so, the authors recognized that even clonal reproductive mechanisms such as suckering and flood training are influenced by hydrologic events.

Rood *et al.* (1993a) pointed to the alteration of natural flood regimes by diversion for irrigation, as well as by dams, as deleterious to cottonwoods since subsequent instream flows are often depleted, leading to drought stress and accelerated mortality. Other work (Rood *et al.*, 1993b) demonstrated five hydrological elements that are essential for cottonwood seedling establishment and initial survival. First, peak flows must prepare germination sites. Second, floodwaters must recede at the proper time to coincide with seed release. Third, the rate of water table decline must be gradual enough to limit seedling drought stress and promote root growth. Fourth, summer flows must remain high enough to meet the evapotranspirational demands. Fifth, autumn flows must be sufficient to sustain plant water balance and over-winter survival. All these factors strengthen the assertion that the life cycle of cottonwood depends upon the seasonal pattern of flooding (Bradley *et al.*, 1986; Everitt, 1995).

Dendrogeomorphology

Clark (1987) showed that cottonwoods produce annual rings; thus, the age of a cottonwood can be determined by counting its rings. She used precisely-dated cottonwood chronologies to gain a more thorough understanding of a fluvial system. An increment borer is inserted into the bole of a tree and directed at the tree center so as to extract the pith

(Maeglin, 1979; Phipps, 1985). Some species grow with enough uniformity that cores can be extracted at breast height and an age correction factor can be added to account for rings missed below breast height. Unfortunately this is not the case with cottonwoods. Typically cottonwoods are cored at the root collar, located at the basal root flare, to ensure that all the rings have been extracted (Clark, 1987; Everitt, 1968; Everitt, 1995; Merigliano, 1996). Finding the root collar sometimes requires excavating the base of the tree due to sediment accumulation from overbank deposition. The level of the root collar is effectively the surface upon which the seed sprouted. Therefore the age of the tree can be considered the age of the alluvial deposit.

Paleohydrology

Historical streamflow data can be invaluable in assessing how mountain streams have adjusted to past changes in land use, hydrology, and climate (Smelser *et al.*, 1998). But such data are not always available: records often have gaps; gages may not have been in place for very long; streams of interest may never have been gaged. In the absence of streamflow data, engineers must rely on indirect methods of analysis to determine the magnitude and frequency of floods (Sigafoos, 1964). Paleohydrology is the study of paleoflood characteristics recorded by historical, botanical, or geological indicators (Wohl *et al.*, 1995). Although incomplete, botanical indicators can provide accurate flood chronologies (Fanok *et al.*, 1997). Botanical indicators include corrasion scars, adventitious roots, ring anomalies, and tree age (Hupp, 1988). Tree age can indicate the age of a disturbance event that produced the tree, and in the case of cottonwoods, the most likely event is flood (Everitt, 1968).

Sigafoos (1964) posited that evidence of floods and floodplain deposition as seen in trees presents an irrefutable record of past floods. He cited the presence of old trees on the vertical face of banks along the Potomac River as evidence that these banks have been stable for the lifespan of the trees.

PURPOSE AND OBJECTIVES

This study seeks to evaluate the use of cottonwoods as indicators to reconstruct past flood events that have shaped Dupuyer Creek. Specifically, the objectives are:

1) to identify abandoned channel segments;
2) to date the activity of those segments with the associated cottonwood ages;
3) to link identified abandoned channel segments from one sampling unit with others; and,
4) to link identified abandoned channel segments with those identified in old aerial photographs.

THE FIELD SITE

Field work was conducted on Dupuyer Creek on the Theodore Roosevelt Memorial Ranch (TRMR), located in Teton County, approximately 120 kilometers northwest of Great Falls, Montana (see figure 3.1). TRMR is owned by the Missoula-based Boone and Crockett Club and is run as a working cattle ranch, wildlife management area. The Ranch is also used for research.

Dupuyer Creek flows northeast from the Sawtooth Mountains in the Northern Rocky Mountain Front and drains 83 square kilometers (see figure 3.2). The estimated drainage density to TRMR, excluding crenulations, is .98 km/km^2, low for the Rocky Mountain region (Moeckel, 1997). The main stem of Dupuyer Creek at the Ranch proper is a sixth order stream. The creek bottom is cut into an alluvial valley with numerous terraces, probably laid down as glacial outwash.

Recent streamflow monitoring yields an estimate for bankfull discharge of 220 cfs at the lower end of the studied reach. Whitaker (1997) demonstrated that Dupuyer Creek is capable of transporting nearly all of its bed material at bankfull discharge. Much of the riparian zone surrounding the main stem is grazed by cattle throughout the spring and summer. Some of the riparian zone is excluded from cattle simply because of steep hillslopes and beaver ponds.

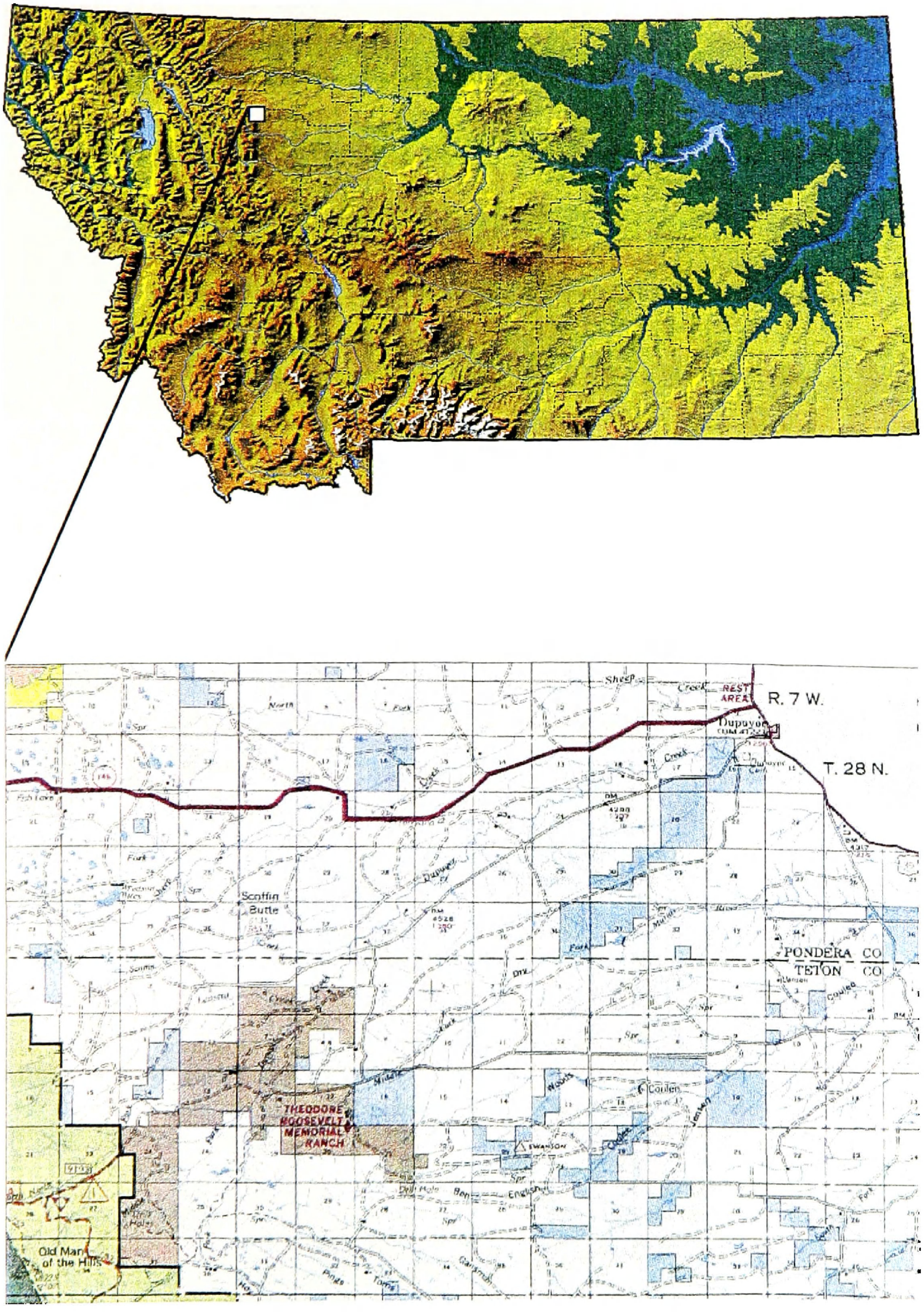

Figure 3.1: Above, shaded relief map of Montana, with the study site indicated; below, Lewis and Clark National Forest map with TRMR's boundaries.

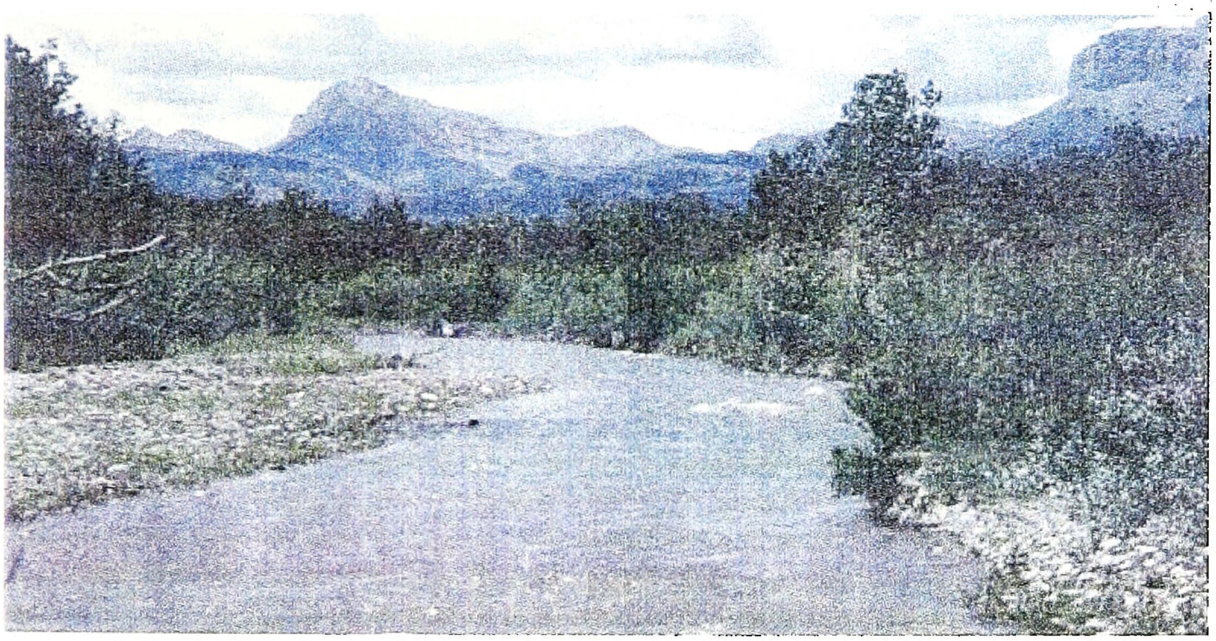

Figure 3.2: Above, photo looking up Dupuyer Creek towards Bob Marshall Wilderness in June, 1998; below, 1995 aerial photograph of Dupuyer Creek.

The creek bottom is characterized by abandoned watercourses and raw cut banks. Avulsion has occurred in many places, and the abandoned segments have become shallow ponds and swamps as beaverdams accumulate sediment in their sluggish flows. Recent (in the last 100-200 years) downcutting of the channel beds has initiated rejuvenation of the floodplain over much of the main stem of Dupuyer Creek. Overbank deposition is rare and scour frequent over much of the studied area. These areas of degradation were selected for the purpose of determining the age of floodplain scouring events. One area was selected for its lack of scour, to examine a portion of the creek bottom that had undergone minimal change in this century.

