SECTION E
STREAM CHANNEL CONDITION

INTRODUCTION

This report provides the results of an assessment of the stream channels of the Mendocino Redwood Company (MRC) ownership in the Hollow Tree Creek watershed analysis unit (WAU). The assessment was done following a modified methodology from the Watershed Analysis Manual (Version 4.0, Washington Forest Practices Board). The stream channel analysis is based on field observations and stream channel slope class and channel confinement information developed from a digital terrain model in the company's Geographic Information System (GIS).

The goals of the assessment were to determine the existing channel conditions and identify the sensitivity of the channels to wood and sediment. Stream channels are defined by the transport of water and sediment. A primary structural control of a channel in a forested environment, besides large rock substrate, is from woody debris. Channel morphology and condition therefore reflect the input of sediment, wood and water relative to the ability of the channel to either transport or store these inputs (Sullivan et. al., 1986).

Stream channel conditions represent the strongest link between forest practices and fisheries resources. Changes in channel condition typically reflect changes to fish habitat. Because of this the fish habitat and stream channel assessments were done in the same reaches. The results for the fish habitat parameters are presented in Section F - Fish Habitat Assessment.

METHODS

The methods of the stream channel assessment are designed to identify channel segments that are likely to respond similarly to changes in sediment or wood and group them into distinct geomorphic units. These geomorphic units enable an interpretation of habitat-forming processes dependent on similar geomorphic and channel morphology conditions. The channels are also evaluated for current channel condition to provide evaluation of habitat conditions.

Stream Segment Delineation

The stream channel network for the Hollow Tree Creek WAU was partitioned into stream segments based on three classes of channel confinement and several classes of channel gradient. These classifications were based on channel classifications prepared from digital terrain data in Mendocino Redwood Company's Geographic Information System (GIS). The slope classes used for delineation are 0-1%, 1-2%, 2-4%, 4-8%, 8-12%, and 12-20%. Channel confinement was classified by confined, moderately confined, and unconfined. Confined channels have a valley to channel width ratio of <2, moderately confined channels have a valley to channel width ratio of <4, and unconfined channels have a valley to channel width ratio of >4.

Channel segments were delineated based on either a change in slope class, change in channel confinement or broken at watershed or major tributary confluences if the slope or confinement does not change for long reaches. The channel segments were numbered with a two letter code, corresponding to the planning watershed the channel segment is located, followed by a unique number (*1 through n* for each planning watershed). For the Hollow Tree Creek WAU data, channels for 5 planning watersheds are delineated. The delineated stream segments are shown on Map E-1.

Field Measurements and Observations

Selection of field sites for stream channel observations was based on gathering a sample of response (0-3% gradient) and transport (3-20% gradient) channels from each planning watershed of the WAU. No attention was focused on the source reaches (>20% gradient), this was assumed to be covered in the mass wasting analysis.

For each channel segment channel dimensions of bankfull width and valley width were observed. Channel morphology types based on Montgomery and Buffington (1993) and Rosgen (1994) classify the segment. The channel morphology is further interpreted by flood plain interaction for segment (continuous, discontinuous, inactive, none) and channel roughness characteristics. Streambed sediment characteristics are interpreted from observations of gravel bars, channel aggradation or degradation and particle size of the stream bed material. A pebble count of 50 randomly selected pebbles is counted at the cross section to determine the D50 (median particle size) of the streambed. Large woody debris (LWD) functioning in the channel is tallied (presented in detail in Riparian Function section). The number and type of pools (LWD forced, bank forced, boulder forced, free formed) are observed. Also, the average canopy closure over the watercourse is presented (discussed in detail in the Riparian Function section). The field observations are summarized and defined in Table E-1.

Geomorphic Units

Channel segments were grouped into geomorphic units by similar attributes of channel condition, position in the drainage network, and gradient/confinement classes. The intent of the geomorphic units are to stratify channel segments of the WAU into units which respond similarly to the input factors of coarse and fine sediment, and LWD. These geomorphic units can then be interpreted to have similar habitat-forming processes.

Interpretations related to sediment supply, transport capacity and LWD response were the basis for development of sensitivity of geomorphic units to coarse sediment, fine sediment and LWD inputs. These interpretations were based primarily on existing conditions observed in the stream channels of the WAU. The channel sensitivity to changes to coarse sediment, fine sediment and LWD are based on how the current state of the channel is likely to respond to inputs of these variables.

Long-Term Stream Monitoring Sites

To monitor stream channel morphology conditions and stream sediment characteristics related to fish habitat, 4 long-term stream channel monitoring segments were established in the Hollow Tree Creek WAU. Along these segments longitudinal profiles, cross sections and streambed size distribution measurements were surveyed. Stream gravel bulk samples and permeability of spawning gravels are also measured (methods and results presented in the Fish Habitat section)(at 5 stream segments). These long-term segments will be re-surveyed and monitored over time to provide insight into long term trends in channel morphology, sediment transport and fish habitat conditions. The long-term stream channel monitoring segment locations are shown on Map E-1.

The stream monitoring segments are typically 20-30 bankfull channel widths in length. Permanent benchmarks (PBMs) are placed at the upstream and downstream ends of the monitoring segment. The PBMs are monumented with nails in the base of large trees along with a re-bar pin in the ground adjacent to the nail.

The longitudinal profile is a survey of the thalweg, or deepest point of the channel excluding any detached or "dead end" scours and/or side channels, along the channels path. At every visually apparent change in thalweg location or depth, the distance along the channel is measured and the elevation is recorded. In the absence of visually apparent changes, thalweg measurements are taken every 15-20 feet along the channel. A profile graph of the channel's thalweg is created from the survey (see Appendix E for longitudinal profiles). A computer program (Longpro2) developed by the United States Geological Survey for Redwood National Park was used to analyze the profiles. This program converted the surveys into standardized data sets with uniform spacing between points and determined the residual water depth of each point. The residual water depth is the depth of water in pools of the channel segment defined by the riffle crest height at the outlet of the pool. No minimum pool depth is specified. The distribution, mean and standard deviation of the residual water depths for the longitudinal profile are calculated. This provides the ability to statistically evaluate changes in the residual water depths from the longitudinal profile over time.

Along the monitoring segment, 3-5 channel cross sections are surveyed (locations are permanently monumented). The cross sections are located along relatively straight reaches in the monitoring segment. Cross sections, when possible, are surveyed from above the floodprone depth of the channel. A graph of the cross section is created from the survey (see Appendix E for cross sections graphs). At each cross section a pebble count is conducted, to determine the particle size distribution and median particle size (D50), by measuring 100 randomly selected pebbles along the cross section fall line. In 2003 the location of LWD along the longitudinal profile was included.

RESULTS

Stream Channel Observations

Field channel surveys or observations were taken on 24 stream reaches in the Hollow Tree Creek WAU during the summer of 1999. Table E-1 provides a summary of the data collected. Further detail specific to in-channel fish habitat relationships is found in Section F - Fish Habitat Assessment of this report. LWD data is presented in the Section D – Riparian Function.

Key to Table E-1:

Stream Channel Dimensions

Category	Description
ID #	The stream identification number (see Map E-1), two letter planning watershed code followed by unique number for the planning watershed. RL - Lower Hollow Tree Creek RM – Middle Hollow Tree Creek RU – Upper Hollow Tree Creek RG – Low Gap Creek RI – Mill Creek
GU	Number of the geomorphic unit the channel segment is in.
Channel confinement	Confined-channel width to valley width ratio < 2, moderately confined-channel width to valley width ratio 2-4, unconfined-channel width to valley width ratio >4.
Surveyed Length	Length of segment surveyed.
GIS slope category	Slope class as designated by DTM in GIS.
Observed Slope	Mean slope of segment as observed in field.
Bankfull width	Bankfull width of the channel.
Valley Width	Width of the canyon.
Montgomery/Buffington Class	The channel morphology type: PR = pool/riffle, FP/R = forced pool/riffle, SP = step pool, PB = plane bed, CAS = cascade (Montgomery and Buffington, 1993)
Rosgen Class	Rosgen channel morphology classification, (Rosgen, 1994).
Floodplain Continuity	Description of floodplain/channel interaction either: continuous, inactive, discontinuous or none.

Sediment/Bedform Characteristics

Category	Description
Past Aggradation/Degradation	Evidence of past problems.
Current Aggradation/Degradation	Current status.
Channel Roughness	B =boulders, C=cobbles, F=bedforms, V=live woody veg., W=large woody veg., R=bedrock, Bk=banks and roots.
Gravel Bar Abundance	Qualitative measure of amount of gravel bars in segment. F = few, C = common, A = abundant.
Gravel Bar Type	Gravel bar type either: A=alternating point bars, P=point, M=medial or F=forced.
Gravel Bar Proportion Class	Proportion of stream segment in gravel bars: 0-25%, 25-50%, 50-75%, 75-100%.

Fine Sediment Abundance	sparse, moderate, abundant
Fine Sediment Type	type of fine sediment accumulation: P=isolated pockets, M=moderate accumulations, B=high accumulations including in gravel bars.
D50	Median gravel size of the stream bed particle distribution.

Pool Characteristics

Category	Description
Free	number of free formed pools in segment.
LWD Forced	number of LWD forced pools in segment.
Boulder Forced	number of boulder forced pools in segment.
Bank Forced	number of bank forced pools in segment.
Total # Pools	total number of pools in segment.
Pool Spacing	average space between pools by bankfull widths.
Mean Res. Pool Depth	The average of all residual pool depths in segment.

Table E-1. Channel Condition Observations for Hollow Tree Creek WAU.

Hollow Tree Creek WAU - 1999					Channel Dimensions						
Segment Name	Seg. #	GU	Confinement	Surveyed Length (ft)	GIS Slope Category (%)	Observed Slope (%)	Bankfull Width (ft)	Valley Width (ft)	Montgomery/ Buffington Class	Rosgen Class	Floodplain Continuity
Hollow Tree	RM5	I	Confined	1291	0-1	0.9	51.3	60	pb, cas, p/r	F4, F1	None
Lost Pipe Creek	RM48	IV	Confined	387	4-8	6.9	12	18	cas,p/r	G1,G4	None
Hollow Tree	RM3	I	Confined	1427	0-1	1.2	58.8	73	pb,p/r	F4	None
Lynch Creek	RU9	IV	Confined	226	4-8	5.0	19.5	28	fp/r,sp	A4	None
Doctors' Creek	RU12	II	Confined	436	2-4	2.1	10.3		p/r,fp/r	G4	None
Hollow Tree	RM6	I	Confined	907	0-1	1.4	48	53	p/r	F4	None
Butler Creek	RU6	II	Confined	740	1-2	1.6	23.5	45	p/r	F4	None
Hollow Tree	RU5	II	Moderately	551	1-2	1.1	18.6	40	p/r	G3,F4	Inactive
Hollow Tree	RU4	II	Confined	444	1-2	1.9	33	54	p/r	F3,F4	None
Hollow Tree	RU2	I	Confined	1074	0-1	1.1	40	43	p/r	F4	None
Bond Creek	RM110	II	Moderately	858	2-4	2.8	28.3	70	p/r,sp	G4,G3	Inactive
Bond Creek	RM109	II	Confined	732	1-2	1.6	20.3	32	p/r,sp	F4,F3	None
Michaels Creek	RU8	II	Confined	833	1-2	1.1	24.8	37	p/r	F4	None
Waldron Creek	RU25	II	Confined	720	2-4	6.8	16.5	29	sp,cas	F3,F1	Discontinuous
Hollow Tree	RL4	I	Confined	1413	0-1	0.9	65.3	70	p/r,pb	F4	None
Hollow Tree	RL3	I	Confined	1515	0-1	0.7	72	122	p/r,pb	F4	None
Redwood Creek	RM68	III	Unconfined	508	1-2	<1	30.5	300	p/r		Continuous
Redwood Creek	RM69	II	Unconfined	517	1-2	1.3	14	300	p/r	F4	Discontinuous
Huckleberry Creek	RU64	II	Moderately	942	2-4	1.3	17.3	40	p\r,sp	F4	Discontinuous
Huckleberry Creek	RU7	II	Confined	756	1-2	3.6	21	30	p/r,sp	G1,F1,F3	None
Bear Wallow	RU57	II	Moderately	619	2-4	1.7	18.3	53	p/r	F4	None
Little Bear Wallow	RU65	IV	Unconfined	377	4-8	2.2	7.3	71	fp/r, sp	G4	Discontinuous
Bear Creek	RM54	II	Confined	263	2-4	3.7	15.9	23	sp,p/r,fp/r	F4	None
SF Redwood Creek	RM88	II	Moderately	495	1-2	1.2	16.8	48	p/r		Discontinuous
Walters Creek	RM43	II	Confined	945	4-8	1.5	22.5	34	p/r	F4	None

Table E-1 (continued). Channel Condition Observations for Hollow Tree Creek WAU.

Hollow Tree Creek WAU - 1999				**Sediment/bedform Characteristics**						
Segment Name	Seg. #	Past Aggredation or Degradation	Current Aggredation or Degradation	Channel Roughness	Gravel bar Abundance	Gravel Bar Type	Gravel Bar Proportion	Fine Sediment Abundance	Fine Sediment Type	D50 (mm)
Hollow Tree	RM5			R,F	C	A, P	25-50%	sparse	P	30
Lost Pipe Creek	RM48		Agg.	R,C,F	C	A	25-50%	sparse	P	-
Hollow Tree	RM3			R,C,F	C	A-P	25-50%	moderate	M	49
Lynch Creek	RU9			R,C	F	F-A	0-25%	moderate	M	78
Doctors' Creek	RU12			R,C,BK	F	F	0-25%	sparse	P	41
Hollow Tree	RM6			C,R,V	F	P-A	0-25%	sparse	P	40
Butler Creek	RU6			C,R,V	F	A	0-25%	sparse	P	45
Hollow Tree	RU5	Agg.	Degr.		C	A	25-50%	moderate	M	42
Hollow Tree	RU4			C,R	C	A,M,F	25-50%	sparse	P	45
Hollow Tree	RU2			B,C,R	F	M,A	0-25%	sparse	P	44
Bond Creek	RM110	Agg.		C,B,R,F	F	A	0-25%	sparse	P	36
Bond Creek	RM109	Agg.		B,C,R	F	A,F	0-25%	moderate	M	51
Michaels Creek	RU8			B,C,R	F	A	0-25%	sparse	P	48
Waldron Creek	RU25			R	F		0-25%	sparse	P	22
Hollow Tree	RL4			B,R	C	A	0-25%	sparse	P	-
Hollow Tree	RL3			C,R,BK	F	A,M	0-25%	sparse	P	-
Redwood Creek	RM68			V,W	F		0-25%	abundant	M	34
Redwood Creek	RM69		Degr.	F,W	C	P	25-50%	moderate	M	27
Huckleberry Creek	RU64			C,R,W	C	A	25-50%	moderate	M	-
Huckleberry Creek	RU7			R,V,B	F	A	0-25%	sparse	P	26
Bear Wallow	RU57			B,C,R	C	A,P	25-50%	sparse	P	34
Little Bear Wallow	RU65	Agg.	Degr.	C,BK,W				sparse	P	27
Bear Creek	RM54	Agg.	Degr.	R,W	F	P,M	0-25%	moderate	M	60
SF Redwood Creek	RM88	Agg.	Degr.	F,V	F	A	0-25%	moderate	M	35
Walters Creek	RM43	Agg.	Degr.	C,R,V,F	F	F-A	0-25%	sparse	P	71

Table E-1 (continued). Channel Condition Observations for Hollow Tree Creek WAU.

Hollow Tree Creek WAU - 1999			**Pools**								
Segment Name	Seg. #	Free	LWD Forced	Boulder Forced	Bank Forced	Total # pools	Pool Spacing	Mean Res. Pool Depth (ft.)	Shade Canopy (%)	Comments
Hollow Tree	RM5	12	0	0	4	16	1.6	5.9	55	
Lost Pipe Creek	RM48	4	0	0	0	4	8.1	1.7	92	
Hollow Tree	RM3	0	1	0	6	7	3.5	3.7	48	
Lynch Creek	RU9	0	5	1	7	13	0.9	1.3	87	
Doctors' Creek	RU12	3	3	0	6	12	3.5	1.3	98	
Hollow Tree	RM6	2	2	0	3	7	2.7	3.1	89	
Butler Creek	RU6	0	8	1	1	10	3.1	2.2	92	
Hollow Tree	RU5	1	3	2	4	10	3.0	2.2	96	
Hollow Tree	RU4	1	4	1	3	9	1.5	1.6	96	lots of CCC structures in segment
Hollow Tree	RU2	0	3	2	0	5	5.3	1.7	85	
Bond Creek	RM110	0	5	2	4	11	2.8	1.6	96	
Bond Creek	RM109	0	5	0	4	9	4.0	1.6	96	
Michaels Creek	RU8	1	5	0	1	7	4.8	1.7	81	
Waldron Creek	RU25	6	3	0	4	13	3.4	2.1	88	
Hollow Tree	RL4	3	0	0	4	7	3.1	3.5	58	
Hollow Tree	RL3	2	2	0	4	8	2.6	4.2	58	
Redwood Creek	RM68	2	10	0	0	12	1.4	2.2	90	
Redwood Creek	RM69	0	11	1	1	13	2.8	2	86	
Huckleberry Creek	RU64	5	11	3	6	25	2.2	2.1	92	
Huckleberry Creek	RU7	6	4	1	0	11	3.3	2.1	85	LWD is primarily CCC structures
Bear Wallow	RU57	1	3	1	6	11	3.1	1.5	92	
Little Bear Wallow	RU65	1	5	0	3	9	5.7	1.5	90	
Bear Creek	RM54	2	6	0	1	9	1.8	1.2	86	
SF Redwood Creek	RM88	1	9	2	5	17	1.7	1.4	93	
Walters Creek	RM43	2	3	2	2	9	4.7	1.2	81	

Stream Geomorphic Units

Stream geomorphic units were developed for the stream network on the MRC property in the Hollow Tree Creek watersheds. These units are general representations of stream channels with similar sensitivities to coarse sediment, fine sediment and large woody debris inputs. Seven stream geomorphic units were developed for interpretation of stream channel response to forest management interactions in the Hollow Tree Creek WAU. The seven stream geomorphic units are described below.

Geomorphic Unit I. Highly Confined Low Gradient Channels within Inner Gorge Topography.

Includes Segments: *Field observed* – RL3, RL4, RM3, RM5, RM6, RU2
Extrapolated - RL1, RL2, RM1, RM2, RM4, RU1, RU3
General Description: Stream channels within this unit flow through confined inner gorge canyon bottoms in the Hollow Tree Creek watershed. Typically the channel banks are the side slopes of the inner gorge with no room for floodplain or terrace development. Lateral channel migration is controlled by frequent bedrock outcrops and the gorge's side slopes. The channels in this unit are low gradient (0-2 percent), but sediment transport capacity is high due to the highly confined channel keeping water energy directed within the channel. High flow events within these channels will move all but the most stable large woody debris (LWD) accumulations or push accumulations to the channel margins. The channel bed varies from gravel to cobble sized particles, with many areas bedrock dominated.

Associated Channel Types:
This unit primarily exhibits pool/riffle and plane bed morphology. The Rosgen classifications (Rosgen, 1994) for these channels are predominantly F4 and F1.

Fish Habitat Associations:
The highly confined channels of this units have a high sediment transport capacity during high flows, which flushes fine sediment, creating cleaner, high quality spawning gravel. This same high-energy transport, in conjunction with a lack of wood, creates free-formed pools in which the energy of the water creates the scour associated with the pool. Typically, free-formed pools have low shelter complexity because they are not associated with large wood and there is low refuge for fish. However, the deep bedrock controlled pools found within this unit does provide some refuge during high flows, overall this unit creates only some habitat for the over-wintering life stage of salmonids.

Conditions and Response Potential:

Coarse Sediment: Moderate Response Potential
The highly confined water flow of this unit creates high coarse sediment transport capacity. Coarse sediment can deposit in these confined high-energy channels if the coarse sediment supply surpasses the transport capacity. The impact can be filling of pools or increased scour of the bed. Coarse gravel accumulations are common in alternating point and medial gravel bars in this unit. The high amount of bedrock control of these channels forces pool scour and coarse sediment transport. As a whole the channels in the unit currently do not show evidence of either aggrading or degrading.

Fine Sediment: Moderate Response Potential
The channels of this unit have high fine sediment transport capacity due to high flow capacity of the channel. However, when there is a high fine sediment supply in transport, accumulations of fine sediment can occur in pools or the bed texture could become finer. High accumulations of fine sediment were not observed in this unit. Fine sediment accumulations that were observed in this unit were on the top of gravel bars, accumulated in the bed of plane bed reaches, along pool margins, and in some pools.

Large Woody Debris: Moderate Response Potential
Large woody debris is sparse in this unit. The LWD that is present is providing stream habitat development and cover. The high flows confined within the channels of this unit require very large LWD pieces or debris jams to keep the LWD in place. Very large LWD is recruited into channels infrequently due to the long growing times of streamside trees. However, LWD in this unit is important because the channels in this unit gain greater pool depths and cover, for fish habitat diversity, with increased LWD.

Geomorphic Unit II. Confined to Moderately Confined Moderate Gradient Channel Segments.

