In Response to the
State Water Resources Control Board
Order Nos. 98-05 and 98-07

Compliance Reporting

Stream Monitoring
Fish Monitoring
Waterfowl Monitoring
Runoff Forecast and Operations

May, 2005

Los Angeles Department of Water and Power

May 12, 2005

Ms. Victoria Whitney, Chief
Division of Water Rights
State Water Resources Control Board
1001 I Street
Sacramento, California 95812

Dear Ms. Whitney:

Subject: Compliance with State Water Resources Control Board Order Nos. 98-05 and 98-07

Pursuant to the State Water Resources Control Board (SWRCB) Decision 1631 and Order Nos. 98-05 and 98-07, and in accordance with the terms and conditions of the Los Angeles Department of Water and Power (LADWP) Mono Basin Water Right License Nos. 10191 and 10192, enclosed is a submittal entitled "Compliance Reporting", which contains the four reports required by the Orders. The reports are as follows:

- Mono Basin Operations for Runoff Year (RY) 2005-2006
- Fisheries Monitoring Report for Rush, Lee Vining, Parker, and Walker Creeks, 2004
- Mono Basin Tributaries: Lee Vining, Rush, Walker, and Parker Creeks – Monitoring Results and Analysis for Runoff Season 2004-05
- Mono Basin Waterfowl Habitat and Population Monitoring 2004-2005

In addition to the four reports, the first section is a report entitled "Compliance with State Water Resources Control Board Order Nos. 98-05 and 98-07". This report summarizes LADWP's restoration and monitoring activities performed during RY2004-05 and the restoration and monitoring activities proposed for RY 2005-06.

The filing of the reports and the restoration and monitoring performed by LADWP in the Mono Basin fulfills LADWP's requirements for RY 2004-05 as set forth in SWRCB

Decision 1631 and Order Nos. 98-05 and 98-07. Electronic copies of the report on compact disc have been provided to the interested parties as noted in the attached mailing list. Hard copies of the report will follow shortly for you and your staff.

If you have any questions, please contact Dr. Mark Hanna of my staff at (213) 367-1289.

Sincerely,

Original Signed Richard F. Harasick for

Thomas M. Erb
Director of Water Resources

MH:mm

Enclosure

c: Attached Mailing List (w/ enclosure)
Dr. Mark Hanna

Mono Basin Distribution List
May 2005

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Section 1

Compliance with State Water Resource Control Board Order Nos. 98-05 and 98-07

Compliance with State Water Resources Control Board Decision 1631 and Order Nos. 98-05 and 98-07

May, 2005

Los Angeles Department of Water and Power

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Introduction

Pursuant to State Water Resources Control Board (SWRCB) Decision 1361 and Order Nos. 98-05 and 98-07 (Orders), the Los Angeles Department of Water and Power (LADWP) is to undertake certain activities in the Mono Basin to be in compliance with the terms and conditions of its water right licenses 10191 and 10192. In particular, the Orders state that LADWP is to undertake activities to restore and monitor the fisheries, stream channels, and waterfowl habitat. This summary provides an overview of all of the activities LADWP and its consultants completed during Runoff Year (RY) 2004-05 for compliance. This summary also provides a list of planned work/activities for RY 2005-06.

RY 2004 was the sixth full field season after the adoption of the Orders. As such, LADWP is continuing the implementation of its revised Stream and Stream Channel Restoration Plan, revised Grant Lake Operation and Management Plan, and revised Waterfowl Habitat Restoration Plan. This required, among other things, scheduling field crews and other resources, coordinating with various other agencies, and preparing work plans. LADWP has completed most of the planned work/activities for compliance.

Please see **Figure 1** for an aerial image of Mono Basin, showing major streams and LADWP facilities.

Figure 1: Aerial Photograph of Mono Basin

Work Performed During Runoff Year 2004-05

Restoration Activities

Streams

In 2004, LADWP undertook and completed several measures that were outlined in the Mono Basin Stream and Stream Channel Restoration Plan (1996). These include:

- Installation and preliminary operation of the Lee Vining Diversion Facility Upgrade;
- Exploration of methods for improving the facilities for Rush Creek augmentation directly from the Lee Vining Conduit.
- Development of preliminary plans for upgrading Mono Gate One.
- Investigation of Sediment Bypass for Parker and Walker Creeks;
- Continued Investigation of Side-Channel Openings on Rush Creek; and
- Continued with the grazing moratorium.

Lee Vining Diversion Facility Upgrade

LADWP completed the installation of the Lee Vining Creek diversion facility upgrade during the fall and winter of 2004-05. The facility upgrade will provide LADWP with the ability to more accurately monitor and control releases to Lower Lee Vining Creek and provide for the opportunity to bypass sediment during high flow events.

Facilities for Rush Creek Augmentation

LADWP began preliminary investigations for upgrading the Lee Vining Conduit to provide specific flows to Rush Creek when needed. Presently this is possible by blocking water in the conduit and forcing it out through the 5-Siphon Bypass. Some variation of this will be the final design.

Mono Gate One Facility Upgrade

LADWP developed preliminary plans for upgrading Mono Gate One to efficiently provide specific flows to Rush Creek throughout the runoff year.

Sediment Bypass for Parker and Walker Creeks

LADWP continued investigating sediment bypass options on Walker and Parker Creeks at the points of diversion. Currently the plan remains as a “dredge and place” operation where LADWP staff will periodically dredge the sediments trapped by the diversion facilities and place this material at strategic locations below the facilities. The timing and locations are yet to be determined. LADWP personnel are drafting a preliminary proposal that will be submitted to contracted sediment experts for their review. Once their review is complete the sediment bypass operations plans for both Walker and Parker Creeks will be drafted for review by interested parties.

Side-Channel Openings

The following is a summary of side channel construction sites, their condition, and current implementation status on Rush Creek:

- **Reach 3D:** Construction was completed by LADWP in 2002 based on the floodplain design developed collaboratively between LADWP and McBain and Trush (presented in RY2001 Report); manual revegetation of the floodplain may occur if necessary after five years from completion of project (2008).
- **Reach 4A:** The east side 1A channel in Reach 4A was specified to receive approximately 15 cfs of baseflow to achieve approximately 1,020 ft of rewatered channel. This channel presently is dry during summer baseflow condition, but appears influenced by groundwater during higher baseflows and spring snowmelt periods. The present primary channel appears to be recovering, and provides good habitat and geomorphic features, although the channel is somewhat straighter than the abandoned 1A. Riparian vegetation is regenerating rapidly in this reach with the higher water table producing diverse wetlands in depressional areas.
- **Reach 4B:** The channel 4bii complex was specified to receive approximately 10 cfs of baseflow to rewater approximately 3300 ft of channel. Waterfowl habitat was specified as a goal primarily due to persistence of old beaver pond structures. This channel area gets flows when main channel flows are above approximately 300 cfs, and receives a considerable amount of groundwater seepage during other times. Riparian and depressional wetland vegetation appears to be regenerating rapidly in this reach. The initial rewatering intent was to jump start riparian growth but at this point in time it does not appear to be necessary. Vehicle and equipment access is difficult. LADWP, McBain and Trush, and C. Hunter recommend deferring construction at this site.
- **Reach 4C:**

  - The Channel 14 complex was to be rewatered with approximately 10 cfs of baseflow to achieve 1,300 ft of channel. The excavated channel entrance site was to be selected to minimize mechanical intervention. However, local head-cutting and main channel downcutting have caused the 14-Channel to become perched considerably higher than its relative position in the recent past. Rewatering would require extensive excavation that would disrupt the main channel and surrounding area. Considerable tradeoffs would occur due to fishery, riparian, and avian habitats that have developed in the main channel that will be impacted by rewatering efforts. Riparian regeneration is occurring in this area, and appears to be on a recovery trajectory. Upstream of the 14-Channel, the 13-Channel complex receives hyporheic flows from the upstream floodplain and flow from a small side-channel exiting the right bank. This small channel does not appear stable and persistent in the long term. Riparian vegetation appears to be regenerating rapidly in this reach. Research shows the increasing presence of willow flycatcher in this area, benefiting from a diverse willow community with a good understory. LADWP, McBain and Trush, and C. Hunter recommend deferring construction at this site because the dynamic nature of the entire system will likely result in better long term habitat conditions.
  - The Channel 8 complex was to be unplugged to allow 1 to 2 cfs into the channel. Construction was completed in 2002. In contrast to rewatering for a constant flow, the final design called for flow overtopping the bank and flowing into the 8-Channel at approximately 250 cfs and above. This design was intended to avoid significant reduction of the main channel flow, and to reduce risk of channel capture by a rewatered 8-Channel. This channel will receive more surface water in the future which will encourage production of floodplain wetlands for waterfowl and other species.

- The Channel 11 complex was to be unplugged to allow 1 to 2 cfs into the channel. This channel/plug site is located approximately 50 ft upstream of the downstream 10-Channel confluence. This is an old condition and recently the channel has been aggrading even though this channel is still perched. In spite of these conditions, the riparian vegetation appears to be regenerating naturally in this area. The potential benefits of re-opening this channel are minor, whereas the mechanical intrusion would be quite disruptive. LADWP, McBain and Trush, and C. Hunter recommend deferring construction at this site.

Grazing Moratorium

There was no grazing on LADWP's land in the Mono Basin during RY 2004-05. The grazing moratorium is still in effect for all lands in the Mono Basin and will be continued for a total of at least 10 years, per the Mono Basin Stream & Stream Channel Restoration Plan (LADWP, 1996).

Waterfowl

Channel Rewatering:

Plans to rewater the channels described in the waterfowl plan have been postponed until further notice based on recommendations from the Stream Scientists (see discussion above).

Monitoring

Streams

Monitoring and Reporting

During RY 2004, McBain and Trush continued their monitoring program developed in 1997 and 1998 following the White and Blue book principles. Three monitoring reaches have been established on Rush Creek, two reaches on Lee Vining Creek, and one reach on each of Parker and Walker creeks. Detailed descriptions of McBain and Trush's monitoring of reaches, water temperature, and channel dynamics are found in their report titled "Monitoring Results and Analyses for Runoff Season 2004-05 – Mono Basin Tributaries: Lee Vining, Rush, Walker, and Parker Creeks". This report is included in Section 4 of the Compliance Report.

Fishery

Monitoring and Reporting

Mr. Hunter continued the monitoring program originally developed in RY 1997 and 1998 according to the White and Blue book principles. This plan was altered during the course of its implementation to rely more heavily on electrofishing for population estimates in place of snorkeling, as electrofishing proved to be more accurate in the beginning monitoring seasons. Three planmap sections in Rush Creek (Country Road, Upper, and Lower), two planmap sections on Lee Vining Creek (Upper and Lower), and one planmap section on each of Walker and Parker creeks were studied. Mr. Hunter's detailed methods and findings are described in his report titled "Fisheries Monitoring Report for Rush, Lee Vining, Parker, and Walker creeks – 2004", located in Section 3 of Compliance Reporting.

Waterfowl

Oversight of the Monitoring Program

During RY 2004-05, Dr. White oversaw the Waterfowl Habitat Restoration Program in the Mono Basin. He facilitated outside review and documentation of a revised waterfowl monitoring plan and reviewed the annual reports on Lake Limnology and waterfowl distribution and abundance.

Introduction

In RY 2004-05, LADWP continued its waterfowl habitat monitoring and restoration program. The following is a summary of activities:

- Monitored Mono Lake hydrology;
- Monitored lake limnology;
- Monitored lake ornithology.

Mono Lake Hydrology

The elevation of Mono Lake was monitored on a weekly basis, weather permitting. Over the course of the runoff year, the lake elevation ranged from 6381.4 feet amsl on April 1, 2004 to 6381.2 feet amsl on March 31, 2005. The average surface area during RY 2004-05, based on the Pelagos Corp. 1986 bathymetric study, was approximately 70.1 square miles, or 44,864 acres.

Mono Lake Limnology

Lake limnology was monitored by UC Santa Barbara. Meromixis terminated in RY 2003. As a consequence, the lake mixed to the bottom for the first time since the winter of 1995. The resulting nutrient pulse supported annual primary production that was 57% higher than the long-term mean. The first generation *Artemia* abundance in 2004 was the highest on record.

Lake Ornithology

Ms. Deborah House, Watershed Resources Specialist with LADWP, conducted three summer waterfowl ground surveys and six fall aerial surveys. Photos of waterfowl habitats at Mono Lake, Bridgeport Reservoir and Crowley Reservoirs were taken from a helicopter on September 23, 2004.

Expert for Peer Review

Robert McKernan, director of the San Bernardino County Museum, was selected in 2003 to provide peer review of the field methodologies used for monitoring waterfowl, and to review the waterfowl survey report every five years, starting with the 2003 report. His review of the field methodologies was included in section 5 of last year's report. His review of the 2003 report is included in section 5 of this year's report. Comments made were incorporated in this year's waterfowl report.

LADWP personnel collected hydrology data for the four streams and Mono Lake.

Informational Meetings

The LADWP sponsored two meetings during the RY 2004 for the experts and interested persons to present and discuss restoration and monitoring activities, hydrology, and other issues related to the Mono Basin. The meetings were held on April 30, 2004 and November 30, 2004.

April Meeting: This meeting, held on Friday, April 30, 2004, provided an opportunity for the Stream Scientists to present the findings of their RY 2003 monitoring activities and discuss their proposed RY 2004 scope of work.

Ken Knudson of the Chris Hunter fisheries monitoring group expressed that they plan to move forward with a fish movement study to determine where the fish swim during their annual life cycles. He also planned to move forward with otolith sampling to determine ages of fish. The trout populations are steady and most fish are in good condition.

Bill Trush of the stream monitoring group stated that because flows are expected to exceed 380 cfs, geomorphology monitoring on Rush Creek will occur. Bill displayed the aerial imagery he obtained in June of 2003. He also expressed that they will quantify the termination criteria later this year. Bill went on to discuss the groundwater monitoring and assured the group that he was not interested in establishing a detailed groundwater model.

Brian White reported on the limnological monitoring and the waterfowl monitoring. The limnology report describes nothing out of the ordinary except that Mono Lake turned over in 2003. As well, there was the largest primary production ever recorded. The waterfowl monitoring protocol was reviewed by Robert McKernan and he states that Debbie House of LADWP is performing the waterfowl surveys correctly.

In addition, the preliminary RY 2004 runoff forecast and operations were discussed by LADWP. The preliminary runoff forecast indicated a “Dry Normal II” year. Because the SWRCB requested that LADWP test the newly refurbished return ditch, LADWP discussed various hydrographs that may be supplied to Rush Creek. LADWP also expressed their willingness to help maintain Grant Lake Reservoir elevations by halting exports until after the Grant Lake Reservoir marina closes in early October. LADWP also discussed agreement with Walker Lake managers to not drain the lake in the winter necessitating refilling it in early May, and now they will keep it full year round. This will allow Walker Creek to be completely flow through so flows will not drop in Lower Walker Creek when the managers refill the lake.

Attendees included those shown in **Table 1**.

Table 1
Mono Basin April Meeting Attendees

Name	Agency/Affiliation
Greg Reis	Mono Lake Committee
Lisa Cutting	Mono Lake Committee
Peter Vorster	Mono Lake Committee consultant
Burt Almond	USFS
Darren Mierau	McBain and Trush
Brian Tillemans	LADWP
Brian White	LADWP
Janet Goldsmith	lawyer
Ken Knudson	Hunter
Mark Hanna	LADWP
Jim Canaday	SWRCB
Bill Trush	McBain and Trush
Bob Prendergast	LADWP
Jim Edmondson	CalTrout
Rob Lusardy	CalTrout
Cathy Greenman	LADWP consultant
Wayne Hopper	LADWP (phone)
Charlotte Rodrigues	LADWP (phone)

November Meeting: This meeting, held on Tuesday, November 30, 2004, provided an opportunity for the stream monitoring experts and waterfowl experts to present and discuss their RY 2004 monitoring data. Bill Trush of McBain & Trush outlined their efforts in 1) mapping of 1929 aerial photos, 2) unimpaired flow analyses, and 3) piezometers placement for groundwater monitoring. Chris Hunter reviewed his progress with the fish monitoring. He discussed the conditions of the stream (relatively high ramping rates and peaks on Lee Vining Creek) and some of the things he would like to accomplish, including determining whether the current fish sampling sites are representative of the whole system, beginning a fish movement study, and using otoliths to age fish.

The group began discussions of termination criteria and SWRCB explained how Stream Scientists can recommend changes. Trush explained how he may prefer applying good science to the hydrographs with the understanding that restoration will occur in the future. Hunter described the current termination criteria as vague and would prefer something along the lines of biomass per unit area.

An overview of the runoff recap was also presented at this meeting. LADWP explained that 380 cfs was held in Rush Creek for approximately 21 hours and that peak flows on Lee Vining Creek reached 150 cfs. Attendees included those shown in **Table 2**.

Table 2
Mono Basin November Meeting Attendees

Name	Agency/Affiliation
Lisa Cutting	Mono Lake Committee
Greg Reis	Mono Lake Committee
Peter Vorster	Mono Lake Committee consultant
Bill Trush	McBain and Trush
Chris Hunter	Hunter
Ross Taylor	Hunter
Jim Canaday	SWRCB
Brian Tillemans	LADWP
Dave Martin	LADWP
Mark Hanna	LADWP
Bob Prendergast	LADWP
Milad Taghavi	LADWP
Cathy Greenman	LADWP consultant
Jan Goldsmith	KMTG
Charlotte Rodrigues	LADWP (phone)

Activities Planned for Runoff Year 2005-06

Restoration Activities

Streams

Sediment Bypass at Lee Vining Intake
The design and construction of the sediment bypass at the Lee Vining Intake was completed in the fall of 2004.

Peak Flows, Flow Duration, and Ramping Study
Peak flows, duration, and ramping rates for Rush Creek will be studied more thoroughly during RY 2005-06 if the Rush Creek peak flow variance is granted by the SWRCB. This study will focus on further connecting the hydrology to the geomorphology and biology of the system..

Waterfowl

Channel Rewatering:
Plans to rewater the channels described in the waterfowl plan have been postponed until further notice based on recommendations from the Stream Scientists (see discussion above).

Monitoring

Streams

Dr. Trush will continue the stream channel monitoring program on Rush, Lee Vining, Parker, and Walker creeks. The following specific items will be included in the RY 2005 monitoring:

Post-Transition Flows
Data collection for the determination of post-transition flows and ramping will continue if stream restoration flows are released from Grant Lake. These data support the study that will focus on integrating the physical processes, riparian plant dynamics, and fish habitat into regulated hydrographs that address the range of water year types.

Evaluate Groundwater Dynamics
Baseline groundwater elevations that did not result from high flow releases during RY2003 will now be compared to those recorded during RY 2004, so that in subsequent years' monitoring, higher groundwater elevations would be attributable to the 3D floodplain construction and side-channel re-opening. Soil moisture data monitoring will also be conducted.

Riparian Planting Experiments
Monitoring of plant survival at the Narrows Pilot project will continue, and conditions that favor natural riparian plant recruitment at the 3D Floodplain site and the 8-Channel site will be evaluated.

Sediment Deposition Experiments

Monitoring of sediment deposition on the floodplains in Lower Rush Creek will be monitored to assess the adequacy of the peak flow duration.

LWD Mobilization Experiments

Monitoring of the mobilization of large woody debris (LWD) will be conducted to check the adequacy of the peak flow magnitude.

Temperature Monitoring

Temperature monitoring will be continued for the 12 thermographs in the system.

Fishery

Fish Monitoring

Chris Hunter and his fish monitoring team will utilize the same monitoring sites and methods for Rush, Lee Vining, Parker and Walker creeks that were used in the past. Collection of scale and otolith samples will be continued to better estimate ages of brown and rainbow trout in Rush and Lee Vining creeks.

Fish Movement Study

The fish movement study detailed in last year's report will be conducted by Chris Hunter beginning in RY 2005-06 for the purpose of determining:

1. Whether young fish move into the MGORD from Rush Creek and remain there growing to larger sizes than they would attain in main Rush Creek;
2. Whether larger fish move out of the stream into the MGORD seeking better habitat conditions;
3. Whether mature fish from Rush Creek move into Parker and Walker creeks to spawn, or whether these streams are dependent upon resident spawners to sustain their brown trout populations;
4. Whether fish hatched in Parker and Walker usually recruit to the Rush Creek fishery.

In-Stream Flow Study

The monitoring team will conduct an interagency In-Stream Flow Study to determine future flow regimes that are suitable for the various life stages of the trout fishery.

Waterfowl

Dr. White will continue to oversee the waterfowl monitoring program. This program consists of the following components:

- Limnology: Dr. Jellison and Dr. Melack will continue limnological monitoring in the Mono Basin.
- Waterfowl Population Surveys: Deborah House will perform the waterfowl population surveys in the Mono Basin.

- Aerial Photography: LADWP will conduct aerial photography of the Mono Basin in a GIS-compatible format.
- Hydrology: LADWP will continue to monitor the elevation of Mono Lake and collect hydrologic data in the Mono Basin.

Informational Meetings

LADWP will host two meetings with the researchers and interested parties to discuss restoration and monitoring activities in the Mono Basin. As in previous years, the meetings will be held prior to and after the field season. The first meeting was held on April 20, 2005. The second meeting will be held in November or December, 2005.

Physical Projects Remaining

Streams

Intake Facilities on Walker and Parker Creeks

The control facilities on Walker and Parker creeks will be reconfigured to allow control of the amount of flow being released to the creeks. These facilities need to be designed and constructed. The designs and construction are expected to be completed within five years.

Lee Vining – Grant Lake Conduit Siphon

A retrofit of the Lee Vining – Grant Lake Conduit Siphon will be evaluated to ensure that it can operate as needed to comply with Order 98-05.

Mono Gate Control Facility

The Mono Gate Control Facility will be evaluated to determine the feasibility of a retrofit to better control the division of flows between lower Rush Creek and West Portal.

Waterfowl

Channel Rewatering

Plans to rewater the channels described in the waterfowl plan have been postponed until further notice based on recommendations from the Stream Scientists (see discussion above).

Section 2

Mono Basin Operations
For Runoff Year
2005-06

Mono Basin Operations for Runoff Year 2005-2006

The April 1st Mono Basin Forecast for the 2004-05 Runoff Year is 161,500 acre-feet, or 132% of normal (using the 1951-2000 average of 122,435 acre-feet). The May 1st forecast was not performed this year for several reasons including: April precipitation was only slightly above the median values that LADWP's forecast model assumes; no agency performed snow surveys for May. It is assumed that the May 1 forecast would be substantially the same as the April 1 forecast, and the May 11, 2005 plan titled "Preliminary Mono Basin Operations for Runoff Year 2005-06" (attached) remains unchanged.

As discussed during the April 2005 Mono Basin Restoration Tracking Meeting held in Sacramento, California, on April 20, 2005, LADWP will attempt to accommodate the Stream Scientists' request to operate a one-time experimental hydrograph during peaking operations on Lower Rush Creek. If the variance is granted, the Rush Creek peak operation will begin following the peak on Lee Vining Creek. LADWP will ramp streamflows up by 35% per day to a peak flowrate of 400 cfs, 350 cfs from the MGORD and 50 cfs from augmentation. This peak flowrate will be sustained for eight days. Flows will then be ramped down for 15 to 18 days at approximately 10% per day, until the flowrate is near 100 cfs. Flows will be held at approximately 100 cfs for several weeks into August. Note that at anytime LADWP engineering staff believes that significant damage may occur as a direct result of peaking operations, peak operations will be halted and flows will be reduced to a level deemed safe.

May 11, 2005

Ms. Victoria Whitney, Chief
Division of Water Rights
State Water Resources Control Board
1001 I Street
Sacramento, California 95812

Dear Ms. Whitney:

Subject: Preliminary Mono Basin Operations for Runoff Year 2005-06

The Mono Basin forecast for the Runoff Year 2005-06 (April through March) is 161,800 acre-feet, or 132 percent of normal (using the 1951-2000 average of 122,557 acre-feet). This year is thus classified as "Wet–Normal" according to the provisions of the State Water Resources Control Board (SWRCB) Order 98-05.

To meet SWRCB requirements, the Los Angeles Department of Water and Power (LADWP) intends to follow the guidelines shown in the attachment, with the following modifications: If the SWRCB grants the one-time variance request outlined in LADWP's letter dated May 3, 2005, Rush Creek peak operations will follow the proposed experimental hydrograph. Otherwise, Rush Creek peak operations will follow the guidelines. As well, if the variance is granted, Mono Basin exports will be allocated over the August-to-March period, instead of the entire year. Otherwise, exports will most likely begin in September.

Grant Lake Reservoir Storage: On April 1, 2005, storage in the Grant Lake Reservoir was approximately 15,000 acre-feet, less than one-third of the total reservoir capacity of 47,500 acre-feet. This low level and the projected fluctuation of the reservoir create some concern for the safe operation of the Grant Lake Reservoir Marina for recreational purposes. As addressed below, operational decisions for Mono Basin exports are influenced by this condition and are intended to assist in raising the storage in Grant Lake Reservoir during the recreational period from May to October.

Rush Creek: SWRCB Decision 1631 and Order 98-05 provide base and peak flow requirements for Rush Creek, as shown in the attachment. LADWP intends to abide by those requirements, including the provision that "…the instream flow requirements shall be (those specified in the attachment) or the inflow into Grant Lake Reservoir from Rush Creek, whichever is less." (Decision 1631, page 198). It is expected that on certain days instream flows may be lower than the inflow to Grant Lake Reservoir. Every effort will be made to adjust flows daily to minimize this occurrence. Again, if the one-time variance to operate the experimental peak on Rush Creek is granted by the SWRCB, LADWP will operate accordingly. Otherwise, LADWP will follow the guidelines in the attachment.

Lee Vining Creek: SWRCB Decision 1631 and Order 98-05 provide base and peak flow requirements for Lee Vining Creek. LADWP intends to abide by those requirements, and operate as shown in the attachment. The operation includes diversion of flows in excess of the 54 cfs base flow requirement from April through September, and diversion of flows in excess of 40 cfs from October through March. LADWP will use its facilities to effect this diversion and will make every effort to maintain the required flow. Although the recently upgraded facility should provide greater reliability, it has yet to be operated and calibrated through an entire runoff year. As such, diversion of water this year may result in a short-term flow of less than the required 54 cfs during the April through September period and 40 cfs during the October through March period. LADWP will review Lee Vining Creek flow information daily and make adjustments as necessary to minimize the occasions and duration of releases below the requirements. There will be some precautionary measures taken during periods of diversion as LADWP staff familiarizes themselves with the new facility and also prepares for augmentation of Rush Creek flows.

Walker and Parker Creeks: Walker and Parker Creeks will be managed as shown in the attachment, in accordance with SWRCB Decision 1631 and Order 98-05.

Mono Lake Elevation: On April 1, 2005, Mono Lake's water surface elevation measured approximately 6,381.8 ft amsl (US Geological Survey datum). At this time, LADWP has yet to receive all required data from Southern California Edison to predict Mono Lake elevations throughout the runoff year. As such, the Mono Lake elevation forecast for Runoff Year 2005-06 will be forwarded under separate cover.

Mono Basin Exports: In accordance with Decision 1631, LADWP is permitted to divert up to 16,000 acre-feet during the runoff year. LADWP plans to export the allowed 16,000 acre-feet during the course of the runoff year, with the exception that exports will not occur until the Rush Creek peaking operation is completed. In the long term, LADWP plans to divert the allowed amount in an even, year-round pattern. The operations this year reflect the Grant Lake Reservoir considerations discussed earlier.

Peak Flows: The expected magnitude and timing of the peak flows in Lee Vining, Walker, and Parker Creeks were generated by a predictive model and are shown below:

MAGNITUDE AND TIMING OF PEAK FLOWS IN LEE VINING, WALKER, AND PARKER CREEKS

Creek	**Magnitude**	**Timing**
Lee Vining	323 cfs	June 9, 2005
Walker	44 cfs	June 13, 2005
Parker	59 cfs	June 18, 2005

The model uses regression analysis of historical data to predict future events. Since the actual values depend heavily on ambient temperatures that are difficult to predict with any degree of certainty, it is more than likely that the values in the above table are not accurate. It is intended that they be used as an indicator of magnitude and timing of the peak flows. These predictions are based on the 2005 Mono Basin forecast and assume median precipitation for the following six months.

If you have any questions, please contact Dr. Mark Hanna at (213) 367-1289.

Sincerely,

Original Signed Richard F. Harasick for

Thomas M. Erb
Director of Water Resources

MH:mm

Enclosure

c: attached mailing list
Dr. Mark Hanna

ATTACHMENT

Mono Basin Operations, Guideline E

Year Type:…………………………..……………………………… WET-NORMAL
Forecasted Runoff in acre-feet...……………………………………..130,670 – 166,700

Lower Rush Creek

Base Flows:

	April	May–Jul	Aug–Sep	Oct-Mar
Flow (cfs)	50	100	50	45

Minimum base flows are 47 cfs for Apr-Sep and 44 cfs for Oct-Mar, or the inflow to Grant Lake, whichever is less (flows listed above are for Mono Lake maintenance water). However, if Grant Lake inflow is less than the dry year base flow requirements under Guideline A, dry year requirements apply. If Grant Lake storage drops below 11,500 acre-feet (7,089.4' elevation), base flow requirements for a dry-year under Guideline A also apply (D-1631, p 197-198).

Peak Flows: - 400 cfs for 5 days followed by 350 cfs for 10 days (see augmentation).

Ramping:
- Begin ramping on June 1st (rule of thumb). Note peak operations will take 42 days, so timing this with peak flows in P/W Creeks, with fish movement, and cottonwood germination is beneficial. If augmenting, begin ramping as Lee Vining Creek peaks.
- 10 percent daily change during ascending and descending limbs, or 10-cfs, whichever is greater.

Lee Vining Creek

Base Flows:

	Apr–Sep	Oct-Mar
Flow (cfs)	54	40

Minimum base flows are those specified above or the stream flow at the point of diversion, whichever is less.

Peak Flows: - Allow peak flow to pass through diversion facility.

Ramping:
- Begin ramping on May 15th (rule of thumb).
- 20 percent daily change during ascending and 15 percent during descending limbs, or 10-cfs, whichever is greater.

Diversions:
- Divert flows in excess of base flows until May 15th (rule of thumb).
- Diversions may resume 15 days after peak flow (rule of thumb); divert all flows in excess of base flows.
- If augmenting Rush Creek, begin 14 days after peak flow. Following augmentation resume flow-through conditions for 10 days. Diversions may resume following the 10-day flow-through period.

Augmentation:
- If not spilling Grant Lake, augment flows in Rush Creek with up to 50-cfs from Lee Vining Creek for a max of 5 days. Augmentation should begin 15 days after peak flow in Lee Vining Creek.

Parker and Walker Creeks

Flow-through conditions for entire year.

Exports

4,500 acre-feet scenario – Maintain 6 cfs export throughout the year.
16,000 acre-feet scenario – Maintain 23 cfs export except during peak flow operations in lower Rush Creek. During this time, exports should be zero.

Mono Basin Distribution List
May 2005

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Section 3

Fisheries Monitoring Report for
Rush, Lee Vining, Parker, and Walker Creeks
2004

Fisheries Monitoring Report
for
Rush, Lee Vining, Parker and Walker creeks
2004

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Prepared for:	Los Angeles Department of Water and Power
Date:	May 2005

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Executive Summary

This report presents the results of the sixth year of fish population monitoring for Rush, Lee Vining, Parker, and Walker creeks pursuant to State Water Resources Control Board (SWRCB) Decision #1631 and Orders WR 98-05 and WR 98-07. The 2004 field season occurred between August 28th and September 9th. Mark-recapture electro-fishing techniques were utilized to estimate trout populations in four sections of Rush Creek and two main stem sections of Lee Vining Creek. One of the Rush Creek sections sampled with the mark-recapture methodology was within the Mono Gate One Return Ditch (MGORD), which generated the first population estimate for this section since 2001. Fish population estimates for two Lee Vining Creek side-channels and Parker and Walker creeks were made using electrofishing depletion methods. Scales (120 samples) and otoliths (eight samples) were collected to estimate fish ages.

Density Estimates for Age-1 and older Brown Trout

In all sections of Lee Vining Creek, estimated densities (number per hectare) of age-1 and older brown trout increased in 2004 after experiencing declines in 2003. For the Upper Lee Vining side-channel the 2004 density estimate was the highest ever recorded for this section.

For the three Rush Creek sections sampled annually (Co Road, Lower, and Upper), the estimated densities of age-1 and older brown trout decreased from levels recorded in 2003. Both the Upper and Lower Rush Creek sections recorded the lowest densities for the six years of sampling, with the most dramatic decrease occurring in Lower Rush Creek. The MGORD estimate for 2004 was nearly 50% lower than the previous estimate generated in 2001; however the relative condition factor of larger brown trout (>250 mm in total length) was higher in 2004.

In Walker Creek, densities of age-1 and older brown trout increased slightly in 2004 from the 2003 estimate (which was a dramatic, nearly four-fold, increase from 2002). In contrast; Parker Creek's 2004 density estimate dropped by more than 50% of the 2003 estimate.

Density Estimates for Age-0 Brown Trout

Estimated densities of age-0 brown trout were higher in 2004 than in 2003 for two of the Lee Vining sections (Upper side-channel and Lower main-channel). However, in the other two sections (Lower side-channel and Upper main channel) the estimated densities of age-0 brown trout were lower in 2004 than in 2003. In the Upper main-channel, the 2004 estimate was the lowest recorded during the six years of monitoring.

Estimated densities of age-0 brown trout in the Upper Rush Creek section for 2004 increased by 38% from the all-time low recorded in 2003. In contrast, estimated densities of age-0 brown trout in the other two sections (Lower and Co. Road) dropped in 2004 to the lowest densities ever recorded for these two sections.

In Walker Creek, the estimated density of age-0 brown trout for the 2004 season was the highest ever recorded for this section. Conversely, the 2004 density estimate of age-0 brown trout in Parker Creek dropped by 65% of the 2003 estimate to the lowest ever recorded for this study section.

Density Estimates for Age-1 and older Rainbow Trout

Estimated densities of age-1 and older rainbow trout declined in all sections of Lee Vining Creek from 2003 to 2004 (a continued downward trend after dramatic declines between 2003 and 2002). In all Rush Creek sections, the estimated densities of age-1 and older rainbow trout dropped slightly in 2004 from the 2003 estimates. Rainbow trout numbers have always comprised a minor portion of the Rush Creek trout population.

Density Estimates for Age-0 Rainbow Trout

The numbers of age-0 rainbow trout captured were extremely low in 2004 in all sample sections, except for the Lower Lee Vining side-channel section. This side-channel recorded the highest density estimate for the six years of sampling. In all other sections, the numbers of age-0 rainbow trout were so low that not enough fish were captured to generate estimates either by mark-and-recapture or by depletion. No age-0 rainbow trout were sampled in the Upper Lee Vining side-channel section.

Standing Crop Estimates of Brown Trout

Estimates of brown trout standing crops (kg/hectare) dropped from 2003 to 2004 in all sections of Rush Creek, with the Lower Rush Creek section experiencing the largest drop of 40%. In contrast to Rush Creek, brown trout standing crops increased in all of the Lee Vining sections. In Parker Creek, the estimate of brown trout standing crop dropped by 48% (from 144.1 kg/hectare in 2003 to 75.2 kg/hectare in 2004). In Walker Creek, the estimated standing crop for 2004 dropped slightly (10%) from the 2003 estimate.

Relative Weight and Condition Factor

The relative weights and condition factors of brown trout between 150-250 mm in all study sections don’t appear to be varying much from year-to-year. Condition factors remain close to or slightly above 1.0 for all sections. For most sections, the highest condition factor scores were recorded in 1999.

Scale and Otolith Analyses

For a second straight year, the aging of scale samples found that very few trout in Rush Creek were living longer than age-3. The exception to this was the MGORD section of Rush Creek. Of the 120 scale samples taken in 2004, 109 were from fish sampled in the MGORD. One large brown trout (443 mm in total length) that died during the sampling process had an otolith reading of 11 years old. Numerous MGORD fish were estimated to be four to five years old, while 21 other fish were thought to be at least five to six years old but their scales had regenerated to such an extent that they were unreadable. For several MGORD fish aged at two and three years old, the scales showed extremely fast growth.

There was generally good agreement between ages interpreted from scales and otoliths, especially for younger fish. However, it was not possible to compare ages estimated from scales to ages estimated from otoliths for older fish due to regeneration of scales. Further work is recommended to confirm scale aging for older fish. In two instances the scales had regenerated and were unreadable, but the otoliths aged the fish at five and 11 years of age. When average lengths of similar-aged fish were compared between Rush and Lee Vining creeks it appeared that fish in Lee Vining Creek grew at faster rates.

Termination Criteria

Estimated fish populations for Rush and Lee Vining Creeks were compared to the termination criteria adopted by the SWRCB. The termination criteria are:

1. Lee Vining sustained catchable brown trout averaging 8-10 inches in length. Some trout reached 13 to 15 inches.

2. Rush Creek fairly consistently produced brown trout weighing ¾ to 2 pounds. Trout averaging 13 to 14 inches were also regularly observed.

In 2004, it was estimated that Lee Vining Creek supported 17 to 20 trout per 100 m of channel length or 291 to 389 trout per hectare that were 200 mm (~8 inches) and longer in the main channel and about seven to 11 trout per 100 m or 160 to 237 trout per hectare in side-channel habitats. Most of these larger fish were brown trout. The numbers and densities of larger trout in Lee Vining Creek decreased in 2004, continuing a decline noted in the previous years; thus the stream has still not met termination criteria.

In the three annually sampled Rush Creek sections, only four trout longer than 300 mm (~12 inches) were captured (all were brown trout) during 2004. Only one of these fish was over 300 g (0.66 pounds), but that fish was 541 mm and 1,944 g (4.3 pounds). Although not considered a natural section of Rush Creek or counted towards meeting termination criteria; 97 trout greater than 300 mm in total length were sampled in the MGORD section. These larger trout comprised 21% of the 454 individual fish sampled in the MGORD.

The SWRCB requires monitoring fish populations to determine if existing termination criteria are being met and suggested that these existing termination criteria be evaluated. The SWRCB recommended that additional quantitative termination criteria might be developed for Rush and Lee Vining Creeks and that quantitative termination criteria might also be developed for Parker and Walker creeks. The lack of historical (pre-diversion) fish population data makes it very difficult to objectively evaluate the existing termination criteria with confidence.

We recommend that fish population data continue to be collected for several additional years, so existing termination criteria can be scientifically and statistically evaluated. As part of these evaluations we will also consider additional or alternative termination criteria if we believe additional or alternative criteria would allow us to more objectively assess the status of these fish populations. Additional data collection will also allow us to explore relationships between trout abundance and physical parameters, such as stream flows, water temperatures, and stream channel characteristics, and to better determine the movement patterns and age-class structure of trout.

We have begun to compile and analyze flow and water temperature data. These additional data will help in determining seasonal use of habitats in the system and estimate mortality rates by age and season to better assess termination criteria. We are currently evaluating termination criteria based upon standing crop (biomass per area) because we suggest estimates of this parameter would be more stable, quantifiable, and could potentially be adjusted as habitat conditions improve. We are also evaluating population size structure as possible termination criteria to be used in conjunction with standing crop estimates.

Introduction

This report presents the results of the sixth year of fish population monitoring for Rush, Lee Vining, Parker, and Walker creeks pursuant to State Water Resources Control Board (SWRCB) Decision #1631, Orders WR 98-05 and WR 98-07, and the subsequent Settlement Agreement negotiated among the parties. Fish population monitoring will continue until the streams have met termination criteria included in the Settlement Agreement. These termination criteria describe the presumed pre-project conditions for fish population structure:

1. Lee Vining Creek sustained catchable brown trout averaging 8-10 inches in length. Some trout reached 13 to 15 inches.
2. Rush Creek fairly consistently produced brown trout weighing ¾ to 2 pounds. Trout averaging 13 to 14 inches were also regularly observed.

In addition to these criteria, Order 98-07 states the monitoring team will develop and implement a means for counting or evaluating the number, weights, lengths and ages of fish present in various reaches of Rush Creek, Lee Vining Creek, Parker Creek and Walker Creek. No termination criteria were set forth for Parker and Walker Creeks, tributaries to Rush Creek.

The Settlement Agreement states that the monitoring team will consider young-of-year (age-0) production, survival rates between age classes, growth rates, total fish per mile and any other quantified forms as possible termination criteria, although the Settlement Agreement does not compel the choice of any one form.

This report provides fish population data mandated by the Orders and the Settlement Agreement. In addition we make recommendations for additional termination criteria. Fish length data is reported in millimeters (mm) in this report. For those not used to working in the metric system, an easy numerical reference point is 200 mm which is approximately eight inches. An eight-inch trout is often referred to as the minimum size of a “catchable” trout.

Study Area

The same three population estimate sample sections in Rush Creek (County Road, Lower, and Upper), the four Lee Vining Creek sections (Lower and Upper main, B-1 and A-4 side-channels), and the Walker and Parker Creek sections sampled in previous years were again sampled between August 28th and September 9th of 2004 (Figure 1). In Rush Creek, the MGORD was sampled in 2004 for the first time since 2001.

While we expressed previous concerns (Hunter et al. 2001) about the dynamic nature of the stream channels (particularly in Rush Creek) making sample sections dynamic, it was agreed we would maintain existing sample sections after a site visit with representatives from Los Angeles Department of Water and Power (LADWP) in 2001.

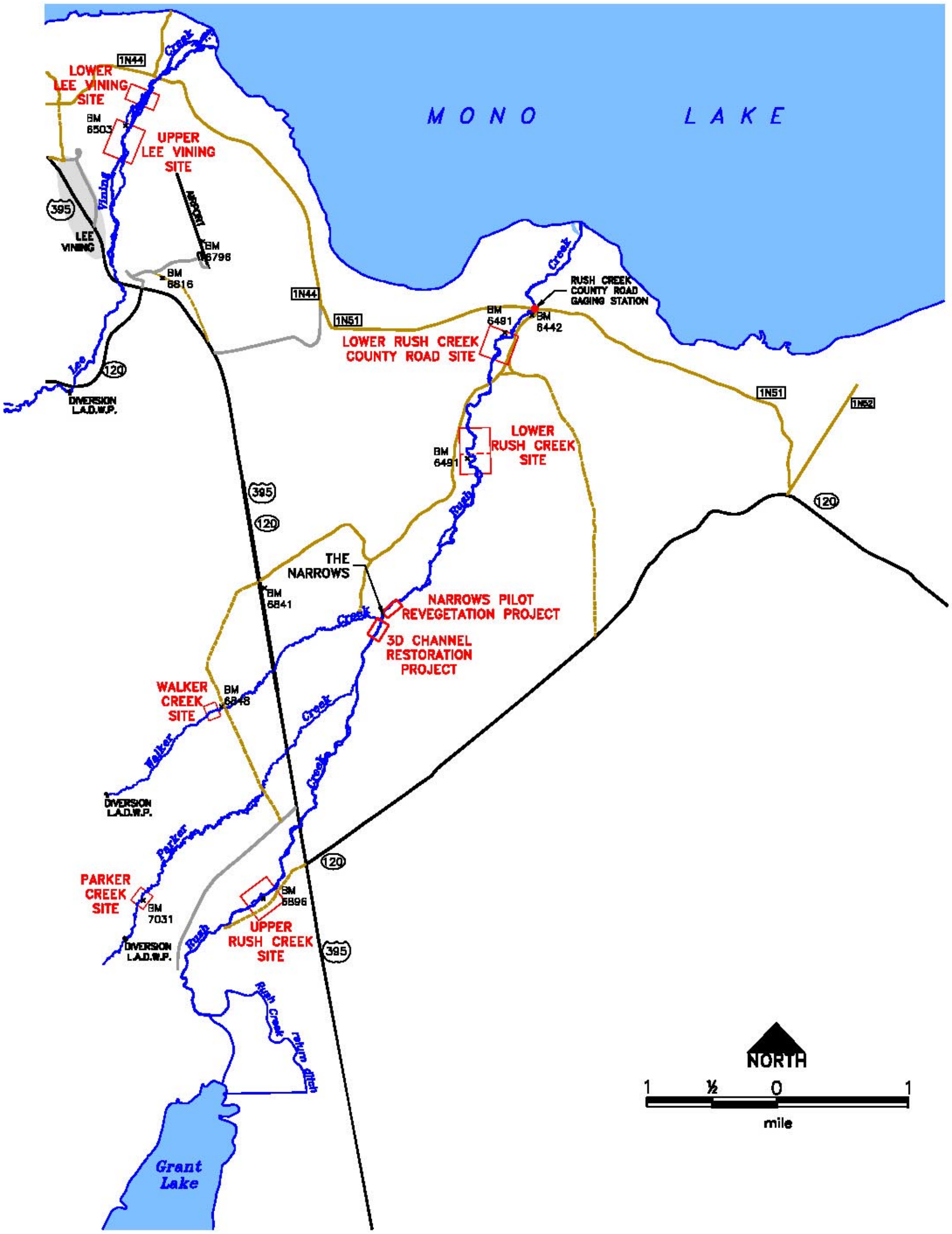


Figure 1. Map of Mono Basin study area with fish sampling sites displayed (from McBain and Trush 2000).

Sample sections experienced negligible channel changes from 2003 to 2004 with the exception of two Rush Creek sections – the County Road section narrowed by an average of 1.1 meters and the Upper Rush section widen by an average of 0.6 meters (Table 1). Although the channel within the County Road section appeared noticeably narrower and deeper, the changes noted in Table 1 may also be the result of where the channel widths were randomly measured. Section dimensions for all sample years (1999-2004) are presented in Appendix A.

Table 1. Total length (m), average wetted width (m), and total surface area of sample sections in Rush, Lee Vining, Parker, and Walker creeks sampled between August 28th and September 9th, 2004. Values for 2003 provided for comparisons. **Bold font** designates noticeable changes in average channel widths between 2004 and 2003.

Section	**Length (m) - 2004**	**Width (m) - 2004**	**Area (m^2) - 2004**	**Length (m) - 2003**	**Width (m) - 2003**	**Area (m^2) - 2003**
Rush – County Road	813	**7.3**	5934.9	813	**8.4**	6,829.2
Rush - Lower	405	6.8	2,754.0	405	6.9	2,794.5
Rush – Upper	430	**8.0**	3,440.0	430	**7.4**	3,182.0
Rush - MGORD	2,230	12.0	26,760.0	N/A	N/A	N/A
Lee Vining – Lower main	155	4.8	744.0	155	4.8	744.0
Lee Vining - Lower-B1	195	4.8	936	195	4.8	936
Lee Vining – Upper main	330	5.8	1914	330	5.8	1914
Lee Vining - Upper-A4	201	4.2	844.2	201	4.2	844.2
Parker	98	2.2	215.6	98	2.2	215.6
Walker	100	1.8	180.0	100	1.8	180.0

Stream flows in Rush Creek differed from the previous years of record, primarily due to the peak flow of 383 c.f.s. released for approximately 21 hours on June 11th to “test” the flow capacity of the reconfigured MGORD (Figure 2). Otherwise the base flow for most of the year, including the fish sampling period, in Rush Creek was similar to previous years. Stream flows in Lee Vining Creek below the intake were fairly similar to the previous five years of the fisheries monitoring project, except for the peak flow of 150 c.f.s that occurred on May 28th was the smallest (magnitude) peak flow to occur during the six years of fisheries monitoring (Figure 3). For Lee Vining Creek, the blue line on the graph represents the amount of water that flowed down the stream channel to Mono

Lake. Flows in Rush Creek are obviously more regulated than flows in Lee Vining as evidenced by the very static base flows between 45 to 52 c.f.s. and very few days when the flows exceed these base flows.

We have begun to summarize stream flow and temperature data to assess potential relationships between these two variables and fish abundance, growth, survival, and condition parameters. Water temperature data from 1999 to 2004 indicated that diurnal water temperatures in Rush Creek did not vary much in the MGORD, but increased in a downstream direction. Diurnal fluctuations and maximum daily stream temperatures increased dramatically between the Narrows and the County Road compared with temperatures between the MGORD to the Narrows.