Previous studies on Dupuyer Creek (Moeckel, 1996; Whitaker, 1997) have focused on the stream channel cross-section and dynamics therein. Moeckel established permanent cross-sections throughout current study area. Given the recency of measurement of those cross-sections, it can be assumed that channel geometries at the time of this study were the same as in 1996.

Dupuyer Creek has abandoned many channel segments during flood events of this century. Flooding has scoured out alluvial deposits meters thick in many locations. Previously abandoned channels have been reoccupied and modified. This magnitude of channel movement and geomorphic change cannot be measured by active channel cross-sectional monitoring. The current study was designed to investigate such change, to measure it using smaller-scale surveying, and to date it using botanical indicators (see figure 3.3). While large-scale channel cross-section monitoring is an important tool in examining the effects of floods and riparian management activities, measurement of valley cross-sections may tell us more about how a stream has responded to catastrophic floods, and perhaps how it may respond to such events in the future.

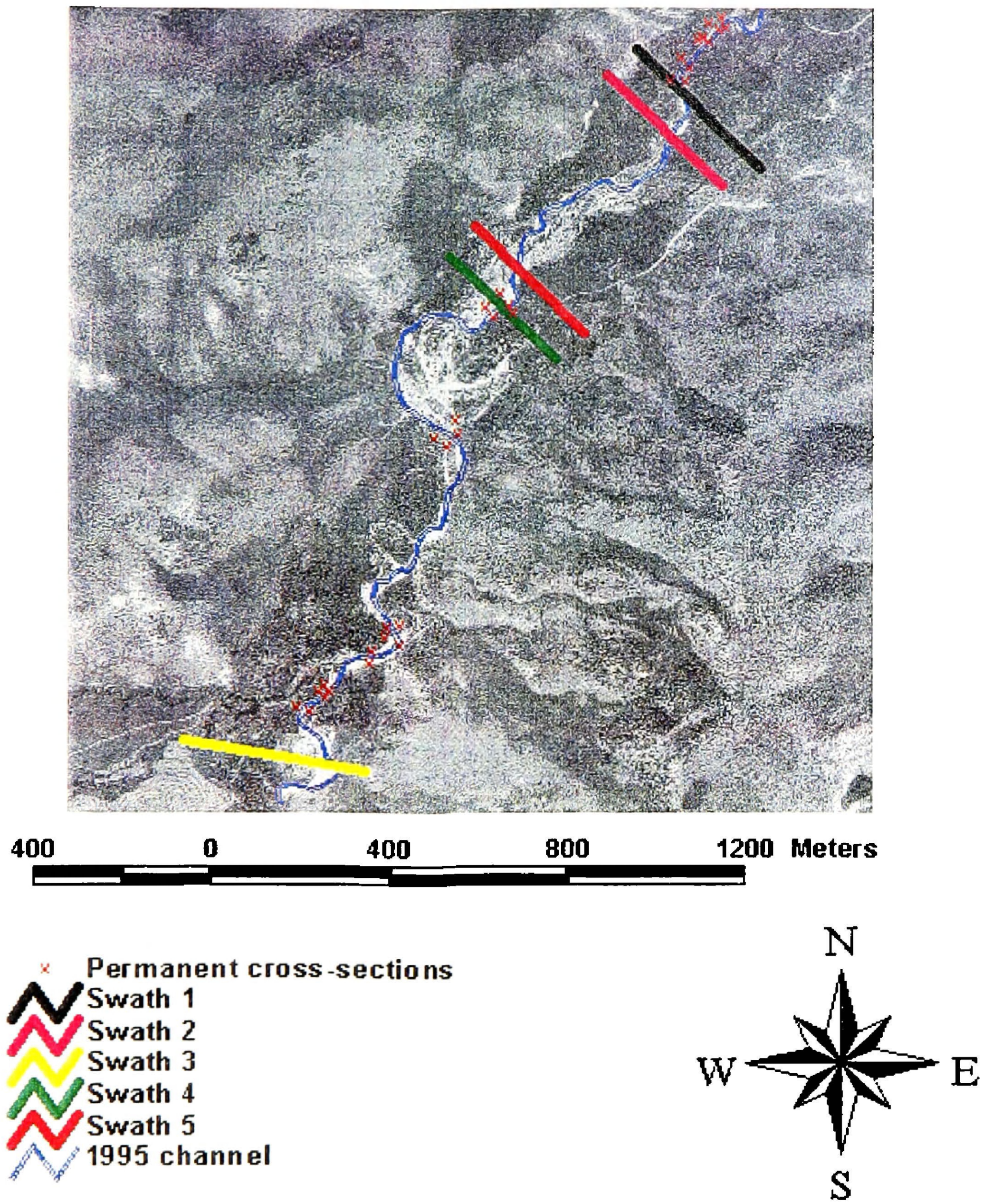

Figure 3.3: Overview showing locations of valley-width cross-sections as well as monumented channel cross-sections.

METHODS

Field Work

The Sampling Unit

The sampling units consisted of pairs of parallel transects perpendicular to valley length. Along these transects elevation data were recorded at about 1 meter intervals. Transects were spaced 15 meters apart. Cottonwoods inside as well as 10 meters outside the paired transects were mapped to provide x, y, and z data for each tree using meter tape, compass, and laser level. This corridor, 35 meters wide, constituted a "swath" (see figure 4.1). Five swaths in all were sampled.

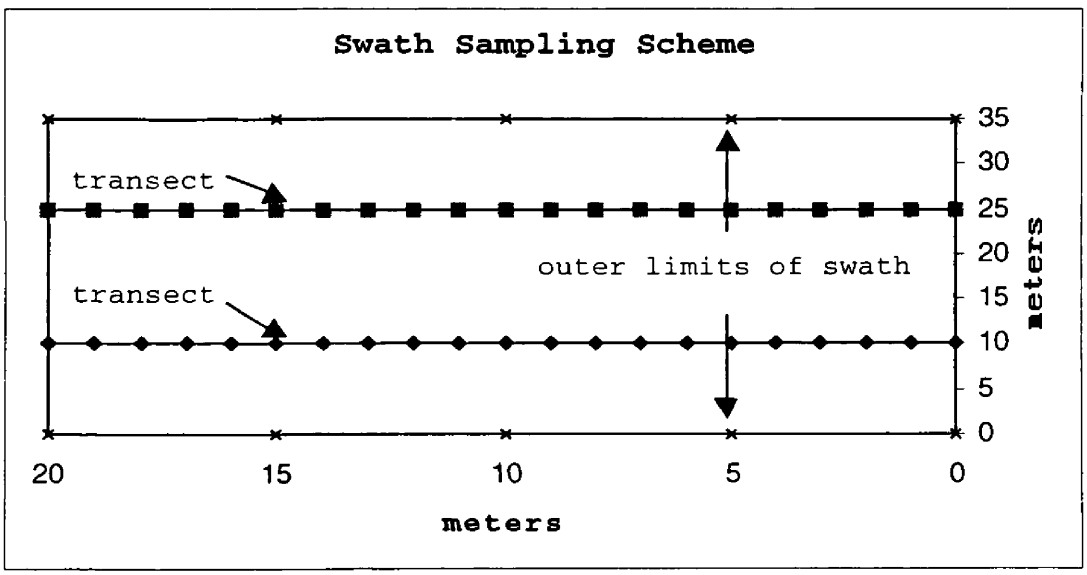

Figure 4.1. Example of the swath sampling scheme.

Elevational data for the transects were recorded. Cottonwoods were mapped on graph paper with .1" squares. Each square represented a half-meter of distance on the ground, thus mapping resolution for cottonwoods was limited to a half meter. The transects served as the basis for measuring x and y positions of the cottonwoods on the landscape. A compass was used to find the path to a tree that was perpendicular to the transect tape. The point of perpendicularity on the tape was noted (x ordinate). A meter tape was then stretched from that point to the tree (y ordinate). This information was recorded as a dot with a circle around it (representing a tree) on the appropriate grid intersection on the map sheet.

Elevations were written next to respective trees on the maps, and each map sheet was labeled according its number in the sequence of sampling a swath, the date it was made, and what the temporary bench mark elevation was for that area.

The laser level was positioned at a spot that would serve for measuring the greatest area, so that as many transect and tree locations could be measured all at once. When the limit of the laser's range or view was reached, a temporary benchmark was chosen and its elevation noted in the field notebook. The laser was then reset, and the temporary benchmark remeasured.

Cottonwoods in each swath were grouped into age categories on a given map sheet, and a number assigned to that group. Groupings were made on the basis of size (dbh) and location: if cottonwoods growing in an area were of similar size, they were assumed to be cohorts from some flood event. While this grouping procedure may seem arbitrary, numerous experiences of coring all the trees in a given area proved that this was a sound assumption. Collecting multiple cores from a group was redundant at times; at others, the decomposition of the interior of the trees necessitated coring a second or third tree just to extract a solid sample.

Coring

Once grouping of cohorts was accomplished, cores were extracted using a 12 mm x 50 cm increment borer. Cores are typically extracted at breast height, and an age-correction factor applied to account for rings that do not reach that height. All the rings can be extracted if a tree is cored at the root collar. But this involves excavation around the tree so that the handles of the borer are free to turn, which is a time-consuming process.

Instead, a quasi-experiment was conducted to see how many rings are lost when cores are extracted approximately one foot from the root collar. The result was that generally five rings were lost, and so five years could be added to each core for a close estimate of cottonwood age.

Cores were arranged on mounting boards and labeled with core numbers corresponding to the groups which they represented. The cores were left untouched for several days to allow them to dry enough to be secured with water-resistant aliphatic resin.

After cores had been laid out and labeled, all the data were entered into spreadsheets and graphed. The graphic maps were compared to the landscape on the next sampling date to confirm that trees had been mapped and entered correctly. A final walk-through of any suspected channels from one swath to its counterpart served as proof that an actual channel had been identified.

Laboratory Work

Tree-Ring Analysis

Cores were sanded flat and smooth. The sanded cores were then soaked in warm water for approximately five minutes before examination under a dissecting microscope. Soaking the wood softened it enough that it could be sliced with a razor. This helped to highlight the parenchyma, the boundary between successive rings. Sanding, too, was effective in contrasting wood cell types: different cell types and cell densities respond to abrasion differently. Ring counts were then added to the cottonwood database.

GIS Techniques

A USGS GeoTIFF DOQ 1:12000 Q-Quad of VOLCANO REEF NE was purchased. A GeoTIFF is a Tagged Information Formatted File with real-world coordinates embedded within the file. A GIS can open a GeoTIFF and position it correctly in space. A DOQ is a digital orthophoto quadrangle, or an electronic file of an aerial photo which has been corrected using a digital terrain model so that its dimensions and positions of features within the photo are as true to the real world as a map. The photograph that the DOQ was based on was taken in September 1995. This GeoTIFF served as the base map for all GIS analyses. No major flooding occurred between September 1995 and August 1998 on Dupuyer Creek, so the landscape of the 1995 photo was considered the same as that of 1998.

As data were recorded linearly in the field, they needed to be corrected to their approximate UTM coordinates. Swaths were mathematically rotated to the appropriate azimuths. Swaths' UTM origins were identified on the GeoTIFF, and were added to the x and y positional data.

Swath data were plotted in ArcView 3.1 GIS as event themes. Within swaths, trees were grouped into five-year age categories, and age categories were then plotted as separate themes so that age groups could be viewed separately. The two transects within a swath were plotted as a single theme. All point themes were then converted to 3d shapefiles and viewed in 3d scenes. This permitted examination of the x, y, and z positions of specific age groups, essentially dating the occurrence of the last alluvial disturbance for a given location of a cottonwood.

Aerial photographs of Dupuyer Creek were taken in 1937, 1941, 1951, 1966, and 1978. All of these photos were scanned and then registered to the 1995 GeoTIFF using ArcView's Image Analysis extension. The resulting images very closely matched the orthophoto, but since they were not orthophotos themselves, some distortion was evident. The active channels in each photo were digitized onscreen and then further rectified to the GeoTIFF using discrete points within the creek bottom.

