

**CHANNEL GEOMETRY DATA OF STREAMS
IN THE LOWER DRIFT RIVER BASIN
AFFECTED BY THE 1989-90 ERUPTIONS
OF REDOUBT VOLCANO, ALASKA**

By Joseph M. Dorava, Benjamin A. May, David F. Meyer, and Lawrence V. Myers

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CONVERSION FACTORS AND VERTICAL DATUM

<u>Multiply</u>	<u>By</u>	<u>To obtain</u>
millimeter (mm)	0.03937	inch
centimeter (cm)	0.3937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
square kilometer (km ²)	0.3861	square mile
cubic meter (m ³)	35.31	cubic foot
kilogram (kg)	2.205	pound

Vertical datum:

In this report, all surveys are referenced to the North American Datum of 1983.

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ABSTRACT

Redoubt Volcano erupted intermittently from December 14, 1989 to April 26, 1990. The eruptions generated debris flows, ice avalanches, pyroclastic flows, and large water floods that altered the streams draining the northern and eastern flanks of the volcano. Streambeds along the main channel of the Drift River and its tributary channels downstream from the volcano scoured or aggraded several meters. Channel widths increased or decreased by as much as several hundreds of meters. Repetitive cross-section surveys document channel erosion or aggradation and bank erosion or accretion from January 1990 through October 1991.

INTRODUCTION

Redoubt Volcano is located 175 km southwest of Anchorage, Alaska, on the west side of Cook Inlet (fig. 1). During 1989-90, volcanic eruptions altered the hydrologic and geomorphic conditions of an area about 327 km² in size, north and east of the volcano. Volcanic activities that affected the watershed include an ice and rock avalanche (Waitt and others, 1990; Trabant and Brabets, 1990); pyroclastic surge and flow (Neal and others, 1990); and lahars (Major and Janda, 1990; Janda and others, 1990; Dorava, 1991a, 1991b). These eruptions (table 1) modified flow patterns in the drainage basin, melted and eroded snow and glacial ice, destroyed riparian vegetation, filled the valley bottom with sediment, and altered stream channel geometry. The investigation of these volcanic eruptions was intensified because of the proximity of the Drift River Oil Terminal, an oil storage and transfer facility located near the mouth of the Drift River (fig. 1).

During this study, monumented channel cross sections were established across three streams in the lower Drift River basin downstream from Redoubt Volcano: Drift River, Rust Slough, and Montana Bill Creek. Cross-section data were collected from the streams during water years 1990, 1991, and part of 1992. This report documents the changes in channel geometry that occurred as streams responded to the altered conditions in the basin.

Table 1.--Redoubt Volcano eruption chronology

[AST, Alaska Standard Time; ADT, Alaska Daylight Time]

Date			Time of eruption	
December	14	1989	0947	AST
			1009	AST
	15		0152	AST
			0338	AST
			1013	AST
			0616	AST
	16		0633	AST
			0629	AST
January	2	1990	1749	AST
			1927	AST
	3		0004	AST
			0014	AST
			0127	AST
			1010	AST
			1342	AST
			2248	AST
			0222	AST
February	7		2314	AST
			0403	AST
			1232	AST
			0505	AST
			0948	AST
March	4		2039	AST
			0951	AST
			0237	AST
			0947	AST
			0404	AST
			1034	AST
April	6		1723	ADT
			1452	ADT
			0611	ADT
			1017	ADT

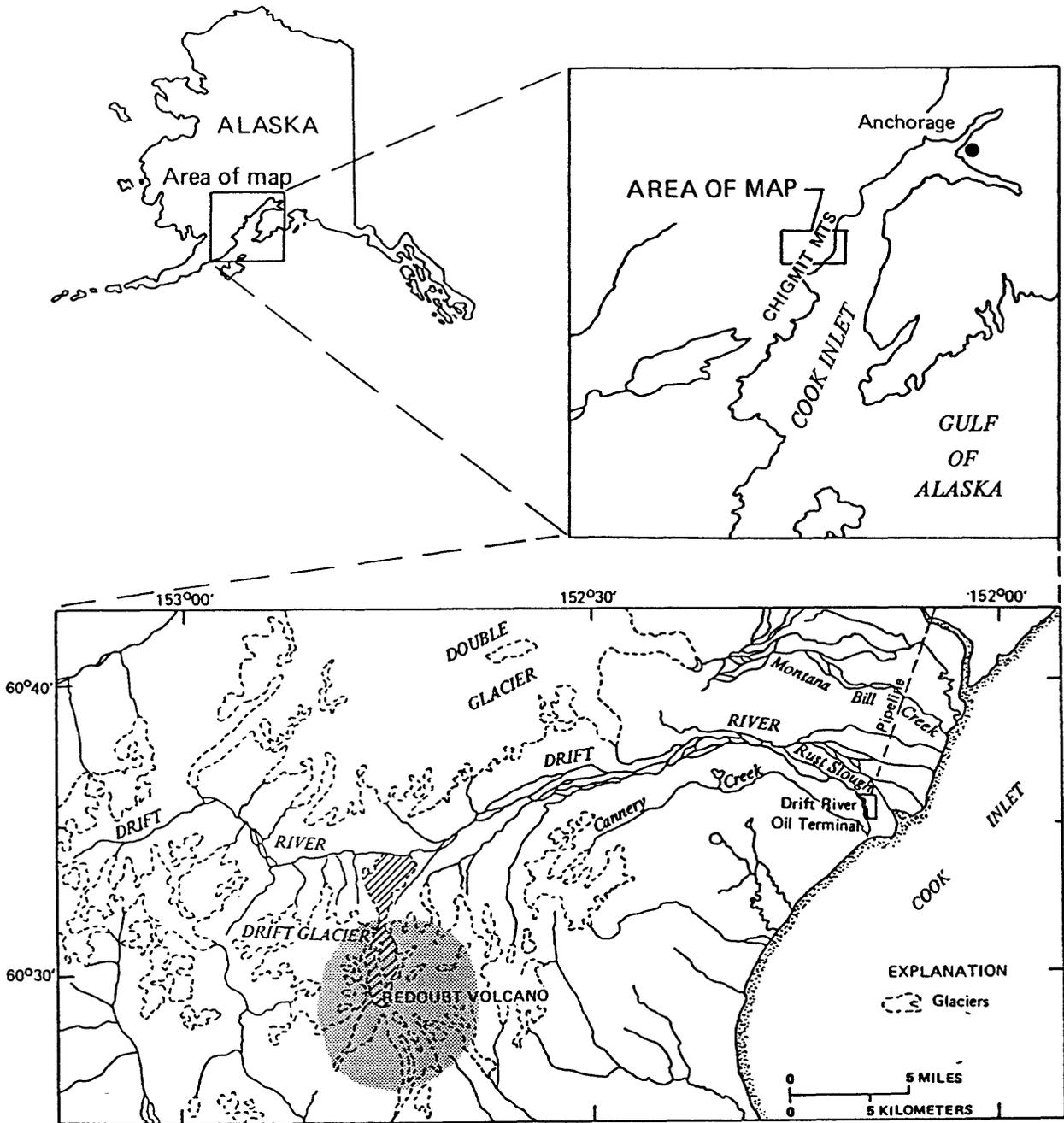


Figure 1.--Location of Redoubt Volcano, Drift River and Drift River Oil Terminal.

HYDROLOGY

The summit of Redoubt Volcano is at approximately 3,110 m altitude; the base is at approximately 700 m altitude, and summer snowline is at about 2,500 m. Mean annual precipitation is about 2,000 mm, about half of which is snow (National Weather Service, 1972). Forty-two percent, or about 240 km², of the Drift River basin is covered by glaciers, and streamflow is normally dominated by seasonal glacier and snowmelt runoff. Annual peak discharge of streams commonly occurs during the warmest period of the year. Mean monthly and mean annual discharges for the Drift River (table 2) were computed from equations developed by Freethey and Scully (1980).

Table 2.--Flow estimates of the Drift River

[Discharge values in cubic meters per second;
standard error in percent]

Month	Mean discharge ¹	Standard error
January	4.5	34
February	3.5	34
March	3.0	35
April	4.0	41
May	17	42
June	54	41
July	82	36
August	76	48
September	40	32
October	22	27
November	9.0	31
December	5.0	36
Annual	25	--

¹Based on equations developed by Freethey and Scully (1980)

Approximately 13 km² of the north flank of Redoubt Volcano is covered by "Drift Glacier" (unofficial name). This glacier extends from the narrow 1.6-km-wide summit crater near an altitude of 3,110 m, to the 5-km-wide piedmont terminus near an altitude of 300 m. At its terminus, the glacier forms the right bank of the Drift River. Drift Glacier calves directly into the river and constricts the river to a narrow 100-m wide canyon between the glacier and the north valley wall.

BASIN CHARACTERISTICS AND VOLCANIC IMPACTS

Drift River

The Drift River (fig. 2) drains an area of approximately 573 km² and flows eastward for about 57 km from its headwaters in the Chigmit Mountains to its mouth at sea level in Cook Inlet. The lower Drift River basin is downstream from Redoubt Volcano and includes 40 km of the river valley and 327 km² of the basin. In this lower part of the basin, the river flows along two distinct reaches: a steep (0.012 m/m), 2-km-wide, 25-km-long mountain-sided valley and a mildly sloping (0.004 m/m), 10-km-wide, 15-km-long alluvial fan that extends from the mountain-sided valley to the coast.

The 327-km² part of the Drift River basin downstream from Redoubt Volcano was significantly altered by the 1989-90 eruptions. The piedmont lobe of Drift Glacier was separated from the upper summit part of the glacier and more than 10⁹ m³ of ice was eroded or melted as a result of this beheading (Trabant and Brabets, 1990). A pyroclastic surge and flow deposited more than 1 m of tephra on Drift Glacier's piedmont lobe (Neal and others, 1990; McGimsey and Gardner, 1990) and destroyed vegetation on the north valley wall across from the volcano (Waitt and others, 1990). Debris flows and lahars altered conveyances of stream channels and changed flow patterns in the lower basin, causing stream avulsion from the Drift River towards the south into Rust Slough and Cannery Creek and later to the north into Montana Bill Creek (Major and Janda, 1990; Janda and others, 1990; Dorava, 1991a, 1991b).

Prior to the 1989-90 eruptions, the Drift River Oil Terminal was protected from floods in the Drift River by a 3-m-high, L-shaped, dirt berm along the eastern and northern sides of the facility. No protection was provided for flows from other directions or other sources; however, individual tanks were inadvertently protected from flooding in all directions by 1-m-high containment dikes that surround each tank to prevent oil loss from a possible tank failure. In July 1990, a new 6-m-high concrete-lined dike was constructed around the perimeter of the oil terminal protecting it from anticipated floods in both Drift River and Rust Slough (Arctic Hydrologic Consultants, 1990).

Rust Slough

The Drift River divides into several distributary channels in the lower alluvial-fan reach downstream from the mountain-sided valley. The main distributary that flows to the south is Rust Slough. This channel flows for approximately 10 km sinuously parallel to the main channel of the Drift River, but about 2 km to the south on the opposite side of the oil terminal (fig. 3). From January 1990 to August 1990, Rust Slough, which is smaller than the main Drift River channel, carried most of the water from the upper Drift River. During this time, overbank flows commonly inundated the forest on the alluvial fan for several kilometers. Since about September 1990, less flow from Drift River has been diverted into Rust Slough and the flow has been either in the main Drift River channel or in Montana Bill Creek.

Along Rust Slough, significant effects of the volcanic eruptions included the overflow of water on February 15, 1990 into one oil tank's containment dike on the oil terminal property, more than 15 m of lateral bank erosion toward the terminal near cross-section R800 (fig. 3), and overland sediment deposition.

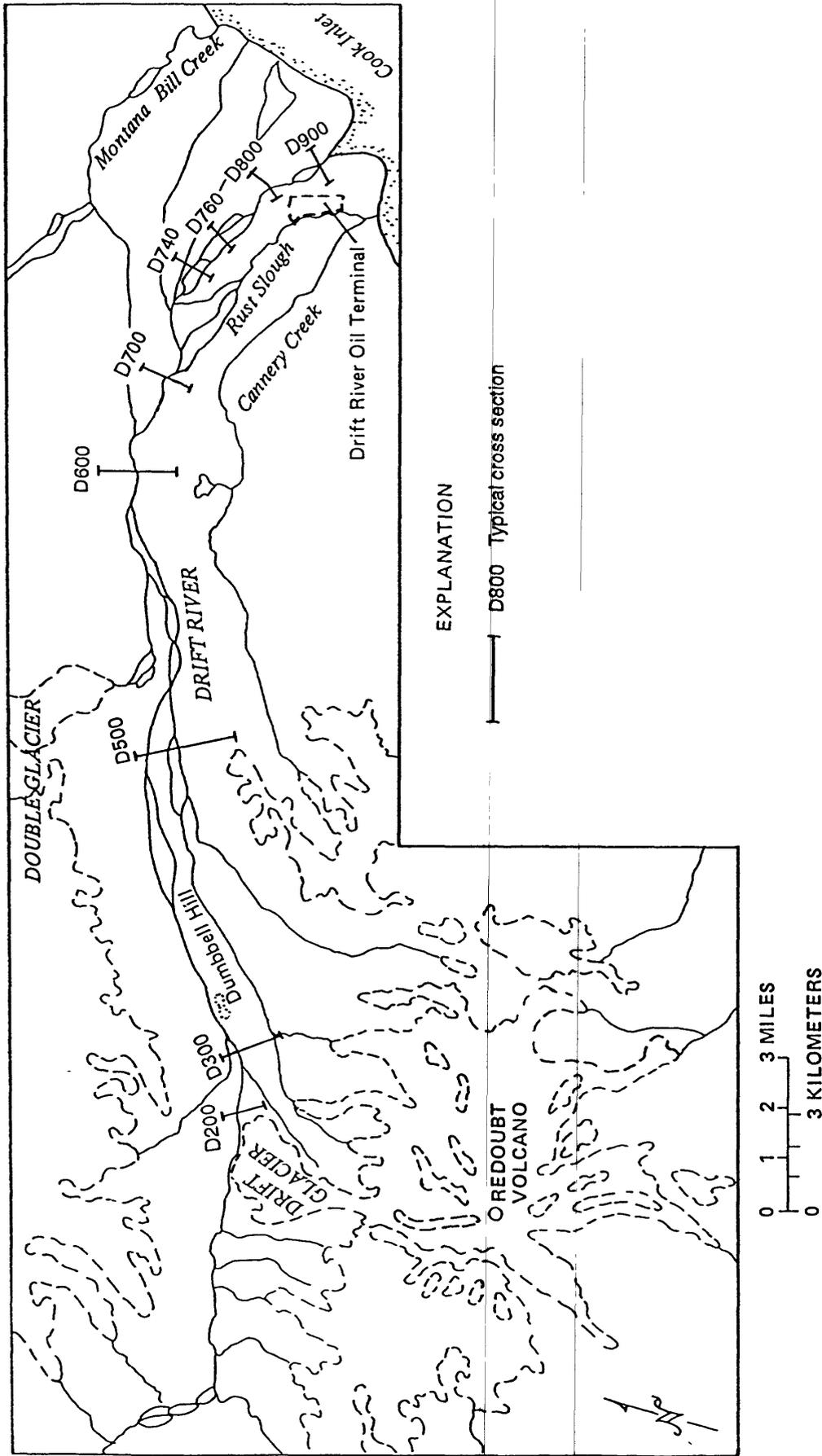


Figure 2.--Location of Drift River cross-sections.

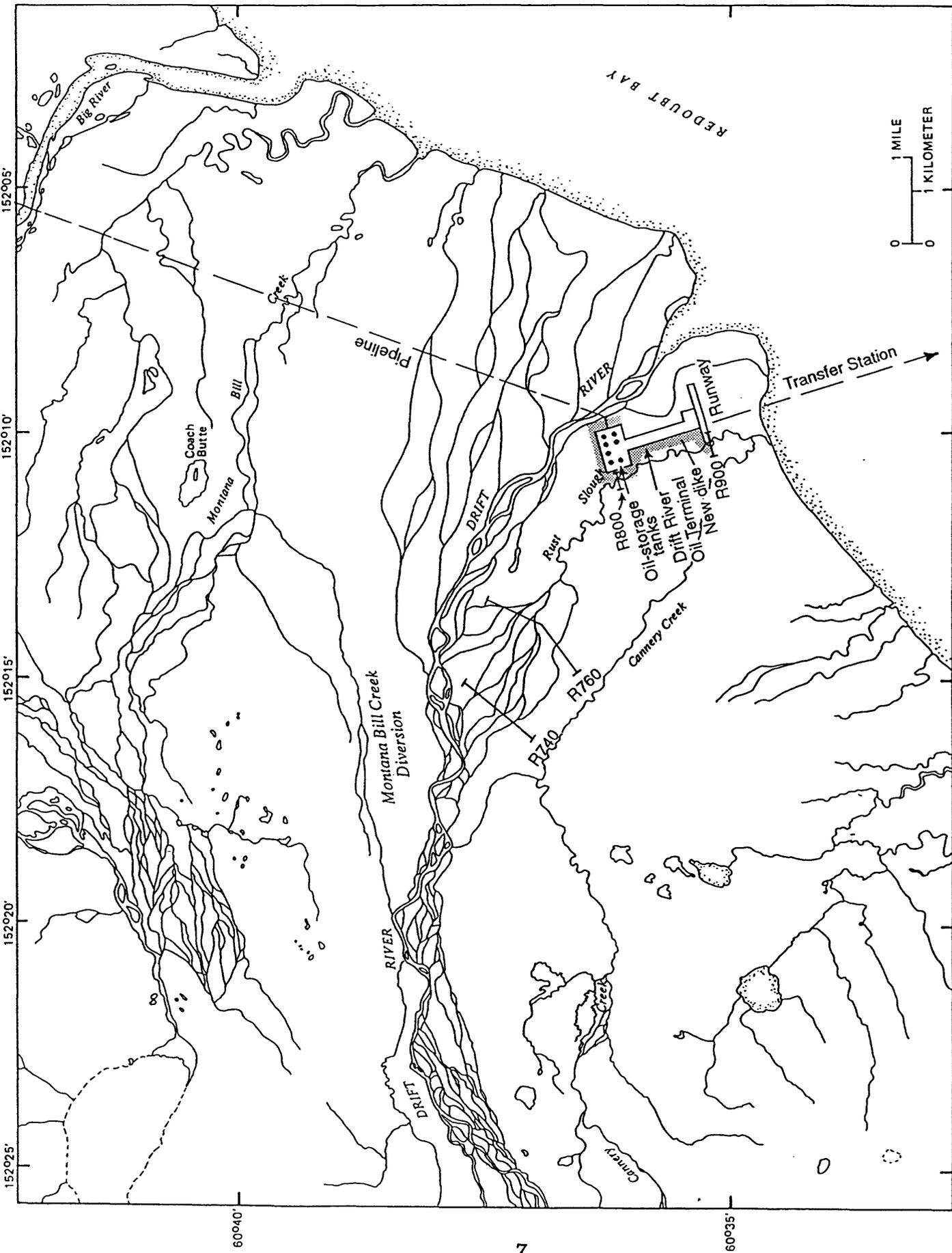


Figure 3.--Location of Rust Slough cross-sections.

Montana Bill Creek

In September 1990, the Drift River migrated to the north into a new channel near the upstream edge of the alluvial fan, approximately 0.5 km downstream from cross-section D600 (fig. 2). This new channel captured a significant part of the Drift River flow by diverting it into the main channel of Montana Bill Creek near Coach Butte (fig. 4). From approximately September 1990 to October 1991, this channel carried between 40 and 70 percent of the Drift River flow.

Along Montana Bill Creek, effects from the eruptions included the aggradation of underfit pre-existing channels at cross section M700 and subsequent migration of the stream channel farther to the north, the overbank flow of water into the pipeline right-of-way, and the erosion of streambed sediments at cross section M800 (fig. 4), which exposed the 50-cm-diameter pipeline that carries the oil from Cook Inlet platforms to the oil terminal.

METHODS OF DATA COLLECTION

Cross-Section Locations

Since January 1990, cross sections have been monitored at 16 locations to measure changes in channel geometry (table 3). These cross sections are grouped into three categories according to the river on which they are located: nine on the main channel of the Drift River (fig. 2), denoted with a "D" in their identifiers; four along the distributary Rust Slough (fig. 3), denoted with an "R"; and two along Montana Bill Creek (fig. 4), denoted with an "M." One other cross section was located on a side channel of the Drift River and it is denoted with a "DM" identifier (fig. 4).

Initially, three cross sections (D300, D500, D600) were monumented and surveyed in the upper reach of the lower Drift River as a method of indirect determination of discharge. These cross-section sites were selected on the basis of channel configuration and high-water marks. In April 1990, an additional 10 cross-section locations were selected according to established flow patterns in the basin: six were on the Drift River and four on Rust Slough. Later in the year, three more cross section locations were selected to monitor migration of water flowing northward into Montana Bill Creek.

The three original cross sections were remonumented and surveyed in greater detail after April 17, 1990, to account for incremental stream channel geometry changes between surveys. Data collected before April 17, 1990 from these three cross sections are shown on separate plots in this report to avoid erroneous comparisons with the later, more detailed cross sections monitored at these locations.

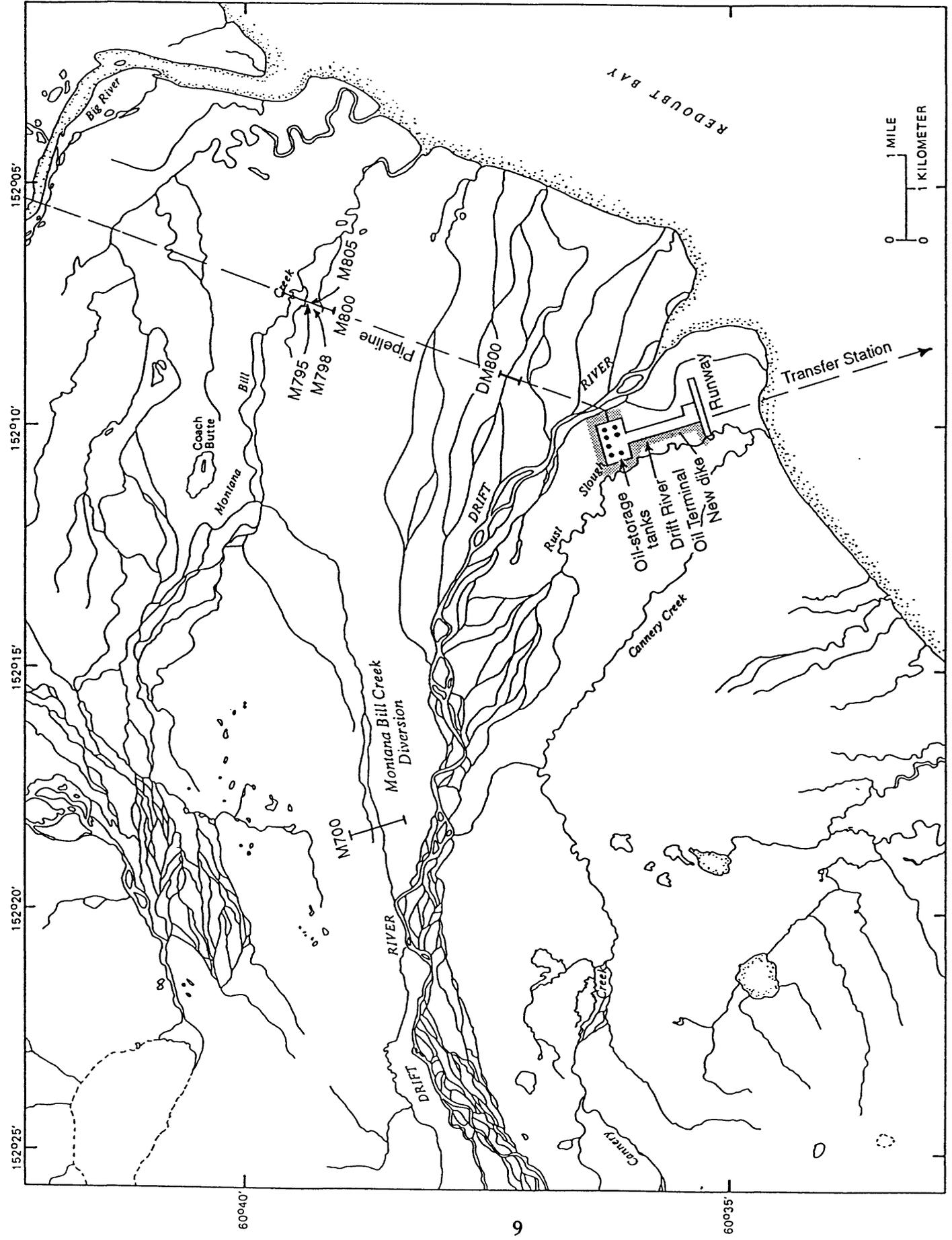


Figure 4.--Location of Montana Bill Creek cross-sections.

