environmental restoration project

A Department of Energy
Environmental Cleanup Program

LA-UR-00-5071
October 2000
ER2000-0477

Evaluation of Possible Sediment Contamination in the White Rock Land Transfer Parcel: Reach CDB-4

Los Alamos
NATIONAL LABORATORY
Los Alamos, NM 87545

Produced by the Canyons Focus Area

Authors: Paul Drakos, Randall Ryti, Steven Reneau, and Keith Greene
Editor: Lisa Levine
Compositors: Pam Maestas and Lisa Levine
Illustrator: Andi Kron

EXECUTIVE SUMMARY

This report presents the results of an investigation of potentially contaminated sediments in Cañada del Buey, within an area known as the White Rock land transfer parcel (canyon reach CDB-4). Cañada del Buey is a canyon that drains part of Los Alamos National Laboratory (the Laboratory), in Los Alamos County, New Mexico. The proposed transfer would move a parcel of land from Laboratory control to Los Alamos County and San Ildefonso Pueblo control.

The objectives of this work included defining the nature and extent of any contamination within the sediments of reach CDB-4, evaluating potential human health and ecological risk, and providing recommendations concerning potential additional assessments or remedial actions prior to any land transfer.

Cañada del Buey may have received contaminants from multiple potential release sites (PRSs) within the watershed, including PRSs within technical area 46 (TA-46), TA-51, TA-54, and former TA-4. However, this investigation identified no contaminants in young (post-1942) sediments from reach CDB-4. Although a series of inorganic chemicals were detected at levels above Laboratory-wide sediment background levels, these results can be attributed to a local background which differs from that of areas previously sampled for background geochemistry. Therefore, it is recommended that no additional assessment or remedial action is required before land transfer.

1.0 INTRODUCTION

1.1 Purpose

This report describes an investigation of sediment in the proposed White Rock land transfer parcel (Figure 1.1-1). This investigation was conducted during 1999 by personnel from the Canyons Focus Area as part of the Laboratory's Environmental Restoration (ER) Project. The investigation focused on a single reach of Cañada del Buey, reach CDB-4, following the technical strategy described in the "Core Document for Canyons Investigations" (the "core document") (LANL 1997, 55622; LANL 1998, 57666). Data collected from reach CDB-4 have been used to evaluate possible contamination resulting from Laboratory activities that might pose a risk to human health or ecosystems and affect the proposed land transfer. The subject medium of the investigation was restricted to sediments because there is no alluvial groundwater in this part of Cañada del Buey and there is no surface water, except for occasional stormwater events. In a future report, these data will be combined with additional data from elsewhere in Cañada del Buey to support an assessment of the entire length of the canyon. That assessment will involve a more comprehensive evaluation of the human health and ecological risk related to present-day levels of contamination and the effects of future transport of contaminants.

1.2 Legislative and Regulatory Context

During November 1997, Congress enacted legislation that required the Secretary of Energy to identify land at the Laboratory for potential conveyance and transfer to either Los Alamos County or to the Secretary of the Interior, to be held in trust for the Pueblo of San Ildefonso (Public Law 105-119, the Departments of Commerce, Justice, and State, the Judiciary, and Related Agencies Appropriations Act, 1998). The White Rock parcel was one of ten areas identified by the Secretary and the Department of Energy (DOE) for possible land transfer (DOE 1998, 58671). Public Law 105-119 also directed the DOE to identify any environmental restoration or remediation that these parcels would require prior to transfer. As presented in "Environmental Restoration Report to Support Land Conveyance and Transfer under Public Law 105-119" (LANL 1999, 63037), the White Rock parcel had not yet been characterized and the extent of any potential contamination was unknown. The work presented in this report was conducted to evaluate the need for any remediation prior to land transfer.

The work presented in this report was also designed to be consistent with other ER Project investigations, and to help satisfy additional regulatory requirements. The regulatory requirements governing the ER Project canyons investigations are discussed in Section 1.4 of the core document (LANL 1997, 55622; LANL 1998, 57666). In particular, these investigations address requirements of Module VIII of the Laboratory's Hazardous Waste Facility Permit (the "HSWA module") (EPA 1990, 01585) under the Resource Conservation and Recovery Act (RCRA). These requirements include addressing "the existence of contamination and the potential for movement or transport to or within Canyon watersheds." In addition to federal and state regulations, DOE Order 5400.5, "Radiation Protection of the Public and the Environment," provides guidance on evaluating residual radioactivity at DOE facilities.

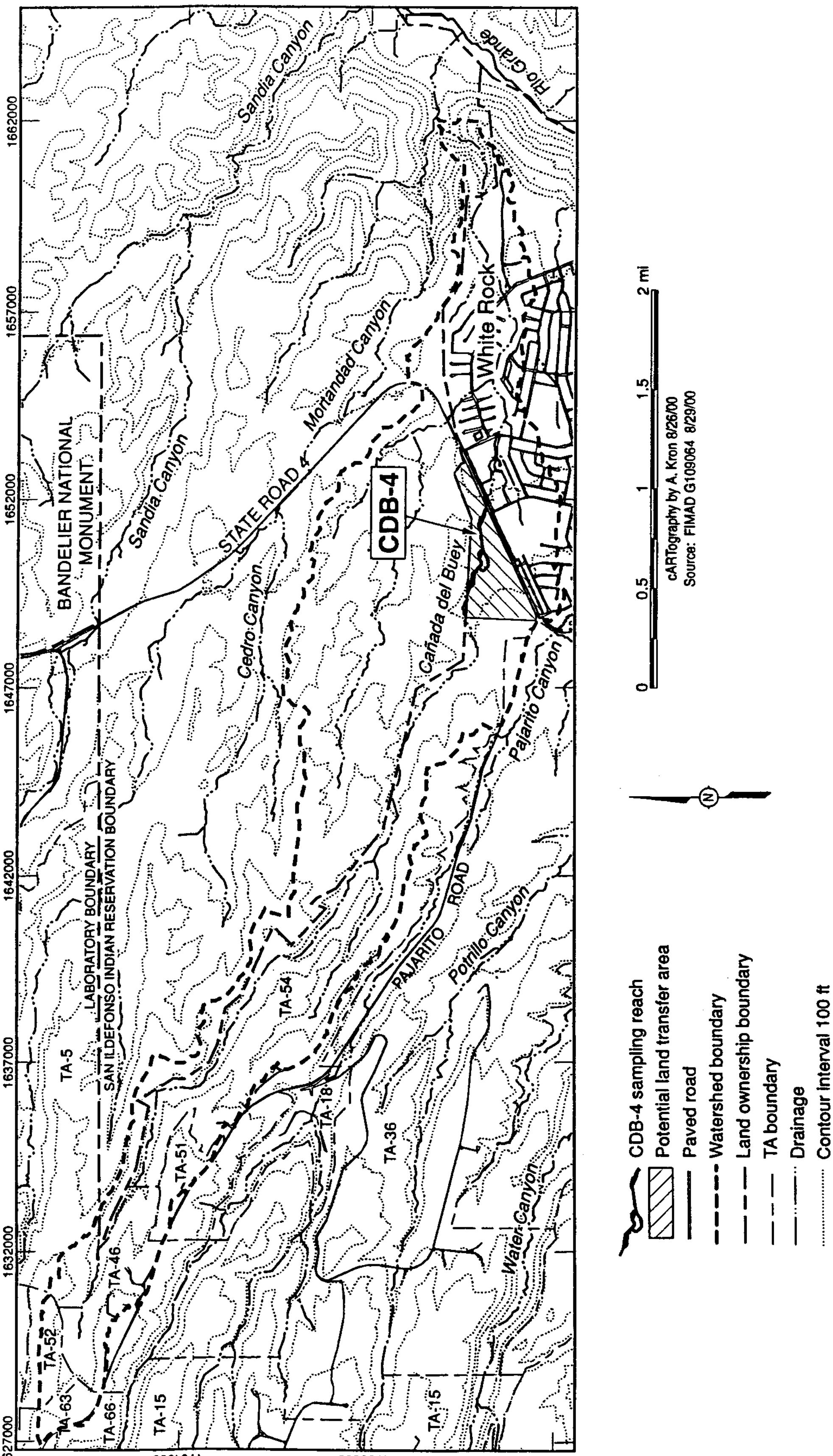

Figure 1.1-1. **Map of the Cañada del Buey watershed, showing property boundaries, Laboratory technical areas, and reach CDB-4**