Abandoned channels visible but healing in the 1937 photo were also digitized onscreen, as were approximate paths followed on the ground linking channel segments from separate swaths. Three-dimensional themes of transects were viewed in 3d scenes and compared to the locations of these abandoned channels and paths to see if and where they coincided.

Examination of Hydrographs

Historical streamflow records were searched for significant floods, i.e. ones that may have contributed to the channel movement evident in the time series of aerial photography. For instance, since major changes were evident between 1941 and 1951, local hydrographs were examined closely for flood events during that period.

RESULTS

Swaths 1 and 2

The valley-width cross-sections in Swaths 1 and 2 demonstrated that the active channel was only one to two meters deeper than the majority of the floodplain (see appendix 1). The active channel from 1937 through 1951 had become an avulsion, and was the approximate depth of the active channel in 1998.

One abandoned channel on the northwest end of the swaths was identified and walked through (see figure 5.1). Its location coincided with an abandoned channel identified in the 1937 photo. Most of the cottonwoods associated with this channel were among the oldest ones sampled in the entire project, from 103 to 145 years old. The channel evident on the ground, however, was not entirely true to the one from the earliest photo; in fact it appeared that a meander had been cut off and mostly filled by overbank deposition. Although uncommon on most of the site, overbank deposition and consequent filling-in of the meander is probably responsible for this finding.

Most of the area sampled in Swaths 1 and 2 was extensively canopied with century-old cottonwoods, indicating general stability of the reach for the past 100 years (see figure 5.2).

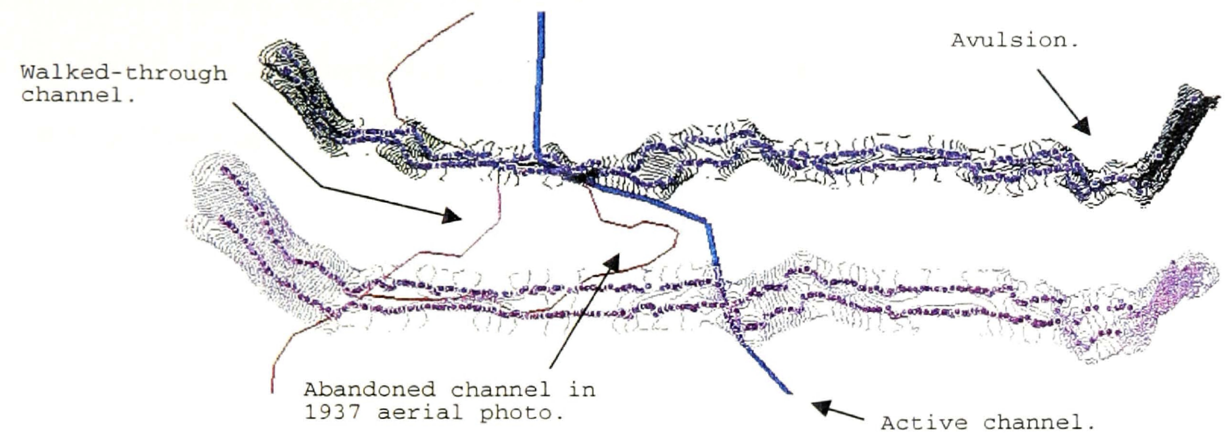

Figure 5.1: Three-dimensional view of Swaths 1 and 2 with associated hydrologic features.

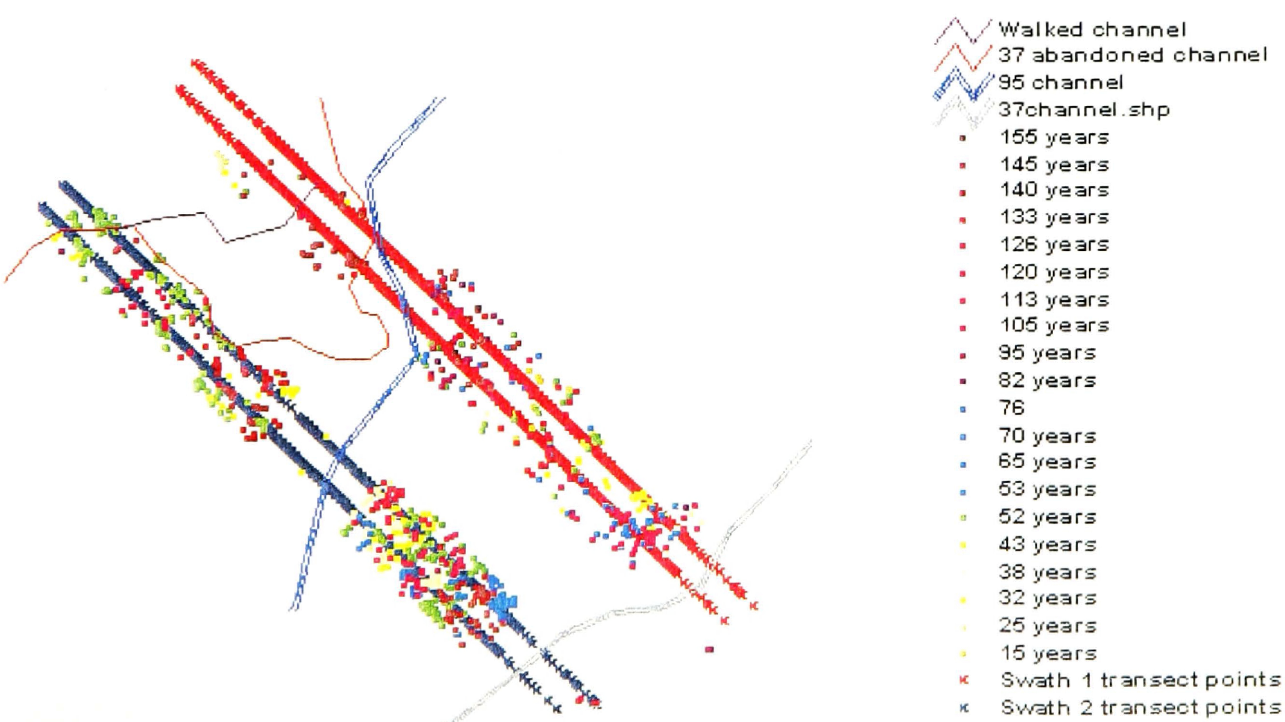

Figure 5.2: Plan view of Swaths 1 and 2 showing cottonwood locations and ages.

Very little overbank deposition was evident for the areas sampled; only one or two trees had any sediment accumulated around their boles. Soil pits were dug at intervals along Swath 1 to determine if there was any pattern to deposition and alluvium disturbance. This practice was discontinued after Swath 1 in the interest of time. Finer sediments (sand/silt/clay) predominate for at least one meter of the soil profiles. The only coarse fragments/bedload particles found were close to the active channel and the avulsion.

An arcuate band of large cottonwoods was discovered in the middle of Swath 1 on early examinations of the study site which suggested a possible abandoned channel (see figure 5.3). There was also a topographic anomaly present that resembled a filled-in abandoned channel. Completion of survey of Swaths 1 and 2 did not conclusively support this suspicion, nor did any channels identified in the time series of aerial photos.

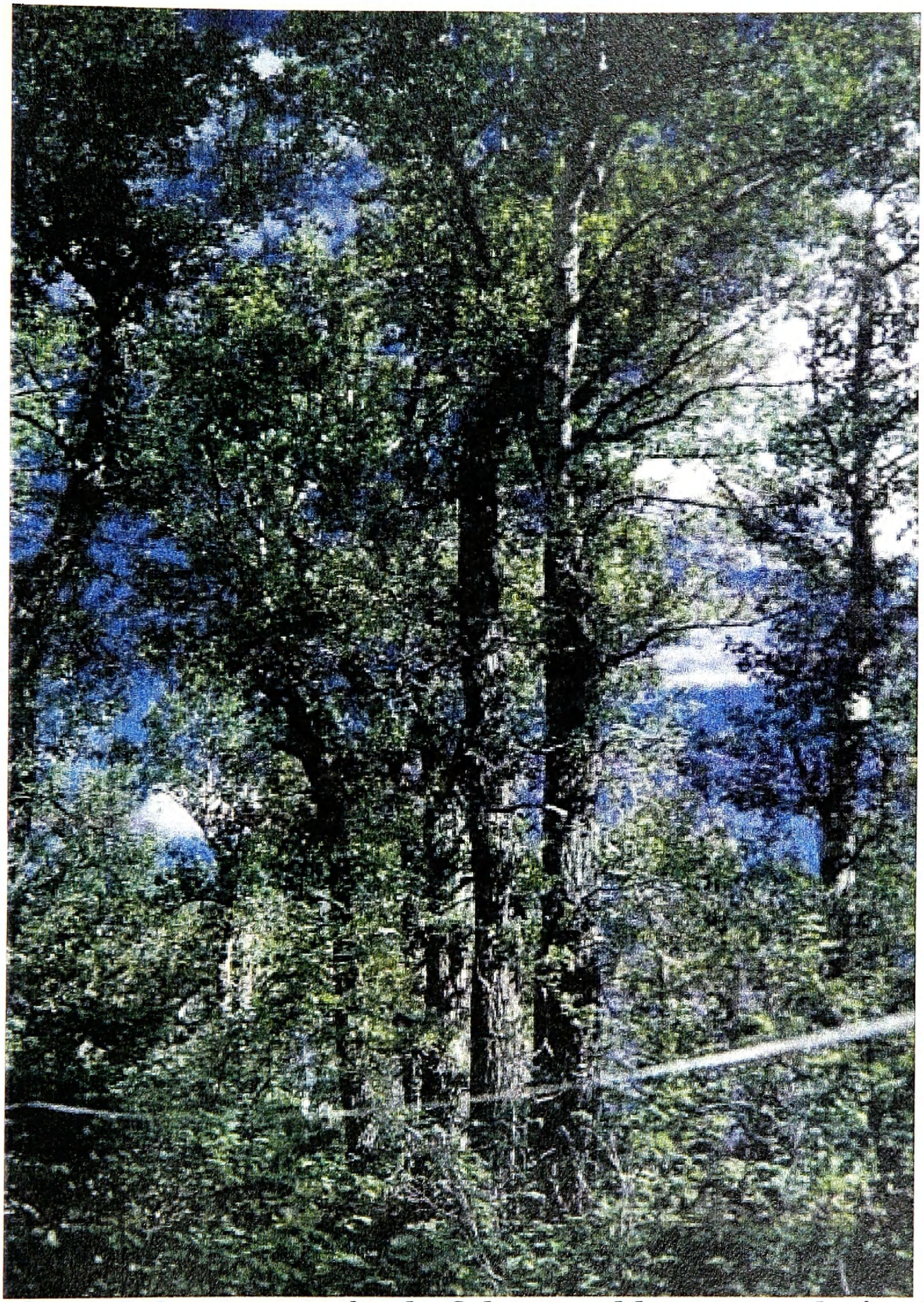

Figure 5.3: Arcuate band of large, old cottonwoods in the middle of Swath 1.

Swath 3

Swath 3 was located farthest upstream of all the sampled areas. A tall scarp face was identified being actively eroded by the creek (see figure 5.4 and appendix 1). The drop from the terrace to the edge of the creek was approximately four meters. No cottonwoods were present on this terrace, suggesting that flood activity had not occurred on that surface for at least the lifespan of a cottonwood tree.