Includes Segments: *Field observed* – RM43, RM54, RM69, RM88, RM109, RM110, RU4, RU5, RU6, RU7, RU8, RU12, RU25, RU57, RU64
Extrapolated – RG1, RI1, RL5, RL6, RL7, RL22, RM8, RM9, RM10, RM26, RM28, RM29, RM36, RM39, RM40, RM42, RM67, RM70, RM89, RM111, RM112, RU15, RU17, RU26, RU40, RU41, RU42, RU48

General Description:
Channels within this unit are confined to moderately confined within canyons or historic terraces. Typically, channels in this unit are at the bottom of "sub-watershed" tributaries of Hollow Tree Creek. Bankfull widths vary from about 10 to 25 feet in width. Channel gradients are moderate (1-4 percent), with isolated low gradient areas (<1 percent). Many of these channels have a high gradient section at their outlet at Hollow Tree Creek. This is because the channels drop steeply into the inner gorge along Hollow Tree Creek; some channels have a waterfall or cascade morphology at their outlet. Sediment transport capacity is high due to moderately confined to confined channels directing water energy within the channel and moderate channel gradients. Channel substrate is typically gravel to cobble sized particles, with some bedrock dominated areas.

Associated Channel Types:
This unit primarily exhibits pool/riffle, forced pool/riffle and step pool morphology. There is isolated sections of cascade morphology. The Rosgen classifications (Rosgen, 1994) for these channels vary from G3, G4, F3, F4 with areas of C4, F1 and G1 depending on the bank configuration and channel substrate.

Fish Habitat Associations:
The confined channels of this units have a high sediment transport capacity during high flows, which flushes fine sediment, with the potential to create high quality spawning gravel. This same high-energy transport, in conjunction with LWD, dominates pool development. Currently this unit has low amounts of large woody debris, however due to the confined canyons, wood recruitment would have a positive effect on the quality of in-stream habitat by making the shelter associated with pools more complex. Overwintering habitat can be limited in areas without large cobble/boulder and bedrock substrates. LWD when present in this unit provides overwintering habitat for juvenile salmonids.

Conditions and Response Potential:

Coarse Sediment: High Response Potential
These channels can be both depositional or transport areas for coarse sediment. If the supply of coarse sediment surpasses the transport capacity of the stream, pools can be filled, and the influence of large woody debris and bedrock controlled sections are lessened. If significant amounts of coarse sediment are supplied to these channels then the channels are vulnerable to widening, creating greater bank erosion, or limited lateral movement reducing meander and increasing bed scour.

Fine Sediment: Moderate Response Potential
The channels of this unit have high fine sediment transport capacity due to high flow capacity of the channel. However, when there is a high fine sediment supply in transport, accumulations of fine sediment do occur in this unit. Moderate to sparse accumulations of fine sediment was observed in this unit. These accumulations were observed in the gravel bars, along channel margins, and in some pools.

Large Woody Debris: High Response Potential
Large woody debris alone or in combination with other elements such as meander bends, boulders, or bedrock are associated with pool maintenance, habitat cover, gravel sorting and gravel bar formation in this unit. Large woody debris is a major factor for pool formation. Due to the moderate gradients, smaller pieces can be transported downstream in this unit facilitating accumulations of large woody debris. Changes in the loading of large woody debris in this unit would have significant impact on pool conditions, sediment storage and movement, and gravel bar development.

Geomorphic Unit III. Unconfined to Moderately Confined Channel Migration Zones.

Includes Segments: *Field observed* – RM68, RM87

General Description: This unit is a unique channel feature isolated to the area around the confluence of Redwood and South Fork Redwood Creek in the Hollow Tree WAU. The channels in this unit are low gradient (0-2 percent), with a high degree of deposition and terrace development. Channels within this unit frequently access the floodplain and abandoned channels at high flows. The unconfined channels in combination with access of the floodplain and abandoned channels during high flows makes channel migration common in this unit. The channel substrate, and adjacent terraces is predominantly a consolidation of fine deposited materials of the silt and clay size classes.

Associated Channel Types:
This unit exhibits pool/riffle morphology. The Rosgen classifications (Rosgen, 1994) for these channels are predominantly E4 and E6, with areas of C4 and F4 depending on the bank configuration.

Fish Habitat Associations:
A high propensity for channel migration causes streams to spread out over the floodplain rather than concentrating flows through a narrow channel. While this increased wetted area may enhance spawning habitat area, it also increases fine sediment deposition in areas of lesser flow. During drought conditions or low summer flows, it is not uncommon for side channel flow to go subsurface. In these situations, rearing habitat is limited to the main channel and deeper residual pools. The unconfined, low gradient nature of these streams combined with large amounts of woody debris result in an abundance of wood-forced pools creating good summer-rearing habitat. These segments are often lacking bedrock and the large cobble/boulder substrates associated with overwintering habitat. However, the LWD provides the roughness element to slow water velocities and provide key overwintering habitat to juvenile salmonids.

Conditions and Response Potential:

Coarse Sediment: Moderate Response Potential
The unconfined to moderately confined channels and migrating channel areas are not considered high sediment transport areas. This unit does provide a large amount of sediment storage opportunities buffering impacts from high coarse sediment loads. However, if coarse sediment supply increases above the transport and storage capacity of this unit then the influence of large woody debris and bank stability will be compromised. This unit can be particularly vulnerable to widening, aggradation, and loss of habitat complexity from coarse sediment.

Fine Sediment: Low Response Potential
Moderate to high accumulations of fine sediment was observed in this unit. However, the substrate and terrace in this unit is composed of fine material. The unconfined and low gradient characteristics of this unit facilitate fine sediment deposition. This deposition provides for the flat morphology of the stream channels, and thus the fine material composition of the channel banks, substrate and terraces. This process of fine sediment deposition appears to be the natural process in this unit. This unit should not be adversely affected by future fine sediment deposition provided the channel migration and floodplain characteristics are not altered.

Large Woody Debris: High Response Potential

LWD is common to abundant in this unit. LWD provides function for pool habitat development or cover in this unit. The greatest portion of pool formation in this unit is LWD forced. The channel substrate and terraces in this unit are predominantly composed on fine particles (silt and clay), providing little in the way of roughness elements for stream habitat or channel diversity. LWD and streamside vegetation in this unit is the primary source of channel roughness for stream habitat development and quality. In the areas where channel migration is prevalent LWD recruitment across the entire canyon bottom is essential to ensure adequate LWD for channel roughness and habitat as the channel migrates.

Geomorphic Unit IV. Moderate Gradient Confined Transport Segments.

Includes Segments: *Field observed* – RM48, RU9, RU65
Extrapolated – RG2, RG5, RG8, RL9, RL12, RL16, RL21, RM11, RM14, RM15, RM22, RM27, RM33, RM35, RM44, RM53, RM57, RM61, RM62, RM65, RM72, RM81, RM83, RM90, RM91, RM96, RM98, RM100, RM104, RM105, RM113, RM114, RU16, RU24, RU27, RU30, RU35, RU43, RU44, RU45, RU50, RU51, RU67, RY68

General Description:
Stream channel segments in this unit are of moderate gradient (4-8 percent) confined within relatively steep side slopes. Typically valley widths are less than 2-3 times the bankfull channel width. This valley width is sufficient to allow some isolated terrace formation and channel meandering. Occasional unique features, only observed in the upper reaches of Huckleberry Creek, have areas of moderate confinement with accumulations of fine sediment in the terraces and floodplain of the valley bottom. These unique areas are meadow-like due to the high moisture retention of the fine particle soil. The channel segments in this unit are near the transition between deposition and transport channels. Due to the moderate gradient (4-8 percent) of the channels, they are responsive to aggradation and degradation from changes in the stream sediment supply. The stream bed of these channels varies from gravel to boulder sized particles. The gradient of the stream is high enough that stream segments in this unit easily downcut through the terrace deposits.

Associated Channel Types:
This unit primarily exhibits step pool and cascade morphology, with some areas of forced pool/riffle morphology. The Rosgen classifications (Rosgen, 1994) for these channels vary from A4, A2, A3 with areas of G1, G2, and G3 depending on the bank configuration and channel substrate.

Fish Habitat Associations:
The moderate gradient of channels of this unit typically forms step-pool, cascade, and some pool-riffle habitat. The step-pools in this unit are typically boulder formed that provides pool depth, substrate refuge, and both rearing and over-wintering habitat. Spawning areas in this unit are infrequent, due to lack of accumulations of gravel sized particles. In the higher gradient, headwater segments of this unit fish spawning and over-wintering habitat is infrequent. Often, the upper reaches of this unit go dry during summer limiting rearing habitat.

Conditions and Response Potential:

Coarse Sediment: Moderate Response Potential
The channels in this unit have relatively high sediment transport capacity. In the lower gradient sections of these channels coarse sediment can create pool filling and aggradation, resulting in increased bank erosion and poor stream habitat. The step pool sections of these channels have relatively stable cobble and boulder component that can remain relatively static except in extreme flows. Increased coarse sediment supply can create pool filling, but is only moderately influential on the morphology because pool filling at these moderate gradients creates lower channel roughness which in turn promotes more step pool or cascade development, provided high inputs of coarse sediment subside.

Fine Sediment: Low Response Potential
The channels of this unit have high fine sediment transport capacity due to high flow capacity of the channel. However, when there is a high fine sediment supply in transport, accumulations of fine sediment do occur but typically have short residence times in this unit. Sparse to moderate accumulations of fine sediment was observed in this unit. These accumulations were observed in the bed and along channel margins.

Large Woody Debris: Moderate Response Potential
The high confinement or entrenchment of these channels provides little opportunity for the channel to meander or develop a floodplain. Water energy is concentrated within the confines of canyon walls or stream banks making the role of LWD less sensitive as channels with less confinement or entrenchment. LWD is less likely to enter the channel because it becomes suspended over the channels narrower bankfull width. The role of LWD is typically as sediment storage or forced step pool development in these channels. Bed morphology in channels with slope gradients of 4-10% is typically step pool (Montgomery and Buffington, 1993). The large bed forming material of step pool morphology is generally stable making the role of LWD in these channels less sensitive than other channel types.

Geomorphic Unit V. High Gradient Transport Segments.

***Includes Segments*:** RG3, RG4, RG6, RG7, RG9, RG10, RG11, RI2, RI3, RL8, RL10, RL11, RL13, RL14, RL17, RL18, RL19, RL20, RL23, RM12, RM13, RM16, RM17, RM18, RM19, RM20, RM21, RM23, RM24, RM25, RM30, RM31, RM32, RM34, RM37, RM38, RM40, RM45, RM46, RM47, RM49, RM50, RM51, RM52, RM55, RM56, RM58, RM59, RM60, RM63, RM64, RM66, RM71, RM73, RM74, RM75, RM76, RM77, RM78, RM79, RM80, RM82, RM84, RM85, RM86, RM92, RM93, RM94, RM95, RM97, RM99, RM101, RM102, RM103, RM106, RM107, RM108, RM115, RM116, RM117, RM118, RM119, RM120, RM121, RM122, RM123, RM124, RM125, RM126, RM127, RM128, RM129, RM130, RU10, RU11, RU13, RU14, RU18, RU19, RU20, RU21, RU22, RU23, RU28, RU29, RU31, RU32, RU33, RU34, RU36, RU37, RU38, RU39, RU46, RU47, RU49, RU52, RU53, RU54, RU55, RU56, RU58, RU59, RU60, RU61, RU62, RU63, RU66, RU69, RU70, RU71, RU72

General Description:
Channel segments in this unit are high gradient transport reaches from 8-20% with high sediment transport capacity. The channel segments in this unit typically flow through tightly confined, steep-sided, V-shaped canyons. These are typically zones of scour during high flows or debris flows. Stream substrate is typically from cobble to large boulders. Typically, there is no water flow in this unit in the summer drought season.

Associated Channel Types:
This unit varies it morphology from step pool to cascades with some occasional waterfalls. The cascades and waterfalls occur in the steepest segments of this unit and only during winter storm events. The Rosgen (Rosgen, 1996) classification for these channels varies between A2, A3, and AA2, AA3 depending on channel gradient and substrate composition.

Fish Habitat Associations:
The high gradient channels of this unit prevent coho salmon from reaching these areas. Steelhead trout are possible, but unlikely due to the dry channels in summer and the higher, 12% to 20% gradient sections.

Conditions and Response Potential:

Coarse Sediment: Low Response Potential
Typically the channel morphology in this unit is cascade, with some step pool morphology at the lower gradients observed in these channels. These channels have bed material that is coarse and relatively immobile. Down cutting or bank erosion are not common in these high gradient, large substrate dominated channels even with increases in sediment supply. Debris flows can cover the substrate creating the cascade morphology but this is generally short-lived due to the high sediment transport capacity of the channels.

Fine Sediment: Low Response Potential
The high gradient of the channels in this unit creates a high fine sediment transport capability. Pools or storage areas for fine sediment in these channels are limited making the impacts from fine sediment minimal. Down cutting or bank erosion are not common in these high gradient, large substrate dominated channels even with increases in sediment supply.

Large Woody Debris: Low Response Potential
The role of LWD in these channels is to provide storage of sediment and also as a source for downstream LWD. LWD is needed in these channels however the need for LWD as a source for downstream LWD is episodic and therefore the least sensitive as other channel types. The storage of sediment by LWD in these channels is necessary, but can be accomplished by a range of size classes of LWD not necessarily large key LWD pieces.

Long Term Channel Monitoring

In 1999, 2001 and 2003 four long term channel monitoring segments were surveyed for longitudinal profiles, channel cross sections, and particle size distributions in the Hollow Tree WAU. In 2003 large woody debris was included in the longitudinal profile observations. The plots of the surveys are included in the appendix of this module (Appendix E). Stream gravel bulk samples and permeability were collected in these segments and are presented in Section F - Fish Habitat Assessment of this report.

Table E-2 presents the statistics calculated for each of the longitudinal profiles. The mean residual depth and standard deviation of the residual depths provide the best indication of aquatic habitat conditions over time. An increase in the mean and standard deviation of residual depths indicates deeper pools and increased complexity of the stream channel profile. In all of the channel monitoring segments the general trend is toward a modestly increased mean and standard deviation of residuals depths. There is a lot of variability between years; however, a slight improvement is observed.

Table E-2. Comparison of Residual Depth Observations for Longitudinal Profiles of Long-Term Channel Monitoring Segments of the Hollow Tree WAU for 1999, 2001, and 2003.

Segment ID	Stream	Year	Maximum Residual Depth (ft)	Mean Residual Depth (ft)	Standard Deviation
RM3	Hollow Tree Creek (lower)	1999	6.89	1.02	1.27
RM3	Hollow Tree Creek (lower)	2001	6.68	1.18	1.48
RM3	Hollow Tree Creek (lower)	2003	6.87	1.14	1.45
RU4	Hollow Tree Creek (upper)	1999	2.92	0.46	0.54
RU4	Hollow Tree Creek (upper)	2001	2.25	0.47	0.54
RU4	Hollow Tree Creek (upper)	2003	5.97	0.99	1.18
RU57	Bear Wallow Creek	1999	1.58	0.33	0.41
RU57	Bear Wallow Creek	2001	2.19	0.39	0.47
RU57	Bear Wallow Creek	2003	2.50	0.40	0.54
RM109	Bond Creek	1999	3.17	0.40	0.55
RM109	Bond Creek	2001	2.31	0.27	0.42
RM109	Bond Creek	2003	3.22	0.47	0.64

Cross sections within the long term channel monitoring segments show some fluctuations in depth and channel shape over time (see graphs in Appendix E). However, generally there is not evidence of channel aggradation or degradation over the last 4 years. At each of the cross sections the particle size distribution of the stream bed has been observed through pebble counts (see graphs in Appendix E). Table E-3 presents one statistic of the stream bed particle size distribution, the median particle size (D50), to allow comparison of the observations over time. Generally, the D50 of the stream bed at the cross sections in the Hollow Tree WAU have shown a slight increase. There is a lot of variability of the observations and the increased D50 is modest. An increase of the D50 can indicate a coarser particle size distribution of the stream bed over time, or in other words less fine particles. An increase in fine particles is usually considered detrimental as it can indicate a high sediment load.

Table E-3. Median Particle Size (D50) for Stream Bed from Pebble Counts at Cross Sections (XS) within Long-Term Channel Monitoring Segments of the Hollow Tree WAU for 1999, 2001, and 2003.

Segment ID	Stream	Year	XS1 D50 (mm)	XS2 D50 (mm)	XS3 D50 (mm)	XS4 D50 (mm)
RM3	Hollow Tree Creek (lower)	1999	21	38	36	39
RM3	Hollow Tree Creek (lower)	2001	16	30	25	91
RM3	Hollow Tree Creek (lower)	2003	40	30	40	54
RU4	Hollow Tree Creek (upper)	1999	15	27	25	30
RU4	Hollow Tree Creek (upper)	2001	14	55	18	31
RU4	Hollow Tree Creek (upper)	2003	22	26	22	42
RU57	Bear Wallow Creek	1999	19	44	24	-
RU57	Bear Wallow Creek	2001	37	89	15	-
RU57	Bear Wallow Creek	2003	36	32	24	-
RM109	Bond Creek	1999	29	19	13	-
RM109	Bond Creek	2001	46	19	13	-
RM109	Bond Creek	2003	56	40	24	-

When combining the general observation of no channel aggradation and degradation in cross sections, a modest increase in mean residual depth and standard deviations of residual depths, and a modest increase in the stream bed particle size distributions, the Hollow Tree WAU long term channel monitoring segments are showing an improving trend from 1999-2003. Albeit the trend is slight and needs to be watched for a longer time frame. The inclusion of LWD observations in the long term channel monitoring segments (2003 was first time for LWD observations) will assist with future interpretations.

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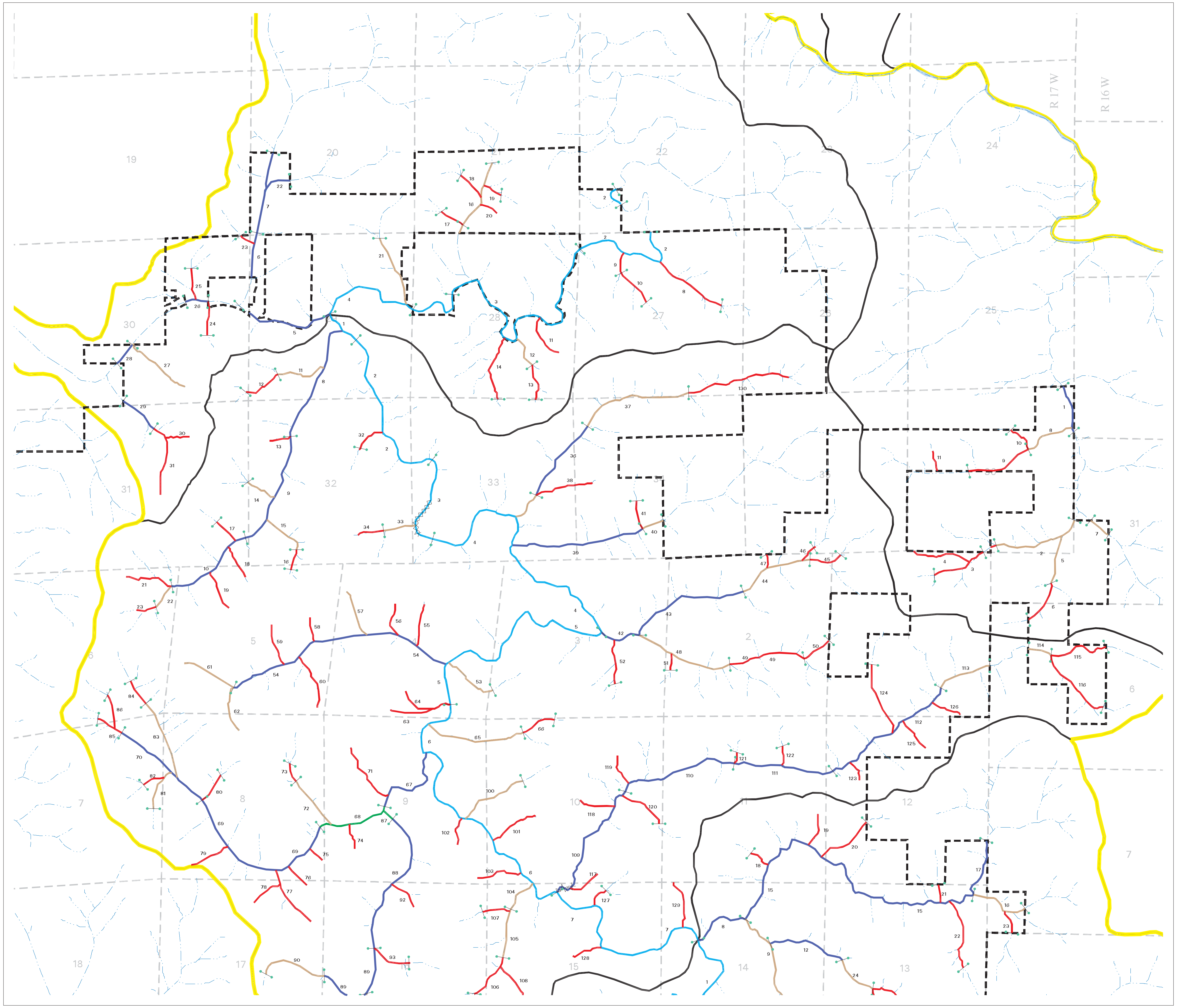
Rosgen, D. 1996. Applied river morphology. Wildland Hydrology, Pagosa Springs, CO.