Table 3.—Dates of cross-sections surveys, 1990-91

[See figures 2, 3, and 4 for cross-section locations; D, Drift River; R, Rust Slough; M, Montana Bill Creek; DM, between Drift River and Montana Bill Creek]

Cross section	Date surveyed		Cross section	Date surveyed		Cross section	Date surveyed	
	1990	1991		1990	1991		1990	1991
D200	5-01	6-25	D700	4-18	5-23	R740	6-07	
	5-31	8-08		5-09	7-02		6-20	
	6-18			6-07	8-29		7-03	
	7-10			6-18			7-19	
	8-08			7-03			8-28	
	9-11			7-18				
	10-31			8-08			R760	6-08
D300	1-26	6-27	8-29		6-20			
	2-01	8-14	9-13		7-03			
	3-13		9-27		7-23			
	3-19		D740	5-25	9-11	8-08		
	4-17			6-12		8-22		
	5-03			6-27				
	6-11		D760	5-24	7-23	R800	6-06	7-18
	6-26			6-12	8-30		6-20	
	7-23			6-27			7-19	
	8-16			7-18		8-07		
	8-28			8-29		8-28		
9-13		9-13			11-06			
D500	2-01	7-02	9-27		R900	6-05	7-18	
	2-20	8-29	10-30			6-20		
	3-19					7-19		
	4-17		D800	5-24	7-02	8-08		
	5-09			6-12	8-30	8-28		
	6-11			6-27		11-06		
	6-26			7-18				
	7-19			8-07		M700	8-22	8-08
	9-11			8-29			9-27	
				9-27			11-06	
D600	2-06	6-25	10-30		M800	10-30	5-23	
	2-20	8-29				7-16		
	3-13		D900	5-24		7-23	8-15	
	3-19			6-12	8-30	10-04		
	4-18			7-03		10-10		
	5-09			7-18				
	6-11			8-28		DM800	10-30	5-23
	6-27			9-27				
	7-23		10-30					
	8-16							
	9-13							
	9-27							

Surveying Methods

Cross sections were established perpendicular to the flow. In the upper reach of lower Drift river, cross sections spanned the valley floor. In the lower reach of the lower Drift River, cross sections spanned the limits of flow on the alluvial fan. Because of lateral channel migration, flow may not remain perpendicular to the cross sections. Endpoints of cross sections are monumented with steel fence posts, wood lathes, or trees, depending on the site. Distances were usually surveyed with electronic distance measuring (EDM) equipment, and horizontal or vertical angles were measured with a theodolite. Commonly, the surveying instruments were set up on line with the cross-section monuments that served as horizontal and vertical control. When deep gullies or steep channels precluded precise measurements in the time allowed, measurements were made using hand levels and tape. If high flows prevented surveying or measuring channel bottoms, the maximum depth was estimated and only the wadeable part of the channel was surveyed. Cross sections at location M800 on Montana Bill Creek incorporated depth soundings acquired from discharge measurements made on the day of the surveys. These depth measurements were made from a boat utilizing a tag line for horizontal distance and a 30-kg sounding weight.

Field data were entered into a computer, converted to relative horizontal distance and vertical altitude, and referenced to monuments with fixed horizontal and vertical positions. All surveys are referenced to the North American Datum of 1983. Surveys were plotted using digital plotters and superimposed on earlier surveys of the same cross section.

Accuracy and precision of surveys depend on the nature of the channels, the weather at the time of the survey, and the surveying techniques. Surveys of wide channels are not as precise as surveys of narrow channels. Selection of surveyed points introduces a large degree of uncertainty in reproducing rough surfaces that have not changed. Inadequate visibility and atmospheric temperature and pressure fluctuations affect the accuracy of EDM measurements. Strong winds, water-saturated ground, or snow cover occasionally cause difficulties in precise leveling. When at least two monuments exist from a previous survey to establish the cross-section bearing and when points that are common to previous surveys are measured consistently, both horizontal and vertical precision are generally within 0.10 m, regardless of adverse weather conditions.

EXPLANATION OF CHANNEL GEOMETRY DATA

A total of 132 channel cross-section profiles that were constructed from the survey data collected during water years 1990, 1991, and part of 1992 are shown in the following sections of the report. The locations of the cross sections are shown in figure 2 for the Drift River, in figure 3 for Rust Slough, and in figure 4 for Montana Bill Creek and for the side channel of the Drift River. A table listing the data points of each cross section is available in electronic form. Procedures for obtaining the data are explained in appendix 1.

The channel geometry data for each cross section are given in two parts. The first part includes: (1) a detailed description of each cross-section location, (2) the specific attributes of reference monuments on a schematic diagram that is not to scale, and (3) remarks. The second part includes the cross-section profiles, which are to scale.

On the schematic diagrams of the reference monuments, all distances between the monuments and altitudes to the tops of monuments are given in meters. The abbreviations on these diagrams are explained as follows:

B	Bank
C	Center
EDVA	Base monument within each cross section located horizontally by Global Positioning System technology and vertically by distance and vertical angle measurements
F	Far
L	Left
M	Monument
N	Near
R	Right
TP	Turning point originally surveyed in May and June 1990

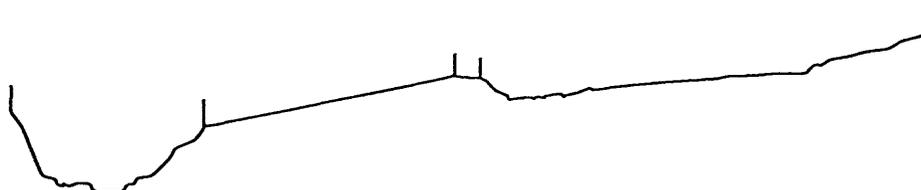
For example, FLBM would be the far left bank monument.

CHANNEL GEOMETRY OF DRIFT RIVER

Cross Section D200

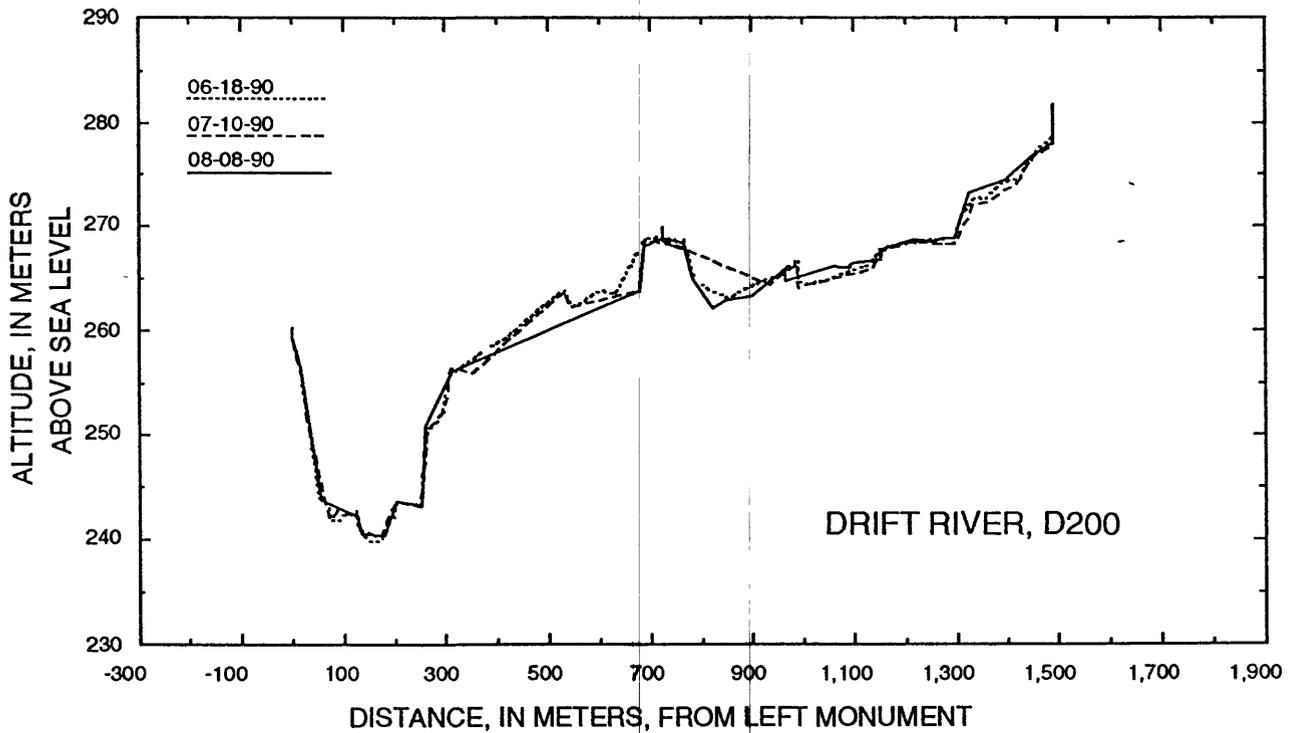
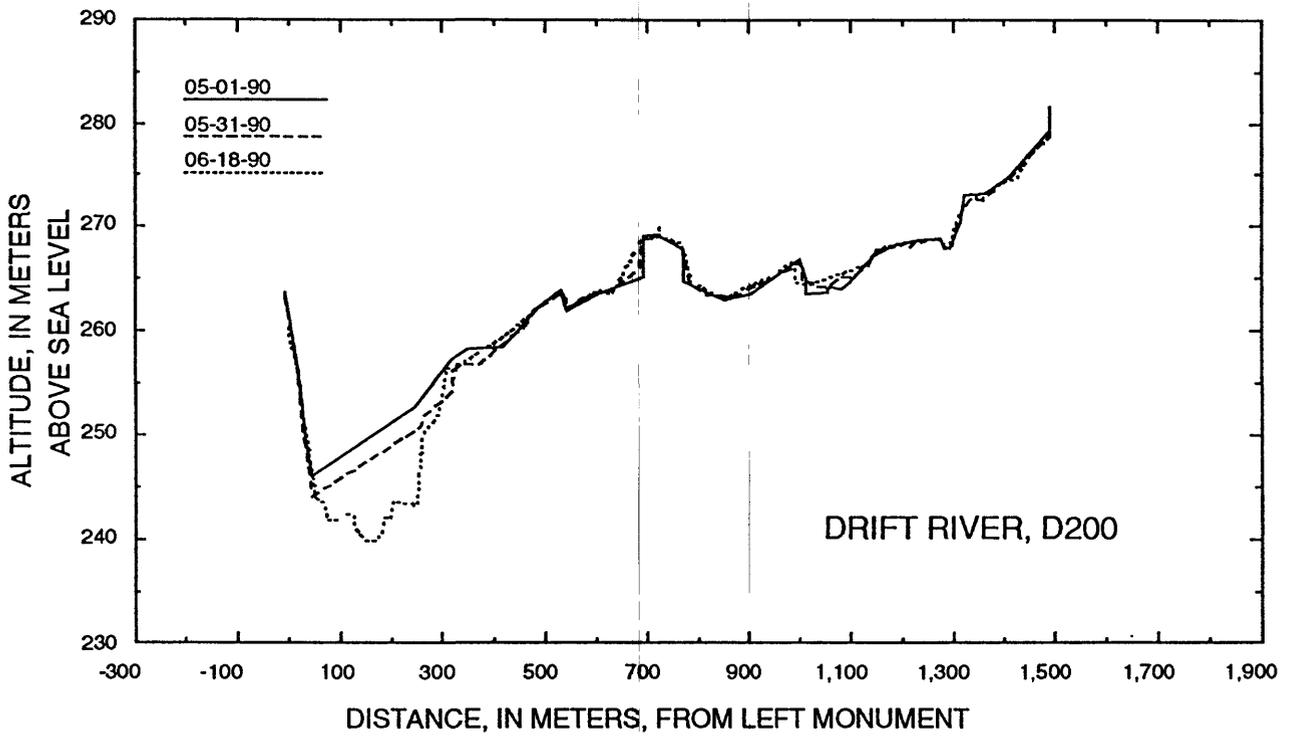
LOCATION. The reference monument, CM, is at lat 60°33'53.2480"N., long 152°42'27.1514"W. near the middle of this 1,490-m-wide cross section. The monument is a 1.06-m-high steel fence post. This cross section is less than 1 km downstream from the terminus of Drift Glacier and 3.5 km upstream from Dumbbell Hill and has an azimuth of about 330°.

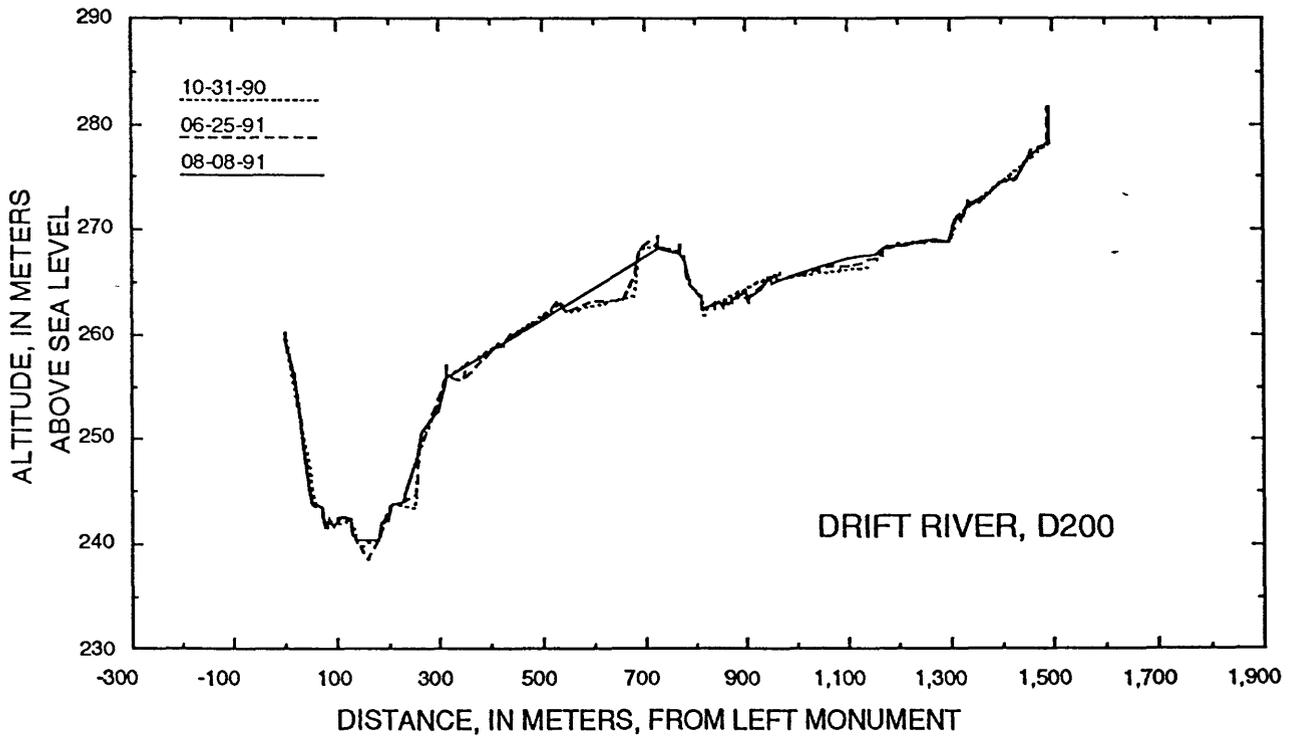
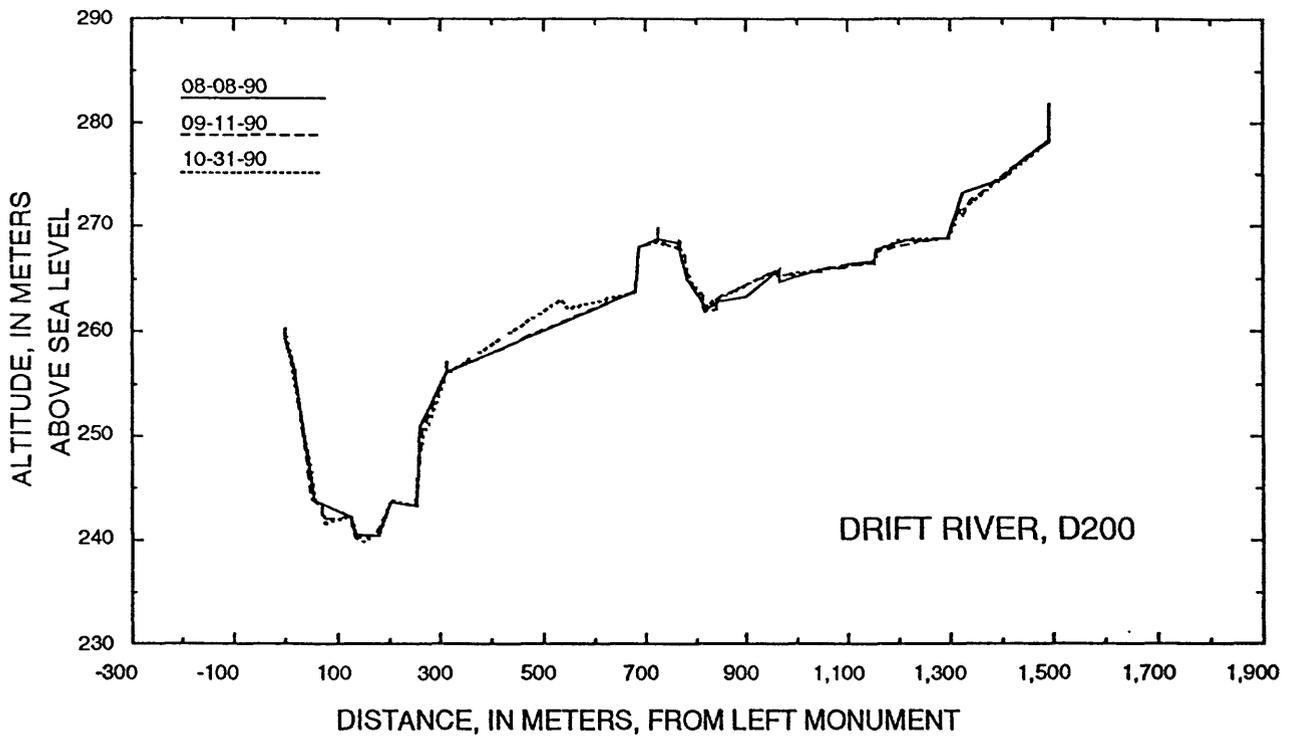
MONUMENTS.



Monument	FLBM	CRBM	CM,EDVA	CLBM	FRBM
Distance	0.00	312.82	725.05	767.87	1489.90
Altitude	260.24	256.93	269.21	268.58	281.71
Height	0.85	1.06	1.06	0.84	3.40

REMARKS. D200 was established to measure the geomorphic response of the upper Drift River valley closest to Drift Glacier. It crosses Drift River on the left and Crater Creek on the right. The substrate of the middle of this cross section is an ice conglomerate (Waitt and others, 1990) and altitude changes of monuments indicate that the conglomerate has been melting and sinking over the measuring period.

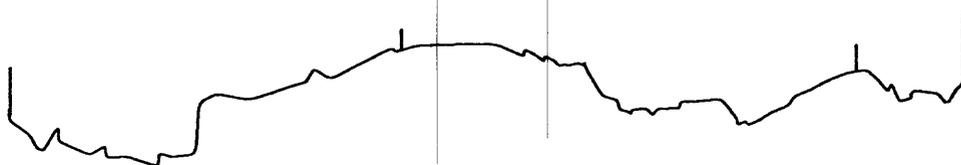




Cross Section D300

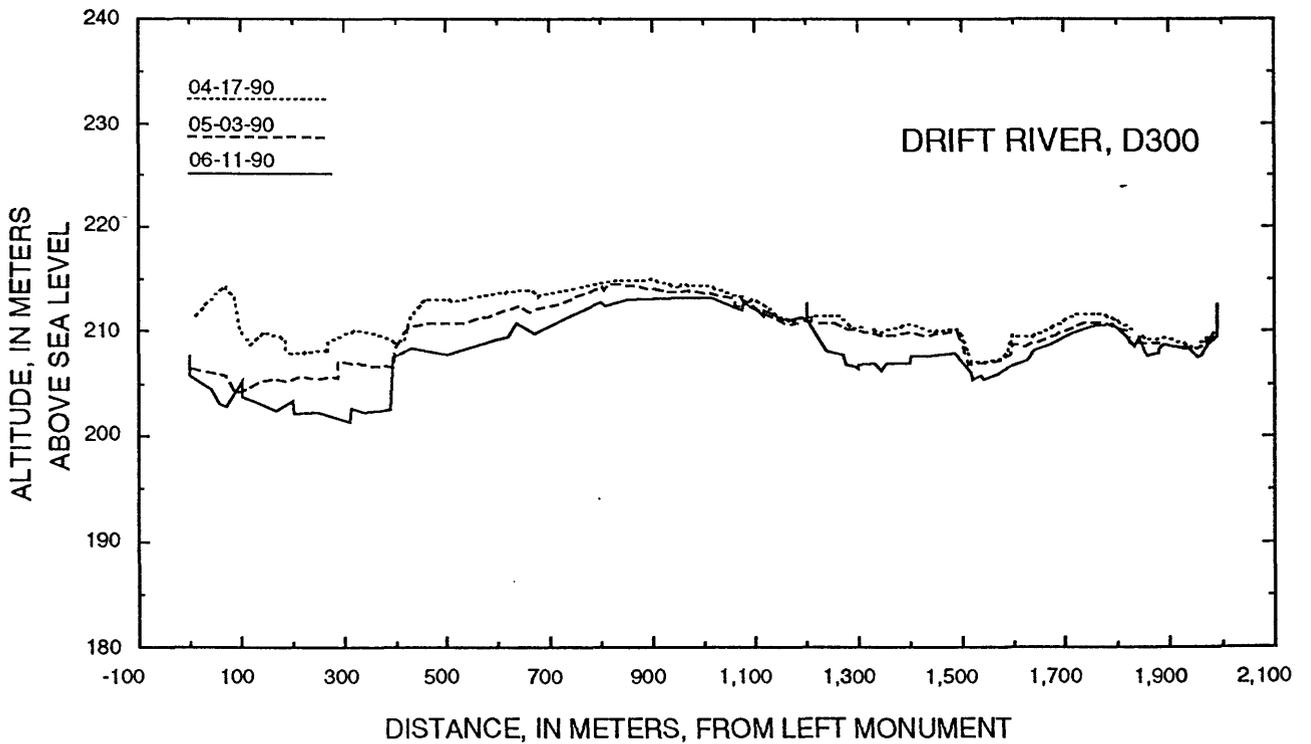
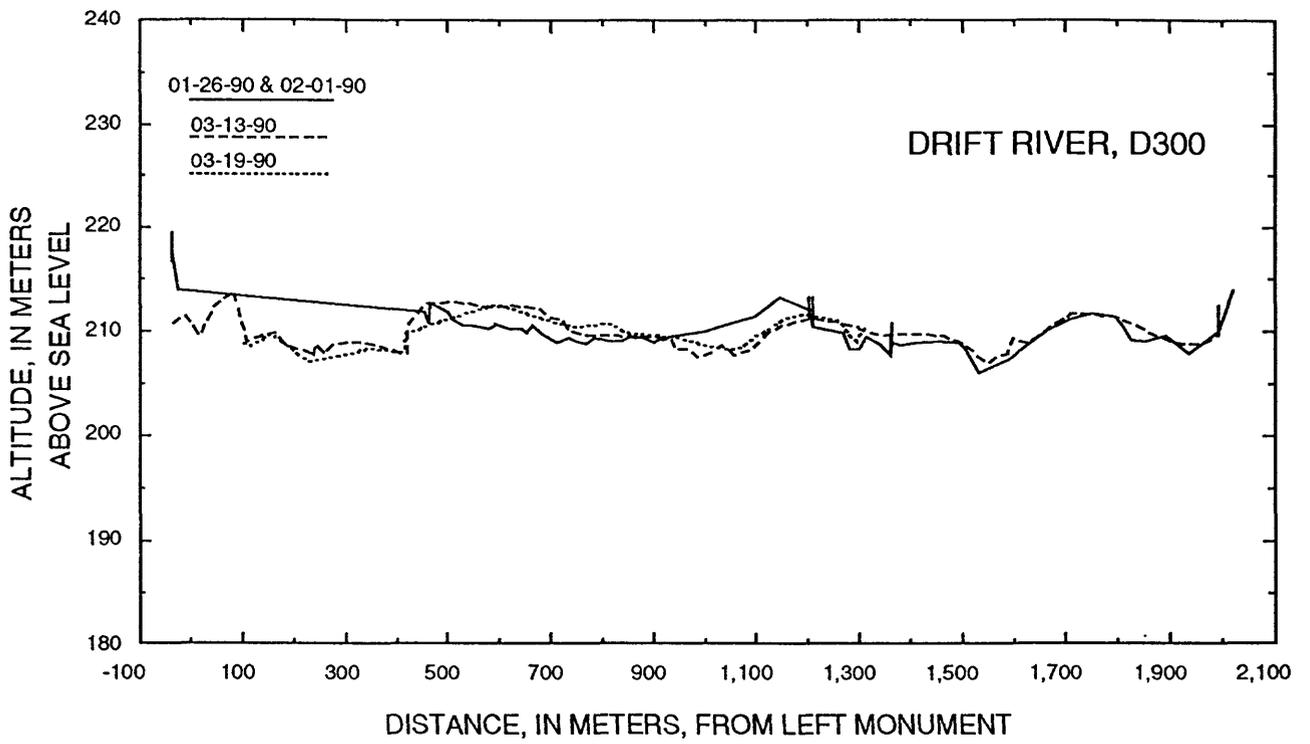
LOCATION. The reference monument, CM, is at lat 60°34'20.4316"N. and long 152°40'31.3192"W. near the middle of this 1992-m-wide cross section. The monument is a 0.25-m-high 2- by 4-cm wooden stake. This cross section is approximately 2.5 km downstream from the terminus of Drift Glacier and 1.4 km upstream from Dumbbell Hill and has an azimuth of about 330°.