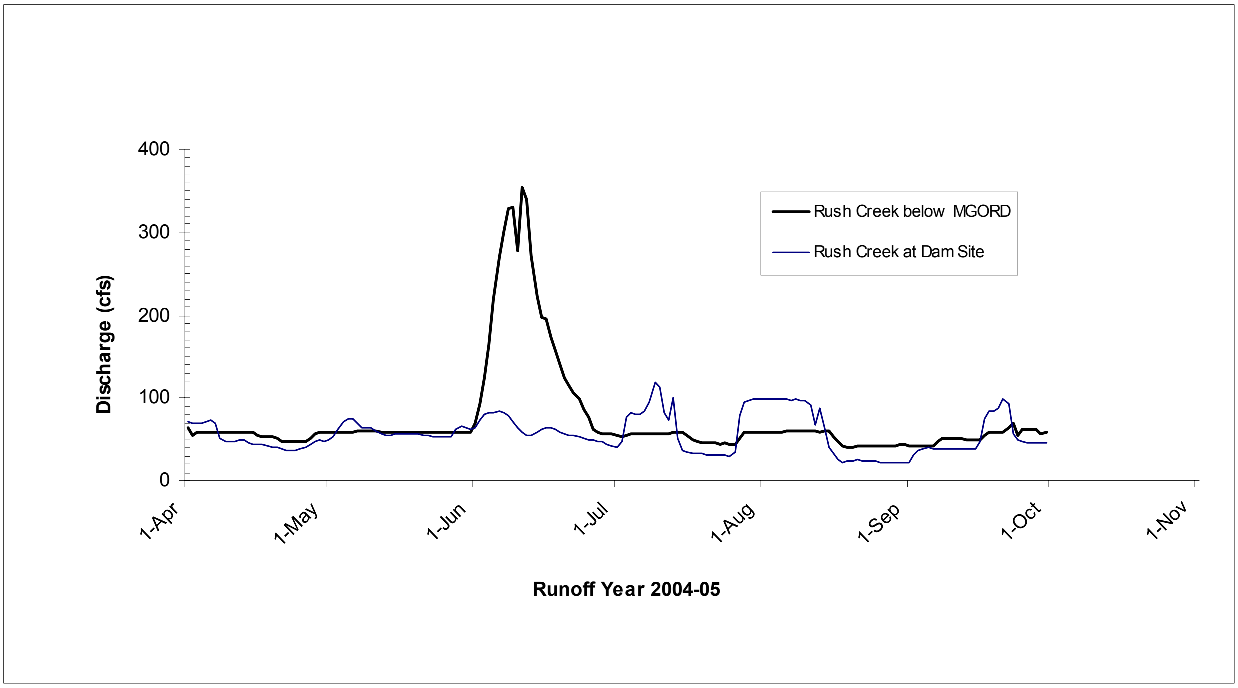


Figure 2. Daily stream flows (cubic feet per second; c.f.s) in Rush Creek at Grant Reservoir dam site and below the MGORD between April and September 2004. Data were provided by Los Angeles Department of Water Power.

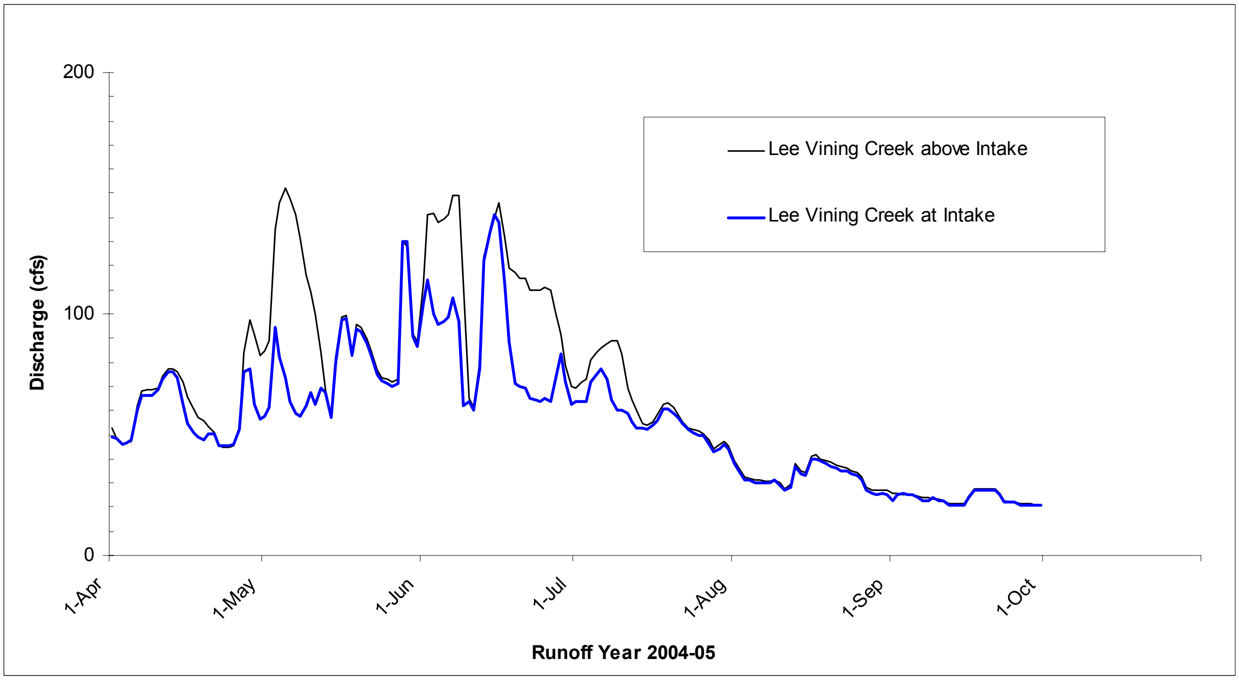


Figure 3. Daily stream flows (cubic feet per second; c.f.s) in lower Lee Vining Creek between April and September 2004. Data were provided by Los Angeles Department of Water Power.

Methods

Fish Population Estimates

Sampling for generating the fish population estimates occurred during the late summer between August 28th and September 9th, 2004. Mark-recapture estimates were made in the County Road, MGORD, Lower, and Upper sections of Rush Creek. For mark-recapture estimates in Rush Creek, fish were captured using a Smith-Root® 2.5 GPP electro-fishing system that consisted of a Honda® generator powering a variable voltage pulsator (VVP) that had a rated maximum output of 2,500 watts. This unit was set at 30 or less pulses per second to reduce risk of injury to fish and voltages were set to allow for capture of fish without harming fish. Obtaining this desired response in fish usually resulted in voltages ranging from 300 to 500 and amperes from 0.3 to 1.5.

During mark-recapture electro-fishing, the generator and VVP unit were transported downstream in a small barge. An insulated cooler with two battery-powered aerators was carried in the barge to transport captured fish. A person operating a mobile anode and a dip netter fished each half of the stream in a downstream direction (total of two anode operators and two dip netters). The fifth crewmember walked the electro-fishing barge downstream and monitored the generator, electro-fishing unit, and condition of captured fish in the live-well, and controlled a safety shut-off switch. All netted fish were placed in the insulated cooler within the barge shortly after capture.

Mark-recapture estimates were also made in the main channel portions of Upper and Lower Lee Vining Creek sections; however the small size of the channel prevented the use of the electro-fishing barge. Depletion estimates were made in one sample section within each of Parker Creek and Walker Creek and in the two side-channels of Lee Vining Creek associated with the Lower and Upper sections. For depletion estimates and the mark-recapture estimates in Lee Vining Creek, Smith-Root® BP backpack electro-fishers (Models 12B and LR-24) were used to capture fish.

Two backpack shockers were used when sampling the Lee Vining main-stem and side-channel sections, whereas a single backpack shocker was used in each of the Walker Creek and Parker Creek sections. At least one dip-netter per electro-fisher netted fish stunned by that shocker. Another crew member served as a backup dip-netter and carried a five-gallon live bucket equipped with an aerator in which all captured fish were placed immediately after capture.

To meet the assumption of closed populations for sampling purposes, all sample sections, except the County Road and MGORD sections, were blocked at both ends prior to sampling. Block fences were not placed at the boundaries of the County Road and MGORD sections; however, these sections were long enough (813 m and 2,230 m, respectively) that effects of movements at the ends of the sample sections should have been low in proportion to the number of fish in the entire section. In the Upper and Lower Rush Creek sections and main channels of the Upper and Lower Lee Vining Creek sections, 12 mm mesh hardware cloth fences were installed at the upper and lower boundaries of the sections. These hardware cloth fences were installed by driving fence posts (metal t-posts) at approximately two-meter intervals through the bottom portion of the hardware cloth approximately 15 cm from its bottom edge. Rope was then strung across the top of each fence post and anchored to fence posts or trees on each bank. The hardware cloth was held vertically by wiring the top of the cloth to this rope with baling wire. These fences were installed prior to the marking run and maintained in place until after the recapture effort was completed. Fences were cleaned and checked at least once daily, and usually twice daily, to ensure they remained in place and for enumerating any dead fish between mark and recapture sampling.

Overall, block fences were maintained for the duration of time between the marking and recapture electro-fishing runs because a single field technician was employed to specifically maintain these fences. However, there was still some difficulty in maintaining the block fences at either end of the Upper Rush Creek Section. During sampling runs, the lower block fence would frequently clog with debris dislodged by five people wading in the channel. Even though one individual was dedicated to cleaning the lower block fence during both sampling runs, a portion of the fence at the lower boundary of the Upper Rush Creek Section went down for a short time during the recapture sampling run. A portion of the upper boundary fence at Upper Rush Creek also went down several times over night from accumulation of leaf debris after periods of high wind. Therefore, the assumption of population closure during the estimates was not fully met for Upper Rush Creek. However, these fences were effective most of the time between the marking and recapture runs. The other three sets of block fences were successfully kept up for the entire seven-day period between mark and recapture electro-fishing runs (lower Rush Creek and the two main channel sample sections in Lee Vining Creek). The implications of this assumption violation are presented in the Discussion. For the side-channel portions of the Upper and Lower Lee Vining Creek sections and the sample sections in Parker and Walker creeks 12 mm mesh block seines were placed at sample section boundaries during depletion efforts.

All captured fish were anesthetized, measured to the nearest mm (total length), and most were weighed to the nearest gram. Data were entered onto both data sheets and into a hand-held personal computer (Compaq iPAC®) in the field. Scale samples were taken from a sub-sample of fish (see “Age-Growth Estimates” section below) for age determinations.

All fish captured in the study sections employing the mark-recapture estimator methodology were given a clip for identification during the recapture electro-fishing run. The upper caudal fin was clipped to mark fish in the County Road section of Rush Creek, the Upper Rush Creek section, and the Upper Lee Vining Creek main channel section. The anal fin was clipped to mark fish in the Rush Creek MGORD. The lower caudal fin was clipped to mark fish in the Lower Rush Creek section and the Lower Lee Vining Creek section. When clipping a fin, scissors were used to make a straight vertical cut from the top, or bottom, of the fin approximately 1-3 mm deep at a location about 1-3 mm from the posterior edge of the fin.

During September 2002, we tagged 101 brown trout longer than 225 mm with individually numbered Floy® anchor tags within our five sample sections in the Rush Creek drainage. We recorded the identification numbers for any tag-recaptures we found during 2004 sampling.

Population and biomass estimates were made for all mark-recapture estimates using an updated version of Montana Fish, Wildlife and Parks' Fisheries Plus analysis package (version 1.10). All estimates were generated using this program and employed the modified Peterson estimator (Chapman 1951, as cited in Ricker 1975).

Length-Weight Regression

Length-weight regressions (Cone 1989) were calculated for brown trout in each section of Rush Creek by year to assess differences in length-weight relationships between sections and years. Log_{10} transformations were made on both length and weight prior to running regressions. Relative condition factors were estimated using standard methodologies (Anderson and Gutreuter 1983; LeCren 1951).

Aging and Age-Growth Estimates

Scale samples were taken from up to ten rainbow and ten brown trout within each 10 mm length group in the MGORD section and from all fish that received a floy-tag. Scales lay down annular marks making it possible to estimate a fish's age. It is important to obtain scales that develop as early as possible to ensure that the first year's annular mark is visible. Thus, scale samples were removed from each fish between the dorsal and adipose fins and about five to seven scale rows above the lateral line, since this is the area of a trout's body where scales first form. Scale samples were pressed onto soft acetate using a high-pressure scale roller. A microfiche reader set at 50X magnification was used to view the acetate impressions and annulus checks were recorded.

Otoliths, an inner ear bone, can also be used to estimate a fish's age and these structures have usually been found to be the most reliable growth structure on trout for interpreting their age (Simkiss 1974). Unfortunately, otoliths can only be obtained by sacrificing a fish. Thus, we removed both otoliths and scale samples from all incidental mortalities associated with sampling to verify scale-aging procedures. All otolith-scale pairs were assigned a unique sample number to ensure they could be matched after analysis. Otolith samples were prepared using the "cracked and burnt" methodology (Campana 1984). Otoliths were first sectioned transversely using a scalpel blade and then charred over an alcohol flame to enhance annular zonation. Charred otolith sections were then mounted in plasticine caps with their cracked surface up and immersed in oil for viewing under a dissecting microscope. Scales and otolith samples were prepared and aged by Jon Tost (North Shore Environmental Services, Thunder Bay, Ontario, Canada).

All age-0 brown trout (<125 mm) had a segment of their left pelvic fins clipped off as a permanent mark to identify them as age-0 fish in 2004 (NOTE: in the lower LV side-channel 34 y-o-y accidentally received right pelvic clips). Empirical growth will be tracked by subsequently recapturing these marked fish to estimate annual growth and verify our scale aging and back-calculations of annual growth. All captured fish were carefully examined to see if they had previously had their adipose fin clipped in 2003, identifying them as an age-0 fish in 2003 and age-1 fish in 2004. All recaptured adipose fin-clipped fish were noted and their lengths and weights were averaged by sample section and by stream name to derive empirical growth rates.

Back-calculations of length-at-age from scale samples from Rush and Lee Vining creeks for 2003 were done by two different methods and compared. Simple regression on natural log transformed fish length (mm) and scale radii (mm; measured from the focus to the edge) and Fraser-Lee methods were used (Busacker et al. 1990). Bivariate plots of log n(scale radius) versus log n(fish length) were assessed for each species among sample sites and between creeks to determine if there appeared to be significant differences among sites within streams or between streams. There did not appear to be much difference among sites within streams, but there appeared to be a difference between streams. To reduce the influence of low sample sizes, species and stream were the strata used for back-calculation estimates by pooling sites within stream for each species. Scale radius, input as the independent variable, was regressed against fish length, as the dependent variable by species and creek. The Fraser-Lee method computes the length-at-age by the formula (Busacker et al. 1990):

$$L_i = a + (L_c - a)*(S_i/S_c);$$

Where L_i = estimated length at age *i*; *a* = intercept of the body-scale regression or a standard value from the literature (typically the length of the fish when scales first form); L_c = fish length at capture; S_i = distance from the scale's focus to annulus *i*; and S_c = distance from the scale's focus to its edge (radius). We applied y-intercept values of 21 mm for brown trout and 20 mm for rainbow trout as rough estimates of when scale formation likely occurs. We found only one citation in a literature search that suggested brown trout first form scales at a length of 35 to 38 mm (Jensen and Johnsen 1982).

Results

Fish Population Abundance

Rush Creek

County Road Section

The majority of the brown trout captured in the County Road Section of Rush Creek were from 60 to 110 mm and the longest brown trout captured was 294 mm (Figure 4). Only eight rainbow trout were captured and four of these fish were over 200 mm (Figure 5). This section supported an estimated 1,161 age-0 and 515 age-1 and older brown trout in 2004 (Table 2). Estimates of brown trout were relatively precise with standard deviations ranging from 4.0 to 4.8% of the estimates. For rainbow trout, the section supported an estimated nine fish (age-0 and older combined); however, this estimate was likely biased due to the low number of recaptures (Table 2).

Lower Section

Length frequencies of brown trout captured in the Lower Section were similar to the distribution observed for the County Road Section, with a majority of the fish sampled less than 110 mm in length (Figure 4). The longest brown trout captured was 322 mm and was sampled on the marking run. This section supported an estimated 789 age-0 and 85 age-1 and older brown trout in 2004 (Table 2). Estimates of all size classes of brown trout were relatively precise with standard deviations ranging from 2.1 to 6.1% of the estimates. Only seven rainbow trout were sampled and three fish were between 200-250 mm (Figure 5). A reliable estimate could not be made for the population of rainbow trout, but when all captured fish were combined this section supported an estimated eight age-0 and older rainbow trout; however, this estimate was likely biased due to the low number of recaptures (Table 2).

Upper Section

Length frequencies of brown trout captured in the Upper Section were similar to the distribution observed for the County Road and Lower Sections, with a majority of the fish sampled less than 110 mm in length (Figure 4). The longest brown trout captured was 541 mm and was sampled on the marking run. The Upper Section of Rush Creek supported an estimated 1,414 age-0 and 211 age-1 and older brown trout in 2004 (Table 2). More rainbow trout were captured in the Upper Section than in the lower two sections, however the numbers have dropped compared to 2003 and 2002 (Figure 5). Due to low numbers on the recapture run, no estimate was generated for age-0 rainbow trout and the estimate of age-1 and older rainbow trout was 12 fish (Table 2). In 2003 this section supported an estimated 56 age-0 and 23 age-1 and older rainbow trout; and in 2002, this section supported an estimated 86 age-0 and 18 age-1 rainbow trout. Rainbow trout estimates for the past three years were likely biased due to the low number of recaptures.

MGORD

Unlike the other three Rush Creek sampling sections, age-0 fish comprised a minor portion of the brown trout sampled in the MGORD section (Figure 6). A total of 25 age-0 brown trout were sampled in the MGORD (15 fish on the marking run and 10 fish on the recapture run). However; no marked fish were sampled on the recapture run, thus an estimate was not generated for age-0 brown trout. The MGORD Section of Rush Creek supported an estimated 656 brown trout in the 150-349 mm size class and an estimated 66 brown trout ≥350 mm in 2004 (Table 2). The longest brown trout captured was 564 mm and was sampled on the marking run. The numbers of rainbow trout in the MGORD were very low (seven fish sampled on the marking run and two fish sampled on the recapture run) and no estimated was generated (Table 2). The largest rainbow trout captured in the MGORD was an impressive 574 mm in length.

In the MGORD, a single adipose fin-clipped brown trout was sampled. This was a recapture of from the age-0 brown trout that were marked in main Rush Creek during 2003, most likely in Upper Rush section, but its original capture location is unknown. The recaptured fish was 210 mm in total length and grew a minimum of 80 mm from 2003 to 2004.

A brown trout that had been floy-tagged just below the Upper Rush electro-fishing section on March 10, 2001, was recaptured in the MGORD on September 8, 2004. When tagged, the fish was 166 mm in length and weighed 43 g. When recaptured, it was 336 mm in length and weighed 454 g (approximately one pound). The annual growth rate for this brown trout (117 g/yr) was two to three times higher than the annual growth rate for brown trout that were tagged and recaptured within the three Rush Creek electro-fishing sections between September 2002 and September 2003 (Hunter et al. 2004）.

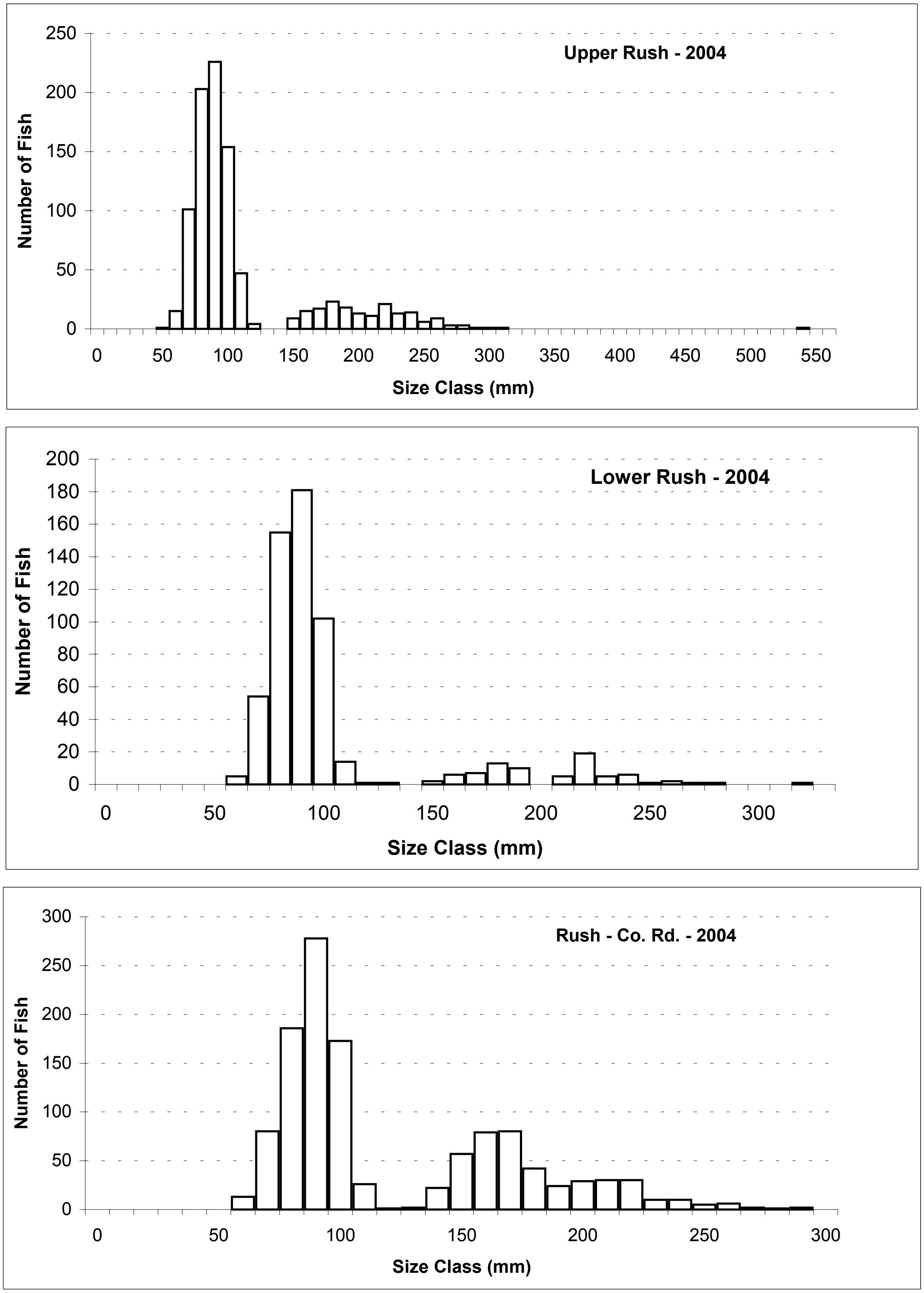


Figure 4. Length frequency histograms of brown trout captured in the Upper (top), Lower (middle) and County Road (bottom) sections of Rush Creek from August 28th to September 9, 2004. Note the different scales on both the vertical and horizontal axes between graphs.

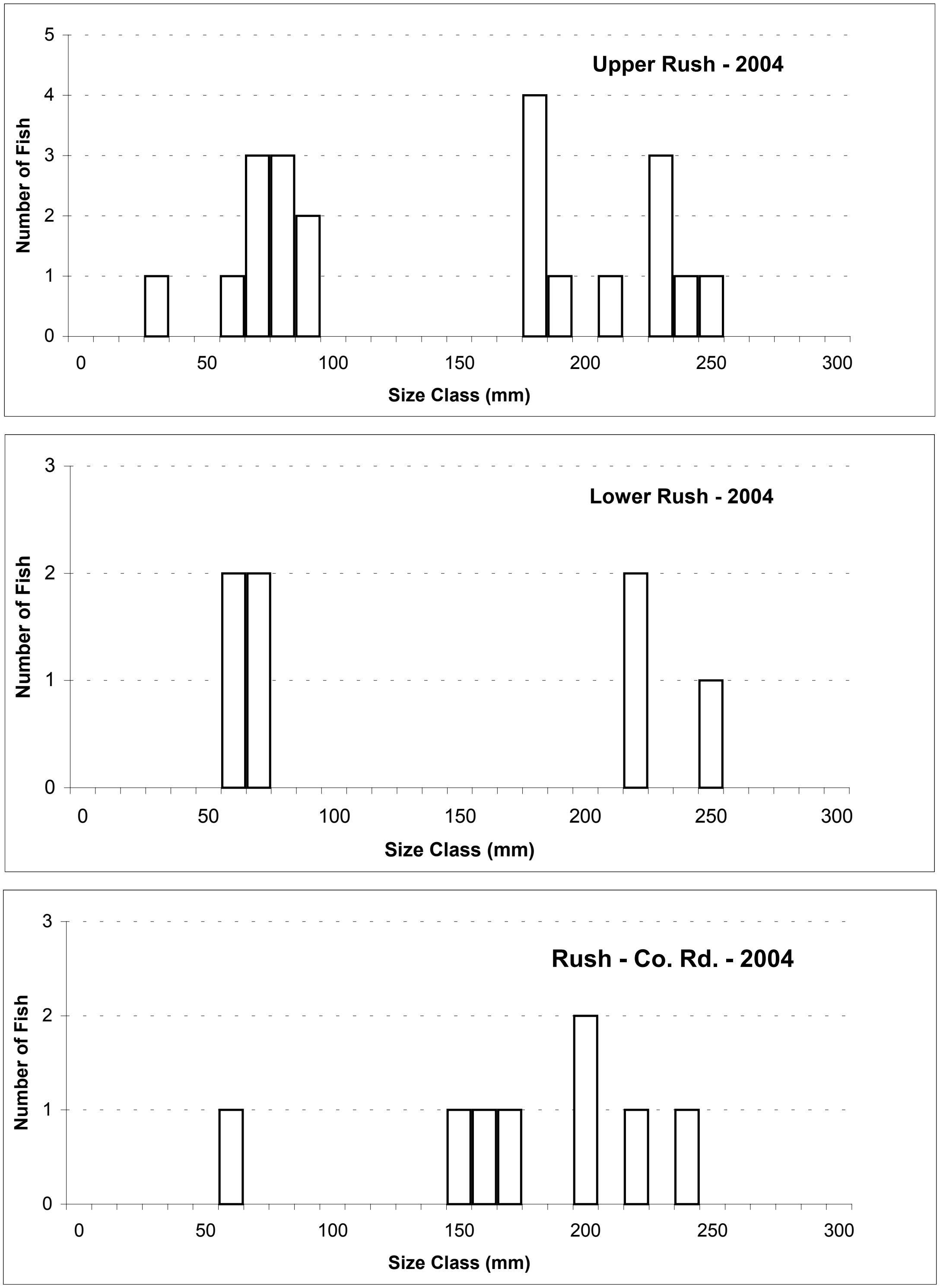


Figure 5. Length frequency histograms for rainbow trout captured in the Upper (top), Lower (middle) and County Road (bottom) sections of Rush Creek between August 28th and September 9th, 2004. Note the different scales on the vertical axes between graphs.

Table 2. Mark-recapture estimates for 2004 showing total number of fish marked (M), number captured on the recapture run (C), and number recaptured on the recapture run (R), and total estimated number and its associated standard error (S.E.) by stream, section, date, species, and size class. Mortalities (Morts) are those fish that were marked, but died prior to the recapture run. These mortalities were not included in the mark-recapture estimate and should be added to the estimate for an accurate total estimate.

Stream Section Date **Species**	Size Class (mm)	Mark-recapture parameter values M	C	R	Morts[1/]	**Estimate**	S.E.
Rush Creek							
County Road							
8/29/2004							
Brown Trout							
	0 - 124 mm	466	452	181	21	**1161**	51.9
	125 - 199 mm	192	221	115	5	**368**	14.9
	200 - 299 mm	89	96	58	1	**147**	7.0
Rainbow Trout							
	0 - 274 mm	6	6	4	0	**9**[2/]	1.1
Lower Rush							
8/31/2004							
Brown Trout							
	0 - 124 mm	326	306	126	9	**789**	41.8
	125 - 199 mm	30	30	21	0	**43**	2.6
	200 - 324 mm	36	37	32	1	**42**	0.9
Rainbow Trout							
	0 - 274 mm	6	4	3	0	**8**[2/]	1.1
Upper Rush							
9/2/2004							
Brown Trout							
	0 - 124 mm	422	417	124	42	**1414**	88.6
	125 - 199 mm	65	56	41	2	**89**	4.2
	200 - 549 mm	70	65	37	0	**122**	8.8
Rainbow Trout							
	0 – 125 mm	3	6	0	0	**NP**[3/]	--
	175 - 274 mm	8	8	5	0	**12**[2/]	1.7

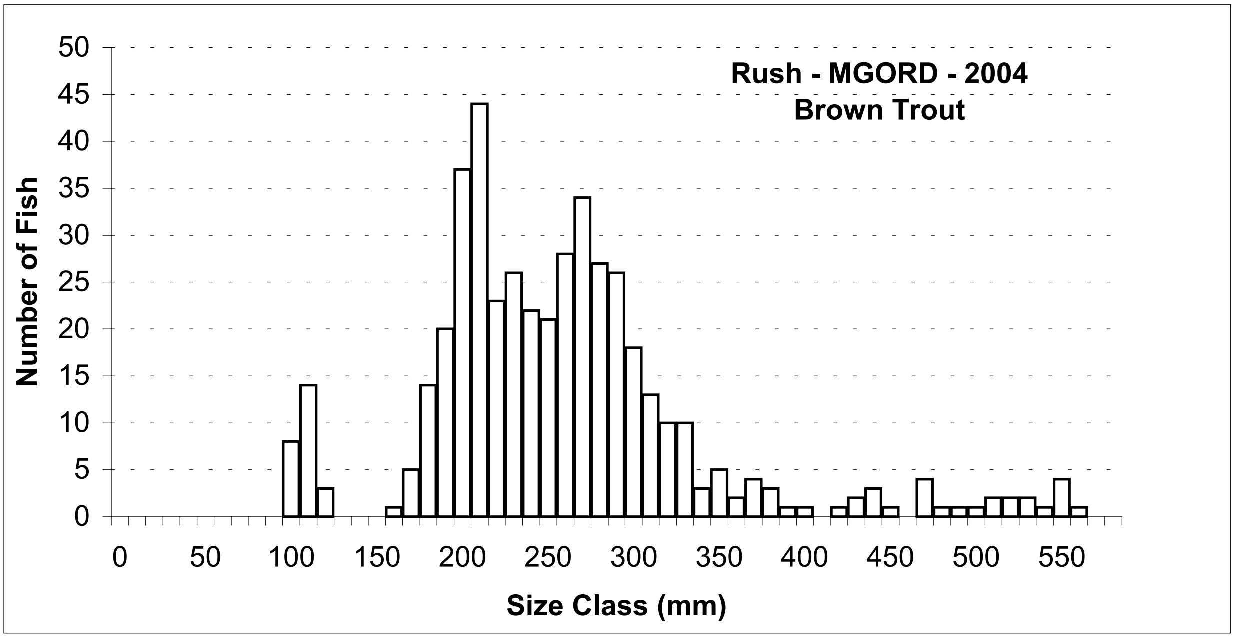
Table 2. (Continued).

Stream Section Date **Species**	Size Class (mm)	Mark-recapture parameter values M	 C	 R	Morts[1/]	**Estimate**	S.E.
Rush Creek							
MGORD							
9/1/2004							
Brown Trout							
	0 - 124 mm	15	10	0	0	**NP**[3/]	--
	150 - 349 mm	242	218	80	2	**656**	47.0
	350 - 574 mm	27	23	9	1	**66**	12.4
Rainbow Trout							
	0 - 574 mm	7	2	1	0	**NP**[3/]	--
Lee Vining Creek							
Lower Main Channel							
8/30/2004							
Brown Trout							
	0 - 124 mm	30	28	2	1	**NP**[3/]	--
	125 - 224 mm	35	15	9	0	**57**	9.0
	225 - 324 mm	25	20	17	0	**29**	1.5
Rainbow Trout							
	0 - 125 mm	1	0	0	0	**NP**[3/]	--
	225 - 249 mm	2	2	2	0	**NP**[3/]	--
Upper Main Channel							
8/31/2004							
Brown Trout							
	0 - 124 mm	31	28	8	0	**102**	23.0
	125 - 199 mm	51	37	21	0	**89**	9.2
	200 - 324 mm	38	33	26	0	**48**	2.3
Rainbow Trout							
	0 - 124 mm	15	9	2	0	**NP**[3/]	--
	125 - 324 mm	9	9	6	0	**13**[2/]	1.5

[1/] To arrive at a complete estimate the mortalities (“Morts”) should be added to the “Estimated number”.

[2/] The number of recaptured fish for these estimates were below 7, the number recommended for an unbiased modified Peterson estimate.

[3/] “NP” indicates no estimate was possible.



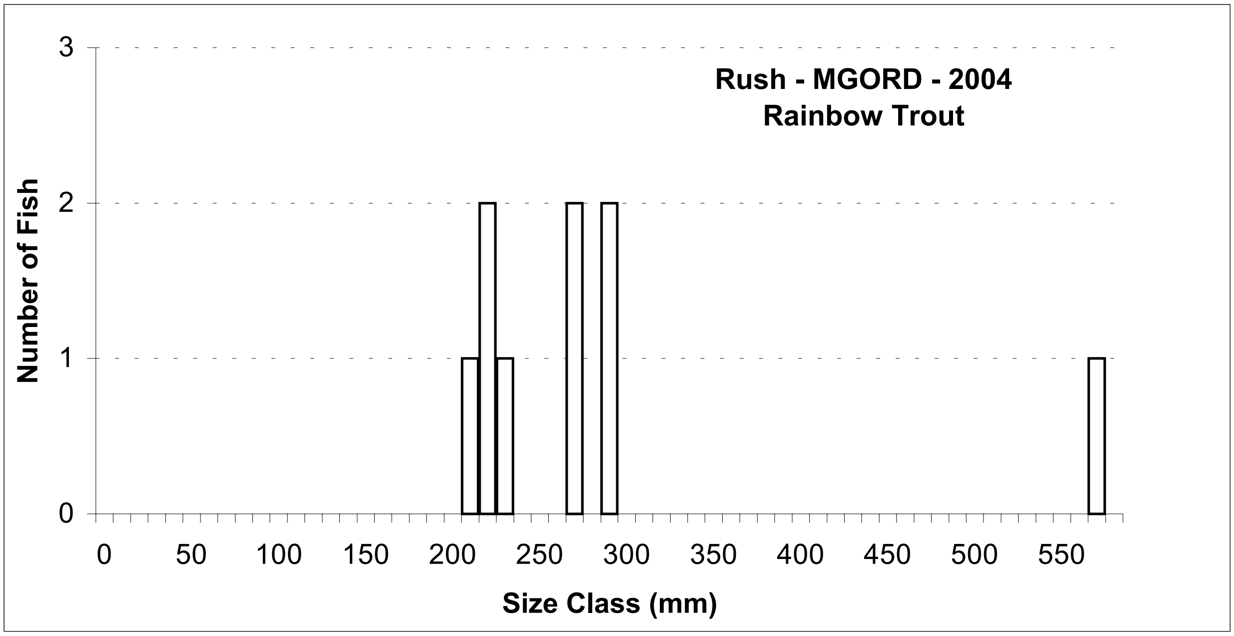


Figure 6. Length frequency histograms for brown trout (top) and rainbow trout (bottom) captured in the MGORD of Rush Creek between August 28th and September 9th, 2004. Note the different scales on the vertical axes between graphs.

Lee Vining Creek

Lower Section

One hundred fifteen age-0 brown trout were captured in main and side-channel sections (Figure 7). Fifty-six of the age-0 brown trout were captured in the main-channel and 59 were captured in the side-channel. In the main-channel no estimate was generated for age-0 brown trout because only two clipped fish were sampled on the recapture run (Table 2). The main-channel supported an estimated 86 age-1 and older brown trout (Table 2). The Lower Lee Vining side-channel supported an estimated 64 age-0 and 27 age-1 and older brown trout (Table 3).

A single age-0 (<125 mm) and two age-1 and older rainbow trout were captured in the main-channel sample section of Lee Vining Creek (Figure 8). Most rainbow trout (117 fish) were captured in the side-channel portion of the Lower Section (Figure 8). For the main-channel no estimates were generated because of low numbers; whereas the side-channel supported an estimated 127 age-0 (± 8.7 fish) and five age-1 and older rainbow trout (Table 3).

Upper Section

More age-0 brown trout (< 125 mm) were captured in the side-channel than in the main-channel, while more age-1 and older brown trout were captured in the main-channel (Figure 7). The main- channel section supported an estimated 102 age-0 and 137 age-1 and older brown trout in 2004 (Table 2). The side-channel section supported an estimated 205 age-0 and 99 age-1 and older brown trout in 2004 (Table 3).

Too few age-0 rainbow trout were sampled in the main-channel (15 on the mark run, nine on the recapture run, but only two clipped fish) and in the side-channel (none captured) to make an estimate for this size class. The main-channel section of Upper Lee Vining Creek supported an estimated 13 age-1 and older rainbow trout (Table 2). Only three age-1 and older rainbow trout were sampled in side-channel section, thus an estimate was not generated (Table 3).

Parker Creek

As in past years, only brown trout were captured in Parker Creek and most of these (77%) were age-0 fish (Figure 9). A total of 53 brown trout were captured in three electro-fishing passes. In 2004, Parker Creek supported an estimated 41 age-0 and 12 age-1 and older brown trout (Table 3).

Walker Creek

As in past years, only brown trout were captured in Walker Creek and most of these (70%) were age-0 fish (Figure 9). A total of 296 brown trout were captured in two electro-fishing passes. In 2004, Walker Creek supported an estimated 207 age-0 and 89 age-1 and older brown trout (Table 3).

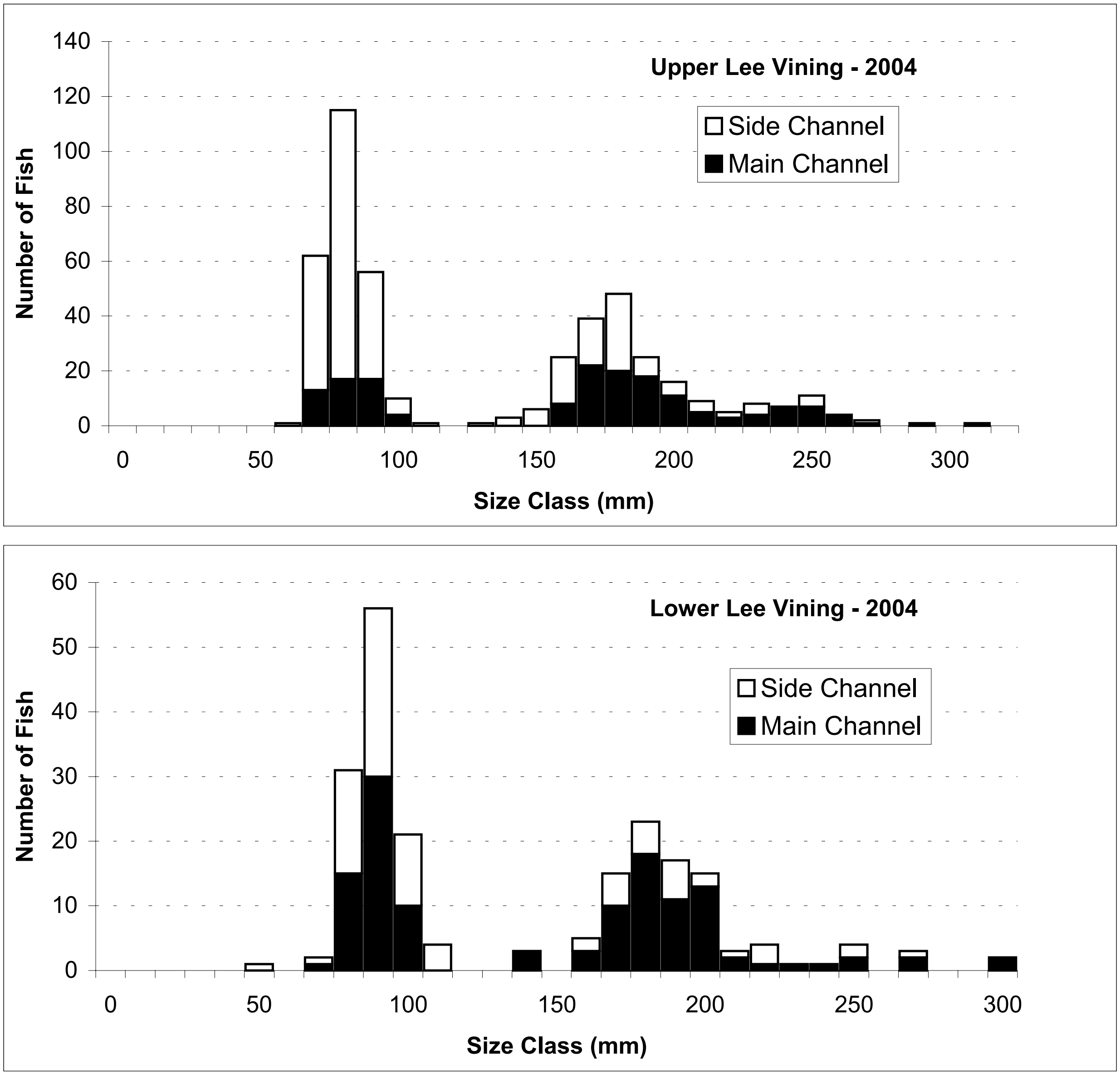


Figure 7. Length frequency histograms for brown trout captured in the Upper (top) and Lower (bottom) sections of Lee Vining Creek during September 2003 showing those fish captured in the main channel (dark bars) and side-channel (cross-hatched bars) portions of each section. Note different scales on vertical axes.

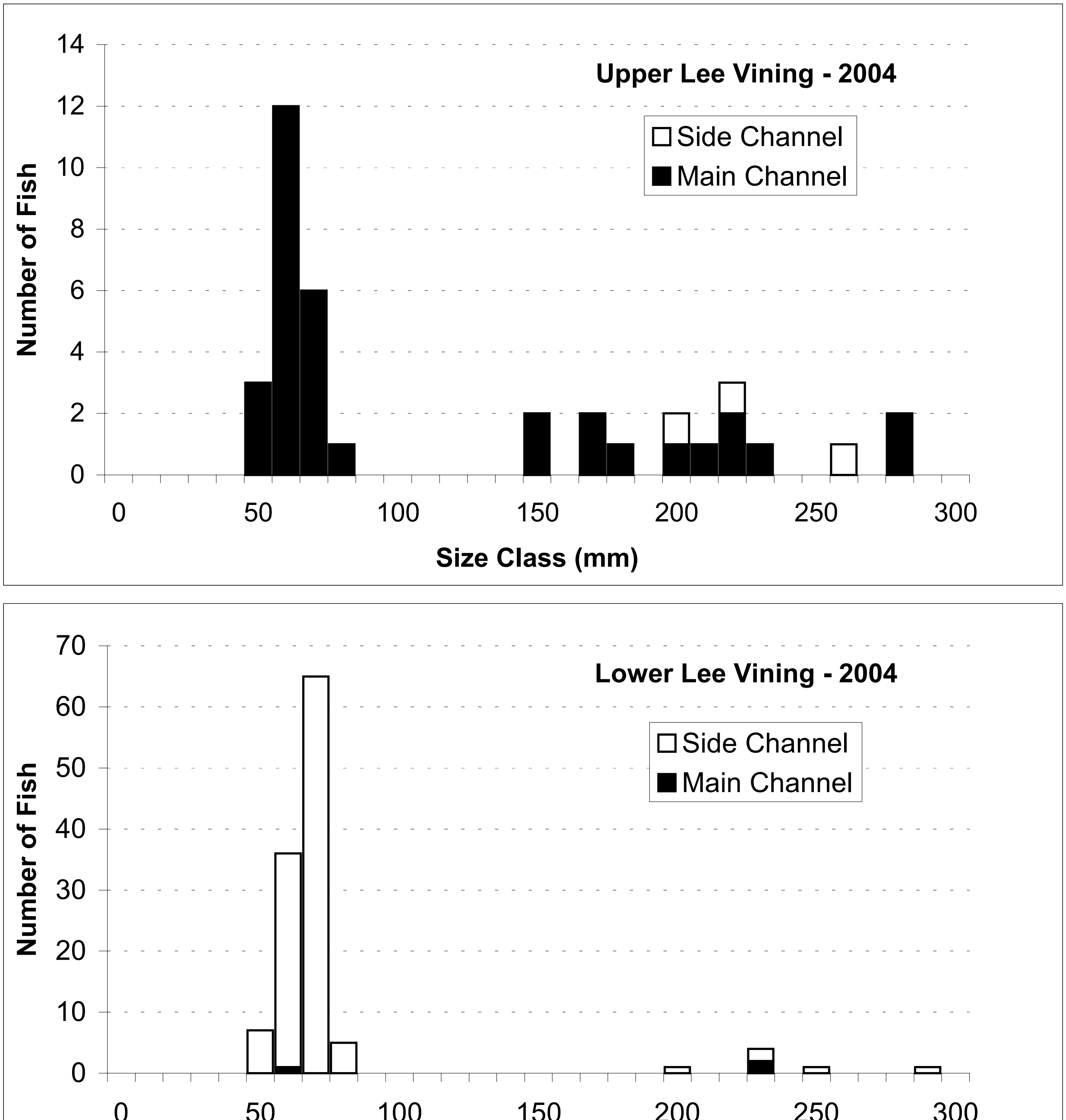


Figure 8. Length frequency histograms for rainbow trout captured in the Upper (top) and Lower (bottom) sections of Lee Vining Creek during September 2004 showing those fish captured in the main channel (dark bars) and side-channel (cross-hatched bars) portions of each section.

Table 3. Depletion population estimates made in the side-channel portions of the Lower and Upper sections of Lee Vining Creek and in Parker and Walker creeks during September 2004 showing number of fish captured on each pass, estimated number, and standard deviation (S.D.) by species and length group (0-125 mm are age-0).

Stream (Section) Species Length Group	Number captured per pass 1	2	3	4	**Estimated number**	S.D.
LV Creek (Lower Side-channel)						
Brown Trout						
0 - 125 mm	45	14	-	-	**64**	4.4
125 - 199 mm	16	1	-	-	**17**	0.3
200 + mm	10	0			**10**[1/]	-
Rainbow Trout						
0 - 125 mm	82	30	-	-	**127**	8.7
125-199 mm	0	0	-	-	**0**[2/]	-
200 + mm	5	0	-	-	**5**[1/]	-
LV Creek (Upper Side-channel)						
Brown Trout						
0 - 125 mm	156	38	-	-	**205**	5.6
125-199 mm	78	1	-	-	**79**	0.1
200 + mm	20	0	-	-	**20**[1/]	-
Rainbow Trout						
0 - 125 mm	0	0	-	-	**0**[2/]	-
125 + mm	3	0	-	-	**3**[2/]	-
Parker Creek						
Brown Trout						
0 - 125 mm	31	6	4	-	**41**	1.0
125-199 mm	2	2	0	-	**4**	0.5
200 + mm	7	1	0	-	**8**	0.1
Walker Creek						
Brown Trout						
0 - 125 mm	175	28	-	-	**207**	3.0
125-199 mm	70	3	-	-	**73**	0.4
200 + mm	15	1	-	-	**16**	0.3

[1/] Maximum likelihood estimate not possible because all fish captured on the first pass. The estimate was considered as the first pass catch.

[2/] No fish were captured in any of the passes indicating that no fish of this size were present.

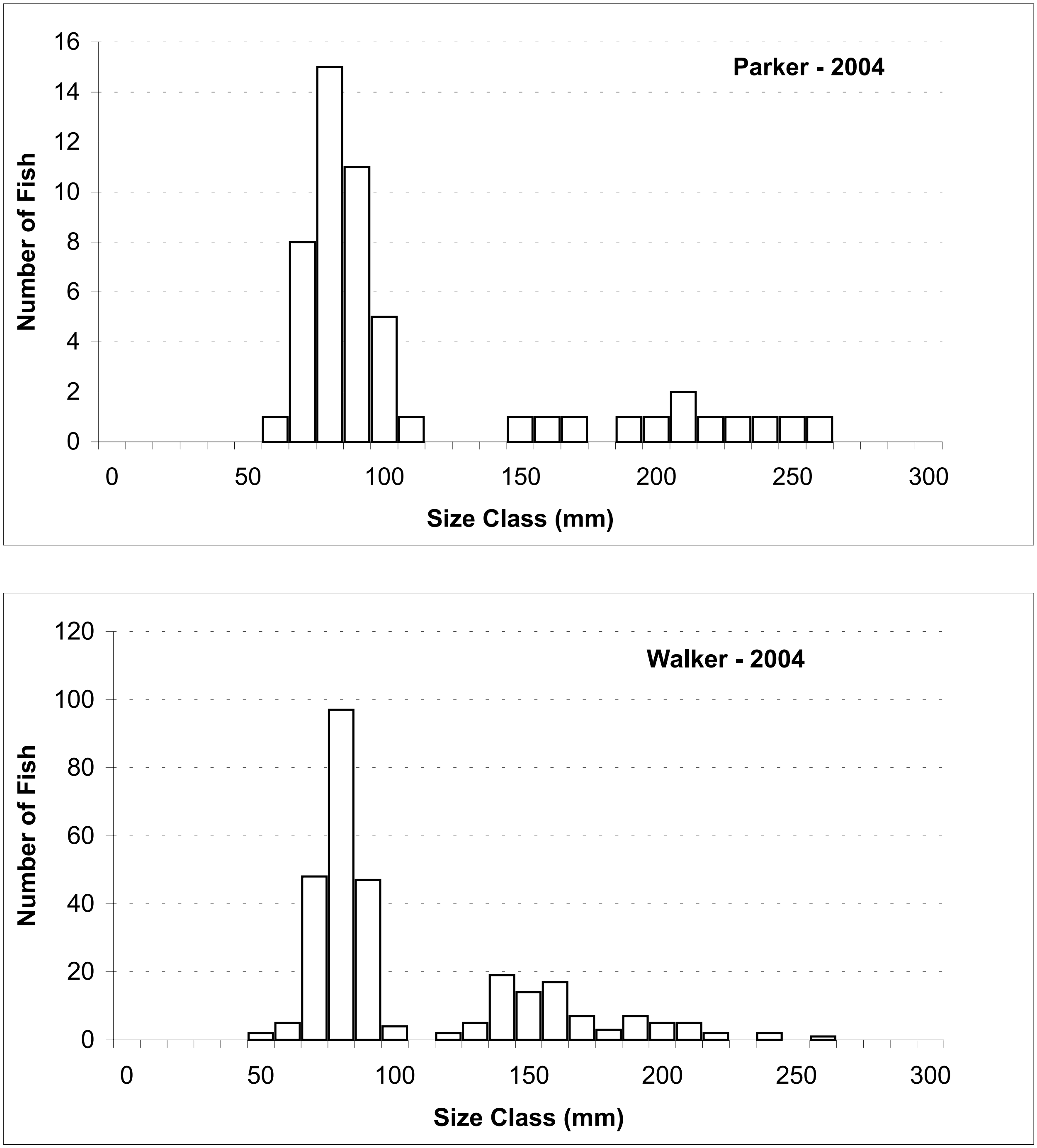


Figure 9. Length frequency histograms for brown trout captured in Parker (upper) and Walker (lower) creeks during September 2004. Note the different scales on the vertical axes.