Sullivan, K., T. Lisle, C. Dollhof, G. Grant, and L. Reid. 1986. Stream channels: the link between forests and fishes. In: Salo E.O. and T. Cundy. Streamside Management: Forestry and Fishery Interactions. Proc. of Symposium held at the Univ. of Washington, Feb 12-14, 1986, Seattle, WA: 39-97.

Washington Forest Practice Board. 1997. Standard methodology for conducting watershed analysis. Version 4.0. WA-DNR Seattle, WA.

Appendix E

Stream Channel Condition Module



Hollow Tree Creek Watershed Analysis Unit

Map E-1 Stream Channel Geomorphic Units and Segments

This map presents the stream channel network for the Hollow Tree WAU partitioned into stream segments based on channel confinement and channel gradient. Channel segments were grouped into geomorphic units by similar attributes of channel condition, position in the drainage network, and gradient/ confinement classes. The intent of the geomorphic units are to stratify channel segments of the Hollow Tree WAU into units which respond similarly to the input factors of coarse and fine sediment, and LWD. These geomorphic units can then be interpreted to have similar habitat-forming processes and responses to forest management effects.

Geomorphic Classes

- Highly Confined Low Gradient Channels within Inner Gorge Topography
- Confined to Moderately Confined Moderate Gradient Channel Segments
- Unconfined to Moderately Confined Channel Migration Zones
- Moderate Gradient Confined Transport Segments
- High Gradient Transport Segments

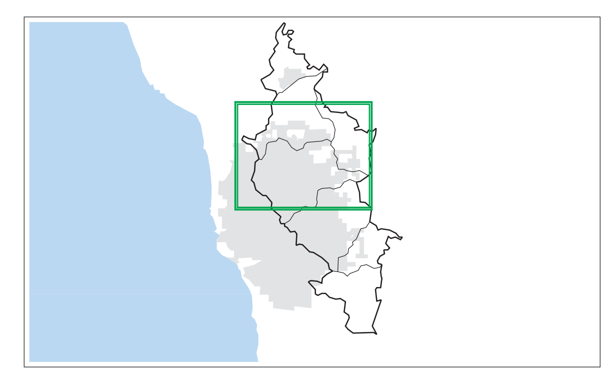
- Long Term Channel Monitoring Sites

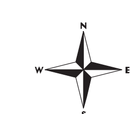
- MRC Ownership
- Planning Watershed Boundary
- Hollow Tree Creek Watershed Analysis Unit Boundary

Flow Class

- Class I
- Class II
- Class III

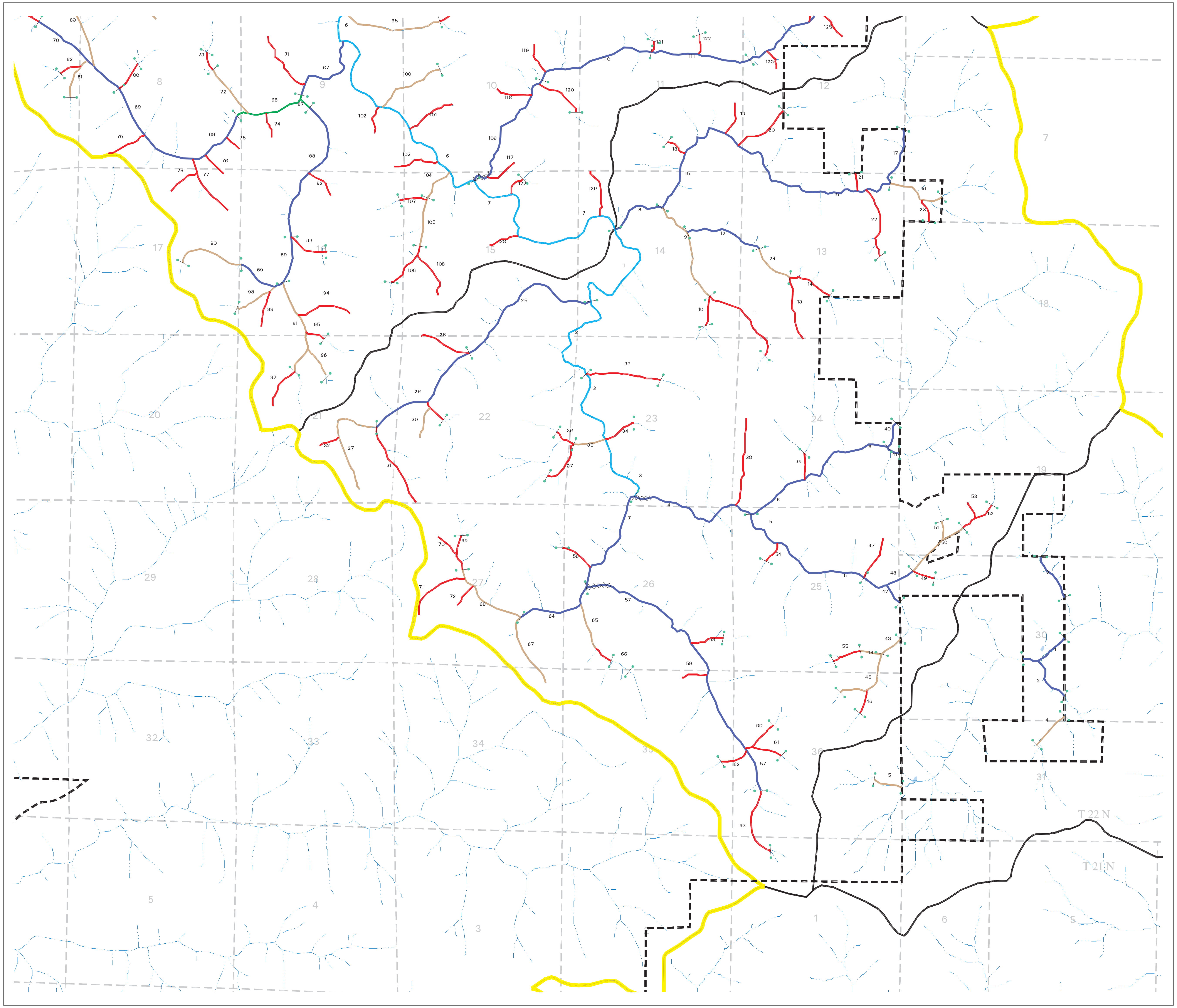
Sheet 1





0 1/2 1 Mile

December 2003



Hollow Tree Creek Watershed Analysis Unit

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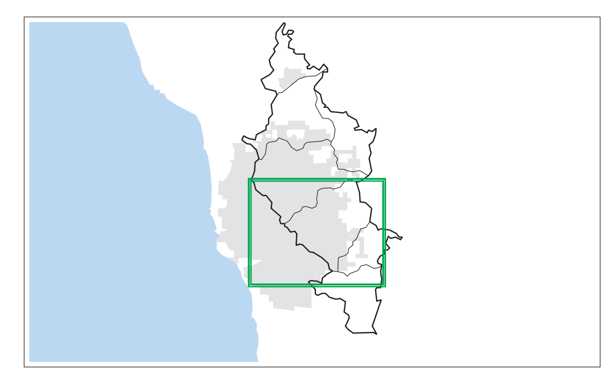
- Moderate Gradient Confined Transport Segments
- High Gradient Transport Segments
- Long Term Channel Monitoring Sites

- MRC Ownership
- Planning Watershed Boundary
- Hollow Tree Creek Watershed Analysis Unit Boundary

Flow Class

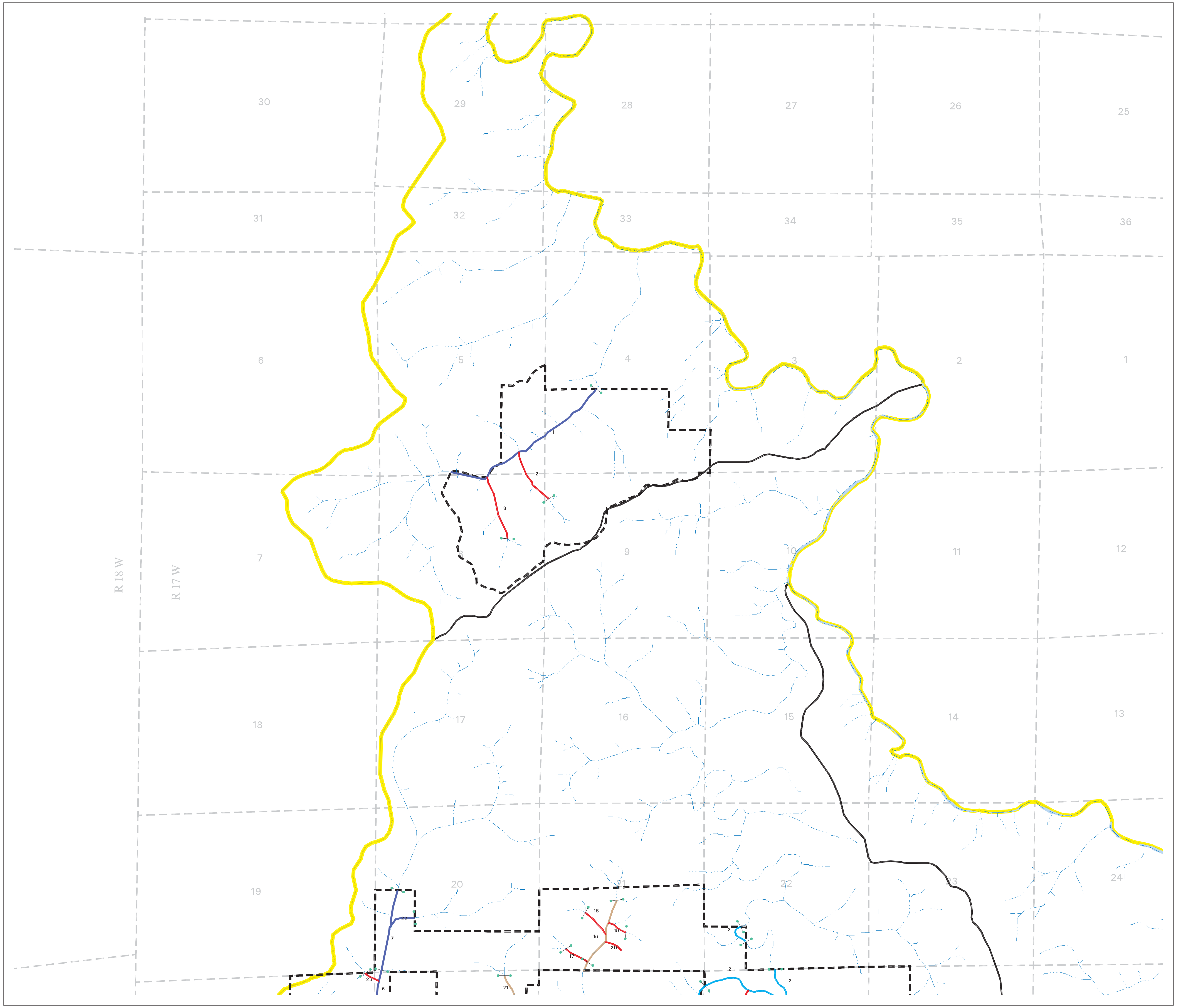
- Class I
- Class II
- Class III

Sheet 2



0 1/2 1 Mile

December 2003



Hollow Tree Creek Watershed Analysis Unit

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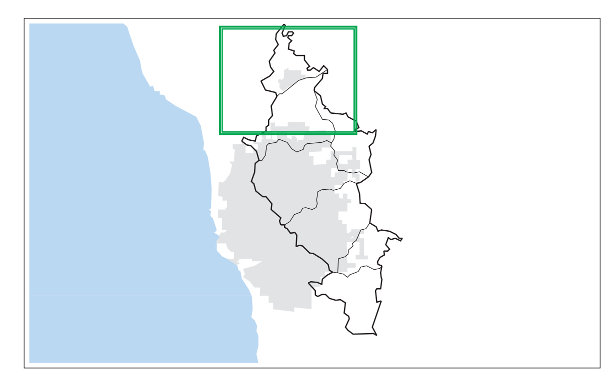
- Hollow Tree Creek Watershed Analysis Unit Boundary

Flow Class

- Class I
- Class II
- Class III

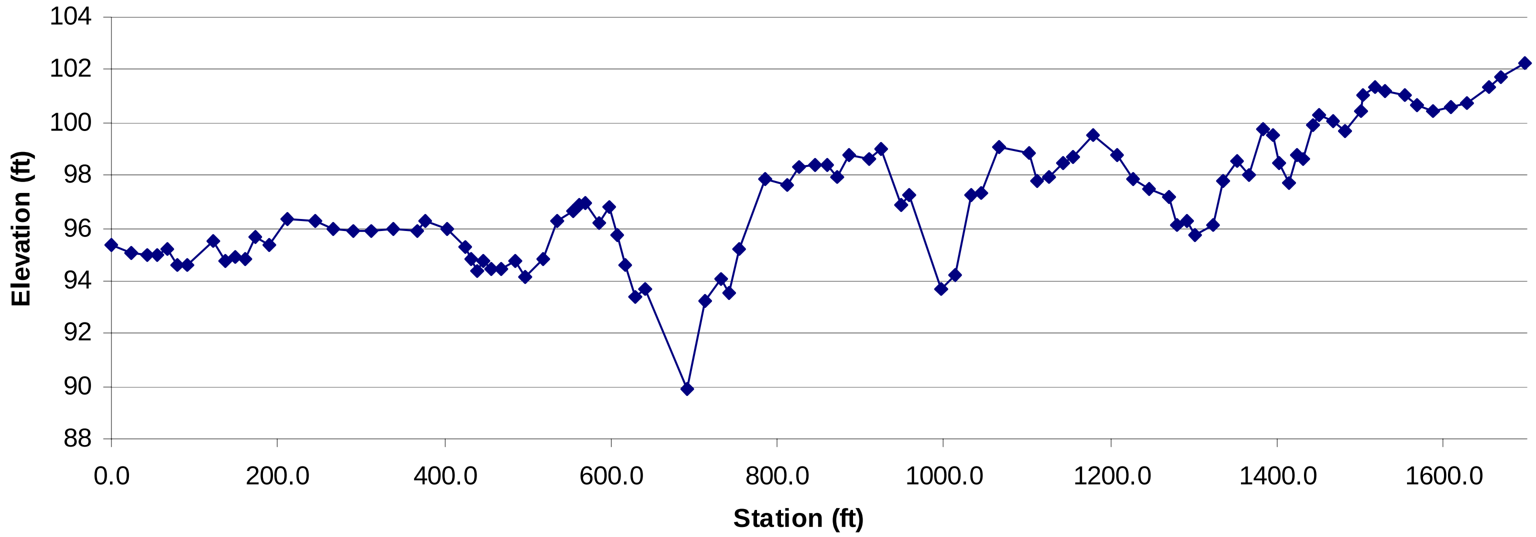
Sheet 3

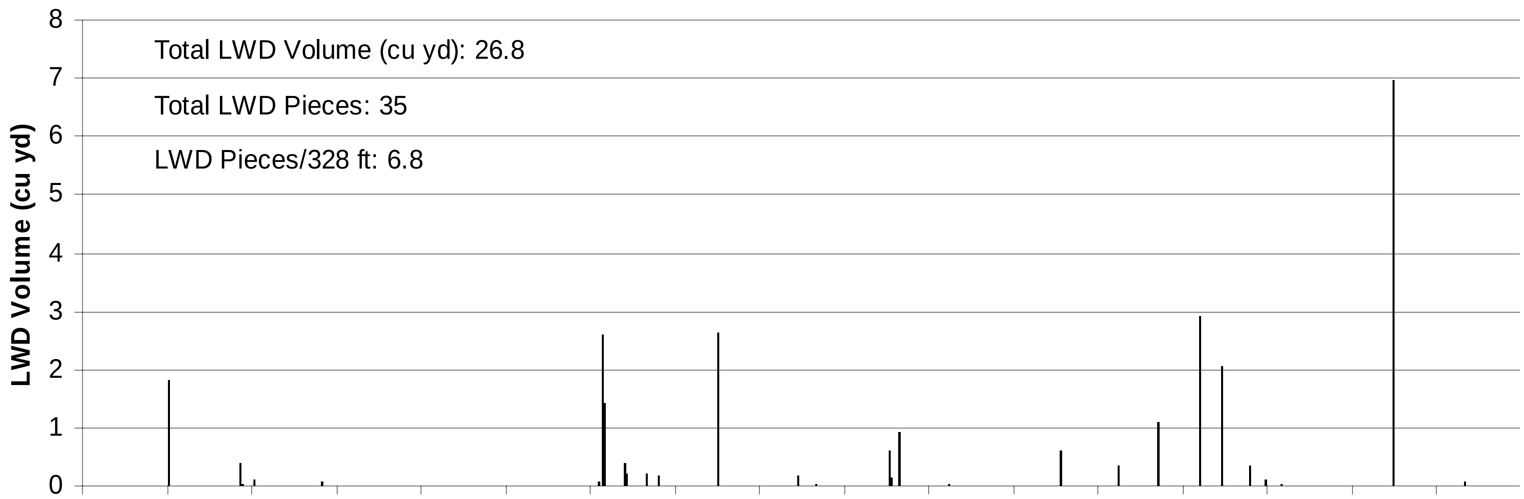


0 1/2 1 Mile

December 2003

Lower Hollow Tree Creek Long Term Channel Monitoring, Longitudinal Profile and Large Woody Debris, October, 2003





Lower Hollow Tree Segment RM3 Oct.03

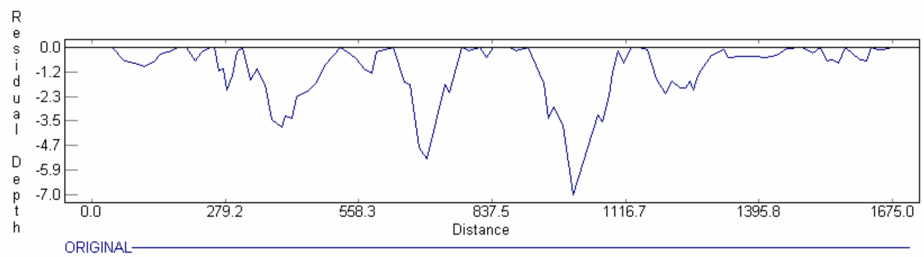
Top Elevation: 102.27
Bottom Elevation: 89.91
Reach Length: 1675.00

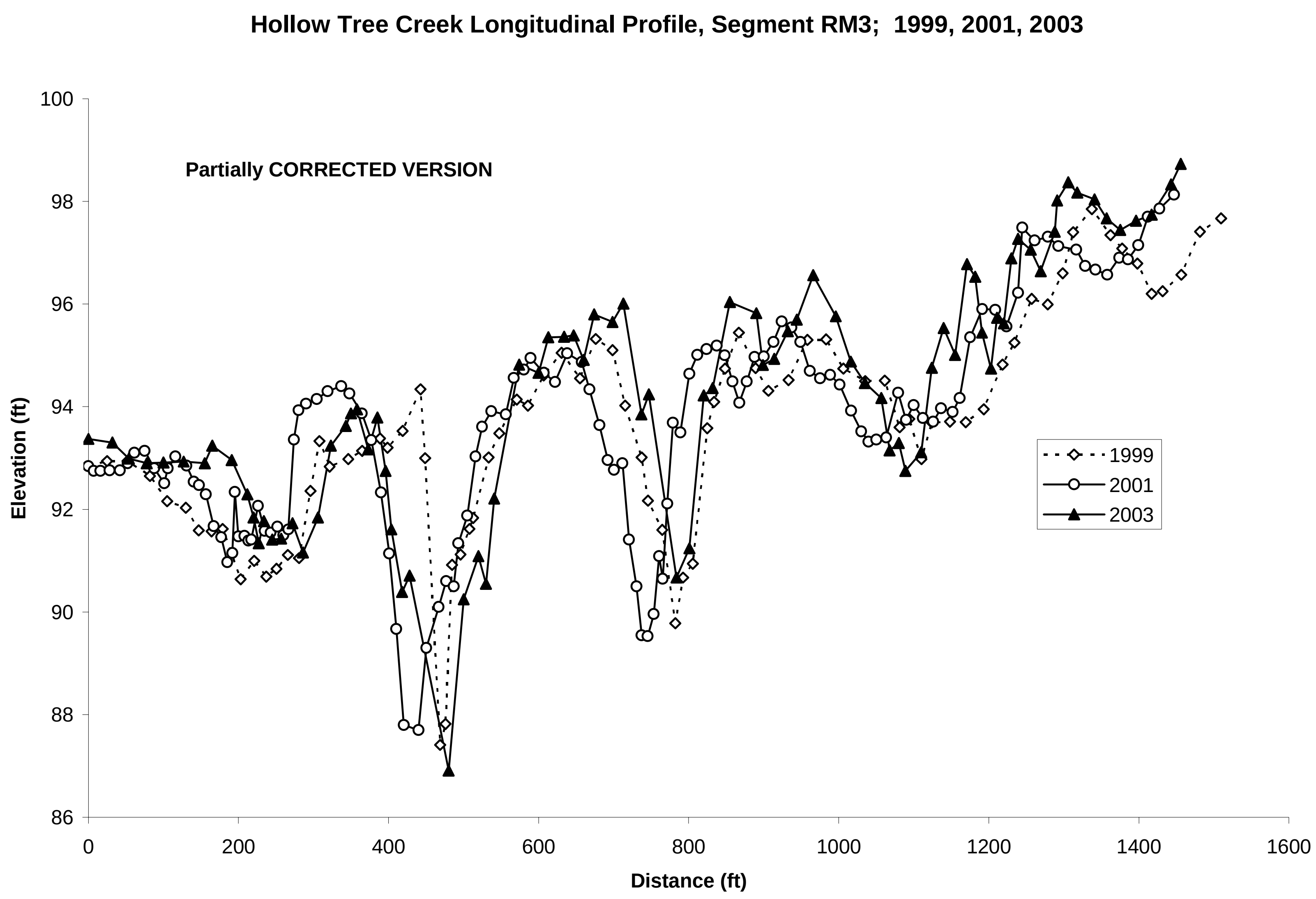
Standardized Statistics:
Number of data points in raw data: 100
Number of data points in Standardized data: 100