1.3 Background

1.3.1 Geography, Geology, and Hydrology

Cañada del Buey heads on the Pajarito Plateau (on Laboratory land) and extends eastward through the community of White Rock to its confluence with Mortandad Canyon (on San Ildefonso Pueblo land) (Figure 1.1-1). Reach CDB-4 is that part of Cañada del Buey that lies within the proposed White Rock land transfer parcel, and it extends for 0.8 km west from highway NM 4, immediately west of White Rock. Upstream from NM 4, Cañada del Buey has a drainage area of approximately 5.5 km^2 and a basin length of approximately 9 km. The primary geologic unit that is exposed within the watershed upstream from NM 4 is the Tshirege Member of the Bandelier Tuff, which consists of Quaternary ignimbrites (Griggs 1964, 08795; Smith et al. 1970, 09752; Dethier 1997, 49843). Pliocene basaltic rocks of the Cerros del Rio volcanic field are exposed along the stream channel in reach CDB-4 and on adjacent slopes.

Stream flow in reach CDB-4 consists of infrequent, short-duration runoff from rain storms on the plateau. Bedrock occurs at a shallow depth below the stream channel, and no alluvial groundwater has been observed in hand-dug holes that extended to bedrock or in areas where alluvium pinches out on bedrock.

1.3.2 Laboratory History and Operations

Several Laboratory sites within the Cañada del Buey watershed may have contributed contaminants to the stream channel, as is summarized in the "Work Plan for Sandia Canyon and Cañada del Buey" (LANL 1999, 64617). TAs that might have been sources of contaminants include former TA-4 (currently within the boundaries of TA-52), TA-46, TA-51, and TA-54 (Figure 1.1-1). Summaries of pertinent information about key sites in the Cañada del Buey watershed are presented below.

1.3.2.1 TA-4

Former TA-4 was located on the mesa between Cañada del Buey and Ten Site Canyon and now lies within the boundaries of TA-52. It was occupied from approximately 1944 to 1955. The only known source of contamination at TA-4 that involved releases to Cañada del Buey was an outfall, PRS 4-003(a), from photo-processing facilities (LANL 1999, 64617, p. 2-46). Analytes that have been detected above background levels at this PRS include arsenic; chromium; lead; plutonium-239, -240; and pentachlorophenol.

1.3.2.2 TA-46

TA-46 is located on Mesita del Buey, between Cañada del Buey and Pajarito Canyon, and was established in 1954 as a weapons assembly site. Since that time, laboratories at TA-46 have been used for a variety of programs, including the development of nuclear reactors for propulsion of space rockets, the development of uranium-isotope separation methods, laser research, and solar-energy research. Various outfalls from TA-46 have discharged contaminants into Cañada del Buey. Analytes that have been detected above background levels at TA-46 outfalls include metals (arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc); radionuclides (plutonium-238, uranium-234, uranium-235, and uranium-238); and a variety of organic chemicals (LANL 1996, 54929; LANL 1999, 64617).

1.3.2.3 TA-51

TA-51 is located on Mesita del Buey, between Cañada del Buey and Pajarito Canyon, and was established in 1980 as an experimental engineering test facility. The only known source of potential contaminant releases from TA-51 into Cañada del Buey is an inactive septic system designated PRS 51-001 (LANL 1999, 64617, p. 2-60). No data regarding this PRS have been reported.

1.3.2.4 TA-54

TA-54 is located on Mesita del Buey, between Cañada del Buey and Pajarito Canyon, and was established in 1957 as a disposal area for low-level radioactive waste. It was also the site of a radiation exposure facility and has been used for disposal of administratively controlled wastes and chemical waste, for land farming of petroleum-contaminated soils, and for waste storage. Various analytes have been detected above background levels downgradient from TA-54 PRSs in the Cañada del Buey watershed. These include metals (aluminum, barium, calcium, chromium, copper, iron, lead, and magnesium) and radionuclides (americium-241; cesium-137; cobalt-60; plutonium-238; plutonium-239, -240; polonium-210; strontium-90; technetium-99; tritium; uranium-235; and yttrium-90) (LANL 1996, 54462)

1.4 Land Use

The area of Cañada del Buey that lies within reach CDB-4 is currently owned by the DOE. This area has been left in a natural state and has not been used for any Laboratory activities. The area that includes reach CDB-4 is being considered for transfer to Los Alamos County and/or San Ildefonso Pueblo (DOE 1998, 58671). Los Alamos County and San Ildefonso Pueblo have proposed a combination of residential and commercial use and cultural preservation for this land (LANL 1999, 63067).

1.5 Previous Sediment Investigations

Potential contaminants associated with sediments in reach CDB-4 have been investigated as part of the Laboratory's Environmental Surveillance Program since 1978 (e.g., Environmental Surveillance and Compliance Programs 1997, 56684). This work has included the annual sampling of active channel sediments immediately upstream from NM 4. A compilation of the sediment data through 1997 indicated that several analytes had maximum results at low levels above background levels: barium, cadmium, lead, selenium, americium-241, tritium, and plutonium-238 (LANL 1999, 64617, p. 3-85 to 3-87).

1.6 Preliminary Conceptual Model and Technical Approach

The available data from PRSs in the Cañada del Buey watershed indicate that a variety of metals, radionuclides, and organic compounds could be present as contaminants in canyon bottom sediments, although prior data from Cañada del Buey sediments are insufficient to determine if contaminants are systematically present above background levels. Because of their geochemical characteristics, most of the contaminants are expected to be adsorbed onto sediment particles, and transport downstream from the release sites would be largely controlled by sediment transport processes. Contaminants associated with sediments could have been dispersed, via floods, downstream to reach CDB-4.

The concentrations of any contaminants in the watershed are expected to vary greatly and to be related to such factors as distance from the source, sediment particle size, and age of the deposit. Contaminant concentrations are expected to be generally higher in sediment deposits closer to the source and to be higher in finer-grained sediments than in downstream deposits or in coarser-grained sediments.

Contaminant concentrations are also expected to be higher in sediment deposits that are relatively close to the age of the peak contaminant releases and to be lower in younger sediments.

The technical approach that was used in this investigation includes detailed geomorphic mapping and sediment sampling of the entire length of Cañada del Buey within the White Rock land transfer parcel. The methodology that was followed is presented in the core document (LANL 1997, 55622; LANL 1998, 57666). The work focused on determining the nature and extent of contamination, evaluating risk (if necessary), and testing components of the preliminary conceptual model in a phased approach. Geomorphic mapping and sediment sampling concentrated on identifying and characterizing post-1942 sediments (i.e. those sediments younger than the Laboratory). An evaluation of data from the first sampling phase was used to revise the conceptual model, identify key uncertainties, and focus subsequent data-collection activities. Investigation goals included evaluating present and future potential risk, evaluating sediment transport processes, and providing the data needed to make decisions about possible remedial action alternatives.