Relative Condition of Brown Trout

Log_{10} transformed length-weight regressions for captured brown trout 100 mm and longer had R^2-values over 0.98 for almost all sample events, indicating that weight was strongly correlated to length (Table 4). A condition factor of 1.00 is considered average and most computed conditions factors were close to 1.00 in 2004, indicating brown trout condition was about average when compared to other waters. Regression data for 2004 indicated that condition was very similar among the four Rush Creek sample sections (Table 4). Relative conditions of brown trout captured during 2004 were similar to those found in 2002 and 2003 in the three Rush Creek sections, but condition of brown trout in the MGORD was slightly better in 2004 than in 2001 (Figure 10). In the MGORD, the differences in condition factor between the 2001 and 2004 sample seasons were most noticeable for brown trout greater than 300 mm in total length (Figure 10). The better condition of larger brown trout in the MGORD in 2004 was probably related to the lower population of fish in the MGORD. Condition of brown trout was better in 2000 than any other sample-year for the three sections of Rush Creek that have been annually sampled (Figure 10).

Computation of condition factors for brown trout between 150 to 250 mm in total length showed that Lower Rush Creek brown trout in this size range were in slightly better condition than those in the lower two sections (Figure 10). In 2004, condition factors for brown trout in all Lee Vining Creek sections were slightly higher than those for any of the other streams. Over all six years of sampling, the condition factors for brown trout in Lee Vining Creek were the highest in 2000.

In Parker Creek, the condition factor for brown trout (150 to 250 mm in total length) improved in 2004 from 2003, but was still less than the highest value recorded in 2002 (Figure 10). In Walker Creek, the condition factor for brown trout (150 to 250 mm in total length) dropped slightly in 2004 from 2003 (Figure 10).

Table 4. Regression statistics for $\log_{10}$ transformed length (L) to weight (WT) for brown trout 100 mm and longer captured in Rush Creek by sample section and year. The 2004 regression equations are in **bold font**.

Section	Year	N	Equation	R^2	P
County Road	2000	412	$Log_{10}(WT) = 2.936*Log_{10}(L) – 4.827$	0.987	< 0.01
	2001	552	$Log_{10}(WT) = 2.912*Log_{10}(L) – 4.815$	0.979	< 0.01
	2002	476	$Log_{10}(WT) = 2.946*Log_{10}(L) – 4.884$	0.993	< 0.01
	2003	933	$Log_{10}(WT) = 3.004*Log_{10}(L) – 5.008$	0.988	<0.01
	2004	**655**	$\mathbf{Log_{10}(WT) = 2.968*Log_{10}(L) – 4.937}$	**0.994**	**<0.01**
Lower	1999	314	$Log_{10}(WT) = 3.027*Log_{10}(L) – 5.078$	0.992	< 0.01
	2000	230	$Log_{10}(WT) = 2.975*Log_{10}(L) – 4.904$	0.985	< 0.01
	2001	350	$Log_{10}(WT) = 2.975*Log_{10}(L) – 4.939$	0.986	< 0.01
	2002	250	$Log_{10}(WT) = 2.907*Log_{10}(L) – 4.784$	0.994	< 0.01
	2003	348	$Log_{10}(WT) = 3.003*Log_{10}(L) – 5.019$	0.991	<0.01
	2004	**215**	$\mathbf{Log_{10}(WT) = 2.935*Log_{10}(L) – 4.843}$	**0.995**	**<0.01**
Upper	1999	317	$Log_{10}(WT) = 2.933*Log_{10}(L) – 4.843$	0.981	< 0.01
	2000	309	$Log_{10}(WT) = 3.001*Log_{10}(L) – 4.958$	0.981	< 0.01
	2001	335	$Log_{10}(WT) = 2.987*Log_{10}(L) – 4.958$	0.992	< 0.01
	2002	373	$Log_{10}(WT) = 2.945*Log_{10}(L) – 4.859$	0.989	< 0.01
	2003	569	$Log_{10}(WT) = 2.959*Log_{10}(L) – 4.892$	0.992	<0.01
	2004	**400**	$\mathbf{Log_{10}(WT) = 2.975*Log_{10}(L) – 4.944}$	**0.994**	**<0.01**
MGORD	2001	769	$Log_{10}(WT) = 2.873*Log_{10}(L) – 4.719$	0.990	<0.01
	2004	**450**	$\mathbf{Log_{10}(WT) = 2.986*Log_{10}(L) – 4.978}$	**0.988**	**<0.01**

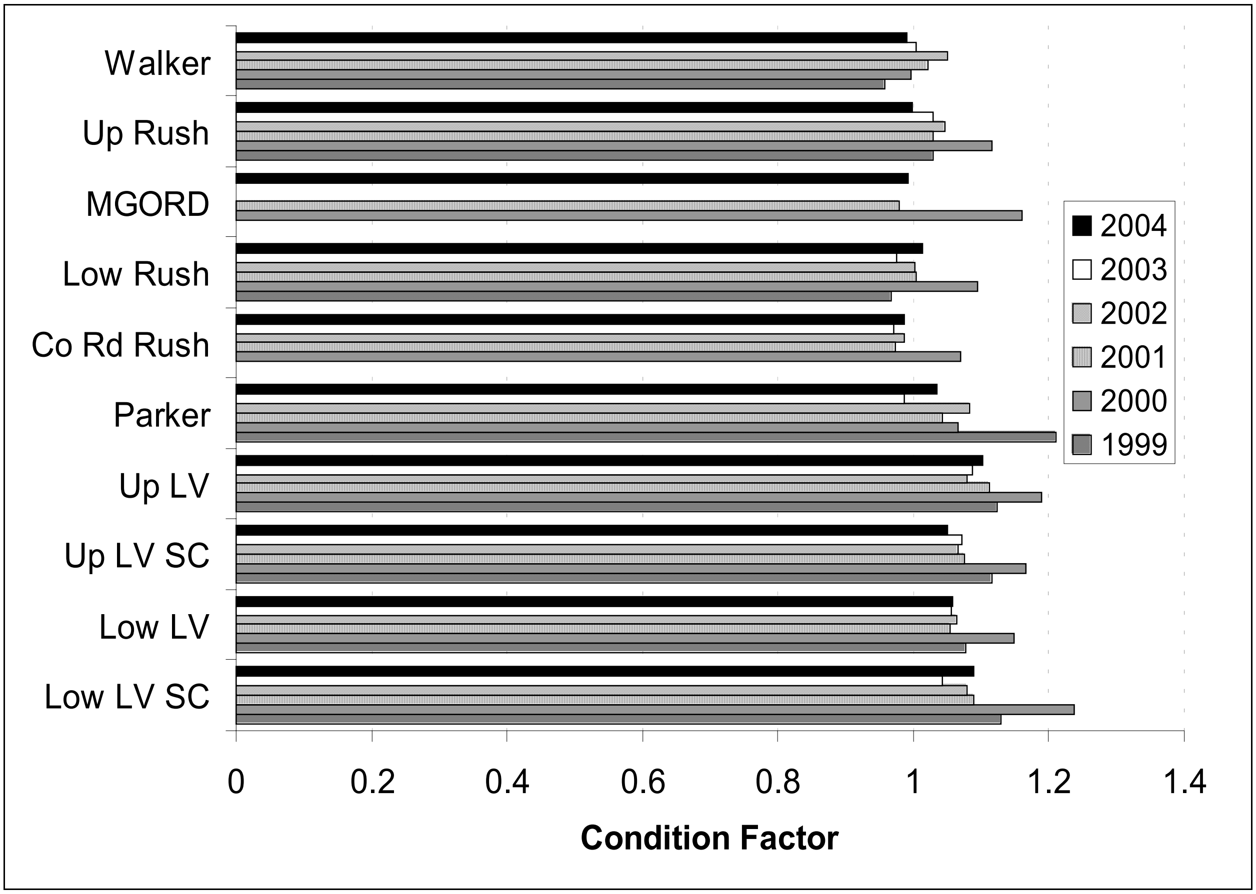


Figure 10. Condition factors for brown trout 150 to 250 mm long in Mono Lake tributaries from 1999 to 2004.

Age Estimates of Brown Trout

In 2004, scale samples were obtained from 120 brown trout in Rush Creek; of which 109 fish were sampled from the MGORD (Figure 11). For a second straight year, the aging of scale samples found that very few trout in most sections of Rush Creek were living longer than age-3. The exception was the MGORD section of Rush Creek. One large brown trout (443 mm in total length) that died during the sampling process had an otolith reading of 11 years old (Table 5). Numerous MGORD fish were estimated to be four to five years old, while 21 other fish were thought to be at least five to six years old but their scales had regenerated to such an extent that they were unreadable. For several MGORD fish aged at two and three years old, the scales indicated extremely fast growth rates.

There was generally good agreement between ages interpreted from scales and otoliths. In two instances the scales had regenerated and were unreadable, but the otoliths aged the fish at five and 11 years of age (Table 5).

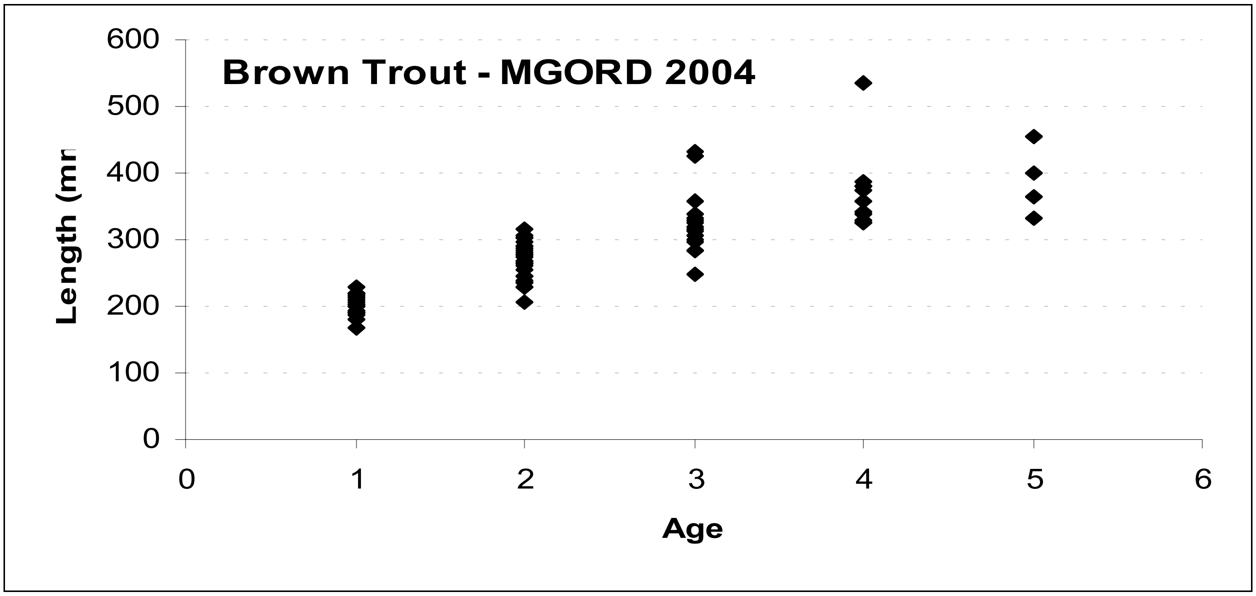


Figure 11. Distribution of lengths at age for brown trout in the MGORD section of Rush Creek in 2004 based on ages interpreted from 120 scale samples.

Table 5. Age interpreted from scales (Scale Age) and otoliths (Otolith Age) for brown and rainbow trout captured in Rush and Lee Vining creeks during 2004.

Stream	Section	Species	Length (mm)	Scale Age	Comments	Otolith Age
Rush Creek	County Road	Brown Trout	154	1		1
Rush Creek	County Road	Brown Trout	205	2		2
Rush Creek	County Road	Brown Trout	208	2		2
Rush Creek	County Road	Brown Trout	230	3		3
Rush Creek	Upper Rush	Brown Trout	315	Unknown	Scale regeneration	5
Rush Creek	MGORD	Brown Trout	187	1		1
Rush Creek	MGORD	Brown Trout	325	3		3
Rush Creek	MGORD	Brown Trout	443	Unknown	Scale regeneration	11

During the 2003 sampling season 2,823 age-0 brown trout received a complete adipose fin-clip so that survival and growth of this cohort of fish could be tracked in subsequent years (Table 6). In 2004, 123 of the adipose fin-clipped brown trout were re-captured (Table 7). Growth of adipose-clipped brown trout from age-0 to age-1 ranged from 74 to 99 mm and from 42 to 61 grams (Table 7). Growth averaged 88 mm and 59 g in Lee Vining Creek and 86 mm and 50 g in Rush Creek. By section, the recapture rate of clipped fish was variable and ranged from a low of 0.8% in Lower Rush Creek to a high of 19.5% in the Upper Lee Vining side-channel (Table 7). One of the recaptures occurred in the MGORD, revealing movement of young brown trout in an upstream direction. This age-1 brown trout exhibited higher growth rates than the recaptured trout in all other Rush Creek sections (Table 7).

During the 2004 sampling season 2,586 age-0 brown trout and 115 age-0 rainbow trout (<125 mm) had a segment of their left pelvic fins clipped off as a permanent mark so that survival and growth of this cohort of fish could be tracked in subsequent years (NOTE: in the lower LV side-channel 34 age-0 brown trout accidentally received right pelvic clips) (Table 8).

Table 6. Age-0 brown trout that received adipose fin-clips during the 2003 sampling season, by stream reach.

Collection Location	Number Of Fish Clipped	Average Total Length (mm)	Minimum Total Length (mm)	Maximum Tota Length (mm)	Average Weight (g)
Lee Vining – Upper Side	123	97	75	118	9
Lee Vining – Lower Side	66	98	76	116	10
Lee Vining – Upper Main	72	97	67	123	10
Lee Vining – Lower Main	83	97	77	119	9
Rush – Co Road	983	87	61	111	7
Rush Ck– Lower	738	92	69	120	8
Rush Ck – Upper	547	104	73	125	12
Parker Creek	76	81	66	99	5
Walker Creek	135	88	66	102	8

Table 7. Age-1 brown trout captured in 2004 with adipose fin-clips administered during the 2003 sampling season, by stream reach.

Collection Location	Number of Fish Recap	Ave. Total Length (mm)	Min. Total Length (mm)	Max. Total Length (mm)	Average Weight (g)	Percent Recap.	Growth – Average Length (mm)	Growth – Average Weight (g)
Lee Vining – Upper Side	24	179	151	203	61	19.5%	82	51
Lee Vining – Lower Side	1	179	179	179	69	1.5%	81	59
Lee Vining – Upper Main	5	188	168	207	68	6.9%	92	58
Lee Vining – Lower Main	14	187	150	207	69	16.9%	90	60
Rush – Co Road	59	171	140	197	49	6.0%	84	42
Rush – Lower	6	191	182	198	69	0.8%	99	61
Rush – Upper	13	178	159	189	57	2.4%	74	45
Rush – MGORD	1	271	271	271	198	N/A	N/A	N/A

Table 8. Total number of age-0 trout that received left pelvic fin-clips during the 2004 sampling season, by stream reach. Number in (#) denotes rainbow trout.

Collection Location	Number of Fish Clipped	Average Total Length (mm)	Minimum Total Length (mm)	Maximum Total Length (mm)	Average Weight (g)
Lee Vining – Upper Side	192 (0)	86	69	112	7
Lee Vining – Lower Side	137 (94)	92 (71)	59 (53)	107 (84)	8 (4)
Lee Vining – Upper Main	27 (7)	89 (71)	75 (66)	106 (80)	7 (4)
Lee Vining – Lower Main	42 (1)	94 (66)	77 (66)	106 (66)	9 (4)
Rush – Co Road	732 (0)	94	64	124	8
Rush – Lower	470 (4)	93 (73)	69 (69)	126 (80)	9 (4)
Rush – Upper	723 (9)	93 (83)	60 (66)	129 (96)	9 (6)
Rush – MGORD	21 (0)	114	101	124	15
Parker Creek	39 (0)	89	70	108	8
Walker Creek	203 (0)	85	58	104	7

Age and Growth Estimates of Brown Trout

Back-calculations of length-at-age from scale samples from Rush and Lee Vining creeks for 2003 were developed for both brown trout and rainbow trout (Table 9). However, it appears that Lee Vining Creek rainbows may be either stocked fish that were put in at larger sizes or the estimate of age-1 length from regression is off (yellow highlight) due to too small a sample size and no age-0 fish to reasonably estimate the body-scale relationship.

Survival Estimates of Brown Trout

The 2003 aging data were also used to generate estimates of year-to-year survival (September 1st to September 1st) of specific cohorts of brown trout, starting in the year 2000 (Table 10). To follow a cohort from age-0 through age-4, start with the age-0 estimated number of fish value and read across left-to-right in a *diagonal* direction. For example; in 2000 there were 2,497 age-0 brown trout in Rush Creek Co. Road section, in 2001 there were 595 age-1 fish, in 2002 there were 84 age-2 fish, in 2003 there were 71 age-3 fish, and in 2004 there were 16 age-4 brown trout left from the year 2000 cohort.

Survivals of brown trout from age-0 to age-1 in Rush Creek appeared to generally range from about 10 to 25% and survivals appeared higher in the County Road Section than the other sections. Survivals from age-0 to age-1 were even lower than 10% during a few years. Survivals from age-1 to age-2 appeared to vary a little more, ranging from about 10 to 45%, while annual survival estimates increased after age-2, but were even more variable. In Lee Vining Creek, survivals were much higher for brown trout from age-0 to age-1, ranging from about 40 to 90%, but were similar for brown trout from age-1 to age-2.

Regardless of the age-0 recruitment and the survival of those fish to age-1, there appears to be minimal variation in estimated numbers of age-2 and older brown trout. Based on the limited 2003 scale analyses, no brown trout in Lee Vining Creek were living past age-2.

Table 9. Comparison of back-calculated estimates of length-at-age (mm) by the natural log transformed regression method and Fraser-Lee method to empirical measurements (sample sizes in parentheses under the estimates) of fish made in September, prior to annulus formation, by species and stream (Rush Creek and Lee Vining = LV) from scales and empirical measurements made in 2003.

		Browns				**Rainbow**			
Age	Method	Rush		LV		Rush		LV	
Age 1	Empirical	97	(57)	97	(31)	81	(15)	-	
	In transform regression	96	(195)	107	(104)	79	(28)	150	(29)
	Fraser-Lee	100	(196)	114	(104)	86	(28)	107	(29)
Age 2	Empirical	169	(102)	191	(56)	174	(20)	210	(20)
	In transform regression	173	(93)	191	(48)	171	(8)	212	(9)
	Fraser-Lee	183	(93)	212	(48)	177	(8)	199	(9)
Age 3	Empirical	220	(47)	254	(48)	228	(6)	263	(7)
	In transform regression	211	(46)	-		195	(2)	253	(2)
	Fraser-Lee	222	(46)	-		213	(2)	275	(2)
Age 4	Empirical	244	(36)	-		-		-	
	In transform regression	227	(10)	-		-		-	
	Fraser-Lee	253	(10)	-		-		-	

Table 10. Survival estimates of brown trout in Rush and Lee Vining Creeks between 2000-2004.

			Estimated Number of Fish by Age-class					Survival Estimates			
Stream	Section	Year	Age-0	Age-1	Age-2	Age-3	Age-4+	Age 0 to Age1	Age 1 to Age 2	Age-2 to Age-3	Age-3 to Age-4
Rush Ck	Co.Rd.	2000	2497	435	70	84	14	N/A	N/A	N/A	N/A
		2001	1308	595	108	53	7	0.238	0.249	0.762	0.086
		2002	1655	293	84	48	9	0.224	0.141	0.446	0.169
		2003	1894	454	73	71	16	0.274	0.250	0.846	0.326
		2004	1161	355	70	74	16	0.187	0.155	1.004	0.230
Rush Ck	Lower	2000	1270	160	41	22	4	N/A	N/A	N/A	N/A
		2001	839	241	15	21	6	0.190	0.094	0.510	0.268
		2002	1207	69	18	25	7	0.082	0.075	1.680	0.343
		2003	1238	191	15	21	6	0.158	0.224	1.193	0.243
		2004	789	46	14	20	6	0.037	0.073	1.278	0.261
Rush Ck	Upper	2000	4226	421	119	21	7	N/A	N/A	N/A	N/A
		2001	2420	231	79	19	6	0.055	0.188	0.162	0.313
		2002	2236	262	88	18	6	0.108	0.381	0.222	0.304
		2003	770	194	97	24	8	0.087	0.371	0.270	0.451
		2004	1417	85	89	26	9	0.110	0.459	0.270	0.366
Lee Vining	Lower	2000	192	52	32	0	0	N/A	N/A	N/A	N/A
		2001	131	81	26	0	0	0.422	0.500	0.000	0
		2002	33	97	39	0	0	0.740	0.481	0.000	0
		2003	128	32	17	0	0	0.970	0.175	0.000	0
		2004	299	78	6	0	0	0.609	0.188	0.000	0
Lee Vining	Upper	2000	246	66	26	0	0	N/A	N/A	N/A	N/A
		2001	136	95	14	0	0	0.386	0.212	0.000	0
		2002	55	89	31	0	0	0.654	0.326	0.000	0
		2003	162	47	27	0	0	0.855	0.303	0.000	0
		2004	102	108	28	0	0	0.667	0.596	0.000	0

Discussion

Reliability of Estimates

As explained in the methods, our sampling activities and high winds/leaf litter immediately after the marking runs in 2004 caused both the upper and lower block fences to fail in the Upper Rush Creek section, but these fences were down over relatively short time periods. The occurrence of these brief block fence failures most likely did not significantly affect population estimates in the Upper Rush Creek section. Block fences did not fail in the Lower Rush Creek and Lee Vining Creek sections. Having a field technician dedicated to maintaining block fences dramatically improved the ability to keep these fences functional. However, the inability to totally meet the population closure assumption could have resulted in an over-estimate of the fish population in the Upper Rush Creek section, especially if marked fish moved out of, or unmarked fish moved into, the sample section. However, we do not believe violations of population closure assumptions significantly affected population estimates in 2004.

Improved techniques were used to calculate mark-recapture estimates in 2004. The estimates from previous years were re-calculated using the new methods, which resulted in some slight changes in estimates reported from previous years. Standardization of the estimation technique will allow us to make more reliable comparisons among sections within a year and among years within a section.

Estimated Trout Density Comparisons

Trout populations were dominated by brown trout in all sample sections during 2004, similar to past years (Figure 12; Hunter et al. 2000; 2001; 2002; 2003; 2004). The high proportion of brown trout to rainbow trout in both Rush and Lee Vining creeks is typical of most trout streams in the Mono Basin and the Owens River watershed. Studies by the Department of Fish and Game documented brown trout as the dominant trout species in all 130 electrofishing reaches sampled within 52 different Mono Basin streams and Owens River tributaries (Dienstadt et al. 1985, 1986, 1997). Kondolf et al. (1991) suggest that periodic mobility of gravels may explain why brown trout are more abundant than rainbow trout in many eastern Sierra streams where high flows typically occur in May and June due to snow melt when rainbow trout eggs (or alevin) are in the gravel, and thus, more vulnerable to scour during larger snowmelt flows.

Estimated densities (number per hectare) of age-1 and older brown trout increased in 2004 in all sections of Lee Vining Creek, but declined in all sections of Rush Creek (Figure 13). Densities also declined dramatically in the MGORD, possibly due to the re-construction of this diversion canal that occurred during 2002 to 2003, followed by the peak flow release of 380 c.f.s. to test the re-constructed canal in June of 2004. Although the density of age-1 and older brown trout in the MGORD declined by nearly 50%, the condition factor of the trout >300mm in length was higher. We expect the brown trout population within the MGORD to recover as the reconstructed channel stabilizes and the elodea beds become fully re-established in the disturbed sections of the canal.

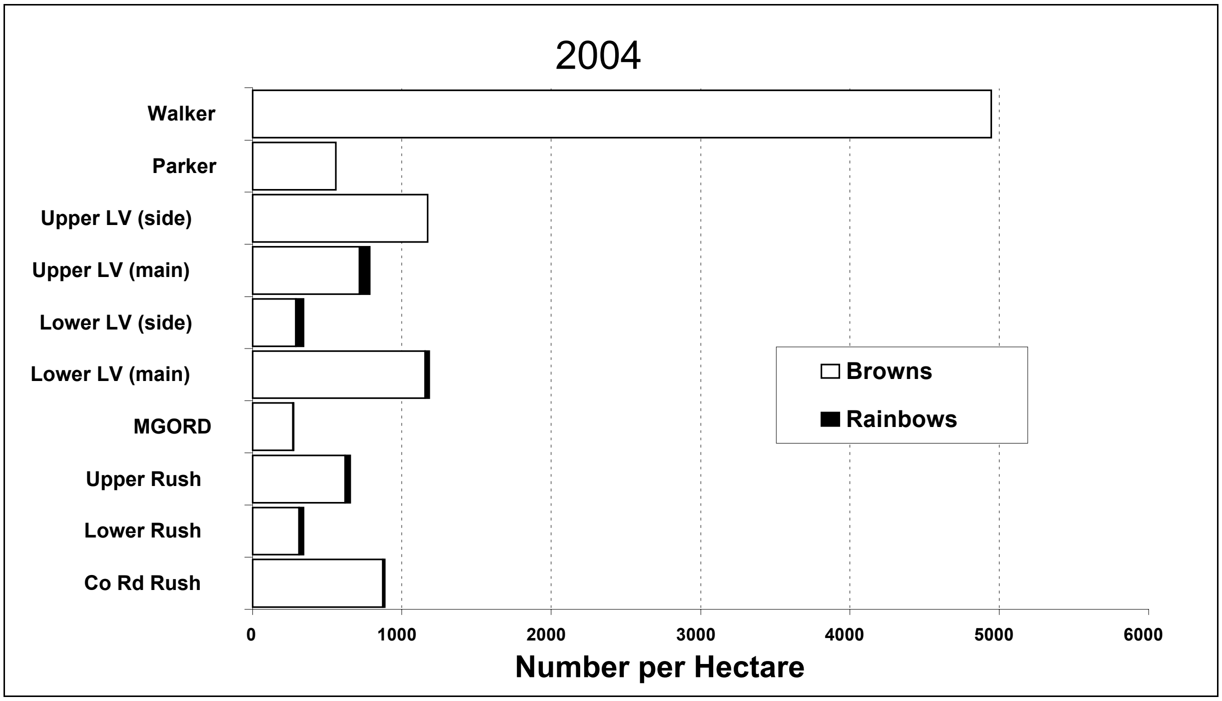


Figure 12. Densities (number/hectare) of age-1 and older brown and rainbow trout in selected Mono Lake tributaries in 2004.

Densities of age-1 and older brown trout declined from 2002 to 2004 in Parker Creek and increased in Walker Creek. Densities in Parker Creek during 2004 were similar to densities estimated in 1999 and 2000, while estimated densities in Walker Creek were the highest ever recorded since sampling started in 1999. Two recent events may provide plausible explanations for the dramatic increase in Walker Creek's brown trout population in the past two years. The first being the Highway 395 reconstruction project completed in 2002 which included replacing old, under-sized culverts that were potential migration barriers with new crossings designed to facilitate fish passage (properly-sized concrete box culverts embedded with stream substrate). It's plausible that re-opening access to Walker Creek has increased the number of adult trout migrating from Rush Creek into Walker Creek for spawning purposes; however Parker Creek received the same treatment and has failed to show a similar response. Secondly, the management of Walker Lake has recently changed. For years, the private landowners manipulated the flash-boards at the lake's outlet in a way that was probably detrimental to lower Walker Creek. The flash-boards were pulled in the winter in an attempt to flush sediments accumulated in the lake; then in the spring the boards were put back in place to refill the lake at such a rate that de-watering often occurred in the downstream channel. Since 2003, the property owners responsible for management of Walker Lake no longer manage Walker Lake in such a manner that dewaters Walker Creek below the lake.

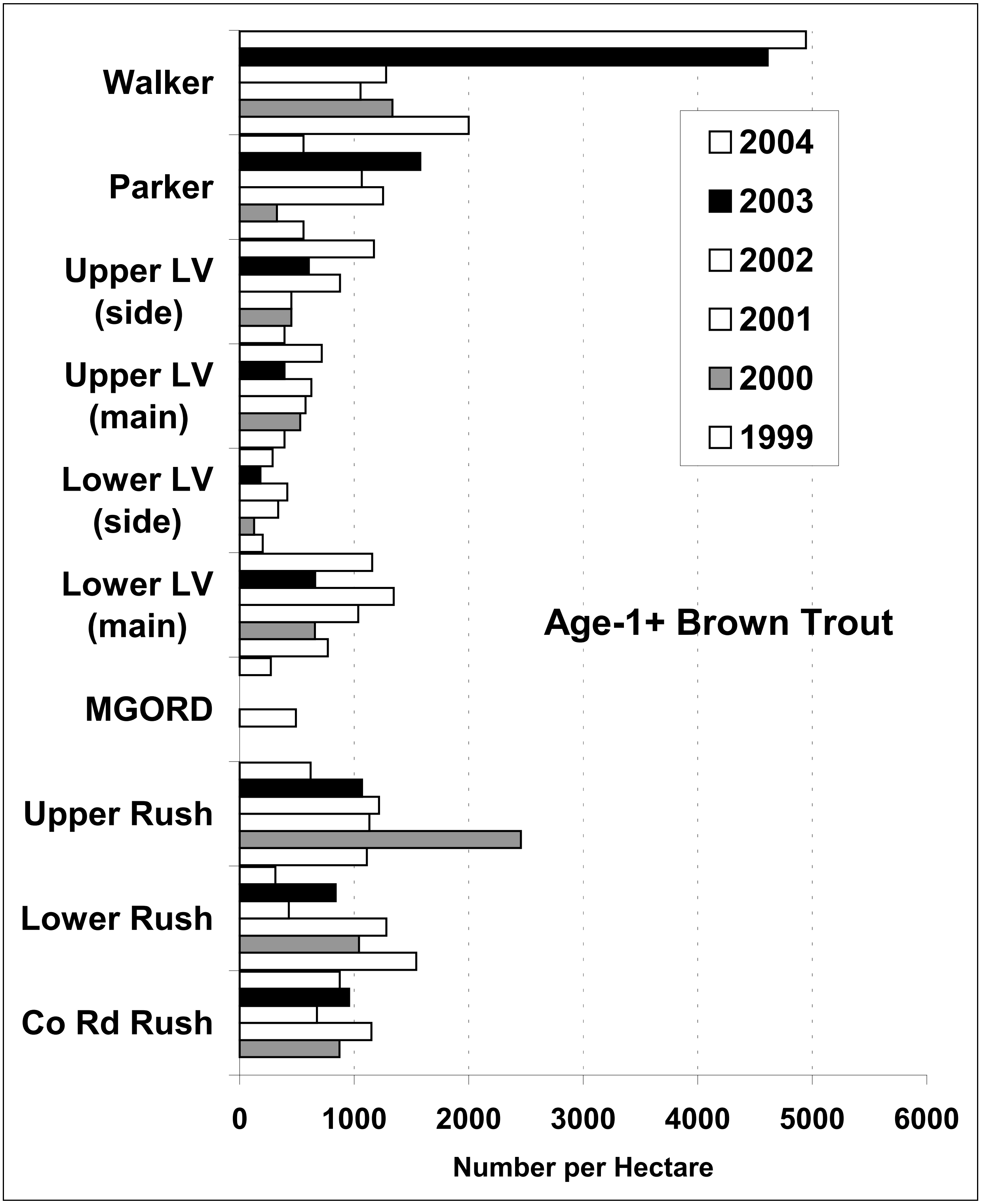


Figure 13. Estimated number of age-1 and older brown trout per hectare in sections of Walker, Parker, Rush, and Lee Vining creeks during September from 1999 to 2004.

The age-0 trout populations were also dominated by brown trout in all sample sections during 2004, similar to past years; however, by stream and reach, the densities were variable compared to the 2003 estimates. Estimated densities (number per hectare) of age-0 brown trout increased from 2003 to 2004 in two sections of Lee Vining Creek (Lower main-channel and Upper side-channel), but declined in the other two Lee Vining Creek sections (Figure 14).

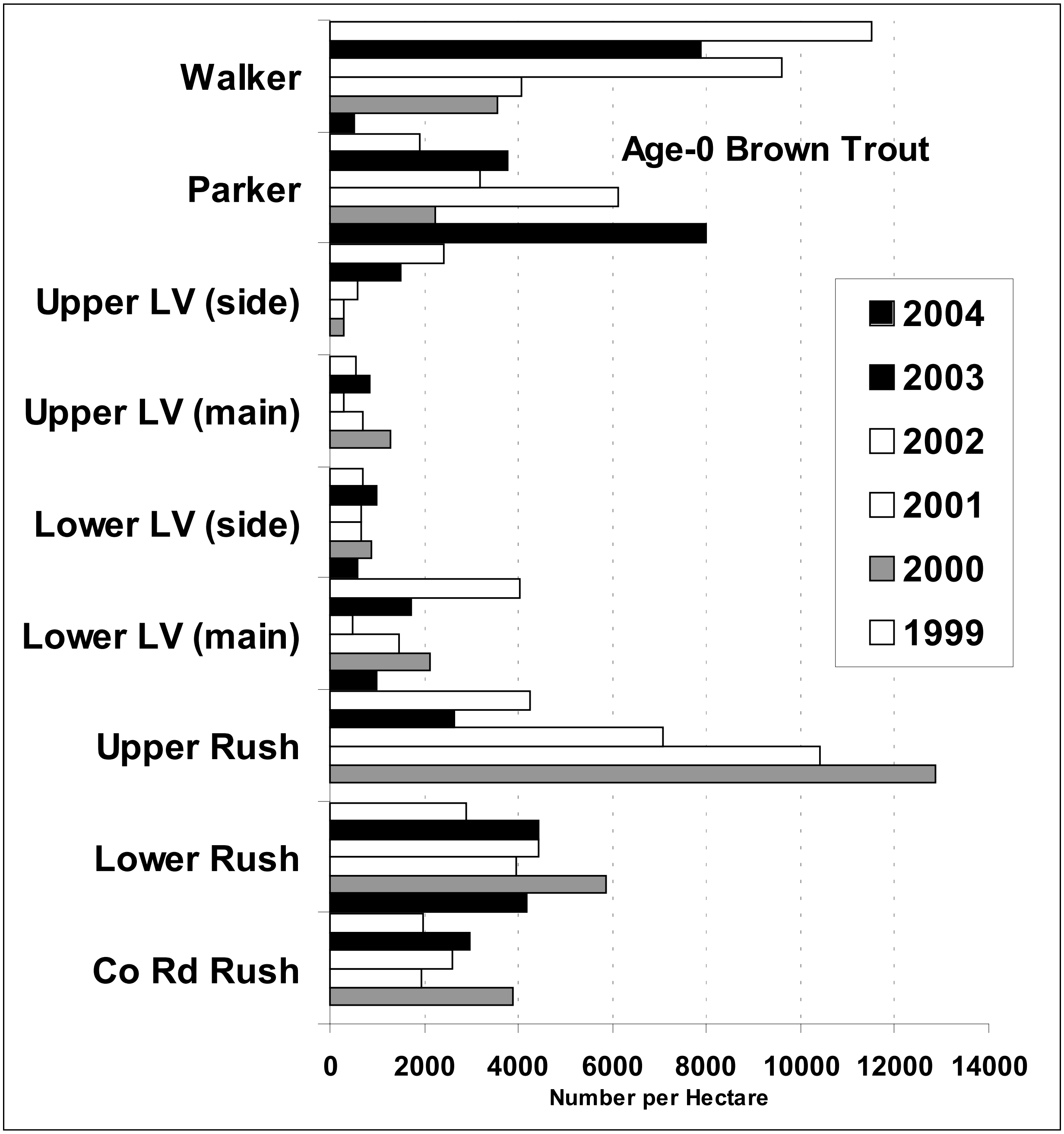


Figure 14. Estimated number of age-0 brown trout per hectare in sections of Walker, Parker, Lee Vining, and Rush creeks during September from 1999 to 2004.

In the Upper Rush Creek section, the estimated densities of age-0 brown trout increased by 38% from the all-time low recorded in 2003. In contrast, estimated densities of age-0 brown trout in the other two sections (Lower and Co. Road) dropped in 2004 to the lowest densities ever recorded for these two sections. Only 25 age-0 brown trout were sampled in the MGORD, which is not surprising given the diversion canal's relative lack of shallow margin habitat for juvenile rearing and numbers of larger, piscivorous brown trout. However, the age-0 brown trout in the MGORD were already exhibiting growth rates superior (average length = 114 mm and average weight = 15 g) to age-0 brown trout from all other sample sections in Rush and Lee Vining creeks (Table 7).

In Walker Creek, the estimated density of age-0 brown trout for the 2004 season was the highest ever recorded for this section. Conversely, the 2004 density estimate of age-0 brown trout in Parker Creek dropped by 65% of the 2003 estimate to the lowest ever recorded for this study section.

The reasons for the wide range of variability of the densities of age-0 brown trout in the study sections are uncertain. The fisheries literature summarizes several reasons for variable recruitment of age-0 trout, mostly related to stream hydrology. For example:

- Pender and Kwak (2002) studied brown trout reproductive success in Ozark tail-water rivers indicated that fecundity (number of eggs) and pre-spawning condition factors of female trout affected age-0 recruitment. However, on the White River widely fluctuating discharges at hydro-electric facilities affected redd survival.

- Gonzalez et al. (2002) investigated brown trout recruitment in the Central Iberian Peninsula detected two strong linear relationships between young-of-year recruitment and the frequency and magnitude of flood events between spawning and emergence. These relationships suggest that when more frequent floods occur between spawning and emergence, recruitment is lower. This paper also cited several other studies that came to similar conclusions (Jensen and Johnson 1999; Spina 2001; Cattaneo 2002). However, Cattaneo (2002) concluded that hydrology only constrained trout dynamics during the critical emergence period, after which intra-cohort interactions regulated age-0+ densities in 30 French stream reaches.

- Orth et al. (2003) examined the influences of fluctuating releases on brown trout habitat in the Smith River below Philpott dam over a four-year study period. In 2003, the densities of brown trout in all study sections were significantly lower than densities estimated in 2000-02. In 2003, the Army Corps of Engineers increased the occurrence, magnitude, and duration of peak flows during the incubation period due to frequent rain events.

- Nuhfer et al. (1994) monitored brown trout populations in the South Branch of the Au Sable River in Michigan for 16 years and used linear regression to test empirical relationships between age-0 recruitment and stream flow and winter severity. Results indicated that variations in stream flow (higher discharges) during the 30-day period corresponding to brown trout emergence and initial foraging behavior was when flow significantly influenced recruitment. No other time period (including spawning and incubation period) showed statistical relationships between flow and age-0 recruitment. No relationship was found between age-0 recruitment and measures of winter severity.

For a second straight year, the estimated densities of age-1 and older rainbow trout declined dramatically in all sections of Lee Vining Creek, including only three fish sampled in the Upper side-channel (Figure 15). These low numbers and continued decline are not surprising considering the extremely poor recruitment of age-0 rainbow trout in Lee Vining in 2003 and 2002. In Rush Creek, all three annually-sampled sections experienced declines, although not as severe as the Lee Vining Creek sections (Figure 15).

Estimated densities of age-0 rainbow trout were extremely low in 2004 in all sample sections except for the Lee Vining Creek Lower side-channel section (Figure 16). No age-0 rainbow trout were captured in Lee Vining Creek in 2003 and very low numbers were sampled in 2002. Rainbow trout spawn during the spring, thus their embryos remain within the gravel through much of the high water period and they often emerge as peak flows begin declining. Extremely high stream flows can mobilize the streambed, crushing incubating embryos. Rapidly varying flows soon after emergence occurs can either strand or flush newly emerged fry because they are relatively poor swimmers.

Kondolf et al. (1991) documented spawning gravel distribution and bed mobility in seven high-gradient stream reaches in the eastern Sierras over two seasons, 1986 (a wet year) and 1987 (a dry year). During the wet year, all tracer rocks placed in spawning gravel pockets were swept away, and substantial scour, fill, and channel changes were noted throughout their study streams. The authors theorized that periodic mobility of gravels may explain why brown trout are more abundant than rainbow trout in many eastern Sierra streams where high flows occur in May and June due to snowmelt. Brown trout are fall spawners, and their fry emerge long before high snowmelt flows; whereas rainbow trout are spring spawners whose eggs (or alevin) are in the gravel, and thus, more vulnerable to scour during snowmelt flows. Interestingly, these authors noted that most of their study streams looked more like typical rainbow trout streams, yet brown trout have been much more successful in these systems (Kondolf et al. 1991).

We offer these speculative ideas on why we have found either few or no age-0 rainbow trout fry in Lee Vining Creek between 2002 and 2004. Since 1999, it appears that recruitment has been lower following winters with deeper snow-packs and higher spring run-offs in Lee Vining Creek.

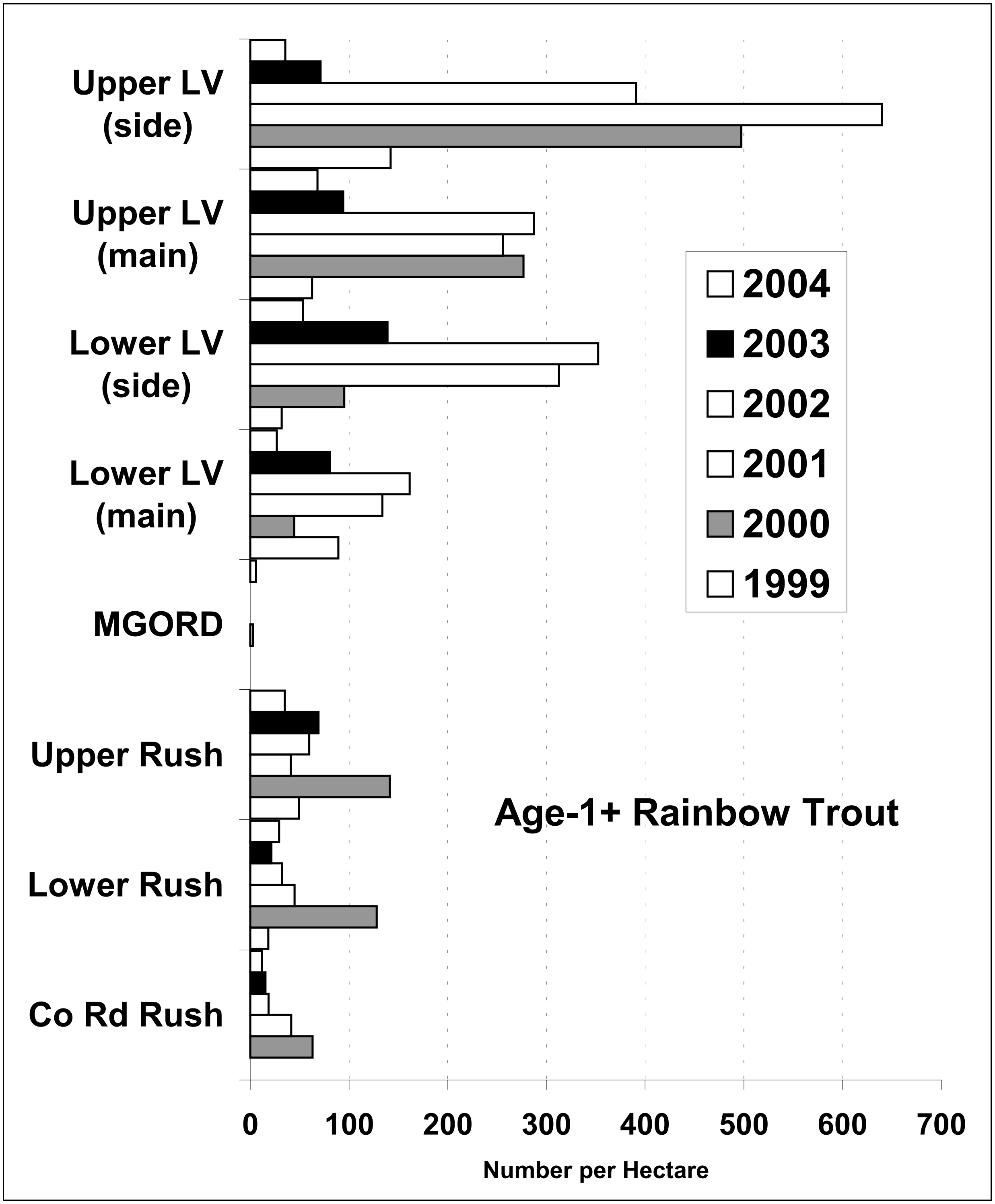


Figure 15. Estimated densities (number per hectare) of age-1 and older rainbow trout in sample sections of Lee Vining and Rush creeks.

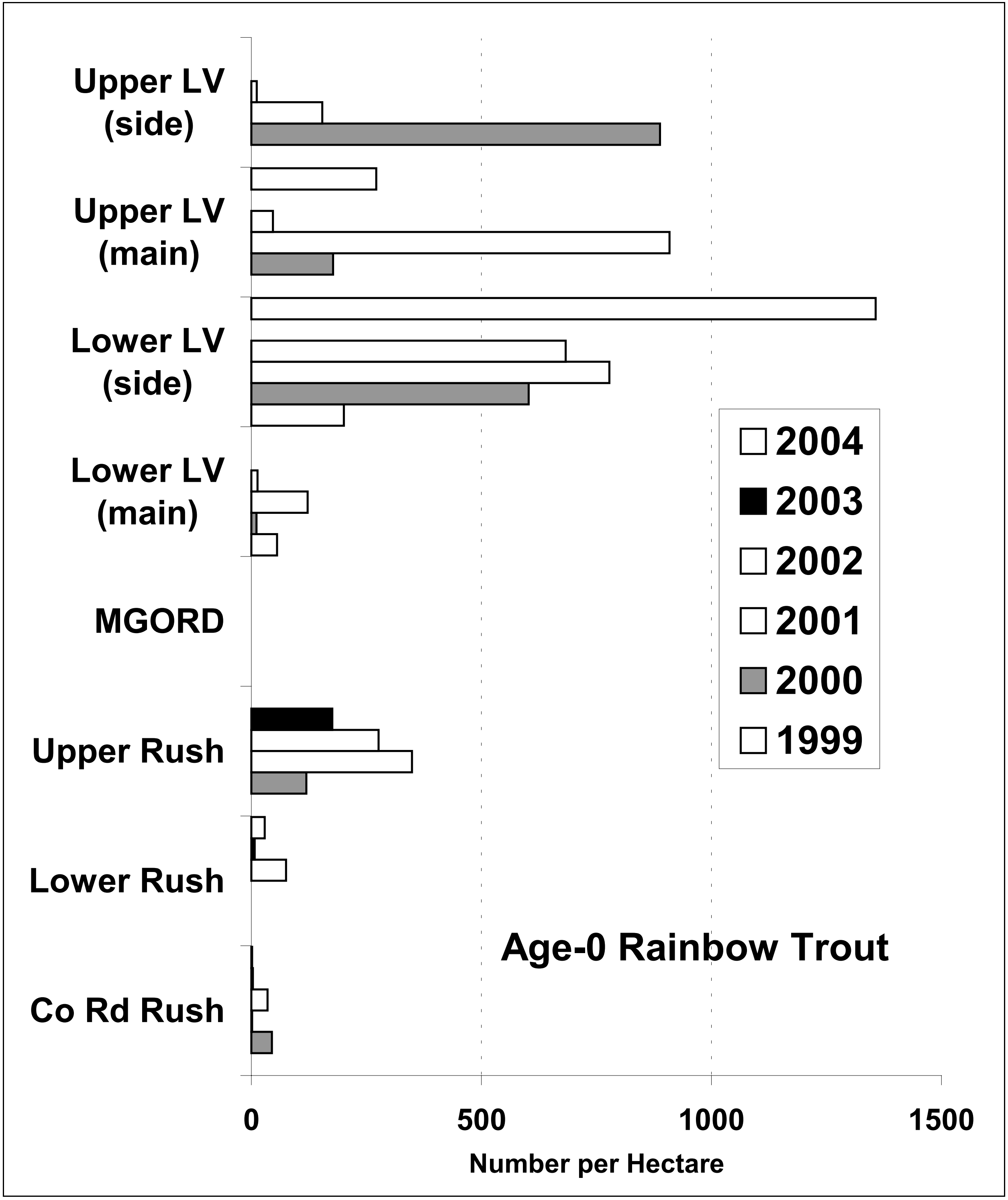


Figure 16. Estimated densities (number per hectare) of age-0 rainbow trout in sample sections of Lee Vining and Rush creeks.