Three cutoff chutes were identified inside the creek's meander. Two of these chutes were flanked by cottonwoods. The third, perhaps the most recently incised, contained no vegetation. Its elevation was lower than the thalweg of the active channel, and it contained water in August, making cottonwood survival there impossible. The other two cutoffs coincide with the 1978 and 1966 active channels (see figure 5.6). Their cottonwoods' ages further corroborate this evidence: trees in the 1978 channel were approximately 22 years old, suggesting that they were recruited soon after the 1975 flood; trees in the 1966 channel were approximately 33 years old, suggesting that the were recruited soon after the 1964 flood (see figure 5.7). Beyond these chutes was a meadow, with a depression running through the middle of it parallel to the cutoffs. No cottonwoods were found along

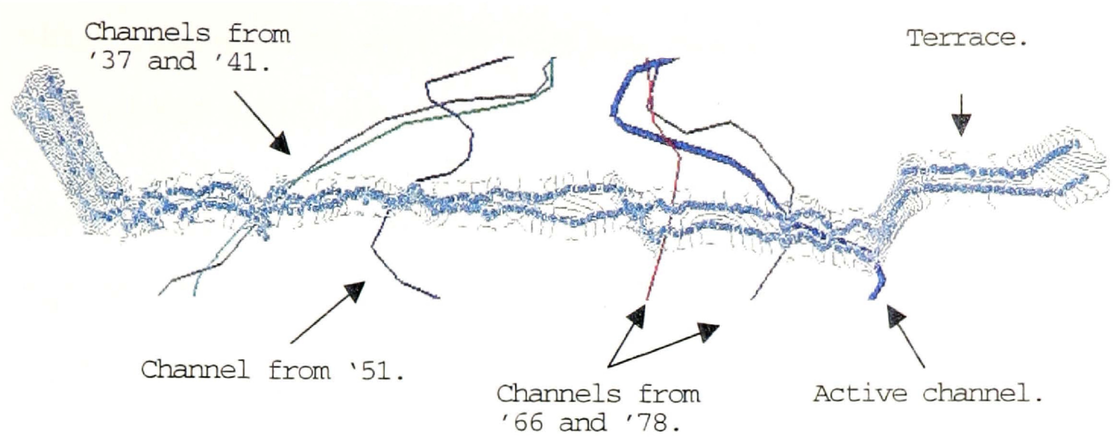

Figure 5.4: Three-dimensional view of Swath 3 and associated hydrologic features.

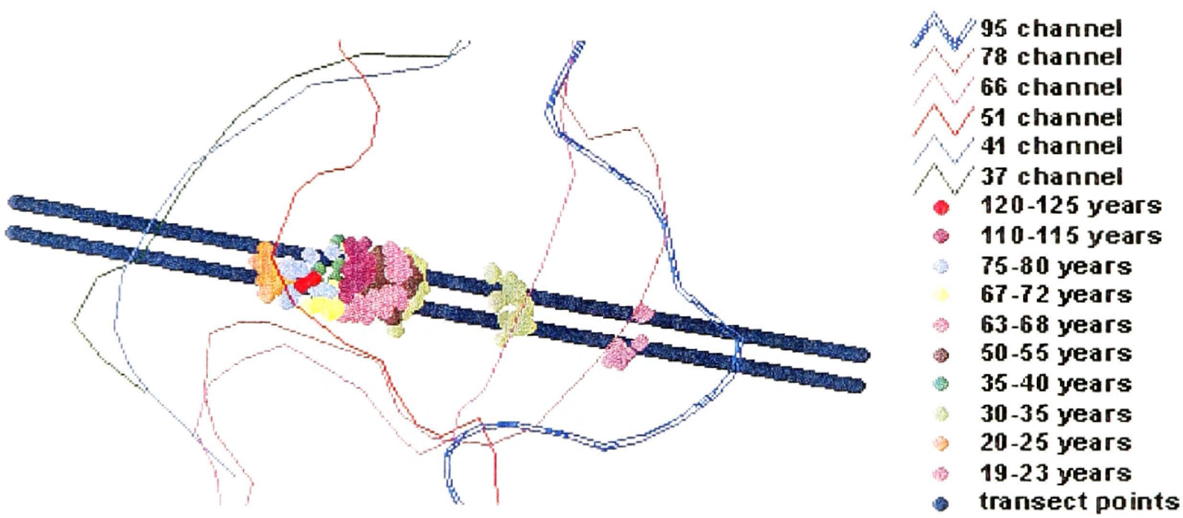

Figure 5.5: Plan view of Swath 3 showing cottonwood locations and ages.

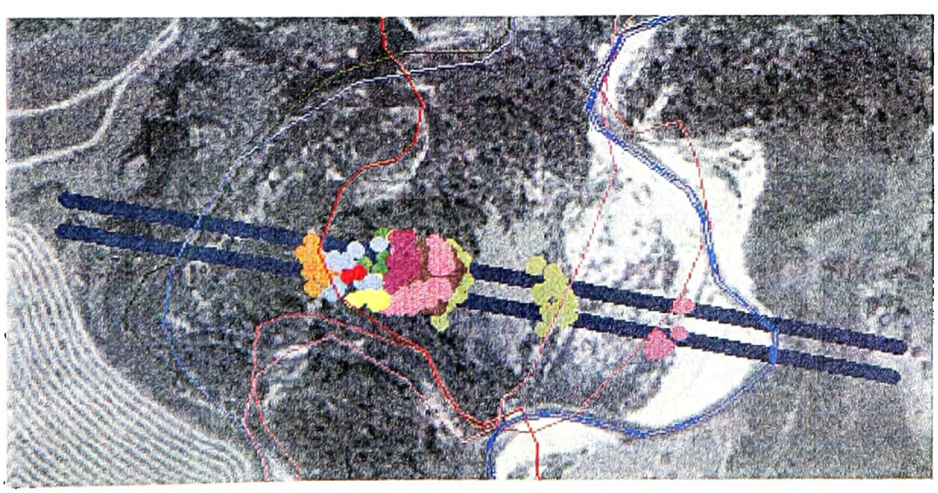

Figure 5.6: Plan view of Swath 3 superimposed over aerial photograph.

this depression and no active channel from the aerial photos coincided with it.

The meadow was flanked by bands of even-aged stands of cottonwoods, progressively older to the west. These stands comprised a thick canopied wood. The oldest trees (~100 years old) in this swath were found on the western edge of the wood. Surrounding the oldest of these trees was a heap of cobbles and boulders approximately two meters deep (see figure 5.7). The heap was probably created by the 1964 flood, the 1975 flood, or both.

To the north and south of the heap ran a depression indicative of a channel, and examination of the aerial photos suggests that the active channel was here some time before 1937.

Beyond the heap to the west the landscape was hummocky and riddled with rivulets. At the far western edge of the swath were many obvious water courses, still flowing, although restricted by numerous beaver dams. The bottoms of some of the channels were thickly layered with fine sediments and black, rich organic material, but others still had firm, cobbled beds, relict from old creek activity or flood deposition.

The elevation of the oldest cottonwood in Swath 3 was only about two meters higher than the active channel, indicating that channel incision and rejuvenation of the reach started at least as long ago as the age of that tree.

Figure 5.7: Heap of cobbles, boulders, and organic debris from 1964 and/or 1975 flood in Swath 3.

Swaths 4 and 5

Swath 4 was located just downstream from an area of interest of previous researchers (Moeckel *et al.*, 1996). An arcuate band of 80 year-old cottonwoods was mapped on the high terrace at the south-eastern side of the valley. Although subtle, there was a slight depression in the surface of the terrace that led to another patch of cottonwoods in Swath 5, also containing 80 year-old trees. This suggests that a channel was incised on what is now terrace about 80 years ago.

More mature trees were mapped at the edge of the terrace. The drop from the terrace to the channel was three meters (see figure 5.10 and appendix 1). Cutoff chutes were identified immediately across the creek, and associated cottonwoods dated the channel to the 1975 flood (see figures 5.8, 5.9, and appendix 1). This meander cutoff did not continue to the subsequent swath.

The floodplain surface from the meander cutoff was even but rocky. The terrace scarp profile showed a similar pattern to the one seen in Swath 3. Fine sediments dominated the profile, interspersed with layers of cobbles and gravel (see figure 5.10). The active floodplain was dominated by a matrix of fine sediments and cobbles to boulders. This matrix may have simply been a lens that underlay the entire valley bottom, including the terrace, and the catastrophic

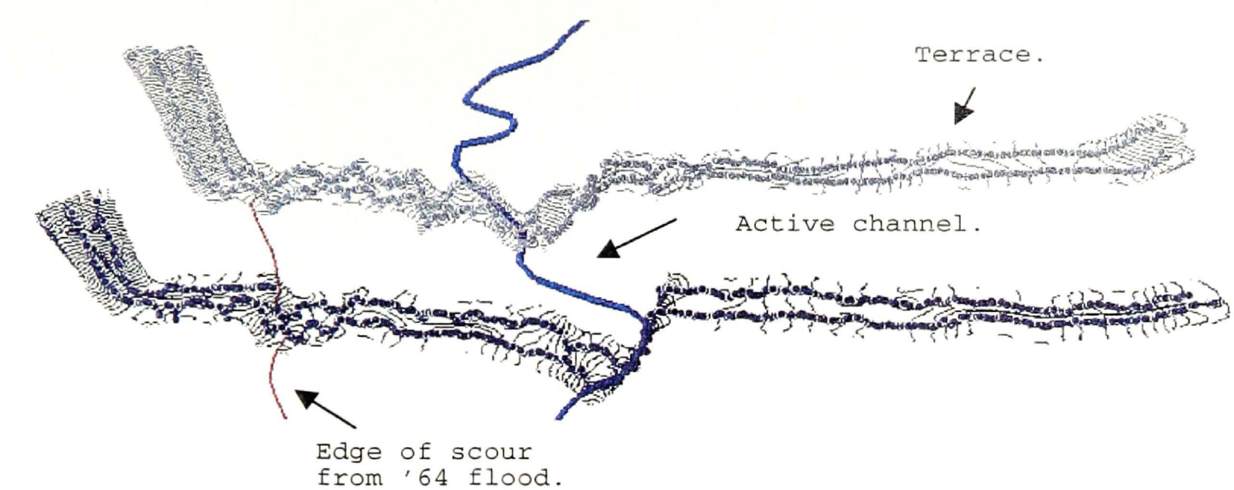

Figure 5.8: Three-dimensional view of Swaths 4 and 5 with associated hydrologic features.

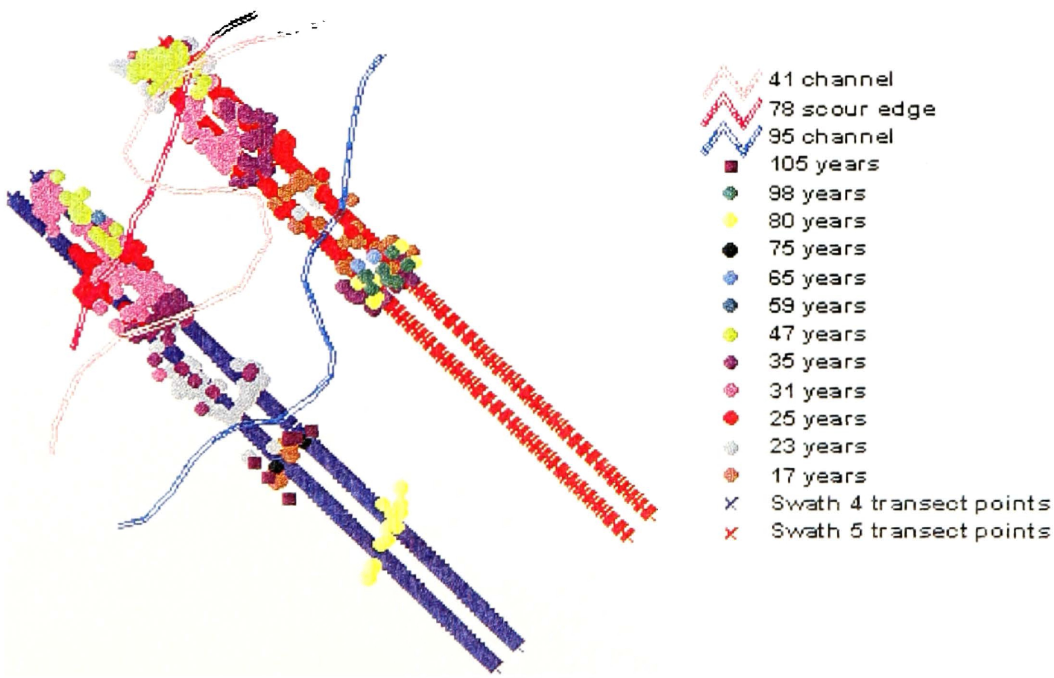

Figure 5.9: Plan view of Swaths 4 and 5 showing cottonwood locations and ages.