1.7 Unit Conventions

This report uses primarily metric units of measure, although English units are used for contours on topographic maps, for references to elevations derived from topographic maps, and for New Mexico State Plane coordinates as shown on some maps. English units are also used for radioactivity (curies [Ci] instead of becquerels [Bq]). Two scales, one with metric units of distance and one with English units of distance, are shown on maps. A table for converting metric to English units is presented in Appendix A.

1.8 Report Organization

Section 2 of this report presents the results of the field investigations of reach CDB-4 sediments. Section 2.1 introduces the reach and its major geographic characteristics. Section 2.2 describes the methods of investigation, including geomorphic mapping, physical characterization of young sediments, radiological field measurements, and sediment sampling activities. Section 2.3 presents the results of these field investigations, including physical characteristics of the geomorphic units and key aspects of the post-1942 geomorphic history.

Section 3 of this report presents analytical results from the sediment samples collected in reach CDB-4. Section 3.1 comprises a data review that evaluates which radionuclides and organic and inorganic chemicals should be retained as chemicals of potential concern (COPCs). Section 3.2 examines each COPC in the contexts of likely sources within the Cañada del Buey watershed and possible collocation with other COPCs.

Section 4 of this report presents a conceptual model of potential contamination in reach CDB-4 sediments that has been revised and refined from the preliminary conceptual model using the results of this investigation. Section 4.1 discusses those analytes that are present above Laboratory-wide background levels. Section 4.2 discusses sediment sources. Section 4.3 discusses potential future contamination.

Section 5 of this report serves as a placeholder for site assessments, although no assessments of potential human health risk or ecological risk were made because no contamination was measured in reach CDB-4 sediments.

Section 6 of this report summarizes the key conclusions of this investigation and provides recommendations concerning possible additional assessments, data collection, and/or remedial action.

Section 7 lists the references cited in this report.

Appendix A presents a list of acronyms used in this report as well as a conversion table of metric units to English units.

Appendix B presents supplemental information about the characterization of geomorphic units found in reach CDB-4. Section B-1.0 presents data regarding the thickness of post-1942 sediment in the different geomorphic units. Section B-2.0 presents data concerning particle-size characteristics, organic matter content, and pH in the sediment samples. Section B-3.0 presents the chronology of sediment-sampling events in reach CDB-4 and the primary goals of each sampling event. Section B-4.0 presents the geomorphic context in which the sediment samples were taken.

Appendix C presents the results of quality assurance (QA) and quality control (QC) activities pertaining to the reach CDB-4 sediment samples. Section C-1.0 summarizes the QA/QC activities. Section C-2.0 addresses inorganic chemical analyses. Section C-3.0 addresses organic chemical analyses. Section C-4.0 addresses radionuclide analyses. Section C-5.0 presents data qualifiers for the samples.

Appendix D presents analytical suites and the results of the sediment analyses performed during this investigation. Section D-1.0 presents target analytes and detection limits. Section D-2.0 presents sample request numbers and analytical suites for each sample. Section D-3.0 presents summaries of analytical results. Section D-4.0 presents analytical results for detected inorganic chemicals and radionuclides.

Appendix E presents supplemental statistical analyses of the analytical results of this investigation. Section E-1.0 presents statistical evaluations of the inorganic chemical data. Section E-2.0 presents statistical evaluations of the radionuclide data.

1.9 Acknowledgments

The authors of this report had the following responsibilities: Paul Drakos was principal investigator for sediment characterization during the fieldwork and was responsible for documenting the field investigations; Randy Ryti was responsible for data review and statistical analyses and was also the lead for statistical analysis during all phases of the field investigation; Steven Reneau provided technical oversight and contributed to data interpretation, technical editing, and report compilation; Keith Greene was responsible for the data validation activities included in this report.

In addition to the authors of this report, numerous individuals contributed to this investigation: Deborah Steven, Jenny Harris, and Mark Van Eeckhout contributed to the geomorphic characterization activities and sediment sampling; Bill Hardesty contributed to the data validation activities; Marcia Jones provided geographic information system (GIS) support; Al Funk was the field team manager; Lisa Levine served as editor for this report; Andi Kron was the graphic artist; and Lisa Levine and Pam Maestas were the compositors. Review comments on this report were provided by Ted Ball, Don Hickmott, Danny Katzman, Rich Mirenda, Paul Schumann, Lars Soholt, and Holly Wheeler-Benson. Finally, as leader of the Canyons Focus Area, Allyn Pratt supported all phases of this investigation.

2.0 FIELD INVESTIGATIONS

2.1 Introduction to Reach CDB-4

Reach CDB-4 is that portion of Cañada del Buey that lies within the proposed White Rock land transfer parcel, and it extends for 0.8 km west from State Road NM 4. The entire canyon bottom within CDB-4 was mapped, including both areas that were affected by post-1942 flooding and adjacent areas. The location of reach CDB-4 within the Cañada del Buey watershed is shown in Figure 1.1-1. The extent of post-1942 channels and floodplains within CDB-4 is shown in Figure 2.1-1. The inner canyon floor is relatively narrow through CDB-4, and the stream is locally incised into basaltic rocks of the Cerros del Rio volcanic field. For over 150 m, the channel splits around a basalt "island" in the middle of the reach. It is also broken into several braids along the eastern part of the reach. The general nomenclature for the geomorphic units used in this report is discussed in section 2.2.1, and the specific units in the reach are discussed in section 2.3.1.

2.2 Methods of Investigation

2.2.1 Geomorphic Mapping

Field investigations in reach CDB-4 began by preparing a preliminary geomorphic map that focused on identifying young (post-1942), potentially contaminated sediment deposits and subdividing these deposits into geomorphic units with different age and/or sedimentological characteristics. These geomorphic units delineate the horizontal extent of post-1942 sediments in the reach and group areas with similar physical characteristics. Where uncertainties existed about the limits of potentially contaminated sediments, boundaries were drawn conservatively such that the area potentially affected by post-1942 floods was overestimated rather than underestimated.

The mapping of reach CDB-4 was performed at a scale of 1:200. It involved taping the distances along the channel between surveyed control points and frequently measuring unit widths. Aerial photographs were not useful for mapping CDB-4 because of the narrow active canyon floor and the density of vegetation. The boundaries between geomorphic units were typically defined on the basis of topographic breaks, vegetation changes, and/or changes in surface sediments, although, in some areas, boundaries are more approximate.

Geomorphic mapping was iterative, and the map was revised after each phase of the investigation. For example, a relatively high-discharge flood event on June 17, 1999, altered some geomorphic units that had been mapped in May, leading to a revision of map units. In addition, the geodetic surveying of sample locations that followed each sampling event often led to revising the map so that the surveyed sample locations fell within the appropriate geomorphic unit. For example, the surveyed coordinates of a sample site that was located on a stream bank could fall within the active channel on a preliminary geomorphic map because of small inaccuracies in unit boundaries. Refinements to the conceptual model that were made during the investigation also resulted in reexamining and revising the maps.