Estimated Trout Standing Crop Comparisons

Estimates of brown trout standing crops (kg/hectare) in all four Lee Vining Creek sections increased from 2003 to 2004, with the Upper main-channel and Upper side-channel sections experiencing increases of nearly 30% and 35%, respectively (Table 11). In contrast, brown trout standing crops dropped from 2003 to 2004 in all three of the annually sampled Rush Creek sections, with the largest decrease occurring in the Lower section (Table 11). The MGORD's 2004 standing crop estimate was 77% lower than the 2001 estimate. For all age classes combined, standing crops in Walker Creek decreased from 2003 to 2004; however there was an increase in the standing crop of age-0 brown trout (Table 11). In Parker Creek, the standing crop estimate dropped by nearly 50% between 2003 and 2004 (Table 11). Most standing crop estimates were 50 kg/ha or higher, except in the MGORD (23.7 kg/ha) and the Lee Vining Creek Lower side-channel (33.1 kg/ha)(Table 11).

Total trout standing crops (all age classes and species combined) have been estimated since 1999 to determine potential trends (Figure 17). Total standing crop takes into account the total biomass of fish per unit area, not necessarily the age-class structure of the trout populations. In Rush Creek, where brown trout have dominated the fish community, the County Road section's standing crop has remained fairly constant, while standing crops at the Upper and Lower Rush Creek sections have generally declined. In the Lower Main section of Lee Vining Creek, where brown trout have also been the dominant species, total standing crop values have steadily increased. At the other three sections of Lee Vining Creek, where relatively higher proportions of rainbow trout were present from 1999-2004, standing crops have exhibited more up-and-down variability. Standing crops for the brown trout populations on Parker and Walker creeks have demonstrated an overall upward trend during the study period.

Between 1984 and 1991, the California Department of Fish and Game (CDFG) conducted extensive electro-fishing surveys of eastern Sierra streams in the Mono Lake basin and in the Owens River watershed as part of their wild-trout management program (Dienstadt et al. 1985; 1986; 1997). Although the CDFG surveys typically sampled much shorter stream sections (240 to 380 foot long sections) than we are currently sampling, some comparisons can be made, especially for the sections of Rush Creek that overlap. The recent (2003-04) standing crops estimates are fairly similar to CDFG's estimates and also exhibit less fluctuation (Table 12). During the initial CDFG surveys (conducted in November 1984 and June 1985) no age-0 brown trout (<125 mm) were captured in any of the Rush Creek sections.

Standing crop estimates generated by CDFG for the Owens River and its tributaries also exhibited a wide range of production between streams and between sections within the same stream. The initial Owens River report summarized information collected in 80 sections within 29 streams that produced an average brown trout standing crop of 135.6 kg/hectare (Dienstadt et al. 1985). Four sections within the Owens River main-stem, two sections in the Bishop Creek Canal, and a Hot Creek section had extremely high standing crops that probably skewed the average of the 1985 report (range of 427 – 829 kg/hectare for these seven sections). In most stream sections, the standing crops of brown trout were between 30 to 120 kg/hectare. The second Owens River report summarized information collected in 50 sections within 23 streams that produced an average brown trout standing crop of 85.6 kg/hectare (Dienstadt et al. 1986). The 1986 report also included a Hot Creek section with an extremely high standing crop (717 kg/hectare) and five other stream sections with standing crops ranging between 385 – 605 kg/hectare. The remaining 45 sections had standing crops between 0 – 350 kg/hectare; with 18 stream sections having brown trout standing crops of less than 150 kg/hectare (Dienstadt et al. 1986).

Table 11. Comparison of 2003 and 2004 brown trout standing crop (kg/ha) estimates in Mono Lake tributaries.

Collection Location	2003 Total Standing Crop	2003 Standing Crop Age-0	2003 Standing Crop Age-1 and older	2004 Total Standing Crop	2004 Standing Crop Age-0	2004 Standing Crop Age-1 and older	Percent Change Between 2003 and 2004 – total standing crops
LV – Upper Side	67.3	14.2	53.0	102.6	17.1	85.5	+34.4%
Lee Vining Lower Side	30.0	10.2	19.8	33.1	6.2	26.9	+9.4%
Lee Vining Upper Main	51.7	8.0	43.7	73.5	4.1	69.4	+29.6%
Lee Vining Lower Main	121.1	16.1	104.9	133.6	34.4	99.3	+9.3%
Rush Co. Road	79.7	20.6	59.1	75.9	16.9	59.0	-4.8%
Rush Lower	92.8	34.8	58.1	55.8	25.2	30.6	-39.9%
Rush Upper	124.9	31.7	93.2	106.5	36.4	70.1	-14.7%
Rush MGORD	103.1*	0.0	0.0	23.7	0.0	23.7	-77%
Parker Creek	144.1	20.6	123.5	75.2	15.0	60.2	-47.8%
Walker Creek	375.3	59.8	315.5	338.5	75.2	263.3	-9.8

*2001 standing crop value for MGORD

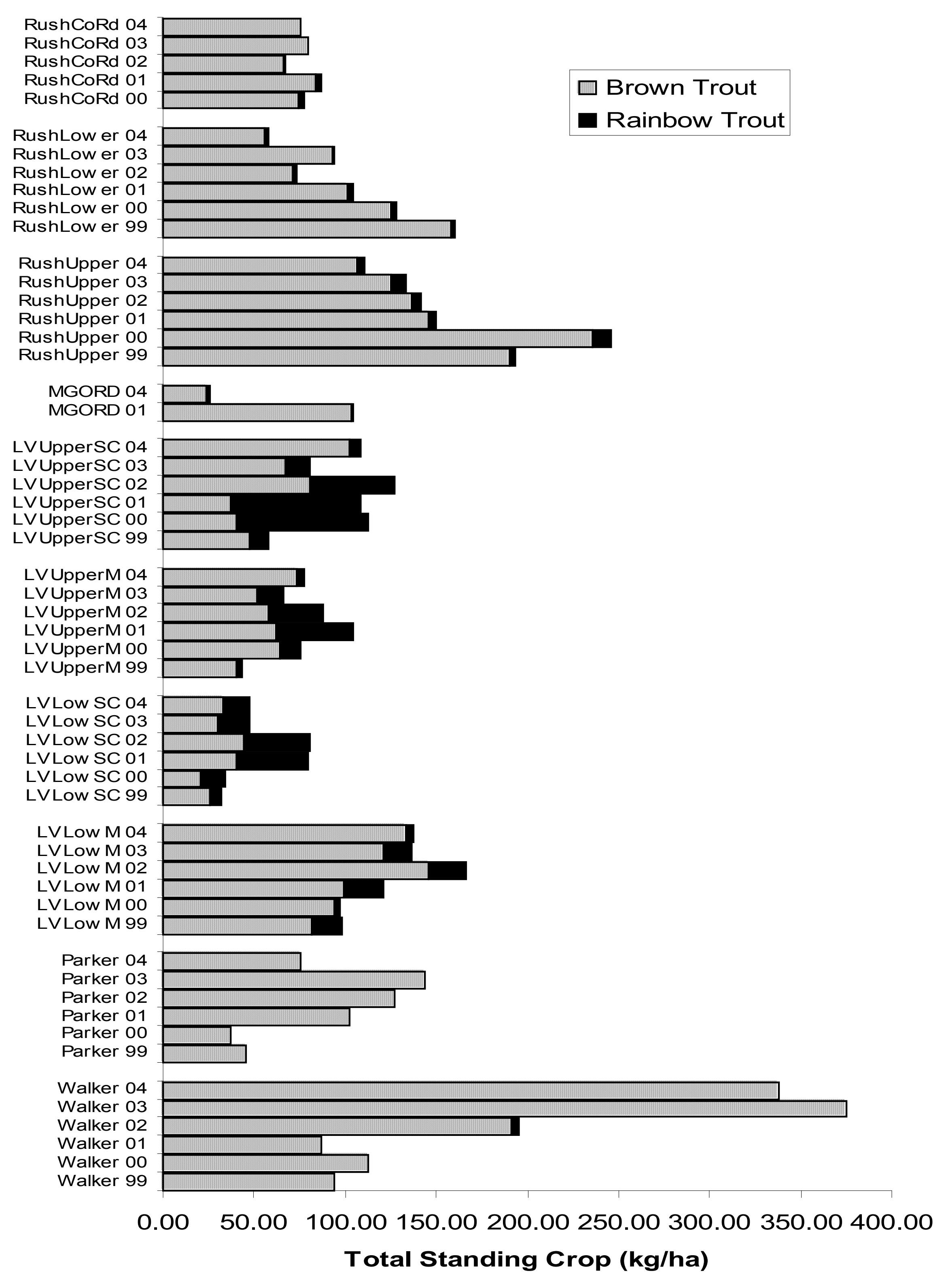


Figure 17. Total standing crop (kilograms per hectare) of brown trout and rainbow trout in all sample sections, 1999 - 2004.

Table 12. Comparisons of LADWP and CDFG's brown trout standing crop (kg/hectare) estimates in three sections of Rush Creek.

Collection Locations Similar to both Studies	2003 Total Standing Crop	2004 Total Standing Crop	1984/85 Total Standing Crop	1986 Total Standing Crop	1991 Total Standing Crop
Rush Creek - Co. Road	79.7	75.9	88.6	54.2	131.5
Rush Creek - Lower	92.8	55.8	152.0	99.3	72.1
Rush Creek - Upper	124.9	106.5	95.8	131.3	91.1

While these reports provided some of the best available information on standing crop estimates and age-class structures for other eastern Sierra streams; most of these sections were sampled only once by CDFG. In addition, these sampled streams represented a wide variability of drainage areas, channel slopes, flow volumes, elevations, and management activities and impacts. Further examination of these streams may be useful to select only those sites that have similar geomorphic and hydrologic characteristics of the Rush and/or Lee Vining creeks' study sections to make more appropriate comparisons.

Age, Growth, and Survival

Age information collected to date still supports our original assumption that trout populations in Mono Basin tributaries generally contain relatively short-lived individuals, helping to explain the paucity of larger trout and the continued failure to meet the termination criteria adopted by the SWRCB. The one exception is the MGORD section of Rush Creek where the scale samples indicated that numerous brown trout were at least age four and five years old; and probably older. Many scale samples from larger fish (>350 mm) were unreadable due to scale regeneration. The oldest confirmed age for a brown trout was 11 years old read from an otolith collected from a 443 mm mortality.

It appears that the MGORD section of Rush Creek provides several attributes conducive to growing older and larger brown trout that are possibly limiting in other sections of Rush Creek, including:

- Depth and cover. Much of the MGORD is >1.0 meter in depth and the elodea beds create extensive overhead cover.
- Low velocity. Compared to other sections of Rush Creek, the MGORD has relatively slower velocities.

- Abundant food supply. Besides caddisflies and scuds, the MGORD supports a viable crayfish population that is not apparent in other Rush Creek sections.

- Stable temperature regime. Compared to lower sections of Rush Creek, the MGORD has a more stable temperature regime with lower maximums, higher minimums, and lower diurnal fluctuations. For example, in 2002 the number of days where the water temperature exceeded 70^{o}F was 11 days in the MGORD and 39 days in the County Road section. In August of 2002, the diurnal fluctuation in the averaged 4.9^{o}F in the MGORD and 12.8^{o}F in the County Road section. In lower sections of Rush Creek widely varying diurnal fluctuations occur as early as May and continue through September. Needham (1969) concluded that both absolute temperature and thermal constancy determine habitat suitability, and that trout in streams with springs and relatively constant temperatures experienced high growth rates. Brown trout are regarded as one of the most temperature-tolerant trout species as it can withstand temperatures of up to 77 °F. Temperatures of 70-77° F, however, are considered stressful for brown trout (Galli 1990). While brown trout may be able to survive relatively extreme fluctuations in temperature, the food they rely on, mainly aquatic insects, may not. In a Maryland study it was determined that many coldwater insect species would be eliminated or reduced by the thermal enrichment of a stream. Important species to the trout, such as stoneflies, mayflies, and caddis flies, would be severely impacted or stressed by stream temperature fluctuations (Galli 1990). Thus stream temperature fluctuations have not only the potential to stress the trout directly, but indirectly through their food source as well.

The survival estimates based on the 2003 scale and otolith analyses for Rush and Lee Vining creeks revealed an interesting trend. It appeared that a variable number of age-0 trout produced in any given year had relatively consistent survival rates that translated to variable numbers of age-1 brown trout the following year; however, the subsequent year's number of age-1 brown trout appeared to have limited influence on the following year's estimate of age-2 fish. This trend appears to carry through that cohort's progression to age-3 and age-4, suggesting that habitat availability may be influencing Rush and Lee Vining creeks' carrying capacities for older trout. At this point we are uncertain of what type of habitat is limiting the survival of older brown trout, but variables such as low-velocity pools, over-wintering habitat, and/or food should be investigated as possible limiting factors.

The Fraser-Lee back-calculations of length-at-age interpreted from scales produced better estimates than the natural log transformed regression method for scales and otoliths collected in 2003. It is important to remember that empirical lengths were measured in September and these fish will likely experience additional growth before laying down their next annulus.

Methods Evaluation

Mark-recapture electrofishing has provided relatively reliable estimates; however, our difficulty in maintaining block fences in Upper Rush Creek may be biasing estimates for this section. A recent paper by Young and Schmetterling (2004) suggests that movement of trout in the week-long redistribution period between mark and recapture electrofishing sampling runs was insignificant in mountain streams of Montana. This paper was reviewed and discussed by the Mono Basin Fisheries monitoring team and it was decided to continue the use of block fences with the annual sampling. Although the limited tagging data appears to support the hypothesis that trout are not moving too extensively, at least during the time when sampling has occurred in Rush Creek, the Fisheries team was concerned about the effects of driving fish downstream out of the sampling sections during electrofishing runs. Having a field technician dedicated to maintaining block fences reduced the frequency of block net failures in 2003 and 2004 compared to previous years, and is probably providing better estimates than if no block fences were employed.

Between 2003 and 2004, sample sections experienced negligible changes in channel geometry with the exception of two Rush Creek sections – the County Road section narrowed by an average of 1.1 meters and the Upper Rush section widen by an average of 0.6 meters. These changes resulted in a 13% decrease in surface area of the County Road section and a 7.5% increase of surface area in the Upper Rush Creek section. These changes may have been caused by Rush Creek's 2004 peak flow of 380 c.f.s., which in the County Road section visibly deepened a number of pools resulting in better habitat for age-1 and older trout. However, slight year-to-year variations in channel widths may also be influenced by the random selection of where widths were measured. The side-channel in the County Road Section of Rush Creek that captured about 30% of the stream's flow between 2002 and 2003 was sampled again in 2004.

The changing channel configurations within sample sections could change the amount of habitat sampled especially if the creek were to abandon its current main channel and occupy a completely new channel. While the recent changes have probably not yet been significant enough to render annual comparisons invalid, it is possible that future channel changes following major high-flow events may be significant enough to make annual comparisons difficult. The upstream and downstream boundaries of all sample sections have been permanently marked. Regardless of noticeable change in the channel, channel lengths and wetted widths are re-measured annually. We have sketched rough field maps of each sample section. We will re-map these sections if we notice any significant channel change to ensure documentation of significant channel changes within the sample sections.

Termination Criteria

The agreed upon termination criterion for Lee Vining Creek is to sustain a fishery for naturally-produced brown trout that average eight to 10 inches in length with some trout reaching 13 to 15 inches. In 2004, the main channel sections of Lee Vining Creek supported 14.5 and 18.7 trout ≥200 mm (~8 inches) per 100 meters of channel length and the side-channel sections supported five (Upper section) and 10 (Lower section) brown trout ≥200 mm per 100 meters of channel (Table 13). During 2004, no trout were captured in Lee Vining Creek that exceeded 330 mm (~13 inches) and only three trout over 300 mm (~12 inches) were captured. In 2004, the density of trout ≥200 mm in the four Lee Vining Creek sections ranged from 160 to 390 trout per hectare and brown trout predominated rainbow by a ratio of more than 9:1 (Figure 18). Using the proportion of captured trout that were longer than 250 mm (~10 inches) for those length groups for which a modified Peterson mark-recapture estimates were made and multiplying the length-group estimate by those proportions provided estimates of the larger trout captured. It was estimated that the two Lee Vining Creek sections supported about 90 to 130 trout > 250 mm per hectare (Figure 19). The densities of these larger trout indicate Lee Vining Creek probably did not meet termination criteria in 2004.

The agreed upon termination criterion for Rush Creek states that Rush Creek fairly consistently produced brown trout weighing 0.75 to 2 pounds. Trout averaging 13 to 14 inches (330 to 355 mm) were also allegedly observed on a regular basis prior to the 1941 diversion of this stream. In the three Rush Creek sections sampled annually, only four trout longer than 300 mm (~12”) were captured (all were brown trout) during 2004. However, only one of these fish was over 300 g (0.66 pounds), but that fish was 541 mm and 1,944 g (4.3 pounds). The estimated densities of larger trout in Rush Creek (excluding the MGORD) during 2004 do not indicate that this stream is close to reaching termination criteria (Figures 18 and 19).

Although the MGORD is not considered a natural section of Rush Creek or counted towards meeting termination criteria; 97 trout greater than 300 mm in total length were sampled this section in 2004. These larger trout comprised 21% of the 454 individual fish sampled in the MGORD. As previously discussed, the MGORD is probably able to support these larger fish by providing extensive cover, more deep pools, low velocities, abundant food, and relatively stable temperature regime as compared to the natural channel sections of Rush Creek.

Table 13. Estimated numbers of brown trout greater than 200 mm and estimated numbers of brown trout greater than 200mm per unit channel length in Mono Basin tributaries for sampling season 2004.

Stream Name and Section	Number of Brown Trout ≥ 200 mm	Length of Section (m)	Number of Brown Trout ≥200 mm per 100 m of Channel
Lee Vining – Upper Main Channel	48	330	14.5
Lee Vining – Lower Main Channel	29	155	18.7
Lee Vining – Upper Side-channel	10	201	5.0
Lee Vining – Lower Side-channel	20	195	10.3
Rush Creek – County Road	147	813	18.1
Rush Creek – Lower Section	42	405	10.4
Rush Creek - Upper Section	122	430	28.4
Rush Creek - MGORD	668	2,230	30.0

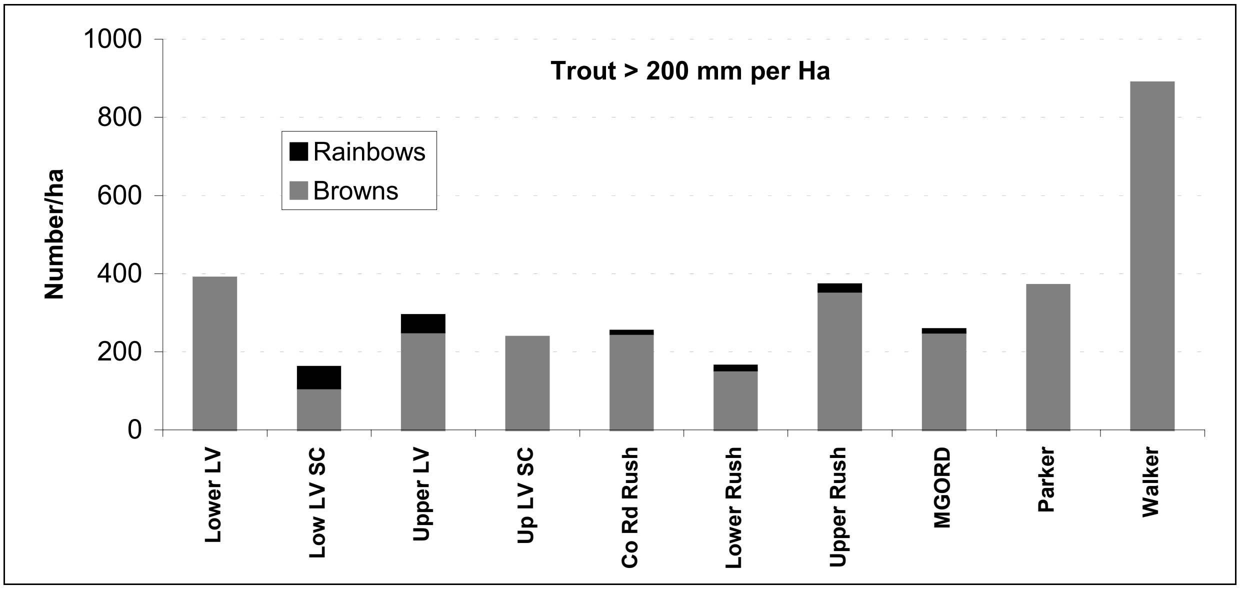


Figure 18. Density (number/hectare) of rainbow and brown trout ≥200 mm in Lee Vining Creek and Rush Creek sample sections in 2004.

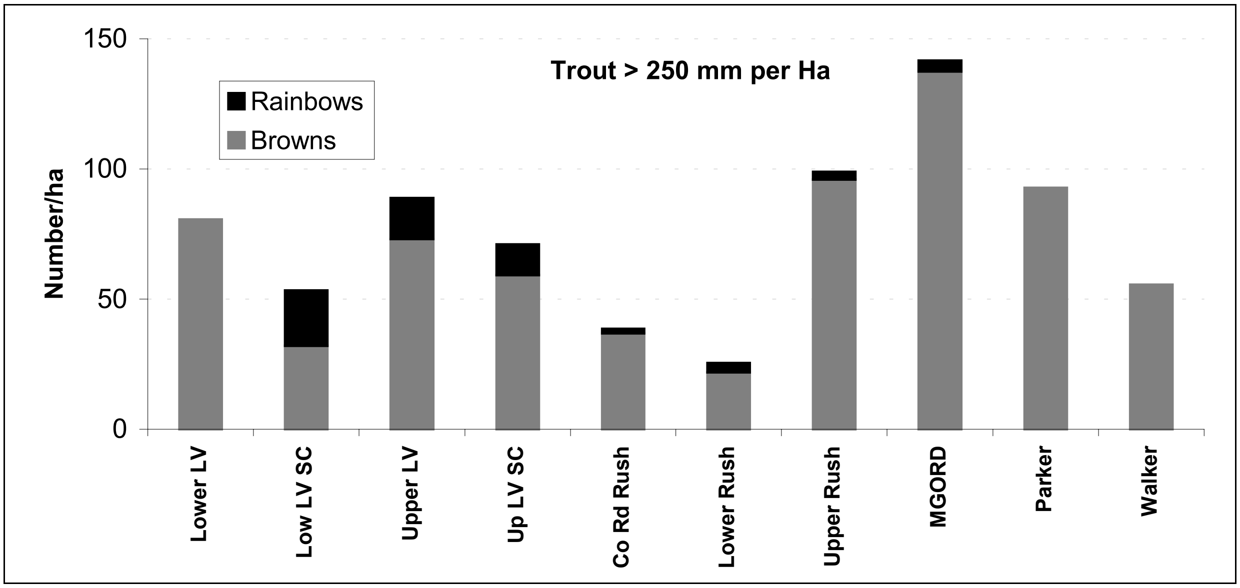


Figure 19. Density (number/hectare) of rainbow and brown trout ≥250 mm in Lee Vining Creek and Rush Creek sample sections in 2004.

Recommended Termination Criteria

Our 2000 report noted that there is virtually no data available that provides an accurate picture of trout populations that these streams supported on a self-sustaining basis prior to 1941 (Hunter et al. 2000). We recommended that additional fish population data be collected from these streams for several years until we have a suitable amount of data to objectively evaluate the current termination criteria (Hunter et al. 2000, 2001, 2002, 2003, 2004). This continues to be our recommendation. We also believe that obtaining at least six, and preferably ten, years of continuous fish abundance information will allow us to assess potential relationships between fish populations and physical habitat components, such as flows, physical habitat parameters, and water temperatures. Starting in 2005, a study to examine changes in habitat quality and quantity as related to discharge and a radio-telemetry/movement study should provide additional information in the relationships between flow, habitat availability, and movement of brown within Rush Creek.

The data collected over the past six years suggests that Rush and Lee Vining creeks in their current condition are probably incapable of sustaining trout populations with age and size-class structures consistent with the termination criteria adopted by the SWRCB. The data strongly suggests that outside of the MGORD, very few trout are surviving past age-3 or 4; thus termination criteria are not being met. These results raise several questions for consideration:

- Were peoples' recollections accurate in portraying what the fishery was like pre-1941? As decades went by, did the recollections of how good the fishing was become inflated?

- If the pre-1941 fisheries information was accurate, what were the habitat features in Rush Creek that grew these larger fish? Were these natural features or the result of irrigation or other activities that are no longer practiced?

- Is the recovery of “big-trout” habitat dependant on the maturation of cottonwoods and Jeffery pines within the riparian zone and the eventual recruitment of these trees as LWD to form complex in-stream habitat? If so, it make take many decades before a significant increase in larger trout occurs.

- What time of year does most of the mortality of trout occur? Is this mortality related to a habitat limitation and, if so, can flows be managed to reduce this mortality? We suspect that most of the mortality is occurring during the winter months and will be exploring this issue further. An anchor-ice study in Lee Vining Creek is currently being conducted by Tom Jenkins through SNARL and may provide information regarding habitat limitations during winter months.

We are currently evaluating potential termination criteria that would be based upon standing crop estimates. We believe standing crop estimates would be more stable, more quantifiable, and would potentially relate to carrying capacities of particular stream sections. We also believe some secondary criteria related to population size structure could be developed. Both trout standing crop and size structure criteria could be related to habitat capability, thus as habitat conditions improve, as expected in Mono Basin streams, both standing crops and proportions of larger fish within the populations should increase.

The final reports of the electro-fishing surveys conducted by CDFG in the Mono Lake basin and the Owens River watershed provide standing crop and age-class data for 59 eastern Sierra streams and could be used for developing methods to assess the Mono Lake basin streams currently being monitored (Dienstadt et al. 1985, 1986, 1997). In most cases the stream reaches surveyed by CDFG supported similar standing crops and age-class structures as we have estimated in Rush, Lee Vining, Walker, and Parker creeks over the past six years. The exceptions were highly productive stream reaches in the Owens River, Hot Creek, and the Bishop Creek canal that emulate conditions typical of spring creeks.

As we previously mentioned, most of these sections were sampled only once by CDFG and it is unknown if estimates they made represent an “average” year or an outlier (either low or high). These streams and sections also cover a wide variability of drainage areas, channel slopes, flow volumes, elevations, and management activities and impacts. Further examination of these streams may be useful for selecting only sites that have similar geomorphic and hydrologic characteristics of our Rush and/or Lee Vining creeks’ study sections to make more appropriate comparisons. If this method is employed, the collection of additional standing crop data from these streams may be needed to examine their variability.

Acknowledgements

We would like to thank Los Angeles Water Power for their continued support of this project, especially Mark Hanna and Dave Martin. Dave Martin of LADWP has provided technical support and field help. In 2004, Nik Schnieder provided his second year of high-quality field assistance with block net set-up and maintenance, fish sampling, and block net break-down and storage. The Mono Lake Committee has assisted with copying field data sheets and allowing us to use their Internet computer terminals. McBain and Trush Consultants provided maps, water temperature information, and completed physical surveys of sample sites. The owners and staff of the Latte Da and Mobile Station in Lee Vining, and Boulder Lake Lodge at June Lake have consistently provided good lodging, excellent food and beverages, and lively conversation.

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Appendix A. Sample Section Dimensions for 1999 – 2004

Section	Length (m) - 1999	Width (m) - 1999	Area (m^2) - 1999	Length (m) – 2000	Width (m) - 2000	Area (m^2) - 2000
Rush – County Road	N/A/	N/A	N/a	813	8.0	6,504.0
Rush - Lower	405	5.4	2,187.0	405	5.4	2,187.0
Rush – Upper	430	7.1	3,053.0	430	7.4	3,182.0
Rush - MGORD	N/A	N/A	N/A	N/A	N/A	N/A
Lee Vining – Lower main	187	4.8	897.6	187	4.8	897.6
Lee Vining - Lower-B1	189	5.0	945.0	189	5.0	945.0
Lee Vining – Upper main	330	5.8	1,914.0	330	5.8	1,914.0
Lee Vining - Upper-A4	201	4.2	844.2	201	4.2	844.2
Parker	98	2.2	215.6	98	2.2	215.6
Walker	100	1.9	190.0	100	1.8	180.0

Section	Length (m) - 2001	Width (m) - 2001	Area (m^2) - 2001	Length (m) - 2002	Width (m) - 2002	Area (m^2) - 2002
Rush – County Road	813	8.0	6,504.0	813	8.0	6,504.0
Rush - Lower	405	5.5	2,227.5	405	6.9	2,794.5
Rush – Upper	430	7.4	3,182.0	430	7.4	3,182.0
Rush - MGORD	2,230	12.0	26,760.0	N/A	N/A	N/A
Lee Vining – Lower main	187	4.8	897.6	155	4.8	744.0
Lee Vining - Lower-B1	262.0	5.0	1,310.0	195	4.8	936.0
Lee Vining – Upper main	330	5.8	1,914.0	330	5.8	1914
Lee Vining - Upper-A4	201	4.2	844.2	201	4.2	844.2
Parker	98	2.2	215.6	98	2.2	215.6
Walker	100	1.8	180.0	100	1.8	180.0

Section	**Length (m) - 2004**	**Width (m) - 2004**	**Area (m^2) - 2004**	**Length (m) - 2003**	**Width (m) - 2003**	**Area (m^2) - 2003**
Rush – County Road	813	**7.3**	5934.9	813	**8.4**	6,829.2
Rush - Lower	405	6.8	2,754.0	405	6.9	2,794.5
Rush – Upper	430	**8.0**	3,440.0	430	**7.4**	3,182.0
Rush - MGORD	2,230	12.0	26,760.0	N/A	N/A	N/A
Lee Vining – Lower main	155	4.8	744.0	155	4.8	744.0
Lee Vining - Lower-B1	195	4.8	936	195	4.8	936
Lee Vining – Upper main	330	5.8	1914	330	5.8	1914
Lee Vining - Upper-A4	201	4.2	844.2	201	4.2	844.2
Parker	98	2.2	215.6	98	2.2	215.6
Walker	100	1.8	180.0	100	1.8	180.0

Section 4

Mono Basin Tributaries:
Lee Vining, Rush, Walker, and Parker Creeks

Monitoring Results and Analysis
For Runoff Season 2004-2005

Monitoring Results and Analyses for Runoff Year 2004-05

Mono Basin Tributaries: Lee Vining, Rush, Walker, and Parker Creeks

April 18, 2005

Mono Basin Tributaries:
Rush, Parker, Walker, and Lee Vining Creeks

Monitoring Results and Analyses for
Runoff Year 2004-05

Prepared for:
Los Angeles Department of Water and Power

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April 18, 2005

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1 INTRODUCTION

In June 2004, Rush Creek received the largest peak Stream Restoration Flow (SRF) since 1998. Monitoring of these flows began in May 2004, initiating the sixth consecutive year of official monitoring in the Mono Basin (Figure 1) following the State Water Resources Control Board (SWRCB) Decision 1631 and Order 98-05. Lee Vining Creek experienced a small snowmelt runoff in 2004. Spring and summer monitoring tasks were therefore focused primarily on Rush Creek.

In May and June 2004, we collected bed mobility and scour data with painted tracer rocks and scour cores, resurveyed cross sections and longitudinal profiles, installed additional water temperature recorders, and collected numerous synoptic discharge measurements. In July and August 2004 we replicated the riparian corridor vegetation mapping on each of the four tributaries to quantify riparian vegetation acreages for the Termination Criteria. At the reconstructed 3D Floodplain and 8 Floodplain, we also evaluated vegetation responses to the Rush Creek SRF releases. In addition, during the Rush Creek SRF releases, we initiated in-depth studies of groundwater and soil moisture dynamics at the *3D Floodplain* and 8-Channel sites, and we studied floodplain-building processes at the 3D site and three Lower Rush Creek sites. In November, we replicated planmapping of three Rush Creek study sites. Finally, we updated the geomorphic Termination Criteria for channel length, gradient, and sinuosity for Rush Creek and Lee Vining Creek.

This RY 2004 Annual Report also presents a GIS-compatible Riparian Vegetation Atlas that culminates several years' efforts to map and quantify desert and riparian vegetation along the four Mono Basin stream corridors, using 1929, 1999, and 2003 aerial photographs. This Atlas organizes the aerial photographs into numbered photos of similar scale; vegetation mapping is overlain onto the photos. As new vegetation maps are generated during the five-year periodic mapping cycles, they will be added to these maps already in the Riparian Vegetation Atlas.

2 HYDROLOGY

For the Runoff Year (RY) 2004-05, the April 1, 2004 runoff forecast was approximately 97,400 acre-feet (af), or 80% of the 1941-1990 average. This percentage is thus defined as Dry-Normal II conditions, according to the provisions of the State Water Resources Control Board (SWRCB) Order 98-05. Based on the 1941-1990 average runoff of 122,124 acre-feet, approximately 64% of runoff years are wetter (the exceedence probability is 64%). The final runoff year yield will likely differ from the predicted value.

2.1 Runoff Year 2004-05 Annual Hydrographs

2.1.1 Rush Creek

In Rush Creek, by SWRCB Order 98-05, baseflow requirements are 44 cfs (April through September), and 47 cfs (October through March). Stream Restoration Flow (SRF) releases for a Dry-Normal II year are 250 cfs for 5 days. In RY 2004, LADWP conducted a higher peak SRF release (than the required 250 cfs) to test the newly rehabilitated Return Ditch. This test proposed ramping flows at the Return Ditch up to a peak of 380 cfs (the maximum capacity of the Ditch) for a two-day peak duration. Prior to RY 2004, the last peak flow to exceed 380 cfs was the 538 cfs spill event of 1998(Table 1).

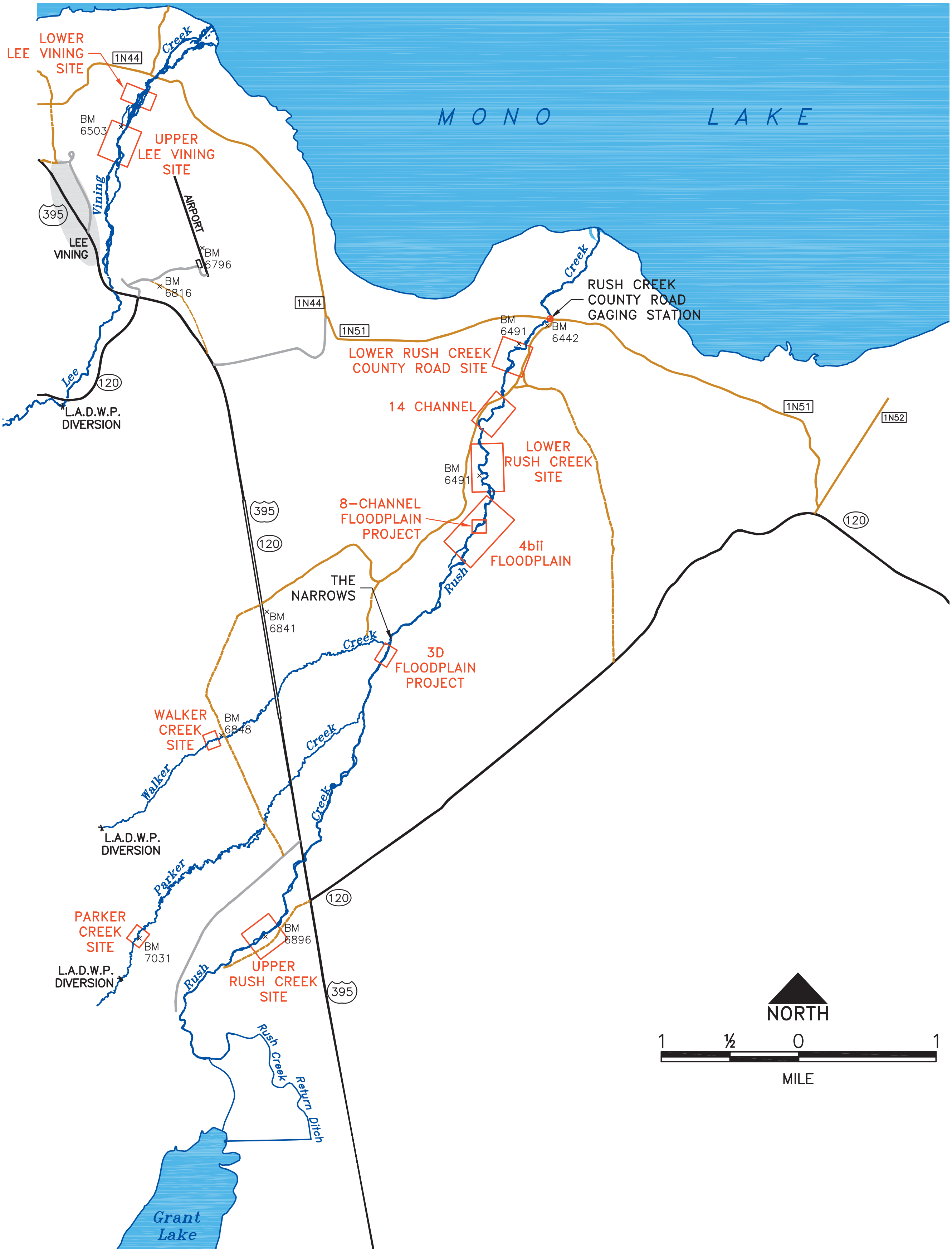

Figure 1. Location of the four Mono Basin tributaries: Rush, Parker, Walker, and Lee Vining creeks, and the study sites on each creek.

Table 1. Summary of peak discharge and dates for the Mono Basin tributaries the past eight years of monitoring. Values are daily average discharge (in cfs), with some instantaneous values reported in parentheses. Stations left-justified are data reported by LADWP or computed from their data; stations right-justified are an estimated proportion of the LADWP values based on regression analysis of synoptic discharge measurements.

Station	*RY 1997*	*Peak Date*	*RY 1998*	*Peak Date*	*RY 1999*	*Peak Date*	*RY 2000*	*Peak Date*	*RY 2001*	*Peak Date*	*RY 2002*	*Peak Date*	*RY 2003*	*Peak Date*	*RY 2004*	*Peak Date*
Rush Creek Runoff [1]	411	31-May-98	601	22-Jul-98	405	30-Jun-99	502	20-Jun-00	491	26-May-01	243	31-May-02	460	19-Jun-03	228	5-May-04
Rush Creek at Damsite (5013)	250	31-May-98	495	22-Jul-98	222	2-Jul-99	372	20-Jun-00	231	26-May-01	102	01-Jun-02	311	19-Jun-03	118	9-Jul-04
Rush Creek blw Return Ditch	175	18-May-98	538	23-Jul-98	201	10-Jul-99	204	30-Jun-00	162	11-Jun-01	168	8-Jun-02	203	7-Jun-03	343 (384)	11-Jun-04
Rush Creek blw Narrows (unimpaired) [2]	467	1-Jun-98	718	22-Jul-98	463	1-Jul-99	582	20-Jun-00	576	25-May-01	306	01-Jun-02	518	19-Jun-03	239	5-May-04
Rush Creek blw Narrows (actual) [3]	233	20-May-98	635	24-Jul-98	247	11-Jul-99	284	1-Jul-00	202	11-Jun-01	225	8-Jun-02	283	3-Jun-03	354 (413)	11-Jun-04
[Lower Rush Creek Main Planmap Reach]	147	20-May-98	396	24-Jul-98	155	11-Jul-99	161	1-Jul-00	128	11-Jun-01	144	8-Jun-02	181.12	3-Jun-03	241 (281)	11-Jun-04
[Lower Rush Creek 10-Channel]	89	20-May-98	259	24-Jul-98	95	11-Jul-99	99	1-Jul-00	76	11-Jun-01	81	8-Jun-02	101.88	3-Jun-03	113 (132)	11-Jun-04
Rush Creek at County Road Culvert (5186)											151	8-Jun-02				
Lee Vining Creek above Intake (5008)	378 (404)	31-May-98	419	9-Jul-98	285	19-Jul-99	264	28-May-00	201	17-May-01	238	30-May-02	332	30-May-03	152	5-May-04
Lee Vining Creek at Intake (5009)	354 (399)	31-May-98	391	9-Jul-98	274	19-Jul-99	258	28-May-00	201	17-May-01	236	31-May-02	317	31-May-03	141	15-Jun-04
[Upper Lee Vining Creek Mainstem]	245	31-May-98	270	9-Jul-98	190	19-Jul-99	179	28-May-00	140	17-May-01	164	31-May-02	231	31-May-03	103	5-May-04
[Upper Lee Vining Creek A-4 Channel]	126	31-May-98	140	9-Jul-98	96	19-Jul-99	90	28-May-00	69	17-May-01	82	31-May-02	105	31-May-03	47	5-May-04
[Upper Lee Vining Creek B-1 Channel]	159	31-May-98	176	9-Jul-98	122	19-Jul-99	115	28-May-00	89	17-May-01	105	31-May-02	139	31-May-03	62	5-May-04
[Lower Lee Vining Creek Main Channel]	195	31-May-98	215	9-Jul-98	152	19-Jul-99	143	28-May-00	112	17-May-01	131	31-May-02	178	31-May-03	79	5-May-04
[Lower Lee Vining Creek B-1 Channel]	159	31-May-98	176	9-Jul-98	122	19-Jul-99	115	28-May-00	89	17-May-01	105	31-May-02	139	31-May-03	62	5-May-04
Parker Creek (5003)	48	20-Jun-98	72	9-Jul-98	52	24-Jun-99	49	25-Jun-00	56	26-May-01	37	1-Jun-02	49	31-May-03	33	7-Jun-04
Walker Creek (5002)	34	1-Jun-98	47	21-Jul-98	30	29-May-99	31	28-May-00	42	16-May-01	26	2-Jun-02	43	May 30-03	20	6-Jun-04

[1] Computed natural flows, assuming no flow regulation;

[2] Computed by adding Rush Creek Runoff+Parker+Walker;

[3] Computed by adding RCBRD+Parker+Walker;

[4] Only gauged stations provide instantaneous peak discharges; stations that are calculated provide only the maximum daily average discharge;

Runoff Year 2004 SRF releases began June 1, 2004 and ramped to the peak release on June 11 (Figure 2). Ramping rates were accelerated compared to the recommended 10% ramping rates specified in the SWRCB Order 98-05 (up to 39% change per day), primarily to counterbalance the increased water required to reach the higher-than-required 380 cfs peak. The annual maximum instantaneous peak of 384 cfs was attained for a portion of one day on June 11 (Figure 3), and resulted in a daily average (calendar day) maximum of 343 cfs at the Return Ditch (Table 1) for June 11. Because flow changes during the ramping period occurred between 8 AM and 12 AM, the maximum flow averaged over a 24-hour period did not correspond to a calendar day. This flow was therefore computed from the 15-minute data, and was 374 cfs at the Return Ditch. Combined with Parker and Walker creeks, the annual maximum instantaneous peak below the Narrows was approximately 412 cfs, with a daily average (calendar day) maximum of 354 cfs. The 384 cfs instantaneous maximum has a recurrence interval of 1.34 years on the unregulated (Rush Creek Runoff) record, 2.33 years at the Return Ditch, and 5 years for Rush Creek at Damsite. The recurrence interval for the 412 cfs peak below the Narrows was 1.6 years. Rush Creek daily average flows exceeded 100 cfs for 20 days and 200 cfs for 10 days in June, 2004

The computed unimpaired Rush Creek Runoff had a daily average peak discharge of 228 cfs, with recurrence interval of approximately 1.1-yr. Thus, what would be a 1.1-yr event if flows were unregulated by LADWP is a 5-yr event based on SCE flows upstream of Grant Reservoir, and a 2.3-yr event based on LADWP regulation downstream of Grant Reservoir.

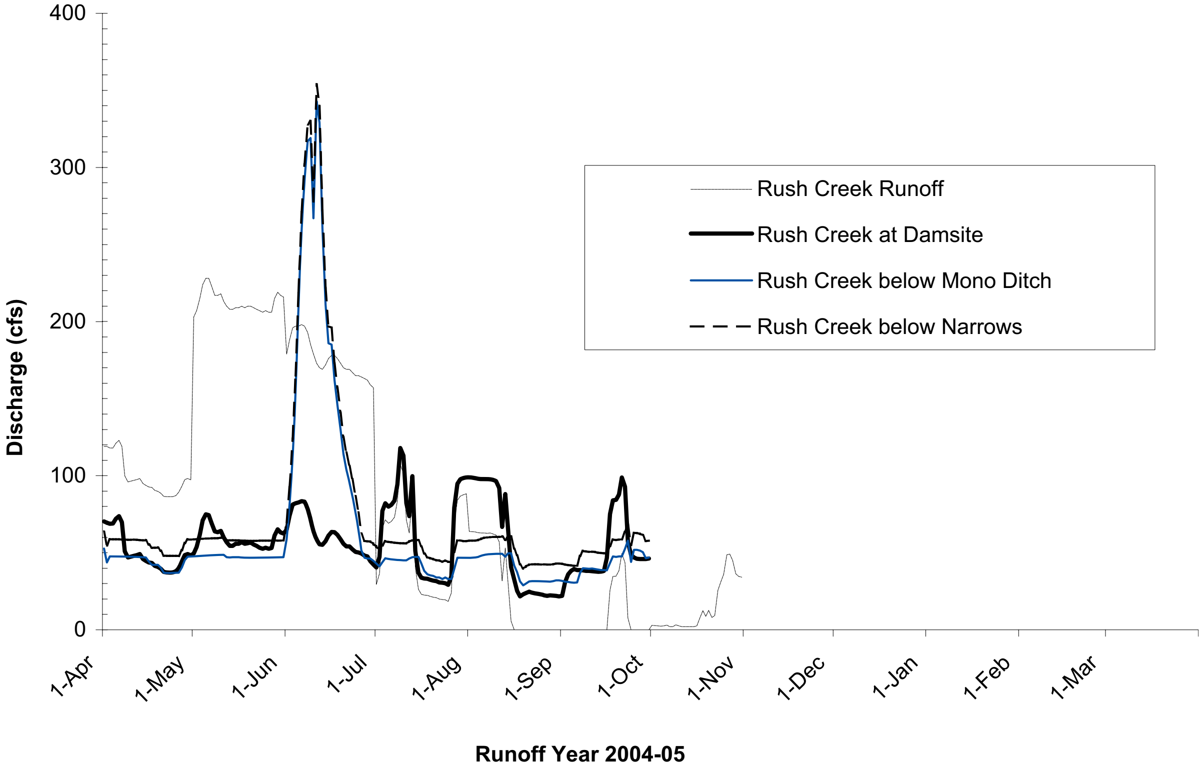

Figure 2. Annual hydrographs for Rush Creek for the first half of Runoff Year 2004-05.