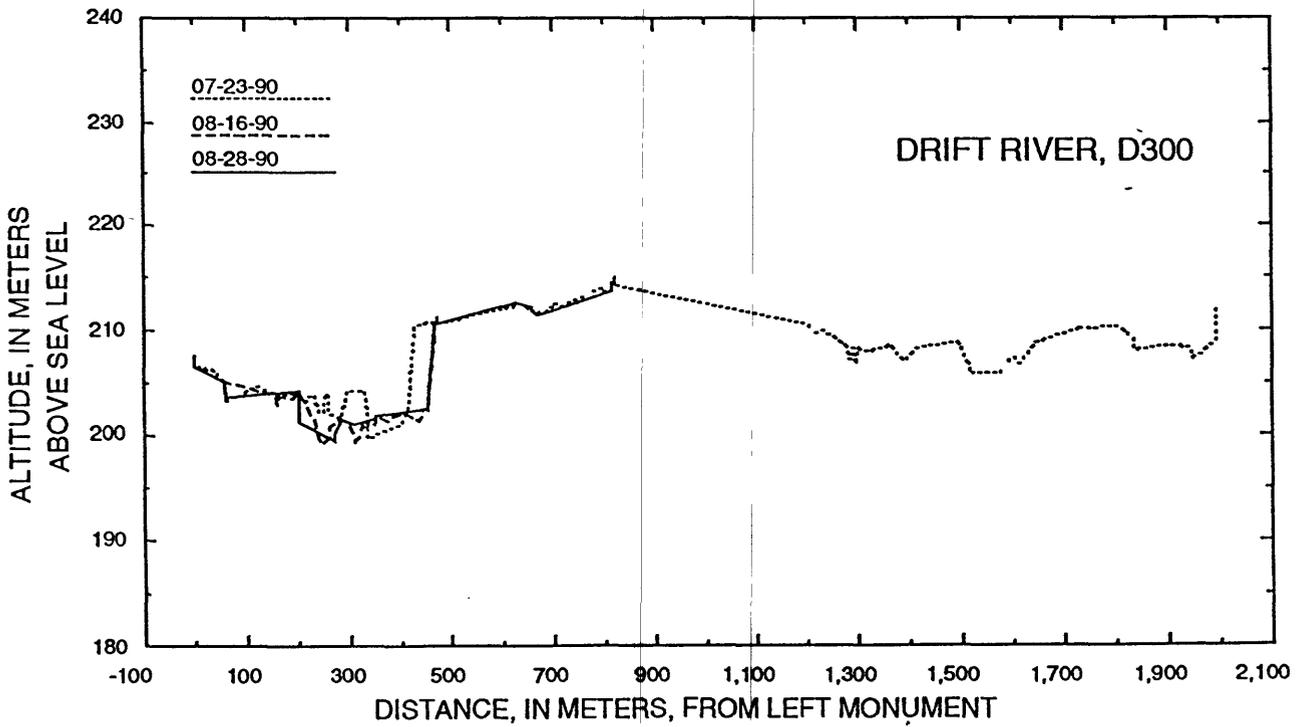
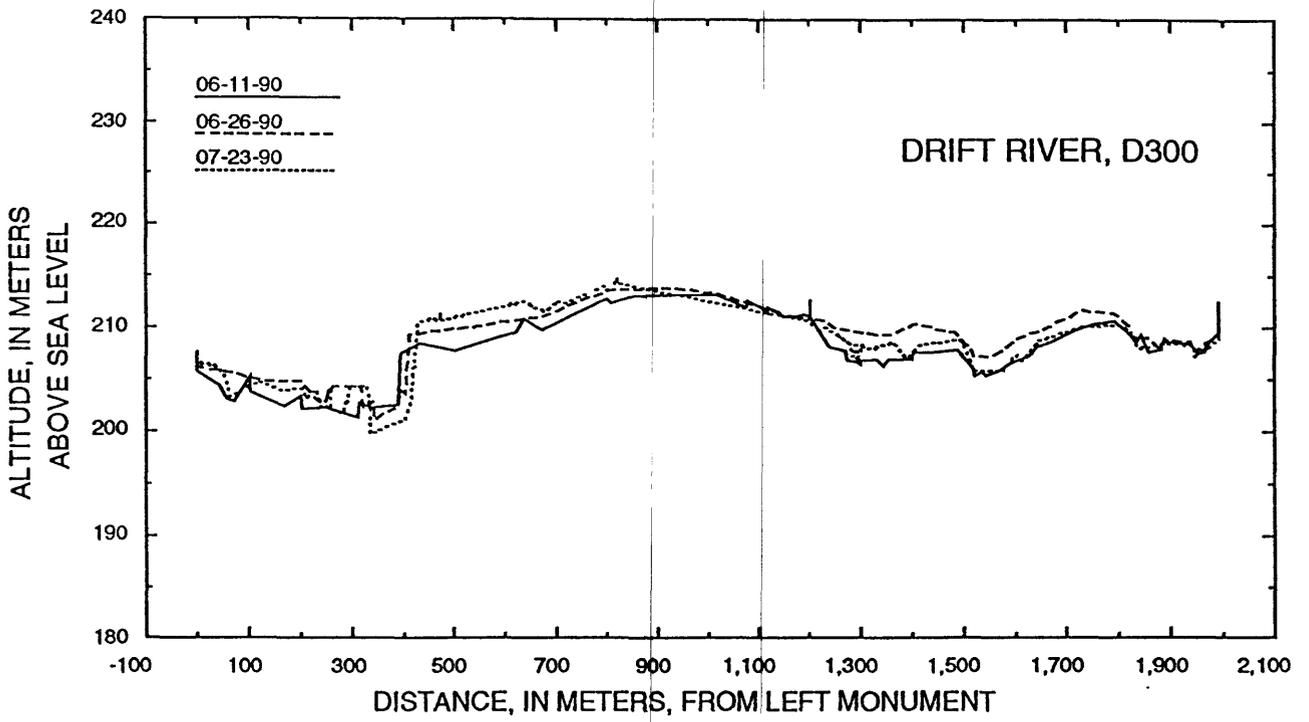
MONUMENTS.

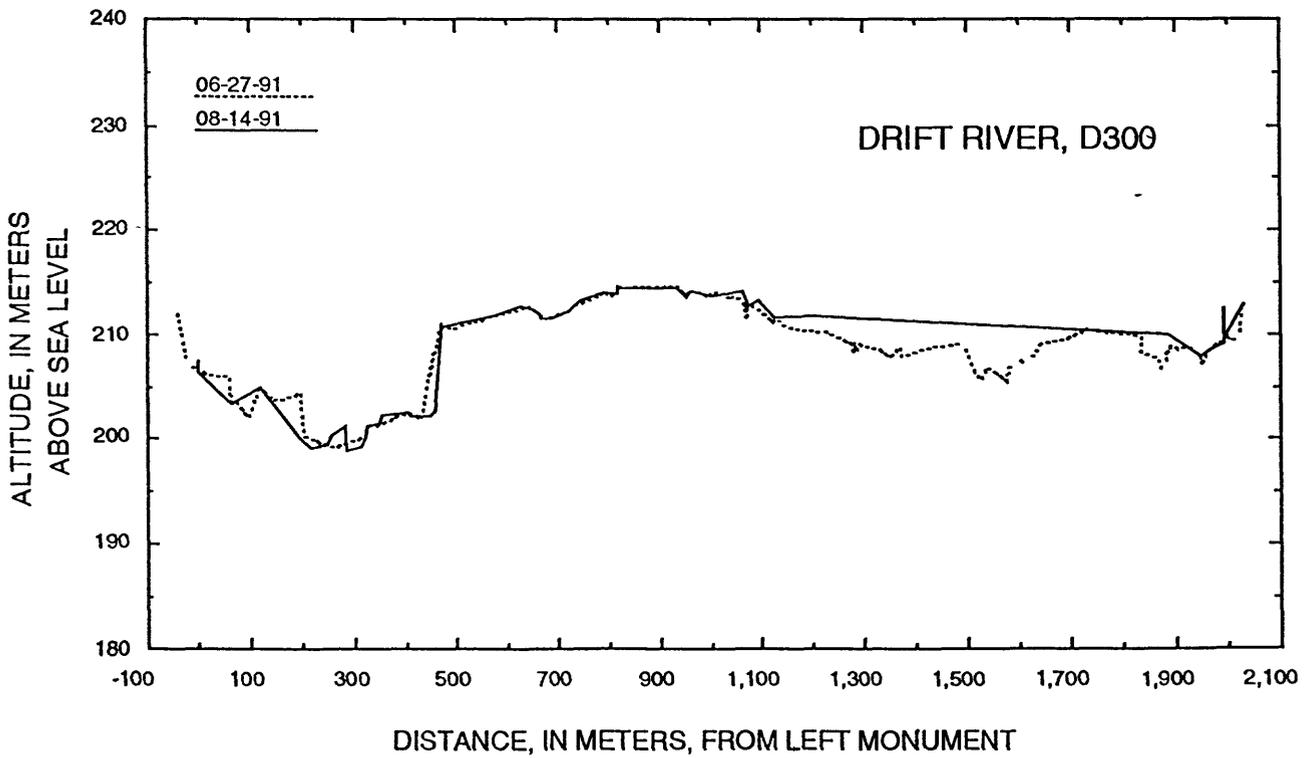
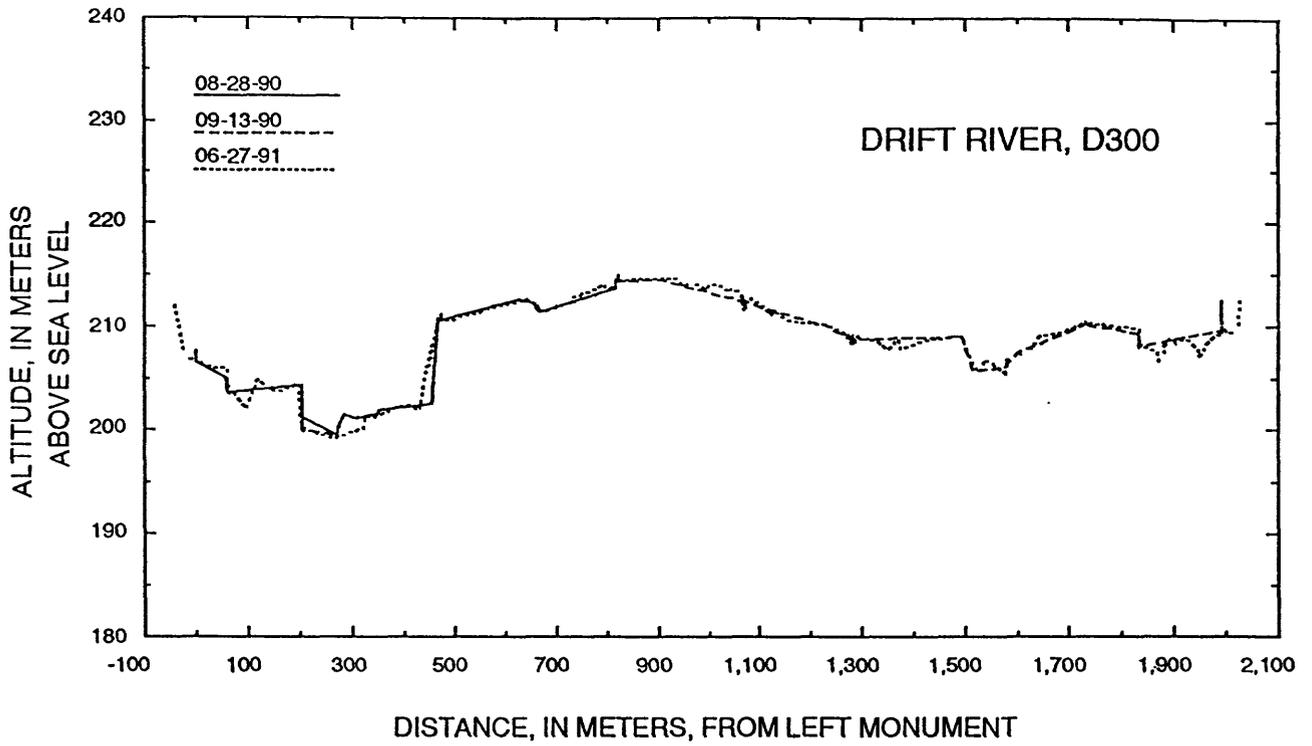


Monument	FLBM	CM, EDVA	NRBM	FRBM
Distance	0.00	822.19	1731.90	1991.99
Altitude	207.59	214.69	210.56	212.50
Height	1.11	0.25	0.19	3.21

REMARKS. D300 was the first cross section surveyed to provide data on the geomorphic response of the Drift River valley to the 1989-90 eruptions of Redoubt Volcano. The cross section was initially surveyed on January 26, 1990 and monumented with additional datum control on April 17, 1990. The cross section crosses the Drift River on the left and Crater Creek on the right.



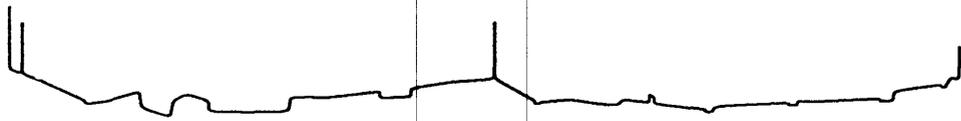




Cross Section D500

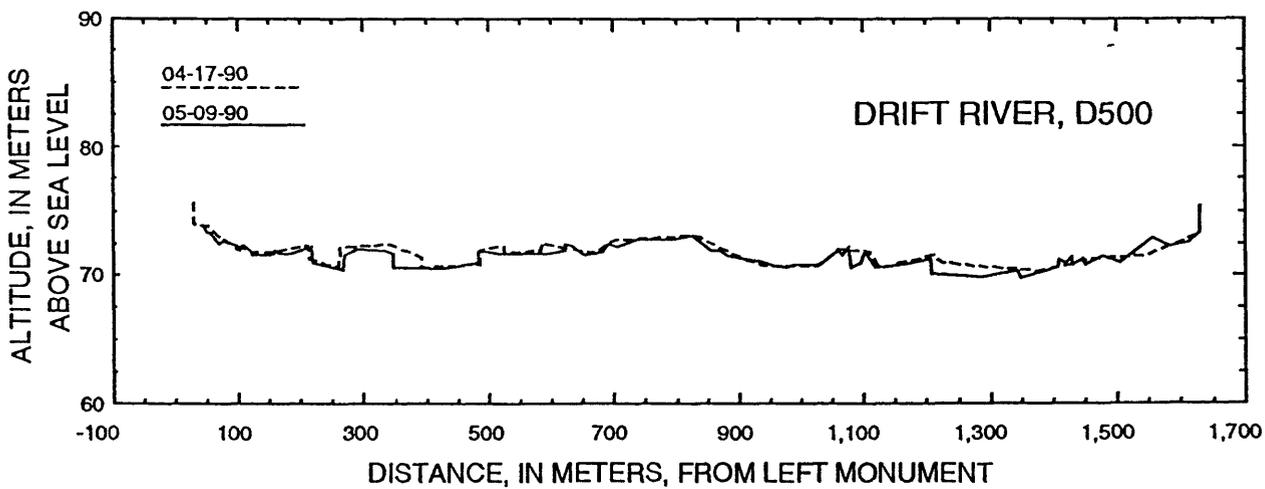
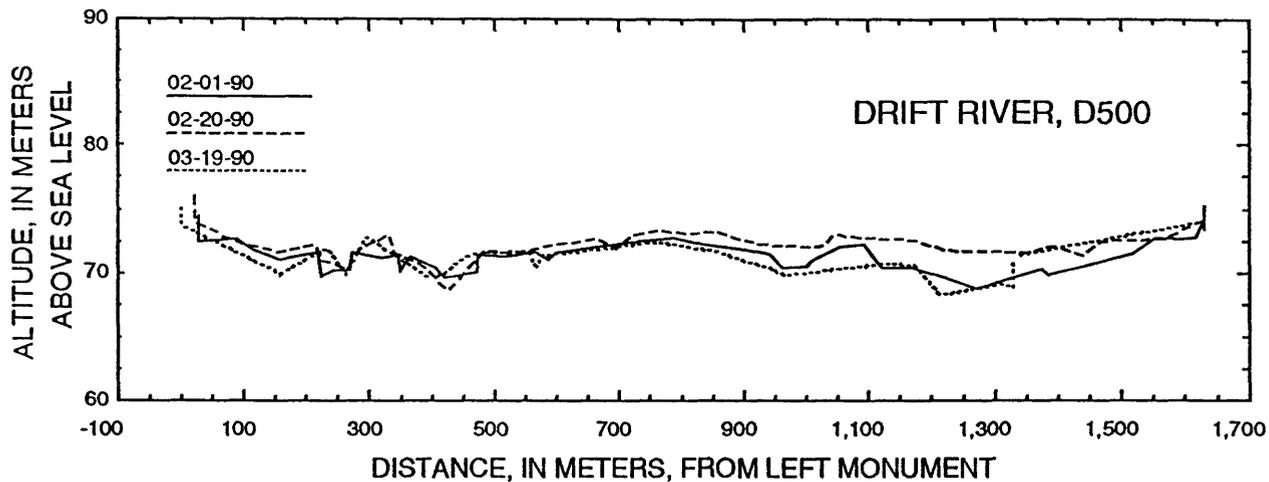
LOCATION. The reference monument, CM, is at lat 60°36'47.1943"N. and long 152°30'06.6108" W. near the middle of this 1,629-m-wide cross section. The monument is a 1.17-m-high steel fence post. This cross section is approximately 9 km downstream from Dumbbell Hill and about 1 km upstream from the outwash fan from the Drift River lobe of Double Glacier. It has an azimuth of about 340°.

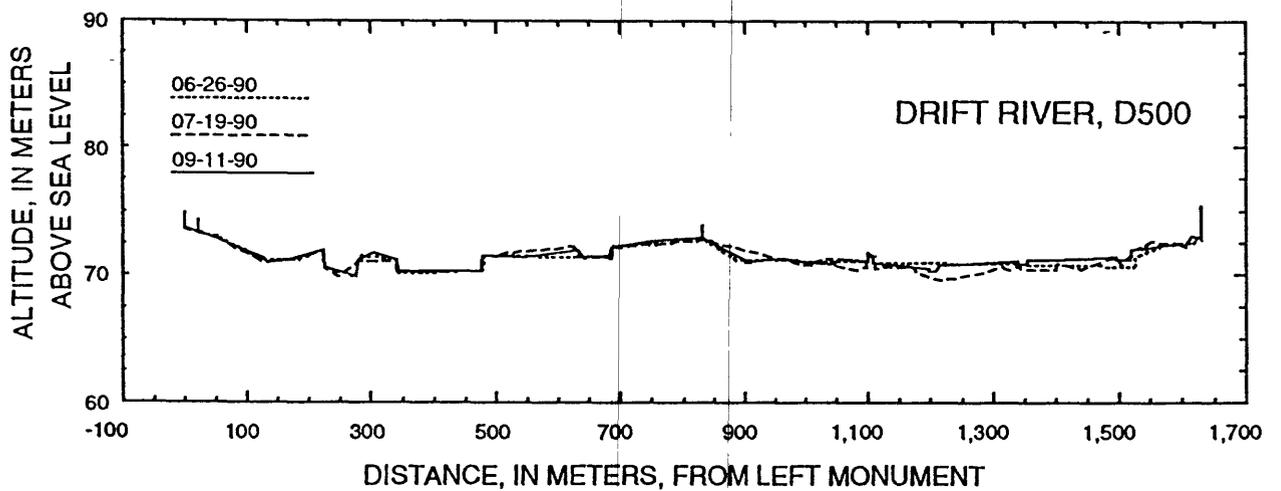
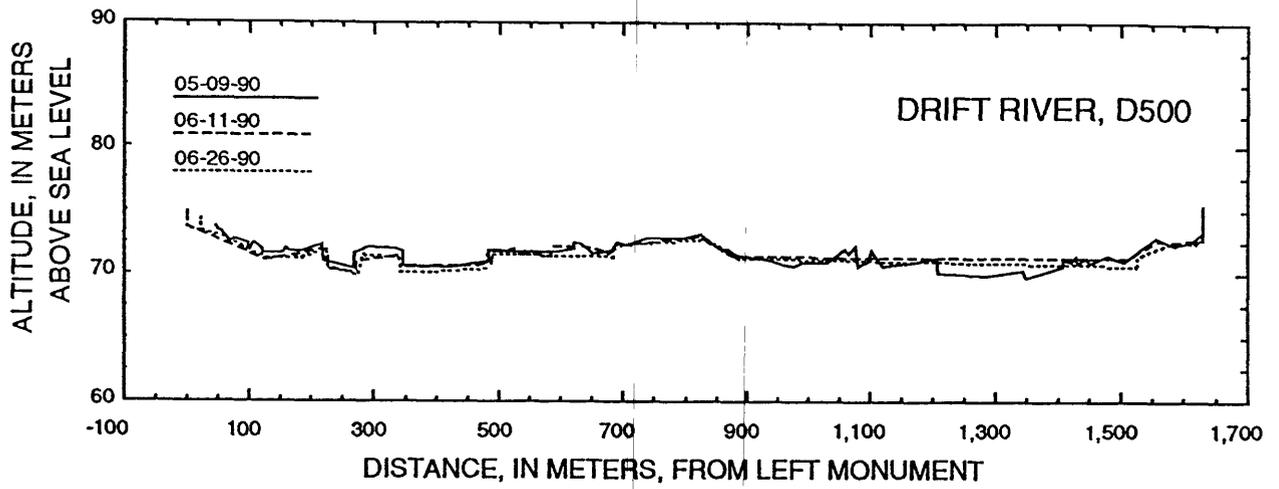
MONUMENTS.

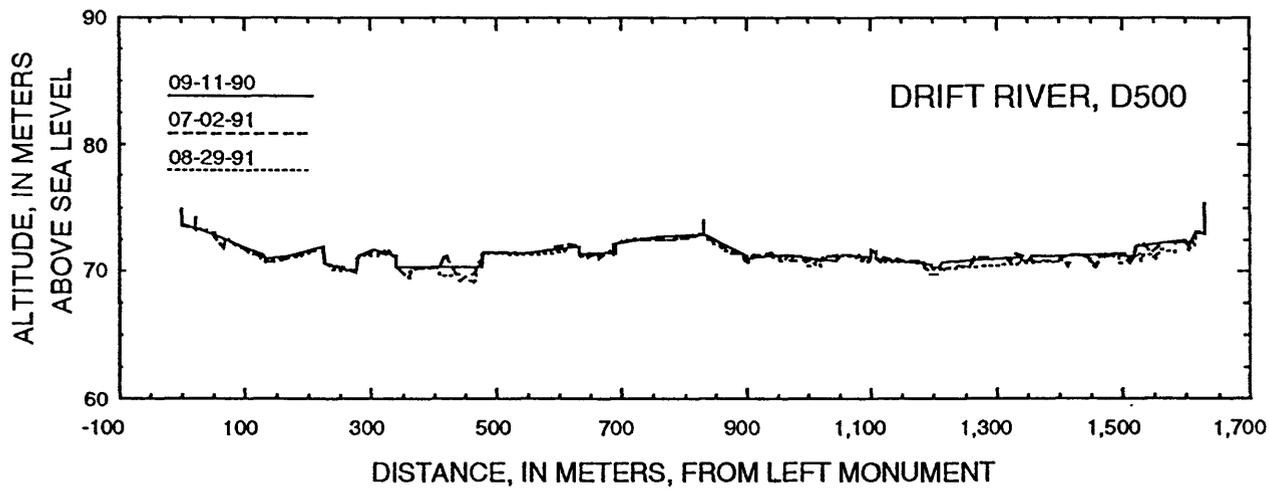


Monument	FLBM	NLBM	CM,EDVA	FRBM
Distance	0.00	22.84	831.05	1628.56
Altitude	74.82	74.27	74.01	75.37
Height	1.21	0.95	1.17	2.31

REMARKS. D500 was one of the initial three cross sections surveyed to provide data on the geomorphic response of the Drift River valley to the 1989-90 eruptions of Redoubt Volcano. The cross section was first surveyed on February 1, 1990 and monumented with additional datum control on April 17, 1990.







Cross Section D600

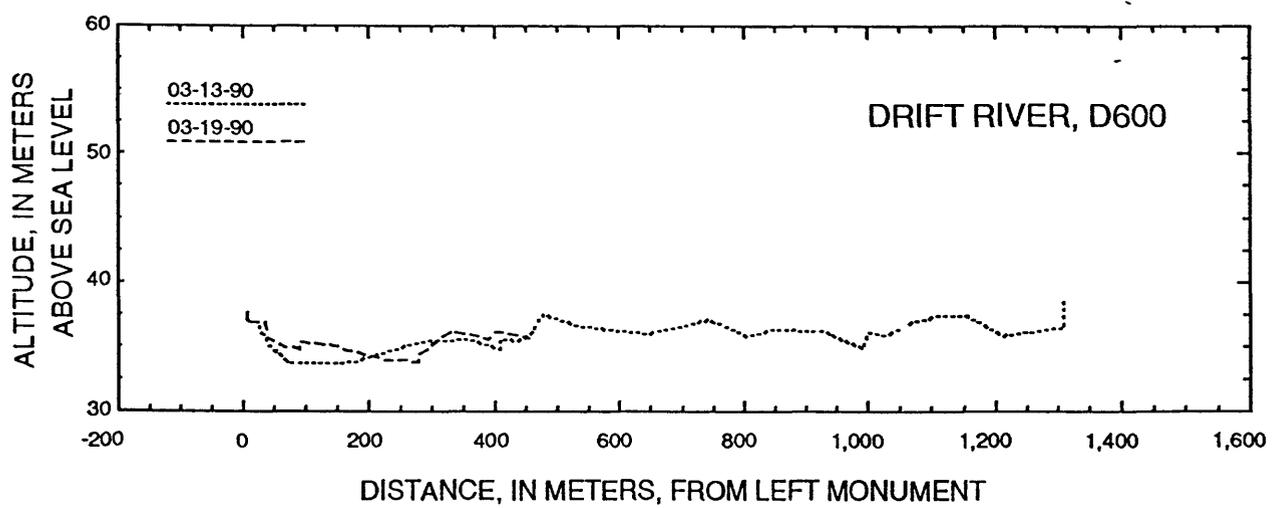
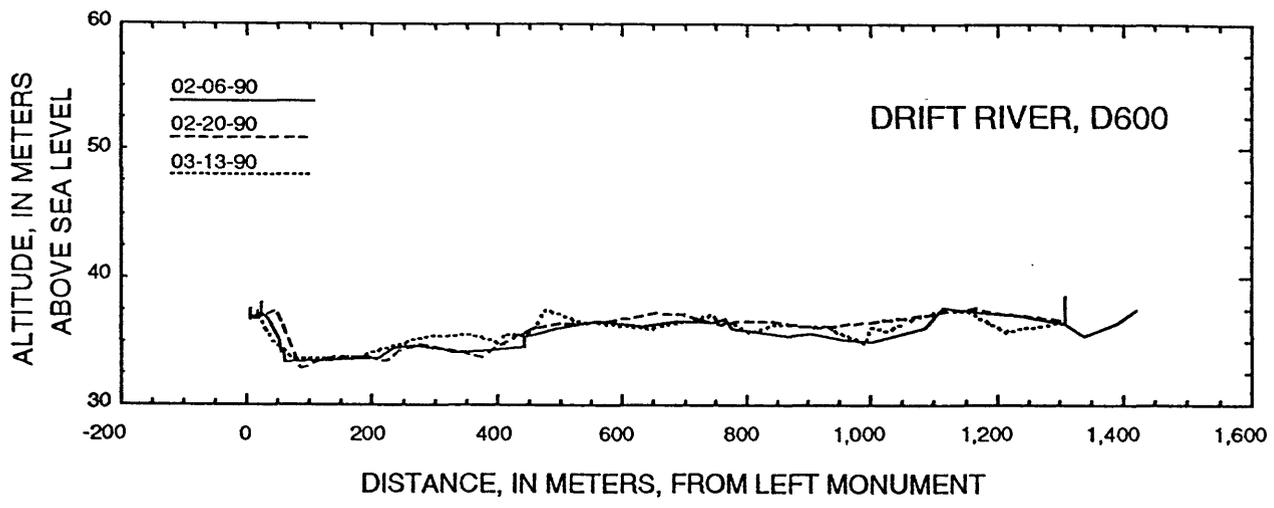
LOCATION. The reference monument, LCM, is at lat 60°37'56.7797" N. and long 152°21'18.5227"W. near the middle of this 1,309-m-wide cross section. The monument is a 0.42-m-high steel fence post. This cross section is approximately 6 km downstream from the outwash fan of the Drift River lobe of Double Glacier and about 1 km upstream from the end of the steep south valley wall. It has an azimuth of about 350°.