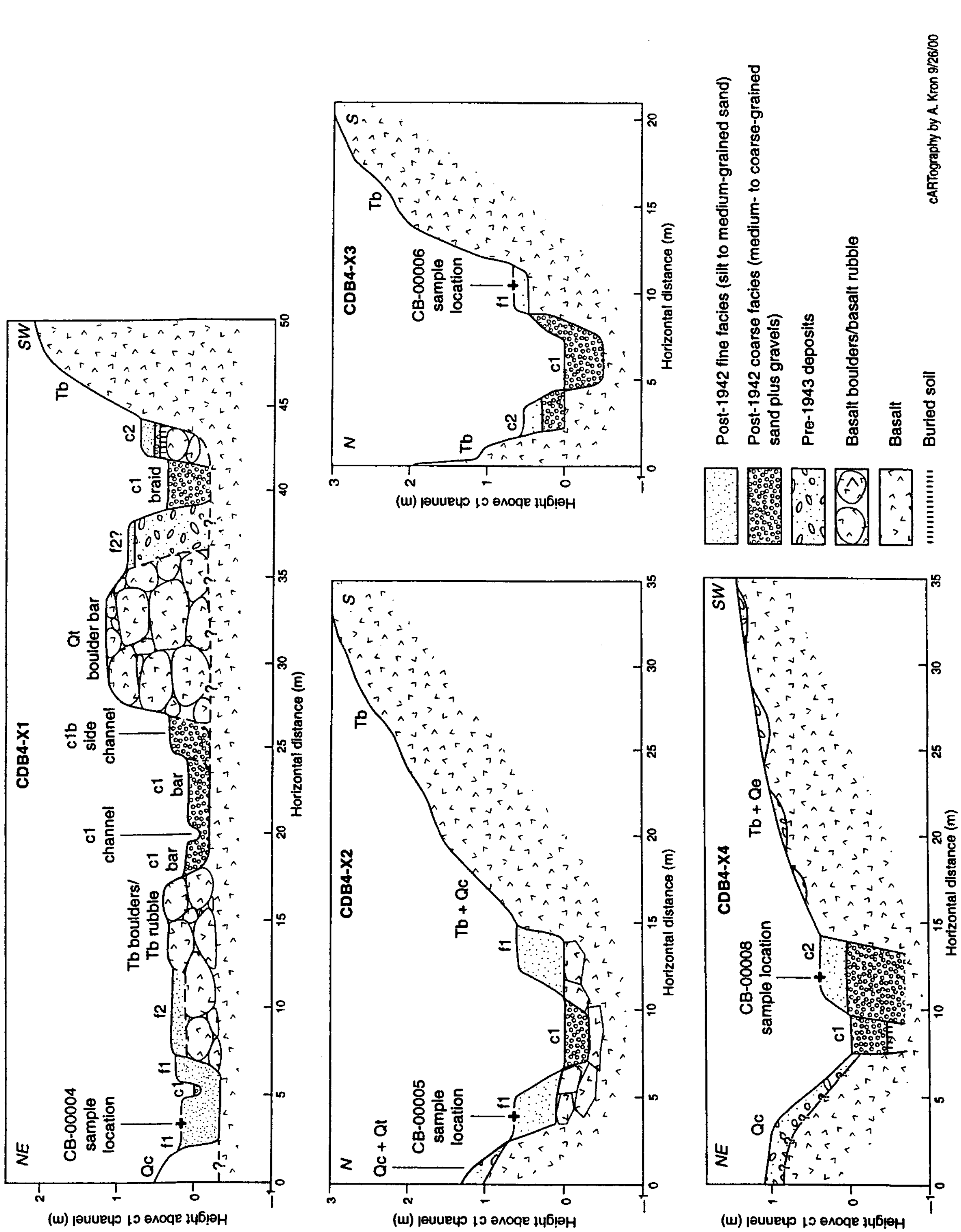

Figure 2.1-1. Topographic map of reach CDB-4 and vicinity, showing area of post-1942 sediments and index to detailed geomorphic maps

The following general conventions were used when naming the units in reach CDB-4.

- The designation *c* refers to post-1942 channel units, which are areas that were either occupied by the main stream channel or had experienced significant deposition of coarse-grained channel sediments sometime in the post-1942 period. The active channel was designated *c1;* the abandoned channel units, which were typically vegetated and topographically higher than the active channel, were designated *c2.* The designation *c1b* was used in CDB-4 to distinguish two types of channel segments: (1) recently abandoned channel segments adjacent to the main channel that were unvegetated or poorly vegetated, and (2) channel segments that appeared to receive intermittent stream flows at a lower frequency than the main c1 channels.
- The designation *f* refers to floodplain areas that were, or may have been, inundated by overbank floodwaters since 1942 but that were not occupied by the main stream channel. Areas that had probably been inundated by floods during this period, as shown by geomorphic evidence, were indicated by *f1.* Areas that had possibly been subjected to minor inundation, but where the evidence was generally inconclusive, were indicated by *f2.* If f2 surfaces had been inundated, the thickness of post-1942 sediment would be small. The designation *f1b* refers to areas that were located at a height correlative with f1 surfaces and that had indicators of recent flow such as pine needle mounds or vegetation mats pushed up against standing vegetation, but had no evidence of post-1942 sediment deposits.

Other designations on the geomorphic maps delineate areas that have not been directly affected by post-1942 floods downstream from potential contaminant sources. Following standard geologic nomenclature, *Q* indicates geologic units of the Quaternary period and *T* indicates geologic units of the Tertiary period. *Qal* refers to active channel alluvium in tributary drainages. *Qc* refers to colluvium. *Qt* refers to pre-1943 stream terraces that have not been inundated by post-1942 floods. *Qf* refers to fans from tributary drainages. *Qe* refers to eolian deposits (wind-blown sediment). *Qbt* refers to the Tshirege Member of the Bandelier Tuff. *Tb* refers to basaltic rocks of the Cerros del Rio volcanic field.

2.2.2 Physical Characterization of Young Sediments

Physical characterization of the geomorphic units included measurements of the thickness of post-1942 sediments, general field descriptions of particle size, and laboratory particle-size analysis for samples submitted for standard chemical and/or radiological analyses. The determination of unit thicknesses used a variety of approaches, including identifying the depth to which the bases of trees were buried by sediment, recognizing buried soil horizons, and searching for the presence of "exotic" material that indicated a post-1942 age (e.g., quartzite clasts imported from quarries off Laboratory land). Additional details concerning the methods and results of the physical characterization of post-1942 sediments in reach CDB-4 are presented in Appendix B.

An important distinction within the post-1942 sediments involves general variations in particle size. This is because contaminant concentrations tend to be higher in finer-grained sediments of a given age. The term *facies* is used to describe the observed texture of a deposit (primarily grain size). Two primary facies are described in this report: the fine facies, which generally contains median particle sizes of fine sand (0.125–0.25 mm) or smaller, and the coarse facies, which generally contains median particle sizes of coarse sand (0.5–1.0 mm) or greater. Medium sand (0.25–0.5 mm) can be assigned to either facies, depending on the stratigraphic context. The fine-grained sediments are generally transported as suspended load during floods and are commonly deposited on floodplains by water that overtops stream banks. The coarse-grained sediments are generally transported as bed load and deposited along the main stream channel. However, neither of the two facies are restricted to specific geomorphic units.

Although fine facies sediment typically forms upper layers on floodplains and abandoned channel units, it can also be found in thin layers along active channels. And coarse facies sediment can be deposited on floodplains during large floods. It should also be stressed that these distinctions are somewhat arbitrary, and that gradations commonly occur. Nevertheless, the distinctions form an important basis for differentiating sediment deposits of similar age that may contain highly variable levels of contamination.

2.2.3 Radiological Field Measurements

Field screening for gamma and beta radiation was performed using a sodium iodide probe with a 1- by 1-in. detector and a Ludlum ESP-1 probe. The screening indicated that post-1942 sediments in reach CDB-4 do not exhibit field-measured radiation levels above background levels. Therefore, these measurements were not useful for distinguishing potentially contaminated sediments and are not discussed further in this report.