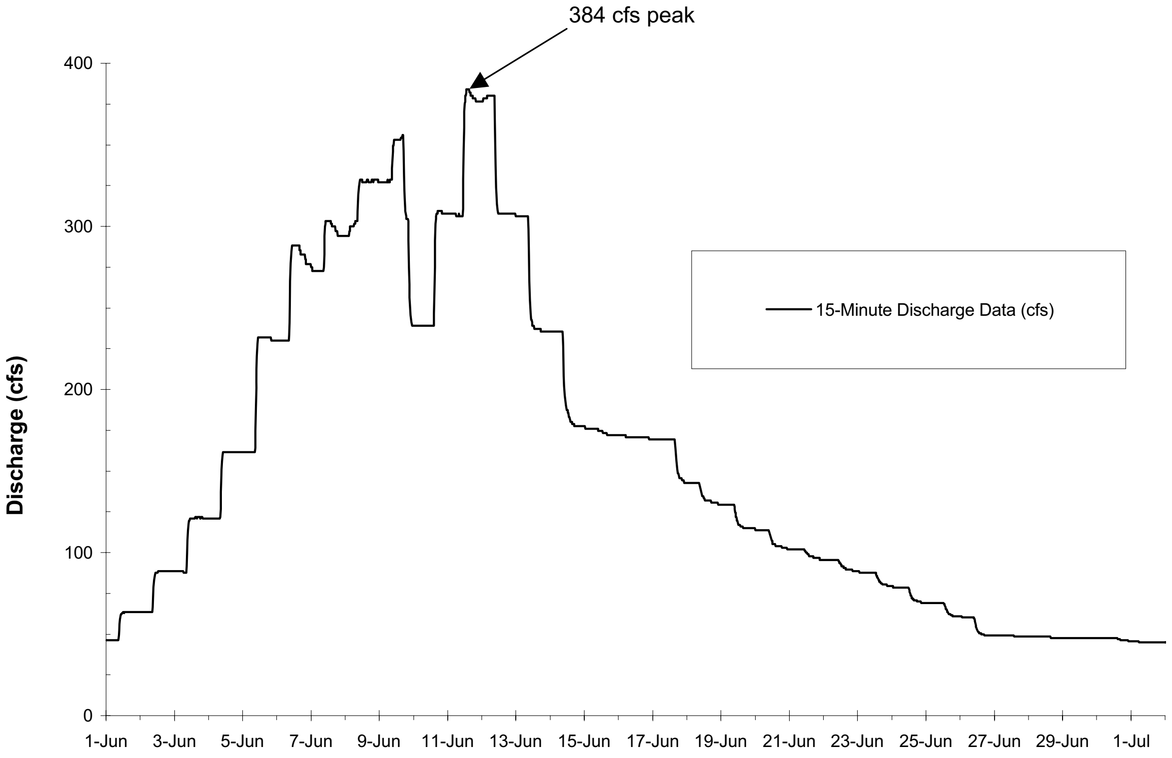

Figure 3. Rush Creek hydrograph for June 2004 with the LADWP 15-minute data for Mono Gate One Return Ditch.

2.1.2 Lee Vining Creek

Lee Vining Creek had a peak snowmelt runoff event that more typically resembled a Dry-Normal runoff year (Figure 4). The snowmelt hydrograph was characterized by several minor snowmelt floods, but no dominant peak event. Lee Vining above Intake had four snowmelt peaks of comparable magnitude (152, 149, 146, and 141 cfs) over a six week period from approximately May 1 to June 18, with the annual maximum peak of 152 cfs occurring May 5, 2004. The two early-season peaks were captured by LADWP diversions. The annual peak discharge of 141 cfs for Lee Vining Creek at Intake occurred June 15, 2004. This peak had a recurrence interval of 1.1-yr on the Lee Vining Creek regulated (LVC at Intake) flood frequency curve. The computed unimpaired Lee Vining Creek Runoff annual peak discharge was 183 cfs on May 5, 2004, also with a 1.1-yr recurrence interval on the unimpaired (LVC Runoff) flood frequency curve. No additional synoptic discharge measurements were made in Lee Vining Creek in RY 2004.

2.1.3 Parker and Walker Creeks

Parker and Walker creeks also had moderate snowmelt peak events in RY 2004 (Figure 5 and 6). No diversions occurred from Parker and Walker creeks, so the “above Conduit” and “at Conduit” hydrographs were identical. Parker Creek peaked at 33 cfs on June 8, 2004, and had two subsequent peaks of moderate magnitude, 31 cfs on June 19 and 26 cfs on July 9. Walker Creek had two moderate snowmelt peaks, the annual maximum discharge on June 6 of 19 cfs and a subsequent peak on June 18 of 17 cfs. Baseflows ranged from 5 to 10 cfs and 4 to 6 cfs for Parker Creek and Walker creeks, respectively.

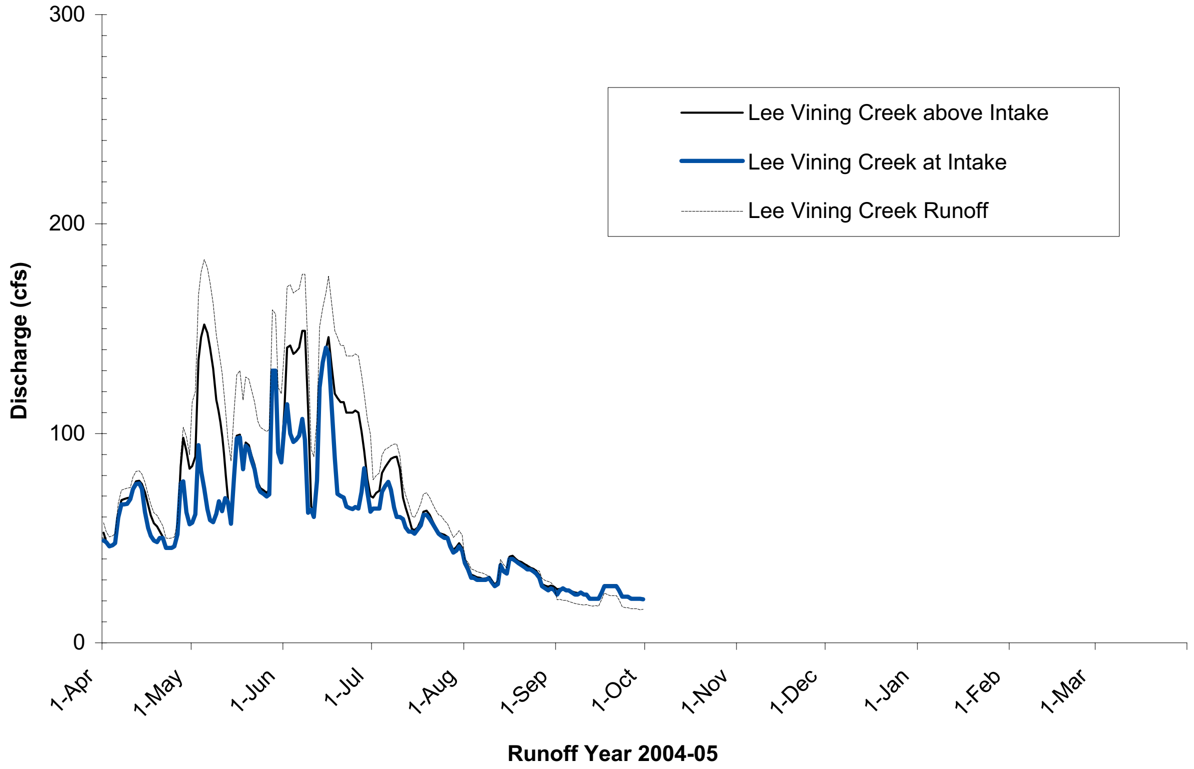

Figure 4. Annual hydrographs for Lee Vining Creek for the first half of Runoff Year 2004-05.

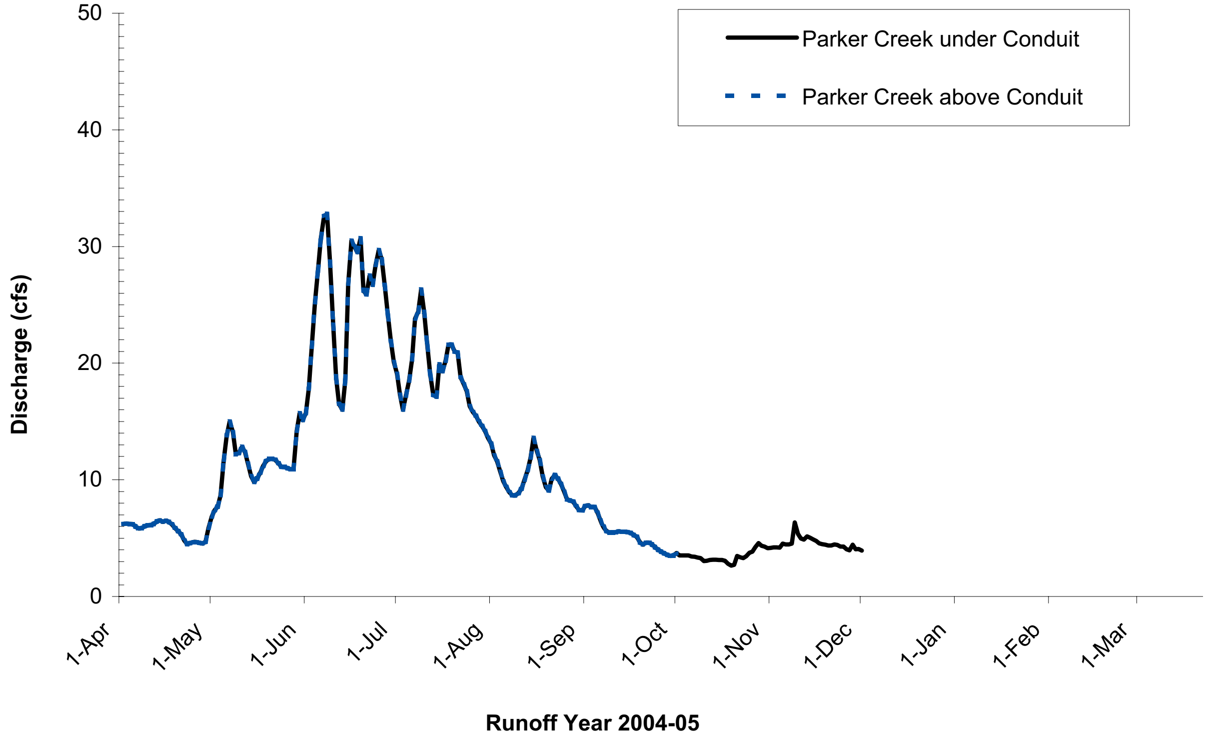

Figure 5. Annual hydrographs for Parker Creek for the first half of Runoff Year 2004-05.

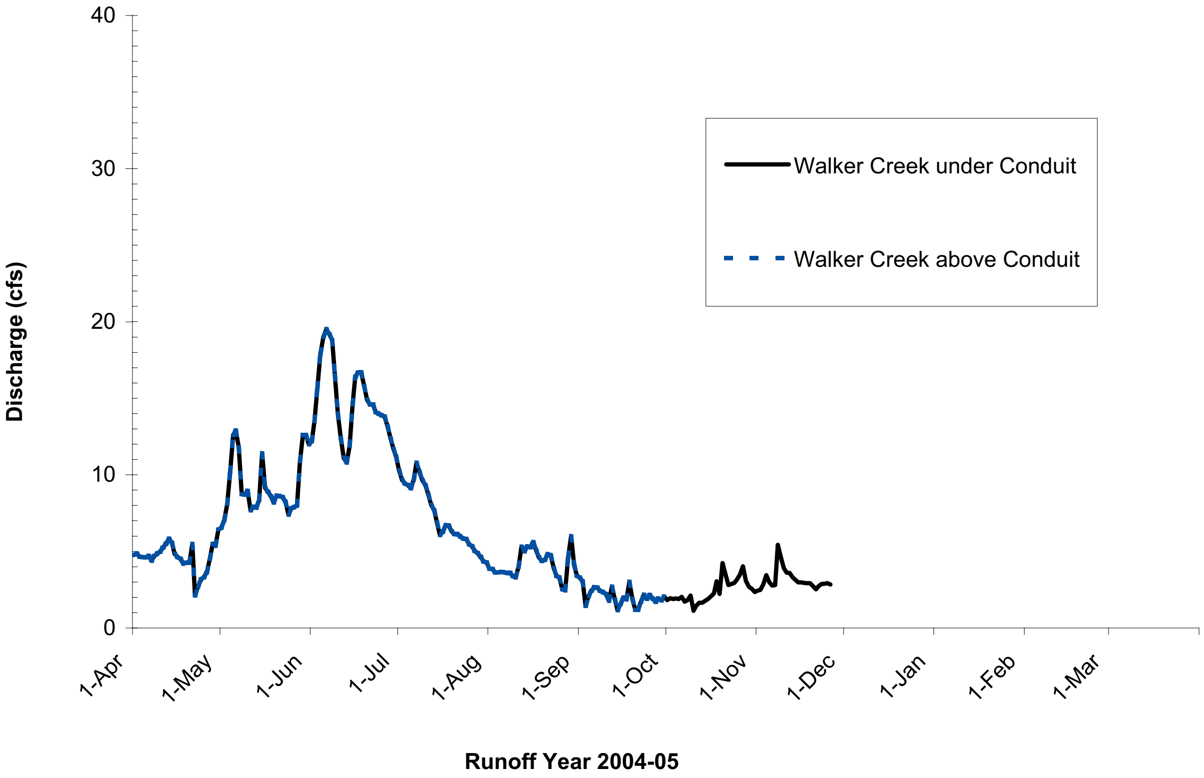

Figure 6. Annual hydrographs for Walker Creek for the first half of Runoff Year 2004-05.

2.2 Streamflow Gaging and Water Temperature Monitoring

2.2.1 Synoptic Discharge Measurements

During the June 2004 SRF releases on Rush Creek, several synoptic discharges were measured in the field, primarily to determine the actual discharge in the Lower Rush Creek study reach, where flows are split among several channels and the proportion varies with discharge. Also, measuring discharge in the main channel of lower Rush Creek (below the 10-Channel at XS –9+82 where all the flow is contained in one channel), estimates the proportion of the total flow release lost to floodplain inundation (i.e., measures gains and losses along the Rush Creek valley).

Primary sites for synoptic discharge measurements on Rush Creek were:

- Lower Rush Creek XS 10+10, which measures flow in the main channel of the planmap reach (excludes discharge in the 10-Channel).
- Lower Rush Creek XS –9+82, which measures flow below the 10-Channel confluence (thus measuring total discharge).
- Lower Rush Creek 10-Channel XS 1+10, which measures flow in the 10-Channel downstream of the 10 Return Channel.

Five measurements were taken downstream of XS 10+10, ranging from 149 cfs to 223 cfs. The data were used to develop a discharge rating curve for the datalogger installed on Lower Rush Creek in association with the floodplain aggradation monitoring (described in Section 3.3). The data were also used to update flow proportion tables (Table 2) and linear regressions that compare the proportion of discharge in the main channel versus the 10-Channel at a range of total discharge. This information was used to track annual changes in the flow volume entering each split channel. For example,

Table 2. Synoptic discharge measurements for Lower Rush Creek study site and LADWP flow data for the corresponding dates. Data were used to develop regressions to estimate discharge in split channels.

	LADWP Gauge Data		***Measured Flow Proportions***				
Date	***Rush Creek blw Return Ditch (cfs)***	***Rush Creek blw Narrows (cfs)***	***Main Channel in Study Reach***		***10 Channel***		***Main Channel at XS -9+82***
	Q (cfs)	Q (cfs)	Q (cfs)	% of total Q	Q (cfs)	% of total Q	Q (cfs)
4-Jun-98	54	67	42	65%	23	35%	65
3-Jul-98	267	321	198	61%	127	39%	325
6-May-99	51	54	42	80%	10	20%	52
4-Jun-99	53	87	57	76%	18	24%	75
27-Jul-99	85	105	72	63%	41	37%	113
7-Oct-99	49	58	24	54%	21	46%	45
14-Jun-00	52	109	54	60%	36	40%	90
10-May-01	49	97	57	66%	29	34%	87
3-Jun-01	86	142	70	60%	47	40%	117
4-Jun-01	94	139	68	60%	45	40%	113
5-Jun-01	114	153	77	60%	51	40%	128
6-Jun-01	122	160	78	61%	51	39%	129
7-Jun-01	126	169	83	60%	55	40%	138
12-Jun-01	159	201	104	60%	68	40%	172
5-Aug-01	53	70	36	69%	16	31%	52
11-Jun-02	165	201	104	60%	68	40%	173
13-Jun-02	127	166	88	59%	61	41%	149
14-Jun-02	90	132	83	64%	47	36%	130
13-Sep-02	48	55	33	76%	10	24%	43
18-Mar-04	46	53	38	78%	11	22%	48
5-Jun-04	208	219	149	68%			
6-Jun-04	260	271	194	72%			
7-Jun-04	291	302 (347)	195	64%			303
9-Jun-04	319	330 (390)	216	64%			339
11-Jun-04	343	354 (412)	224	60%			375
25-Oct-04	47	54	37	69%	17	31%	53

comparing the last entry in Table 2 (discharge below the Narrows = 54 cfs) to May 6, 1999 (discharge below the Narrows = 54 cfs) showed the percentage of flow in the main channel dropped from 80% to 69%. The data also indicated that the 10-Channel generally captured a higher proportion of flow as total discharge increased.

At the Lower Rush Creek XS –9+82 site, four discharge measurements were made in RY 2004 (Table 2). A comparison of these measured flows to LADWP instantaneous flows for ‘Rush Creek below Narrows’ provides a rough estimate of flow losses to groundwater and/or floodplain storage. The instantaneous discharge corresponding to the three synoptic flow measurements taken at XS –9+82 are included in Table 2 (in parentheses next to the daily average flow). The instantaneous data are LADWP 15-minute data 2.5 hours prior to the start of the discharge measurement, which thus adjusts for flow travel time from the Return Ditch to Lower Rush Creek (6.8 miles at an approximated 4.0 ft/sec velocity). Flow losses ranged from approximately 23-53 cfs during these three synoptic measurements.

At the 10-Channel, one discharge measurement was taken in RY 2004. At a total discharge (below Narrows) of 54 cfs, the 10-Channel had 17 cfs or 31% of the total discharge (Table 2). This flow proportion was compared to September 13, 2002 (55 cfs below Narrows, 24% in 10-Channel) and May 6, 1999 (54 cfs below Narrows, 20% in 10-Channel), indicating the 10-Channel has progressively captured a higher proportion of the baseflow from 1999 to 2004.

2.2.2 Rush Creek County Road Gage

Stage height data from the County Road site datalogger were available for March 13 to August 11, 2004. We evaluated the datalogger data to determine if the stage-discharge rating curve developed by McBain and Trush staff during and after the gage installation (November 2000 to September 2002) was still useful in converting the stage data to discharge. The stage height from the County Road datalogger corresponding to the peak discharge measured at XS -9+82 on June 11, 2004 (375 cfs) was 1.75 ft. The computed discharge using the McBain and Trush rating curve was much lower than the known discharge, indicating a shift in the rating curve. One discharge measurement was made at the gaging station on October 25, 2004, which showed a considerable rating shift compared to previous measurements (Figure 7). We re-surveyed the cross section traversing the riffle crest in the pool downstream of the culvert on June 29, 2004 (Figure 8). The cross section plot shows a 0.7 ft change (lowering) in the cross section thalweg elevation in 2004. We therefore assume the rating curve developed in 2001-02 is no longer accurate in predicting discharge for the County Road stage data. Stage data from the datalogger were not compiled to compute discharge for the existing period of record.

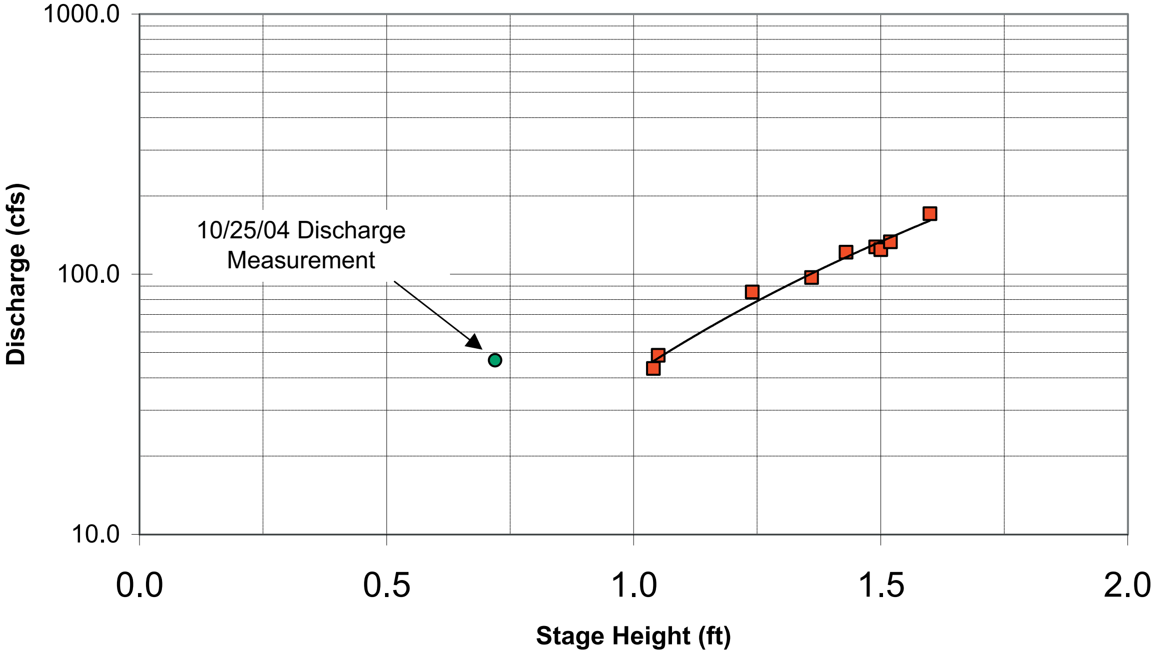

Figure 7. Stage discharge rating curve developed by McBain and Trush during 2000-02 for the Rush Creek County Road gage, with recent data point from October 2004 showing a substantial shift in the rating curve.

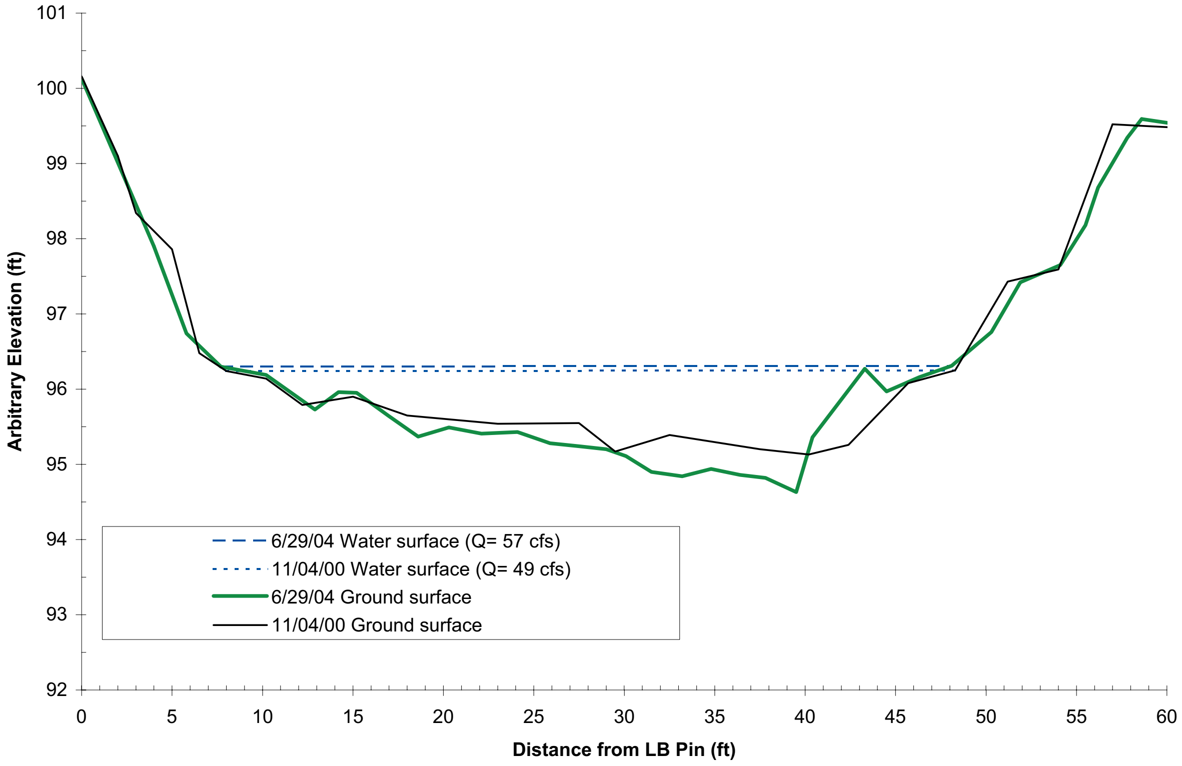

Figure 8. Cross section survey of the riffle crest downstream of the Rush Creek Test Station Road culvert pool, which controls water surface elevation at the gaging station staff plate.

2.2.3 Water Temperature Monitoring

Beginning in 1999, water temperature recorders were deployed in the four Mono Basin tributaries. In RY 2004 we replaced the original six temperature sensors with factory-refurbished thermographs (new battery and factory recalibration), and added six new data sensors, bringing the total to twelve. Henceforth, water temperature data will be collected hourly at these locations:

- Rush Creek Return Ditch at the "A" Ditch declivity
- Rush Creek at the Old Highway 395 crossing
- Rush Creek at the Narrows, just downstream of the Walker Creek confluence
- Lower Rush Creek at the upstream end of the study site
- Lower Rush Creek at Test Station Road (the County Road culvert)
- Lee Vining Creek downstream of the LADWP Intake structure
- Lee Vining Creek at the confluence of the A-4, B-Connector, and B-1 channels
- Lee Vining Creek at the County Road crossing
- Parker Creek downstream of the Intake
- Parker Creek at the Rush Creek confluence
- Walker Creek downstream of the Intake
- Walker Creek at the Rush Creek confluence

We encountered two significant problems with temperature thermographs this year that resulted in irretrievable loss of temperature data. Data from four thermographs were downloaded in May 2004 with laptop computer in the field, and the thermographs were not re-launched. Data were thus not collected during the critical SRF release and summer periods for the Rush Creek Return Ditch, Rush Creek at Narrows, and the Upper Parker and Walker sites. Additionally, the thermograph deployed at the Old Highway 395 crossing was swept away in the June SRF releases, and was not recovered. The remaining thermographs continued to provide water temperature data; summary data from these sites are reported in Table 3.

2.3 Groundwater Dynamics

2.3.1 Background

All void spaces are filled by water in the ***saturated***, or ***groundwater***, zone. Only a portion of all voids is occupied by water in the overlying ***unsaturated***, or ***vadose***, zone. The ***phreatic surface***, or ***groundwater table***, is an imaginary boundary that separates the saturated zone from the unsaturated zone. Figure 9 illustrates the location of both zones and portrays a typical soil moisture profile from the ground surface down to the groundwater table (Figure adapted from Shan 2003).

A ***capillary fringe*** is associated with very near-saturated moisture conditions. Capillary pores in the vadose zone draw up water from saturated pores in the groundwater zone. Thickness and irregularity (therefore labeled 'fringe') of the capillary fringe are functions of soil texture and spatial heterogeneity, ranging from almost 0 ft in coarse alluvial deposits to more than 6 ft in fine-grained soils (Table 4).

Not much higher than the top of the capillary fringe, soil moisture drops to ***field capacity*** where gravitational forces are resisted as continuous films of water around individual soil particles held by surface tension. At field capacity, the voids are not saturated. Higher in the soil profile, moisture content continues dropping (Figure 9 and 10). Often it declines to the ***wilting point***, the moisture content at which plants cannot withdraw water from the soil. The difference in moisture content between field capacity and wilting point is considered water available to established plants, in addition to ample water available below the elevation of field capacity

Approaching ground surface, soil moisture can start rising due to infiltration (recent rain or snow) or fall even more from evaporation and plant transpiration (if not already at the wilting point) (Figure 9). Moisture content near the surface, therefore, is strongly influenced by environmental conditions at the surface. Late-spring rains or local snowmelt can temporarily saturate the upper soil profile. Snowmelt flows accessing the floodplain via side-channels also can temporarily saturate the upper soil profile.

Table 3. Summary of temperature data collected during RY 2004 spring and summer months for the Mono Basin tributaries.

	Water Temperature (°F) April 1 - June 30				Water Temperature (°F) July 1-August 31			
	DAILY MINIMUM	DAILY AVERAGE	DAILY MAXIMUM	DAILY FLUCTUATION	DAILY MINIMUM	DAILY AVERAGE	DAILY MAXIMUM	DAILY FLUCTUATION
Rush Creek at Return Ditch	Data Not Available							
Rush Creek at Hwy 395 Bridge	Data Not Available							
Rush Creek at Narrows	45.7	56.5	68.4	16.3	49.6	59.9	72.3	14.3
Lower Rush Creek (at XS 10+10)	43.1	54.2	66.5	18.2	52.9	61.5	73.9	16.2
Rush Creek at County Road	35.3	53.4	68.9	23.5	52.1	62.4	75.2	18.3
Lee Vining Creek below Intake	Data Not Available							
Lee Vining Creek at A-4 Channel	32.7	46.1	60.2	15.4	45.7	55.7	68.6	18.1
Lee Vining Creek at County Road	36.9	49.3	58.8	13.4	47.9	56.1	65.9	13.1
Parker Creek at Intake	Data Not Available							
Parker Creek at Rush Confluence	Data Not Available							
Walker Creek at Intake	Data Not Available							
Walker Creek at Rush Confluence	40.7	55.1	67.2	16.4	46.3	59.5	73.1	20.0

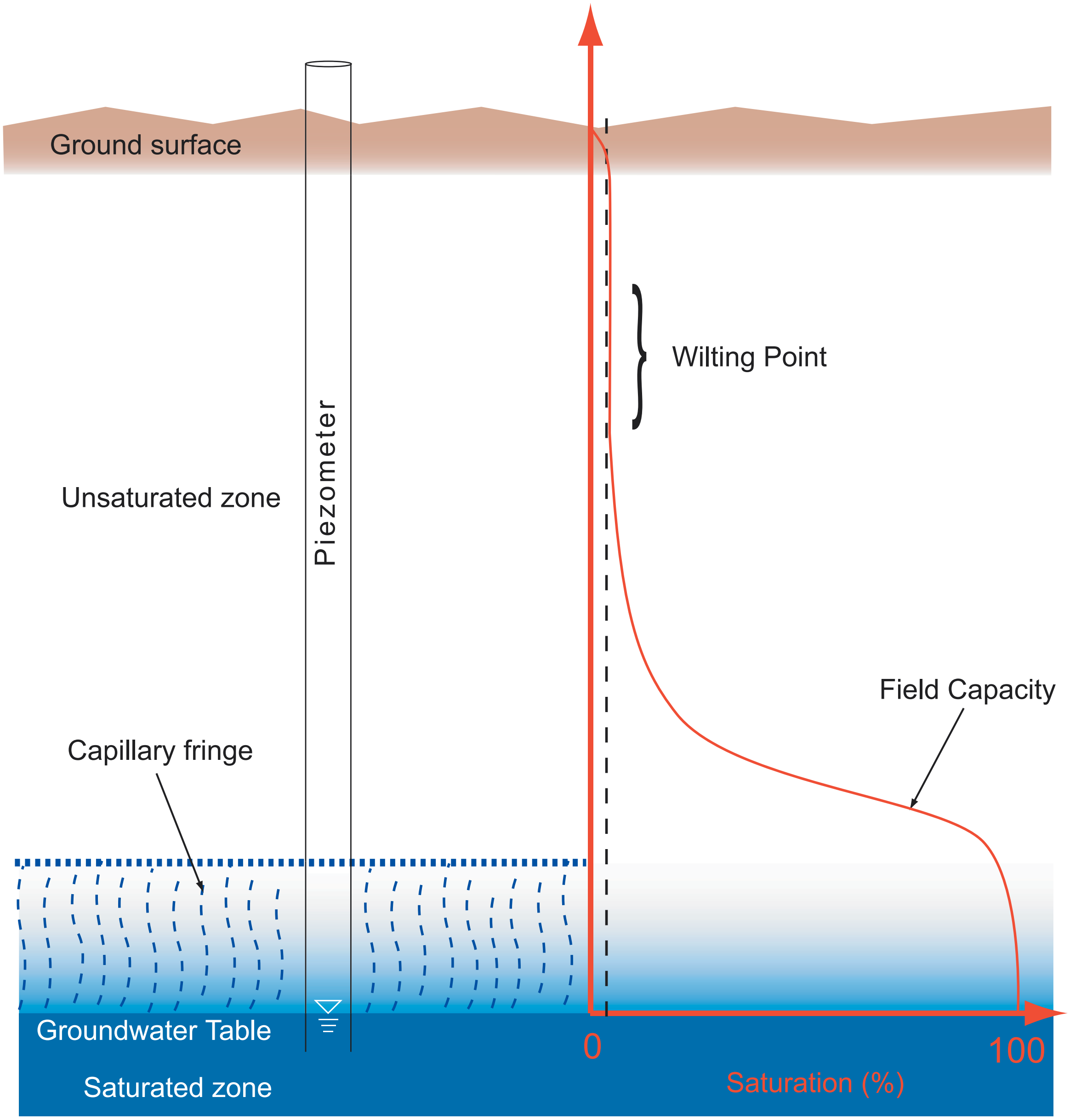

Figure 9. General soil moisture profile for Rush Creek bottomlands.

Soil moisture retention will depend, in large part, on soil composition. A silt loam at saturation (20.2%) will decline to a moisture content of 14.7% 60 days later; the decline in sand is much faster (Dunne and Leopold 1978 Chapter 6). As a riparian plant community matures, building a fine grained soil high in organic matter, more influence (positive and negative feedback loops) can be exerted on the upper soil moisture profile. Moisture loss can be delayed by a more mature soil and shading of the ground surface, but greater plant transpiration will further deplete soil moisture. During late-summer through early-fall, near-surface soil moisture through most of the 8 Floodplain will be extremely low from lack of precipitation, high wind evaporation, plant transpiration, and a poorly developed (if not absent) surface organic layer.

Table 4. Capillary rise as a function of soil composition.

Sediments	***Capillary Rise (cm)***	***Capillary Rise (ft)***
Fine silt	750	24.6
Coarse silt	300	9.8
Very fine sand	100	3.3
Fine sand	50	1.6
Medium sand	25	0.8
Coarse sand	15	0.5
Very coarse sand	4	0.1
Fine gravel	1.5	0.0

Figure 10. Cut-bank at Rush Creek 3D side-channel eroded during the June 2004 SRF releases, exposing underlying sediments and stratigraphy.

Groundwater texts and lectures rarely dwell on the uppermost 0.05 ft of the soil moisture profile! Yet this is the environment for germinating seeds. When the capillary fringe extends up to the ground surface, the surface needs to remain saturated at least 7 days for successful cottonwood seed germination (Young and Young 1992). Seeds may germinate under conditions less than saturation, but for our analysis only saturated conditions will be considered.

2.3.2 2004 Field Season Methods and Results

The snowmelt signature for the June 2004 release was expected to have at least these two roles: (1) creating a ground surface that promotes successful seed germination and (2) recharging soil moisture, making water readily available to established plants. Both roles can be accomplished by elevating the groundwater table via streamflow in the mainstem, by watering primary and secondary stream channels across the floodplain, and/or by inundating floodplains.

8 Channel and Floodplain

Six piezometers and three adjacent staff plates in mainstem Rush Creek were monitored during and after the June 2004 flow release in the 8 Floodplain of the Rush Creek bottomlands (Figure 11). Piezometer 8C-1 had a continuous groundwater elevation recorder; the other piezometers and the staff plates were synoptically monitored at variable times from June 4 through July 8 by McBain and Trush staff (during and shortly after the flow release) and during August and September by the Mono Lake Committee staff (Table 5). During the release, pits were hand-dug adjacent to the piezometers to identify the top of the capillary fringe by finding where the soil was wet. This observational technique likely identified a soil moisture level slightly less than that of the capillary fringe but greater than that at field capacity.

Groundwater and surface water stage heights from three piezometers, 8C-1, 8C-4, and 8C-6, illustrate what happened in 2004 (Figures 12, 13, and 14). Our principal findings are as follows: (1) prior to, during, and after June's flow release, groundwater elevations remained below the stage height elevation of the released streamflows in the mainstem, (2) groundwater elevation responded rapidly to stage height changes (Figure 15), even farther back into the 8 Floodplain at Piezometer 8C-6, (3) the field measured capillary fringe was from 1.2 ft to 1.5 ft above the groundwater surface recorded at the piezometers; the capillary fringe never intersected the ground surface at the piezometers, but did reach the surface in some scour channels on the floodplain surface, (4) the groundwater table at Piezometer 8C-1 (the one with a continuous stage recorder) fluctuated diurnally, and (5) groundwater elevations did not return to pre-release elevations until late-August.

The rapid groundwater response to stream stage changes was best documented by the 15-minute data recorded with the datalogger at Piezometer 8C-1 (Figure 15). This response is illustrated by the following three observations:

(1) At the start of the hydrograph (Figure 15), stream stage height increased sharply beginning at 09:30 on June 1. By 18:00 the same day (approximately 10 hours later), groundwater began to rise in Piezometer 8C-1. During the next 9 days, stream stage height and groundwater elevation rose in tandem.

(2) On June 9, LADWP operators reduced flow releases at the Return Ditch for maintenance and safety purposes. Stream stage height at the 8 Channel entrance dropped at 16:45 by approximately 0.5 ft. By 21:00 the same day groundwater responded to the reduced stage, and dropped nearly 0.2 ft.

(3) On June 11 at 18:30 the stream stage at the 8 Channel reached it's peak of 6517.46 ft and remained at roughly this elevation for approximately 17 hours before ramping down. This peak discharge and stage height precipitated a corresponding rapid increase in groundwater elevation that began almost simultaneously with the stage change and peaked on June 12 at 11:00. Both stage height and groundwater then simultaneously receded.

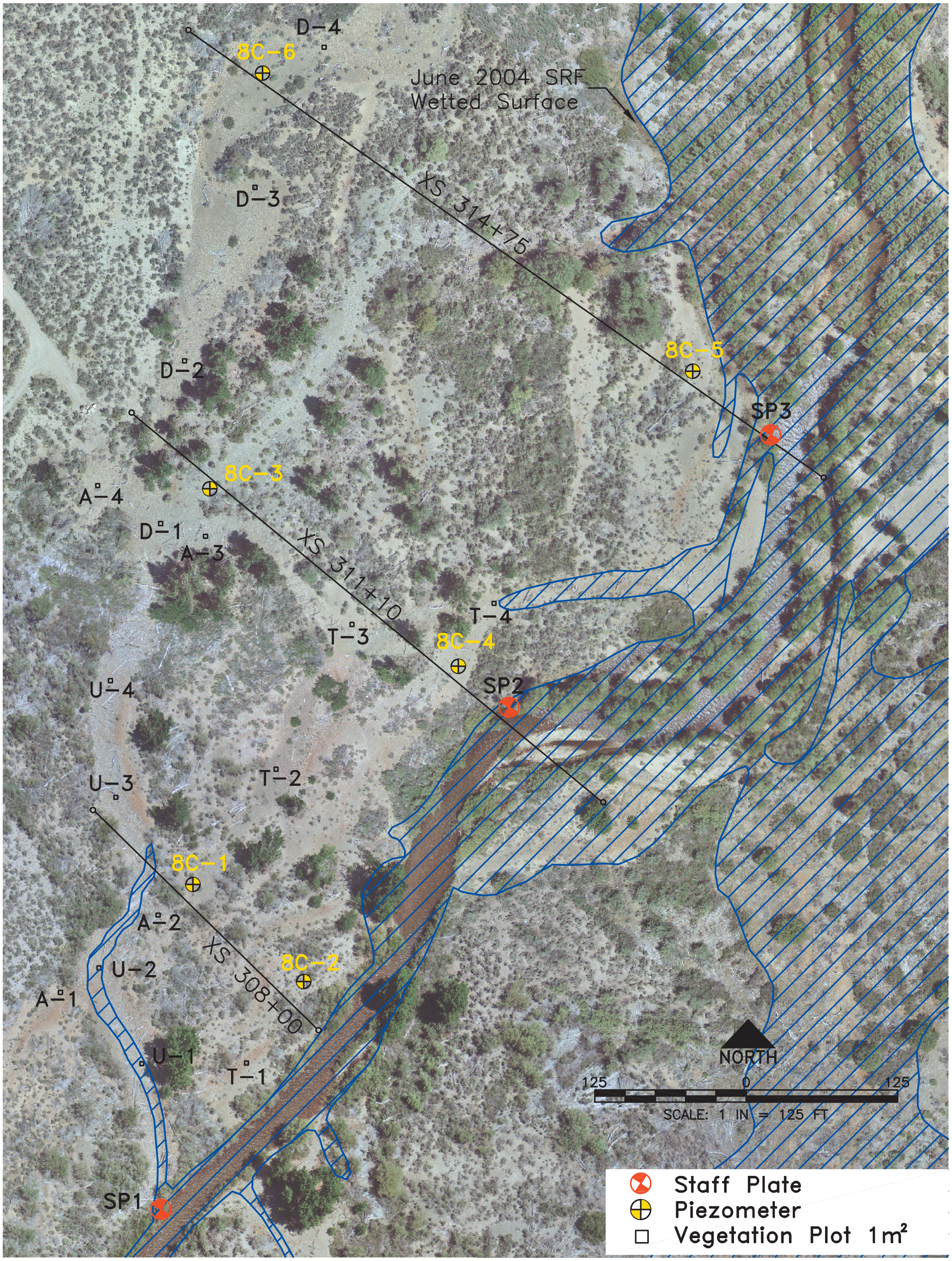

Figure 11. Rush Creek's 8 Channel and floodplain with locations of piezometers, staff plates, cross sections, and vegetation monitoring pins. The wetted surface (including inundated area) from the June 2004 SRF release is indicated. Vegetation plot symbols are relative to the 8 Channel Entrance as follows: U=upstream, D=downstream, A=adjacent, T=Terrace.

Table 5. Groundwater and stream stage data from the 8 Floodplain from piezometers and staff plates, collected by McBain and Trush with assistance from the Mono Lake Committee during RY 2004.

		Groundwater Elevation (ft) at Piezometers						Water Surface Elevation (ft)			Daily Average Discharge (cfs)	
Date	*Time*	*8C-1*	*8C-2*	*8C-3*	*8C-4*	*8C-5*	*8C-6*	*Staff Plate #1*	*Staff Plate #2*	*Staff Plate #3*	**Date**	*At the Narrows*
11-Sep-03	N/A	6511.51	6511.86	6509.64	6506.89	6500.99	6499.75				**11-Sep-03**	56
7-Oct-03	N/A	6511.25	6511.37	6509.67	dry	dry	dry				**7-Oct-03**	54
16-Mar-04	10:00 AM	6510.97	6511.21	6509.63	6506.27	dry	dry	6517.70	6513.06	6507.39	**16-Mar-04**	52
3-May-04	1:45 PM	6511.22	6511.63	6509.63	6506.90	dry	dry	6517.70	6513.08	6507.51	**3-May-04**	59
6-May-04	3:00 PM	6511.42	6512.23	6509.61	6507.42	6501.32	dry	6517.89	6513.15	6507.51	**6-May-04**	59
01-Jun-04	3:00 PM	6511.58	6512.39	6509.77	6507.58	6501.48	dry	Not surveyed	Not surveyed	Not surveyed	**1-Jun-04**	70
01-Jun-04	12:00PM	6511.58	6512.14	6509.62	6507.49	6501.61	dry	6517.9	Not surveyed	Not surveyed	**1-Jun-04**	70
4-Jun-04	4:00 PM	6512.98	6514.55	6509.57	6510.51	6505.27	dry	6518.51	6513.71	6508.10	**4-Jun-04**	165
5-Jun-04	4:00 PM	6513.56	Not surveyed	Not surveyed	Not surveyed	Not surveyed	Not surveyed	6518.76	Not surveyed	Not surveyed	**5-Jun-04**	219
6-Jun-04	10:00 AM	6513.95	6515.51	6509.57	6511.42	6505.74	6499.79	6518.86	6514.06	6508.50	**6-Jun-04**	271
7-Jun-04	10:00 AM	6514.33	Not surveyed	Not surveyed	Not surveyed	Not surveyed	Not surveyed	6518.96	Not surveyed	Not surveyed	**7-Jun-04**	302
9-Jun-04	2:30 PM	6514.82	6516.13	6509.59	6512.21	6506.17	6502.65	6519.11	6514.41	6508.75	**9-Jun-04**	330
10-Jun-04	10:30 AM	6514.71	6515.80	6509.57	6511.89	6505.90	Not surveyed	6518.81	6514.41	6508.45	**10-Jun-04**	278
11-Jun-04	9:00 AM	6514.84	6516.00	6509.59	6512.09	6506.00	6503.18	6518.96	6514.08	6508.44	**11-Jun-04**	354
11-Jun-04	3:00 PM	6514.94	6516.12	6510.53	6512.21	6506.15	6503.34	6519.12	6514.46	6508.58	**11-Jun-04**	354
12-Jun-04	8:35 AM	6515.52	Not surveyed	Not surveyed	Not surveyed	Not surveyed	Not surveyed	6519.16	6514.41	6508.55	**12-Jun-04**	340
12-Jun-04	9:05 AM	6515.52	6516.35	6510.51	6512.34	6506.14	6503.41	6519.09	6514.41	6508.52	**12-Jun-04**	340
12-Jun-04	11:25 AM	6515.50	6516.25	6510.50	6512.30	6506.05	6504.44	6518.96	6514.24	6508.44	**12-Jun-04**	340
12-Jun-04	4:00 PM	6515.18	6516.10	6510.41	6512.18	6506.03	6502.61	6518.90	6514.18	6508.42	**12-Jun-04**	340
13-Jun-04	9:30 AM	6514.98	6516.02	6509.56	6512.09	6506.03	6503.43	6518.89	6514.18	6508.42	**13-Jun-04**	272
13-Jun-04	4:30PM	6515.43	6515.43	6510.46	6511.43	6505.94	6503.59	6518.89	6514.18	6508.42	**13-Jun-04**	272
14-Jun-04	9:30 AM	6514.83	6515.30	6509.56	6511.04	6505.94	6503.64	6518.79	6514.08	6508.34	**14-Jun-04**	222
15-Jun-04	11:30 AM	6514.70	6515.71	6509.60	6511.75	6505.80	6503.67	6518.66	6513.96	6508.24	**15-Jun-04**	197
15-Jun-04	2:30 PM	6514.69	6515.70	Not surveyed	6511.77	6505.80	Not surveyed	Not surveyed	6513.96	6508.24	**15-Jun-04**	197
21-Jun-04	1:30 PM	6514.27	6515.20	6509.60	6511.06	6505.41	6503.49	6518.18	6513.61	6508.03	**21-Jun-04**	115
24-Jun-04	3:00 PM	6514.04	6514.91	6509.56	6510.80	6505.24	6503.40	6518.06	6513.42	6507.80	**24-Jun-04**	87
27-Jun-04	4:45 PM	6513.63	6514.51	6509.73	6510.23	6504.82	6502.82	6517.88	6513.24	6507.65	**27-Jun-04**	58
8-Jul-04	3:30 PM	6512.50	6513.13	6509.51	6508.88	6504.08	not surveyed	6517.88	6513.18	6507.69	**8-Jul-04**	56
22-Jul-04	12:55 PM	6512.00	6512.67	6509.56	6508.33	6503.30	6501.42	6517.72	6513.15	Not surveyed	**22-Jul-04**	45
30-Jul-04	12:45 PM	6511.94	6512.67	6509.56	6508.26	6503.09	6501.12	6517.76	6513.18	Not surveyed	**30-Jul-04**	58
6-Aug-04	12:42 PM	6511.71	6512.34	6510.48	6507.94	6502.57	6500.89	6517.73	6513.16	Not surveyed	**6-Aug-04**	60
12-Aug-04	3:06 PM	6511.67	6512.35	6509.57	6507.86	6502.43	6500.63	6517.74	6513.07	6507.53	**12-Aug-04**	60
20-Aug-04	11:25 AM	6511.51	6512.01	6509.57	6507.38	6501.79	6500.45	6517.61	6512.91	6507.39	**20-Aug-04**	41
26-Aug-04	10:45 AM	Not surveyed	6511.85	6509.57	6507.03	6501.28	6500.15	6517.61	6512.91	6507.39	**26-Aug-04**	43
27-Aug-04	13:40PM	Not surveyed	6511.85	6509.63	6507.13	6501.05	dry	6517.73	Not surveyed	Not surveyed	**27-Aug-04**	42
16-Sep-04	4:55 PM	Not surveyed	6511.56	6509.57	6506.51	dry	6499.22	6517.62	6512.93	6507.40	**16-Sep-04**	49
26-Sep-04	5:58 PM	Not surveyed	6511.50	6509.57	6506.49	dry	dry	6517.69	6513.02	6507.46	**26-Sep-04**	63
23-Oct-04	1:30 PM	Not surveyed	6510.98	dry	dry	dry	dry	6517.71	6513.02	6507.46	**23-Oct-04**	58

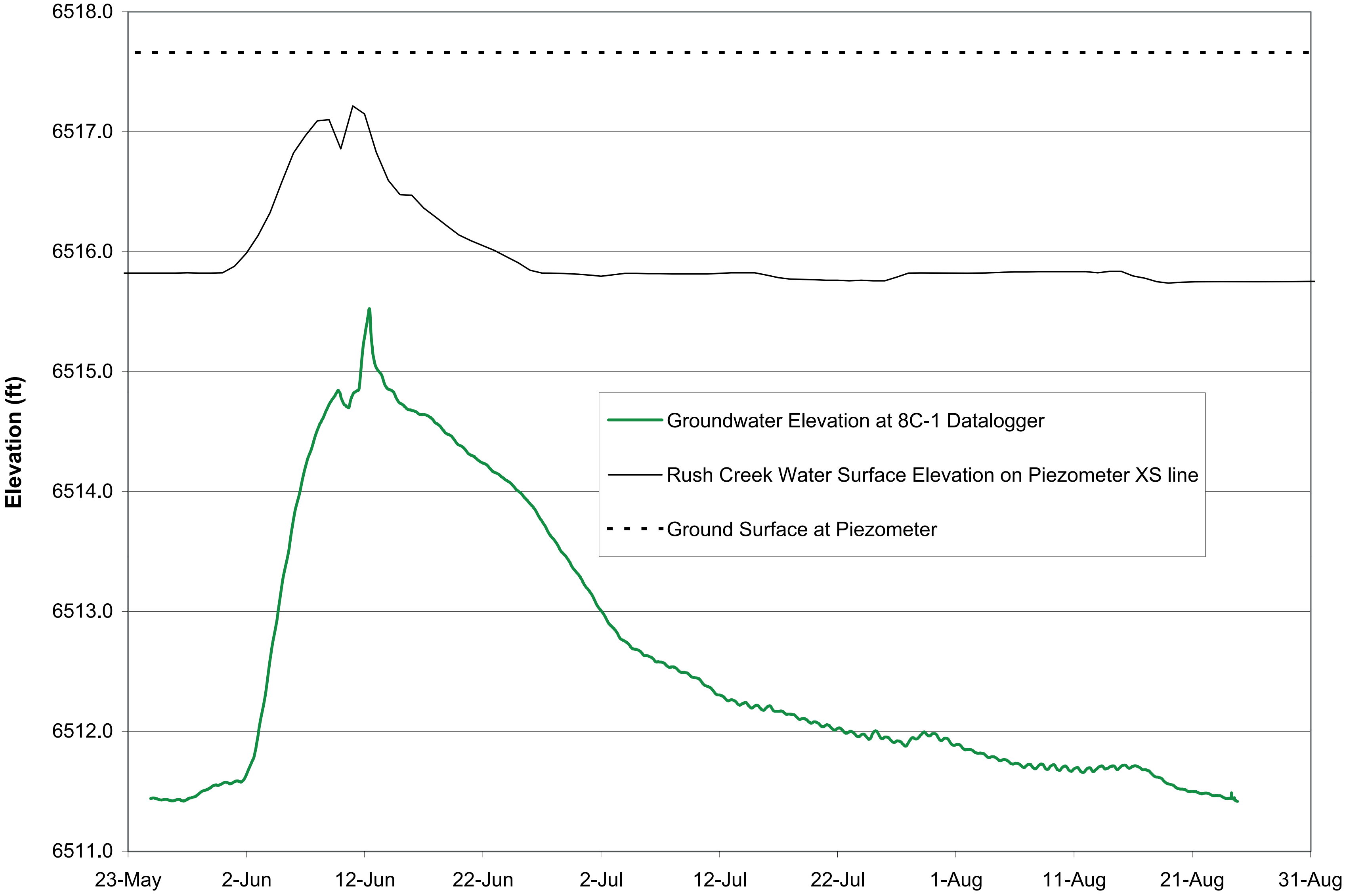

Figure 12. Groundwater elevations from Piezometer 8C-1 with the continuous recording datalogger, and Rush Creek stage height during the June 2004 SRF releases.