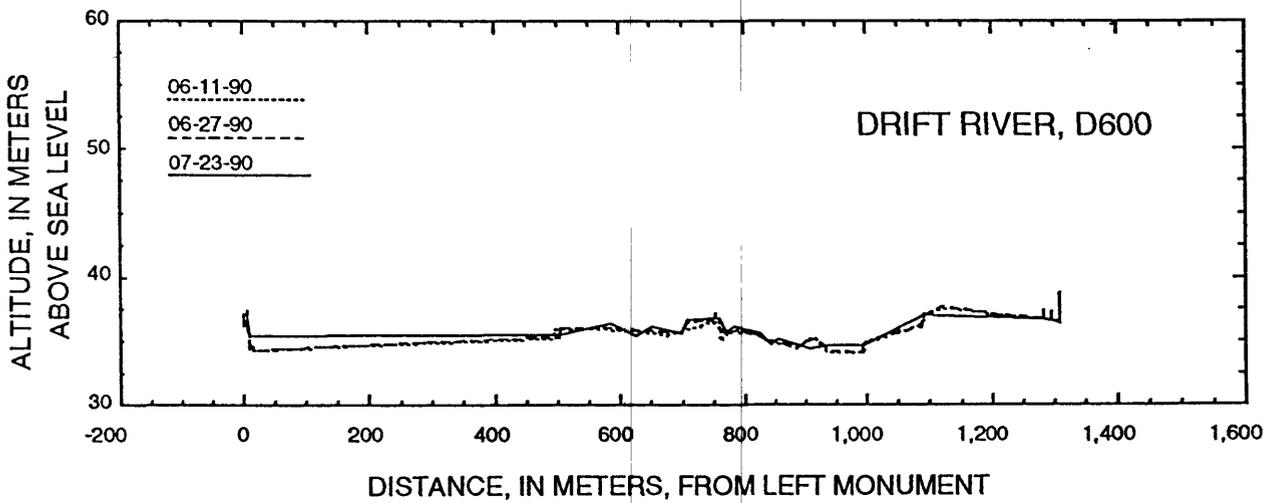
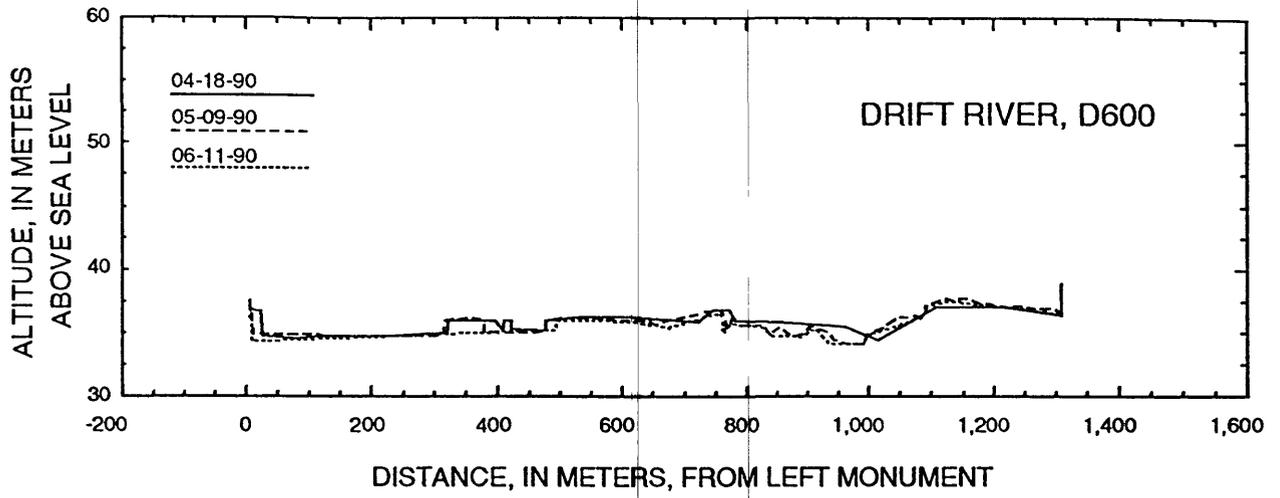
MONUMENTS.

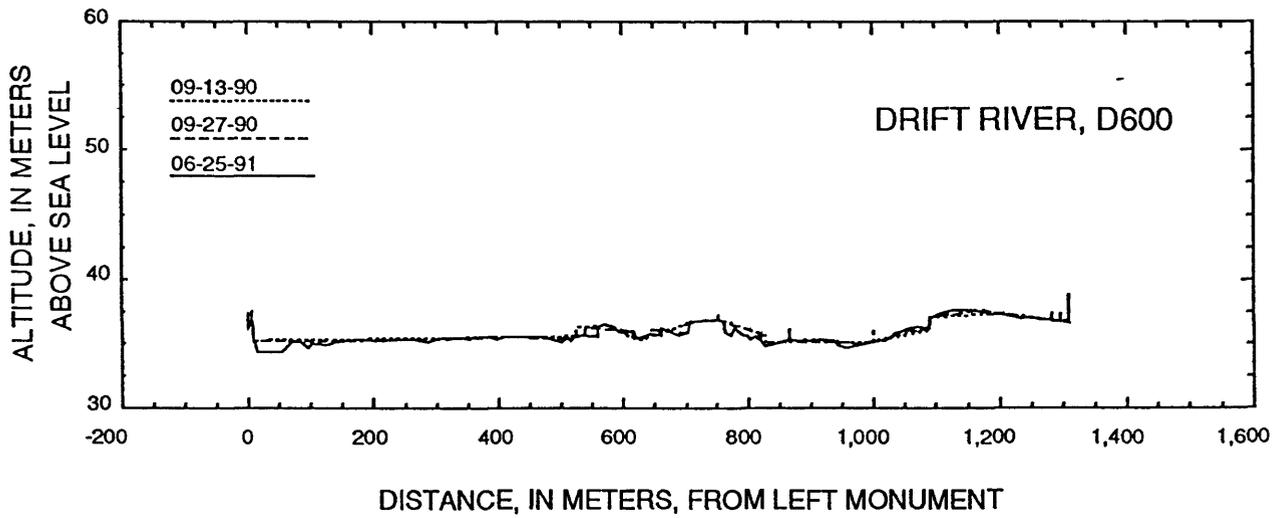
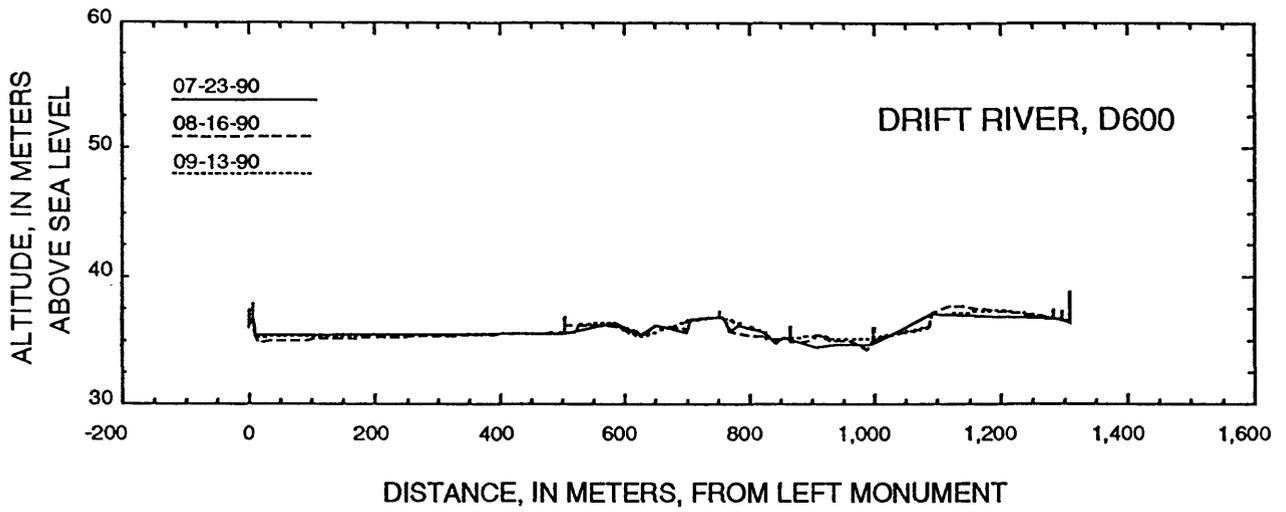


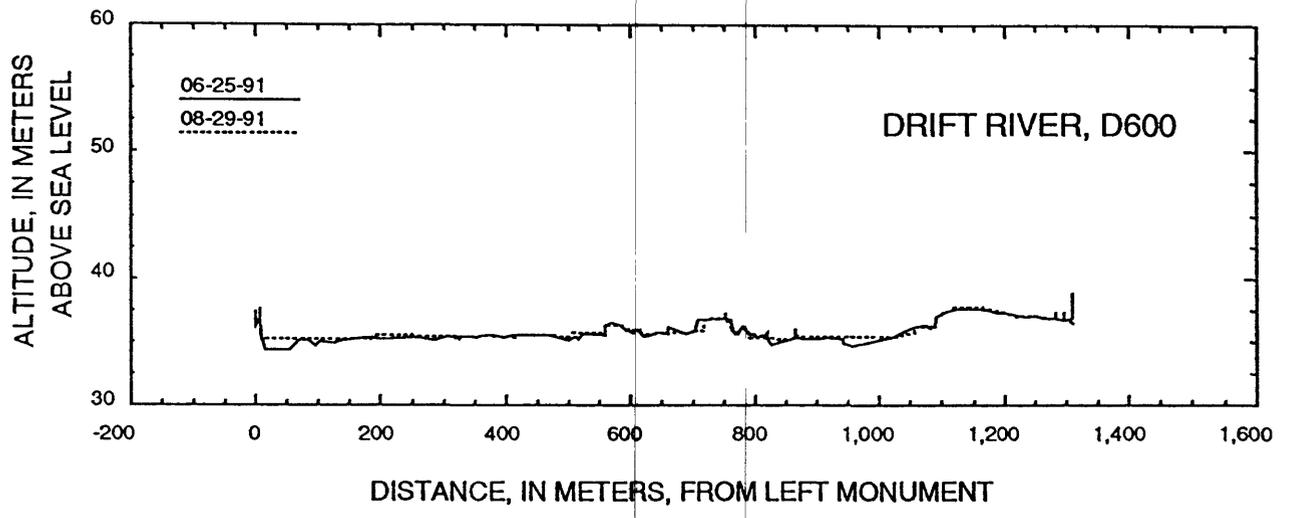
Monument	FLBM	NLBM	LCM,EDVA	NRBM	FRBM
Distance	0.00	7.00	752.69	1282.05	1309.54
Altitude	37.43	37.61	37.32	37.44	38.84
Height	1.08	0.75	0.42	0.59	2.27

REMARKS. D600 was one of the initial three cross sections surveyed to provide data on the geomorphic response of the Drift River valley to the 1989-90 eruptions of Redoubt Volcano. The cross section was first surveyed on February 6, 1990 and monumented with additional datum control on April 18, 1990. The data for this cross section provide information about changes near the end of the steep-sided Drift River valley, the beginning of the Drift River alluvial fan, and the bifurcation of Drift River and Montana Bill Creek.





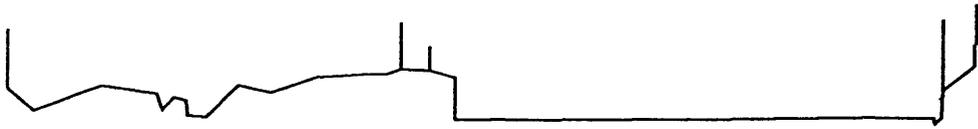




Cross Section D700

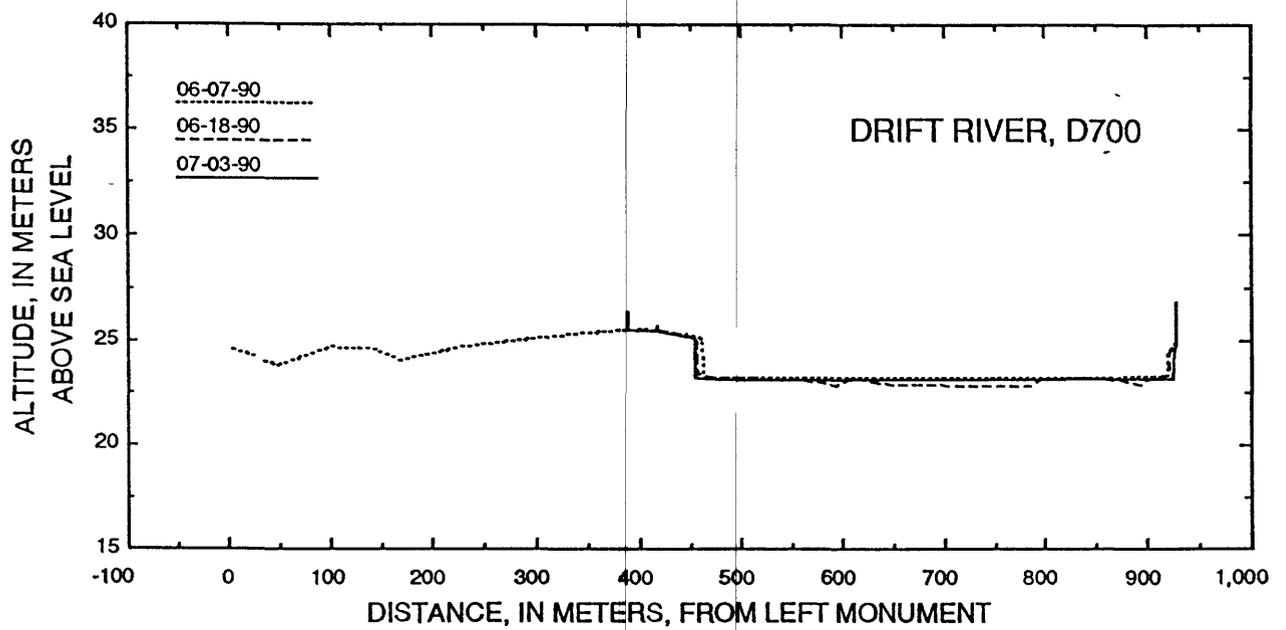
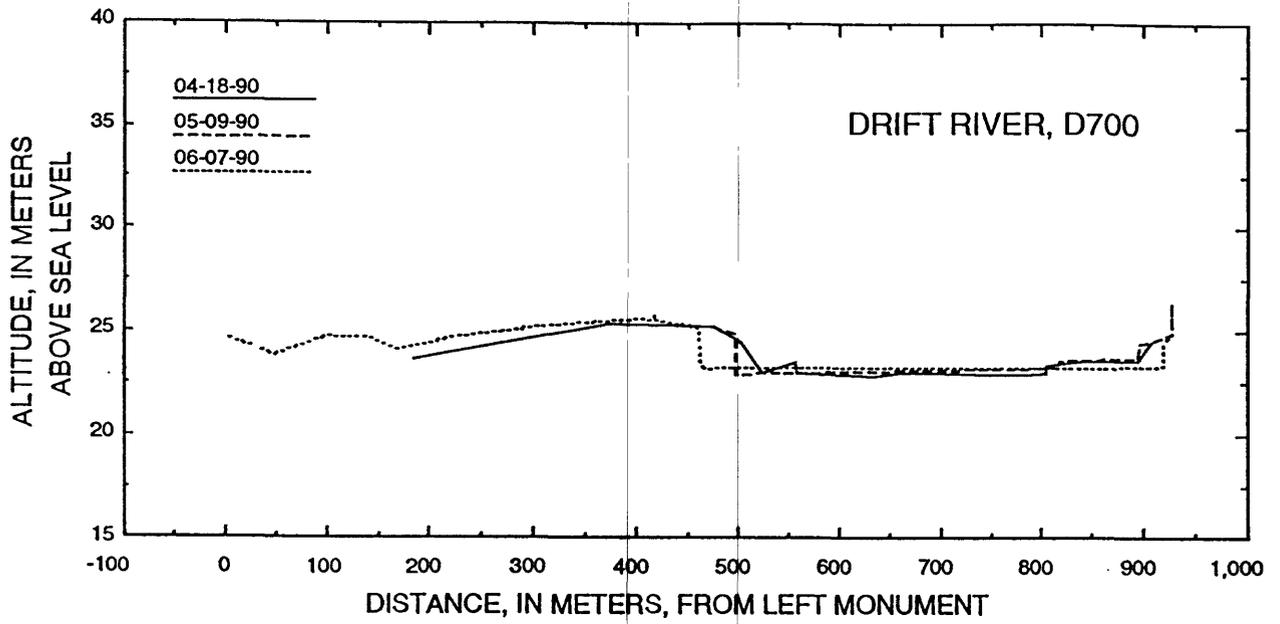
LOCATION. The reference monument, LBM, is at lat 60°37'58.4039"N. and long 152°16'00.5861"W. on the left bank of the main Drift River channel near the middle of this 958-m-wide cross section. The monument is a 0.87-m-high steel fence post. This cross section is at the bifurcation of Rust Slough and Drift River and about 6 km upstream from the northernmost oil tank of the Drift River Oil Terminal. It has an azimuth of about 0°.

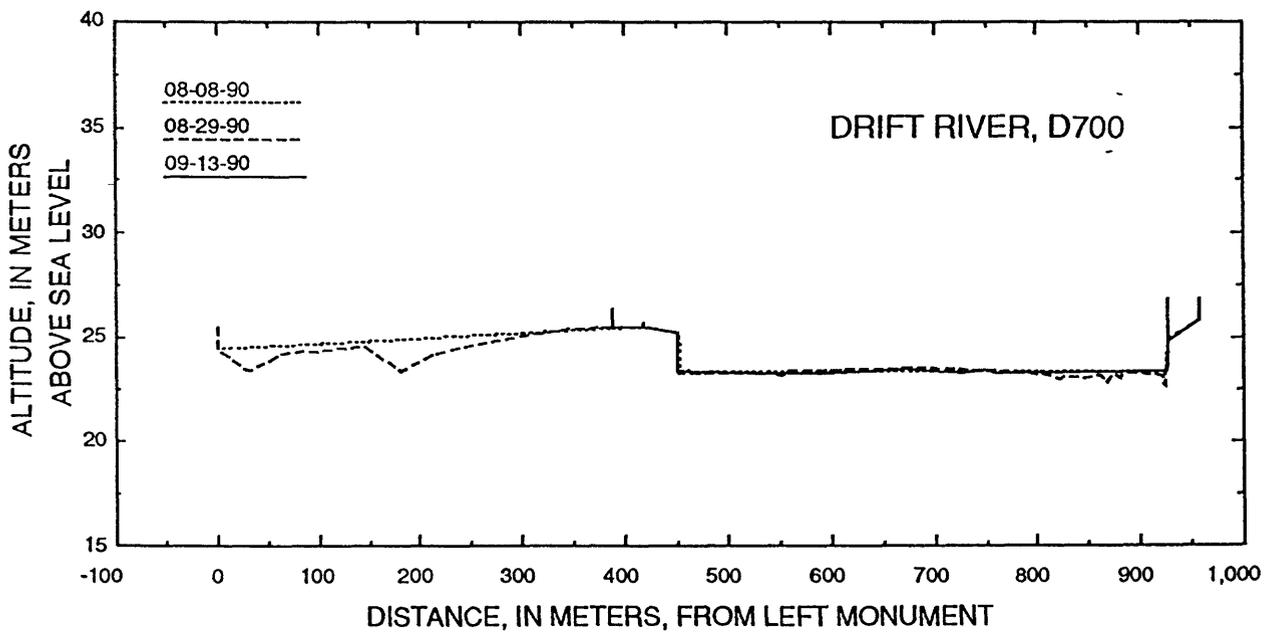
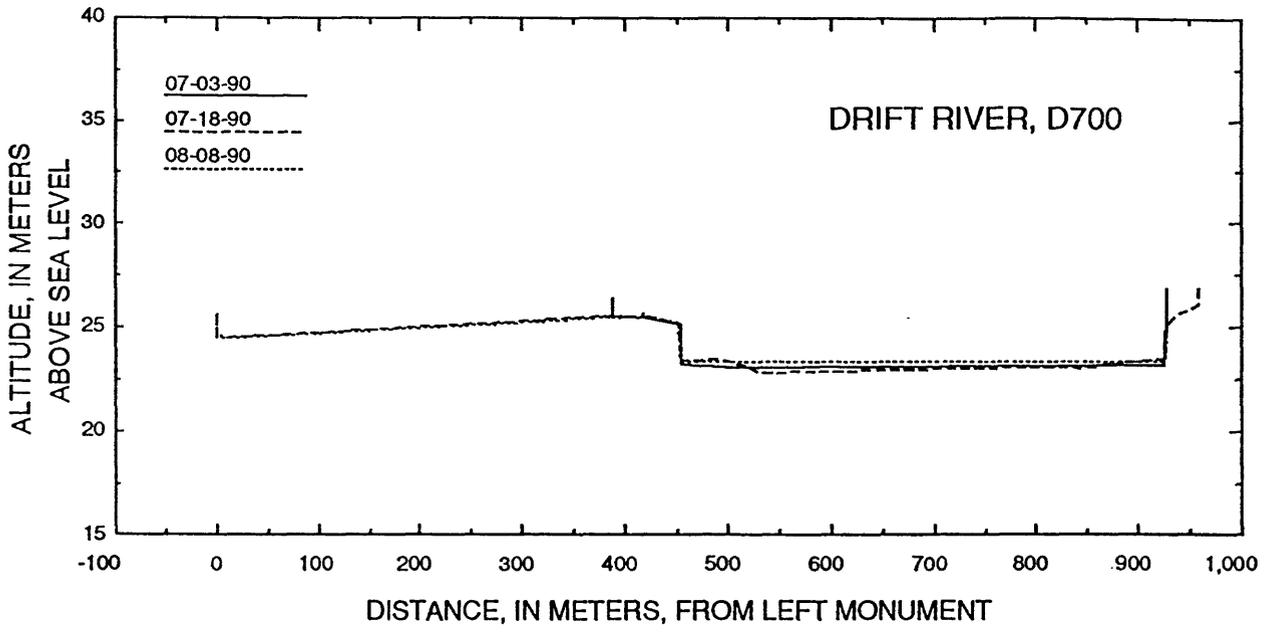
MONUMENTS.