2.2.4 Sediment Sampling and Preliminary Data Evaluation

Sediment sampling in this investigation followed a phased approach that included sampling for both full-suite and limited-suite analyses. A preliminary evaluation of the data after the first sampling phase helped identify uncertainties and focus subsequent sample collection and analysis. The primary goals of each sampling event, as well as other information about the events, are summarized in Appendix B.

Full-suite analyses were performed on samples collected from reach CDB-4 after the initial field-mapping phase. The goals of this sampling event were to identify all analytes that were present above background levels and to determine the primary risk drivers (if any). The sample sites were selected to include representative fine-grained and coarse-grained sediment deposits from the range of geomorphic units. The full-suite analyses included a variety of inorganic chemicals, organic chemicals, and radionuclides (see section 3.1 and Appendix C).

The evaluation of analytical results from the first round of sampling identified only plutonium-239, -240 and a series of metals as chemicals of potential concern (COPCs), although it was not certain if any of these analytes were actually present at levels greater than background levels. The second sampling phase was designed to collect additional data about these limited-suite analytes from both potentially contaminated sediments and from local background sites. The goal was to determine if any potential contaminants exceeded local background concentrations. It had been hypothesized that the local background concentrations of metals differed from Laboratory-wide background levels due to local differences in parent materials (soils and lithology), specifically the presence and weathering of basalt and/or the reworking of eolian deposits and older soils. In addition, second-phase samples were collected for tritium analyses because such analyses had been inadvertently left out of the first sampling phase.

Sites for local background sediment sampling were selected from tributary drainages and side slopes to cover the range of local sediment sources that were contributing sediments to the reach CDB-4 mapping area. None of these sample sites were downslope from areas affected by Laboratory activities. Runoff from the closest potential release sites (PRSs), which are located at Material Disposal Area G at TA- 54, drain into Cañada del Buey 0.7 km upstream from CDB-4. Local background sediment sampling sites included alluvium (Qal) in side drainages heading in areas underlain by Qbt (Bandelier Tuff), Qal side drainages heading on Tb (Cerros del Rio basalt), Qf (Quaternary alluvial fan) deposits, incipient drainages on colluvial slopes (Qc) bordering the active channel, and shallow side drainages in areas where eolian deposits mantle basalt (Tb+Qe) and contribute sediment to the active channel.

2.3 Results

2.3.1 Physical Characteristics

Reach CDB-4 is located in a part of Cañada del Buey where the stream has incised less than 10 m into the top of the Cerros del Rio basalt. Throughout CDB-4, the active channel and its associated historic and Quaternary (prehistoric) geomorphic units are bordered on the north by slopes and low cliffs of Bandelier Tuff (Qbt) as well as colluvium derived from Qbt. They are bordered on the south by basalt, which is overlain in some areas by eolian deposits. A Quaternary terrace (Qt) is present throughout much of the mapping area and is underlain by a well-developed carbonate soil indicative of a pre-Holocene age.

Approximately one-half of the length of CDB-4 is characterized by a braided stream channel. Two channels and bordering geomorphic units were mapped separately between control stakes CDB-4 + 350 m and CDB-4 + 575 m. Multiple channels and bordering geomorphic units were mapped between CDB-4 + 25 m and CDB-4 + 150 m (distances were measured upstream from the State Road NM 4 box culvert).

Calculations of average unit widths were based on a reach length measured along the north channel, which appears to be the predominant channel for conveying active stream flows, and results in a reach length of 775 m. (Areas of geomorphic units were summed where multiple channels were present.) The area that has been affected by post-1942 floods averages approximately 8 to 13 m wide in CDB-4. The areal distribution of the geomorphic units is shown on Figure 2.1-1 and Figure 2.3-1(a–d), and topographic relations are illustrated in the cross-sections of Figure 2.3-2. Physical characteristics of the geomorphic units in CDB-4 are summarized in Table 2.3-1. Data on particle size and unit thickness are presented in Appendix B, Tables B-1.0-1 through B-1.0-4, B-2.0-1, and B-2.0-2.

Table 2.3-1
Geomorphic Mapping Units in Reach CDB-4

Unit	Estimated Average Unit Height Above Channel (m)	Unit Area (m^2)[a]	Average Unit Width (m)	Sediment Facies	Estimated Average Thickness (m)	Estimated Volume (m^3)	Typical Median Particle Size Class (<2 mm fraction)	Notes
c1	0	2800	3.6	Fine	0.08	224	Fine sand[b]	Active channel and adjacent bars
				Coarse	0.28	784	Coarse sand	
c1b	0.25	474	0.6	Fine	0.14	66	Coarse silt—very fine sand	Recently abandoned channels and point bars, sparsely vegetated; 1980s to 1990s?
				Coarse	0.25	119	Coarse sand	
c2	0.35	1110	1.4	Fine	0.3	333	Very fine sand	Abandoned post-1942 channels
				Coarse	0.28	311	Very coarse sand	

Table 2.3-1 (continued)

Unit	Estimated Average Unit Height Above Channel (m)	Unit Area (m²)[a]	Average Unit Width (m)	Sediment Facies	Estimated Average Thickness (m)	Estimated Volume (m³)	Typical Median Particle Size Class (<2 mm fraction)	Notes
f1	0.5	1277	1.6	Fine	0.33	421	Very fine sand	Active floodplains
				Coarse	0.02	26	Medium sand[b]	
f1b	0.5	363	0.5	n/a[c]	0	0	n/a	Active floodplain with no young sediment
f2	0.7	3755	4.8	Fine	<0.05	<188	Fine sand[b]	Potentially active floodplain

[a] Average unit width includes all channel braids and associated geomorphic surfaces, and uses length of 775 m for CDB-4.

[b] Based on field descriptions.

[c] n/a = Not applicable.

The active channel, c1, averages 3.6 m wide in CDB-4. Its bed is composed of coarse sand and gravel with isolated fine-sand lenses. Typically, c1 units lack vegetation. The average thickness of the c1 unit is 36 cm, and it includes an average of approximately 8 cm of fine-grained sediment. Throughout much of reach CDB-4, c1 sediments sit directly on basalt. In areas where older sediments underlie c1 deposits, a buried soil with subangular blocky structure and clay films bridging grains and coating pebbles is usually present. Recently abandoned channels and point bars, c1b, have an average height of 0.25 m above the active channel and an average width of 0.6 m, resulting in a combined average width of approximately 4.2 m for c1 and c1b units. The average c1b thickness of 39 cm includes 25 cm of coarse sand (coarse facies) and 14 cm of coarse silt to very fine sand (fine facies). Unit c1b either rests directly on basalt or welded tuff boulders or is underlain by a buried soil with subangular blocky structure that appears to be the same soil that was observed underlying c1 sediments.

The active channel is bordered intermittently by abandoned post-1942 channel units (c2) that have an average width of 1.4 m and an average height of 0.35 m above the channel. The c2 units include an average of 30 cm of coarse-grained sediments comprising medium sand to very coarse sand. They are capped by an average of approximately 28 cm of fine-grained sediments which are dominated by very fine sand. Unit c2 either rests directly on basalt or welded tuff boulders or is underlain by a buried soil with subangular blocky structure that appears to be the same soil that was observed underlying c1 sediments.

Active floodplains (f1) in CDB-4 are an average of 1.6 m wide. The f1 unit averages 0.5 m above the active channel and is capped by an average of 33 cm of fine-grained sediments dominated by very fine sand. An f1b subunit is distinguished in CDB-4 by indicators of scouring such as organic material caught up in vegetation, vegetation bent over in the downstream direction, and a topographic break creating a small bench, but it is characterized by an absence of post-1942 sediment. Therefore, unit f1b adds to the area of post-1942 geomorphic units but does not contribute to the volume of post-1942 sediments. Unit f1 deposits sit directly on basalt or welded tuff boulders throughout most of the map area, although, in some cases, f1 deposits are also underlain by a buried soil with subangular blocky structure and clay films.