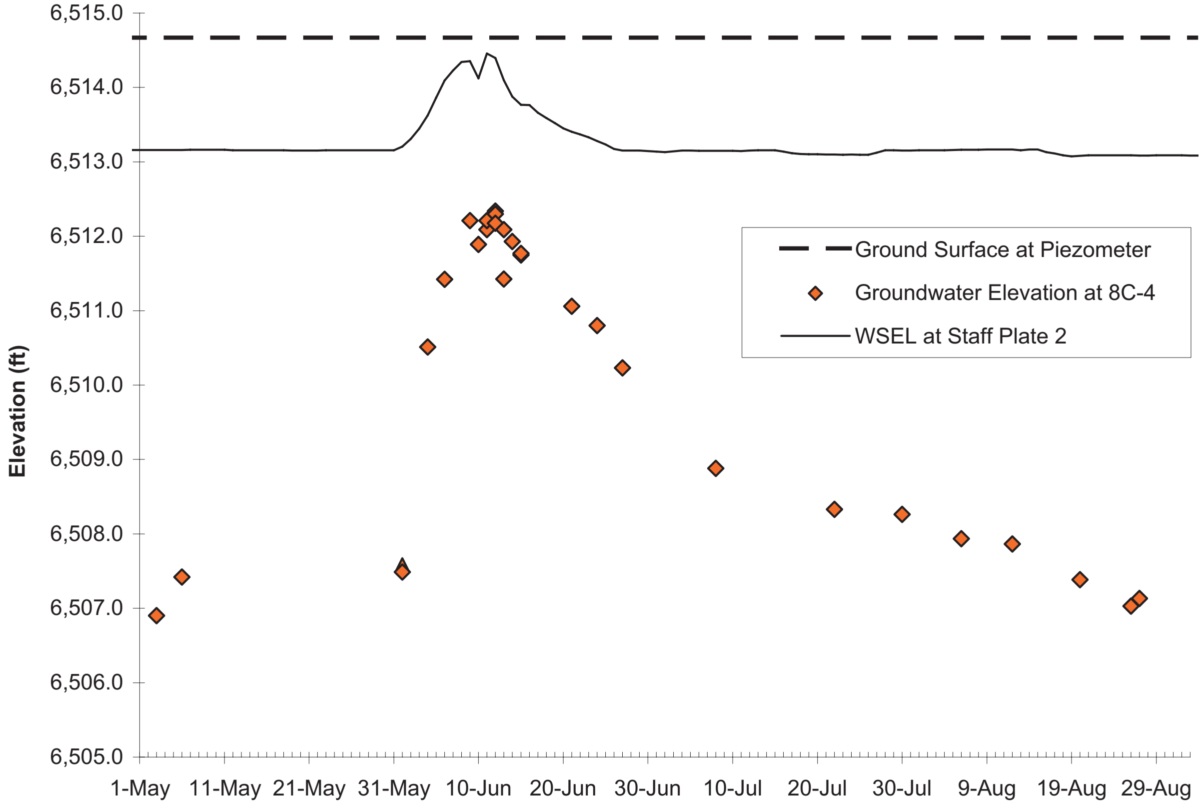

Figure 13. Groundwater elevations from Piezometer 8C-4 recorded synoptically by field staff, and Rush Creek stage height during the June 2004 SRF releases.

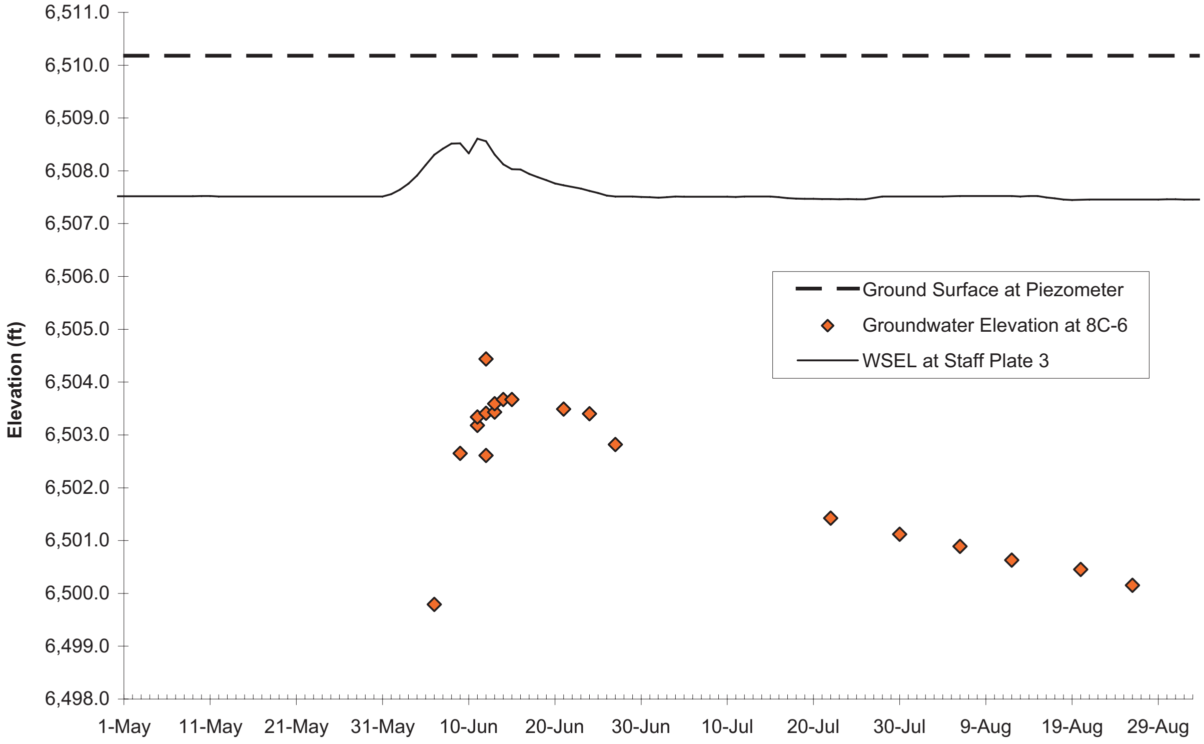

Figure 14. Groundwater elevations from Piezometer 8C-6 recorded synoptically by field staff, and Rush Creek stage height during the June 2004 SRF releases.

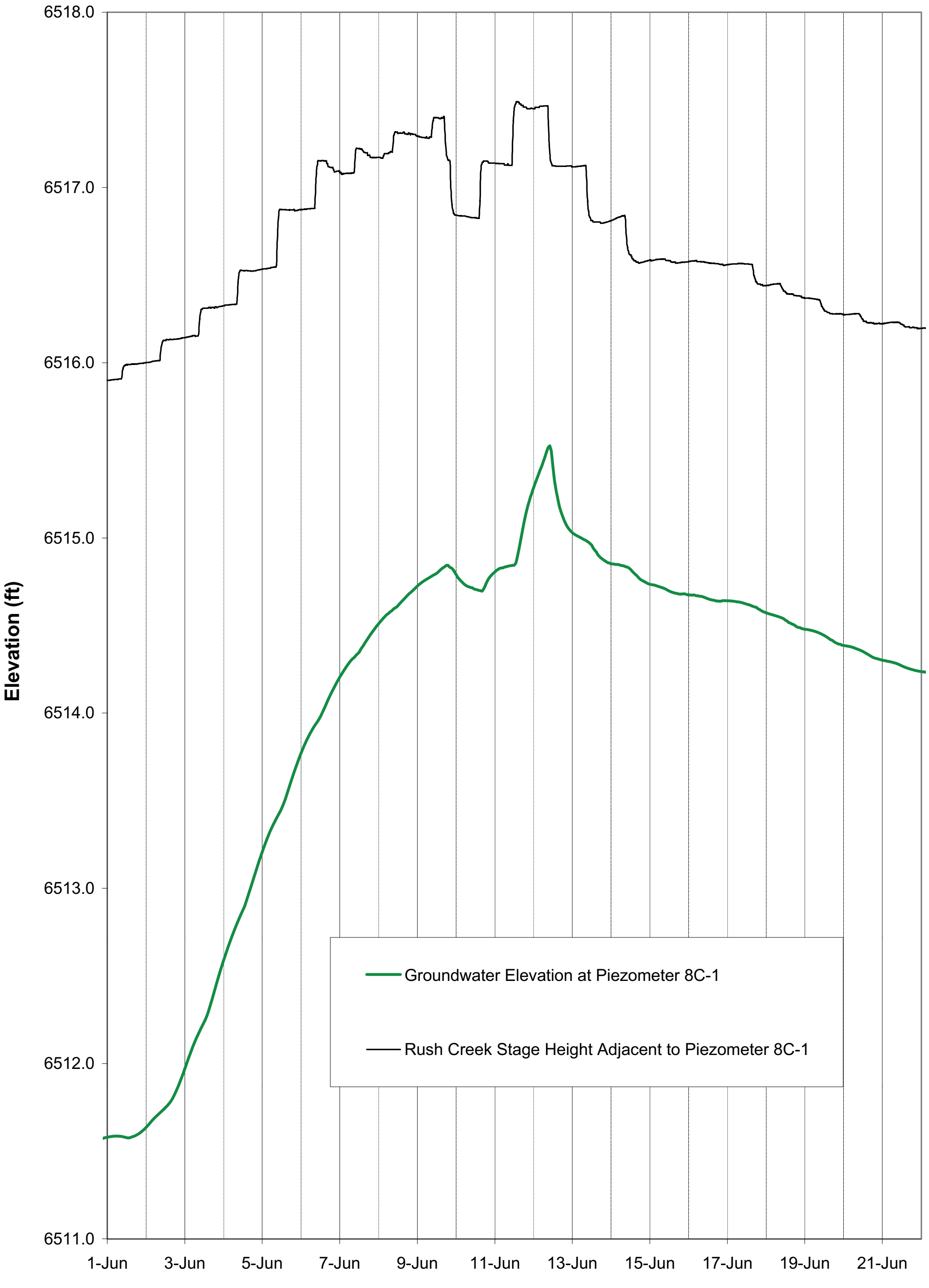

Figure 15. Groundwater elevation from Piezometer 8C-1 and stream stage height in Rush Creek adjacent to the piezometer, showing the rapid response of groundwater elevation to changes in stream stage height.

Monitoring revealed a distinct groundwater signature of the 2004 snowmelt hydrograph release throughout the upper 8 Floodplain of the Rush Creek bottomlands. While flow releases exceeding baseflow terminated June 27, the groundwater table at the piezometers did not return to its baseflow's groundwater elevation until August 29. Plots of groundwater and corresponding staff gage data for all piezometers are presented in Appendix A.

While the capillary fringe never intersected the surface at the piezometers, two saturated surfaces did advance into the 8 Floodplain during the June 2004 flow release (i.e., the capillary fringe did intersect the surfaces of these scour channels). Surface flows overtopping the 8 Channel entrance saturated the surface for approximately 320 ft downstream before disappearing (infiltrating and leaving no trace on the surface) (Figure 16). Another saturated surface advanced 193 ft farther downstream (downstream of Piezometer 8C-4) (Figure 17). Both surfaces remained saturated for at least 7 days following the peak June release. During this period cottonwood and willow seeds were blowing in the wind. However, no seedlings were found at either location in late-summer/early-fall.

4 Floodplain

No piezometers were installed in the 4 Floodplain, but one staff plate was located where the side-channel entrance (4Bii) directed surface flows onto the floodplain (Figure 18). This was the only location where surface flows entered onto the 4 Floodplain. During the June release, flow depth at this side-channel entrance was 1.2 ft deep at the peak release. A streamflow of approximately 5 cfs to 8 cfs with several branches developed throughout the 4 Floodplain, then coalesced as a single channel at the floodplain's terminus and emptied into a deep pool tucked into the back of the mainstem's recently created floodplain. During peak flow release, wet surface areas (i.e., where there was surface flow and where the soil surface was wet) were mapped onto an aerial photograph of the entire 4 Floodplain (Figure 18). At peak release, 47% of the 4 Floodplain's surface was saturated at the surface or actually had surface flow.

3D Floodplain

The constructed 3D Floodplain was monitored for groundwater and surface flow response to the June 2004 high flow release (Table 6). Surface flow elevation was monitored at 5 staff plates in the mainstem and 3 staff plates in the primary side-channel (Figure 19). Nine piezometers were strategically placed to document groundwater response to increasing surface flows (Figure 19). Piezometer 3D-8 had a continuous stage recorder while the others were synoptically monitored shortly before, during, and shortly after the June high flow release. Plots of groundwater and corresponding staff gage data for all piezometers are presented in Appendix A.

Groundwater responses to surface flow on the 3D Floodplain are certainly dynamic. The role of side-channels is particularly striking: without them, the groundwater table slopes steeply away from the mainstem channel (as observed during the 3D excavation work). The June 2004 release provided saturated ground surface conditions that successfully promoted seed germination and provided enough soil moisture for some seedlings to survive through early-fall. The rapid rise and fall of the groundwater may be related to the depositional pedigree of the 3D Floodplain. Much of the 3D Floodplain was created/influenced by massive deposition during a single flood in the 1960's. This loosely consolidated depositional feature of coarse alluvium will not retain groundwater and unsaturated soil moisture as readily as a more typical, multi-layered floodplain. More fine-sediment deposition on the 3D Floodplain could buffer future fluctuations.

Figure 16. Saturated surface in shallow depressions on the 8-Floodplain on June 11, 2004.

Figure 17. Surface flow down the 8 Channel on June 11, 2004. Flow barely overtopped the riparian berm along the main channel at the 412 cfs peak.

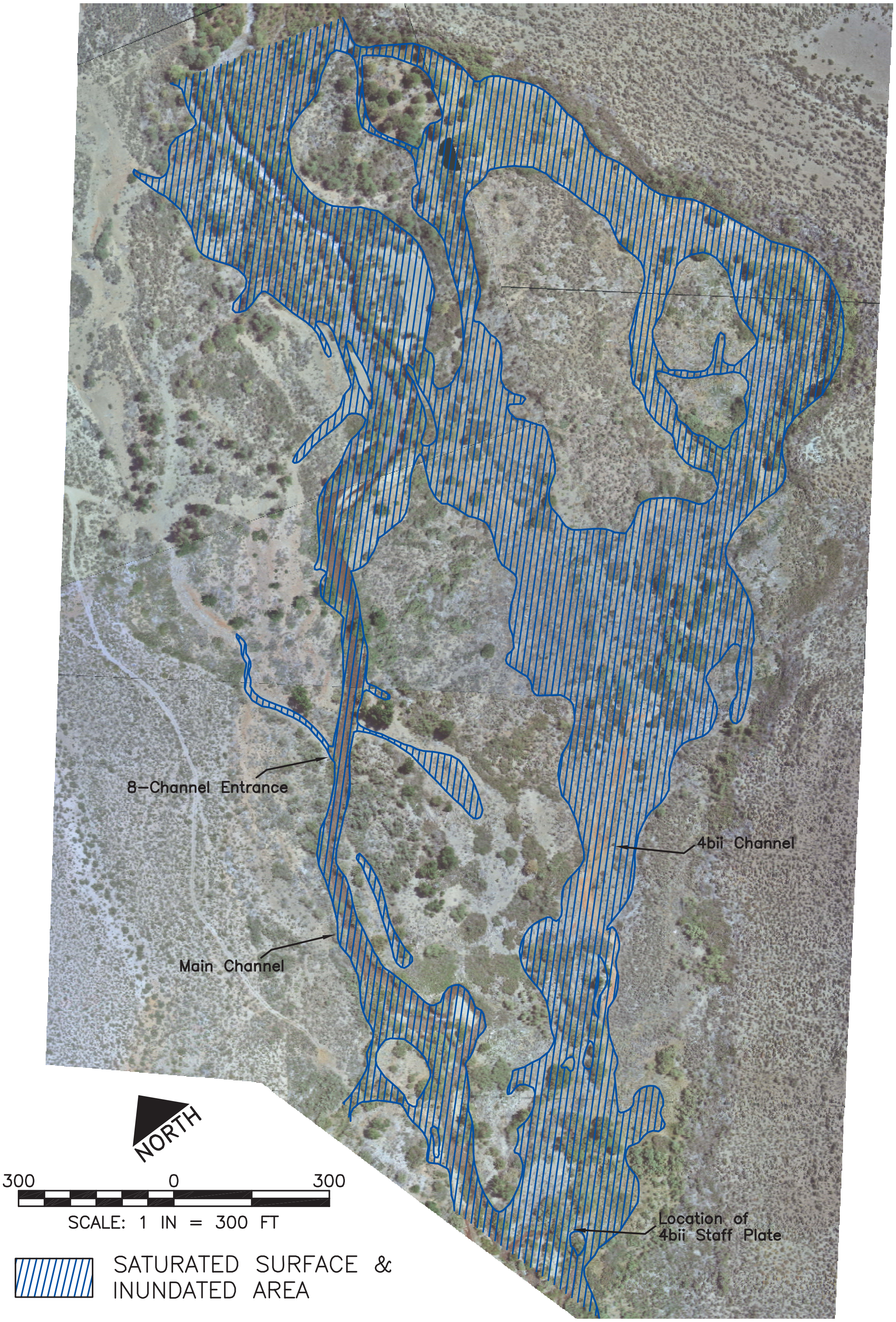

Figure 18. The 4bii Floodplain with the extent of saturated surface and inundated areas on June 13, 2004, resulting from flow entering the 4bii channel.

Table 6. Groundwater and stream stage data from the 3D Floodplain from piezometers and staff plates, collected by McBain and Trush with assistance from the Mono Lake Committee during RY 2004.

		Groundwater Elevation (ft) at Piezometers							
Date	*Time*	*3D-1*	*3D-2*	*3D-3*	*3D-4*	*3D-5*	*3D-6*	*3D-7*	*3D-8*
12-Sep-03	8:00	6633.5	6632.8	6633.0	6626.1	6625.1	6623.6	6621.7	6623.6
7-Oct-03		6632.7	6631.4	6632.4	6625.2	6623.9	dry	dry	6623.5
16-Mar-04	5:00 PM	6632.6	dry	6632.1	6625.2	6624.1	dry	dry	6623.6
3-May-04	8:00 AM	6632.83	6632.96 ft	6632.47	6625.50	6624.12	dry	dry	not surveyed
6-May-04	1:25 PM	6634.31	6632.96 ft	6632.80	6625.90	6624.44	dry	dry	6623.6
4-Jun-04	1:00 PM	6635.36	6634.58 ft	6633.79	6627.89	6627.63	6626.41	6623.63 ft	6624.3 ft
6-Jun-04	10:00 AM	6635.63	6634.83 ft	6634.00	6628.08	6627.83	6627.81	6624.16 ft	6624.7 ft
9-Jun-04	1:20 PM	6635.79	6635.06 ft	6634.09	6628.20	6627.96	6628.29	6624.40 ft	6624.8 ft
11-Jun-04	12:30 PM	not surveyed	not surveyed	not surveyed	not surveyed	not surveyed	not surveyed	not surveyed	6624.8 ft
12-Jun-04	2:05 PM	6635.67	6634.93 ft	6634.76	6628.03	6627.87	6627.80	6624.09 ft	6623.4 ft
15-Jun-04	1:05 PM	6635.44	6634.72 ft	6633.71	6627.77	6627.77	6627.70	6624.22 ft	6623.2 ft
21-Jun-04	12:00 PM	6635.15	6634.42 ft	6633.40	6627.14	6627.43	6626.97	6623.89 ft	6622.8 ft
24-Jun-04	1:30 PM	6634.98	6634.25 ft	6633.02	6626.85	6628.28	6625.65	6623.99 ft	6622.7 ft
27-Jun-04	3:00 PM	6636.26	6633.77 ft	6632.87	6626.46	6626.15	6625.61	6623.54 ft	6622.5 ft
23-Oct-04	9:00 AM	6632.28	dry	dry	dry	dry	dry	dry	not surveyed

	Water Surface Elevation (ft)								**Daily Averag**
Date	*Staff Plate #1*	*Staff Plate #2*	*Staff Plate #3*	*Staff Plate #4*	*Staff Plate #5*	*Staff Plate #6*	*Staff Plate #7*	*Staff Plate #8*	*Date*
12-Sep-03	Staff Plates	not installed	until 3/16/04						12-Sep
7-Oct-03									7-Oct
16-Mar-04	6638.84	6635.14	6633.41	6627.96	6627.14	6624.06	6624.53	6617.48	16-Mar
3-May-04	6638.87	6635.16 ft	6633.45 ft	6627.82 ft	6627.34	6624.07 ft	6624.57 ft	6617.51 ft	3-May
6-May-04	6638.95 ft	6634.96 ft	6633.33 ft	6628.03 ft	6627.73	6624.01 ft	6624.29 ft	6617.94 ft	6-May
4-Jun-04	6639.71 ft	6635.67 ft	6633.67 ft	6628.45 ft	6627.73	6624.59 ft	6625.34 ft	6618.54 ft	4-Jun
6-Jun-04	6640.11 ft	6635.87 ft	6633.82 ft	6628.69 ft	6627.5	6624.59 ft	6625.70 ft	6619.00 ft	6-Jun
9-Jun-04	6640.61 ft	6636.02 ft	6633.77 ft	6628.99 ft	6627.9	6625.19 ft	6625.80 ft	6619.25 ft	9-Jun
11-Jun-04	not surveyed	not surveyed	6633.70 ft	6628.99 ft	not surveyed	not surveyed	6625.75 ft	6619.20 ft	11-Jun
12-Jun-04	6640.33 ft	6636.01 ft	6633.55 ft	6628.84 ft	6627.86	not surveyed	plate washed out	6618.99 ft	12-Jun
15-Jun-04	6639.91 ft	6635.79 ft	6633.23 ft	6628.55 ft	6627.62	6624.61 ft	plate washed out	6618.99 ft	15-Jun
21-Jun-04	6639.37 ft	6635.53 ft	6632.82 ft	6628.32 ft	not surveyed	6624.47 ft	plate washed out	6618.67 ft	21-Jun
24-Jun-04	6639.21 ft	6635.46 ft	not surveyed	6628.23 ft	6627.25	6624.35 ft	plate washed out	6618.10 ft	24-Jun
27-Jun-04	6638.99 ft	6635.32 ft	not surveyed	6628.11 ft	6626.95	6624.16 ft	plate washed out	6617.63 ft	27-Jun
23-Oct-04	6638.75 ft	6635.14 ft	not surveyed	6627.94 ft	not surveyed	6624.05 ft	plate washed out	6617.43 ft	23-Oct

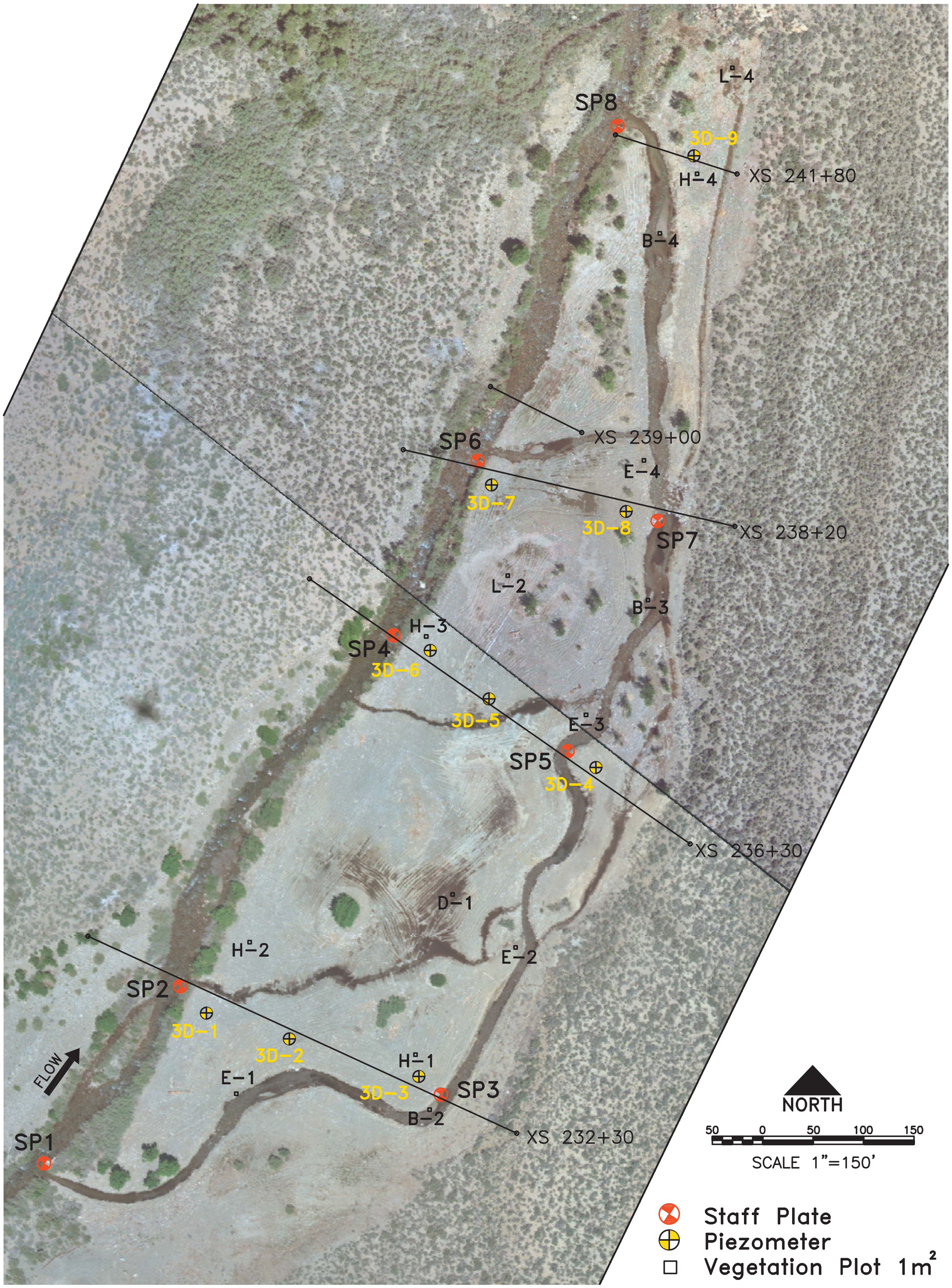

Figure 19. The 3D Channel and floodplain showing locations of piezometers, staff plates, cross sections, and vegetation monitoring pins. Vegetation plot symbols are as follows: H=high ground, B=bar, E=edge, D=depression.

2.3.3 Discussion

For any square foot patch of the 4 Floodplain and 8 Floodplain, water can arrive via (1) a rise in the groundwater table generated by greater mainstem flows, (2) surface flow down side-channels, and (3) rainfall/snowmelt. The tale-of-two floodplains in summer 2004 differed significantly. The 4 Floodplain received sufficient surface flows to sustain an actively flowing multiple branched stream during the flow release. Its soil moisture profile was wetted from above. In contrast, the 8 Floodplain encountered only minor surface flow, and instead relied on rising groundwater level, and its associated capillary fringe, to wet the ground surface. Wetting occurred only at the head of the 8 Channel due to surface flow and downstream in a depression (old scour channel from a large previous flood) where the capillary fringe reached the ground surface. Less than 1% of the 8 Floodplain was wetted, as opposed to 47 % of the 4 Floodplain and essentially 100% of the 3D Floodplain (except on a few ‘islands’ of mature cottonwoods preserved from the excavation work).

If the peak flow release had been sustained for 5, 10, or more days, would groundwater elevations at the 8 Floodplain piezometers have kept rising, eventually approximating the stage height elevation of peak flow release? If so, a greater portion of the 8 Floodplain’s ground surface would have been wetted (mostly by having the capillary fringe intersect the ground surface). The June 2004 release at peak flow unfortunately was not sustained, but dropped briefly (due to sudden cold weather) before returning briefly to peak flow. Although we have not calculated a percentage of likely ground surface area wetted if groundwater elevation approximated the peak release stage height elevation, the percentage would have been much less than the 47% documented in the 4 Floodplain.

Our yardstick for evaluating the effect of the flow releases on Rush Creek floodplains has been the extent to which the ground surface was wetted. The extent of wetting must be considered with the duration of surface wetting. A seed germinating under very-near saturated conditions still requires time to accomplish its mission. As noted, at least 7 days of wetted surface are necessary for a cottonwood seed to successfully germinate. The 4 Floodplain and 3D Floodplain, and to a much less extent the 8 Floodplain, did achieve wetted surface conditions longer than 7 days.

Surface wetting of sufficient duration, when viable seeds are being released, is just one yardstick. Rising groundwater elevation and infiltration from surface flows also change the soil moisture profile during and well after either has ended (in 2004 roughly two months later). This must have a positive effect on established riparian plants and a negative effect of xeric plants. Large areas of sagebrush on the 4 Floodplain, but not the 8 Floodplain, are showing obvious signs of stress (too much water). We do not intend to measure the positive effect on plant growth by restoring soil moisture to field capacity during the summer, but we may want to document the extent of sagebrush retreat as annual high flow releases make the floodplains wetter overall.

At the peak of the June 2004 release, the 3D Floodplain’s surface was almost entirely saturated, either from inundation by multiple constructed side-channels or by the capillary fringe intersecting ground surface (Figure 20). Approximately 46 % of the 6.3 acre floodplain was inundated at the height of the peak SRF releases. During the peak release the side channel conveyed in excess of 30 cfs and discharge increased in the downstream direction as tertiary channels joined the side channel. The influence of multiple side-channels on groundwater elevation is evident in Figure 21. Prior to the June release, groundwater elevation at Piezometer 3D-8 was approximately 6623.5 ft. As expected, groundwater elevation quickly responded to the high flow release. However, during the recession limb groundwater elevation dropped precipitously (Figure 21), below the pre-release elevation. The cause can be traced back to the side-channel adjacent to Piezometer 3D-8. During the peak release the side-channel significantly headcut, lowering the side-channel’s bed (Figure 22) followed by a closing-off of the side-channel’s entrance at the top of the 3D Floodplain that stopped all side-channel flow. By July 22 groundwater elevation had already dropped more than two feet lower than the groundwater

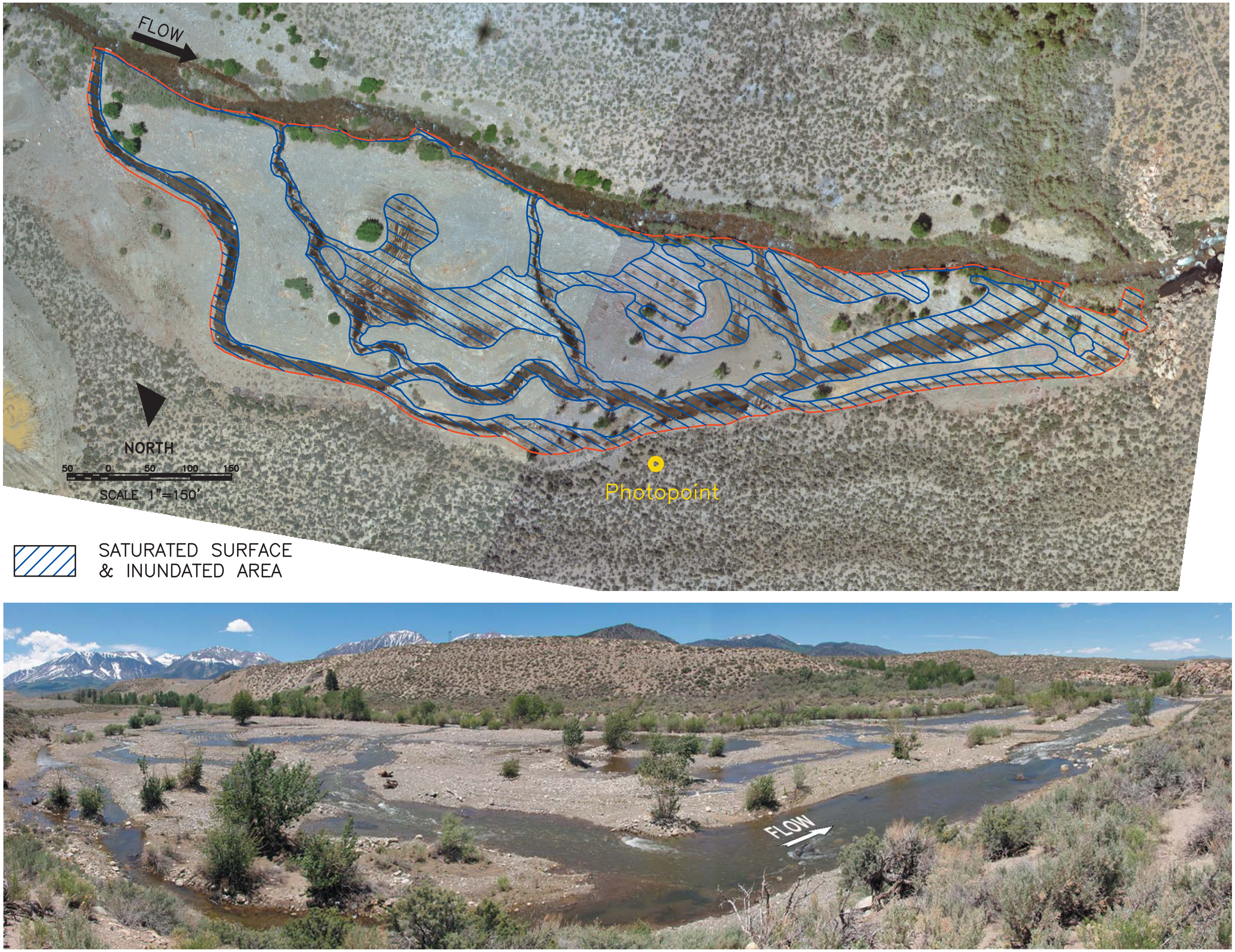

Figure 20. The reconstructed 3D Floodplain showing the extent of inundation on June 11, 2004.

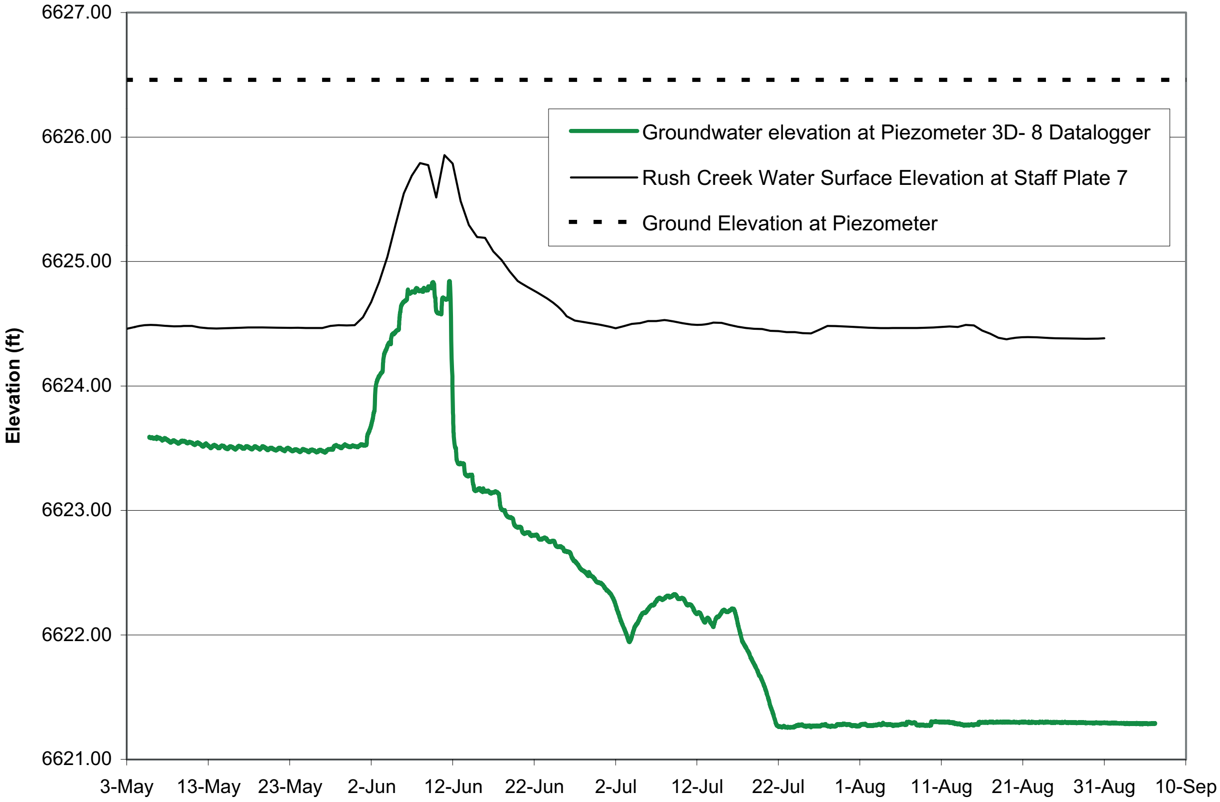

Figure 21. Groundwater elevations from Piezometer 3D-8 with the continuous recording datalogger, and Rush Creek stage height during the June 2004 SRF releases.

elevation prior to the June release (Figure 21). Baseline groundwater elevations observed at piezometers 3D-3, 4, and 7 (those farthest from the main channel) before the June release receded at least 1-2 ft lower after the June release, and had dropped below the bottoms of these piezometers by mid-September. Unfortunately the elevation at the bottom of Piezometer 3D-8 is 6621.25 ft; additional decreases were not documented. If the groundwater elevation trend continued another month, the time when the snowmelt release signature ended in the other floodplains, groundwater elevation likely dropped another 2 to 3 ft minimum.

The 3D side-channel thalweg resurveyed on October 22, 2004 (Figure 22) indicates the upstream plug is only 0.3 ft higher than the pre-flood elevation, just enough to keep baseflows from entering the side-channel but low enough to allow future peak flows to access the side-channel. The post-June 2004 channel bed elevation of the side-channel is approximately 1.0 ft lower than the pre-flood elevation (except where the plug occurred), thus if the plug is scoured out, the side-channel may eventually convey an even larger proportion of the total discharge.

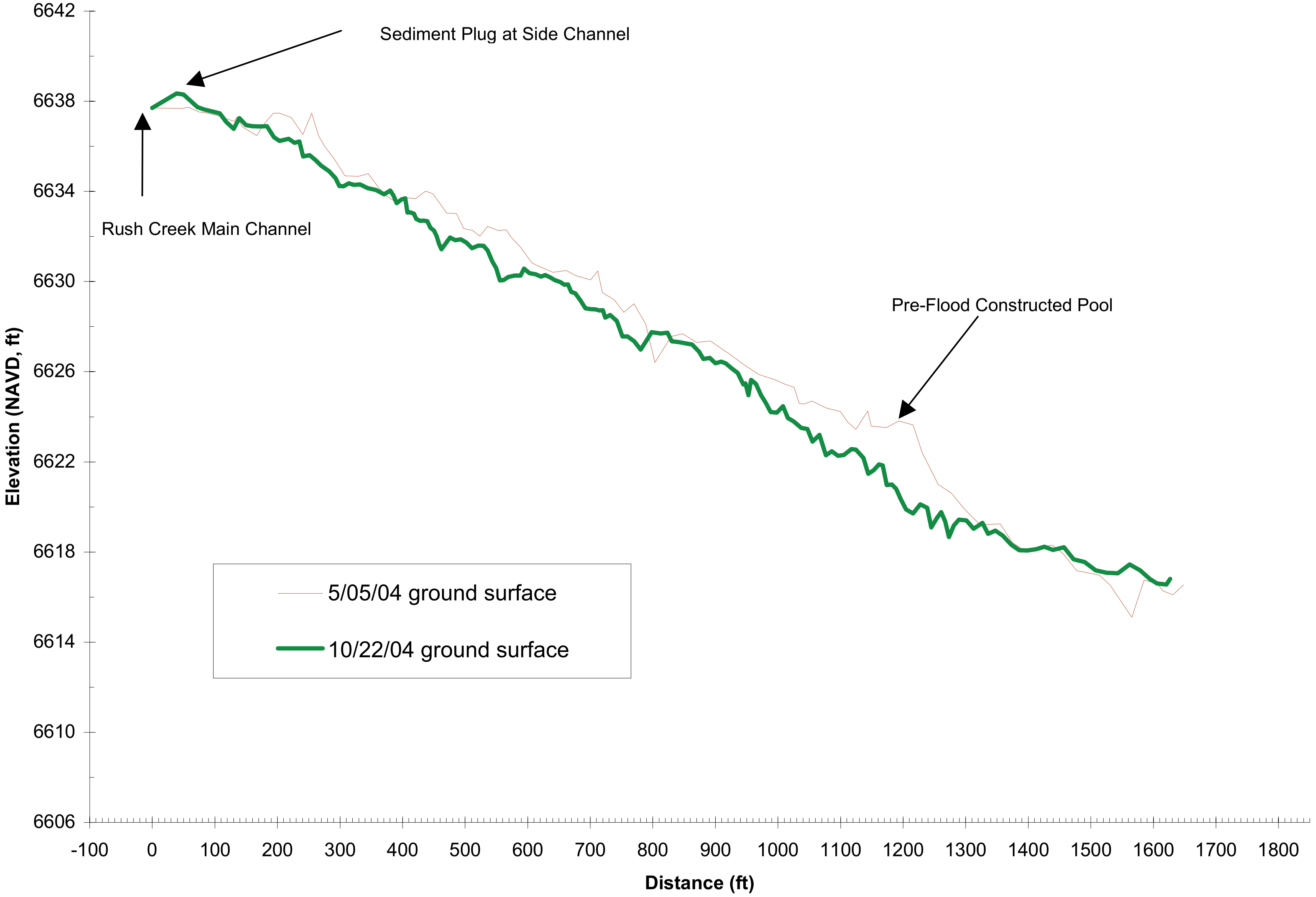

Figure 22. Thalweg profile of the 3D constructed side-channel surveyed in May 2004 prior to the SRF releases and in October 2004 after the SRF releases.

3 GEOMORPHOLOGY

3.1 Channel Dynamics

3.1.1 Cross Section Surveys

There are 53 cross sections installed on Rush, Parker, Walker, and Lee Vining creeks monumented with rebar and referenced with X–Y–Z coordinates. These cross sections track changes in channelbed elevations through time as the creek channels adjust to their current flow regimes. During initial years of monitoring, cross sections were typically re-surveyed annually. In 2004, all cross sections were surveyed to correspond to the 5-year schedule for planmapping. In the future, cross sections will be surveyed based on the schedule recommended in the White Book, following normal or greater than normal peak flows, unless there are specific objectives that require survey data (e.g., floodplain aggradation monitoring) or unless conditions indicate that resurveying is not needed.

Cross sections surveyed in 2004 were plotted with a ground surface and water surface from the original survey or an early survey (usually 1998 or 1999) to demonstrate the degree of changes that have occurred at each cross section during the last five or more years. All cross section plots are presented in Appendix B.

3.1.2 Longitudinal Profile Surveys

White Book Section 3.2.3 specifies that thalweg profiles of the main channels of study sites should be surveyed after years with normal or greater than normal peak flows. Thalweg profile data provide an important longitudinal perspective of channel features not readily apparent or measurable from aerial photography. The data also provide an important context for evaluating detailed mapping of the channels and their riparian vegetation along shorter segments.

Thalweg profiles surveyed at all study sites in 1999 were repeated in 2004 to correspond to the 5-year schedule for planmapping. Previous survey methods used a centerline tape set down the channel, with compass bearings taken on each segment. All survey points in the channel (thalweg ground points, water surface elevations, high water marks, etc.) were referenced to a station number on the centerline. Distance between successive points was measured along the centerline tape and not between the points. This method artificially reduced the station distances to a somewhat arbitrary distance depending on where the centerline tape is set. To obtain precise distances between survey points, thalweg surveys were conducted in 2004 with a total station. The X–Y–Z coordinates were obtained, then the actual distance between points was calculated as a hypotenuse of a right triangle (using Pythagorean Theorem), and stationing was assigned as cumulative distance between points. This method thus provided the best depiction of the channel thalweg and should be used in future thalweg surveys.

To compare successive surveys, thalweg stationing was adjusted in the 1999 data to have a common starting point with the 2004 data. However, comparisons between successive thalweg surveys were confounded by having different profile lengths even though the segment of surveyed channel was the same. The 1999 data were thus adjusted by multiplying the station by the ratio of the profile lengths, thus either compressing or expanding the stationing to fit the 2004 data. Thalweg profiles for each study site are presented in Appendix C. The 2004 data were thus unadjusted data and the 1999 were adjusted to fit the recent data.