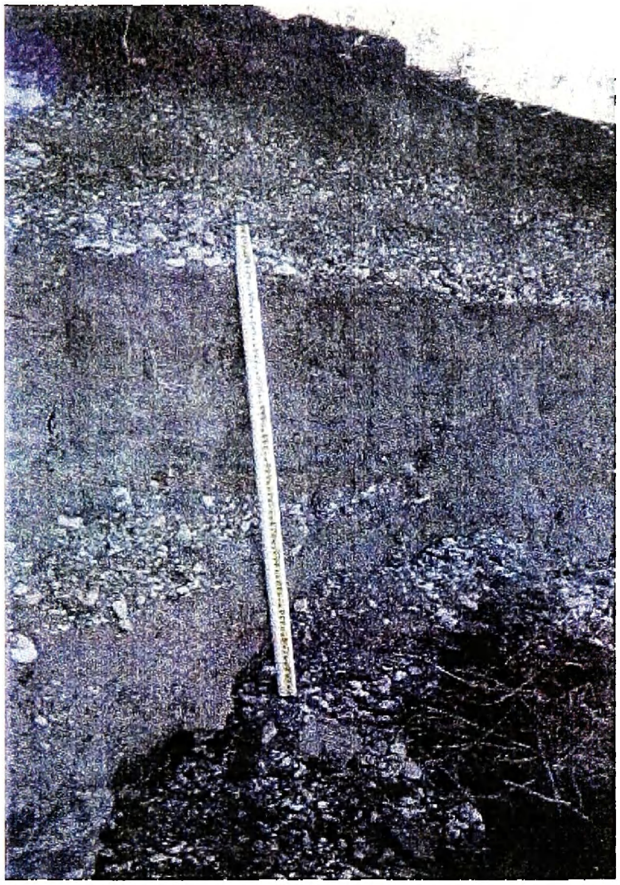

Figure 5.10: Scarp face of terrace in Swath 5.

Figure 5.11: Low cutbank on northwest side of Swath 4.

floods removed all the finer sediments from above. Alternately, the floodplain surface may have been laid down in the floods.

Near the northwest end of Swath 4 a one and a half meter cutbank was discovered that extended across the majority of this section of floodplain parallel to the area of scour evident in the 1966 aerial photo (see figures 5.11 and 5.12). All the cottonwoods between this cutbank and the edge of the terrace were found to be younger than 24 years old. The 1978 aerial photo showed little vegetation left in this area as a result of the 1975 and 1964 floods. Above the cutbank trees were found to be as old as 60 years.

Swath 5 was located 75 meters downstream of Swath 4. It passed through a stand of cottonwoods dominated by 75 to 100 year-old trees situated atop the terrace. Once down from the terrace scarp face, the swath proceeded through the active channel and over an irregular land surface. One cutoff chute was identified. The northwest end of the swath passed through a noticeably wet channel segment at the base of the continuation of the cutbank identified in Swath 4 (see figure 5.13). Cottonwood canopy above the cutbank was dominated by the 40 year-old age class.

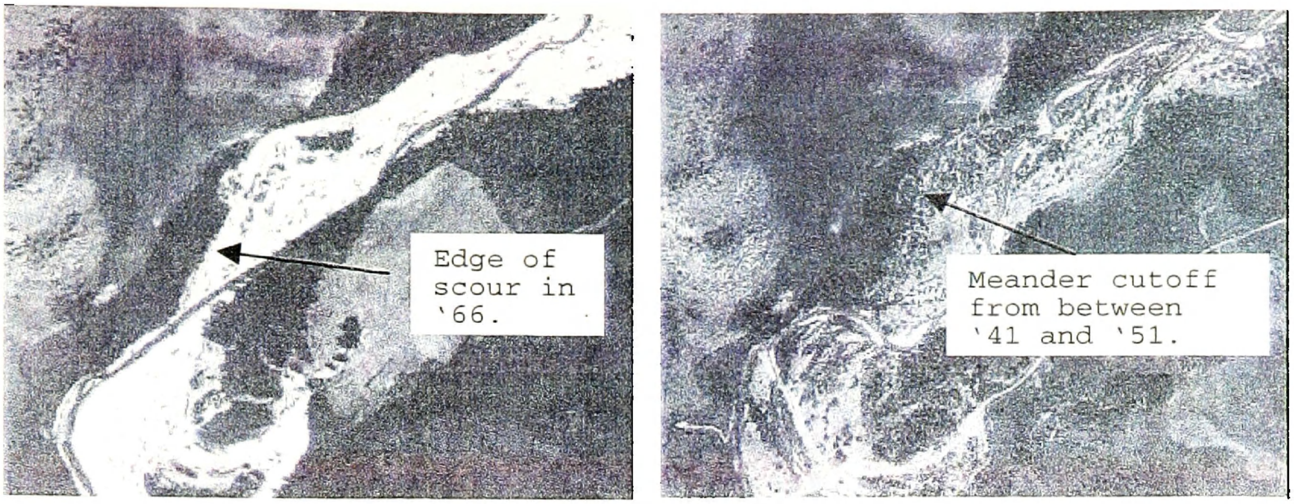

Figure 5.12: 1966 (left) and 1995 (right) aerial photos of Swaths 4 and 5.

Figure 5.13: Abandoned channel segment identified in Swath 5.

The active channels identified in the 1937 through 1951 aerial photo series closely follow the cutbank mapped in this reach. A flood between 1941 and 1951 cut off a tortuous meander that is still evident on the landscape today (see figure 5.12). Subsequent floods effectively left the point bar on the inside of this meander an island, and examination of the cottonwoods on that island could provide an earlier record of flood activity on this reach.

Cottonwood Age Distributions

Exploratory data analysis was conducted on the age distributions of the cottonwoods within each of the three reaches as well as for all the combined data. The combined data resembled a X^2 distribution (see figure 5.14). Cottonwood ages were converted to year of recruitment. The mode of the combined data set coincides with the 1964 and 1975 floods. There were many trees sampled that were recruited between 1843 and 1903, but significantly fewer than from this century. This is probably due to mortality due to age, flood damage or outright removal, and harvest by beavers.

The data from Swaths 1 and 2 closely resemble those from the combined set, with the exception that there appear to be more older trees with significant spikes at 1870 and 1850(see figure 5.15). Also, there appear to have been more cottonwoods recruited in this area 45 to 55 years ago, suggesting flood activity from 1943 to 1953. Data from Swath 3 were gathered from only half the area of the other two groups, but even so there seem to have been significant contributions from flood events 40 and 60 years ago (see figure 5.16). The cottonwood forest in Swaths 4 and 5 was almost exclusively created by the 1964 and 1975 floods and related disturbance (see figure 5.17).

Examination of Hydrographs

Few continuous streamflow records from the Northern Rocky Mountain Front extend back for any great length of time. Gaging station 06099500 near Shelby, MT, on the Marias River has been in operation continuously since May 22, 1902. Annual peak flow data were obtained from the USGS for this station and graphed (see figure 5.18). High peak flows correlate with high cottonwood recruitment: a rather high peak flow in 1948 and another in 1943 coincide with a spike in the cottonwood recruitment histogram (see figure 5.19). Similarly, a high flow in 1934 coincides with another spike in the cottonwood graph.

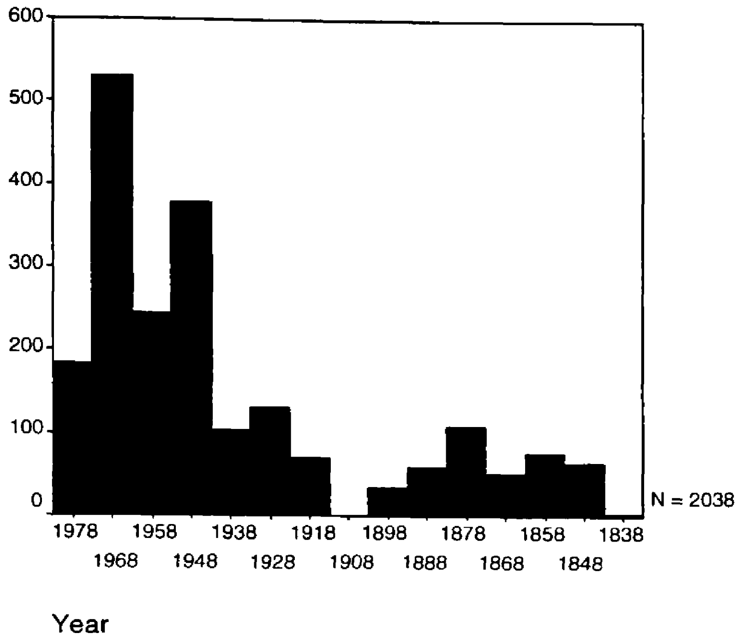

Figure 5.14: Histogram of combined cottonwood age data.

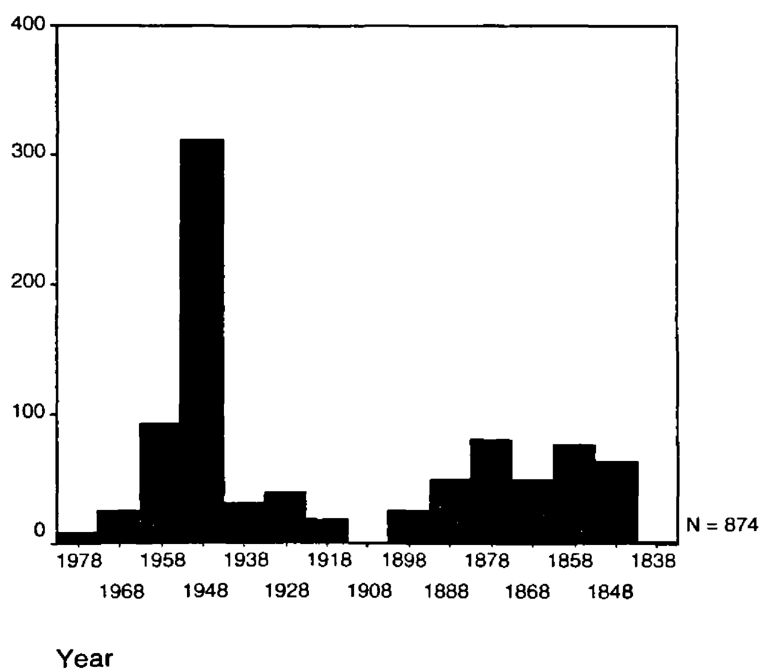

Figure 5.15: Histogram of Swaths 1 and 2 cottonwood age data.

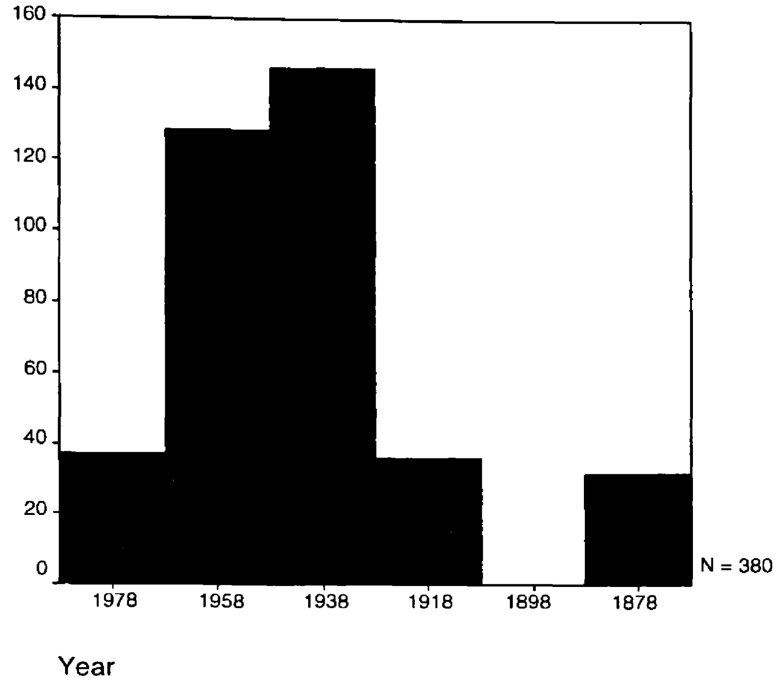

Figure 5.16: Histogram of Swath 3 cottonwood age data.