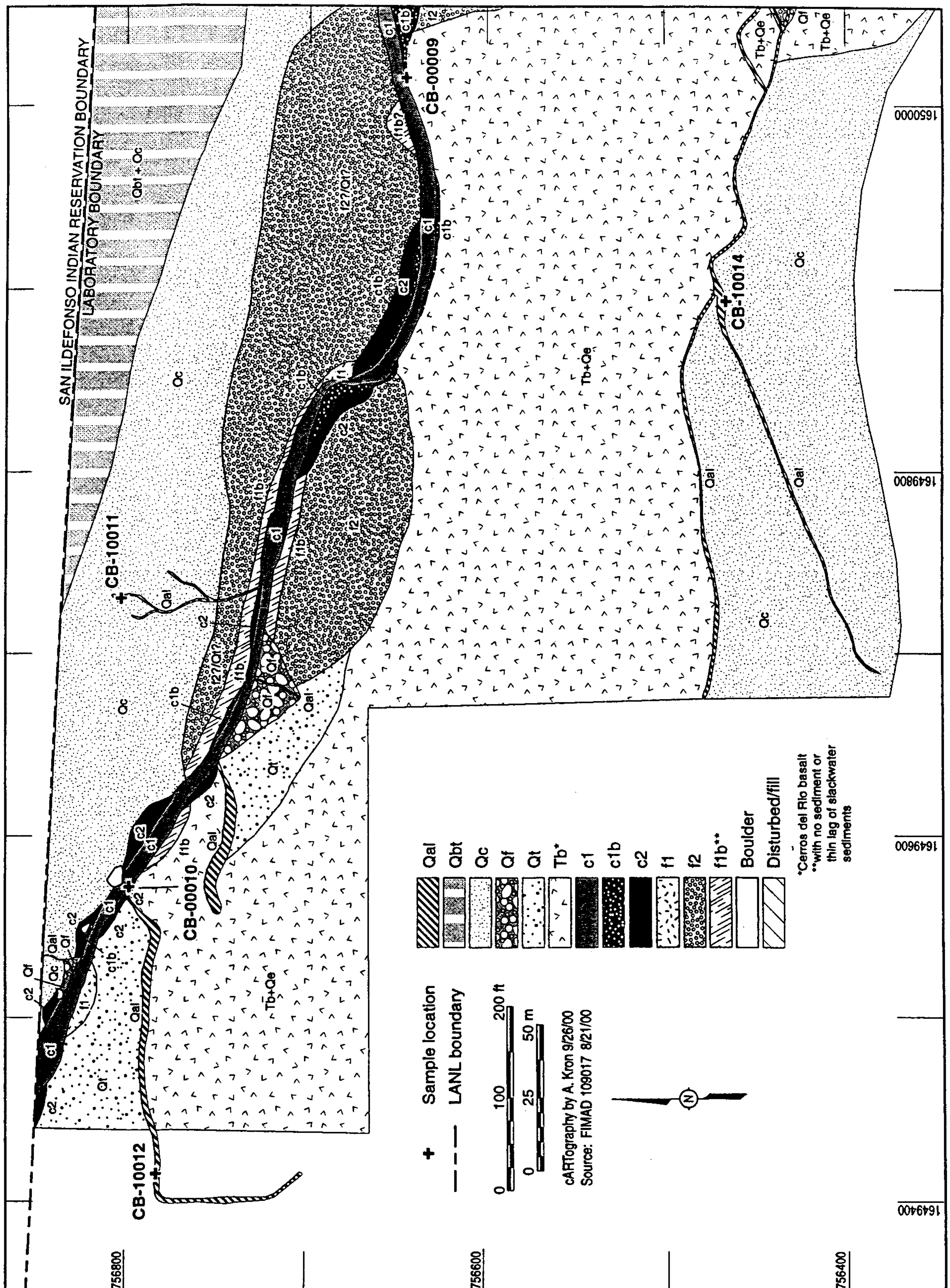

Figure 2.3-1a. Map showing geomorphic units and sample locations in reach CDB-4

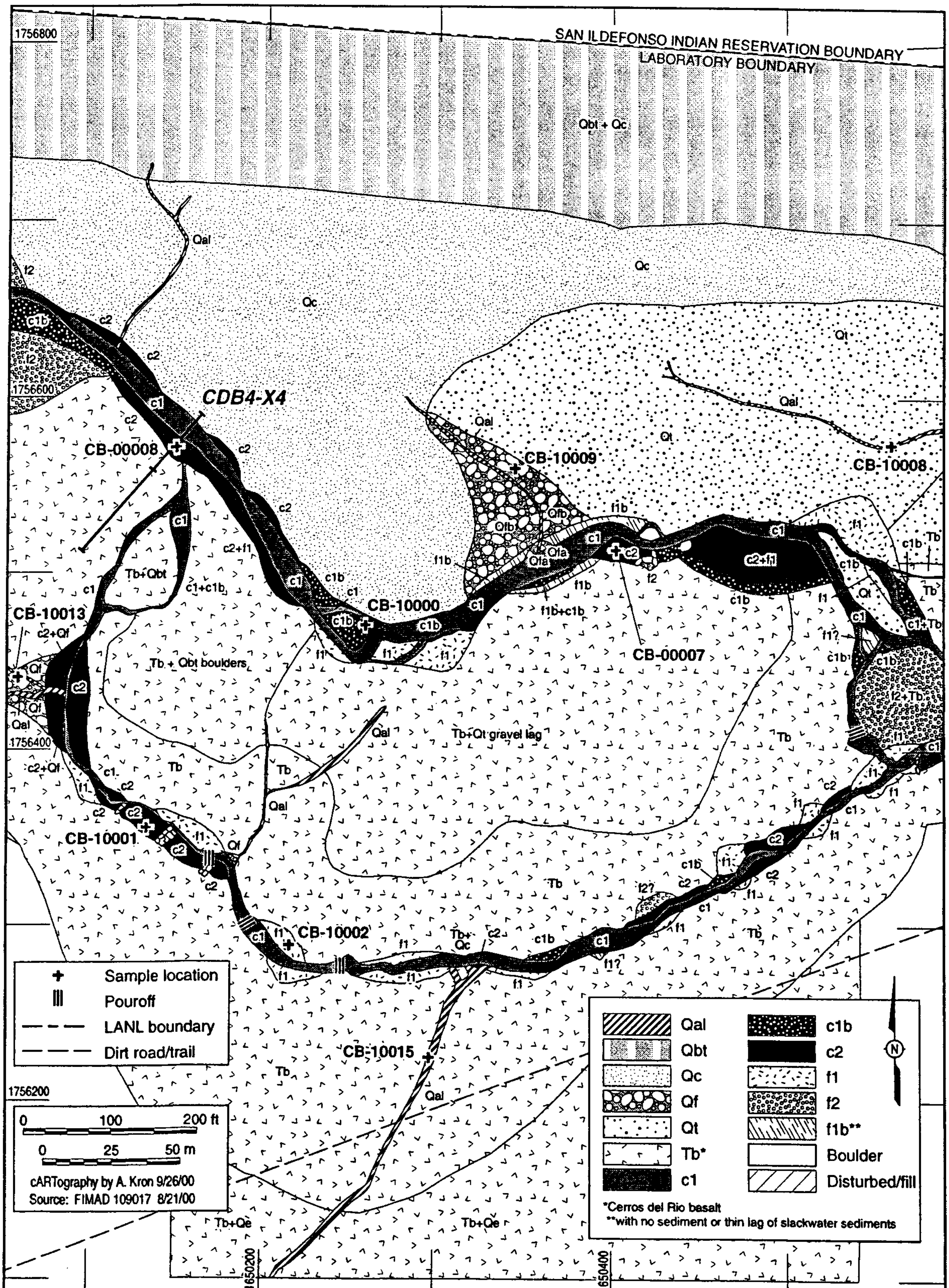

Figure 2.3-1b. Map showing geomorphic units and sample locations in reach CDB-4

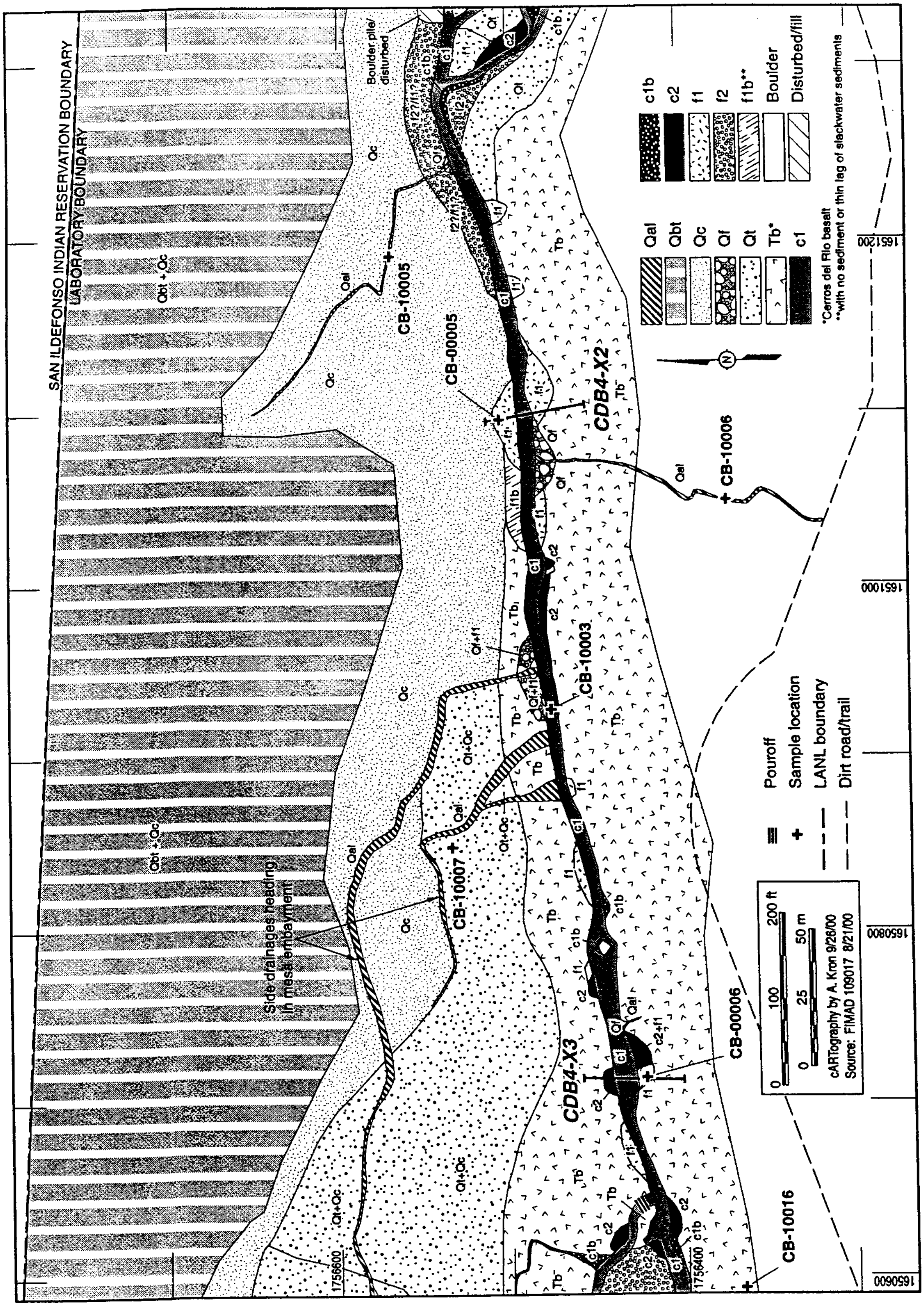

Figure 2.3-1c. Map showing geomorphic units and sample locations in reach CDB-4

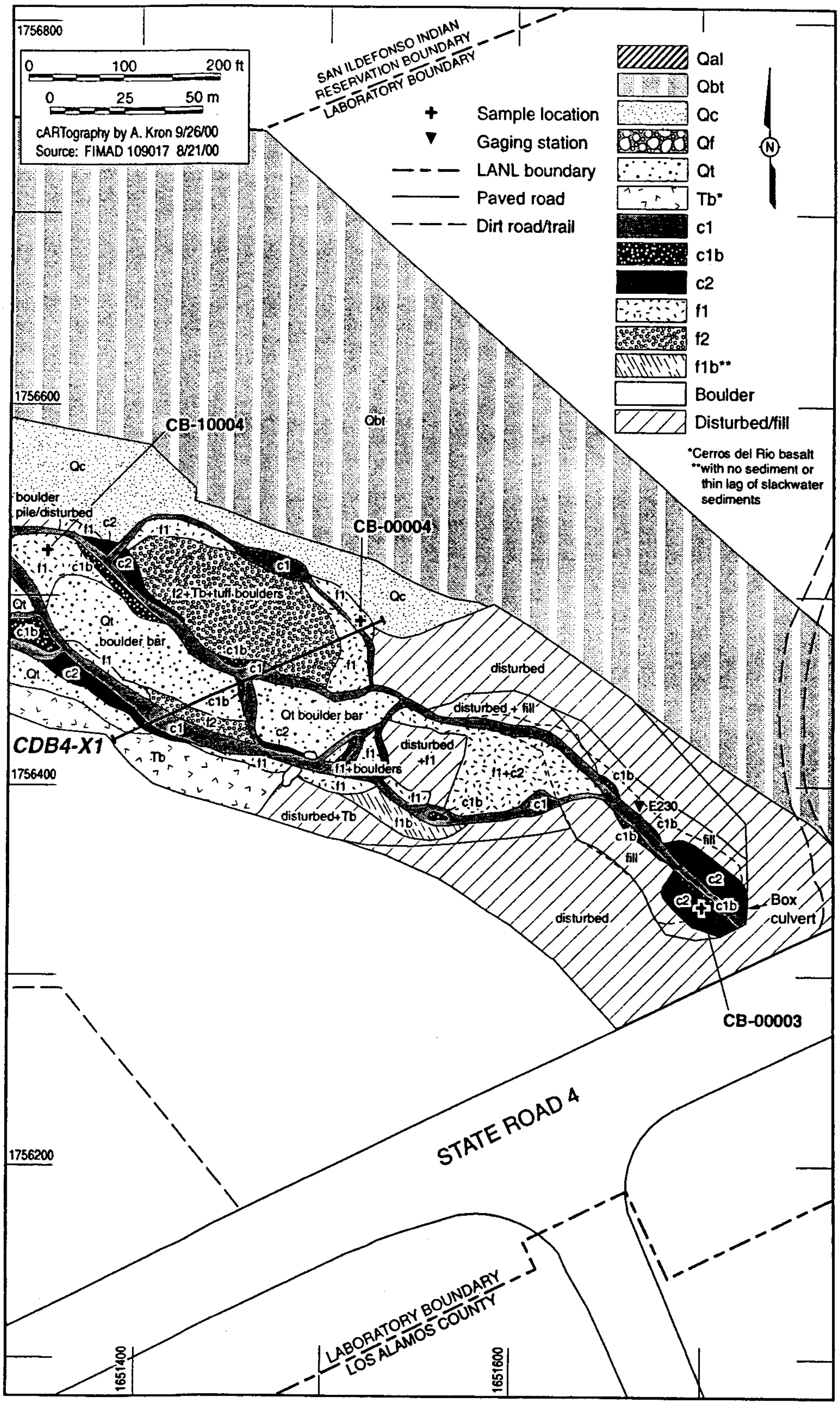

Figure 2.3-1d. Map showing geomorphic units and sample locations in reach CDB-4

Potentially active floodplains (f2) in CDB-4 are slightly higher than f1 and average approximately 5 m in width. It should be noted that the average width of f2 units is somewhat skewed by the presence of several relatively large f2 units, in particular between control stakes CDB-4 + 615 m and CDB-4 + 750 m. These f2 areas either have not been inundated by post-1942 floods or were only briefly inundated, experiencing little or no post-1942 sediment deposition.

An estimated 2300–2500 m^3 of post-1942 sediment are stored in reach CDB-4; this sediment is roughly equally distributed between fine-grained and coarse-grained sediment (Table 2.3-1). The active channel, c1, contains over 60% of the coarse sediment in CDB-4. In contrast, the fine sediment is widely distributed across the f1, c2, and c1 units.

2.3.2 Geomorphic History