Reach Step Distance: 16.75

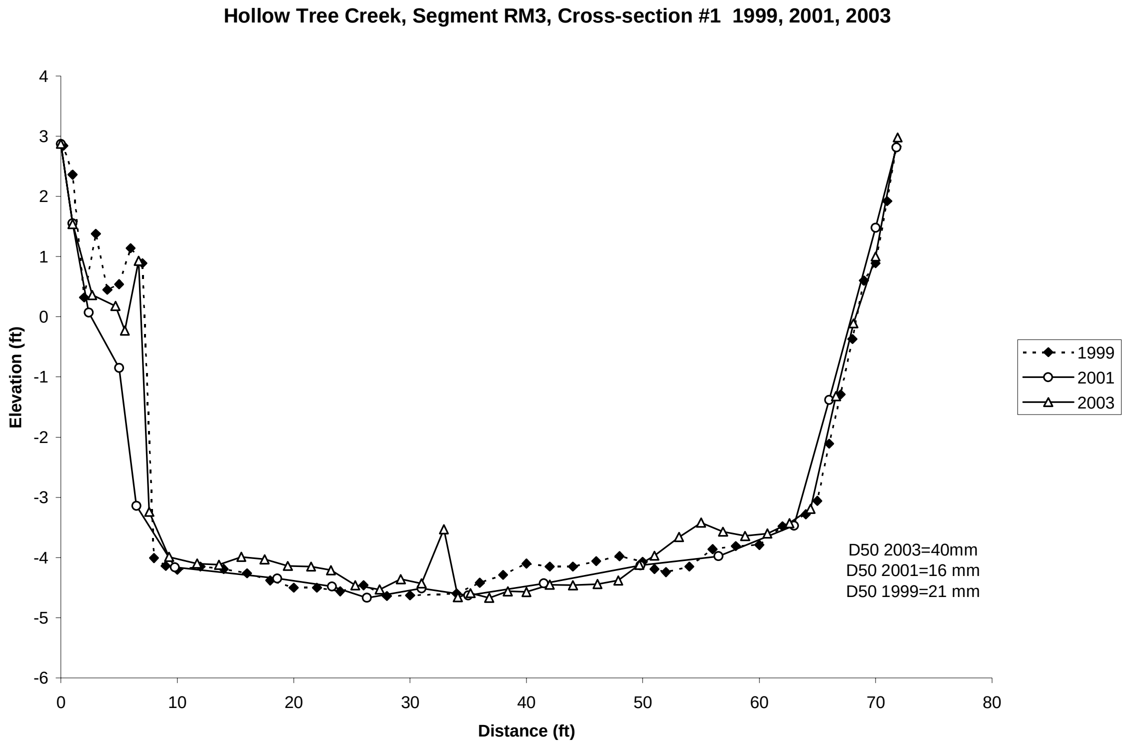
Max Residual Depth: 6.87
Mean Residual Depth: 1.14
Standard Deviation: 1.45

Number of non-zero Residual Depths: 87
Percent of Reach as pool: 87.00
Percent of Reach as riffle: 13.00

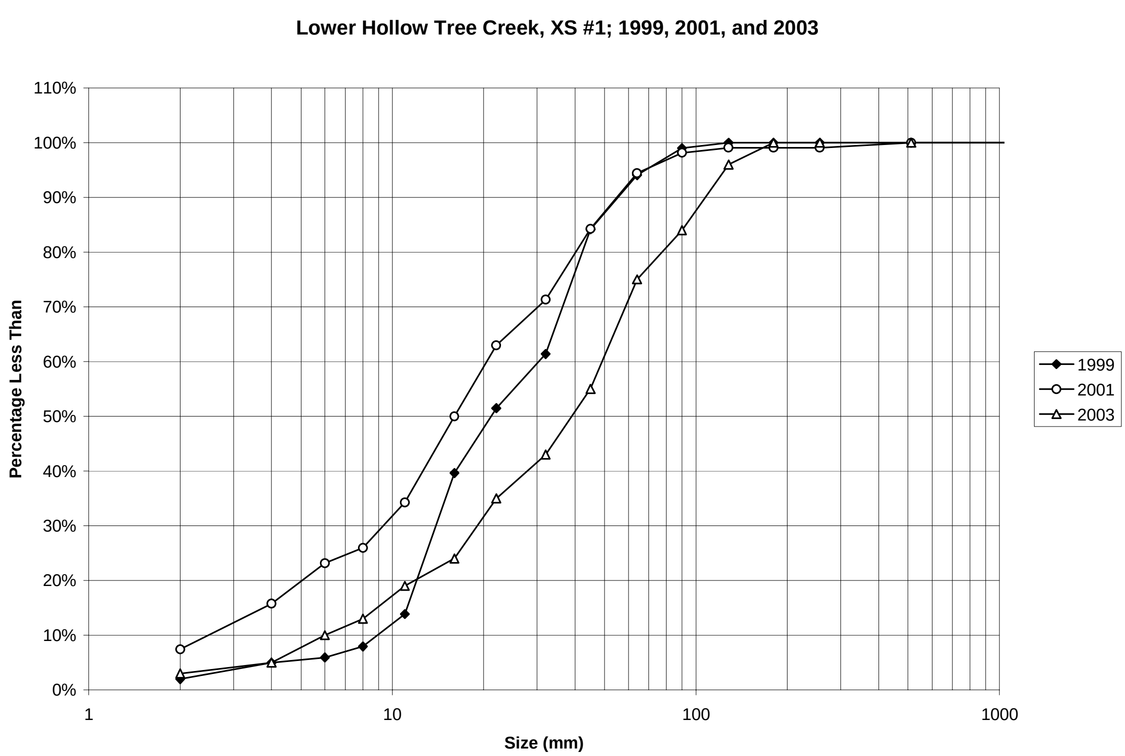


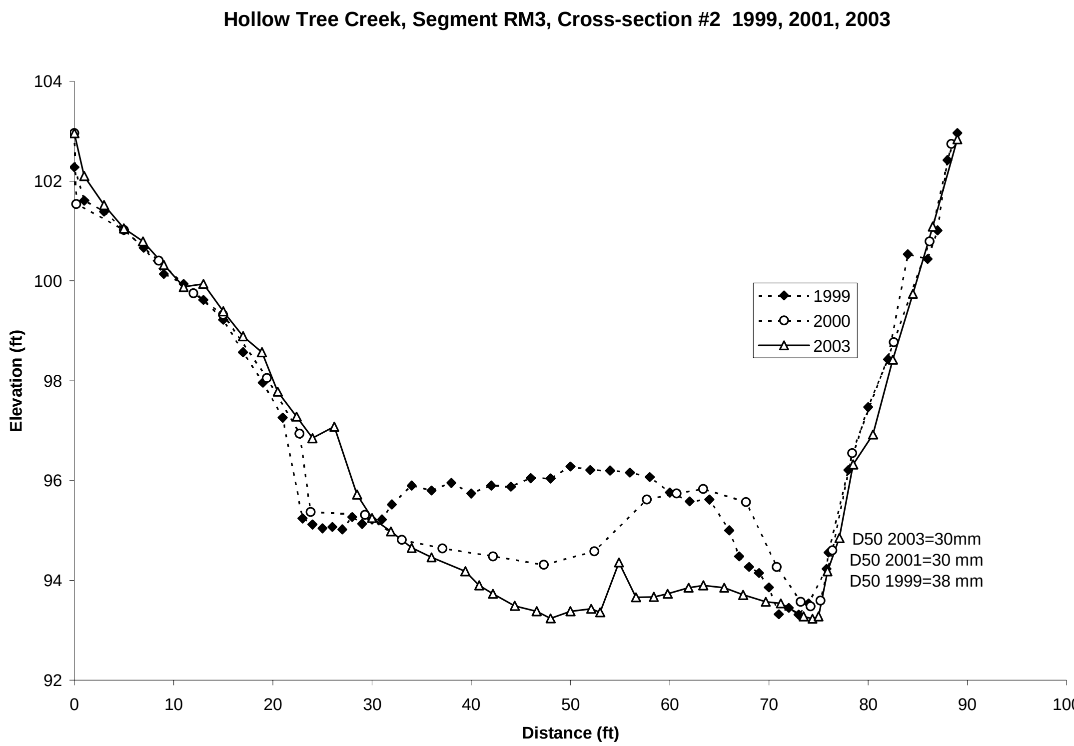


Hollow Tree Creek Longitudinal Profile, Segment RM3; 1999, 2001, 2003
Partially CORRECTED VERSION
Elevation (ft)
100
98
96
94
92
90
88
86
0
200
400
600
800
1000
1200
1400
1600
Distance (ft)
1999
2001
2003

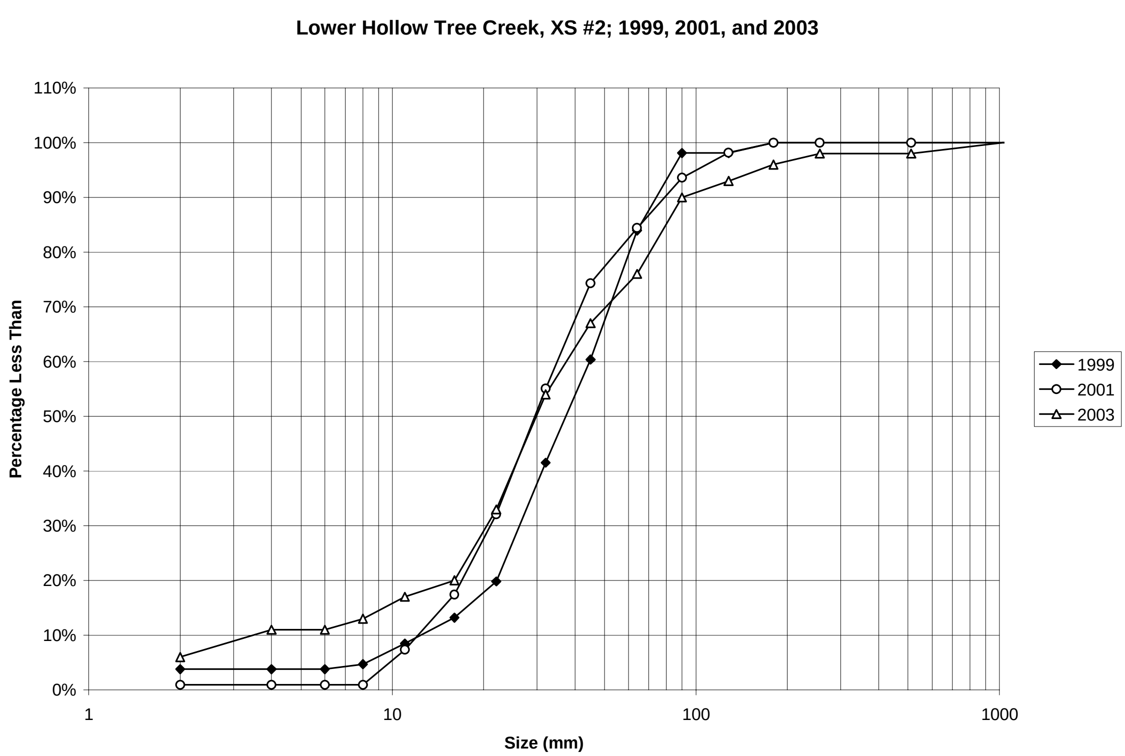


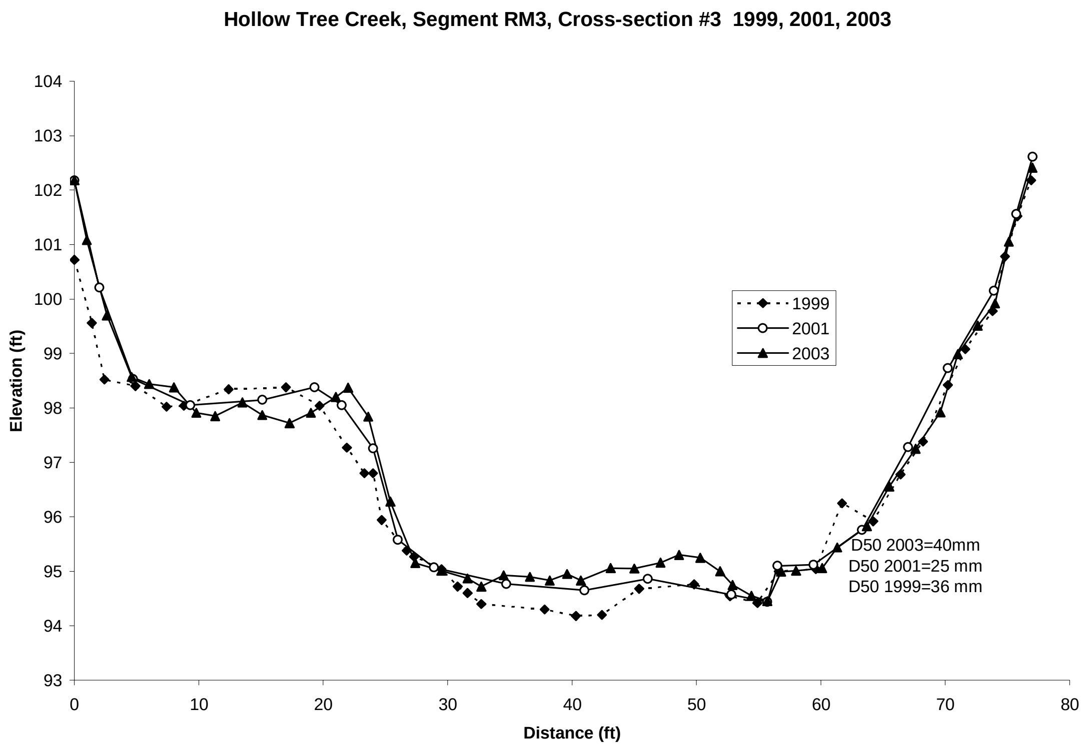
Particle Size Distribution from Pebble Count



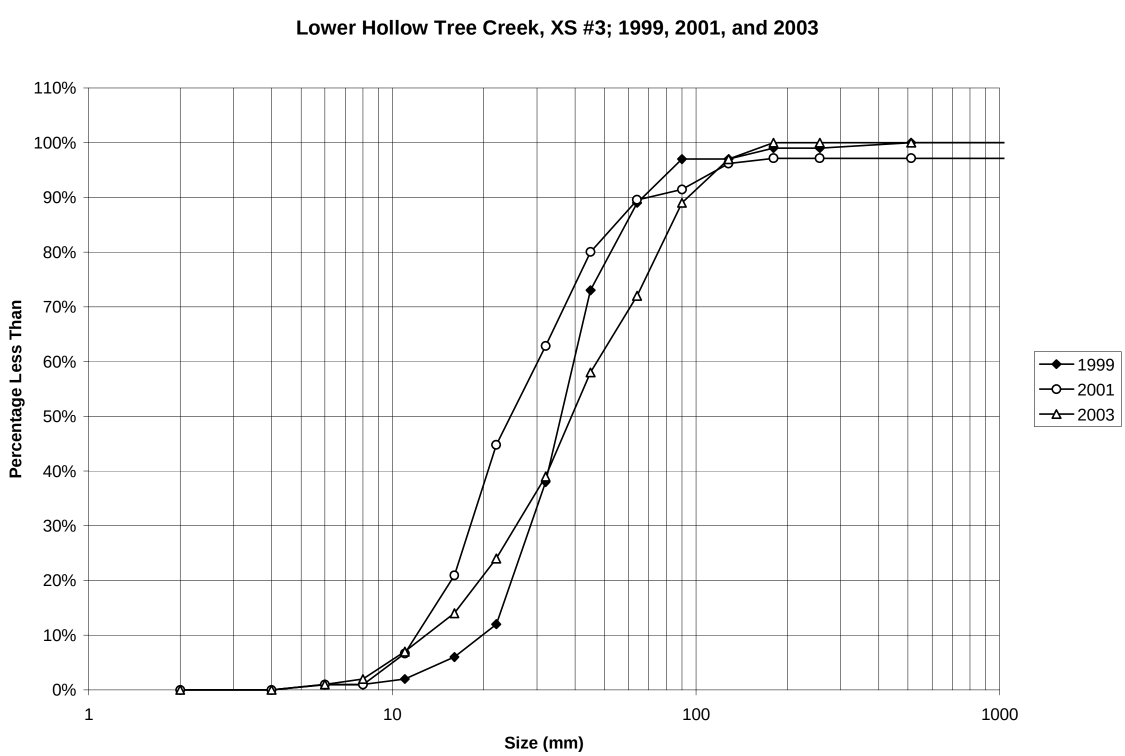


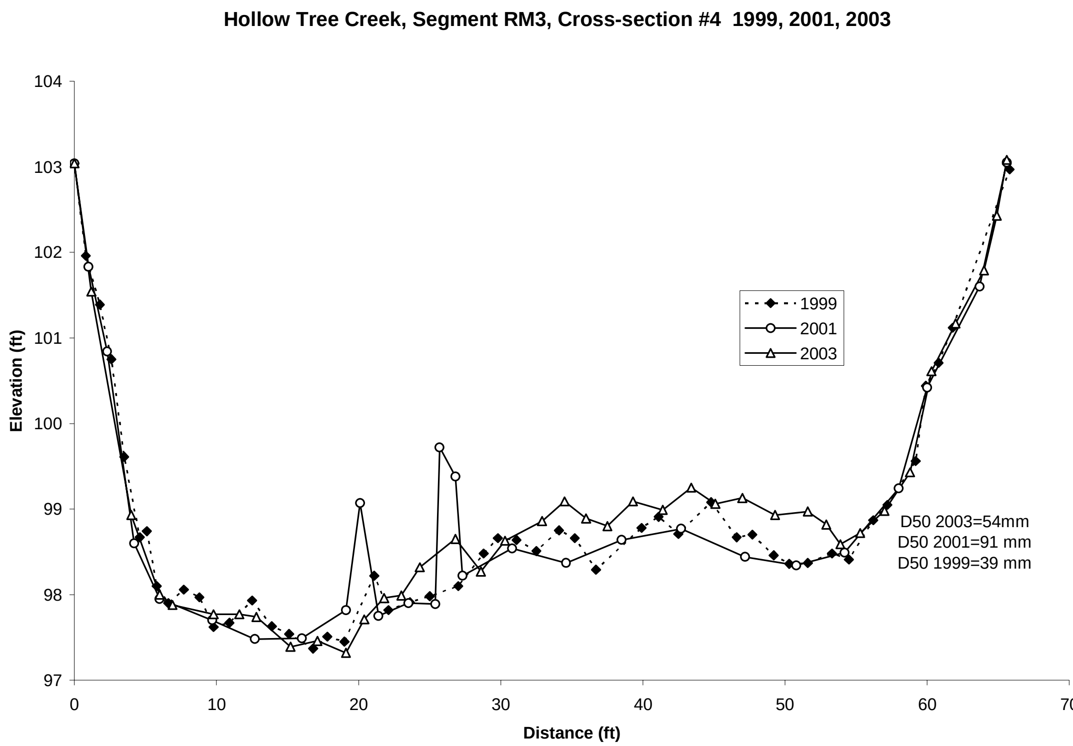
Particle Size Distribution from Pebble Count