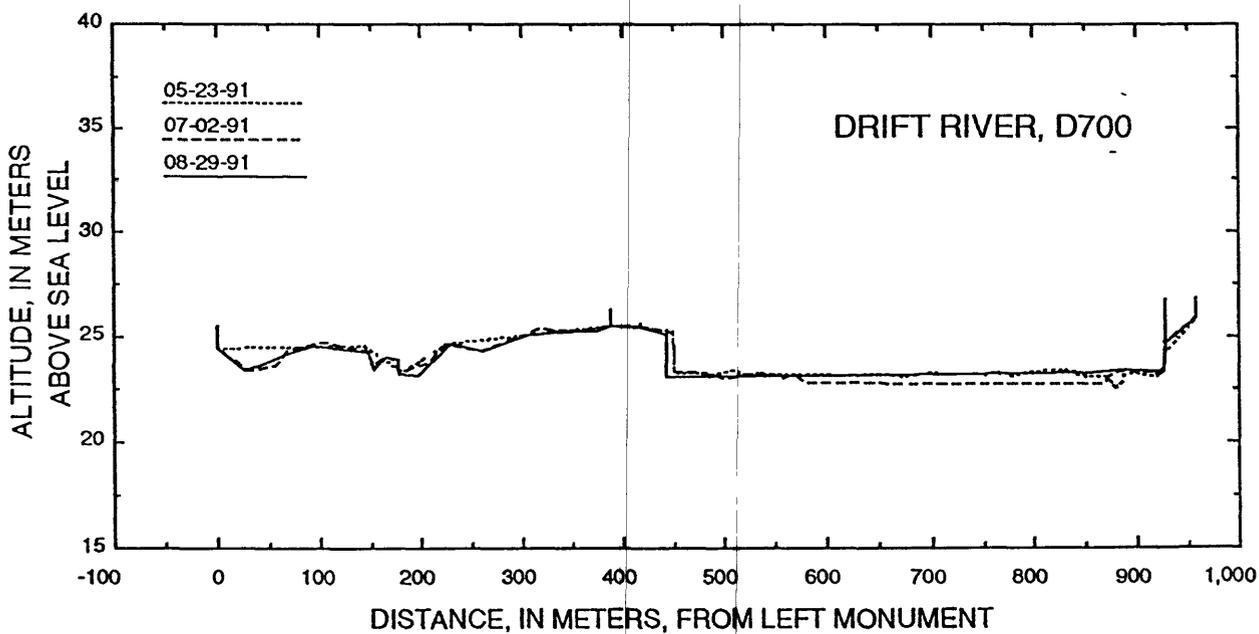
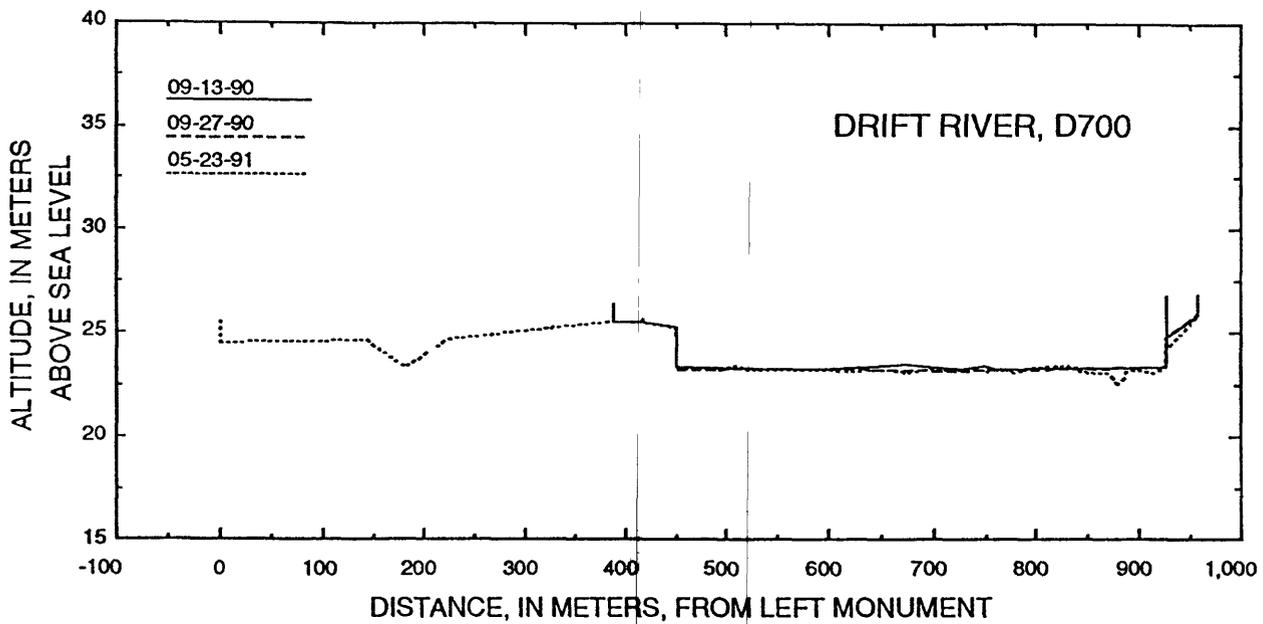


Monument	FLBM	LBM,EDVA	TP16	NRBM	FRBM
Distance	0.00	388.38	416.91	927.52	957.96
Altitude	25.51	26.37	25.75	26.80	26.84
Height	1.02	0.87	0.25	2.15	0.99

REMARKS. Data obtained at D700 show the geomorphic response at the head of the Drift River fan and at the bifurcation of Drift River and Rust Slough. The right side of the cross section covers a few of the distributaries that flow into Rust Slough. Drift River is on the left.



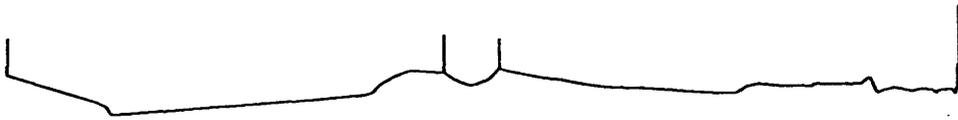




Cross Section D740

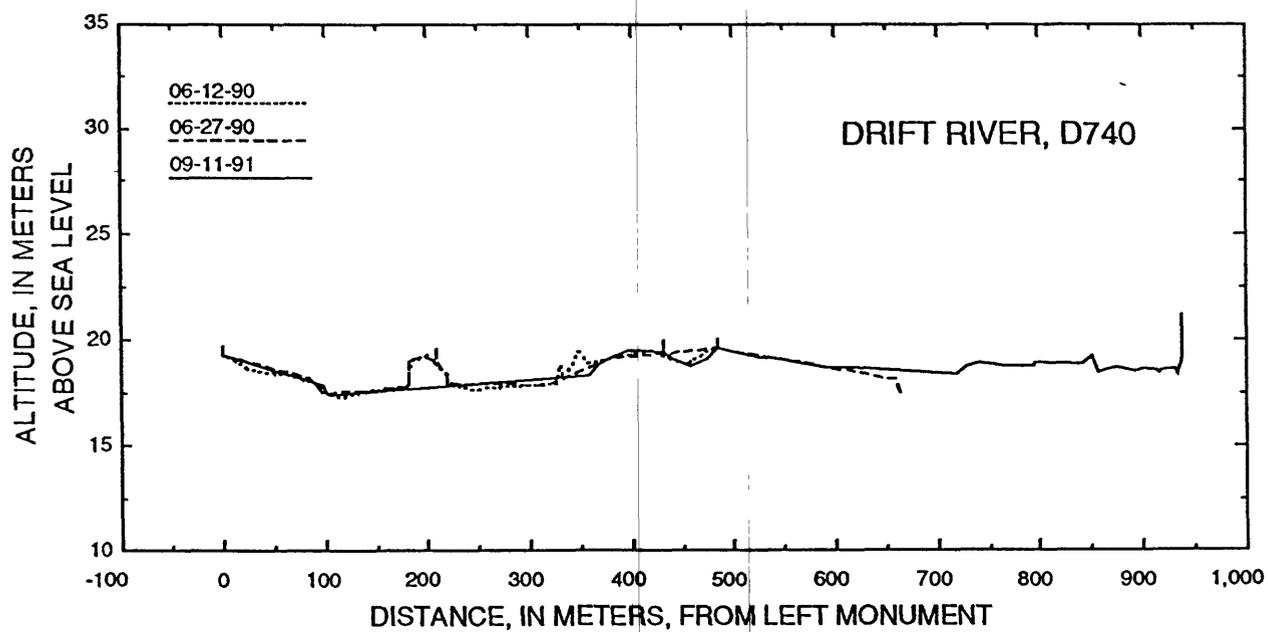
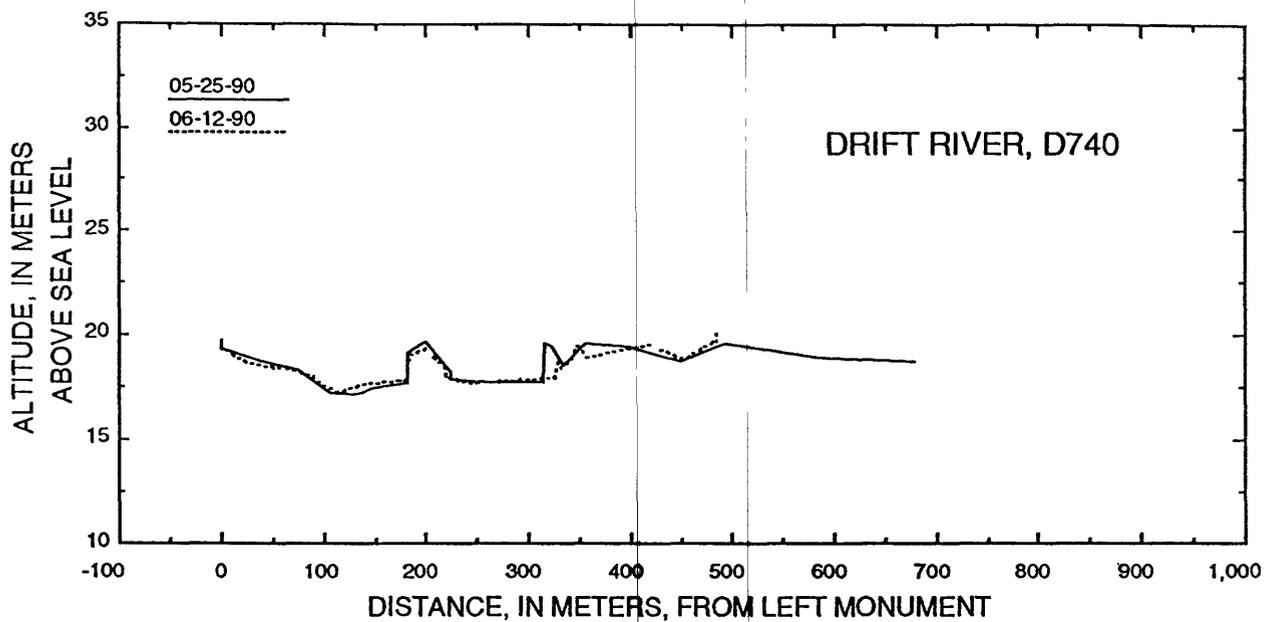
LOCATION. The reference monument, TP-3, was located vertically with EDM surveying and was not located horizontally. This 938-m cross section of Drift River is downstream from the bifurcation of Rust Slough and Drift River. It is about 4.5 km upstream from the northernmost oil tank of the Drift River Oil Terminal and 2.1-km downstream from the LBM of cross section D700. Cross section 740 has an azimuth of about 15°.

MONUMENTS.



Monument	NLBM	TP-3,EDVA	CM	NRBM	FRBM
Distance	0.00	430.96	484.96	937.90	938.05
Altitude	19.76	20.08	20.14	19.35	21.22
Height	0.45	0.63	0.44	0.16	2.00

REMARKS. Data obtained at D740 show the geomorphic response of the Drift River downstream from the bifurcation of Drift River and Rust Slough.



Cross Section D760

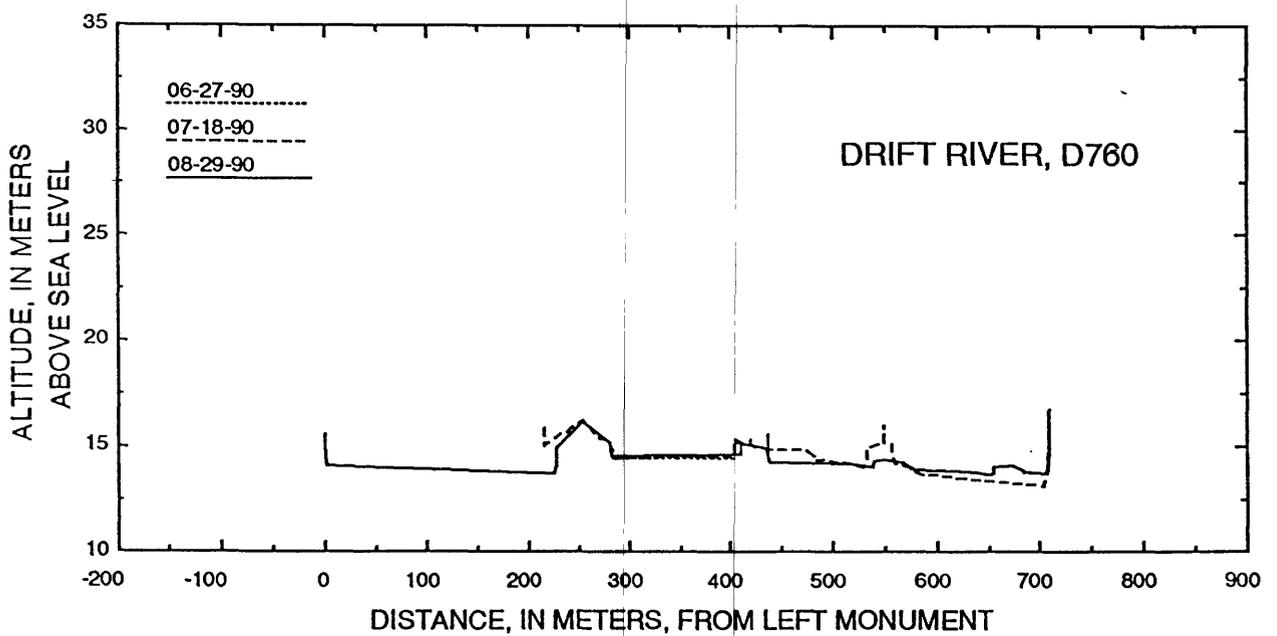
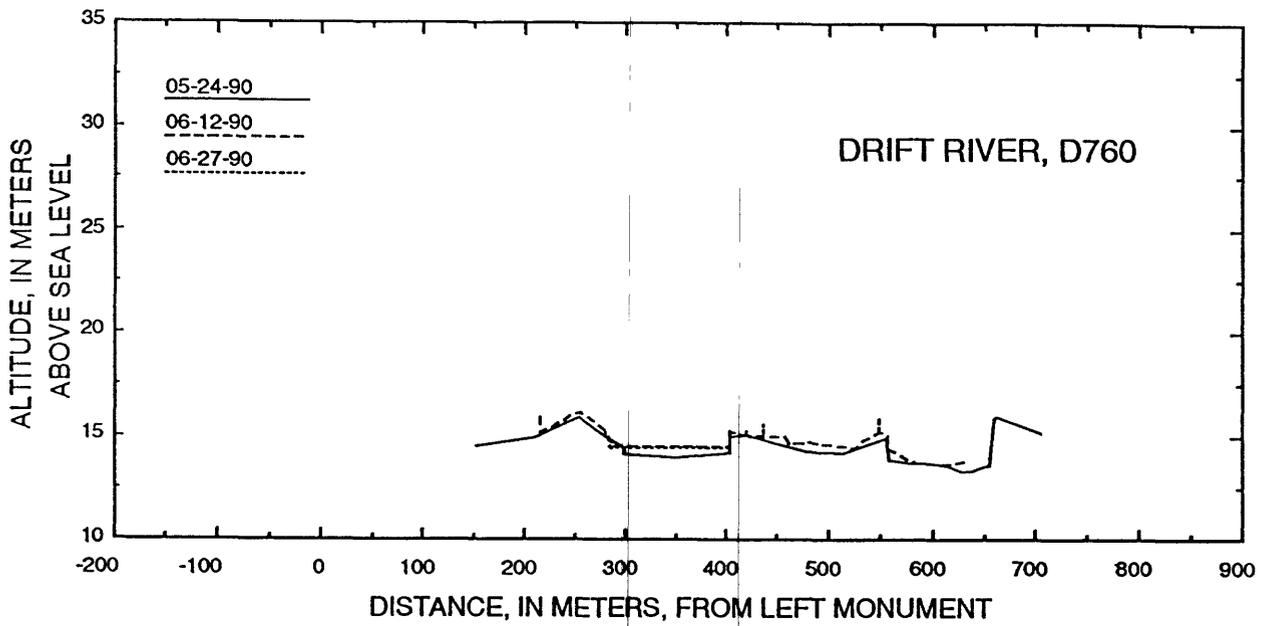
LOCATION. The reference monument, CM, is at lat 60°37'14.7840"N. and long 152°12'09.2755"W. near the middle of this 709-m-wide cross section. The monument is a 1.06-m-high steel fence post. This cross section is about 2.6 km upstream from the northernmost oil tank of the Drift River Oil Terminal and has an azimuth of about 35°.

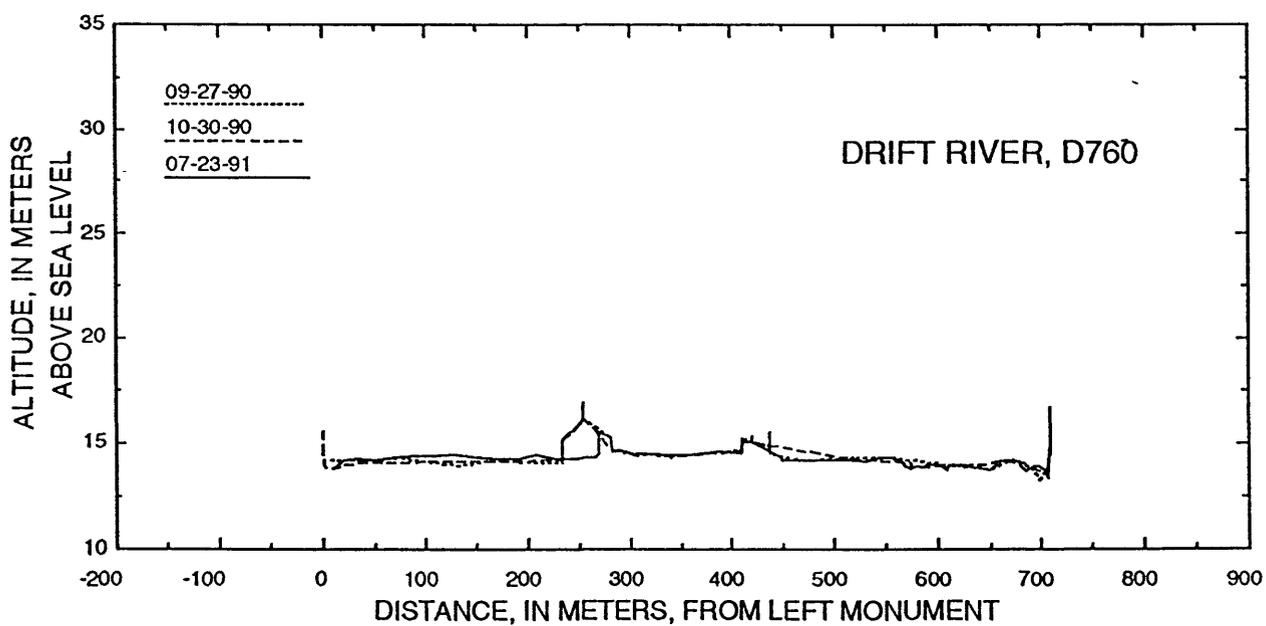
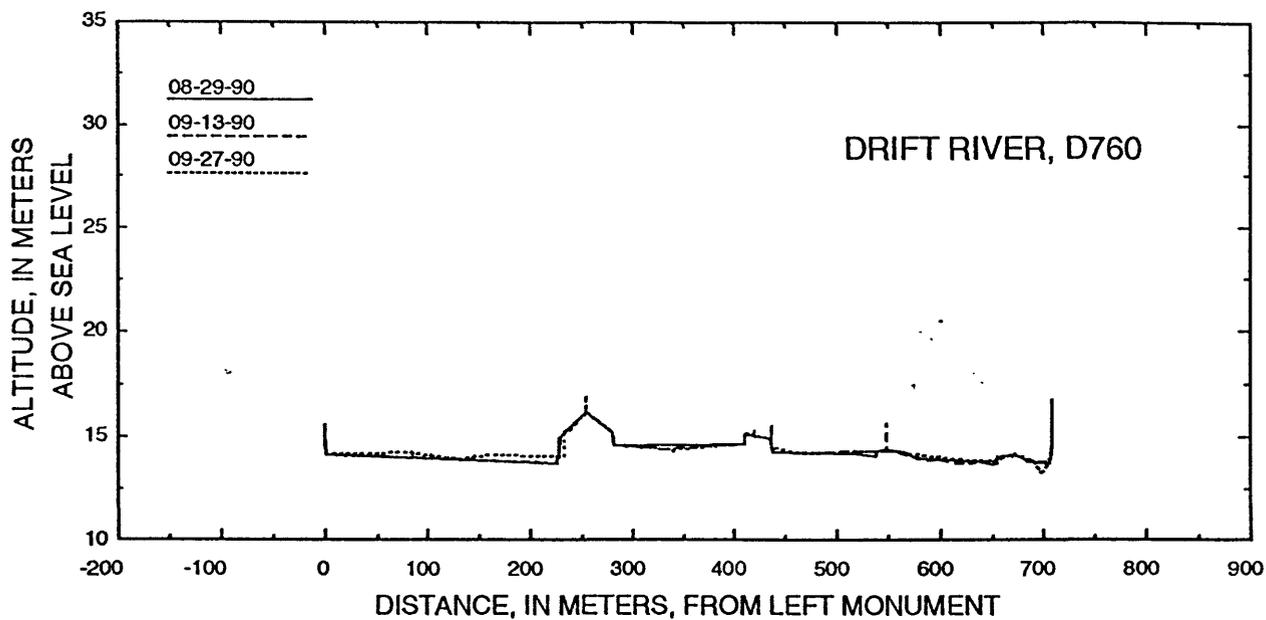
MONUMENTS.

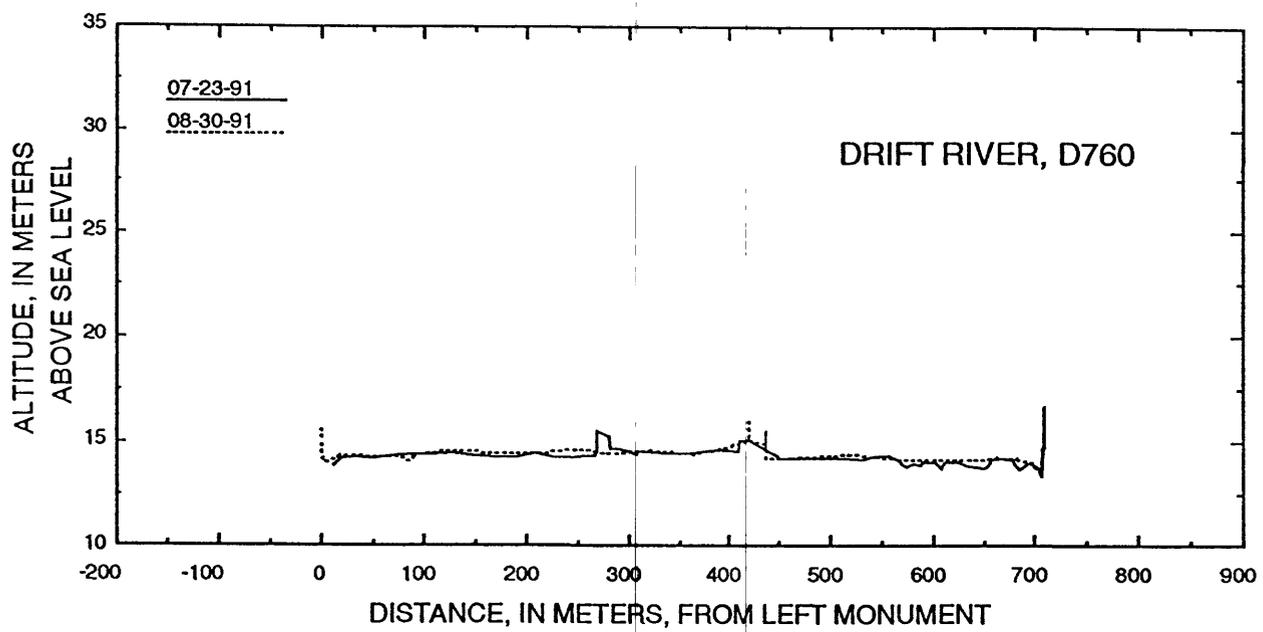


Monument	FLBM	CM,EDVA	TP6	RCM	RBM
Distance	0.00	418.95	419.01	436.62	709.13
Altitude	15.56	16.12	15.34	15.57	16.73
Height	0.50	1.06	0.26	1.00	1.74

REMARKS. D760 was established to evaluate the geomorphic response of Drift River in the lower reach.