3.1.3 Bed Mobility Experiments

Bed mobility experiments were conducted on Rush and Lee Vining creeks during the RY 2004 spring snowmelt floods for the seventh year. Rocks repainted fluorescent yellow were placed into the channel in May 2004, then collected in July 2004 to document the percentage of each rock size class that moved from the cross section, and the distance each recovered rock moved. On Rush Creek, the RY 2004 annual maximum instantaneous discharge of 384 cfs and 413 cfs (below Return Ditch and below Narrows, respectively), was the highest discharge since spring of 1998. Tracer rock sets placed within the low water channel on pool-tail or riffle features generally had mobility ranging from 50–100% (Table 7), the only exception being Upper Rush Creek XS 0+74, a riffle feature that typically shows very little mobility. Highlights of tracer rock mobility data for RY 2004 are bulleted below. Updated mobility figures for each tracer cross section are provided in Appendix D.

- Lower Rush Creek XS 10+10 is a good mobility reference site because of the uniform channel in this reach and 7 years of data . Of the ten D_{84}, D_{50}, and D_{31} tracer rock sets placed (n=30) in RY 2004, only 2 D_{84}'s, 1 D_{50}, and 1 D_{31} remained after the peak, indicating almost complete surface mobility from the 384 cfs peak below the Narrows.
- At Lower Rush Creek XS –9+82 below the 10-Channel confluence, 8 of 12 D_{84}'s mobilized and all those were recovered downstream, ranging in distance moved from 2 ft to 54 ft. All but one of the D_{50}'s and D_{31}'s were mobilized and few were recovered.
- At Upper Rush Creek XS 12+95, the 384 cfs peak fell between two previous peaks (273 cfs and 538 cfs) that had caused significant mobility. The 273 cfs peak achieved 25-42% mobility; the 538 cfs peak achieved 75-100% mobility. The RY 2004 384 cfs peak achieved mobility ranging from 50-70% thus creating a relatively "clean" mobility-discharge curve (Appendix E).

On Lee Vining Creek, tracer rocks were painted and set out in anticipation of a moderate magnitude peak runoff, but the 141 cfs peak discharge was the smallest peak in the last eight years. Tracer mobility was very minimal, with only a few D50's and D31's mobilized (Table 8). Updated mobility figures for each tracer cross section are in Appendix D.

3.1.4 Scour Core Experiments

On Rush and Lee Vining creeks, all scour cores were re-set in May 2004 prior to spring snowmelt, then surveyed in July after the snowmelt flood had receded. Data were compiled with past years' data and are presented in Tables 9 and 10 for Rush and Lee Vining creeks, respectively. In Rush Creek, most scour core sites had minor scour in the range of 0.1–0.2 ft, but with some notable locations where scour was much deeper. Highlights of scour core data from RY 2004 are as follows:

- Upper Rush Creek XS 12+95: the mid-channel scour core at this medium gradient riffle scoured to 0.37 ft and redeposited to a similar pre-scour depth. This scour depth exceeded the depth of scour resulting from the 538 cfs event in 1998, and was significant given the coarse substrate at this site. Narrowing of the channel along the left bank and increased height of the right bank bar have increased channel confinement, causing similar scour depths at lower discharge than in 1998 (see XS 12+95 cross section survey in Appendix B).
- Upper Rush Creek XS 5+45: the lee deposits at this medial bar were relatively mobile and scour ranged from 0.36–0.43 ft across the medial bar. Minor redeposition occurred at these scour cores.
- Upper Rush Creek XS 1+05: the pool-tail downstream of the Trihey rootwad structure had less than 0.2 ft of scour, which is notable given these gravels should be relatively more mobile and subject to scour. The 1998 flood of 538 cfs caused up to 0.7 ft of scour at this pool-tail.

Table 7. Summary of bed mobility data for Rush Creek study sites, showing the percentage of particles moved during each year's peak discharge and the maximum percentage moved at each study site.

Creek	Cross Section	Geomorphic Unit	Observation Date	Discharge at Cross Section	Percent D_{84} Moved	Percent D_{50} Moved	Percent D_{31} Moved
Lower Rush Creek	10+10	Pool Tail	10/3/97	54 cfs	0%	0%	0%
			6/1/98	65 cfs	0%	10%	10%
			7/3/98	224 cfs	90%	80%	80%
			9/10/98	387 cfs	100%	100%	100%
			7/20/99	151 cfs	20%	30%	50%
			8/12/00	153 cfs	23%	62%	77%
			8/5/01	102 cfs	0%	38%	63%
			6/8/02	142 cfs	60%	100%	100%
			6/11/04	224 cfs	80%	90%	90%
				maximum mobility =	100%	100%	100%
Lower Rush Creek	07+70	Riffle	10/3/97	54 cfs	0%	0%	0%
			6/1/98	65 cfs	0%	0%	0%
			7/3/98	224 cfs	88%	100%	100%
			9/10/98	387 cfs	100%	100%	100%
			7/20/99	151 cfs	43%	71%	86%
			8/12/00	153 cfs	50%	70%	100%
			8/5/01	102 cfs	0%	20%	50%
			6/8/02	142 cfs	40%	10%	60%
			6/11/04	224 cfs	90%	90%	90%
				maximum mobility =	100%	100%	100%
Lower Rush Creek	07+70	Floodplain	10/3/97	54 cfs	0%	0%	0%
			6/1/98	65 cfs	0%	0%	0%
			7/3/98	224 cfs	0%	0%	0%
			9/10/98	387 cfs	0%	14%	29%
			7/20/99	151 cfs	0%	0%	0%
			8/12/00	153 cfs	0%	0%	0%
			8/5/01	102 cfs	0%	0%	0%
			6/8/02	142 cfs	0%	0%	0%
			6/11/04	224 cfs	0%	0%	0%
				maximum mobility =	0%	14%	29%
Lower Rush Creek	07+25	Riffle	10/3/97	54 cfs	0%	0%	0%
			6/1/98	65 cfs	0%	0%	14%
			9/10/98	387 cfs	0%	14%	29%
			7/21/99	151 cfs	13%	75%	75%
			8/12/00	153 cfs	0%	13%	13%
			8/5/01	102 cfs	20%	50%	60%
			6/8/02	142 cfs	40%	70%	40%
			6/11/04	224 cfs	60%	60%	100%
				maximum mobility =	60%	75%	100%
Lower Rush Creek	07+25	Floodplain	10/3/97	54 cfs	0%	0%	0%
			6/1/98	65 cfs	0%	0%	0%
			7/3/98	224 cfs	0%	0%	0%
			9/10/98	387 cfs	0%	0%	0%
			7/21/99	151 cfs	0%	0%	0%
			8/12/00	153 cfs	0%	0%	0%
			8/5/01	102 cfs	0%	0%	0%
			6/8/02	142 cfs	0%	0%	0%
			6/11/04	224 cfs	0%	0%	0%
				maximum mobility =	0%	0%	0%
Lower Rush Creek	04+08	Pool Tail	10/3/97	54 cfs	0%	0%	0%
			6/1/98	65 cfs	0%	0%	14%
			7/3/98	224 cfs	100%	100%	100%
			9/10/98	387 cfs	100%	100%	100%
			7/20/99	151 cfs	29%	43%	57%
			8/12/00	153 cfs	20%	20%	60%
			8/5/01	102 cfs	0%	0%	10%
			6/8/02	142 cfs	20%	40%	40%
			6/11/04	224 cfs	100%	100%	100%
				maximum mobility =	100%	100%	100%
Lower Rush Creek	-05+07	Point Bar	6/4/98	56 cfs	0%	0%	0%
			7/3/98	224 cfs	36%	57%	71%
			9/10/98	387 cfs	93%	93%	93%
			7/20/99	151 cfs	14%	36%	29%
			8/12/00	255 cfs	0%	20%	30%
			8/5/01	102 cfs	0%	0%	20%
			6/8/02	142 cfs	10%	20%	40%
			6/11/04	224 cfs	30%	30%	40%

Table 7. Summary of bed mobility data for Rush Creek study sites, showing the percentage of particles moved during each year's peak discharge and the maximum percentage moved at each study site; continued.

Creek	Cross Section	Geomorphic Unit	Observation Date	Discharge at Cross Section	Percent D_{84} Moved	Percent D_{50} Moved	Percent D_{31} Moved
				maximum mobility =	93%	93%	93%
Lower Rush Creek	-09+82	Riffle	10/3/97	68 cfs	0%	0%	0%
			9/10/98	635 cfs	100%	100%	100%
			7/20/99	247 cfs	38%	54%	85%
			8/12/00	255 cfs	9%	64%	91%
			8/5/01	170 cfs	0%	0%	38%
			6/8/02	225 cfs	25%	50%	75%
			6/11/04	413 cfs	67%	100%	92%
				maximum mobility =	100%	100%	100%
Lower Rush Creek	1+10	Riffle	8/12/00	102 cfs	17%	17%	33%
			8/5/01	75 cfs	8%	0%	17%
			6/8/02	83 cfs	20%	60%	70%
			6/11/04	189 cfs	60%	80%	100%
				maximum mobility =	60%	80%	100%
Upper Rush Creek	12+95	Pool tail	6/3/98	55 cfs	0%	0%	0%
			7/1/98	273 cfs	25%	42%	42%
			9/10/98	538 cfs	75%	83%	100%
			7/20/99	201 cfs	0%	22%	33%
			8/13/00	204 cfs	0%	22%	22%
			8/5/01	162 cfs	0%	0%	0%
			6/8/02	168 cfs	10%	0%	20%
			6/11/04	384 cfs	50%	70%	70%
				maximum mobility =	75%	83%	100%
Upper Rush Creek	09+40	Point Bar	5/5/99	55 cfs	0%	0%	0%
			7/20/99	201 cfs	0%	0%	0%
			8/13/00	204 cfs	0%	0%	0%
			8/5/01	162	0%	0%	0%
			6/8/02	168	0%	0%	0%
			6/11/04	384	0%	0%	0%
				maximum mobility =	0%	0%	0%
Upper Rush Creek	05+45	Riffle	6/3/98	55 cfs	0%	0%	0%
			7/1/98	273 cfs	60%	100%	100%
			9/10/98	538 cfs	100%	100%	100%
			7/20/99	201 cfs	10%	30%	50%
			8/13/00	204 cfs	0%	20%	30%
			8/4/01	162 cfs	10%	20%	20%
			6/8/02	168 cfs	10%	20%	20%
			6/11/04	384 cfs	60%	60%	60%
				maximum mobility =	100%	100%	100%
Upper Rush Creek	00+74	Riffle	6/3/98	55 cfs	0%	0%	0%
			7/2/98	273 cfs	0%	0%	6%
			9/10/98	538 cfs	31%	88%	94%
			7/20/99	201 cfs	0%	12%	6%
			8/13/00	204 cfs	0%	12%	12%
			8/5/01	162 cfs	0%	0%	0%
			6/8/02	168 cfs	24%	6%	0%
			6/11/04	384 cfs	18%	35%	53%
				maximum mobility =	31%	88%	94%
Rush Creek County Rc	15+19	Riffle	8/13/00	255 cfs	8%	58%	75%
			8/6/01	202 cfs	0%	17%	58%
			6/8/02	225 cfs	0%	67%	83%
			6/11/04	413 cfs	67%	92%	100%
				maximum mobility =	67%	92%	100%
Rush Creek County Rc	6+85	Point Bar	8/13/00	255 cfs	0%	0%	0%
			8/5/01	202 cfs	0%	0%	0%
			6/8/02	225 cfs	0%	0%	0%
			6/11/04	413 cfs	0%	10%	10%
				maximum mobility =	0%	10%	10%

Table 8. Summary of bed mobility data for Lee Vining Creek study sites, showing the percentage of particles moved during each year's peak discharge and the maximum percentage moved at each study site.

Creek	Cross Section	Geomorphic Unit	Observation Date	Discharge at Cross Section	Percent D_{84} Moved	Percent D_{50} Moved	Percent D_{31} Moved
Lee Vining	13+92	Riffle	10/3/97	17 cfs	0%	0%	0%
			6/2/98	90 cfs	0%	0%	0%
			6/18/98	193 cfs	0%	0%	8%
			9/10/98	242 cfs	0%	25%	42%
			6/5/99	162 cfs	0%	0%	17%
			7/24/99	170 cfs	0%	8%	25%
			6/4/00	204 cfs	0%	0%	0%
			8/3/01	66 cfs	0%	9%	18%
			4/24/02	164 cfs	0%	18%	9%
			6/27/04	45 cfs	0%	9%	9%
				maximum mobility =	0%	25%	42%
Lee Vining	03+45	Pool Tail	10/3/97	17 cfs	0%	0%	0%
			6/2/98	90 cfs	0%	0%	0%
			7/2/98	193 cfs	8%	17%	80%
			9/10/98	242 cfs	47%	60%	80%
			6/5/99	162 cfs	7%	27%	40%
			7/24/99	170 cfs	7%	33%	60%
			6/4/00	204 cfs	21%	14%	7%
			8/3/01	152 cfs	7%	13%	20%
			4/24/02	164 cfs	13%	7%	13%
			6/27/04	105 cfs	0%	0%	0%
				maximum mobility =	47%	60%	80%
Lee Vining	06+61	Point Bar	10/3/97	17 cfs	0%	0%	0%
			6/2/98	90 cfs	0%	0%	0%
			7/2/98	193 cfs	0%	0%	8%
			9/10/98	242 cfs	0%	0%	17%
			6/5/99	162 cfs	0%	0%	0%
			7/24/99	170 cfs	0%	0%	0%
			6/4/00		0%	0%	0%
			8/3/01	152 cfs	0%	0%	0%
			4/24/02	164 cfs	0%	0%	0%
			6/27/04	105 cfs	0%	0%	0%
				maximum mobility =	0%	0%	17%
Lee Vining	09+31	Riffle	10/3/97	17 cfs	0%	0%	0%
			6/2/98	90 cfs	0%	0%	0%
			9/10/98	242 cfs	45%	82%	91%
			6/5/99	162 cfs	27%	36%	36%
			7/24/99	170 cfs	45%	64%	55%
			6/4/00	204 cfs	0%	18%	18%
			8/3/01	152 cfs	0%	0%	18%
			4/24/02	164	27%	82%	82%
			6/27/04	105 cfs	0%	0%	0%
				maximum mobility =	45%	82%	91%
Lee Vining	09+31	Floodplain	10/3/97	17 cfs	0%	0%	0%
			6/2/98	90 cfs	0%	0%	0%
			7/2/98	193 cfs	0%	0%	0%
			9/10/98	242 cfs	0%	0%	0%
			6/5/99	162 cfs	0%	0%	0%
			7/24/99	170 cfs	0%	0%	25%
			6/4/00	204 cfs	0%	45%	55%
			8/3/01	152 cfs	18%	27%	55%
			4/24/02	164 cfs	0%	0%	0%
			6/27/04	105 cfs	0%	0%	0%
				maximum mobility =	18%	45%	55%
Lee Vining	06+80	Riffle	10/3/97	12 cfs	0%	0%	0%
			6/2/98	37 cfs	0%	0%	0%
			7/2/98	118 cfs	17%	83%	100%
			9/10/98	149 cfs	17%	100%	100%
			6/5/99	100 cfs	33%	33%	83%
			7/24/99	104 cfs	20%	60%	80%
			6/4/00	109 cfs	0%	0%	38%
			8/3/01	66 cfs	0%	0%	0%
			4/24/02	82 cfs	13%	0%	13%
			6/27/04	45 cfs	0%	0%	0%
				maximum mobility =	33%	100%	100%

Table 8. Summary of bed mobility data for Lee Vining Creek study sites, showing the percentage of particles moved during each year's peak discharge and the maximum percentage moved at each study site; continued.

Creek	Cross Section	Geomorphic Unit	Observation Date	Discharge at Cross Section	Percent D_{84} Moved	Percent D_{50} Moved	Percent D_{31} Moved
Lee Vining	05+15	Point Bar	10/3/97	12 cfs	0%	0%	0%
			6/2/98	37 cfs	10%	40%	40%
			7/2/98	118 cfs	50%	50%	70%
			9/10/98	149 cfs	50%	50%	70%
			6/5/99	100 cfs	10%	30%	83%
			7/24/99	104 cfs	25%	63%	63%
			6/4/00	109 cfs	0%	9%	36%
			8/3/01	66 cfs	0%	0%	10%
			4/24/02	82 cfs	0%	20%	40%
			6/27/04	45 cfs	0%	10%	10%
				maximum mobility =	50%	63%	83%
Lee Vining	04+04	Riffle	10/3/97	12 cfs	0%	0%	0%
			6/2/98	37 cfs	0%	0%	0%
			7/2/98	118 cfs	10%	40%	40%
			9/10/98	149 cfs	50%	40%	40%
			6/5/99	100 cfs	30%	30%	0%
			7/24/99	104 cfs	40%	40%	20%
			6/4/00	109 cfs	20%	30%	40%
			8/3/01	66 cfs	0%	20%	0%
			4/24/02	82 cfs	40%	40%	50%
			6/27/04	45 cfs	0%	0%	10%
				maximum mobility =	50%	40%	50%
Lee Vining	01+15	Riffle	10/3/97		0%	0%	0%
			6/2/98				
			7/2/98				
			9/10/98		50%	63%	75%
			6/5/99	100 cfs	0%	13%	13%
			7/24/99	104 cfs	14%	14%	29%
			6/4/00	109 cfs	10%	20%	60%
			8/4/01	131 cfs	0%	0%	20%
			4/24/02	131 cfs	10%	30%	50%
			6/27/04	89 cfs	0%	0%	0%
				maximum mobility =	50%	63%	75%
Lee Vining	06+08	Riffle	10/3/97	17 cfs	0%	0%	0%
			6/2/98	48 cfs	0%	0%	0%
			7/2/98	152 cfs	40%	100%	100%
			9/10/98	192 cfs	60%	100%	100%
			6/5/99	100 cfs	40%	20%	100%
			7/24/99	104 cfs	40%	80%	60%
			6/4/00	109 cfs	0%	13%	100%
			8/3/01	66 cfs	0%	13%	0%
			4/24/02	105 cfs	0%	0%	0%
			6/27/04	45 cfs	0%	0%	0%
				maximum mobility =	60%	100%	100%
Lee Vining	00+87	Point Bar	5/4/99	23 cfs	0%	0%	0%
			6/5/99	100 cfs	50%	75%	75%
			7/24/99	104 cfs	67%	83%	75%
			6/4/00	109 cfs	0%	20%	50%
			8/4/01	86 cfs	10%	10%	20%
			4/24/02	105 cfs	20%	10%	40%
			6/27/04	61 cfs	0%	0%	0%
				maximum mobility =	67%	83%	75%
Lee Vining	01+80	Riffle	5/4/99	23 cfs	0%	0%	0%
			6/5/99	100 cfs	0%	33%	100%
			7/24/99	104 cfs	17%	83%	100%
			6/4/00	109 cfs	60%	30%	80%
			8/4/01	86.43	20%	20%	50%
			4/24/02	105	10%	60%	70%
			6/27/04	60.63	0%	10%	0%
				maximum mobility =	60%	83%	100%

Table 9. Summary of scour core data for Rush Creek study sites, showing depth of bed scour and redeposition for each core location.

Reach	Cross Section	Year	Discharge at Cross Section (cfs)	Core #	Scour depth (ft)	Redeposition depth (ft)	Geomorphic feature
Lower Rush Creek	00+86	1998	396	1	0.00	0.00	Upper point bar / floodplain
				2	0.03	0.00	Middle of point bar
				3	0.21	1.14	Point bar within low water channel
				4	0.30	0.77	Point bar within low water channel
		1999	155	1	0.01	0.00	Upper point bar / floodplain
				2	0.03	0.00	Middle of point bar
				3	0.00	0.00	Point bar within low water channel
				4	-	-	Point bar within low water channel
		2000	161	1	0.01	0.00	Upper point bar / floodplain
				2	0.01	0.00	Middle of point bar
				3	0.05	0.00	Point bar within low water channel
				4	-	-	Point bar within low water channel
				5	0.00	0.00	Pool tail
		2001	128	1	0.00	0.00	Upper point bar / floodplain
				2	0.00	0.00	Middle of point bar
				3	0.00	0.00	Point bar within low water channel
				4	-	-	Point bar within low water channel
				5	0.00	0.00	Pool Tail
		2002	144	1	0.00	0.00	Upper point bar / floodplain
				2	0.00	0.00	Middle of point bar
				3	0.00	0.00	Point bar within low water channel
				5	0.00	0.00	Pool Tail
		2004	241 (281)	5	0.47	0.00	Upper point bar / floodplain
				4	0.10	0.21	Middle of point bar
				3	0.00	0.00	Point bar within low water channel
				2	0.00	0.00	Point bar within low water channel
				1	0.00	0.00	Pool Tail
Lower Rush Creek	03+30	1998	396	1	0.47	0.31	Pool tail at low flow, transverse bar at high flow
				2	>0.55	>0.55	Pool tail at low flow, transverse bar at high flow
				3	>0.75	>0.50	Pool tail at low flow, transverse bar at high flow
		1999	155	1	0.05	0.14	Pool tail at low flow, transverse bar at high flow
				2	0.14	0.14	Pool tail at low flow, transverse bar at high flow
				3	-	-	Not surveyed; assume completely scoured.
		2000	161	1	0.00	0.03	Pool tail at low flow, transverse bar at high flow
				2	0.00	0.00	Pool tail at low flow, transverse bar at high flow
				3	-	-	Not surveyed in 1999; assume completely scoured.
		2001	128	1	0.18	0.00	Pool tail at low flow, transverse bar at high flow
				2	0.00	0.02	Pool tail at low flow, transverse bar at high flow
				3	-	-	Not surveyed in 1999; assume completely scoured.
		2002	144	1	0.18	0.00	Pool tail at low flow, transverse bar at high flow
				2	0.16	0.13	Pool tail at low flow, transverse bar at high flow
		2004	241 (281)	1	0.07	0.75	Pool tail at low flow, transverse bar at high flow
				2	0.06	0.00	Pool tail at low flow, transverse bar at high flow
Lower Rush Creek	04+08	1998	396	1	>0.46	>0.46	Low-gradient riffle
				2	>0.67	>0.67	Low-gradient riffle
		1999	155	1	0.17	0.20	Low-gradient riffle
				2	0.13	0.00	Low-gradient riffle
		2000	161	1	0.00	0.00	Low-gradient riffle
				2	0.00	0.00	Low-gradient riffle
		2001	128	1	0.02	0.12	Low-gradient riffle
				2	0.00	0.00	Low-gradient riffle
		2002	144	1	0.09	0.00	Low-gradient riffle
				2	0.00	0.00	Low-gradient riffle
		2004	241 (281)	1	0.01	0.00	Low-gradient riffle
				2	0.16	0.25	Low-gradient riffle
Lower Rush Creek	05+49	1998	396	1	0	0.00	Riffle (transverse bar), within low water channel
				2	0	0.00	Riffle (transverse bar), within low water channel
				3	0	0.00	Riffle (transverse bar), within low water channel
				4	0	0.00	Riffle (transverse bar), within low water channel
		1999	155	1	0.00	0.00	Riffle (transverse bar), within low water channel
				2	0.00	0.00	Riffle (transverse bar), within low water channel
				3	0.00	0.00	Riffle (transverse bar), within low water channel
				4	0.00	0.00	Riffle (transverse bar), within low water channel
		2000	161	1	0	0.00	Riffle (transverse bar), within low water channel
				2	0	0.00	Riffle (transverse bar), within low water channel
				3	0.00	0.00	Riffle (transverse bar), within low water channel
				4	0	0.00	Riffle (transverse bar), within low water channel
		2001	128	1	0.00	0.00	Riffle (transverse bar), within low water channel
				2	0.00	0.00	Riffle (transverse bar), within low water channel
				3	0.00	0.00	Riffle (transverse bar), within low water channel
				4	0.00	0.00	Riffle (transverse bar), within low water channel
		2002	144	1	-0.03	0.15	Riffle (transverse bar), within low water channel
				2	0.05	0.15	Riffle (transverse bar), within low water channel
				3	-0.02	0.14	Riffle (transverse bar), within low water channel
				4	-0.04	0	Riffle (transverse bar), within low water channel
		2004	241 (281)	1	0.02	0.00	Riffle (transverse bar), within low water channel
				2	0.23	0.22	Riffle (transverse bar), within low water channel
				3	0.02	0.48	Riffle (transverse bar), within low water channel
				4	0.21	0.20	Riffle (transverse bar), within low water channel
Lower Rush Creek	07+25	1998	396	1	0.00	0.00	Upper point bar / floodplain

Table 9. Summary of scour core data for Rush Creek study sites, showing depth of bed scour and redeposition for each core location; continued.

Reach	Cross Section	Year	Discharge at Cross Section (cfs)	Core #	Scour depth (ft)	Redeposition depth (ft)	Geomorphic feature
		1999	155	1	0.01	0.00	Upper point bar / floodplain
		2000	161	1	0.00	0.00	Upper point bar / floodplain
		2001	128	1	0.00	0.00	Upper point bar / floodplain
		2002	144	1	0.00	0.00	Upper point bar / floodplain
		2004	241 (281)	1	0.01	0.00	Upper point bar / floodplain
Lower Rush Creek	07+70	1998	396	1	0.00	0.03	Upper point bar / floodplain
		1999	155	1	0.00	0.00	Upper point bar / floodplain
		2000	161	1	0.00	0.00	Upper point bar / floodplain
		2001	128	1	0.00	0.00	Upper point bar / floodplain
		2002	144	1	0.00	0.00	Upper point bar / floodplain
		2004	241 (281)	1	No Data collected		Upper point bar / floodplain
Lower Rush Creek	10+10	1999	155	1	0.04	0.15	Pool tail
				2	0.00	0.11	Pool tail
		2000	161	1	0.00	0.00	Pool tail
				2	0.00	0.09	Pool tail
		2001	128	1	0.04	0.00	Pool tail
				2	0.02	0.14	Pool tail
		2002	144	1	0.03	0.00	Pool tail
				2	0.06	0.12	Pool tail
		2004	241 (281)	1	unknown	0.15	Pool tail
				2	unknown	0.06	Pool tail
Upper Rush Creek	1+05	1998	538	1	0.23	0.24	Constructed pool tail
				2	0.38	0.39	Constructed pool tail
				3	0.69	0.39	Constructed pool tail
		1999	201	1	0.06	0.06	Constructed pool tail
				2	0.00	0.00	Constructed pool tail
				3	0.05	0.00	Constructed pool tail
		2000	204	1	0.22	0.00	Constructed pool tail
				2	0.27	0.00	Constructed pool tail
				3	0.19	0.00	Constructed pool tail
		2001	162	1	0.03	0.00	Constructed pool tail
				2	0.08	0.04	Constructed pool tail
				3	0.11	0.12	Constructed pool tail
		2002	168	1	0.03	0.00	Constructed pool tail
				2	-0.09	0.15	Constructed pool tail
				3	-0.1	0.16	Constructed pool tail
		2004	343 (384)	1	0.00	0.09	Constructed pool tail
				2	0.19	0.13	Constructed pool tail
				3	0.08	0.27	Constructed pool tail
Upper Rush Creek	5+45	1998	538	1	1.04	0.95	Eddy deposit
				2	0.25	0.61	Lee deposit
		1999	201	1	0.03	0.19	Eddy deposit
				2	0.40	0.31	Lee deposit
		2000	204	1	0.00	0.06	Eddy deposit
				2	0.00	0.31	Lee deposit
		2001	162	1	0.06	0.09	Eddy deposit
				2	0.29	0.05	Lee deposit
				3	0.05	0.00	Riffle crest
		2002	168	1	-0.04	0.17	Eddy deposit
				2	0.31	0.22	Lee deposit
		2004	343 (384)	1	0.43	0.02	Eddy deposit
				2	0.36	0.11	Lee deposit
Upper Rush Creek	9+40	1999	201	1	0.00	0.00	Point bar, within low water channel
				2	0.01	0.00	Point bar, within low water channel
		2000	204	1	0.00	0.00	Point bar, within low water channel
				2	0.00	0.00	Point bar, within low water channel
		2001	162	1	0.00	0.00	Point bar, within low water channel
				2	0.00	0.00	Point bar, within low water channel
		2002	168	1	0	0	Point bar, within low water channel
				2	0	0	Point bar, within low water channel
		2004	Cores not Evaluated in 2004				
Upper Rush Creek	12+95	1998	538	1	0.33	0.19	Riffle
				2	0.12	0.10	Riffle
		1999	201	1	0.00	0.28	Riffle
				2	0.08	0.00	Riffle
		2000	204	1	0.09	0.04	Riffle
				2	0.10	0.00	Riffle
		2001	162	1	0.00	0.00	Riffle
				2	0.00	0.00	Riffle
		2002	168	1	0.02	0.16	Riffle
				2	0.17	0	Riffle
		2004	343 (384)	1	0.37	0.45	Riffle
				2	0.01	0.00	Riffle
Rush Creek at County Road	6+85	2004	354 (413)	1	0.06	1.38	

Table 10. Summary of scour core data for Lee Vining Creek study sites, showing depth of bed scour and redeposition for each core location.

Reach	Cross Section	Year	Discharge at Cross Section (cfs)	Core #	Scour depth (ft)	Redeposition depth (ft)	Geomorphic feature
Lower Lee Vining Creek B-1 Channel	00+87	1999	122	1	0.10	0.04	Point bar, pea gravels
		2000	115	1	0.05	0.04	Point bar, pea gravels
		2001	89	1	0.00	0.04	Point bar, pea gravels
		2002	105	1	0.04	0.04	Point bar, pea gravels
		2004	62	1	0.00	0.00	Point bar, pea gravels
				2	0.16	0.11	
Upper Lee Vining Creek	13+92	1998	270	1	0.00	0.11	Eddy deposit, coarse sand
				2	0.20	0.19	Eddy deposit, medium gravels
		1999	190	1	0.08	0.13	Eddy deposit, coarse sand
				2	0.05	0.21	Eddy deposit, medium gravels
		2000	179	1	0.04	0.11	Eddy deposit, coarse sand
				2	0.00	0.07	Eddy deposit, medium gravels
		2001	140	1	0.03	0.12	Eddy deposit, coarse sand
				2	0.01	0.12	Eddy deposit, medium gravels
		2002	164	1	NO DATA		Eddy deposit, coarse sand
				2			Eddy deposit, medium gravels
		2004	103	1	0.02	0.01	Eddy deposit, coarse sand
				2	0.03	0.02	Eddy deposit, medium gravels
Upper Lee Vining Creek	10+44	1999	190	1	23.11	0.06	Eddy deposit, coarse sand
				2	23.02	0.00	Eddy deposit, medium gravels
		2000	179	1	0.05	0.32	Eddy deposit - spawning gravels
				2	0.21	0.00	Eddy deposit - exposed bar
		2001	140	1	0.04	0.46	Eddy deposit - spawning gravels
				2	0.03	0.42	Eddy deposit - exposed bar
		2002	164	1	0.01	0.16	Eddy deposit - spawning gravels
				2	0.02	0.04	Eddy deposit - exposed bar
		2004	103	1	0.01	0.12	Eddy deposit - exposed bar
				2	0.10	0.08	Eddy deposit - exposed bar
Upper Lee Vining Creek	03+73	1998	270	1	0.00	0.04	Point bar - pea gravels
				2	0.57	0.05	Point bar - pea gravels
		1999	190	1	0.30	0.00	Point bar - pea gravels
				2	0.30	0.17	Point bar - pea gravels
		2000	179	1	0.00	0.00	Point bar - pea gravels
				2	0.00	0.15	Point bar - pea gravels
		2001	140	1	0	0.00	Point bar - pea gravels
				2	0	0.18	Point bar - pea gravels
		2002	164	1	0.11	0.24	Point bar - pea gravels
				2	0.16	0.16	Point bar - pea gravels
		2004	103	1	0.00	0.00	Point bar - pea gravels
				2	0.10	0.24	Point bar - pea gravels

- Lower Rush Creek XS 5+49: the low gradient riffle had 0.21–0.23 ft of scour but had nearly 0.5 ft redeposition on one scour core in the middle of the channel. This riffle appears to be aggrading as the downstream right bank scour pool simultaneously deepens (see XS 5+49 cross section survey in Appendix B).
- Lower Rush Creek XS 3+30 had minor scour (less than 0.1 ft) but 0.75 ft of deposition occurred over scour core #1 on the leading edge of the left bank bar as the bar built outward and the channel migrated into the right bank.
- Rush Creek County Road XS 6+85 similarly had as much as 1.38 ft of deposition on top of the scour core, as the right bank bar continued to build and the channel migrated into the left bank floodplain.

In Lee Vining Creek, several scour cores were placed in highly mobile lee deposits, but had only minor amounts of scour (less than 0.1 ft). The only exception was at Lower B-1 XS 0+87 that had only 0.16 ft of scour along the leading edge of the left bank bar.

3.1.5 LWD Transport

Large woody debris (LWD) increases channel complexity, provides cover for fish habitat, promotes sediment scour and deposition, creates scour pools, and provides forage for macro-invertebrates. The 2004 Annual Report hypothesized that Wet runoff year types were capable of LWD recruitment, transport, and formation of logjams, whereas Normal runoff year types contributed only to LWD recruitment. We conducted a pilot study tracking LWD mobility and transport distances to: (1) assess if a Normal water year SRF can move LWD in lower Rush Creek, (2) gain insight on factors which initiate movement of LWD at a given flow, and (3) determine if size of LWD influences the distance a piece travels down channel once in motion. Species of wood was not identified in this task.

In May of 2004, thirty-six pieces of LWD along Rush Creek were marked with metal identification tags and white nylon cord before the high flow release (Figure 23). The location and numeric identifier of each piece were recorded using laminated aerial photographs. Each piece marked was greater than 5 feet long and greater than 0.5 feet in diameter at mid-section. Length, diameter, channel orientation, and description of each piece were recorded in a field book. We also noted if the LWD piece was a “key piece” in anchoring a log-jam. The description summarized whether an individual piece was free lying, lodged in riparian vegetation, or part of a debris jam, and noted its orientation relative to flow direction.

After the June 2004 peak SRF release of 412 cfs below the Narrows, field crews searched the same stream reach for the marked LWD. Presence or absence of each originally marked piece was recorded on the field map, along with the new location of each recovered piece (Figure 24). Channel orientation and position was recorded in a field book. Distance that each recovered piece traveled was calculated by digitizing the likely path of movement on the aerial photographs in AutoCAD.

Figure 23. Large woody debris pieces tagged with white nylon cord on Lower Rush Creek.

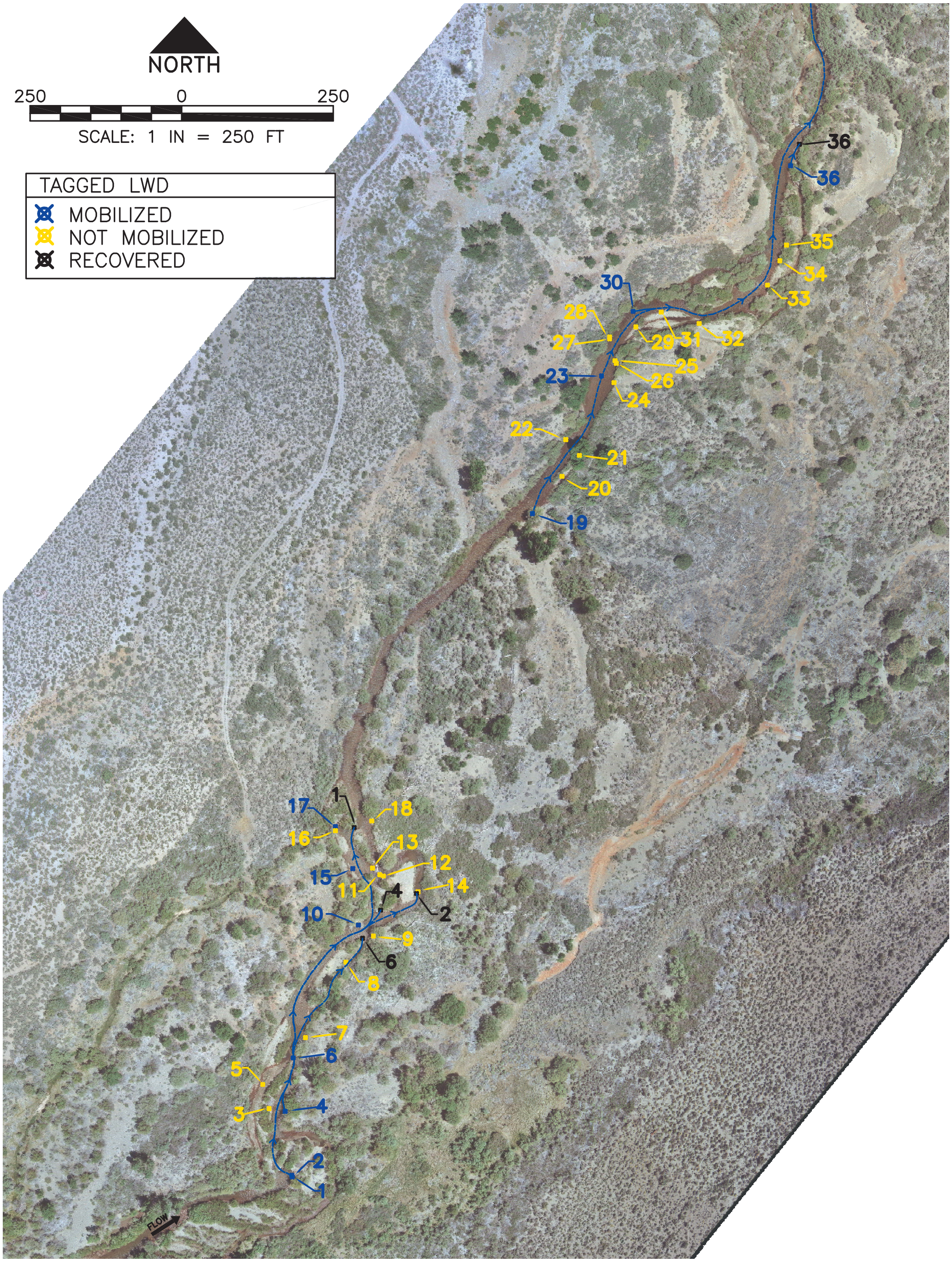

Figure 24. Locations of 36 pieces of LWD tagged on Lower Rush Creek in May 2004 and recovered in October 2004 after the SRF releases. Eleven pieces were transported from the original tagged locations; five of those were recovered.

Of the thirty six initially tagged pieces, eleven LWD pieces were mobilized from their initial locations; five were recovered downstream (Table 11). Our methods aided recovery of the LWD pieces: the white nylon cord was easily identified and remained attached to the wood. Use of the aerial photos in the field to map and digitize wood pieces to estimate their distance moved also proved effective. Future field activity may uncover additional pieces that can subsequently be re-mapped and data collected.

Table 11. Summary of large woody debris pieces mobilized and recovered in the June 2004 SRF releases.

ID #	Length (ft)	Mid-Diameter (ft)	Initial Orientation	Free/Lodged/Jam	Distance Moved (ft)
1	7.8	0.4	Perpendicular	Jam	660
2	19.5	0.6	Longitudinal	Jam	590
4	20.7	1.4	Longitudinal	Free	397
6	31.3	0.7	Diagonal	Free	235
10	5.7	0.8	Perpendicular	Jam	unknown
15	12.7	0.8	Longitudinal	Free	unknown
17	9.4	0.9	Perpendicular	Free	unknown
19	9.4	0.5	Longitudinal	Free	unknown
23	5.8	1.1	Longitudinal	Free	unknown
30	6.6	0.8	Perpendicular	Lodged	unknown
36	15.6	0.9	Diagonal	Free	39

Of the LWD pieces that moved, channel orientation and size did not influence mobility. However, of the eleven pieces that moved, seven were free lying in or along the channel margins and three were part of small debris jams. One piece was identified as lodged in a debris jam. Several pieces were large, exceeding 20 ft long, and 4 of the 5 recovered pieces were transported from 200 to 660 ft downstream. Tagged key pieces in larger debris jams did not mobilize. In conclusion, the RY 2004 peak magnitude appeared capable of mobilizing and transporting LWD; in some cases large pieces were transported significant distances. The RY 2004 peak magnitude did not create or redistribute LWD jams; larger flows are required.

3.2 Planmapping

Planmaps document morphological changes resulting primarily from annual floods, when streamflows erode, transport, and deposit sediment. This flow and sediment interaction is the basis for alluvial river dynamics, where alluvial features are formed and maintained. Changes in channel length, sinuosity, gradient, thalweg meander, areal extent of geomorphic surfaces and alluvial features (such as floodplains and point bars) are indicative of a dynamic alluvial creek. Additionally, the Blue Book lists the following features to be documented by planmapping:

(1) Change in channel width at selected planform locations, i.e., widths at bend apexes and channel crossovers will be treated as statistically separate populations;
(2) Variance in thalweg profiles used to measure channelbed complexity, including residual pool depths;
(3) Small changes in channel curvature and thalweg meander not quantifiable by aerial photography, especially as overhead canopy develops;
(4) Incremental changes in the areal extent of floodplain, low and middle terraces at a level of

detail that cannot be achieved with aerial photos, especially as overhead canopy develops;
(5) Distribution and quantification of large woody debris (LWD) size and species, including root masses of shrubs;
(6) Location and aerial extent of diagnostic alluvial features, such as point bars;
(7) Bed elevation changes in secondary channel entrances, relative to main channel bed elevation;
(8) Small changes in overall channel bed downcutting or aggradation, undetectable with aerial photography or sets of cross-sections;

Planmapping combines aerial photographic interpretation, photogrammetry, and field mapping to delineate geomorphic and aquatic habitat features. Seven planmap reaches are part of the monitoring program: three reaches are located on Rush Creek (Upper and Lower Rush Creek, Rush Creek at County Road), two reaches are located on Lee Vining Creek (Upper and Lower Lee Vining Creek), and one reach is located each on Walker and Parker creeks (Figure 1). Planmapping began in 1997 with selection of study reaches. In 1999, six of the seven study reaches were planmapped (excluding Parker Creek) using tape-and-compass methods to create basemaps upon which geomorphic features and aquatic habitats were mapped. These methods had limited accuracy because they lacked precise survey control. The current planmapping methods use high-quality, low-altitude orthorectified aerial photograph basemaps (flown in June 2003) with one-foot contour interval photogrammetry. The 2003 aerial photographs offer exceptional detail, thereby improving the information that can be collected from the photographs, as well as providing high-resolution imagery for field mapping.

Objectives of the 2004 planmapping were twofold: 1) identify and map channel features to document contemporary geomorphic and aquatic habitat conditions, following the planmapping protocol outlined in the Blue and White books, then 2) compare planform morphology between 2004 and 1999 to describe geomorphic changes. Once planmapping is completed, we will also re-evaluate the utility of the data and the frequency of planmapping in future years' monitoring.

3.2.1 Methods and Analysis

Updated planmapping methods have office and field components. Office-based work includes preparing field basemaps for 2004 mapping, geo-referencing the 1999 planmaps to the 2004 mapping coordinate system, refining mapping terminology, and processing the 2004 field data (e.g., digitizing mapped units and building topology). Our fieldwork component uses orthorectified aerial photograph basemaps to identify and delineate selected features in the planmap reaches. The 2004 planmapping was organized into six steps:

- Review 1999 maps and inventory map features to develop 2004 mapping program;
- Update and improve terminology;
- Conduct 2004 field mapping;
- Digitize map units and prepare 2004 planmaps;
- Prepare 1999 planmaps for comparison with 2004 planmaps;
- Compare 1999 planmaps to 2004 planmaps.

3.2.1.1 Updated Mapping Terminology

The 1999 planmaps were inventoried to develop a list of mapping features. From this list, we developed consistent terminology, determined the relative feature scale and mapping resolution, and then identified mapping boundaries based on the 1999 mapping limits. The updated terminology was based on a combination of the 1999 mapping and on Blue and White Book guidelines. To do this, we grouped all 1999 map units by their major geomorphic or habitat feature types, reduced the units into a common set of terms, and linked them to the 2004 terminology.

Based on a combination of 1999 mapping and Blue and White book guidelines, we delineated three primary mapping groups: Geomorphology, Aquatic Habitat, and Other (Table 12). Features mapped under the geomorphology group use Unit and Qualifier symbols (described below). Aquatic habitat features use a combination of CDFG Level III and IV criteria (CDFG 1998), and therefore use Unit symbols only. Features mapped under the Other group also use the Unit symbols only. A complete listing of all mapping symbols (unit and qualifier) and their definitions are presented in Appendix E, Tables D-1 and D-2.

Geomorphic units are defined based on their surface expression (dominant morphologic origin) and relation to contemporary flows. Each unit was classified using a modified version of the Genesis-Lithology-Qualifier (GLQ) system developed by Keaton (1980). Originally developed for engineering geology, the GLQ system was modified for this application by replacing Genesis and Lithology with the Unit type. The modified system adopts the GLQ symbols, but modifies the primary categories to make this system amendable to the Mono Basin tributaries. Using this system, a unit is identified and assigned a primary symbol denoting its type, followed by one or more qualifier symbols denoting sediment texture and vegetative characteristics. Features are mapped using the following general symbols:

Table 12. Summary of map units in each mapping group. A more comprehensive list of these units and their definitions is provided in Appendix E, Tables E-1 and E-2.

Primary Mapping Group	***Category (Map Units)***
Geomorphology	▪ Bar (point bar, medial bar) ▪ Floodplain (mature floodplain, developing floodplain) ▪ Terrace (low, middle, and high terraces), Bank features (eroding bank) ▪ Hillslope features (hillslope, arroyo, fan) ▪ Channel features (secondary channels, thalweg, headcut)
Aquatic habitat	▪ Pool (constructed pool, scour pool, main channel pool, step pool, pool tail) ▪ Riffle (low and high gradient riffles) ▪ Flatwater (glide, pocket water, run, step run) ▪ Cascade ▪ Backwater (alcove)
Other	▪ Wood (large woody debris) ▪ Debris (debris jam) ▪ Off-channel water (seepage, pond water, standing water) ▪ Channel features (wetted and bankfull channel, thalweg, undercut bank, cutoff channel, boulder weir)

A(b,c)

where A = unit planmap symbol, b = sediment texture qualifier, and c = vegetation qualifier. Additional qualifiers may be identified and listed. Collectively these characteristics describe the geomorphic setting , sediment texture and vegetation type of each unit, and were developed to facilitate comparison between mapping events. Sediment texture qualifiers define the dominant particle size of the mapped feature, using one of the three classes: sand (< 2mm), gravel and cobble (2 – 256mm), or boulder (> 256 mm). Vegetation qualifiers document the dominant vegetation and are classified as one of five types: aquatic, aquatic-emergent, desert or riparian herbaceous, desert or riparian shrub, or desert or riparian tree.

3.2.1.2 2004 field mapping and digitizing

Field mapping was done on 1" = 30' scale basemaps developed from the 2003 aerial photographs, and laminated as 11x17 inch maps for use in the field. The 2004 mapping boundaries were based largely on the 1999 boundaries to ensure overlap for comparison. Some of the 2004 coverage does not overlap with the 1999 mapping, but these areas are limited to locations where no geomorphic change was expected (e.g., high terraces and hillslopes). At present, planmapping at all Rush Creek reaches is complete; mapping Upper and Lower Lee Vining Creek, Parker Creek, and Walker Creek is scheduled for May 2005.

Following the Rush Creek field mapping, mapped units were digitized using AutoCAD. Digitizing and data entry for the Rush Creek sites are complete. The next step was to build topology for each site, where individual polygons were linked to their respective attributes to allow analysis and comparisons to proceed. Presently this step has been done only for the Rush Creek County Road site.

3.2.1.3 1999 planmap preparation and comparison with 2004 mapping

The 1999 planmapping was completed without aerial photographs and were not geo-referenced. To facilitate comparisons with the 2004 maps, the 1999 planmaps were recently converted to real coordinates by geo-referencing control points and monuments common to both planmap sets (e.g., benchmarks, cross section headpins). The resulting correction brought the 1999 mapping into the 2004 mapping coordinates, thereby allowing direct overlay. This work has been completed for all 1999 planmaps. When the 2004 mapping is complete, comparisons between 1999 and 2004 unit locations, positions, and sizes will be made electronically on a feature-specific basis Queries will be made by unit type, qualifier(s), etc. and planmaps will be overlaid to highlight changes.

3.2.2 Results and Discussion

Digitized maps of all Rush Creek planmap reaches are presented in Appendix E, Plates 1 – 4. Polygons were labeled by unit abbreviation only; qualifiers and polygon unit identifier numbers are not shown on the plates, but are linked in the GIS database. A comparison between 1999 and 2004 planmaps will be made after the remaining planmap reaches are mapped and topologies for all reaches built. However, as an interim step, we compared the floodplain units at the Rush Creek County Road site. The following discussion summarizes the results of this comparison; a more detailed evaluation will be made after the remaining planmapping is finished and all sites compared.