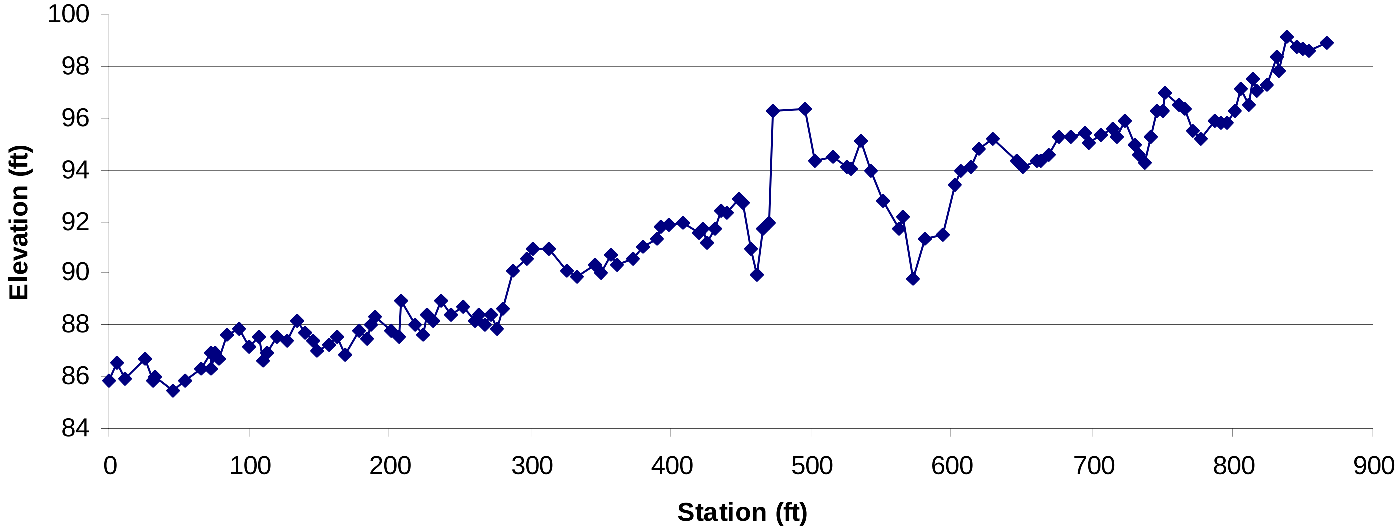
Particle Size Distribution from Pebble Count

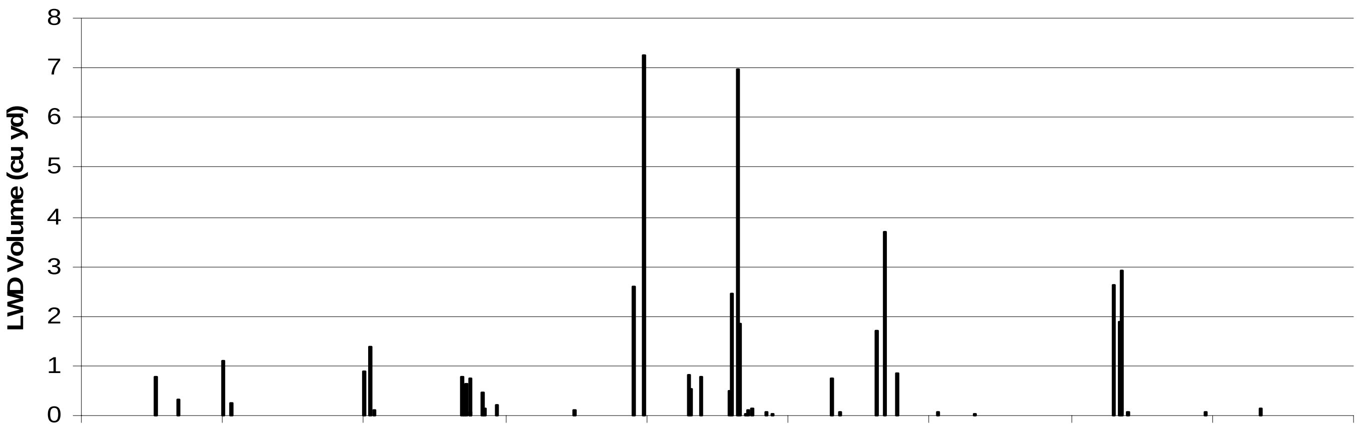




Particle Size Distribution from Pebble Count

Upper Hollow Tree Creek Long Term Channel Monitoring Longitudinal Profile and Large Woody Debris, October, 2003.





Hollow Tree RU4 October, 2003

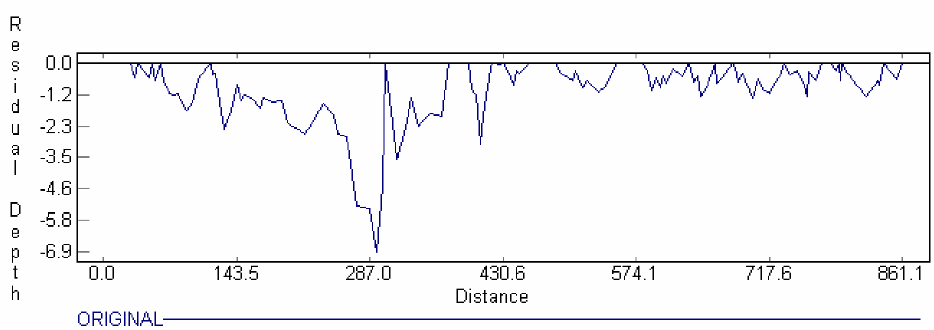
Top Elevation: 99.18
Bottom Elevation: 85.43
Reach Length: 861.10

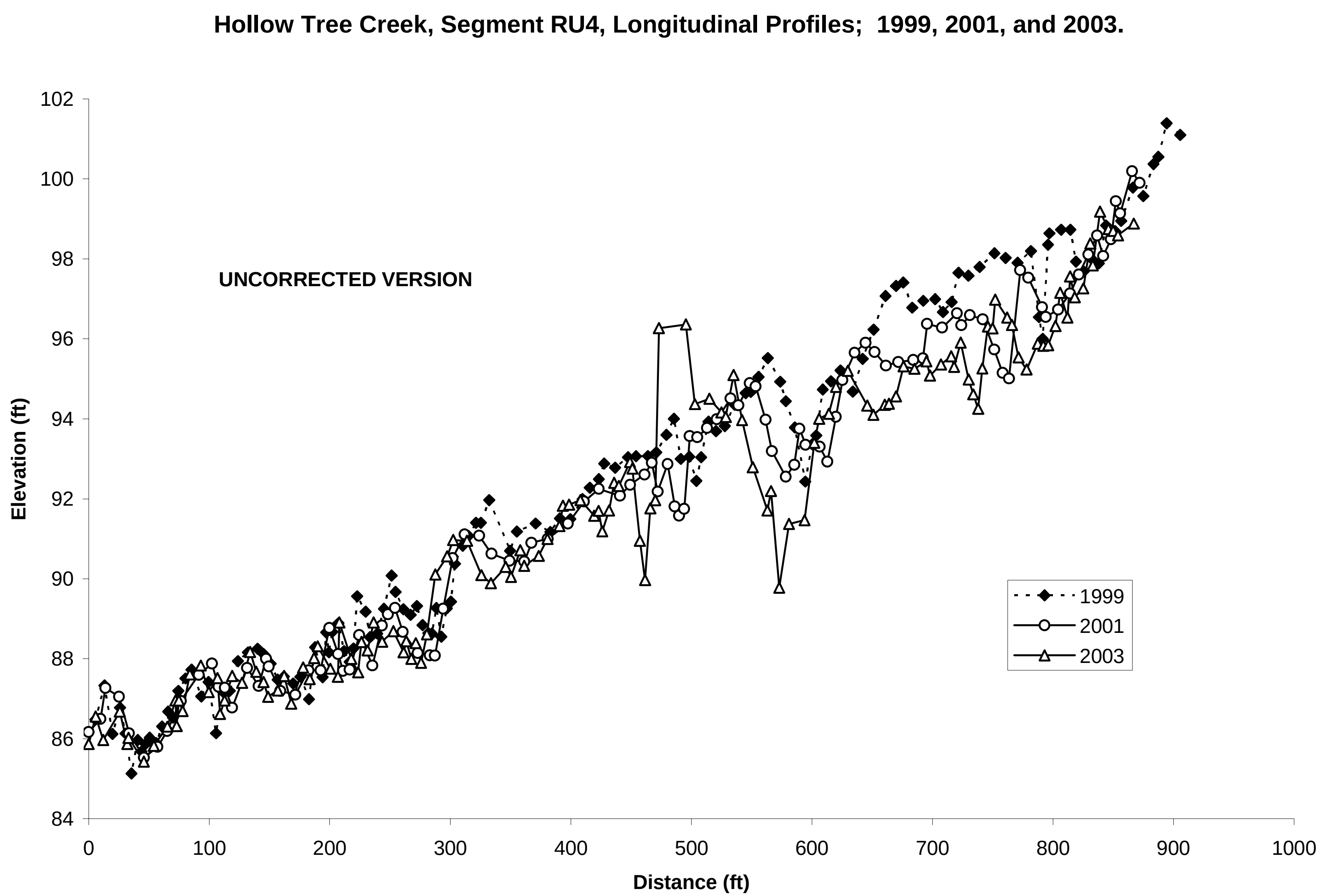
Standardized Statistics:
Number of data points in raw data: 134
Number of data points in Standardized data: 134

Reach Step Distance: 6.43

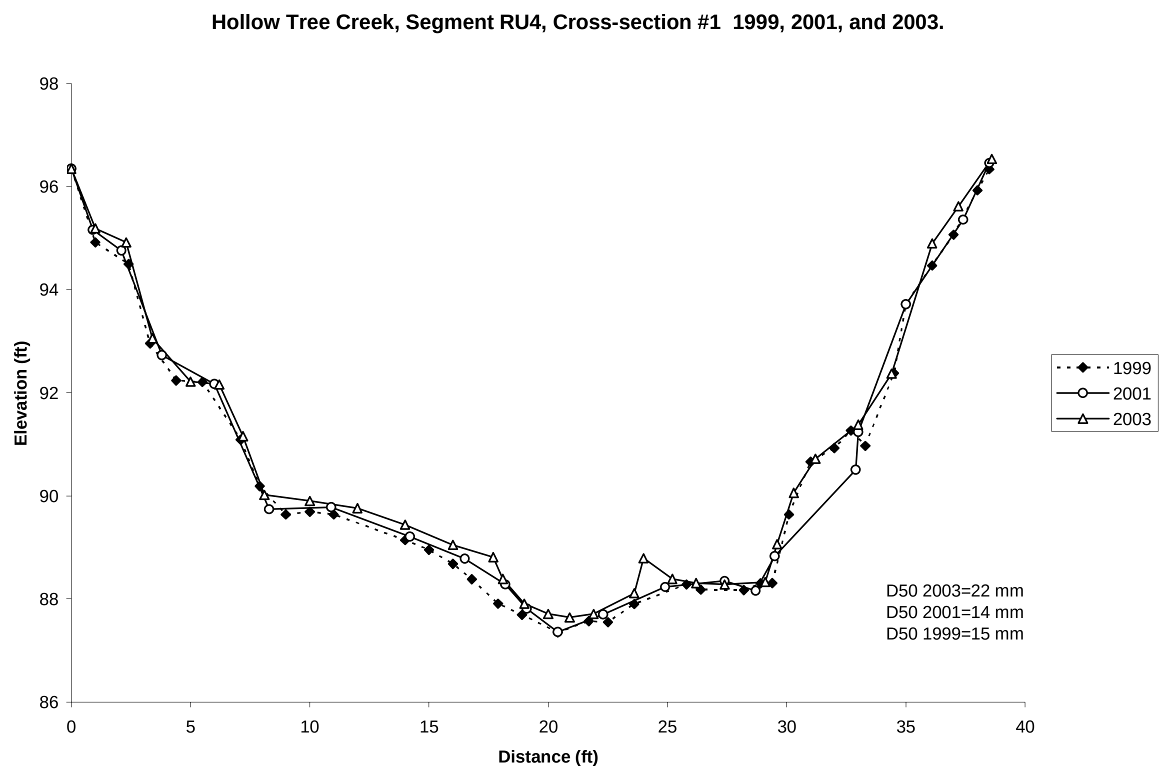
Max Residual Depth: 6.32
Mean Residual Depth: 1.02
Standard Deviation: 1.20

Number of non-zero Residual Depths: 110
Percent of Reach as pool: 82.09
Percent of Reach as riffle: 17.91

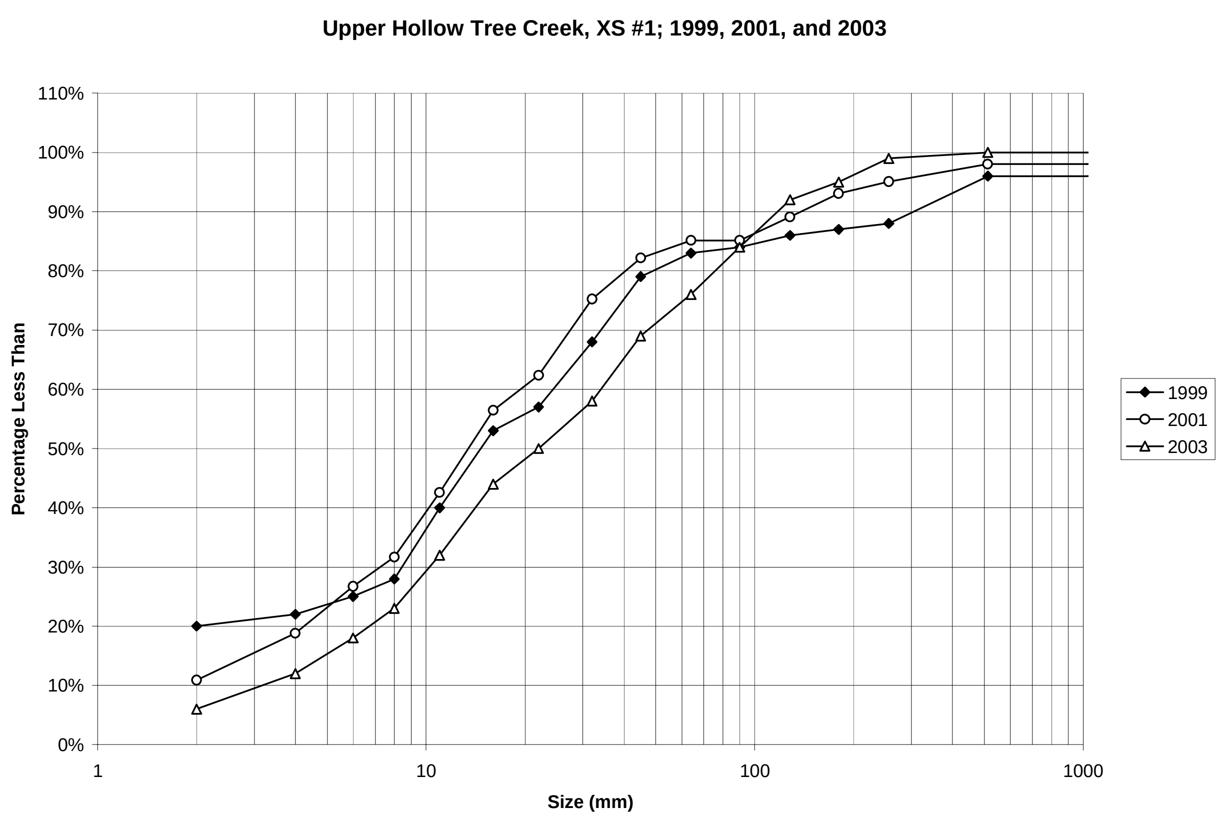


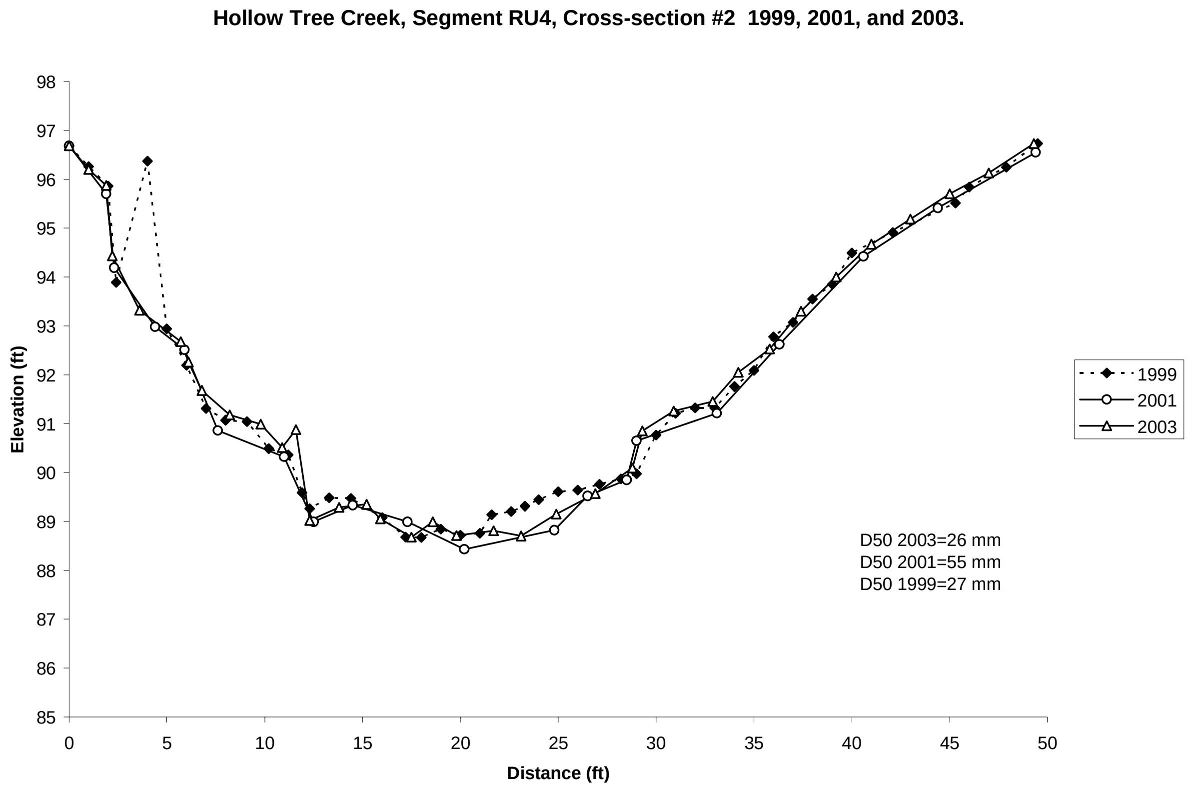


Hollow Tree Creek, Segment RU4, Longitudinal Profiles; 1999, 2001, and 2003.
UNCORRECTED VERSION
Elevation (ft)
102
100
98
96
94
92
90
88
86
84
0
100
200
300
400
500
600
700
800
900
1000
Distance (ft)
1999
2001
2003