Cross Section D800

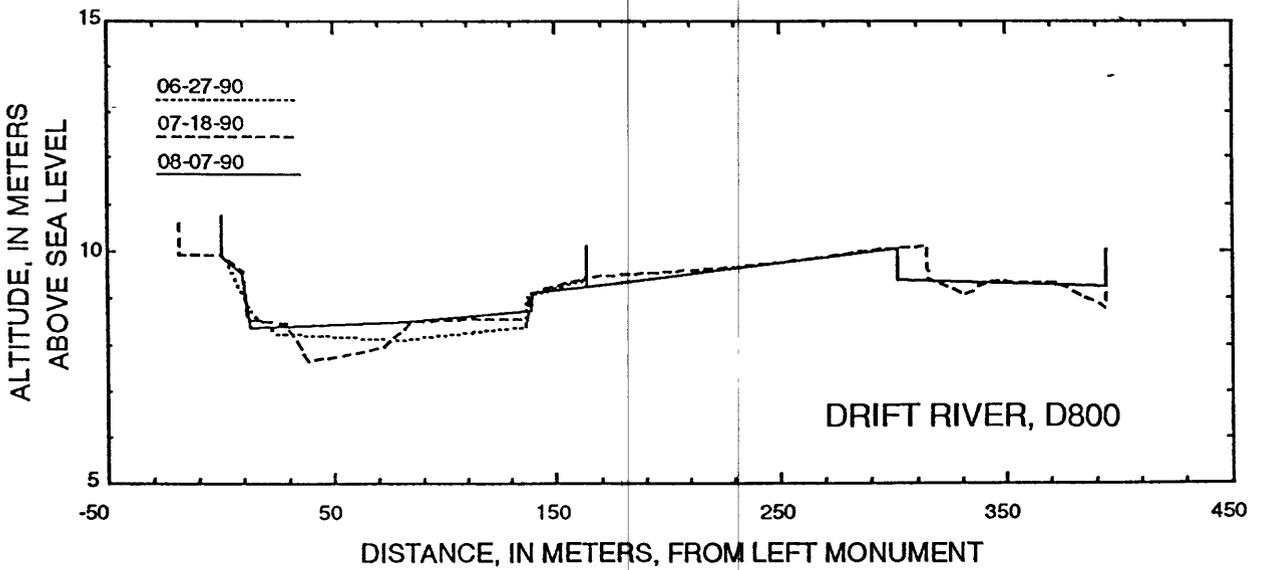
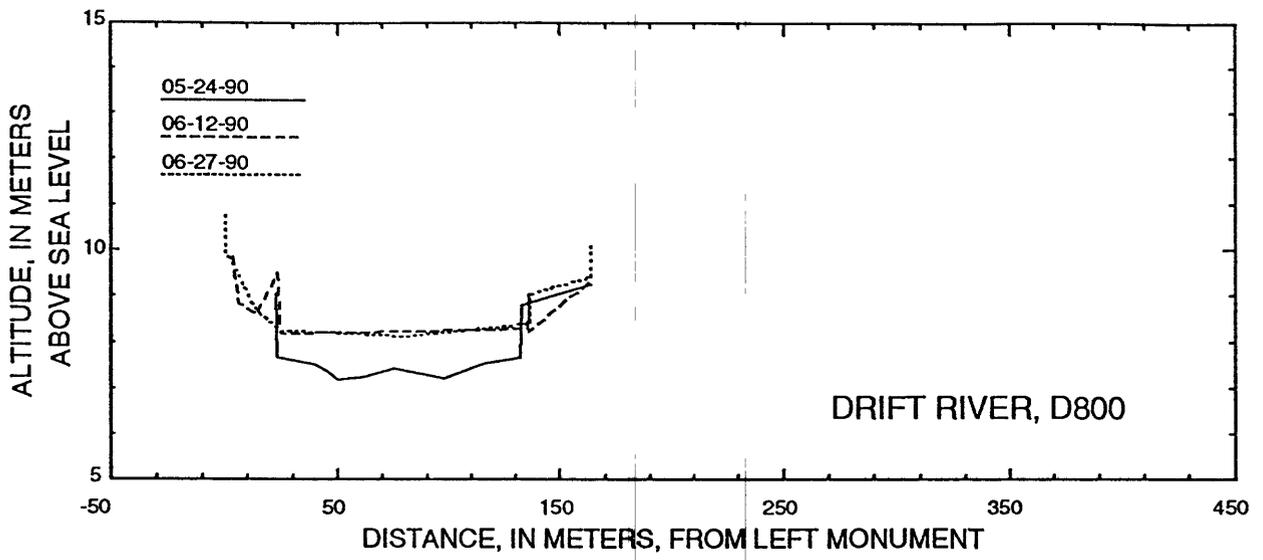
LOCATION. The reference monument, NLBM, is at lat 60°37'14.7840"N. and long 152°12'09.2755"W. at the left edge of this 394-m-wide cross section. The monument is a 0.84-m-high steel fence post. The cross section has an azimuth of about 45°.

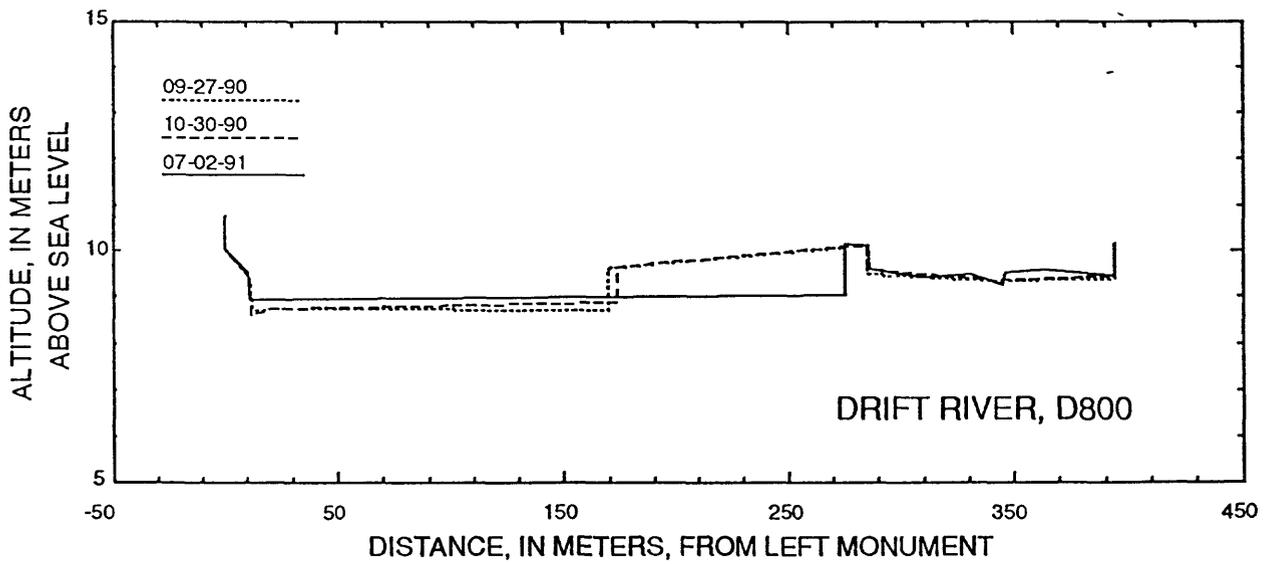
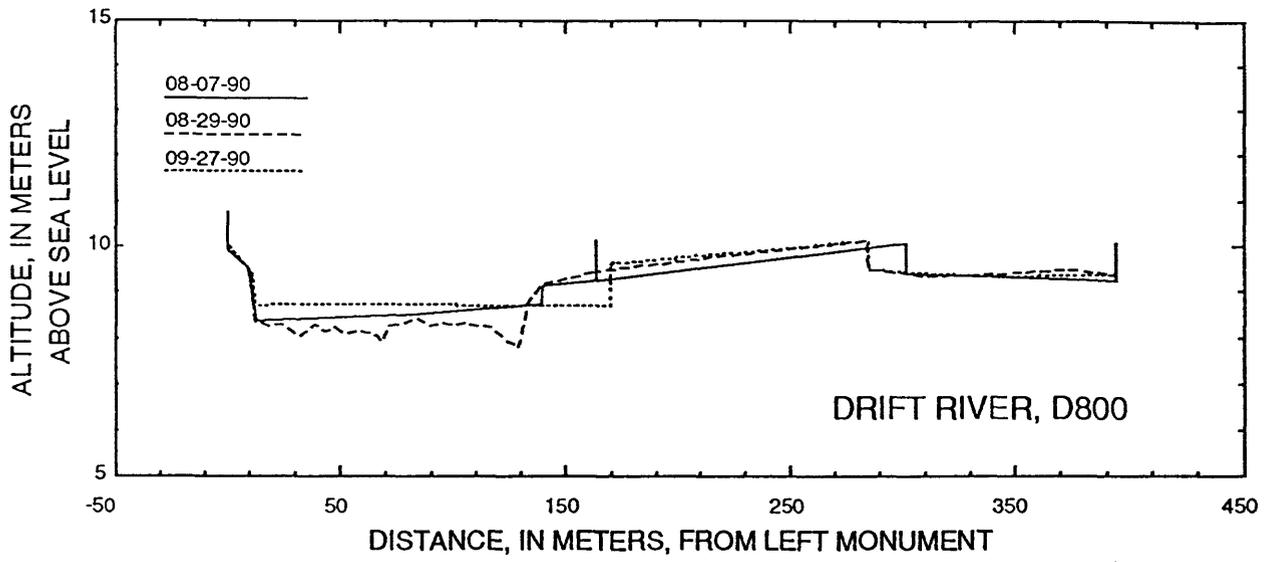
MONUMENTS.



Monument	NLBM, EDVA	FRBM
Distance	0.00	394.16
Altitude	10.76	10.03
Height	0.84	0.51

REMARKS. Data obtained at D800 provide geomorphic response information where the oil pipeline crosses Drift River, about 3.5 km upstream from the mouth of Drift River.





Cross Section D900

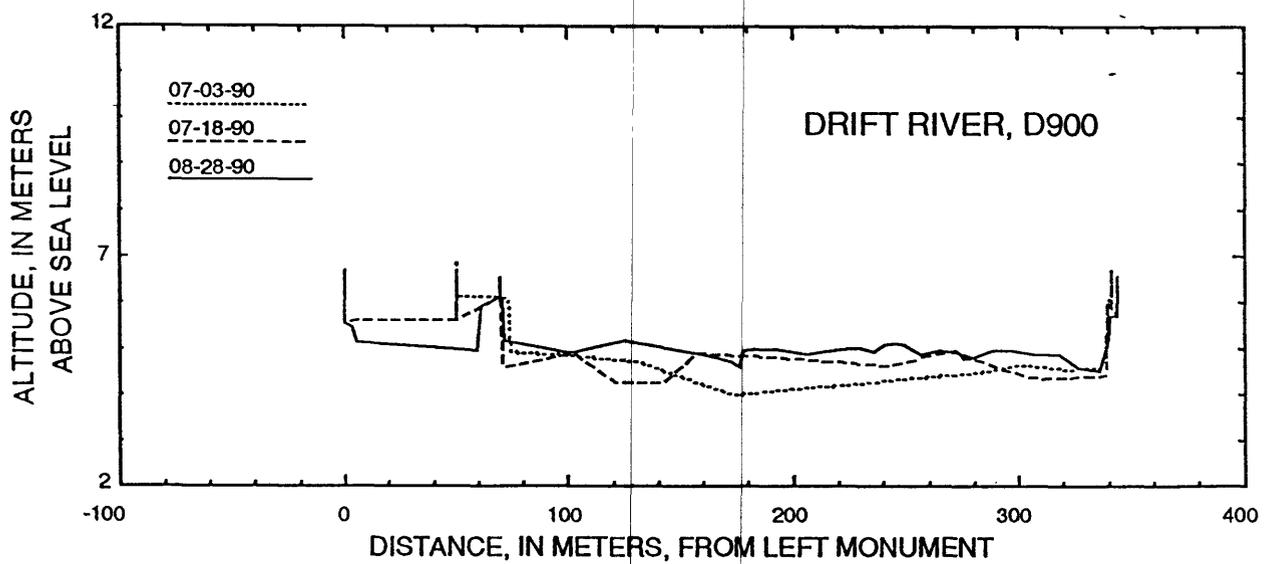
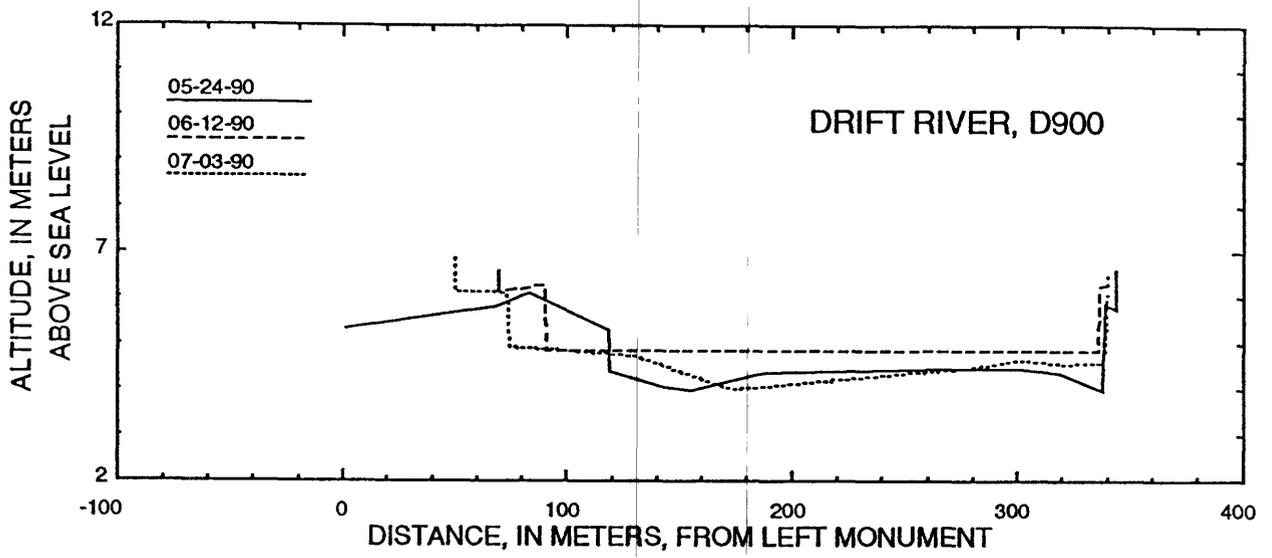
LOCATION. The reference monument, NLBM, is at lat 60°35'47.4575"N. and long 152°08'31.0501"W. on an island near the left edge of this 343-m-wide cross section. The monument is a 0.46-m-high steel fence post. D900 is in line with an extension of the oil terminal runway located across the Drift River and has an azimuth of about 21°.

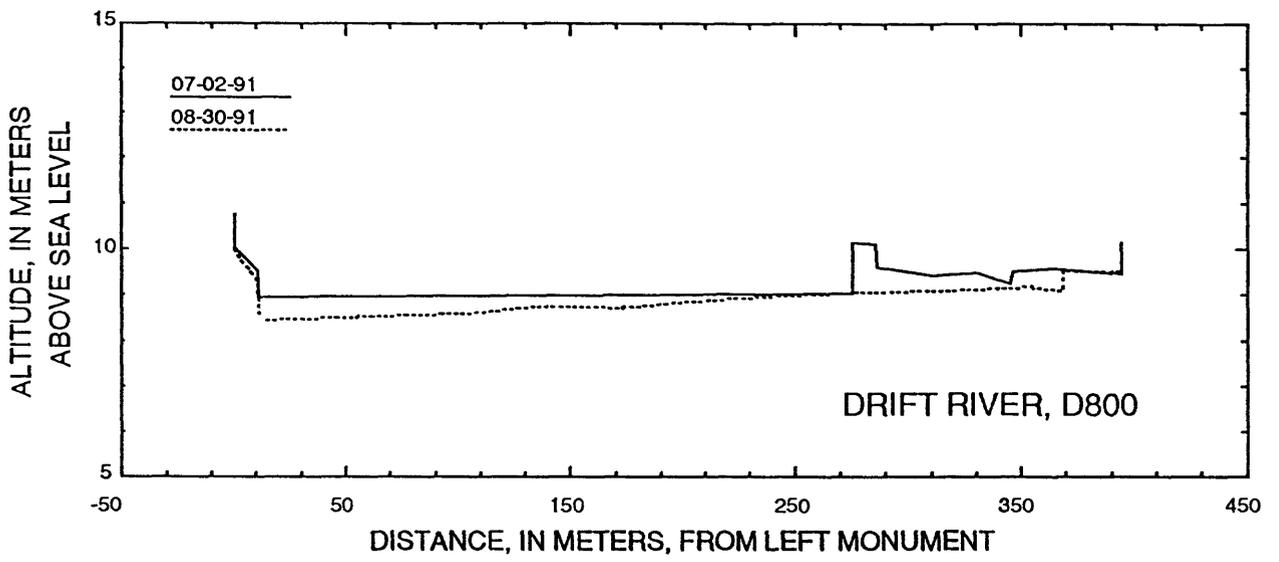
MONUMENTS.

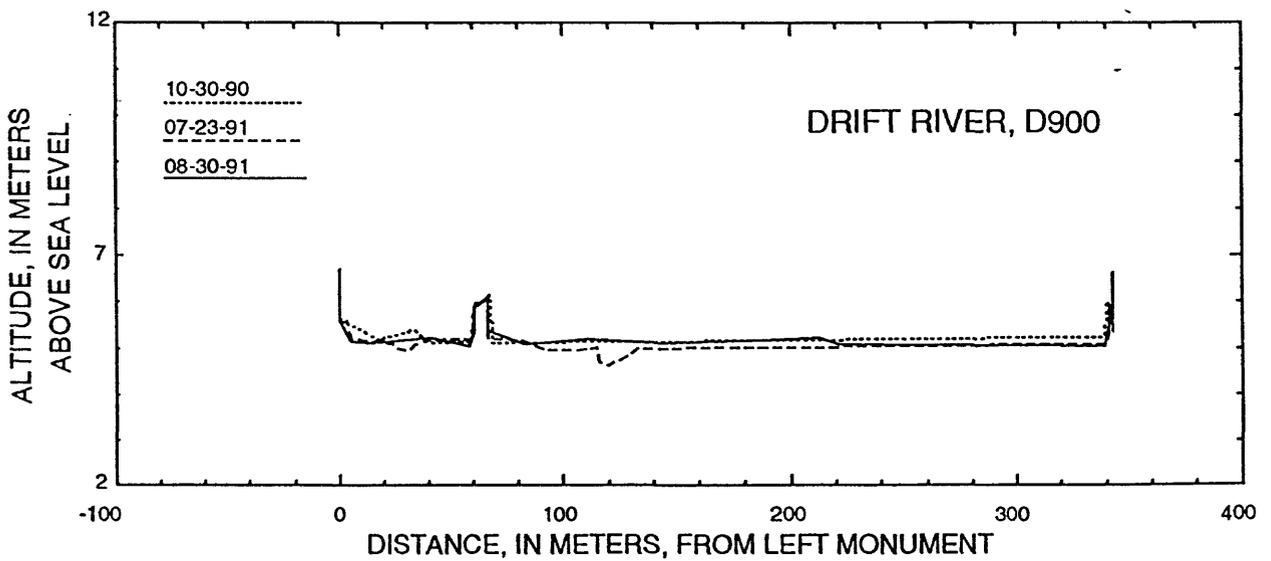
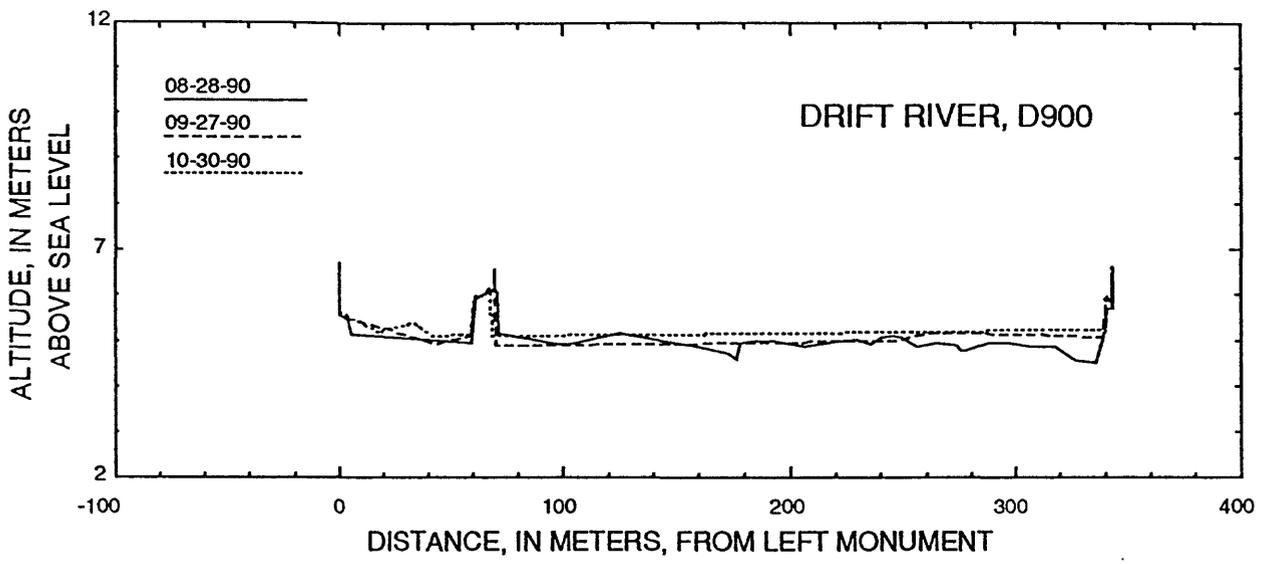


Monument	FFLBM	NLBM,EDVA	FRBM
Distance	0.00	69.80	343.37
Altitude	6.70	6.58	6.61
Height	1.11	0.46	1.00

REMARKS. Data obtained at D900 provide geomorphic response information in the lower Drift River. It is the first cross section above Cook Inlet, approximately 1.5 km above the mouth of Drift River.







Cross Section DM800

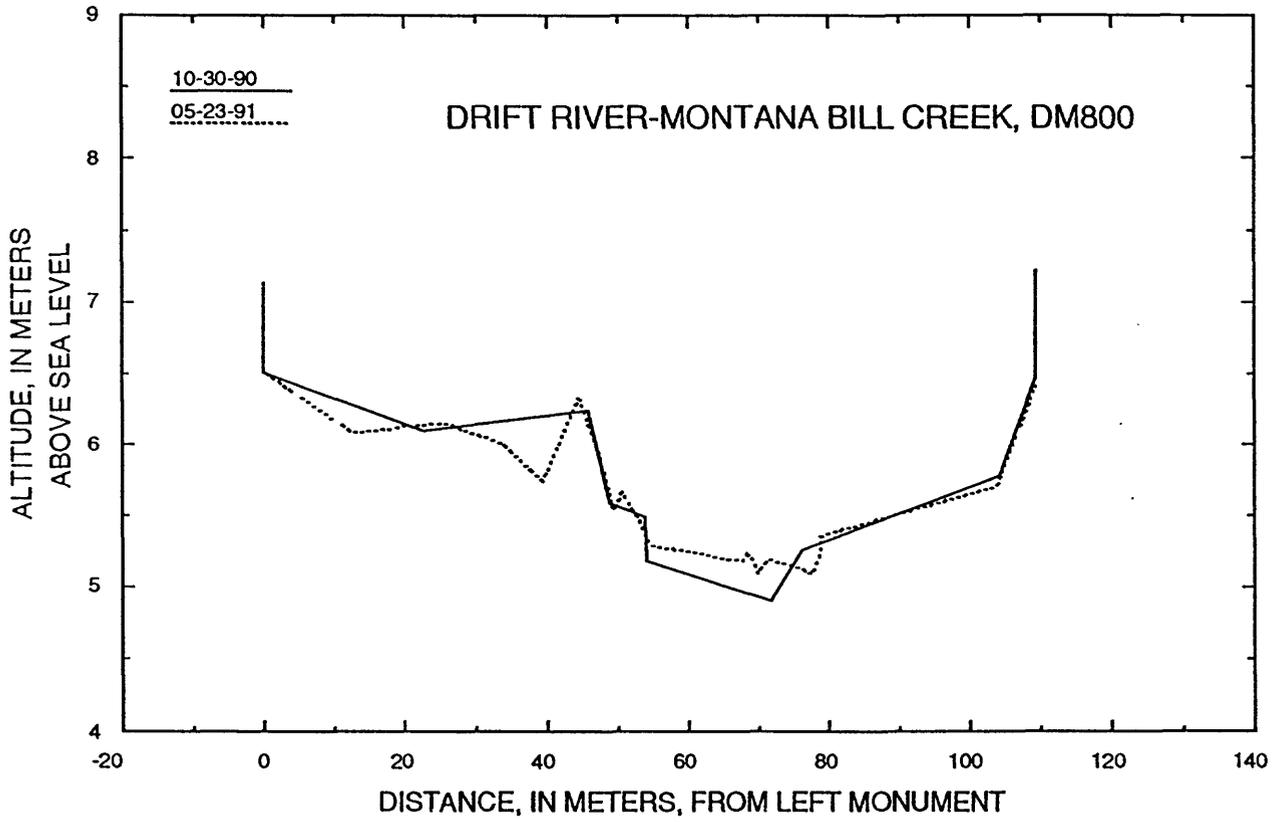
LOCATION. The reference monument altitudes for this cross section have been estimated from adjacent surveys D800 and M800. This cross section is located along the pipeline right-of-way between Drift River and Montana Bill Creek about 2 km north of D800. The stream channel that was surveyed was carrying Drift River water at the time.

MONUMENTS.



Monument	LBM	RBM
Distance	0.00	109.51
Altitude	7.14	7.26
Height	0.62	0.84

REMARKS. Data obtained at DM800 provide information on a side channel that could have become the main Drift River channel but has since gone dry. This cross section was only surveyed twice but is included in case the channel is reoccupied at a later date.