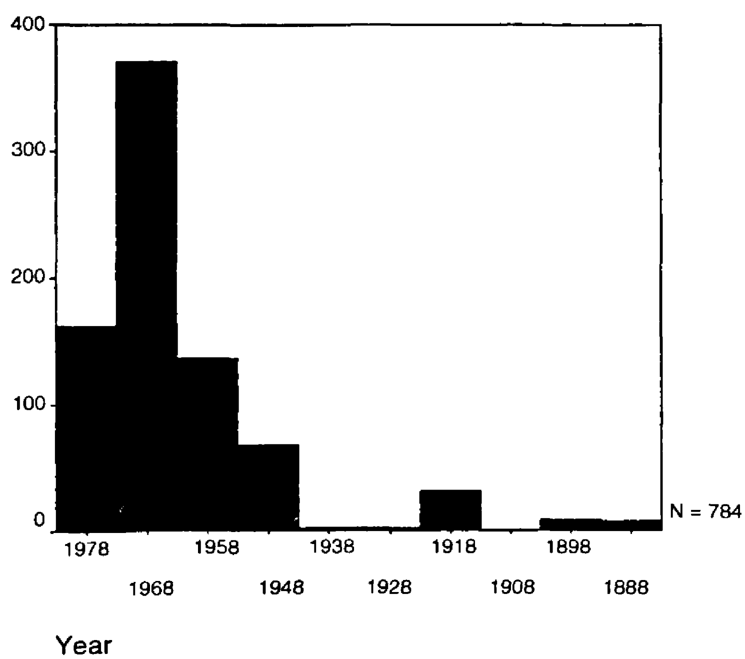

Figure 5.17: Histogram of Swaths 4 and 5 cottonwood age data.

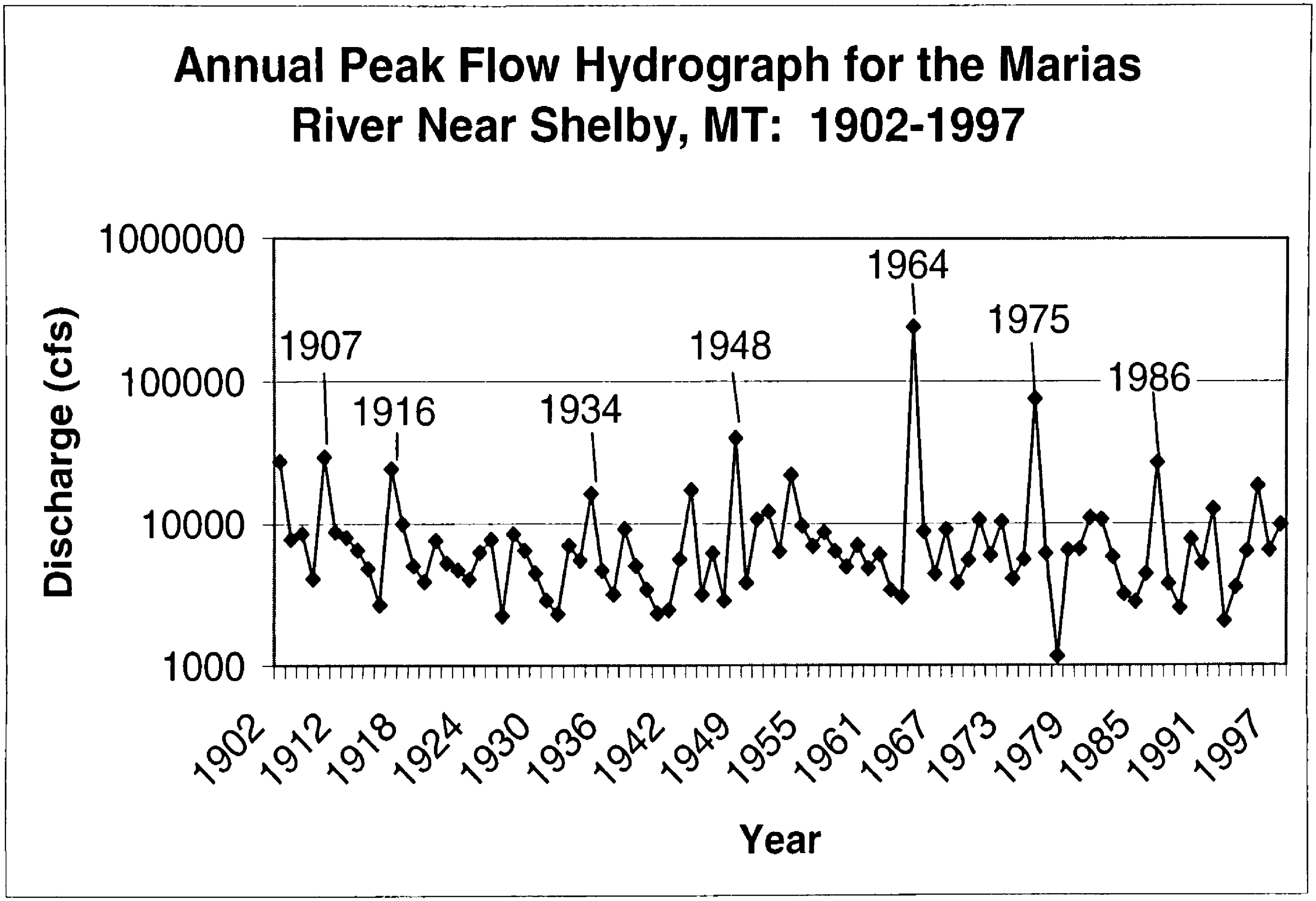

Figure 5.18: Hydrograph of annual peak flows on the Marias River Near Shelby, MT. Significant peaks are labeled with the dates on which the occurred.

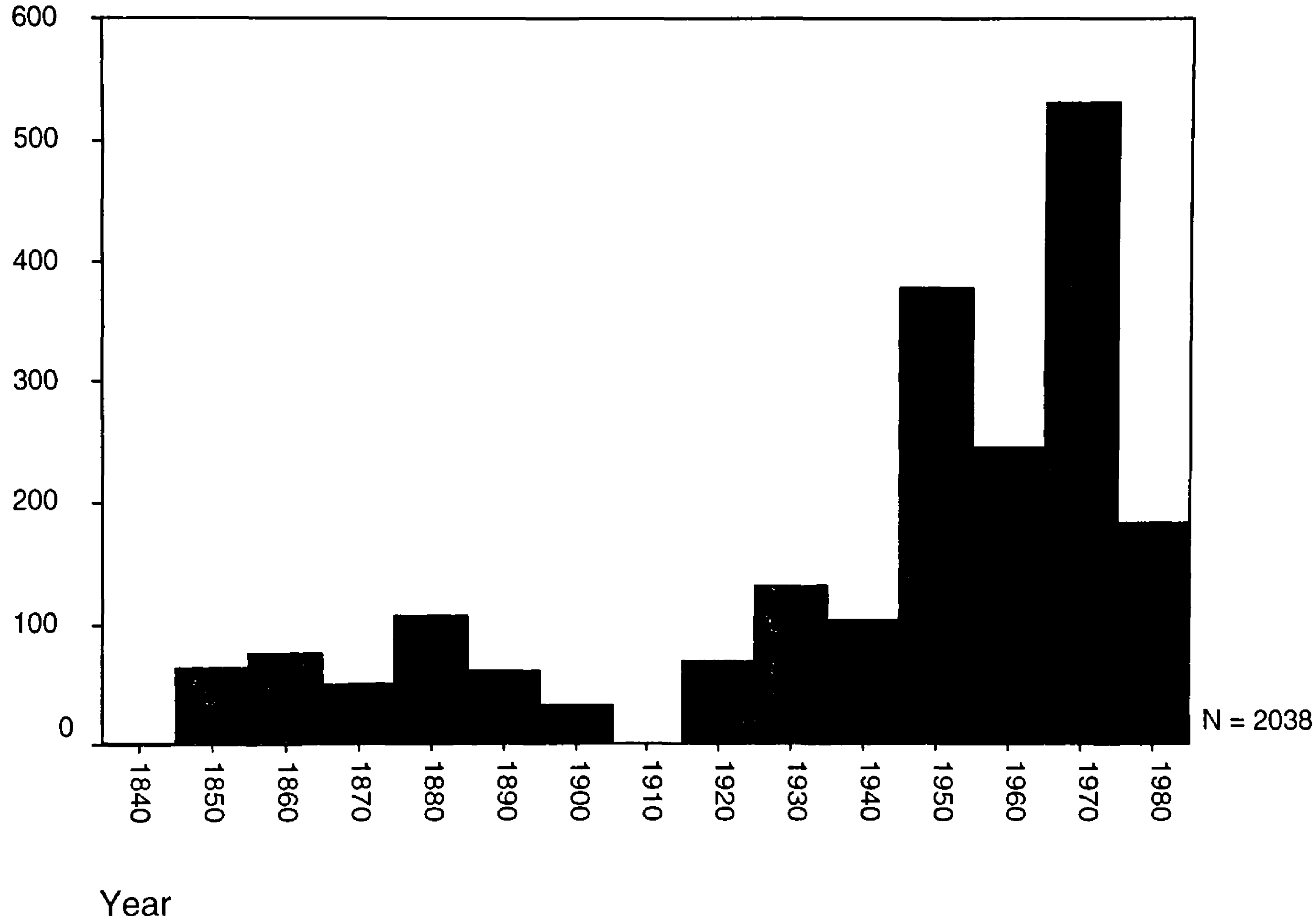

Figure 5.19: Histogram of numbers of cottonwoods regenerated in particular years.

DISCUSSION

Swath 3

At Swath 3 the creation of the terrace appears to have occurred earlier than at Swaths 4 and 5, since the oldest vegetation in this area is low on the active floodplain and precedes any recorded flood event. Channels cut in 1964 and 1975 were abandoned as the active channel migrated eastward. The ages of cottonwoods associated with them closely corresponded to those years.

Some cottonwoods that were recruited around 1951 were associated with the channel from 1951. The canopy in this area was dominated by much older trees (110-125) which suggests that this was the location of the channel in the 1870s and 1880s. From the cross-sectional data it appeared that the channel has not downcut severely in this reach in that time. The channel has merely laterally planated in the direction of the terrace to the east, undermining it during times of significant flood.

Swaths 4 and 5

In Swaths 4 and 5 cutbanks and channel features from the 1937-1951 positions of Dupuyer Creek still exist, and the associated cottonwoods correctly suggest that that channel was active about 50 years ago.

The majority of the cottonwoods in this reach were younger than 35 years. Should these trees live to maturity, an observer in the future would discover a cottonwood forest dominated by trees generated by the 1964 and subsequent floods.

The oldest cottonwoods in this area, 80 to 105 years, are high on the terrace. This suggests that the terrace was the active floodplain about 80 years ago, and that some subsequent flood event initiated downcutting on the northwest side of the valley. Since the valley appears well vegetated for the period between 1937 and 1951, the flood event must have occurred at the time of or shortly after the recruitment of the 80-year cohorts. The brief flow record for Dupuyer Creek at Valier (see figure 6.1) shows two significant floods in two consecutive years, possibly destabilizing some reaches and initiating downcutting at this particular one.

Swaths 1 and 2

Swaths 1 and 2 do not exhibit nearly the amount of scouring as in the other sampling units. Vegetation can be found throughout the creek bottom which predates the '64 flood. Some vegetation in this area is over 150 years old, and exists at some of the lowest elevations within the creek bottom. This suggests that this reach has been stable for at least 150 years.