Since 1943, the geomorphic processes within reach CDB-4 have included the lateral migration of the active channel over an area that averages 6 m wide (represented by the width of the c1, c1b, and c2 units) and the occasional overtopping of higher pre-1943 surfaces during floods. Vertical changes in the elevation of the stream bed have also apparently occurred in CDB-4, resulting in the presence of young (post-1942) channel sediments up to 0.5 m above the active channel. The largest apparent vertical changes were recorded by coarse-grained c2 sediment occurring above the elevation of nearby f1 surfaces at cross-section CDB4-X1, which is located in an area of braided channels (Figure 2.3-2). The configuration of geomorphic units observed at CDB4-X1 may be the result of post-1942 channel migration from southwest to northeast in this part of CDB-4.

Most of the post-1942 fine-grained sediment within reach CDB-4 is stored within the c1, c2, and f1 units, relatively close to the active channel. Smaller amounts may be stored in the f2 units farther away from the channel. The sediments within the c1, c2, and f1 units are particularly susceptible to remobilization by lateral bank erosion during floods, and the average residence time for sediment at these sites is probably less than 50 years. This conclusion is based, in part, on the observation that many of the post-1942 units occur as pockets of sediments located in small embayments along a bedrock-bordered stream channel.

The inundation of the post-1942 geomorphic units during the June 17, 1999, flood provides additional evidence that remobilization of sediment stored in the c1b, c2, and f1 geomorphic units occurs on a time scale of less than 50 years. The June 1999 flood in CDB-4 deposited new sediment on c2 and f1 units throughout the reach, with some aggradation observed on top of previously mapped post-1942 deposits (e.g., deposition of 10 cm of fine sand on top of a previously mapped c2 unit at sample location CB-00007). Some scouring of post-1942 deposits was also observed, although the flood appears to have resulted in a preponderance of additional sediment deposition in the reach, rather than erosion of young sediments. These observations suggest somewhat longer residence times for the post-1942 sediments. The absence of age control for sediments in CDB-4 (except for the June 1999 deposits), however, makes quantifying residence times for sediments stored in post-1942 geomorphic units problematic.

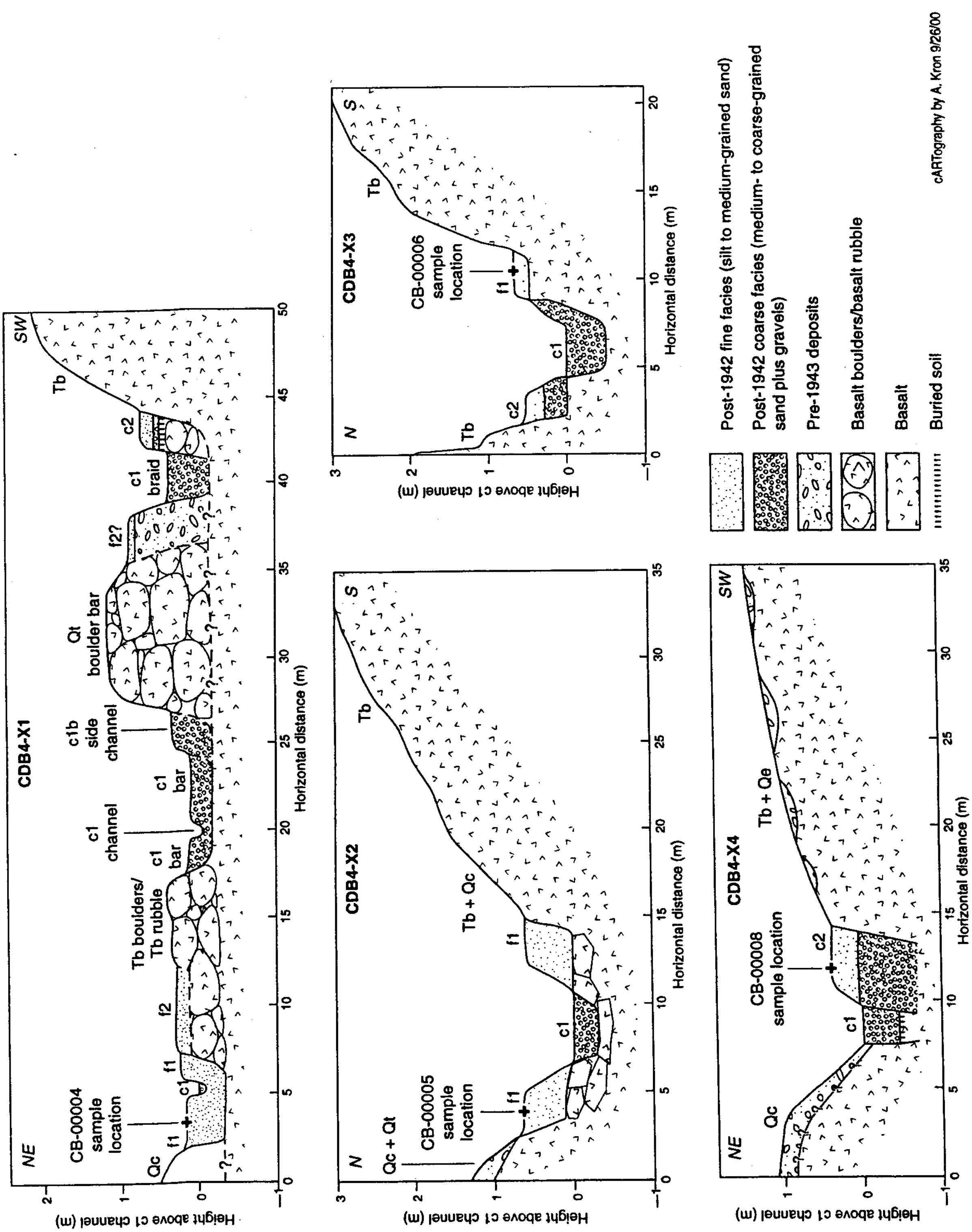

Figure 2.3-2. Schematic cross-sections showing relations between geomorphic units in reach CDB-4