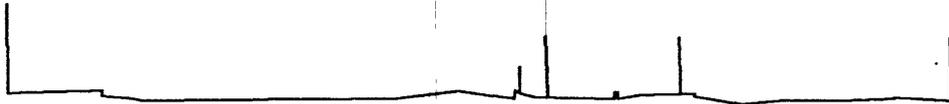


CHANNEL GEOMETRY OF RUST SLOUGH

Cross Section R740

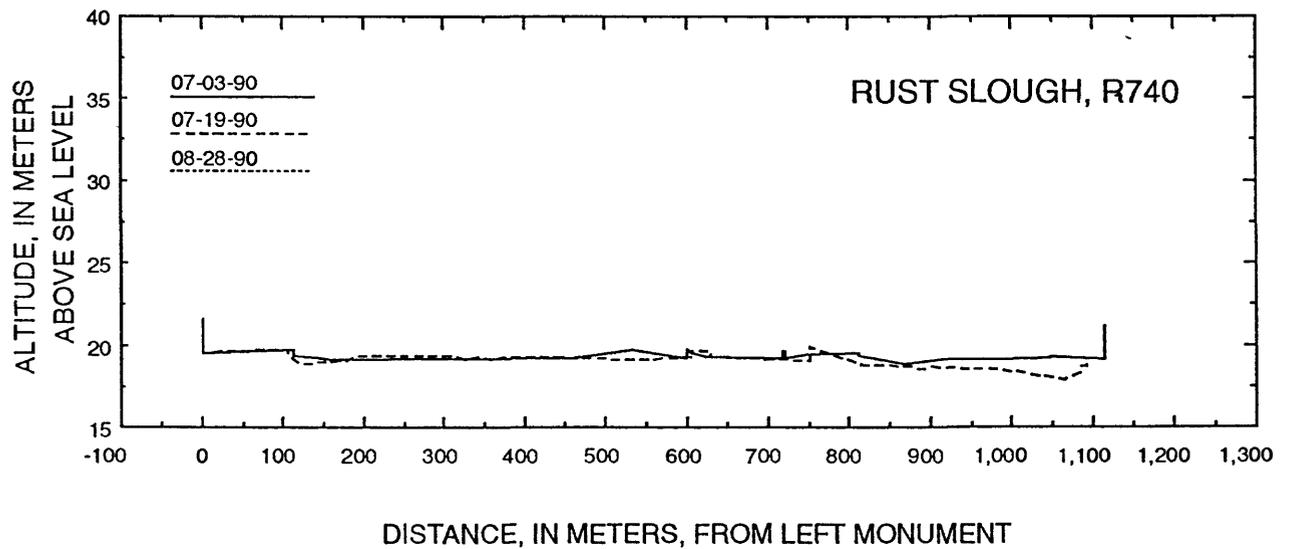
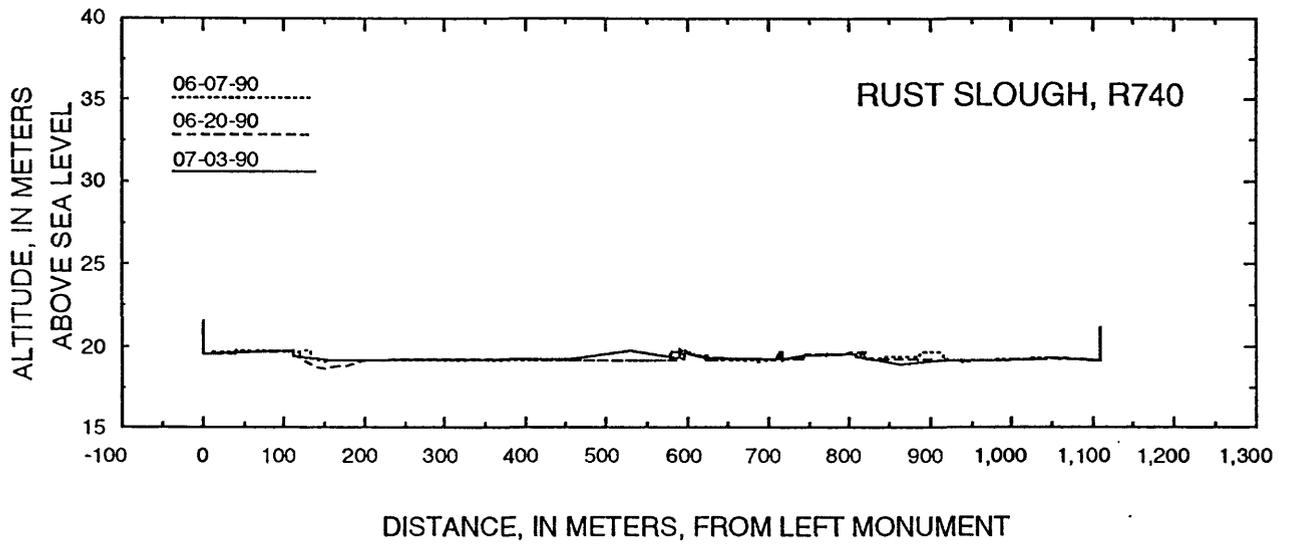
LOCATION. The reference monument, EDVA, is located at lat 60°37'11.6968"N., long 152°14'34.8241"W. near the center of this 1,087-m-wide cross section. The monument is a 0.79-m-high steel fence post. This cross section is approximately 7.0 km upstream from the mouth and 3.0 km downstream from the bifurcation of Rust Slough and Drift River. R740 has an azimuth of about 30°.

MONUMENTS.



Monument	FLBM	TP17	EDVA	CM	FRBM
Distance	0.00	602.95	611.87	621.72	1087.48
Altitude	21.59	19.81	20.45	20.39	19.22
Height	2.07	0.18	0.79	0.79	0.46

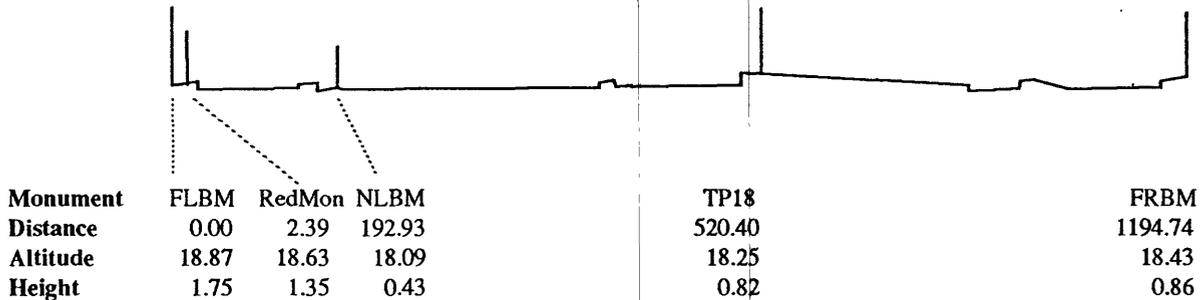
REMARKS. This cross section was established to monitor geomorphic response in Rust Slough near the Drift River bifurcation. Streamflow in this area is usually in many braided shallow channels.



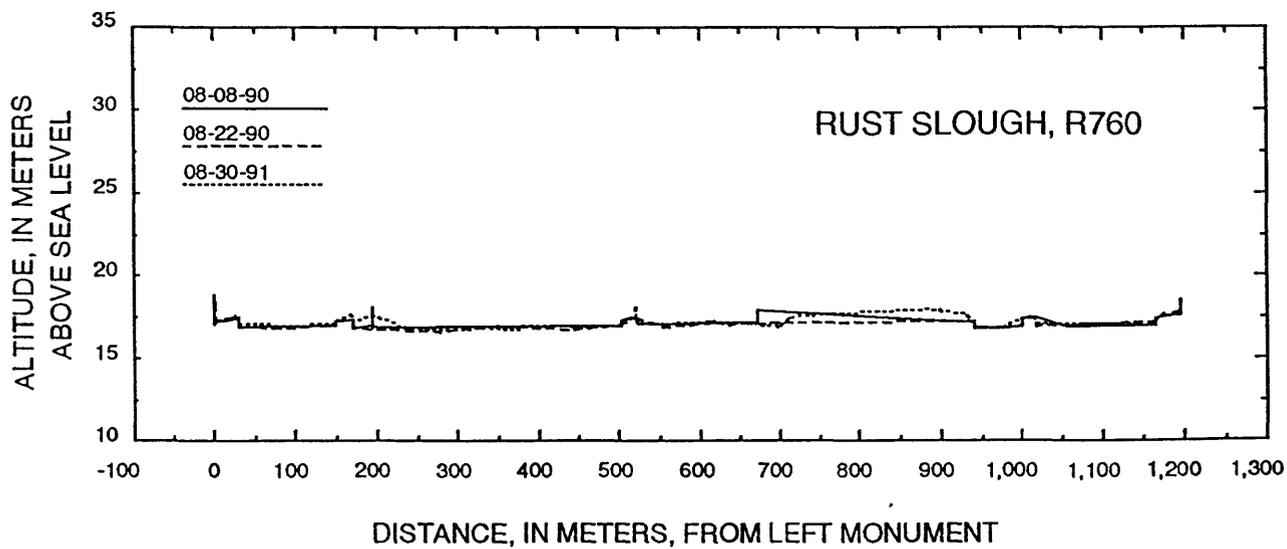
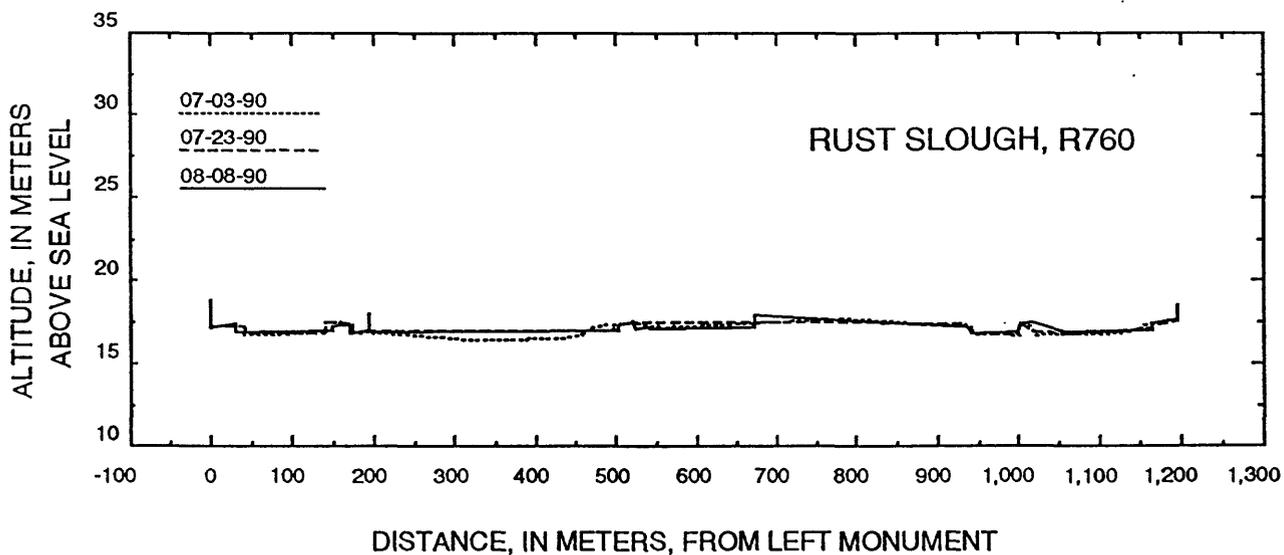
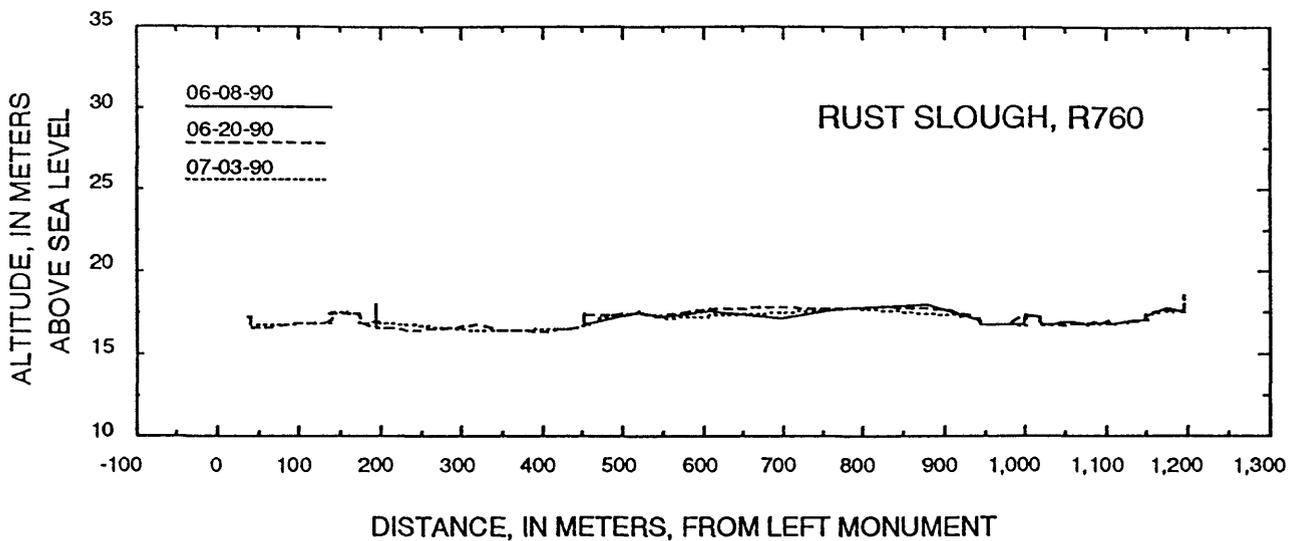
Cross Section R760

LOCATION. The reference monument, TP18, is located at lat 60°36'48.35761"N., long 152°14'25.3885"W. near the center of this 1,195-m-wide cross-section. The reference monument is a 0.82-m-high steel fence post. This cross section is approximately 6.5 km upstream from the mouth of Rust Slough and 3.5 km downstream from the bifurcation of Rust Slough and Drift River. This cross section bends 32° in the middle (fig. 3) at monument TP18 to remain perpendicular to the flow pattern observed during the first survey. The north leg, between FLBM and TP18, has an azimuth of 34 °, and the south leg, between TP18 and FRBM, has an azimuth of 66°.

MONUMENTS.



REMARKS. This cross section was established to monitor stream response in the Rust Slough channel near the bifurcation of Rust Slough and Drift River. Flow in this area is usually in many braided shallow channels. The monument labeled "RedMon" refers to a red-colored monument at this site.



Cross Section R800

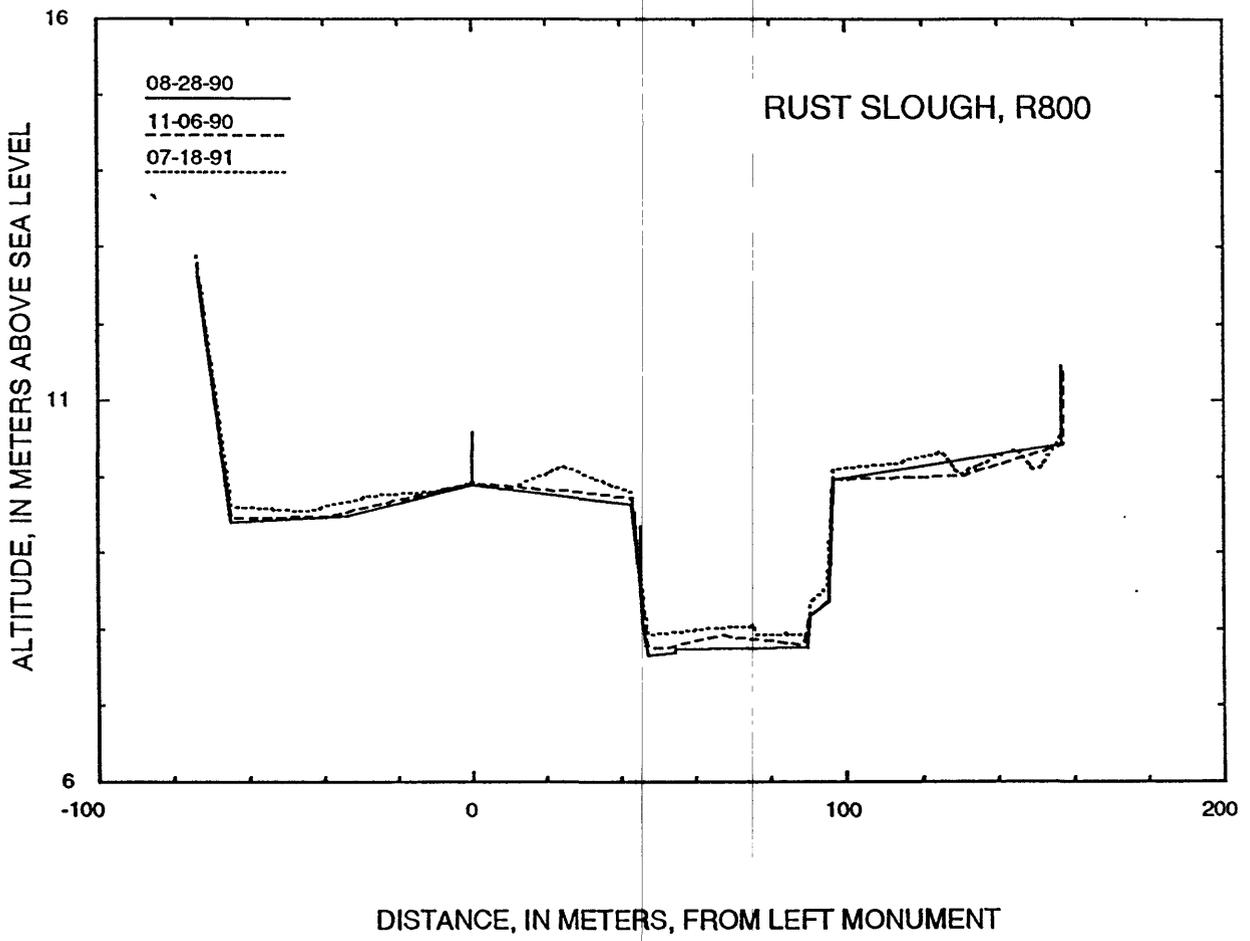
LOCATION. The reference monument, LBM, is located at lat 60°36'05.3021"N., long 152°10'55.2252"W. approximately 74 m towards the stream from the top of the concrete dike. The reference monument is a 0.75-m-high steel fence post. This cross section is approximately 2.8 km upstream from the mouth and 500 m southwest from southwesternmost tank in the oil storage area. R800 has an azimuth of 237°.

MONUMENTS.



Monument	Top Dike	LBM,EDVA	RBM
Distance	-73.91	0.00	156.99
Altitude	12.881	10.61	11.52
Height	3.27	0.75	0.96

REMARKS. R800 was established to monitor stream migration in the direction of the oil storage area. More than 15 m of lateral erosion took place at this location during 1990; however, flow in this channel has been reduced because the Drift River migrated north, distributed much of its water into Montana Bill Creek, and abandoned Rust Slough.



Cross Section R900

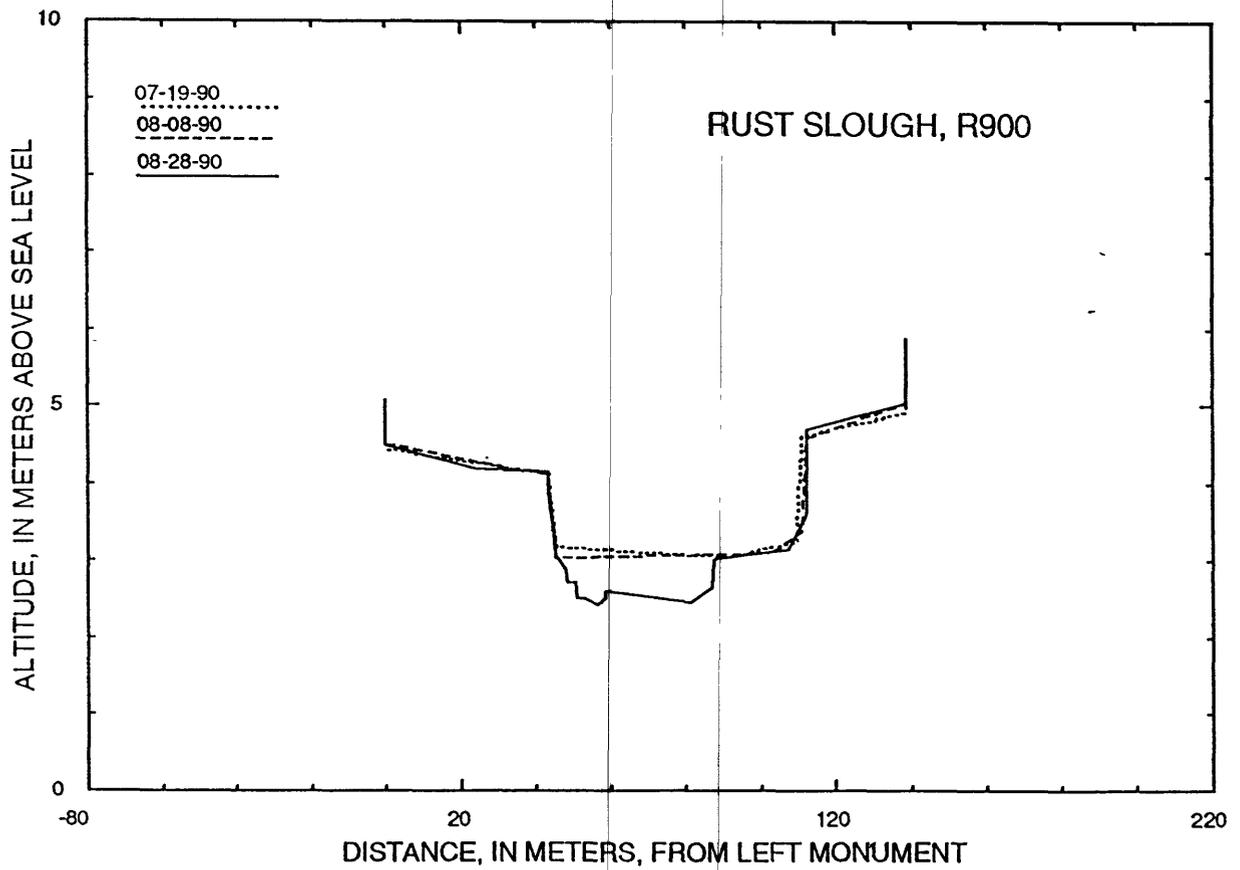
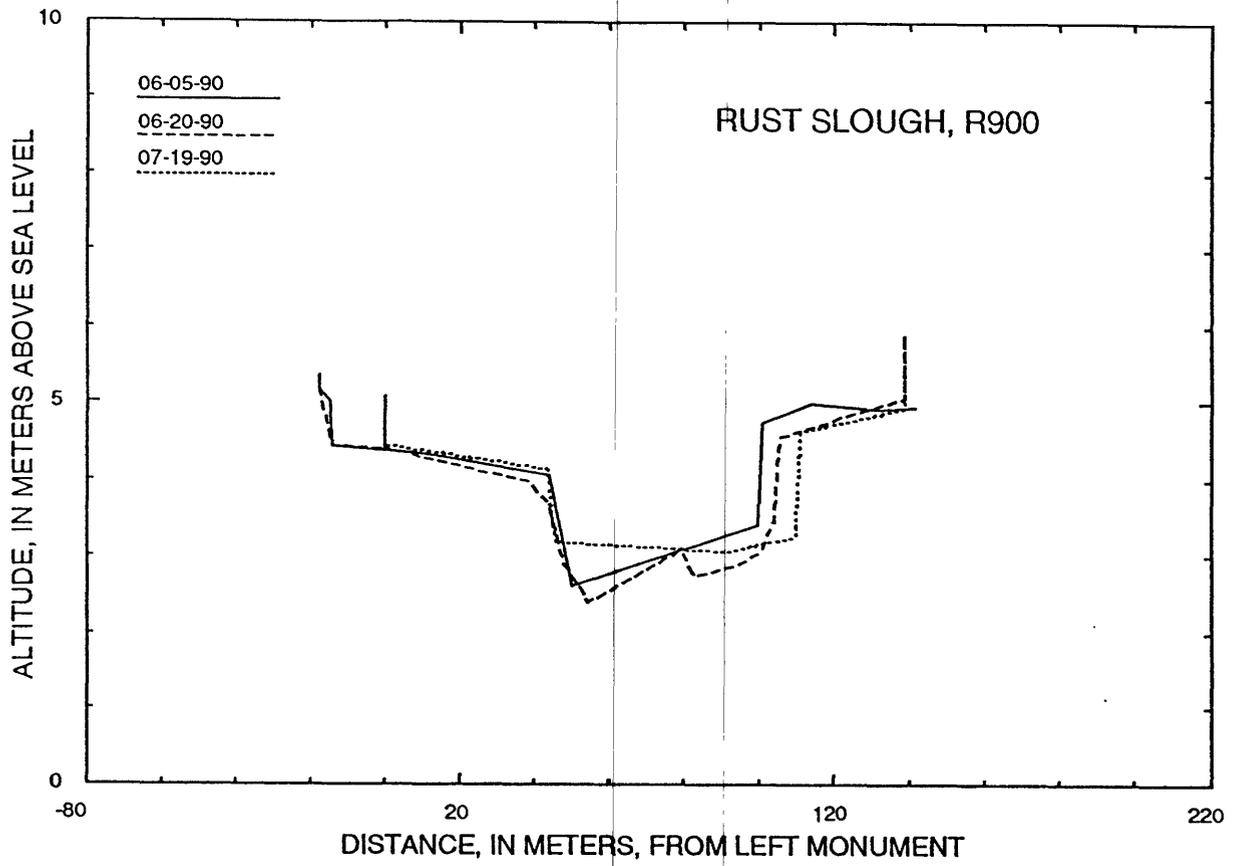
LOCATION. The reference monument, RBM, is located at lat 60°35'09.5142"N., long 152°10'25.8999"W. at the right edge of this 150-m-wide cross section. The monument is a 0.82-m-high steel fence post. This cross section is located near the southwest end of the oil terminal runway, approximately 1 km upstream from the mouth of Rust Slough.