Trees associated with the oldest identified channel in this reach were 145 years old, suggesting that this abandoned channel may have been the active channel in the 1850s. Given the lack of relief in this area it is not surprising that trees from the whole range of age categories are found throughout the width of the valley. Perhaps some large flood event occurred in the mid 1800s which scoured this particular reach at that time, producing the broad even-aged stand of cottonwoods we see today, much like the one currently developing at Swaths 4 and 5. Or perhaps this reach has been riddled with channels for the past 150 years, and occasional flooding reactivates many of them if only for a short duration. This, too, would account for the mixed age structure that we see in this area.

This technique failed to produce the same results in Swaths 1 and 2 that it had in Swaths 3, 4 and 5. A high-water event in 1948 (see figure 6.1) was evident in comparison of the '41 and '51 aerial photos (see figure 6.2), but it is difficult to recognize specific patterns in the cottonwood record that would reflect this.

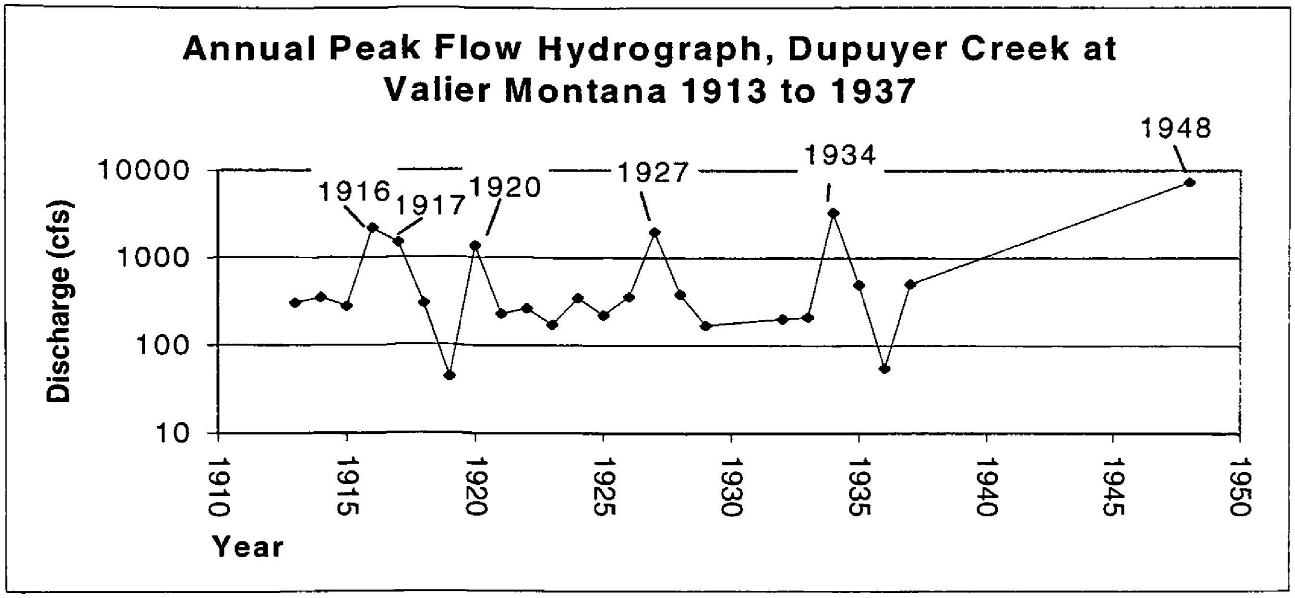

Figure 6.1: Annual peak flow hydrograph of Dupuyer Creek at Valier: 1913-37, 1948.

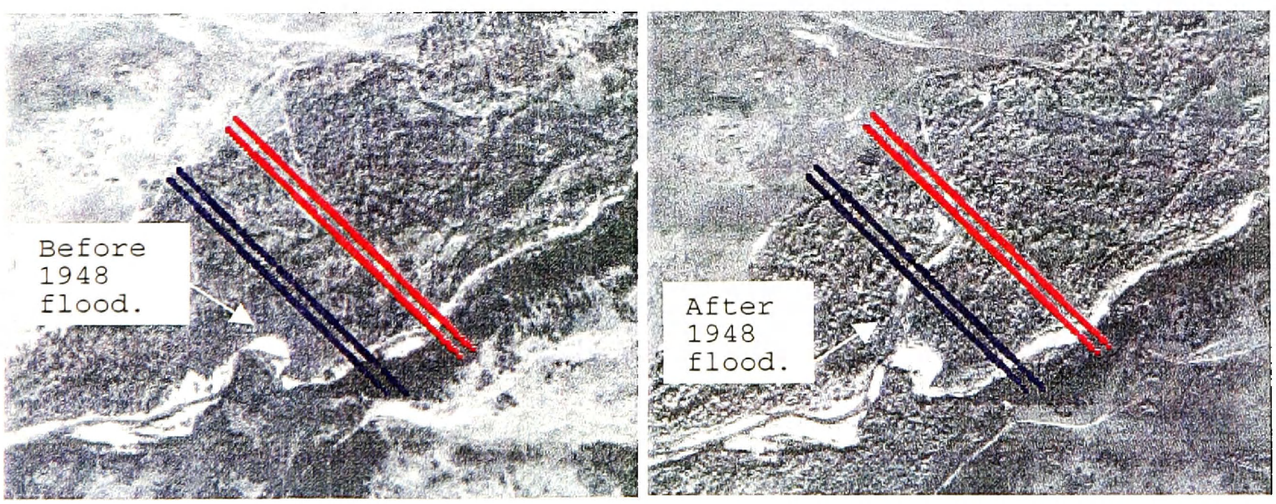

Figure 6.2: Comparison of Swaths 1 and 2 from 1941 (left) and 1951 (right).

CONCLUSIONS

This technique was successful at identifying abandoned channel segments and dating the period of activity of some of them. It provides some clues as to the timing of terrace creation and floodplain scour associated with floods. While detailed inventorying of cottonwood forest was useful in determining the age structure of riparian habitat, it would not be necessary for a simple investigation of a selected fluvial feature.

Implementation of more sophisticated equipment, such as a total station, would allow a researcher to more efficiently survey a reach and tie the data directly to surveys from other reaches. This would allow for comparison of terrace elevations. Had the aerial photos been assembled and examined within the GIS prior to field sampling, more specific questions of channel movement could have been addressed.

Comparison of the aerial photos has shown that many floods—not just the 1964 and 1975 events—have enormously impacted Dupuyer Creek in this century alone. The cottonwood record corroborates this. But while the vegetation provides information to the researcher, it also serves the land manager by softening the blows dealt by floods. This is not to suggest that more cottonwoods could have prevented the damage done in 1964 and 1975. Rather, would be aided by allowing effected areas to develop healthy riparian communities. This can be accomplished by constructing cattle exclosures disturbed areas (much of Dupuyer Creek) and minimizing crossings. Under this scenario vegetation may become established which would subsequently hold substrates in place and accumulate more sediment during subsequent flooding.

As it stands, the cottonwoods produced in the 1964 flood may not survive to become the lush canopy that developed farther down stream. It appeared in August 1998 that the young cottonwood stands down in the floodplain of Swaths 4 and 5 were extremely moisture stressed. They were growing on bare cobbles, with little accumulation of sediments anywhere in the area. With little moisture holding capacity, any trees not rooting deeply enough succumb to drought. It is recommended that cattle grazing in such disturbed areas be discourgaged.