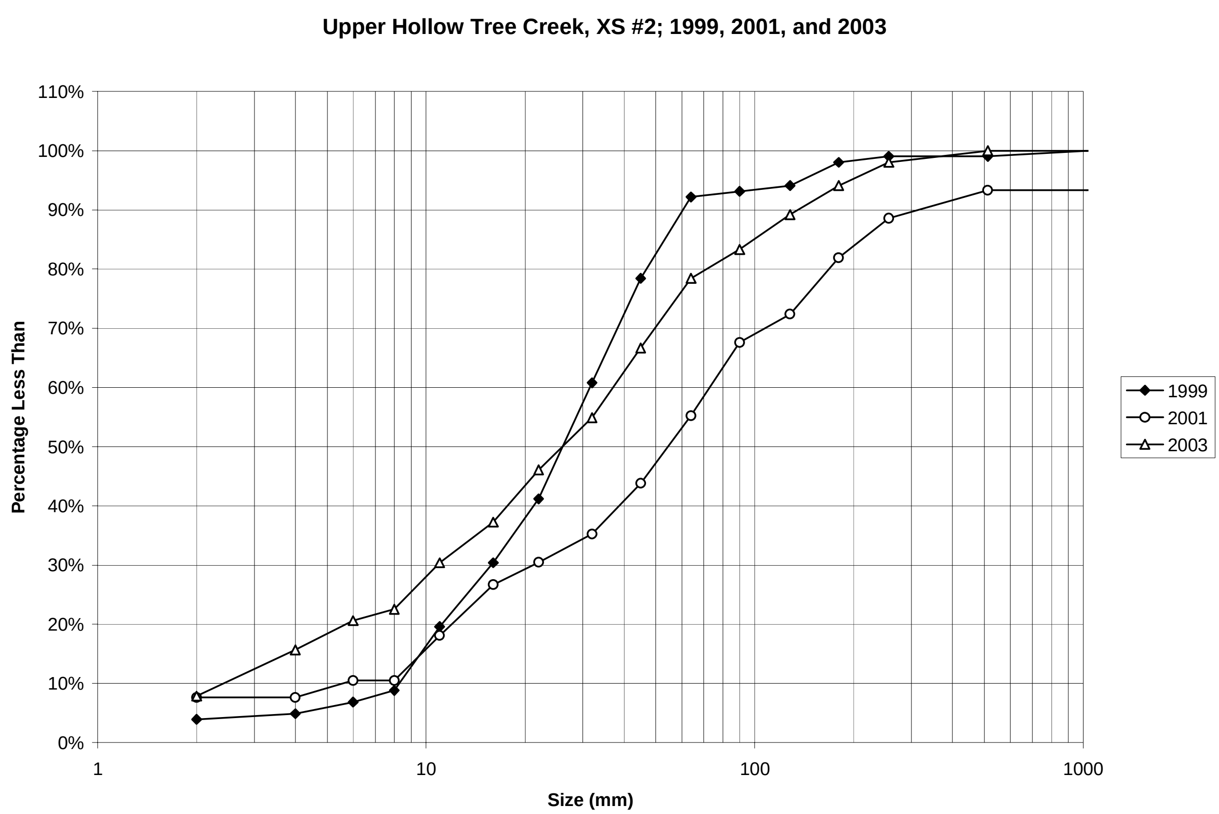


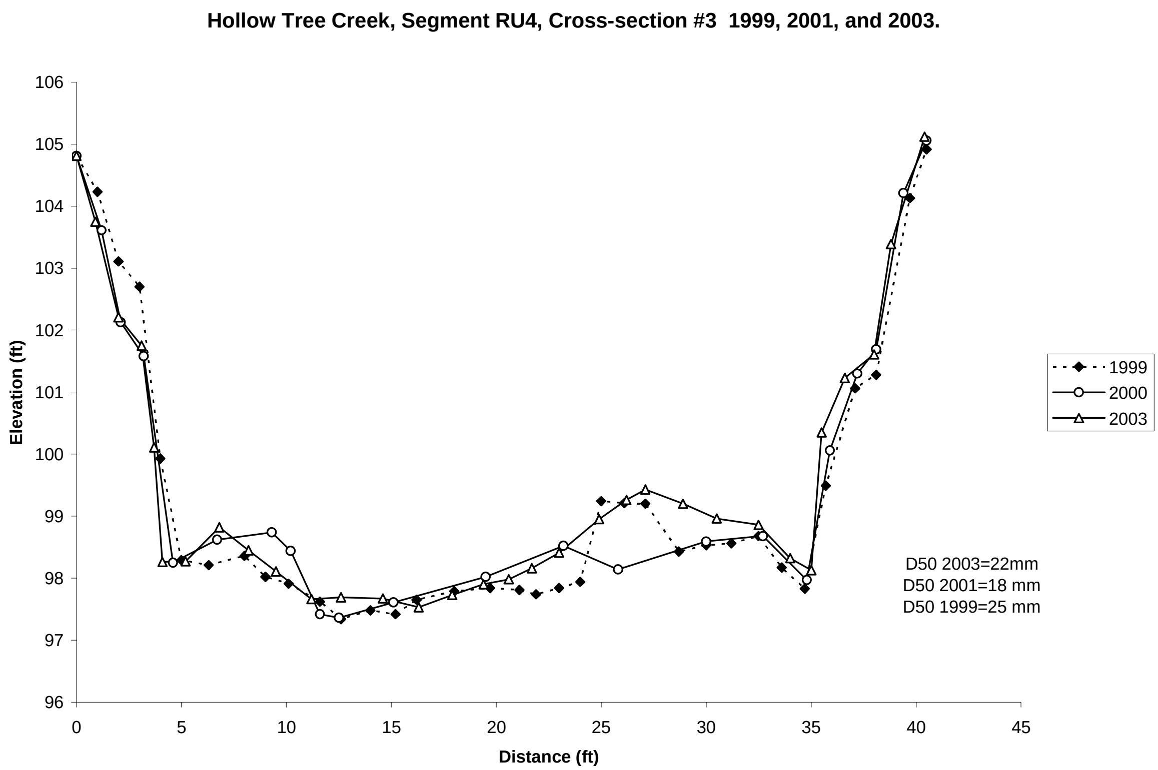
Particle Size Distribution from Pebble Count



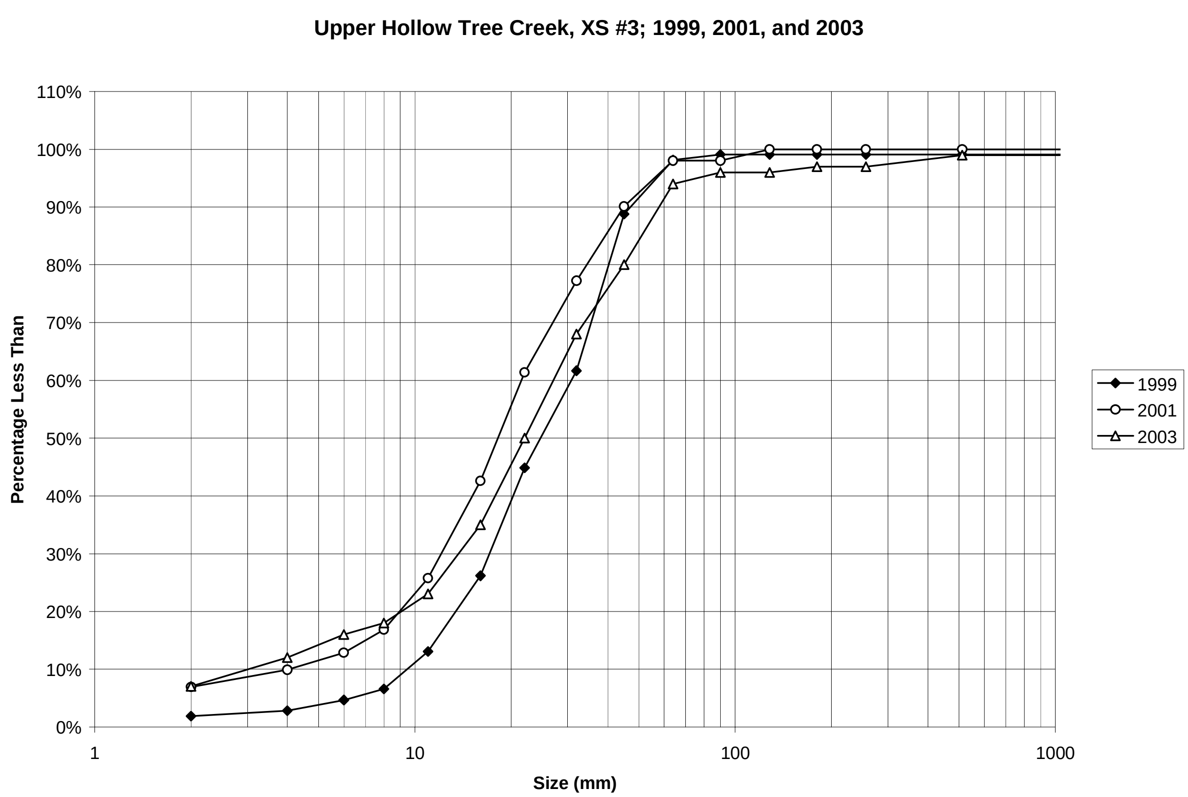


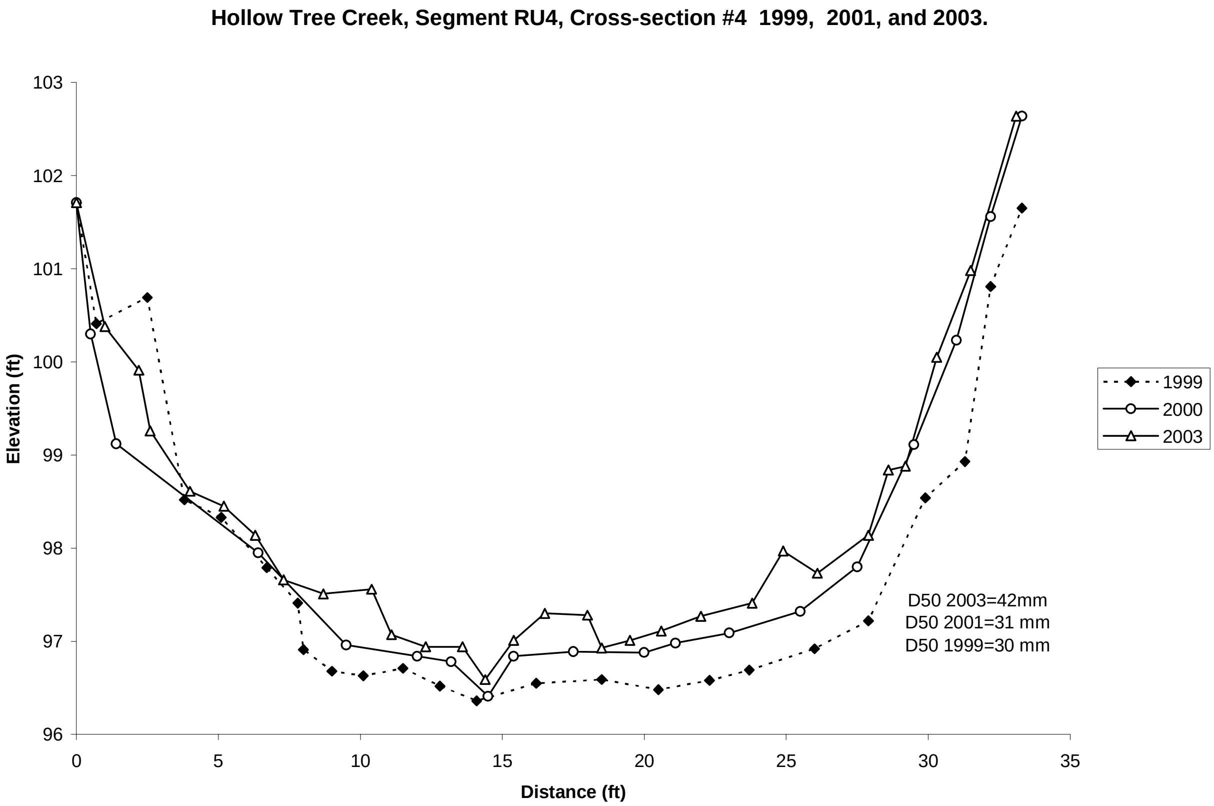
Particle Size Distribution from Pebble Count



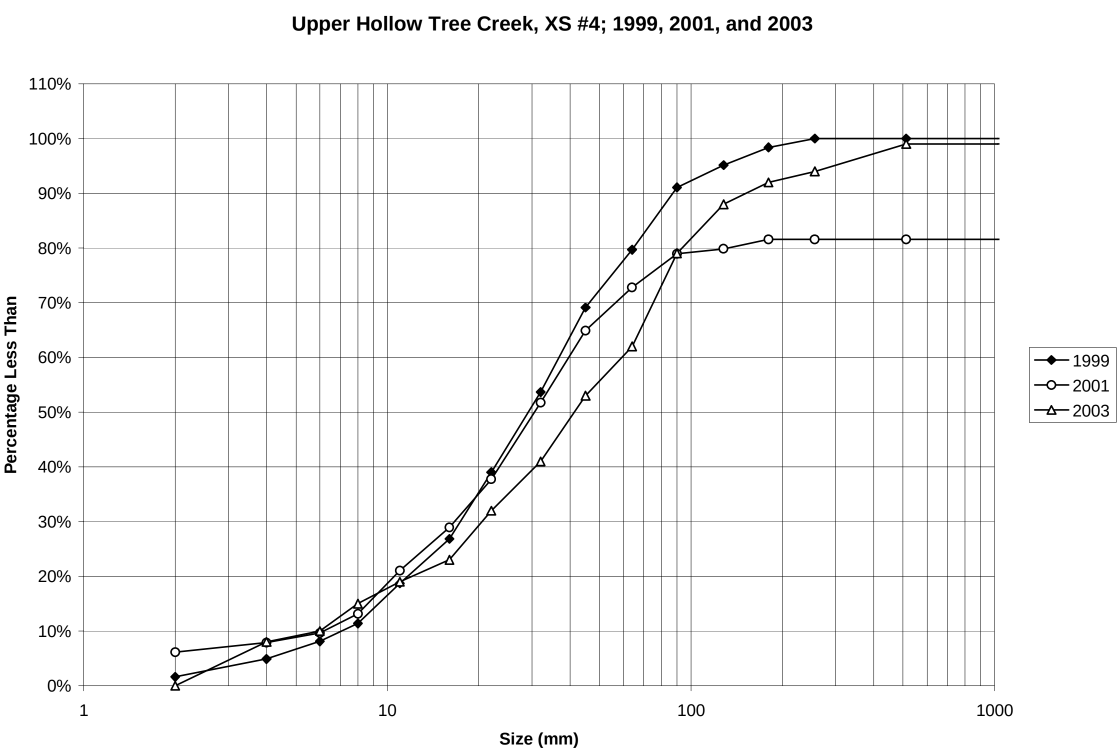


Particle Size Distribution from Pebble Count

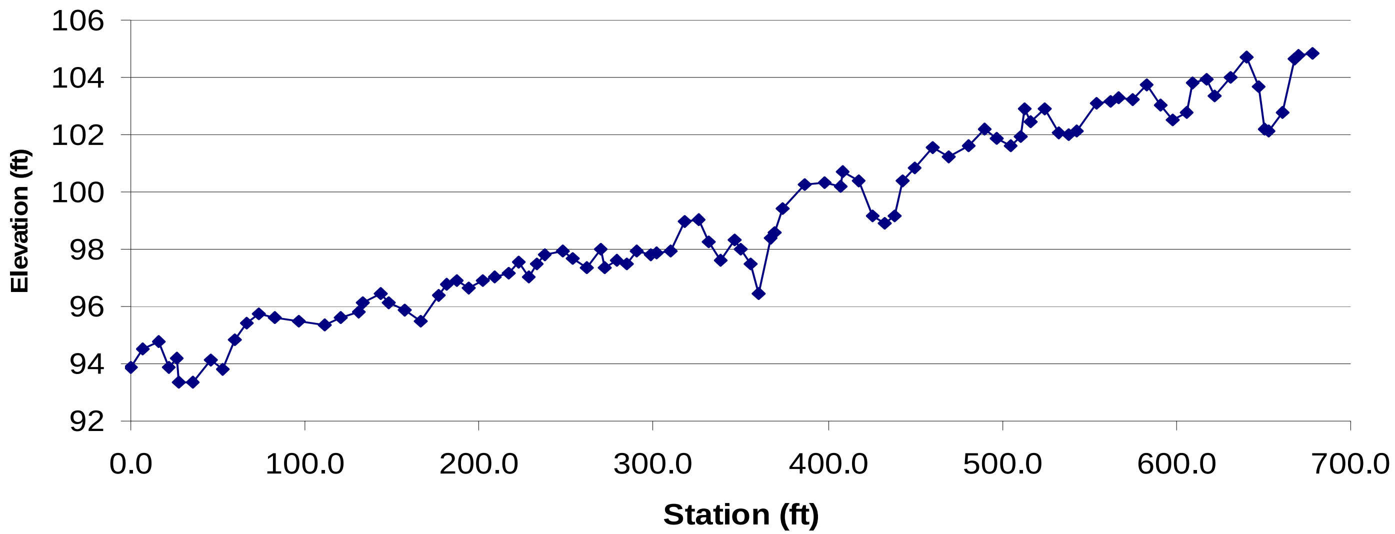


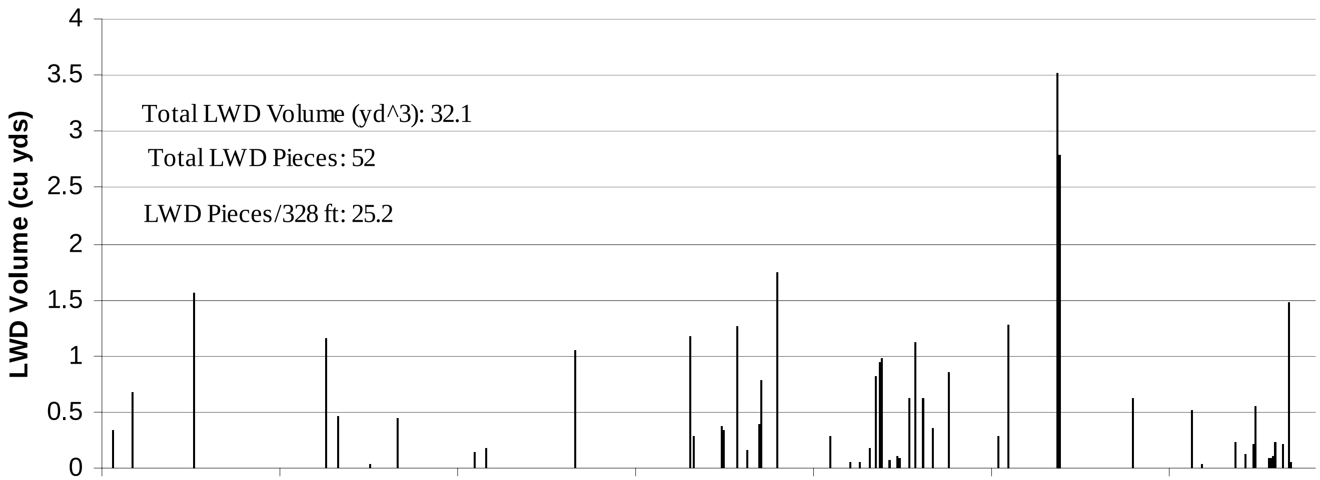


Particle Size Distribution from Pebble Count



Bear Wallow Creek Longitudinal Profile and Large Woody Debris Volume, October, 2003





Bear Wallow Segment RU57
Oct. 2003
Longitudinal Profile Statistics and Residual Depth Graph

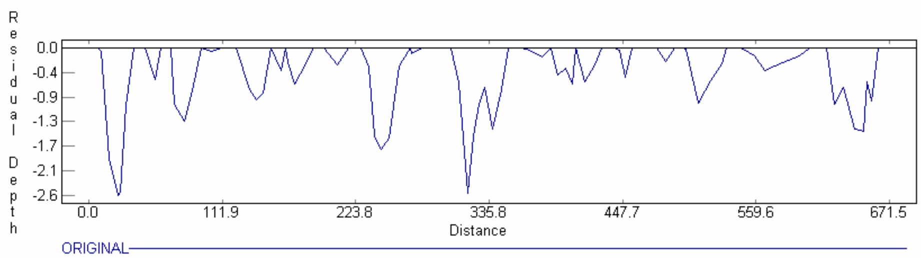
Top Elevation: 104.84
Bottom Elevation: 93.34
Reach Length: 671.50

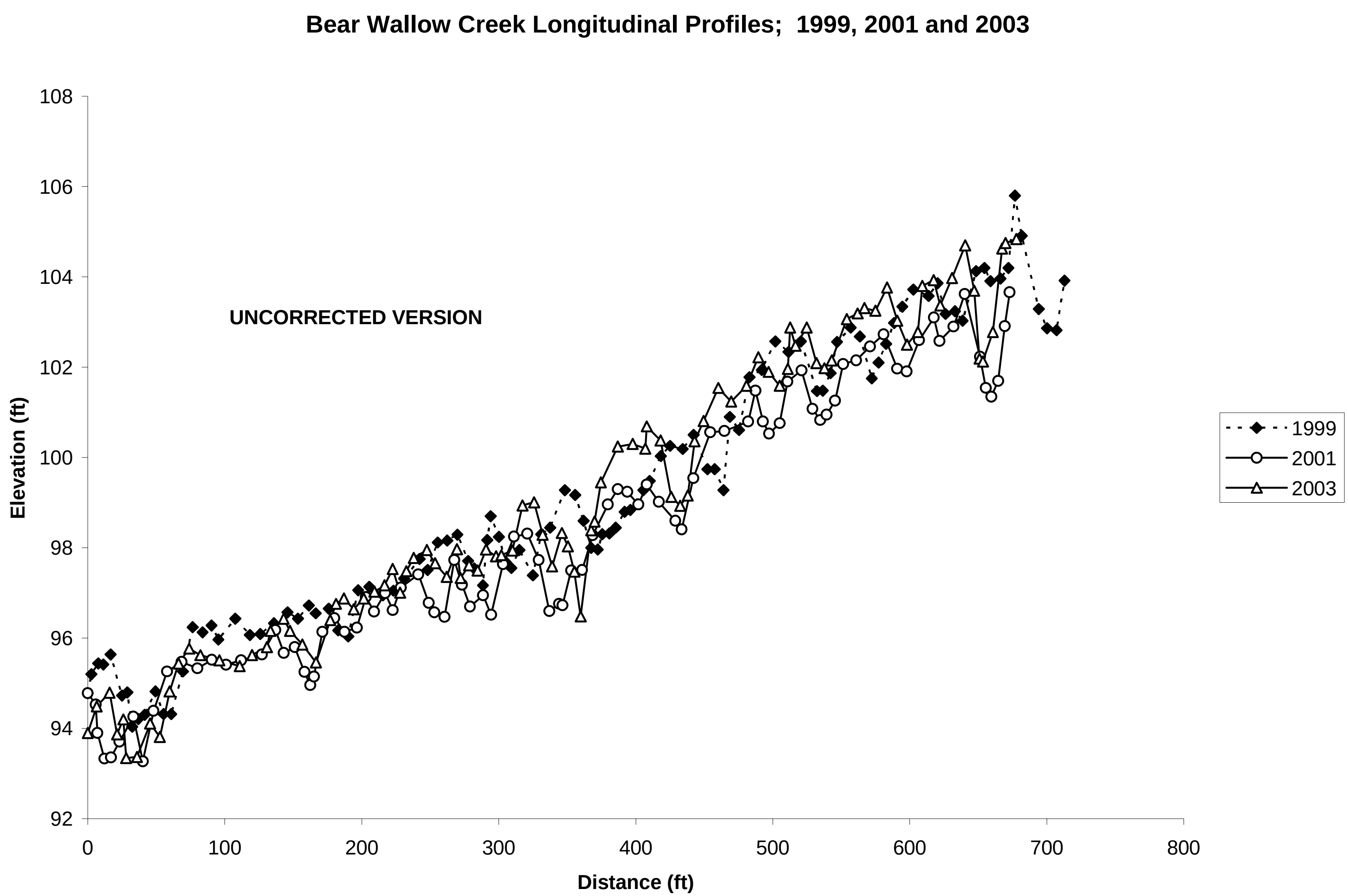
Standardized Statistics:
Number of data points in raw data: 97
Number of data points in Standardized data: 97