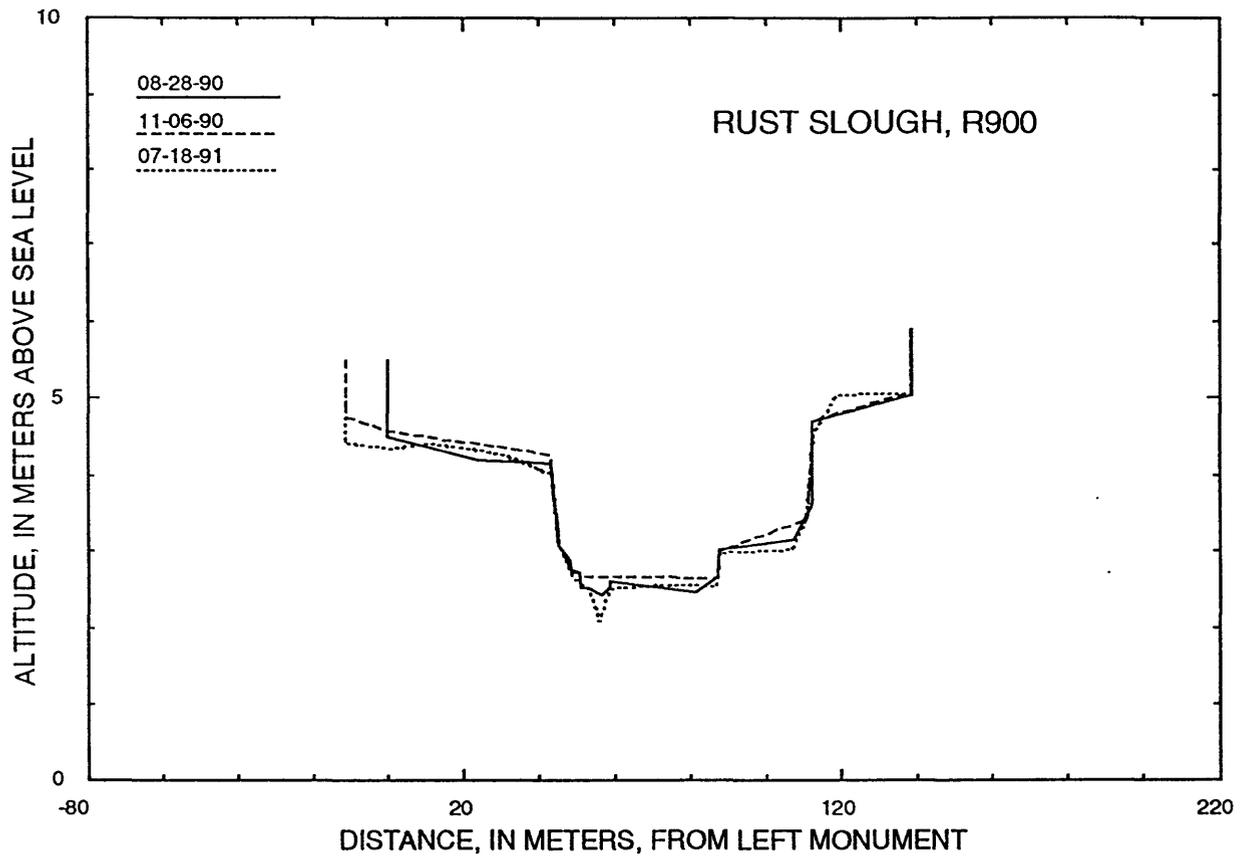
MONUMENTS.



Monument	New FLBM	RBM,EDVA
Distance	-11.36	138.62
Altitude	5.13	5.89
Height	0.71	0.82

REMARKS. Cross section R900 was established to measure the Rust Slough channel response in the lower reach. Debris flow deposits were evident near this site after both the January 2 and February 15, 1990 eruptions. Because extensive reworking and removal of these deposits by heavy equipment resulted in the loss of the left bank monument several times, a new left bank monument has been established at the second-to-last runway light from the southwest corner of the runway.



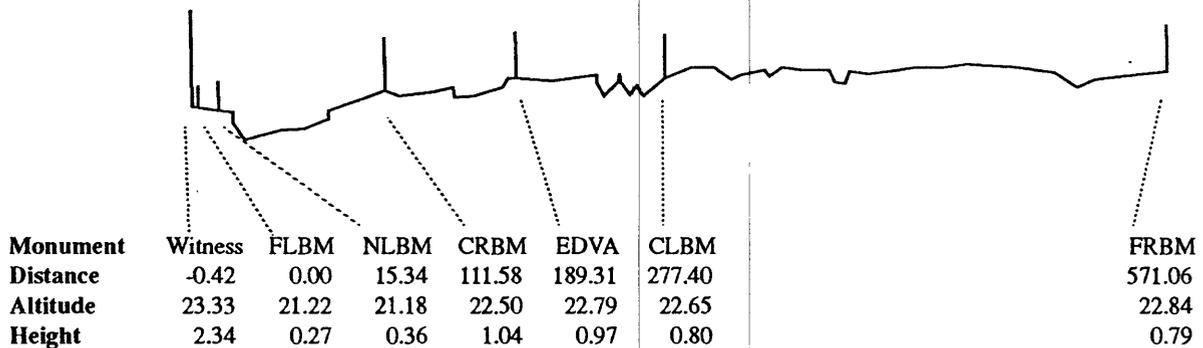


CHANNEL GEOMETRY OF MONTANA BILL CREEK

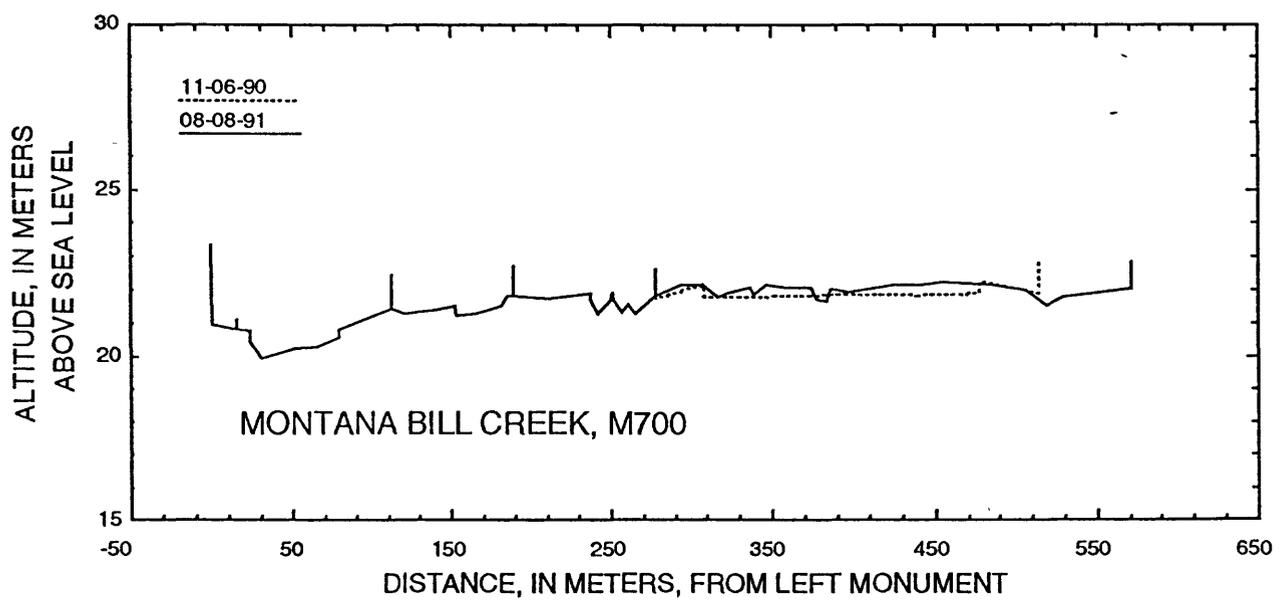
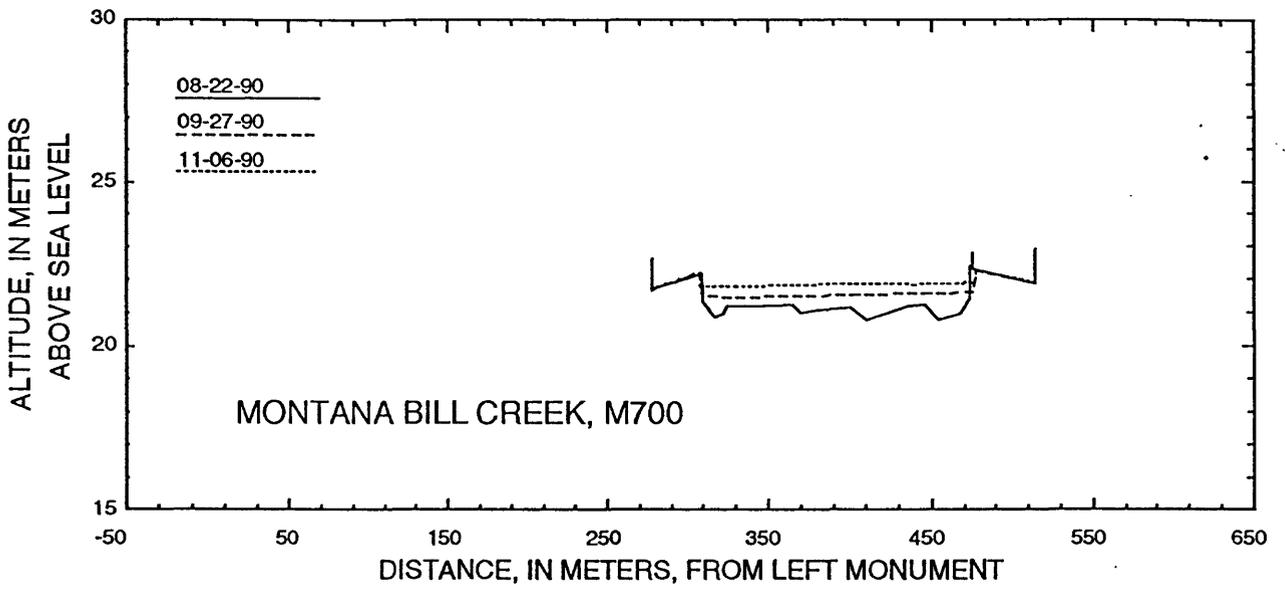
Cross Section M700

LOCATION. The reference monument, EDVA, is located at lat 60°38'50.8388"N., long 152°15'43.4146"W. near the center of this 571-m-wide cross section. The reference monument is a 0.97-m-high steel fence post. This cross section is approximately 5.7 km southwest of the benchmark at Coach Butte and 5.5 km downstream from cross-section D600. It has an azimuth of about 0°.

MONUMENTS.



REMARKS. M700 was established on line and to the north of D700 to measure the response of the new stream channel formed when the Drift River began to migrate north in August 1990. The monument labeled "Witness" represents a large spruce tree used as a secondary reference for the FLBM.



Cross Section M800

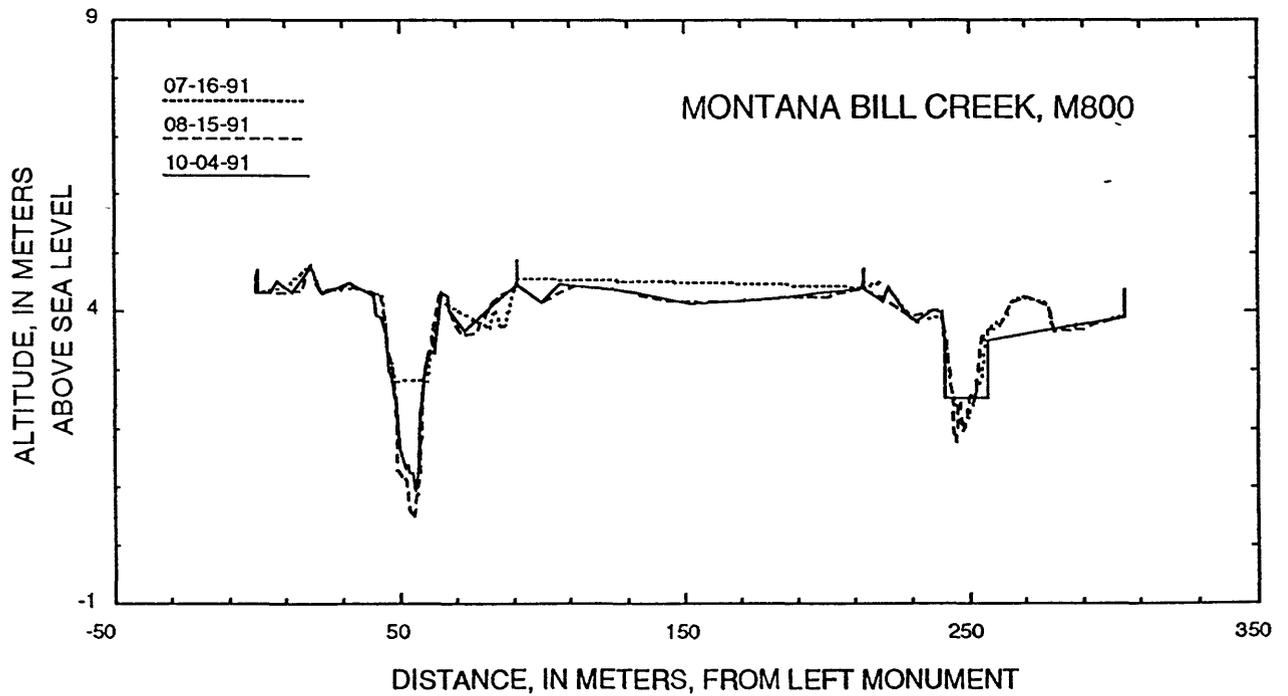
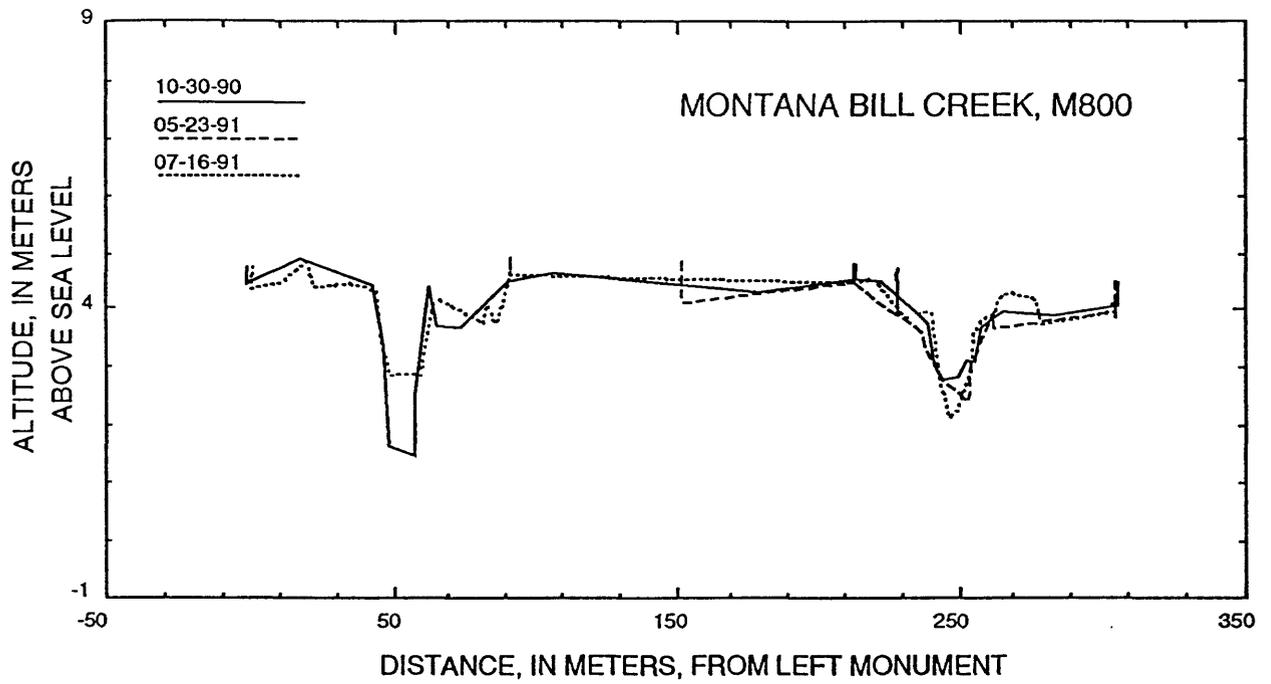
LOCATION. The reference monument, CLBM, is located at lat 60°39'21.8207"N., long 152°07'34.6142"W. near the left bank of the right channel of this 305-m-wide two-channel cross section. The monument is a 0.38-m-high 5-cm-diameter yellow steel pipe. This cross section is approximately 6 km northeast of the Drift River Oil Terminal tank farm on the pipeline right-of-way and has an azimuth of about 20°.

MONUMENTS.



Monument	FLBM	CRBM	CLBM	FRBM	Fence Post
Distance	0.00	91.56	213.05	304.53	305.43
Altitude	4.70	4.90	4.76	4.37	4.58
Height	0.39	0.33	0.38	0.47	1.73

REMARKS. M800 was established on the pipeline right-of-way to monitor streambed scour near the crossing of the 50-cm-diameter pipe that transports oil from Cook Inlet wells to the oil terminal. The channels are informally known as Montana Bill Creek on the left and Montana Bill Creek Slough on the right. Water stage, discharge, sediment, and water-quality data were collected at this site in addition to the surveyed cross-section data.

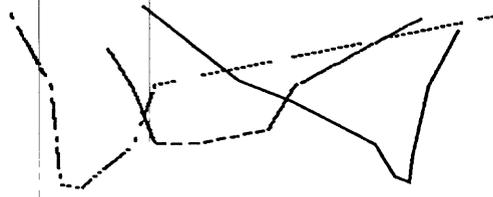


Cross Sections M795, M798, M805

LOCATION. These three cross sections are located at Montana Bill Creek Slough near M800. All use the reference monument CLBM of M800 surveyed on October 4, 1991 (see M800 above). M795 parallels the upstream edge of the cleared pipeline right-of-way, about 16 m upstream from M800. M798 is 2 m upstream from the pipeline and 4 m upstream from M800. M805 runs along the downstream edge of the cleared pipeline right-of-way and is 19 m downstream from M800.

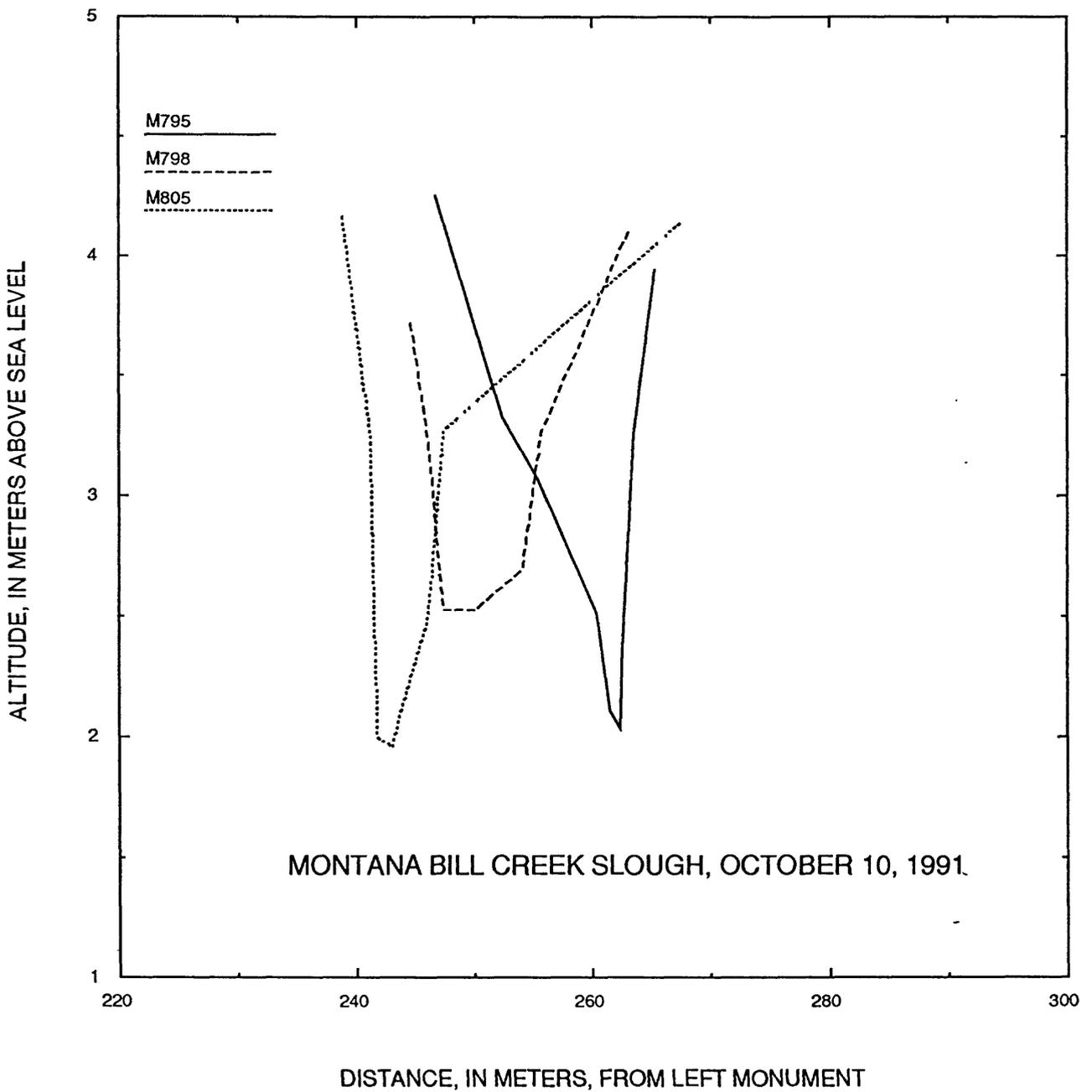
MONUMENTS.

M795
M798
M805



Location	CLBM	Left Bank	Right Bank
Distance	213.28	-242	-265
Altitude	4.76	-4.0	-4.0
Height	0.34		

REMARKS. The three cross sections were established originally to monitor streambed scour near the recently exposed pipeline. They have not yet been resurveyed but are provided here as a base line for future work.



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APPENDIX 1

DATA POINTS FOR EACH CROSS SECTION

On the following page is a sample of the data tables that are available. If you would like to obtain a computer diskette containing the complete set of data tables, please write to the address in the lower left corner on page ii of this report.

1 FILE: DRIFT.D800.900829
 RIVER: DRIFT
 CROSS SECTION: D800
 DATE: 900829
 INSTRUMENT: WILD
 INST MONUMENT: NRBM
 REFERENCE PT: FIRST SHOT
 INITIAL DIST: 0.000
 INITIAL ELEV: 10.760
 ANGLES: DMS
 DISTANCE: DE
 0 DEG: DOWN
 INPUT UNITS: METERS
 OUTPUT UNITS: METERS

WED, FEB 12 1992 09:36:54

SURVEY DATA				COMPUTED DATA				OFFLINE PLOT		COMMENTS	
DISTANCE	REL ELEV	HORZ ANG	ROD STA	INS	DIST	ELEV					
0.000	100.000	0.000	1.657	1.657	163.883	9.458	0.00	X	INSTRUMENT STATION, GROUND		
0.000	100.000	0.000	0.957	1.657	163.883	10.158	0.00	X	INSTRUMENT STATION, MONUMENT		
0.000	100.000	0.000	1.657	1.657	163.883	9.458	0.00	X	INSTRUMENT STATION, GROUND		
163.883	101.645	180.000	2.000	1.657	0.000	10.760	0.00		TOP NLBM, EDVA PT.		
163.893	100.817	180.000	2.000	1.657	-0.010	9.932	0.00		BOT NLBM		
153.244	100.353	180.000	2.000	1.657	10.639	9.468	0.00		TOP L BANK		
152.459	99.539	180.000	2.000	1.657	11.424	8.654	0.00		BOT L BANK		
151.753	99.233	180.000	2.000	1.657	12.130	8.348	0.00		LEOW		
145.895	99.148	180.000	2.000	1.657	17.988	8.263	0.00		CHAN BOT UNDER RUNNING WATER		
139.854	99.171	180.000	2.000	1.657	24.029	8.286	0.00		"		
134.989	99.023	180.000	2.000	1.657	28.894	8.138	0.00		"		
131.006	98.925	180.000	2.000	1.657	32.877	8.040	0.00		"		
125.484	99.177	180.000	2.000	1.657	38.399	8.292	0.00		"		
120.453	99.024	180.000	2.000	1.657	43.430	8.139	0.00		"		
116.411	99.121	180.000	2.000	1.657	47.672	8.236	0.00		"		
111.343	98.975	180.000	2.000	1.657	52.540	8.090	0.00		"		
106.385	99.039	180.000	2.000	1.657	57.498	8.154	0.00		"		
102.430	98.999	180.000	2.000	1.657	61.453	8.114	0.00		"		
97.835	98.935	180.000	2.000	1.657	66.048	8.050	0.00		"		
95.593	98.786	180.000	2.000	1.657	68.290	7.901	0.00		THALWEG UNDER RUNNING		
92.834	99.122	180.000	2.000	1.657	71.049	8.237	0.00		CHAN BOT UNDER RUNNING WATER		
86.474	99.206	180.000	2.000	1.657	77.409	8.321	0.00		"		
79.929	99.232	180.000	2.000	1.657	83.954	8.407	0.00		"		
74.400	99.156	180.000	2.000	1.657	89.483	8.271	0.00		"		
67.879	99.214	180.000	2.000	1.657	96.004	8.329	0.00		"		
62.889	99.153	180.000	2.000	1.657	100.994	8.268	0.00		"		
57.637	99.203	180.000	2.000	1.657	106.246	8.318	0.00		"		
57.608	99.177	180.000	2.000	1.657	106.275	8.292	0.00		"		
46.620	99.121	180.000	2.000	1.657	117.263	8.236	0.00		"		
39.833	98.822	180.000	2.000	1.657	124.050	7.937	0.00		"		
34.953	98.671	180.000	2.000	1.657	128.930	7.786	0.00		"		
31.346	99.406	180.000	2.000	1.657	132.537	8.521	0.00		REOW		
31.214	99.639	180.000	2.000	1.657	132.669	8.754	0.00		FIRST BENCH		
23.927	100.075	180.000	2.000	1.657	139.956	9.190	0.00		R BENCH		
12.045	100.190	180.000	2.000	1.657	151.838	9.305	0.00		RB BENCH		
0.000	100.000	180.000	1.657	1.657	163.883	9.458	0.00		BOT NRBM		
0.000	100.000	180.000	1.657	1.657	163.883	10.158	0.00		TOP NRBM		
0.000	100.856	180.000	2.000	1.657	254.328	9.971	0.00		BOT NRBM		
120.642	101.002	0.000	2.000	1.657	284.525	10.117	0.00		"		
120.837	100.401	0.000	2.000	1.657	284.720	9.516	0.00		"		
147.018	100.223	0.000	2.000	1.657	310.901	9.338	0.00		"		
180.459	100.289	0.000	2.000	1.657	344.342	9.404	0.00		"		
210.531	100.388	0.000	2.000	1.657	374.414	9.503	0.00		"		
230.159	100.261	0.000	2.000	1.657	394.042	9.376	0.00		BASE FRBM		
230.278	100.925	0.000	2.000	1.657	394.161	10.040	0.00		TOP FRBM		