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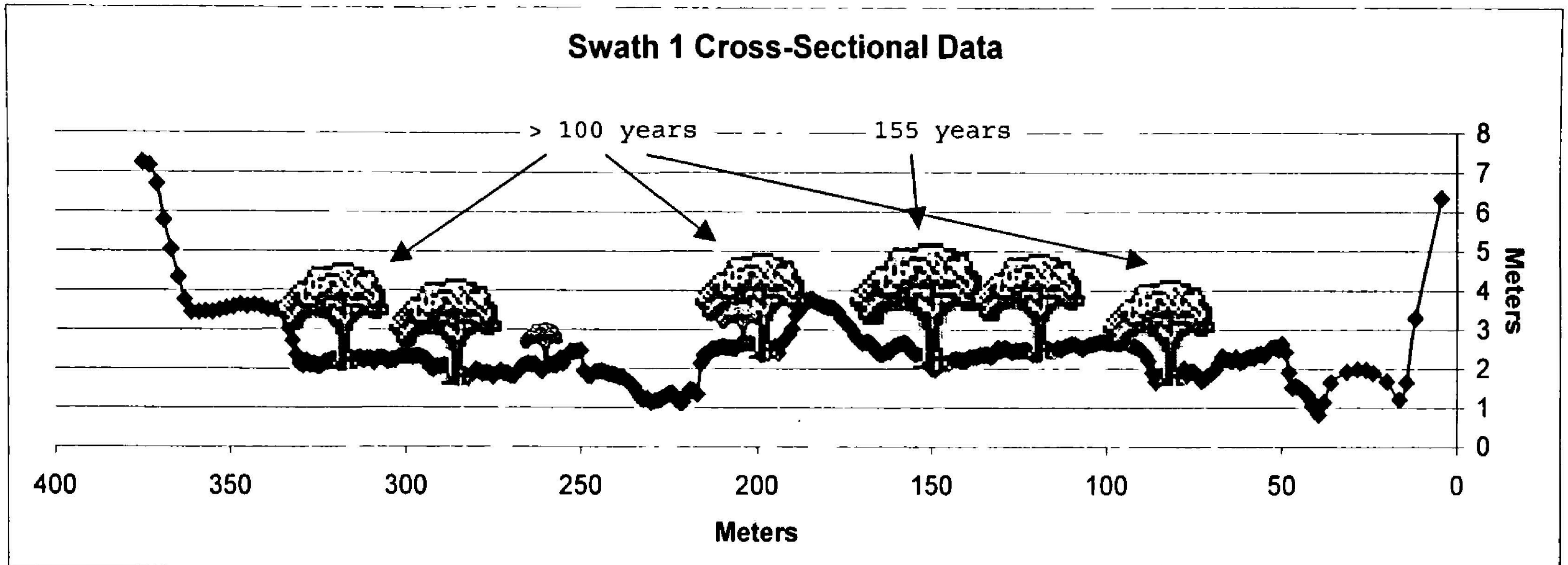
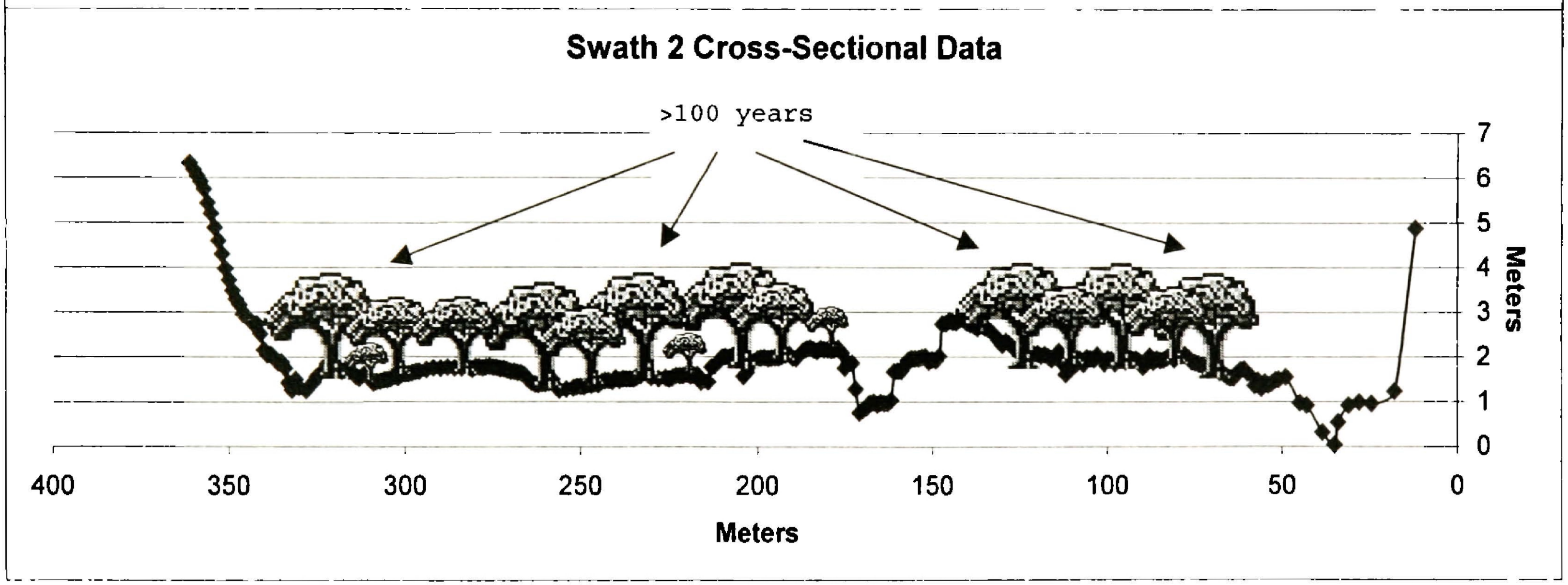
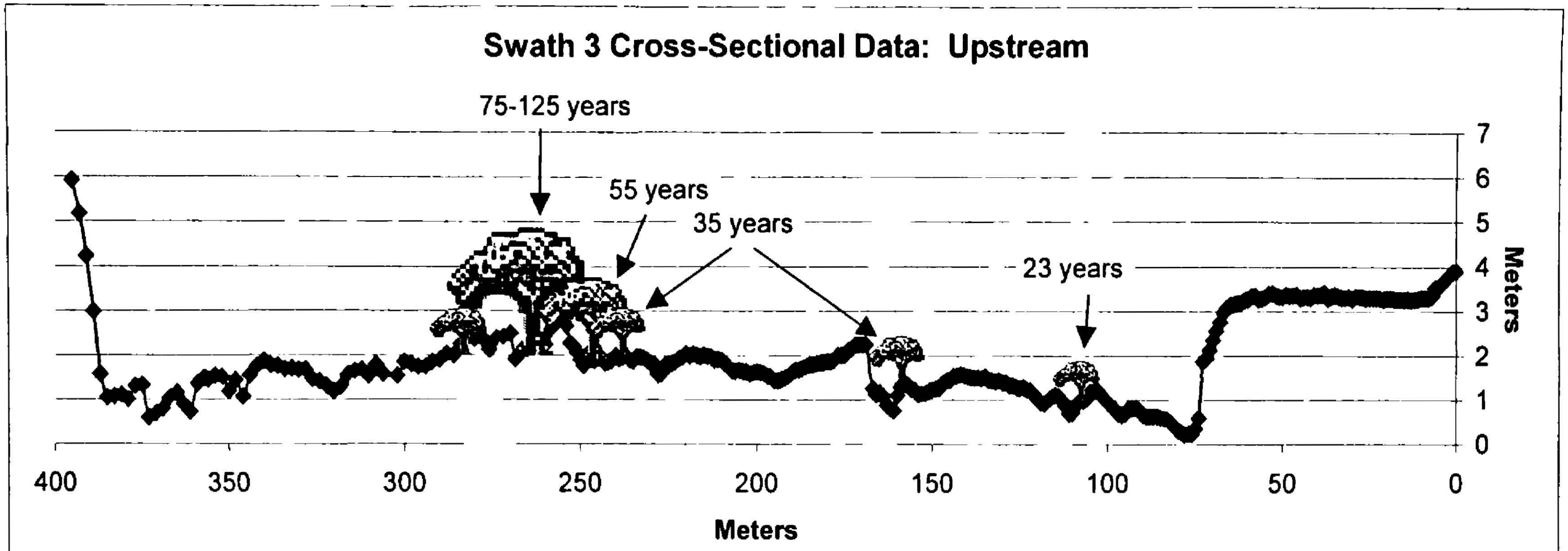
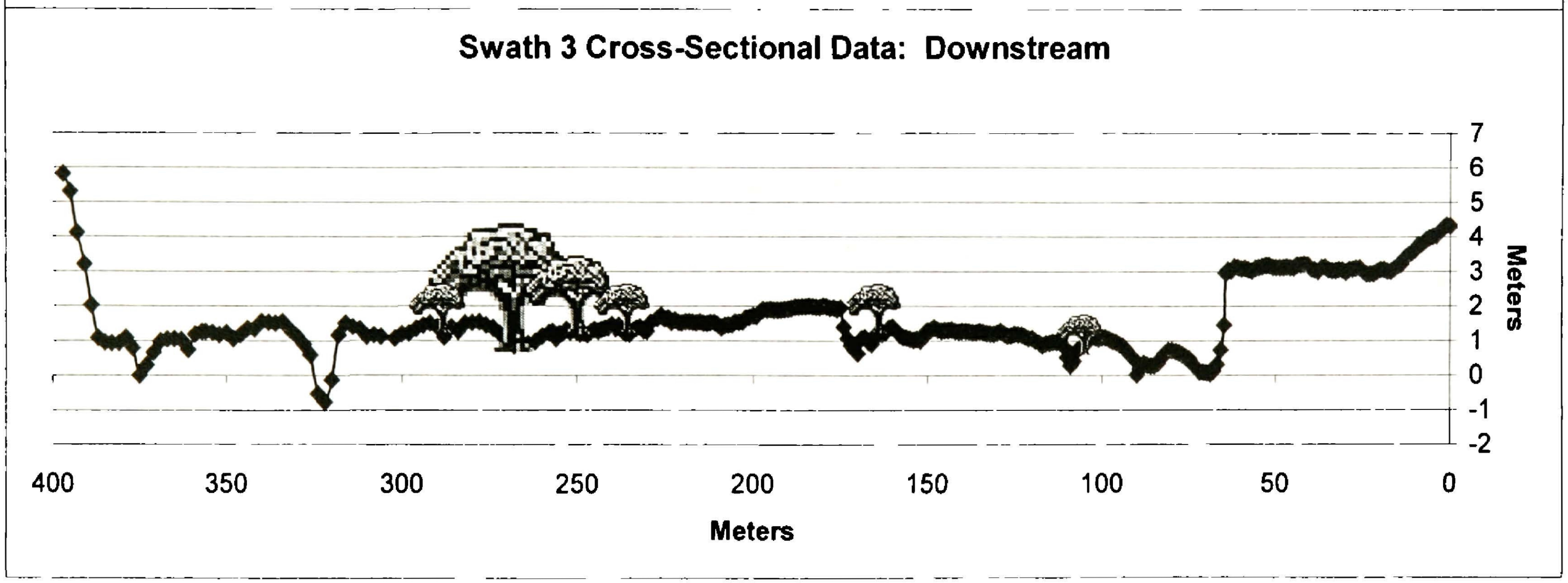

Swath 1 Cross-Sectional Data
> 100 years
155 years
Meters
Meters
400
350
300
250
200
150
100
50
0
0
1
2
3
4
5
6
7
8

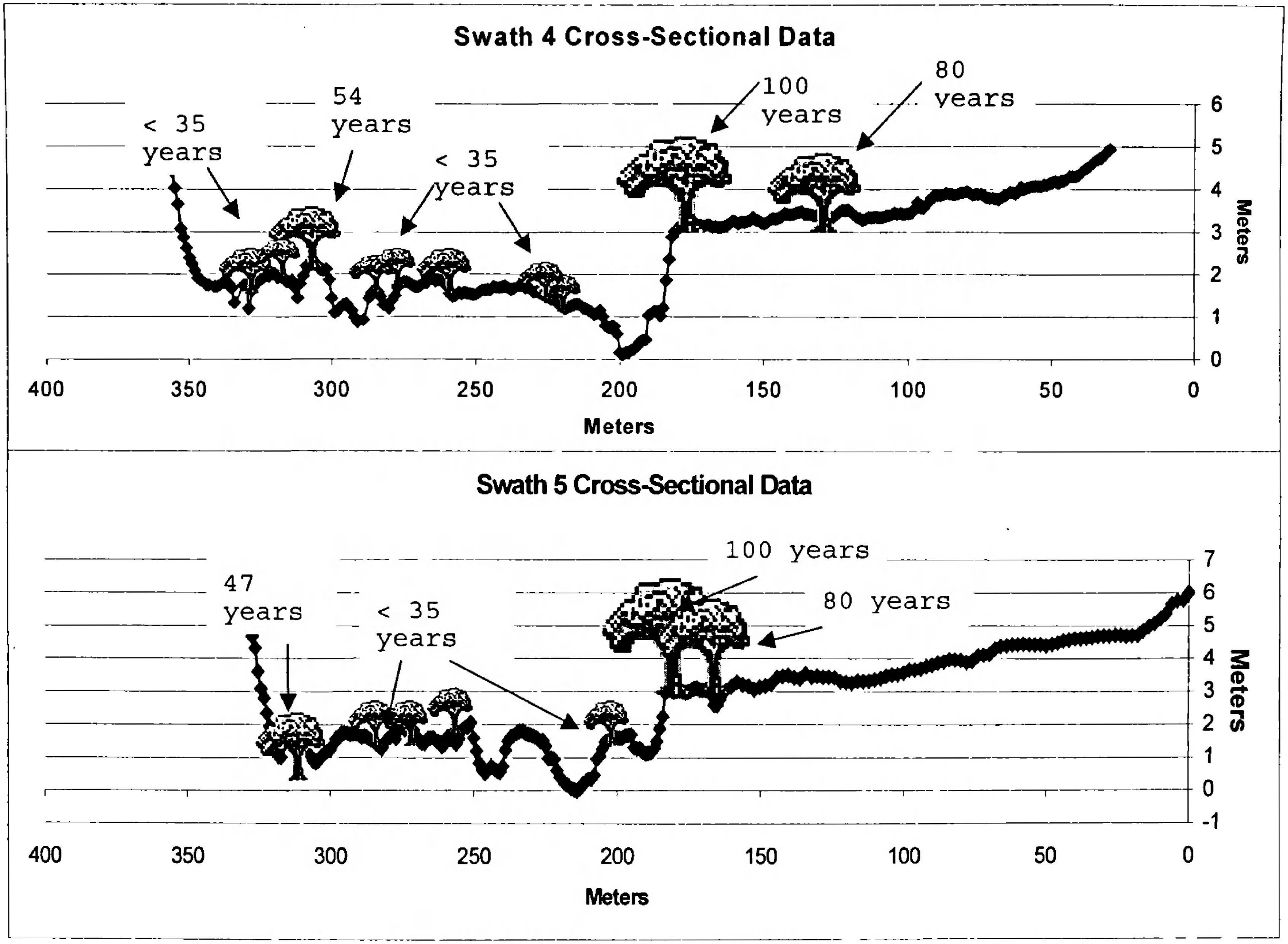

Swath 2 Cross-Sectional Data
>100 years
Meters
Meters
400
350
300
250
200
150
100
50
0
0
1
2
3
4
5
6
7

Appendix 1


Swath 3 Cross-Sectional Data: Upstream
75-125 years
55 years
35 years
23 years
Meters
Meters
400
350
300
250
200
150
100
50
0
7
6
5
4
3
2
1
0


Swath 3 Cross-Sectional Data: Downstream
Meters
Meters
400
350
300
250
200
150
100
50
0
7
6
5
4
3
2
1
0
-1
-2

Appendix 2


Swath 4 Cross-Sectional Data
< 35
years
54
years
< 35
years
100
years
80
years
Meters
Meters
0
1
2
3
4
5
6
400
350
300
250
200
150
100
50
0
Swath 5 Cross-Sectional Data
47
years
< 35
years
100 years
80 years
Meters
Meters
-1
0
1
2
3
4
5
6
7
400
350
300
250
200
150
100
50
0

Appendix 3