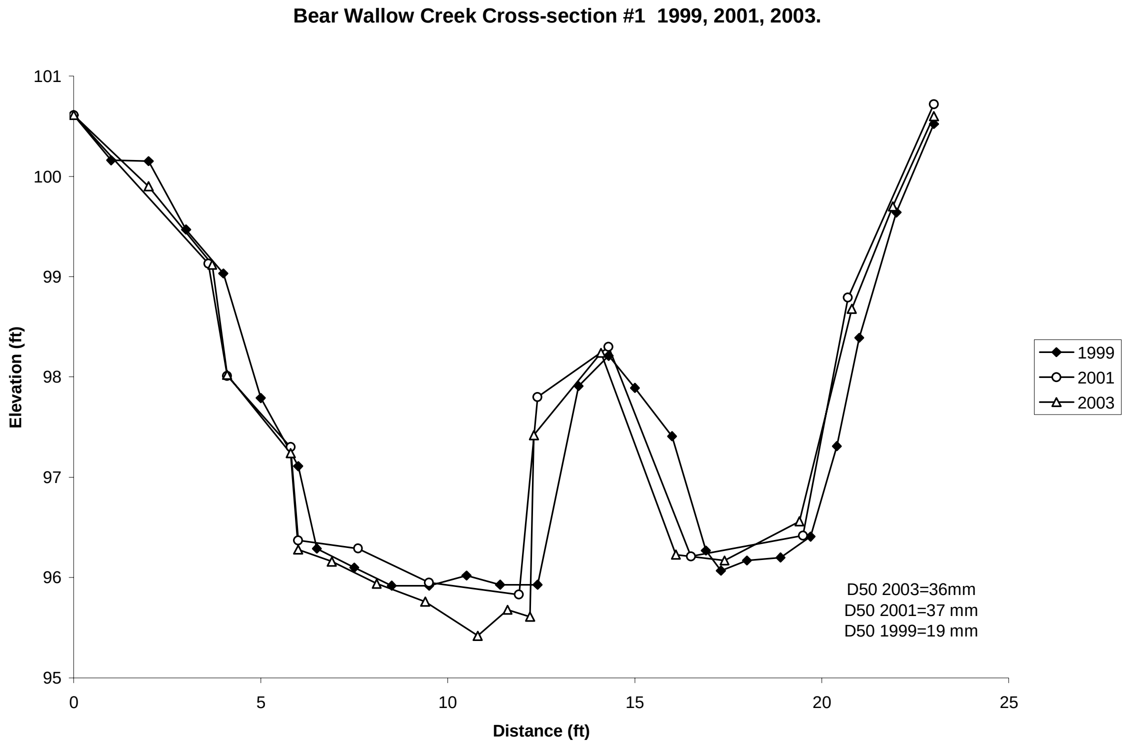
Reach Step Distance: 6.92

Max Residual Depth: 2.50
Mean Residual Depth: 0.40
Standard Deviation: 0.54

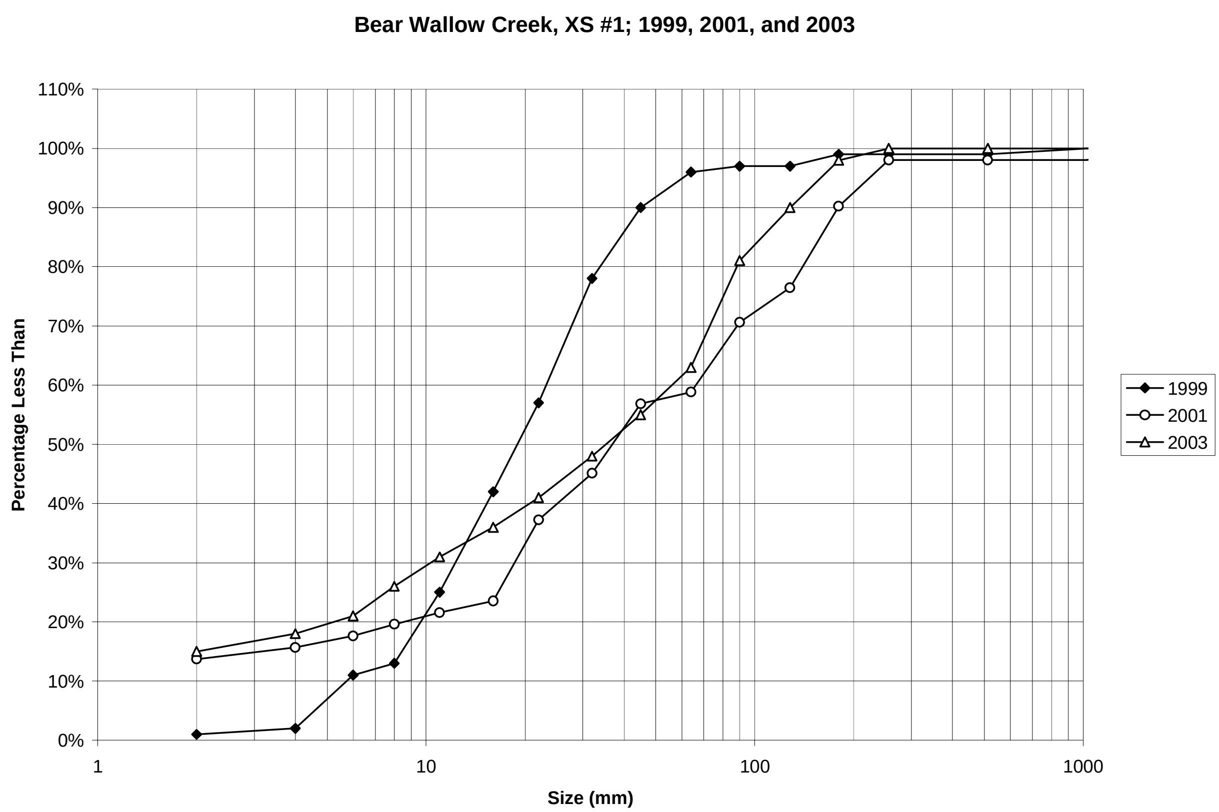
Number of non-zero Residual Depths: 67
Percent of Reach as pool: 69.07
Percent of Reach as riffle: 30.93

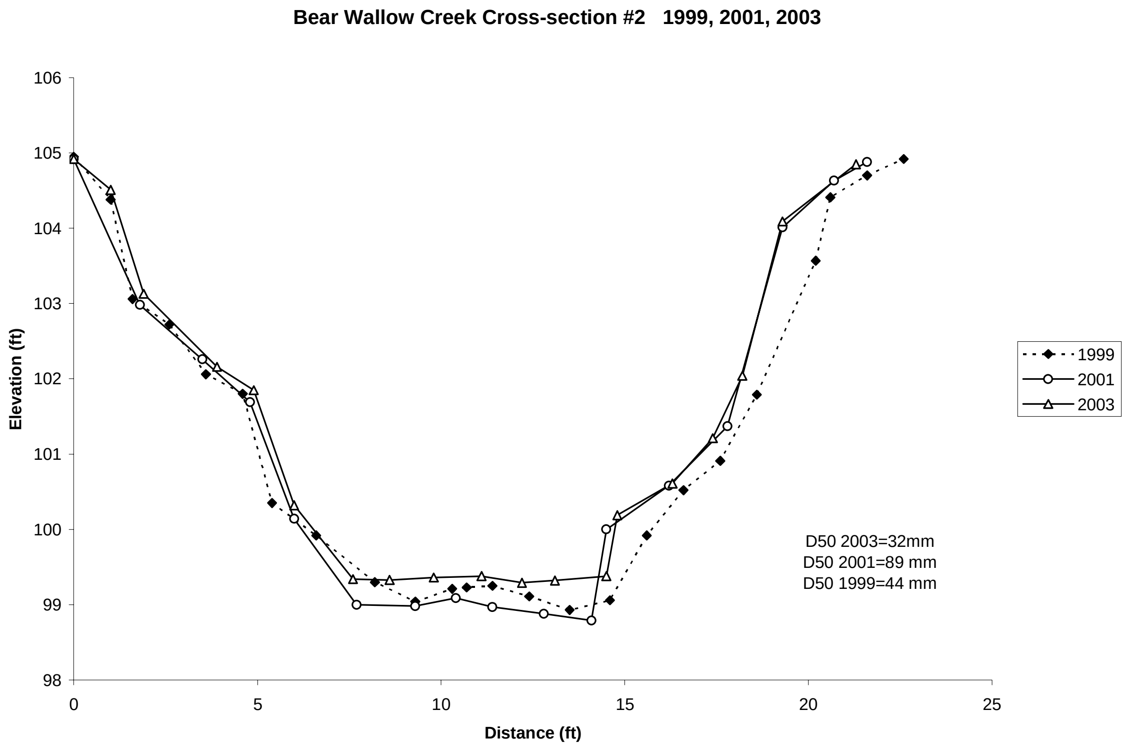



Bear Wallow Creek Longitudinal Profiles; 1999, 2001 and 2003
UNCORRECTED VERSION
Elevation (ft)
108
106
104
102
100
98
96
94
92
0
100
200
300
400
500
600
700
800
Distance (ft)
1999
2001
2003

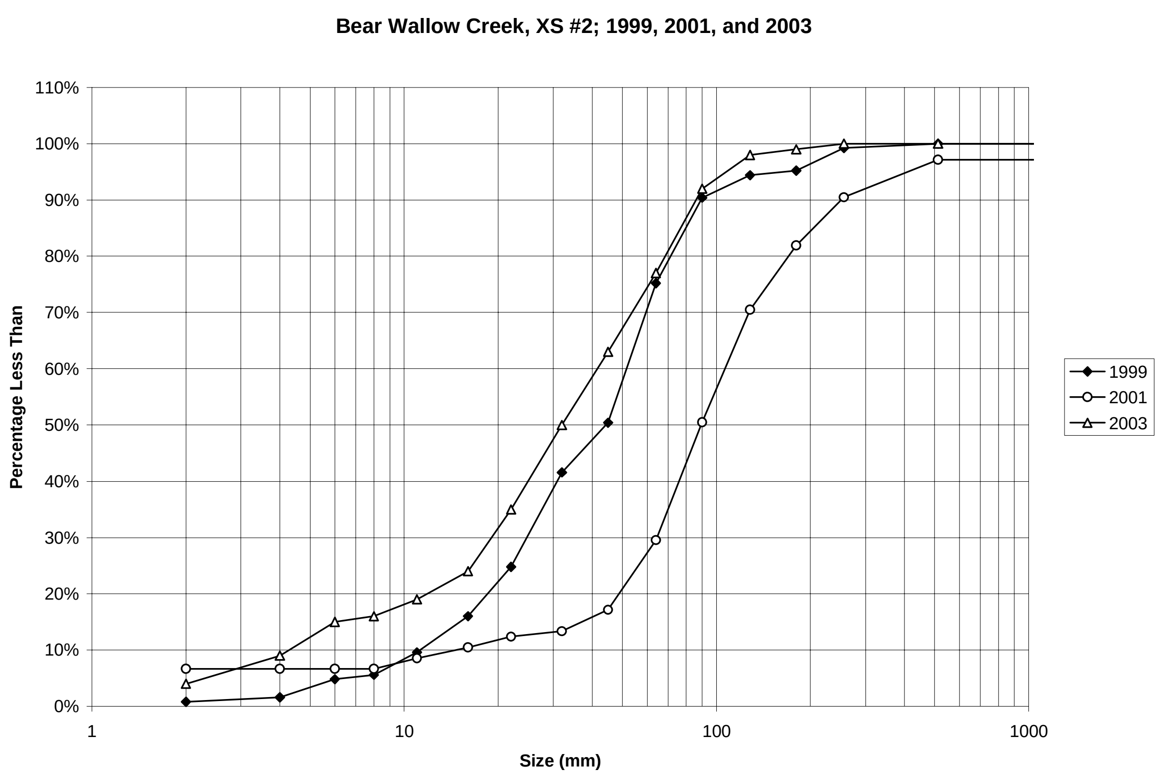


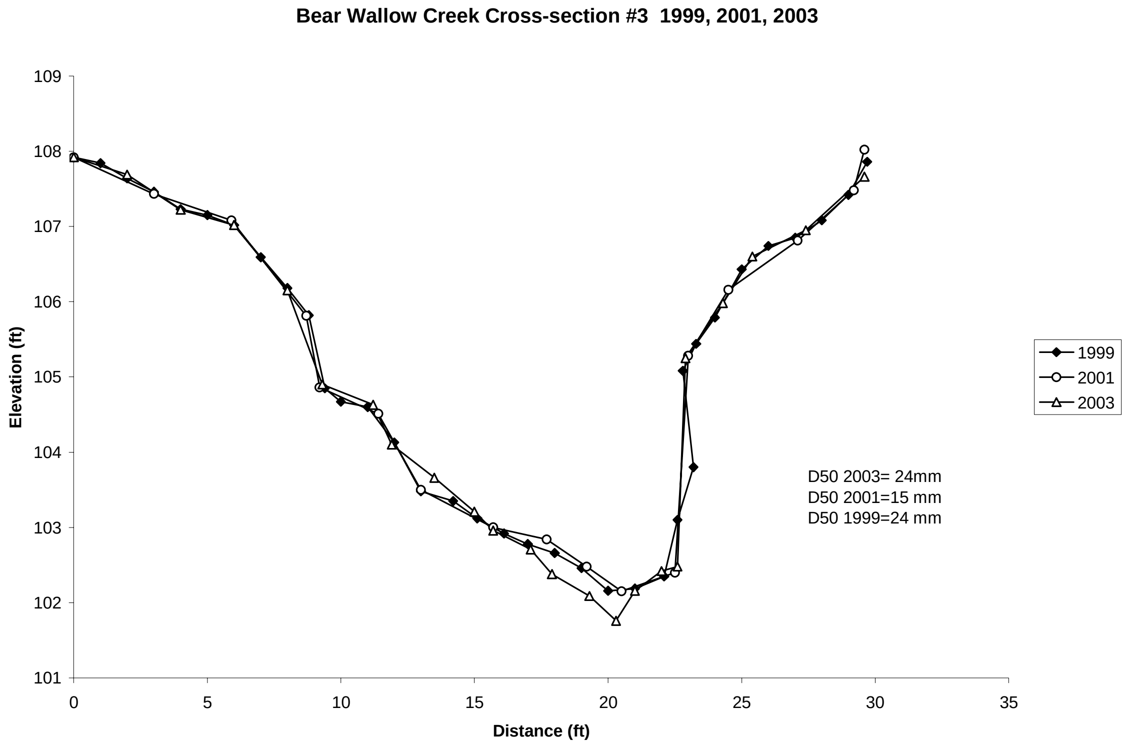
Particle Size Distribution from Pebble Count



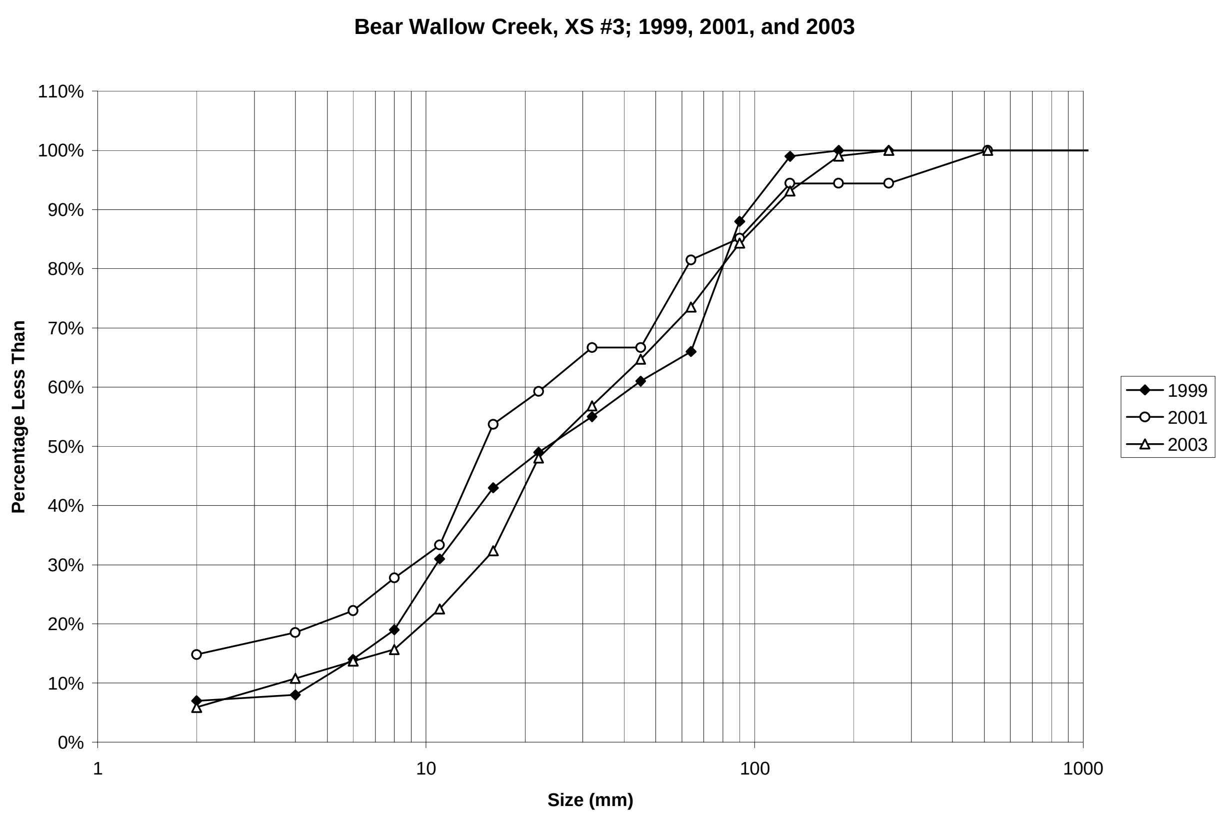


Particle Size Distribution from Pebble Count

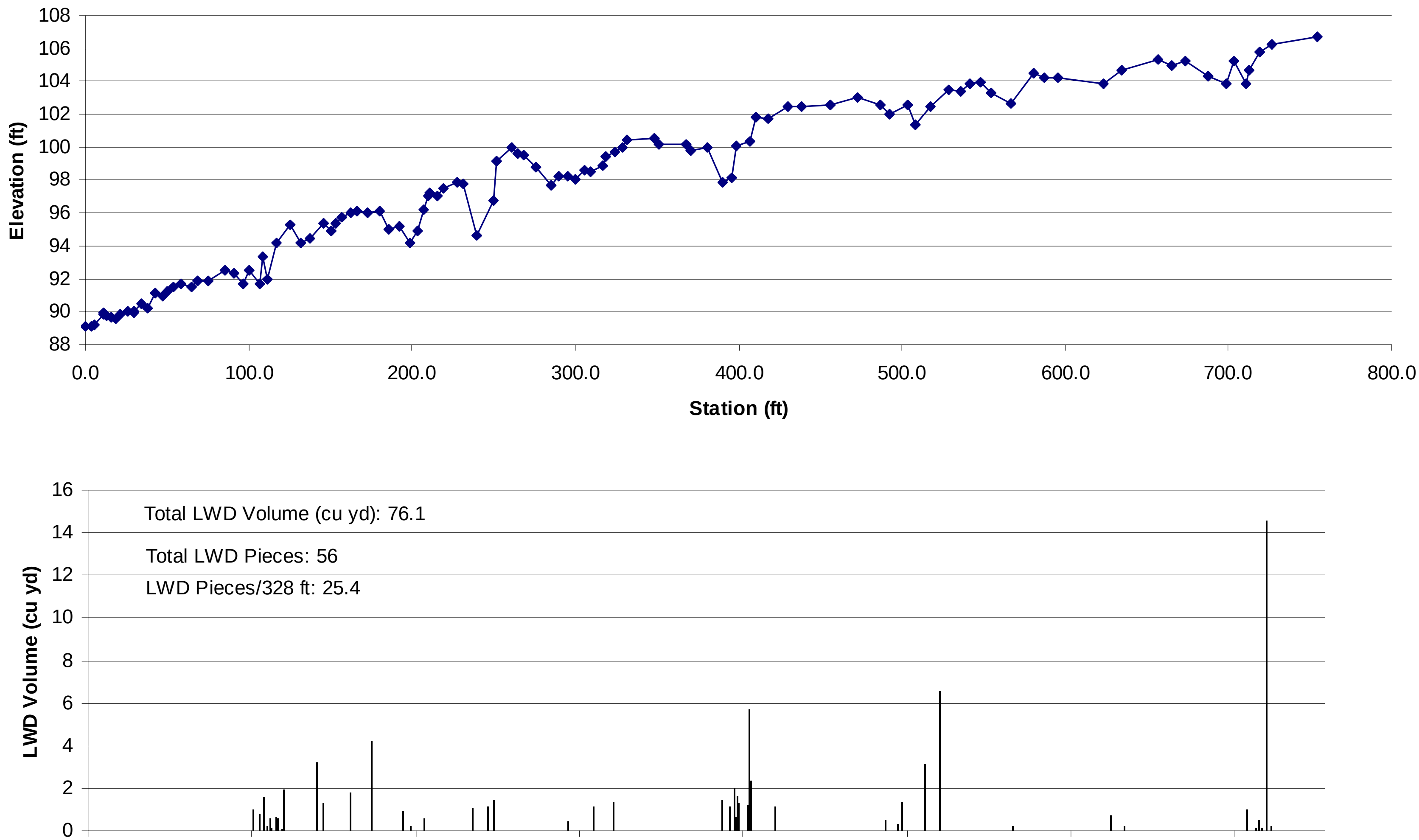




Particle Size Distribution from Pebble Count



Bond Creek Long Term Channel Monitoring Longitudinal Profile and Large Woody Debris, October, 2003



Bond Creek RM109 October 2003

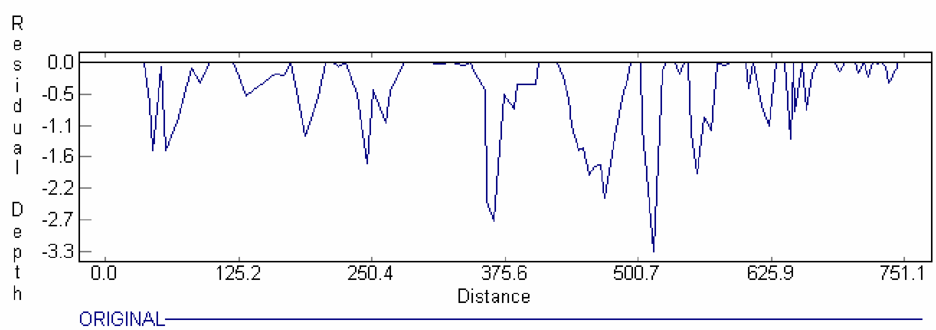
Top Elevation: 106.67
Bottom Elevation: 89.08
Reach Length: 751.10

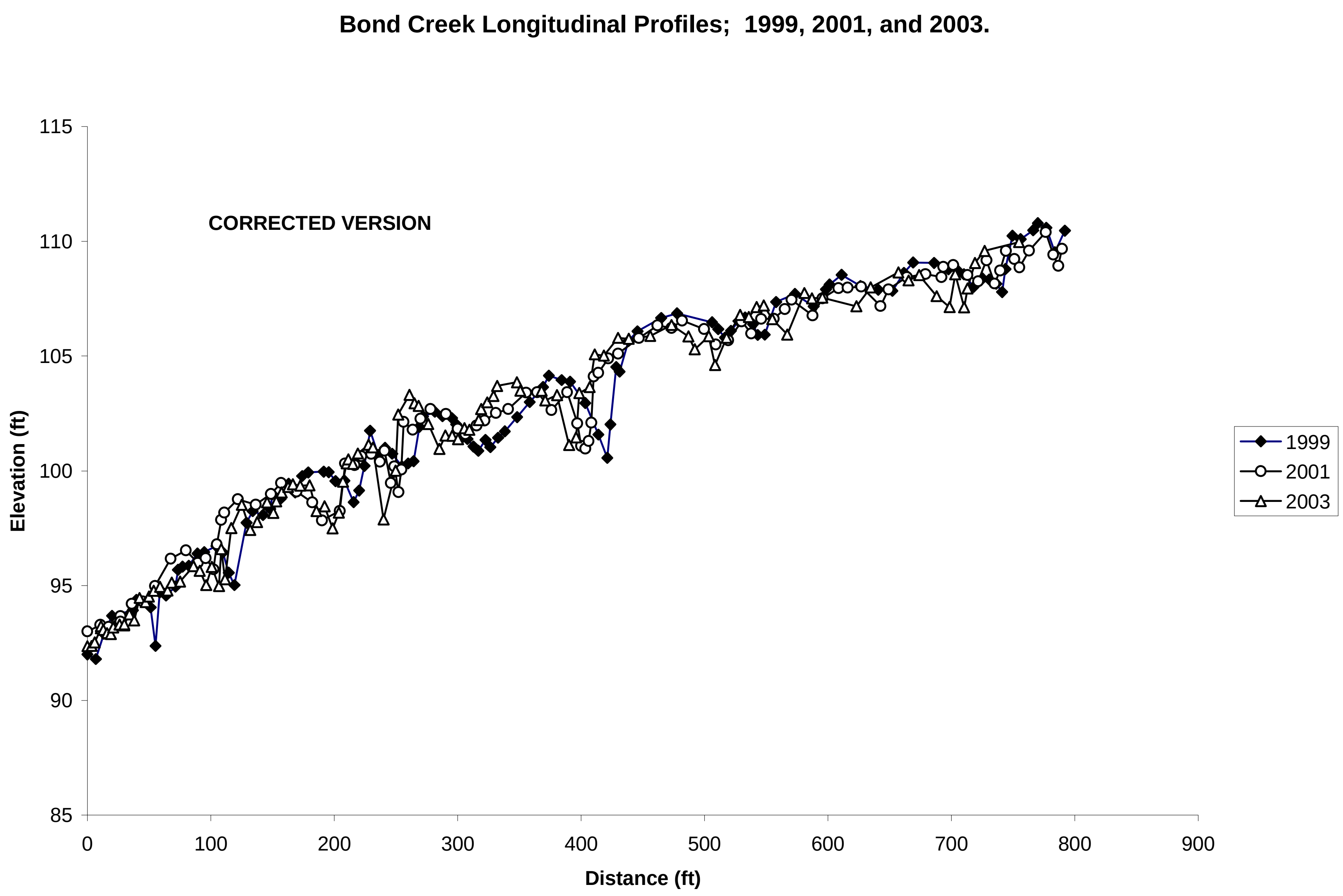
Standardized Statistics:
Number of data points in raw data: 111
Number of data points in Standardized data: 111

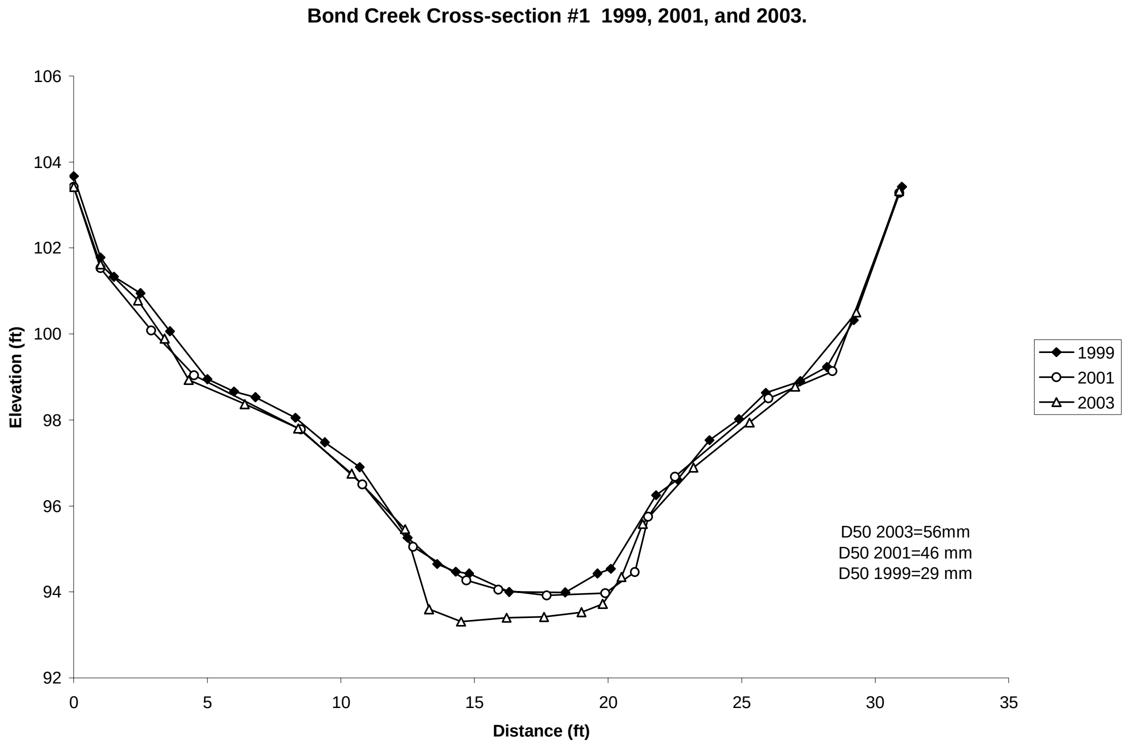
Reach Step Distance: 6.77

Max Residual Depth: 3.22
Mean Residual Depth: 0.47
Standard Deviation: 0.64

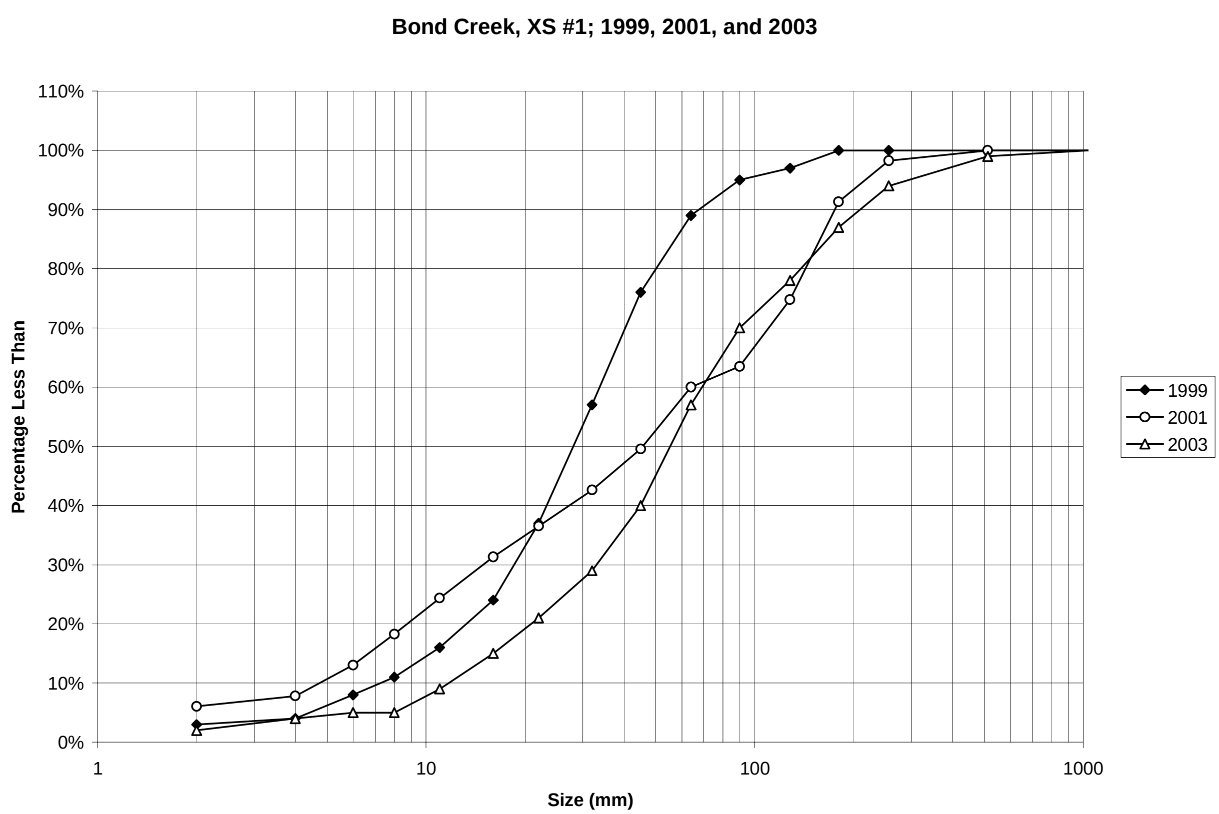
Number of non-zero Residual Depths: 73
Percent of Reach as pool: 65.77
Percent of Reach as riffle: 34.23

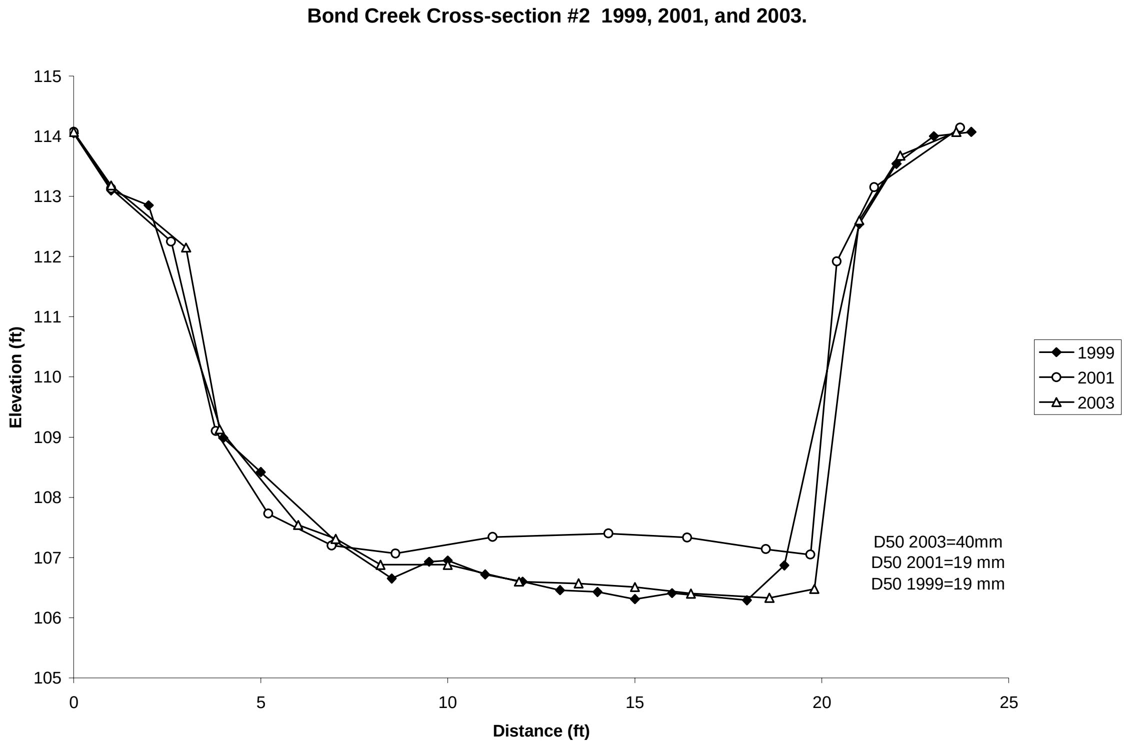



Bond Creek Longitudinal Profiles; 1999, 2001, and 2003.
CORRECTED VERSION
Elevation (ft)
115
110
105
100
95
90
85
0
100
200
300
400
500
600
700
800
900
Distance (ft)
1999
2001
2003

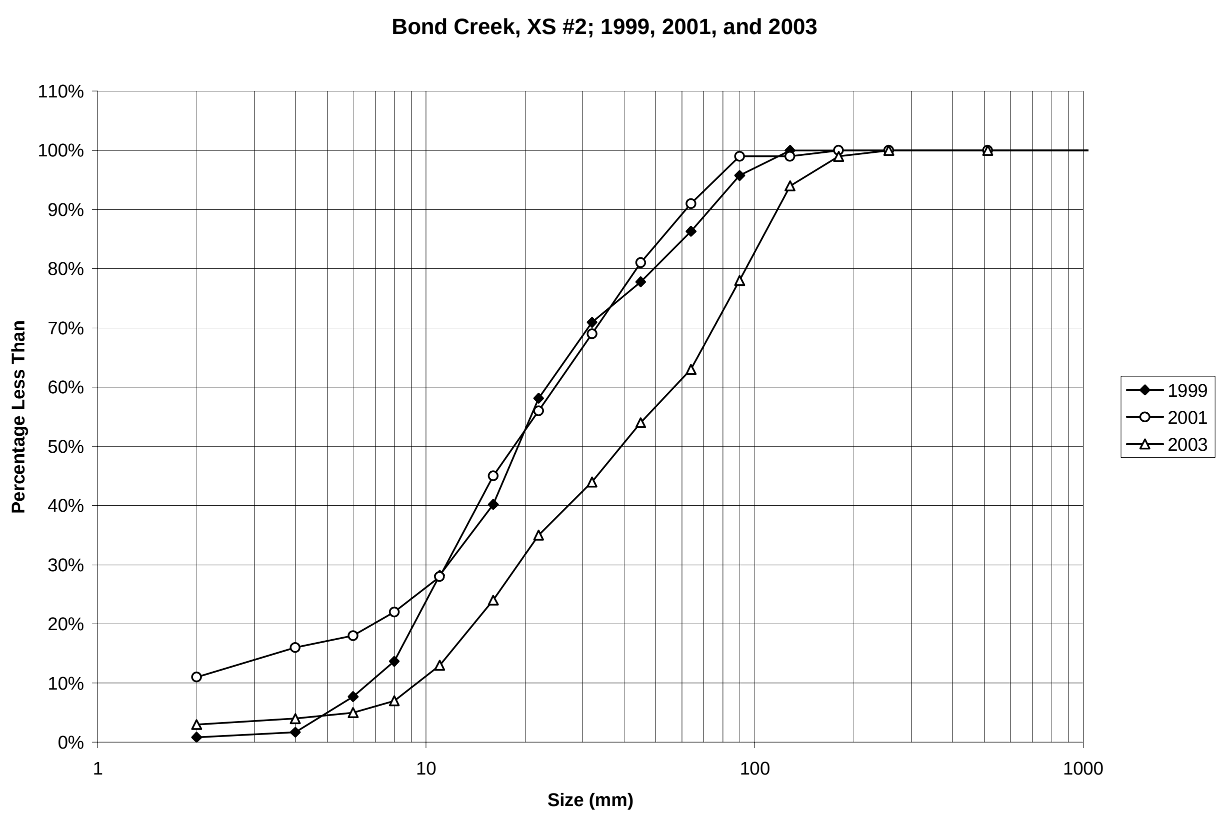


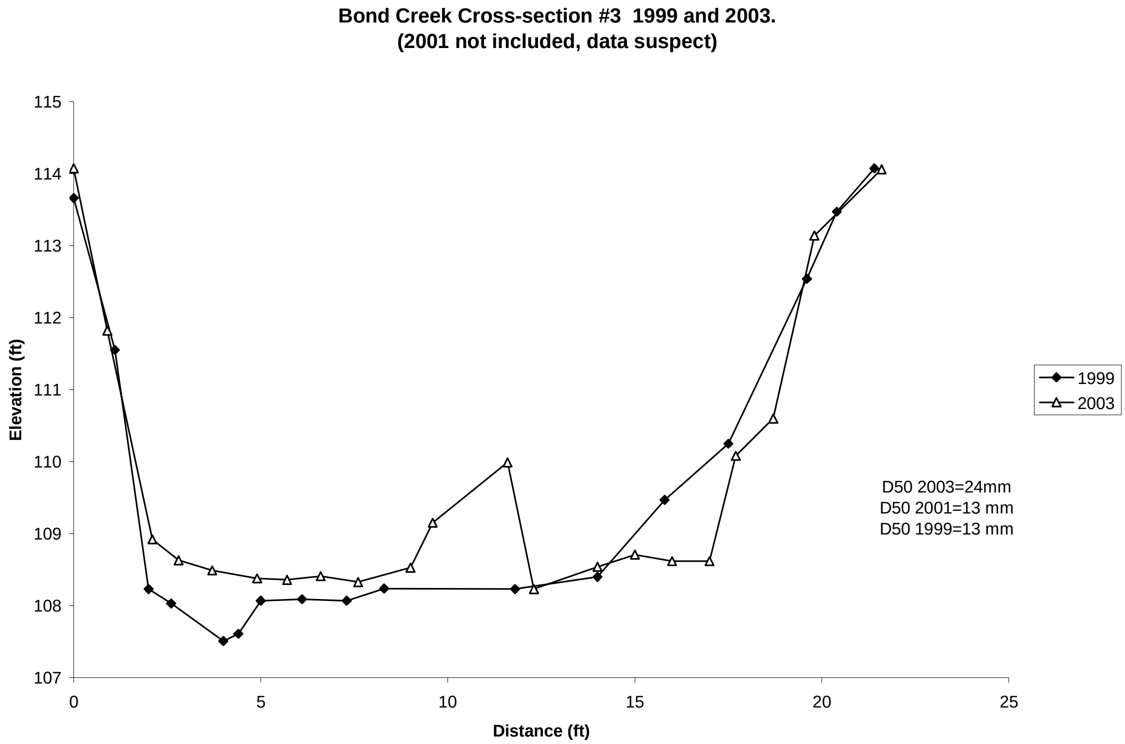
Particle Size Distribution from Pebble Count





Particle Size Distribution from Pebble Count





Particle Size Distribution from Pebble Count