By isolating floodplain areas at the County Road reach, we compared the differences in floodplain planform location and morphology (Plates 5 and 6). Plate 5 presents the 1999 planmapping with updated terminology and map symbols, and Plate 6 presents the 2004 planmapping. For simplicity, we grouped all floodplain types into a single class. Both plates present the floodplain areas as highlighted polygons. Our comparison was made from a visual inspection of these maps; based on the comparison, differences in floodplain locations and morphologies appear significant, which we attribute to at least three possible causes (or a combination of these):

- Geomorphic evolution: Two large floodplain areas mapped in 1999 were mapped as low terraces in 2004. A terrace is an abandoned floodplain; within the past five years these floodplain areas may have been partially abandoned.
- Difference in terminology: although the 1999 planmapping terminology was updated to fit the 2004 mapping system, the 1999 mapping did not assign a geomorphic unit type to all identified features. For example, some polygons were drawn around geomorphic features, but the features were only identified by their texture (e.g., "gravel", or "cobble"). Most of these features were located adjacent to the water's edge and were therefore considered floodplain areas, but the textural descriptions are insufficient to determine if this inference is true. Therefore, we identified these areas as "possible floodplains" and are shown on Plate 5 as hatched polygons, as opposed to solid polygons used for the mapped floodplain areas.
- Interpretation difference between mappers. This is unavoidable with any mapping exercise,

but should be reduced with our improved mapping system and terminology. Although this issue will be a factor when comparing any 1999 map with a 2004 map, the error from this should be reduced for all future planmapping (i.e., when comparing 2004 mapping with subsequent mapping using the same planmap protocol).

3.2.3 Next Steps

Mapping the remaining reaches (Upper and Lower Lee Vining Creek, Parker Creek, and Walker Creek) is scheduled for May 2005. Following all mapping and analysis, we will assess whether the data collected and the level of information provided by the analyses satisfy the planmapping objectives, and/or whether alternative measures exist that are more cost-effective.

3.3 Floodplain Aggradation and Channel Reconfinement Processes

The Mono Basin Stream and Stream Channel Restoration Plan (LADWP 1996), as well as Larson (1994), identified locations of abandoned stream channels on Rush Creek that may be representative of channel morphology prior to diversions. These channels were confined by high floodplains, and willow and cottonwood stumps were buried in several depositional strata, often with several adventitious root series', indicating dynamic depositional processes. Contemporary conceptual models of alluvial rivers suggest flood recurrences exceeding 1.5-yrs are required to inundate floodplains (Leopold et al. 1964). However, initial computations in the RY 1999 Annual Report (McBain and Trush 2000) suggested flows exceeding the unregulated 60-yr flood were required to overtop banks in some historic channels observed on lower Rush Creek. The RY 1999 Annual Report (1) proposed conceptual models describing floodplain processes that lead to confinement and (2) provided preliminary computations to illustrate the flow regime that may have created the floodplain deposition observed in historic channels. The RY 1999 report hypothesized a minimum water depth of 0.5 ft was needed to deposit sediment on a floodplain surface (although there is no distinction between bedload and suspended sediment deposition for this depth criteria). Because of the importance of channel confinement to stream recovery, our evaluation focuses on evaluating the role of SRFs in promoting floodplain deposition.

Confinement is fundamentally related to flood magnitude. Confinement is created when floods of sufficient magnitude deposit fine sediment onto inundated floodplains and terraces. Flood events causing measurable deposition occur infrequently. Sediment thus accumulates intermittently in response to the historical sequence of flood events (Figure 25). The maximum height of floodplain deposition requires the highest flood magnitudes, and therefore floodplain maturation can require a very long period of time. If the flood regime is modified, then floodplain depositional processes and evolution likewise change.

The high flow regime has been significantly reduced on Rush and Lee Vining creeks (see Table 5 in McBain and Trush 2004), which may prevent floodplain confinement from achieving pre-1941 conditions. Our analyses must address the following questions:

- What is the role of flood duration on floodplain aggradation rates?
- What is the role of flood frequency on floodplain aggradation rates?
- What is the importance of bedload transport of fine sediment (lateral point bar accretion) versus suspended sediment transport (overbank vertical accretion) on floodplain formation?
- Can we quantify rates of floodplain aggradation as a function of flood magnitude? What are historic vs. contemporary aggradational rates?
- To restore healthy channel confinement conditions, is the highest depositional strata of a floodplain necessary?

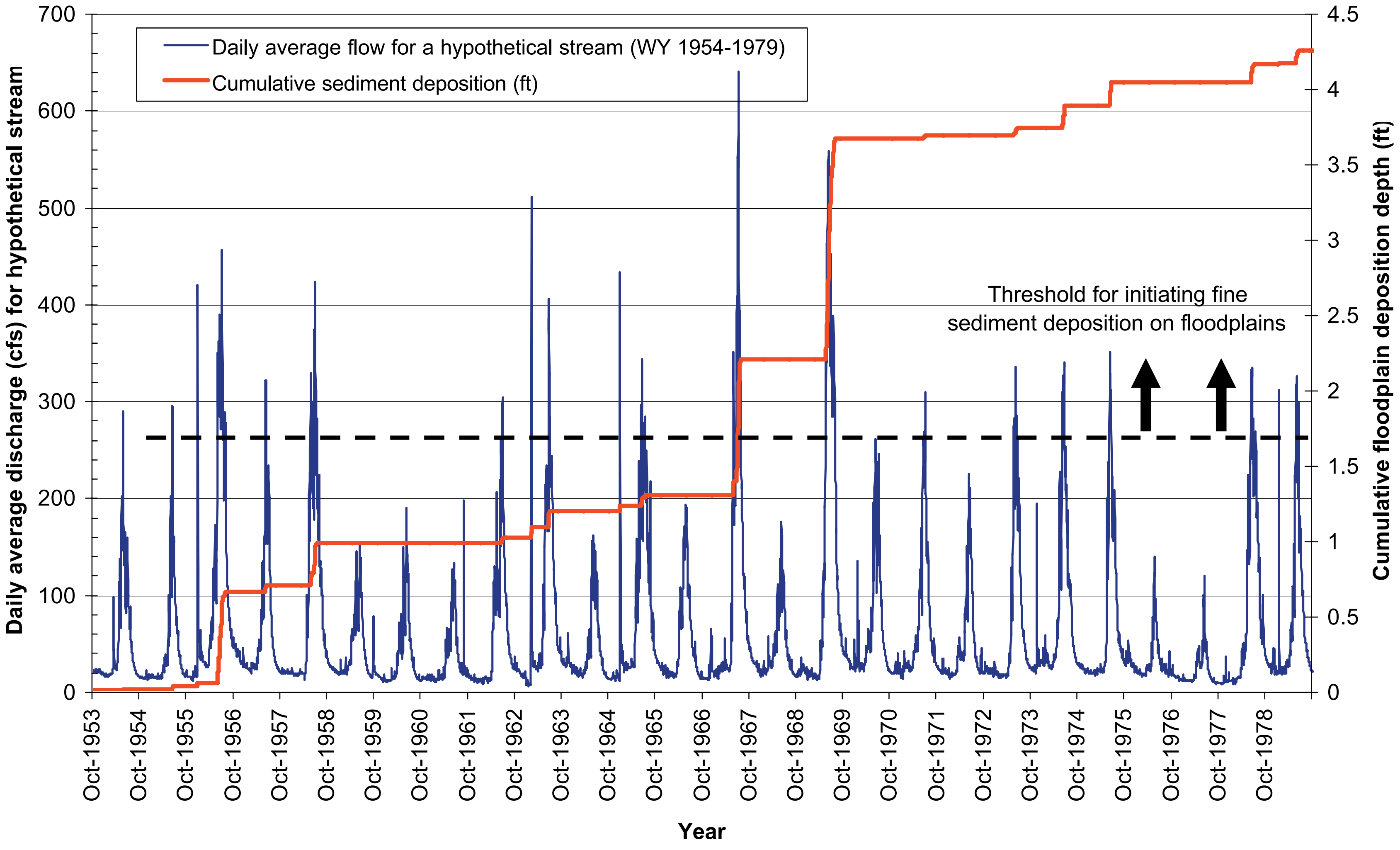

Figure 25. Conceptual relationship between sequences of high flow years and floodplain confinement evolution.

In 2004, we expanded the original conceptual models developed in 1996 and 1999 to address these questions. Our goal is to develop simple predictive tools to evaluate floodplain aggradation and channel confinement evolution that result from different magnitude, duration, and frequency of flood events. Our RY 2004 field evaluations on Rush Creek were intended to provide a foundation for expanding our conceptual understanding of floodplain aggradation processes, help refine subsequent years' field experimentation, and narrow the scope of our analyses. Recent bedload sampling and particle size analysis by Streamwise (2004) will also provide useful sediment transport information related to floodplain aggradation.

3.3.1 Revised Conceptual Model for Floodplain Deposition

There has been substantial work developing sediment transport formulae and routing models for sand bedded and gravel bedded rivers, but the literature is virtually devoid of predictive models for fine sediment deposition on floodplains. The height of fine sediment deposition on a given floodplain (FP) with time (t) is a function of the following variables:

$FP(t)=f(Q_{max}, Q_{dur}, Q_{freq}, Q_{BLsand}, Q_{SS}$, hydraulic roughness, geomorphic unit), where:

Q_{max} = magnitude of the largest flood(s) for a given flow regime,

Q_{dur} = duration of high flows for a given flow regime,

Q_{BLsand} = fine bedload transport rates as a function of flow in the main channel and on potential deposition surfaces,

Q_{SS} = suspended sediment concentrations as a function of flow in the main channel and on potential deposition surfaces,

Hydraulic roughness greatly influences the rate of floodplain deposition, by inducing bedload and/or suspended sediment deposition on that surface,

Geomorphic unit, such as the inside of a meander bend versus the outside of a meander bend, also influences rate of sediment deposition.

The maximum elevation a floodplain can attain is limited by the maximum heights of floods that occur over time (Figures 25 and 26). Our initial conceptual model (McBain and Trush 2000) assumed most fine sediment that deposited onto floodplains resulted from deposition of suspended fine sediment. However, recent observations on the Trinity River and our field investigations on Rush Creek in 2004 suggest floodplain accretion results from a combination of fine bedload (coarse sand) and coarse suspended load (fine sand) (Figure 27A). Incipient floodplains are largely driven by lateral accretion of bedload on the inside of meander bends. Deposition can occur rapidly. As floodplains mature and their elevation increases, depositional processes gradually shift to suspended sediment deposition (Figure 27B). We visualize fine bedload (sand) being deposited on incipient floodplains by short-duration turbulent bursts and sweeps that momentarily suspend bedload particles and shunt them toward the channel margins. These turbulent bursts disperse in vegetative roughness (Figure 28), allowing particles to settle onto the floodplain surface.

In addition to flood magnitude, duration, and frequency, sediment supply is also critically important to floodplain formation (Figure 29). Sediment supply varies longitudinally along Rush Creek. Immediately below Grant Lake, sediment supply is low as a result of sediment being trapped in Grant Lake. Farther downstream, sediment supply increases as valley confinement falls away. The channel erodes banks, migrating into terraces and the glacial outwash fan. Parker and Walker creeks also contribute their sediment supply. This longitudinal variability in sediment supply causes variable fine sediment transport rates (Figure 29A) which then influence rates of floodplain

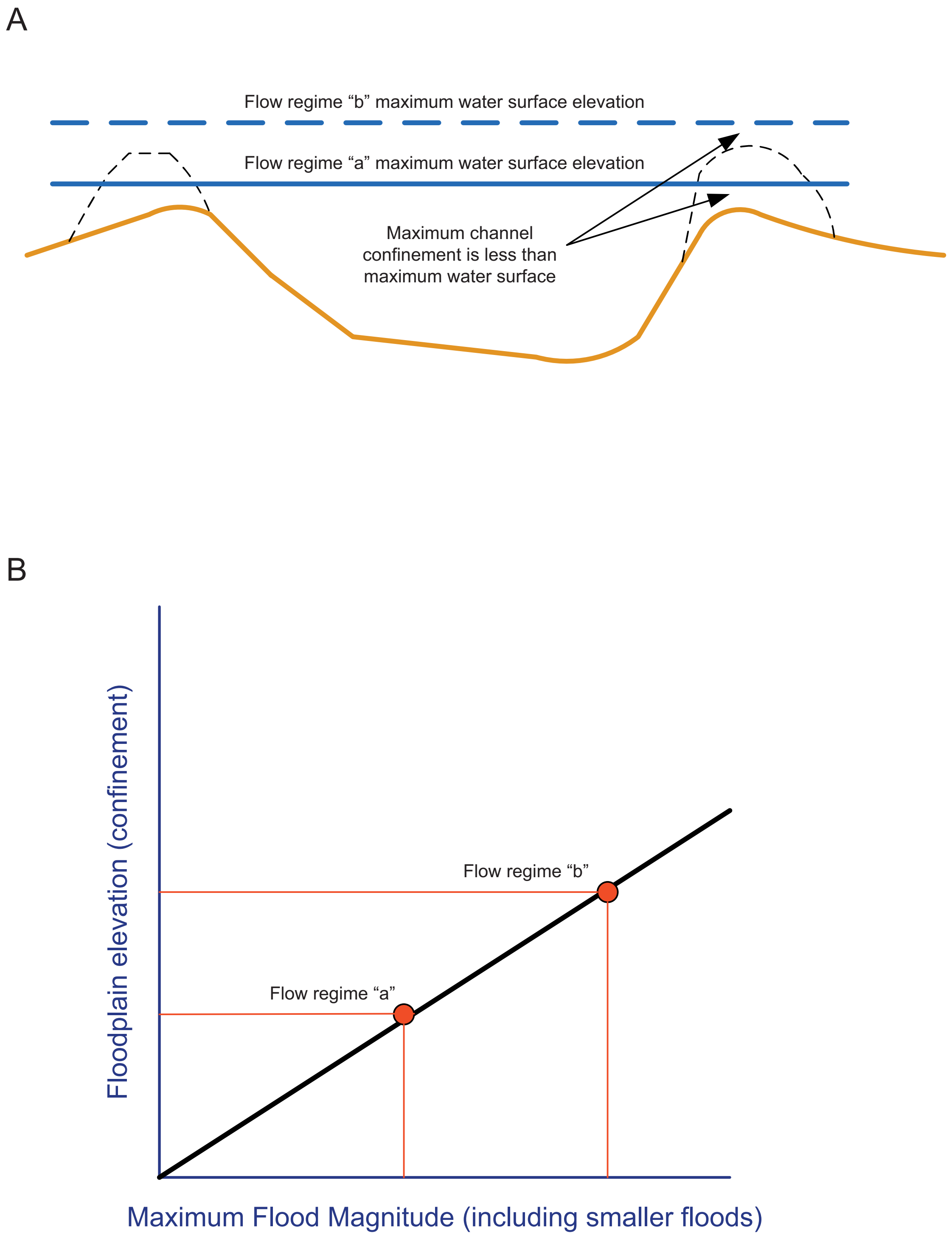

Figure 26. Conceptual relationship between channel confinement and high flow regime. Sediment deposition at a particular location occurs when water depth exceeds the elevation of that location (A), such that cumulative sediment deposition and channel confinement are a function of the maximum height of the high flow regime (B).

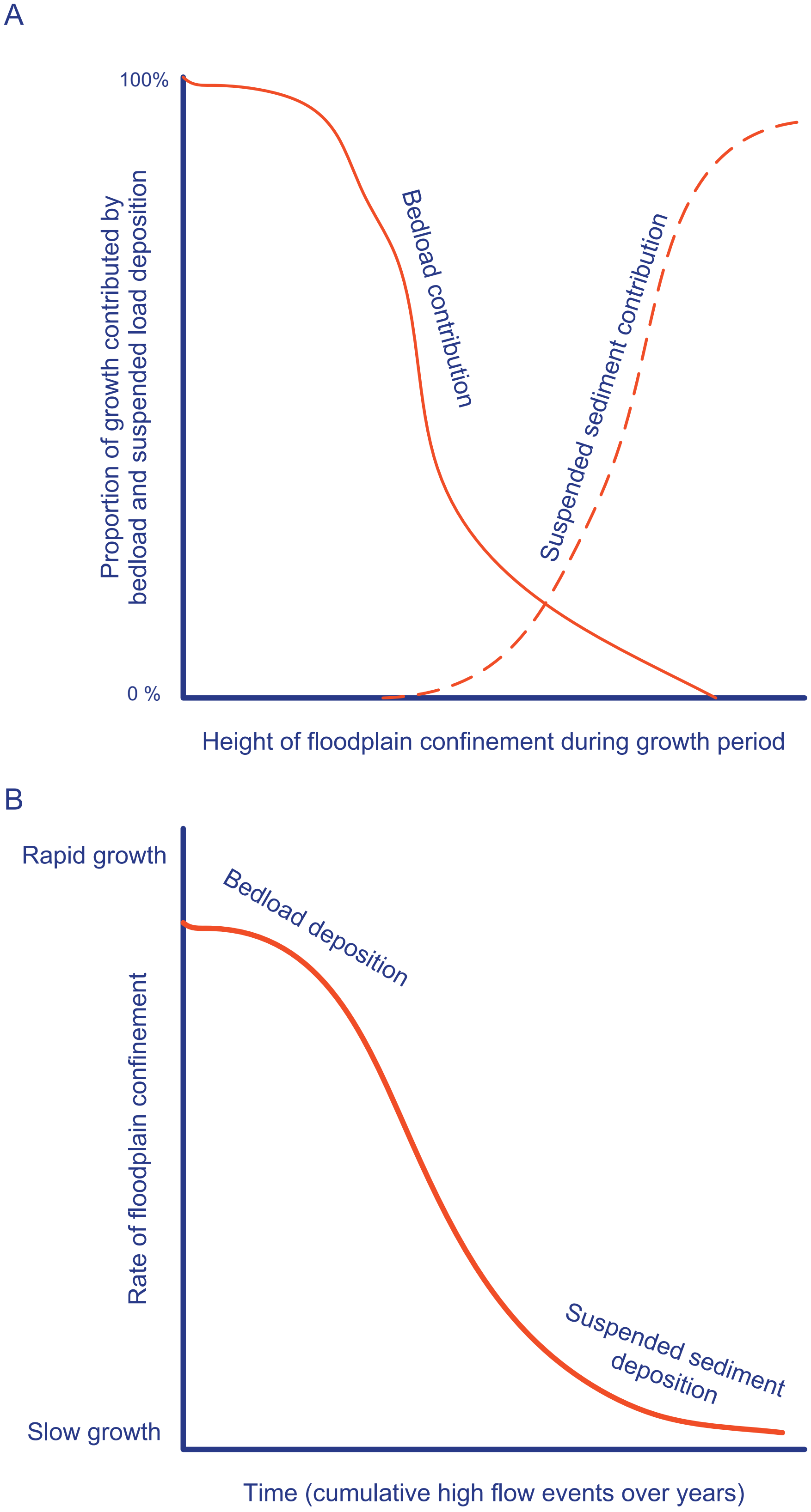

Figure 27. Conceptual relationship between channel confinement and fine sediment regime. Sediment deposition early in the floodplain confinement process is primarily due to sand bedload deposition (A). As floodplain height increases, confinement results from less frequent, larger floods that deposit suspended sediment (B).

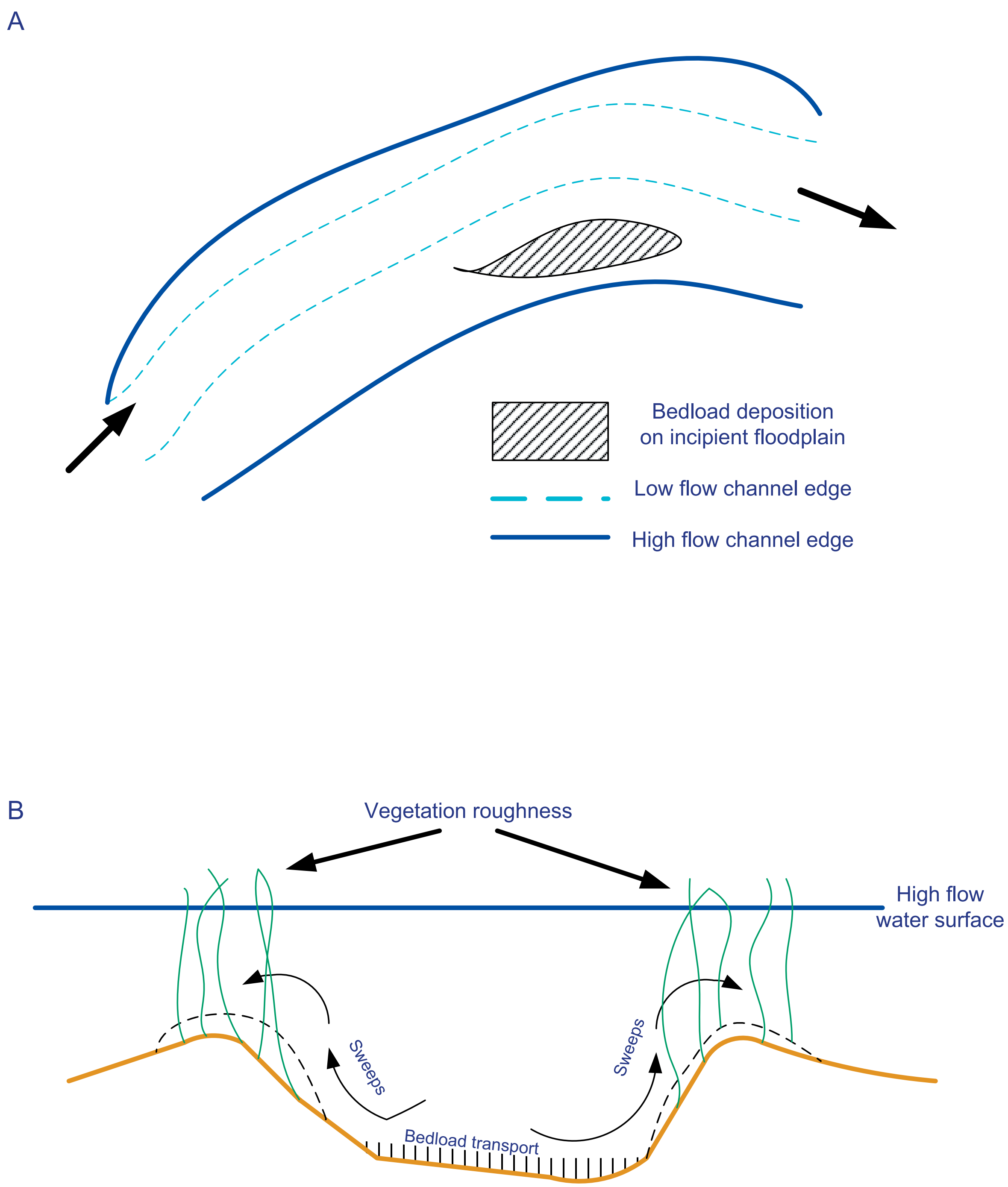

Figure 28. Conceptual depositional processes on incipient floodplains: (A) typical fine sediment deposition on the inside of migrating meander bends, and (B) turbulent bursts and sweeps suspending bedload and laterally transporting to channel margins for subsequent deposition.

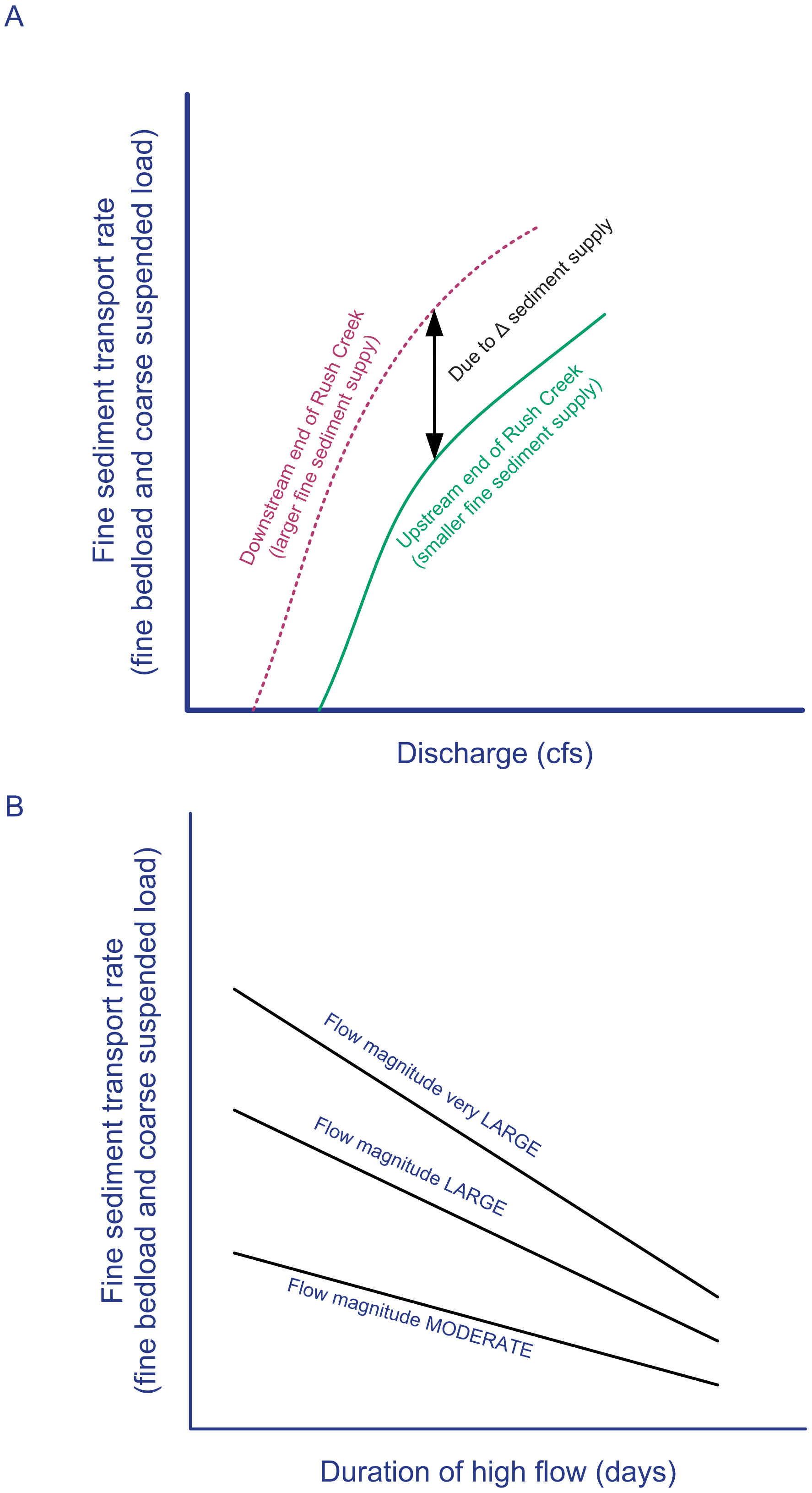

Figure 29. Conceptual relationship between: (A) fine sediment transport rate as a function of supply, where supply is low in upper Rush Creek and higher in lower Rush Creek, and (B) fine sediment transport rate as a function of discharge magnitude and duration, where sediment transport rate decreases with duration of flow.

deposition. Additionally, if the magnitude of a single flood event is held constant and sediment supply is relatively constant, sediment transport and floodplain deposition rates will be higher during early stages of the hydrograph, then decline with the duration of flow (Figure 29B). This temporal variability is common in unregulated streams, but is more pronounced in regulated streams where sediment supply is limited. Therefore, benefits of peak flow magnitude may quickly diminish over the duration of the flood.

Lastly, the roughness of the floodplain surface has a substantial effect on fine sediment deposition (Figure 30) and influences lateral accretion of bedload and vertical accretion of suspended sediment. For example, a smooth cobble bed surface (e.g., 3D construction project) will have lower rates of deposition for a given flood magnitude than a similar substrate surface that is vegetated. Vegetative roughness induces deposition by lowering flow velocities (Figure 30A). An increase in roughness will not only induce more sediment to deposit, but will induce larger grain sizes to deposit (Figure 30B).

3.3.2 Review of Available Predictive Models

Our literature review uncovered just a single process-based predictive model that attempts to quantify rates of floodplain aggradation. Recent work by Dr. Yantao Cui and Dr. Gary Parker on the Ok-Tedi and Fly rivers in Papua New Guinea (Cui and Parker, 1999) is at the forefront of predictive science on floodplain aggradation. Their model takes a mass conservation approach (tracking sediment continuity and particle size distribution), and combines deposition from bed material load and washload to predict floodplain deposition rates. Whereas the Ok-Tedi and Fly rivers are much larger than Rush and Lee Vining creeks, the physical processes are similar. Both are gravel bedded rivers, both have floodplain sediment deposition resulting from bedload and suspended load, and both have downstream controls (Mono Lake for Rush and Lee Vining creeks, confluence of the Strickland River on the Ok-Tedi River). The Cui-Parker model predicts floodplain deposition based on a simple 1-D hydraulic model, a coupled bedload and suspended sediment transport model, and the following input data:

- a long-term hydrologic record,
- sediment volume and grain size supplied to the reach,
- rock abrasion rates,
- simple channel geometry,
- grain size in the channel,
- spatially explicit hydraulic resistance (Manning's roughness on floodplain).

The model is used to predict floodplain sediment deposition rates and depths, and could be applied to predict floodplain evolution on Rush and Lee Vining creeks.

3.3.3 2004 Rush Creek Floodplain Deposition Studies

The purpose of the 2004 Floodplain deposition field studies was to begin evaluating the conceptual models described above by observing depositional processes on lower Rush Creek. Two study sites were selected in May 2004: (1) a low-elevation reconstructed floodplain at the 3D site, and (2) two naturally developing floodplains at the Lower Rush Creek study site (Figure 31). The 3D site was selected to observe fine sediment deposition on a freshly constructed, unvegetated, low elevation floodplain. We expected more substantial deposition would occur at this site than at the Lower Rush Creek site because of its lower elevation and potential to function as a side eddy during high flows. A cross section was installed across the floodplain (XS 239+00), a water stage recorder and staff plate were installed, and fine sediment traps were arrayed along the cross section (Figure 32). The lower Rush Creek site was chosen because several natural floodplains are developing with varying stages of

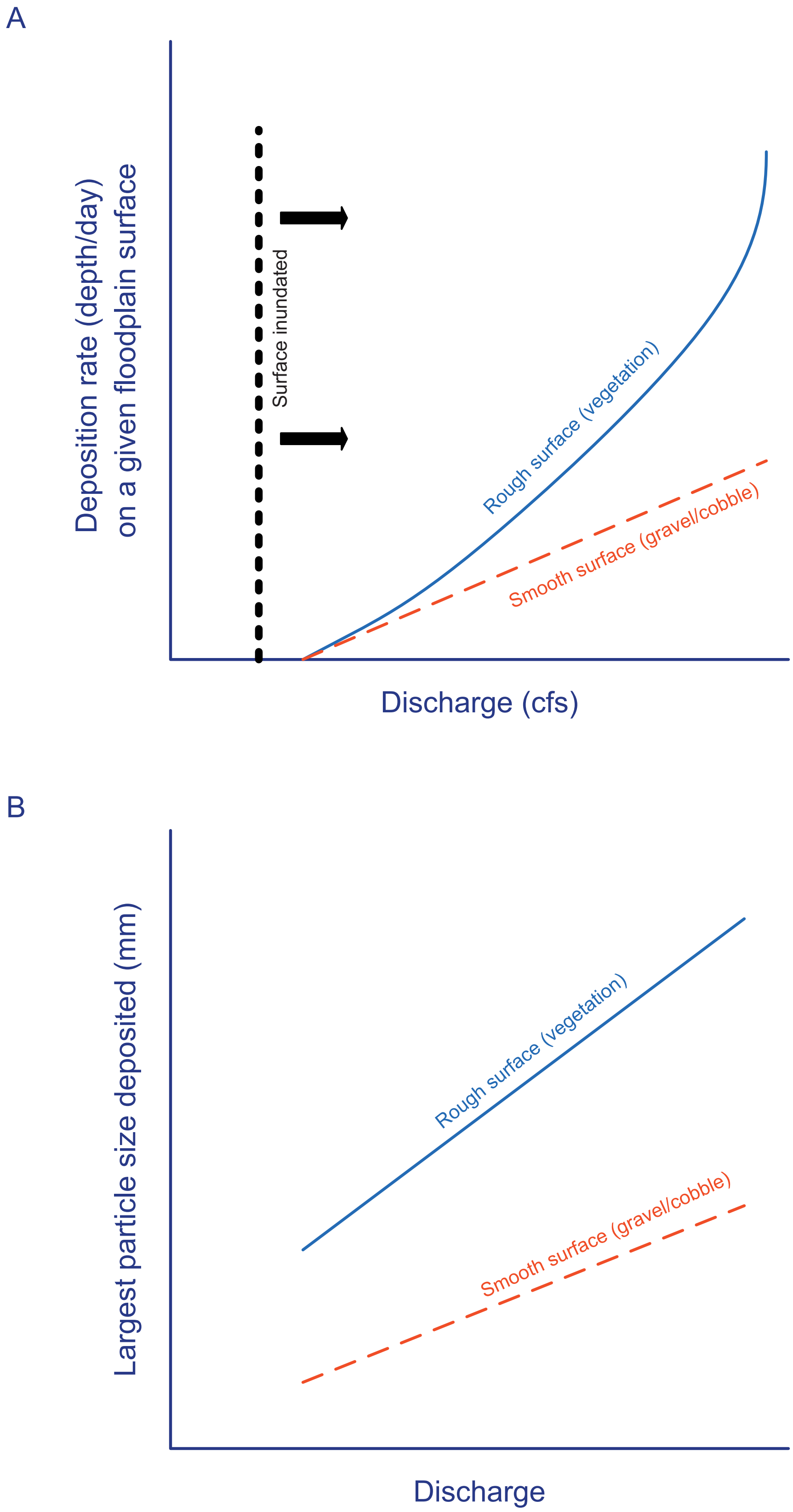

Figure 30. Conceptual relationship between: (A) floodplain deposition rates as a function of floodplain roughness, and (B) minimum particle size deposited on a given floodplain surface as a function of floodplain roughness.

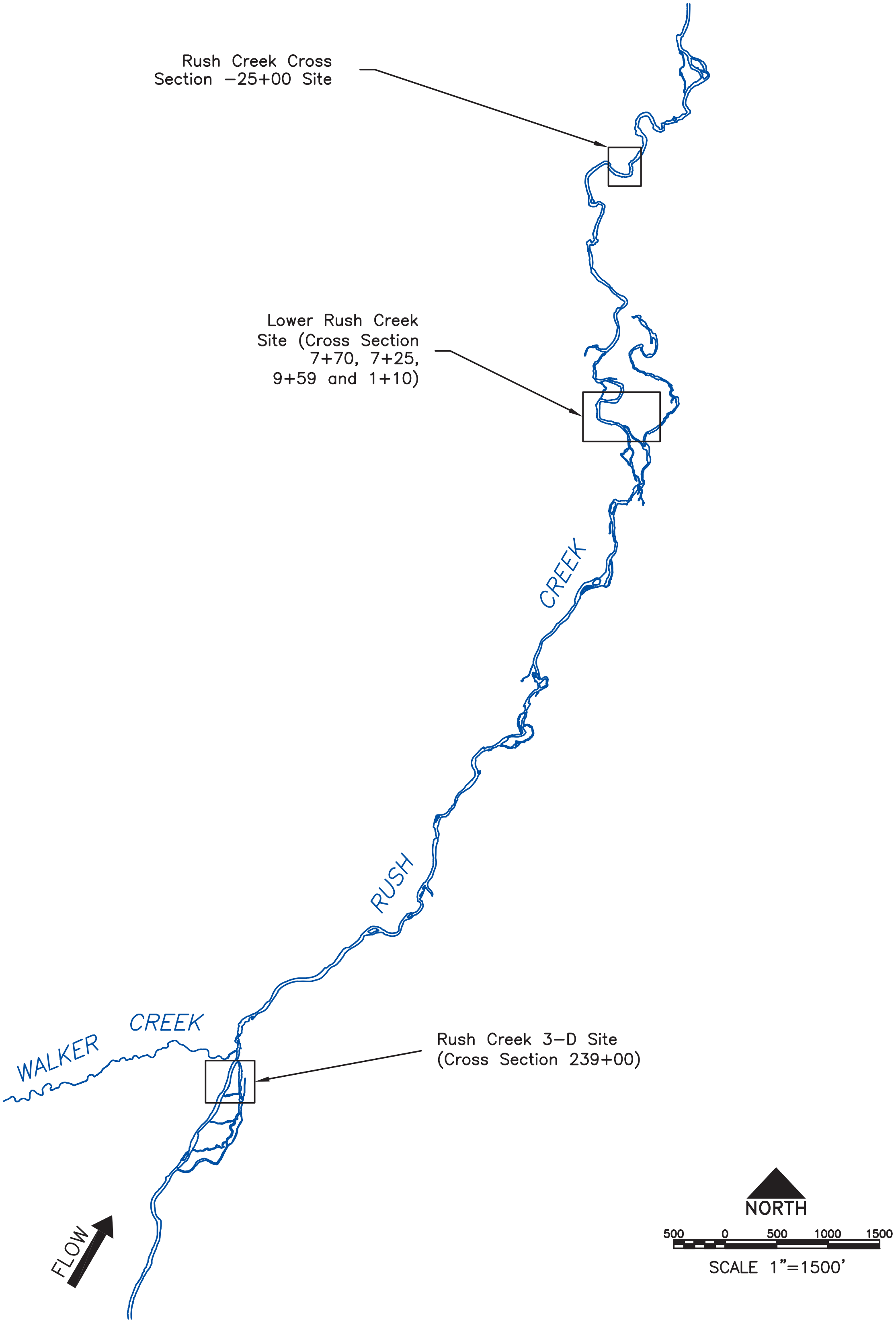

Figure 31. The 2004 floodplain deposition monitoring sites on lower Rush Creek.

vegetative roughness. Several cross sections were installed or re-occupied (XS 7+25, 7+70, 9+59), a water stage recorder and staff plate were installed, and fine sediment traps were arrayed along several cross sections (Figure 33). We expected both sites to be inundated by the June 2004 SRF releases. However, as the flood peak approached in early June, it became apparent that XS's 7+25 and 7+70 at lower Rush Creek site would not be inundated. We therefore installed two additional cross sections (XS 1+10 on the 10 Channel, and XS -25+00 on the mainstem of Rush Creek) in Lower Rush Creek where floodplain inundation and fine sediment deposition data were collected (Figure 31). Experiments conducted during the June 2004 SRF releases are summarized in Table 13.

3.3.4 Preliminary Results and Discussion

Sediment transport and floodplain deposition data collected during the June 2004 SRF releases at the 3D site and in Lower Rush Creek should be considered site-specific, and not extrapolated beyond these sites for the following reasons: (1) there are differences in sediment supply, transport rates, and physical conditions influencing the extent and duration of inundation, (2) low-elevation floodplain sites were selected to increase the probability they would inundate during the June 2004 SRF releases; they were not selected to represent the range of floodplain surfaces found along Rush Creek, and (3) the data are from only one peak flood event, following five years of low-magnitude SRF releases.

The June 2004 SRF releases and corresponding floodplain aggradation monitoring helped expand our conceptual understanding of floodplain aggradation processes, refine the next phase of field experimentation, and focus our analyses on discrete quantitative tasks. Below we summarize: (1) trends observed in fine sediment deposition on low floodplains resulting from the June 2004 SRF releases, and (2) monitoring and/or modeling tasks to be conducted during the next phase of monitoring.

Observations from the June 2004 SRF releases:

- There was an apparent longitudinal increase in fine sediment transport in the downstream direction, although this trend was not clear in the Streamwise 2004 bedload transport data. Photographs at the 3D constructed floodplain monitoring site (Figure 34) and the Lower Rush Creek floodplain monitoring site XS 1+10 (Figure 35) the day after the peak release show a visible difference in turbidity, and fine sediment deposition was much more apparent at the downstream site. As shown in Figure 29, greater sediment supply with increasing distance downstream of Grant Lake should result in higher rates of bedload and suspended sediment transport, which should increase fine sediment deposition on floodplains. We did not attempt corridor-wide sediment transport measurements to quantify the longitudinal difference in transport rates; only synoptic suspended sediment samples were collected at the 3D and Lower Rush Creek sites.
- The peak SRF release magnitude of 384 cfs (above the Narrows) appears to be a minimum threshold for significant fine sediment deposition on incipient floodplains.
- Fine sediment deposition was greatest on the floodplain edge immediately adjacent to the channel margin. Maximum deposition was typically limited to a few inches along the channel margin, quickly dissipating to zero within ten feet of the channel margin. Maximum deposition depth and maximum particle size of deposited material both correlated with the channel margin where velocity gradient (rapid decrease in velocity) was greatest. Sediment deposited onto the passive sediment trap (carpet) on the left bank natural floodplain on XS 9+59 ranged from zero to 0.33 ft deep (Figure 36), and corresponding local D_{95} of deposited sediment and velocities during the peak flow are shown on Figures 37 and 38. At cross section 239+00, results were similar, except that gravels were also deposited along the channel margin. Deposition ranged from zero to 0.32 ft deep on the right bank constructed

Table 13. Summary of floodplain deposition tasks conducted during the spring 2004 release on lower Rush Creek.

DATE	MGORD RELEASE (cfs)	Discharge at Site (cfs)	SITE	Turbidity	Suspended Sediment	Bedload	Survey XS and carpet	Notes
May 2-8, 2004	**Low flow**	**Low flow**	Lower Rush XS 9+59				X	installed cross section; installed passive sediment trap (inverted carpets) on LB and RB; installed stage recorder; mapped sediment facies and estimated roughness values;
			Lower Rush XS 7+70				X	re-surveyed cross section; installed passive sediment trap (inverted carpets) and deposition nails; estimated roughness values
			Rush 3D XS 239+00				X	re-surveyed cross section; installed passive sediment trap (inverted carpets) and deposition nails; estimated roughness values
June 7, 2004	**300**	**213**	Lower Rush XS 9+59	X	X			
		213	Lower Rush XS 7+70					
		321	Rush 3D XS 239+00	X	X			
June 8, 2004	**325**	**228**	Lower Rush XS 9+59	X	X			
		364	Lower Rush XS -25+00				X	Installed cross section
		345	Rush 3D XS 239+00	X	X			
		136	10-Channel XS 1+10				X	installed 3 cross sections, WSEL's, slope;
June 9, 2004	**350**	**227**	Lower Rush XS 9+59	X	X			350 cfs release is “threshold” discharge for sediment depositoin at this location
		362	Lower Rush XS -25+00				X	installed cross section, WSEL's, slope;
		346	Rush 3D XS 239+00	X	X	X		
		135	10-Channel XS 1+10		X	X	WSEL's	
June 10, 2004	**250**	**187**	Lower Rush XS 9+59					[NOT SAMPLED]
		297	Lower Rush XS -25+00			X		Measurements at 350 cfs prior to flow dropping
		283	Rush 3D XS 239+00					[NOT SAMPLED]
		111	10-Channel XS 1+10			X		
June 11, 2004	**380**	**234**	Lower Rush XS 9+59	X	X			
		374	Lower Rush XS -25+00	X	X	X	WSEL's	WSEL's and Bedload in AM at 250 cfs prior to flow increasing; Measurements again in PM at 300 cfs;
		362	Rush 3D XS 239+00	X	X	X		Noticeable sand lens migrating across sediment traps in the first 10 ft along channel margin, with visible deposition on sediment traps. A secondary eddy-line was noticed 10 ft from margin where the faster water from the channel converged with slower moving water further inboard on the floodplain. Eddy line also observed at the channel/floodplain interface with lower flows.
		140	10-Channel XS 1+10		X	X		
June 12, 2004	**300**	**228**	Lower Rush XS 9+59					[NOT SAMPLED]
		364	Lower Rush XS -25+00	X	X	X	WSEL's	Downstream corner of XS -25+00 floodplain, where the main channel bends left, noticed substantial advection of sands within very turbulent water at the eddy interface of the main channel and floodplain.
		353	Rush 3D XS 239+00	X	X	X		All fine sand deposited from previous day’s flows (350-380 cfs) are replaced by large gravels and cobbles on the sediment traps at station 3.5. Only fines remaining on sediment traps start around station 10.0 where furrows in-filled.
		136	10-Channel XS 1+10		X	X	WSEL's	
July 7-10, 2004	**Low flow**	**Low flow**	Lower Rush XS 9+59				X	Sub-sampled LB sediment traps at 0.5’ intervals from the channel interface to station 145.0 and every 1.0’ from station 145.0 to 137.0. The RB sediment traps experienced little deposition of sediment, thus only one composite sample of fines was collected.
			Lower Rush XS -25+00				X	Cross section was resurveyed, and noticable sand deposition was noted (no carpets installed)
			Rush 3D XS 239+00				X	Cobbles to large gravels and sand were transported onto traps on channel margins, transitioning to gravels and sand out to 8 ft from channel margin. Significant in-filling of furrow noticed out to 14 ft from channel margin.
			10-Channel XS 1+10				X	

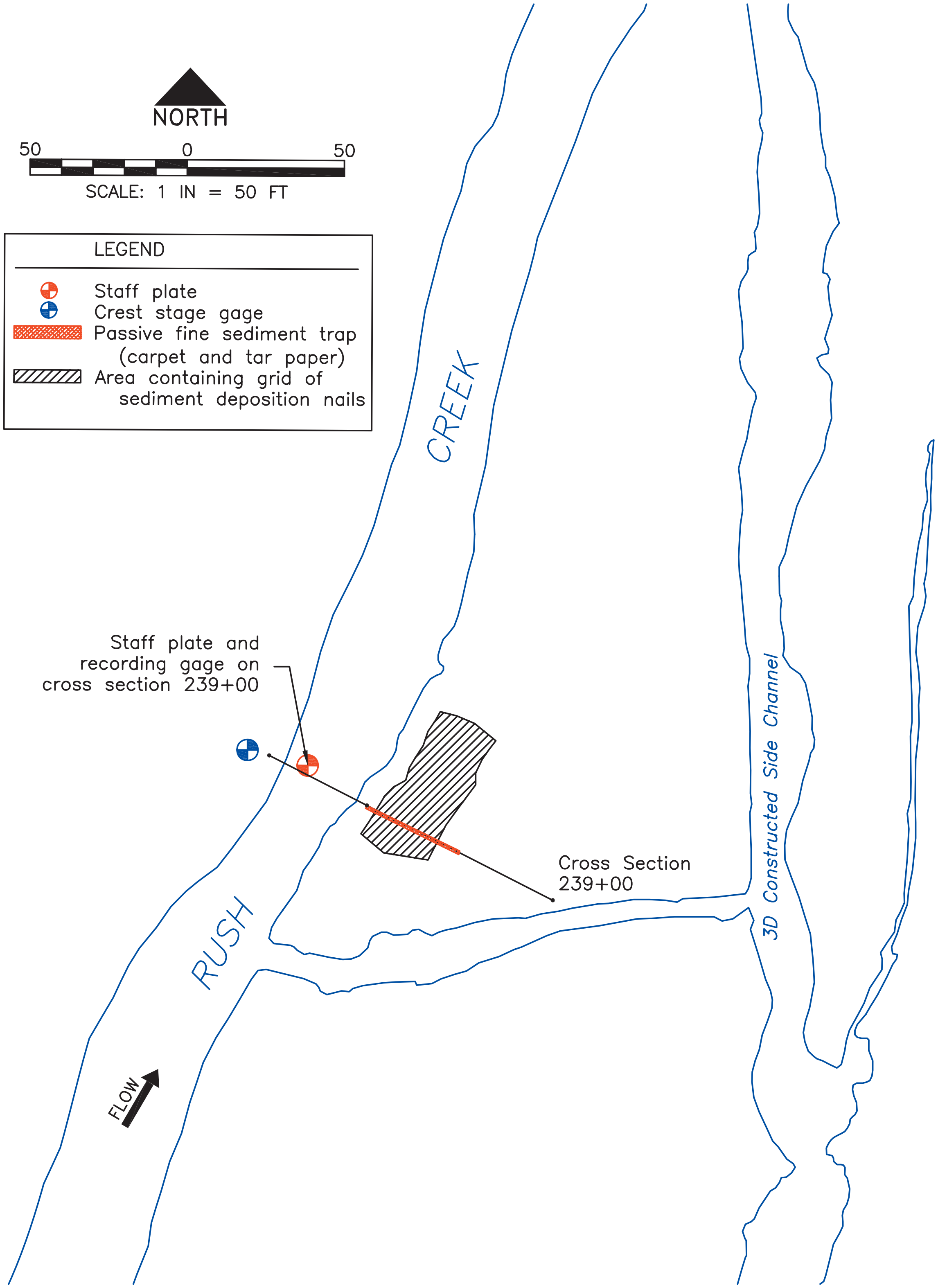

Figure 32. Floodplain deposition monitoring experiments at 3D constructed floodplain monitoring site.

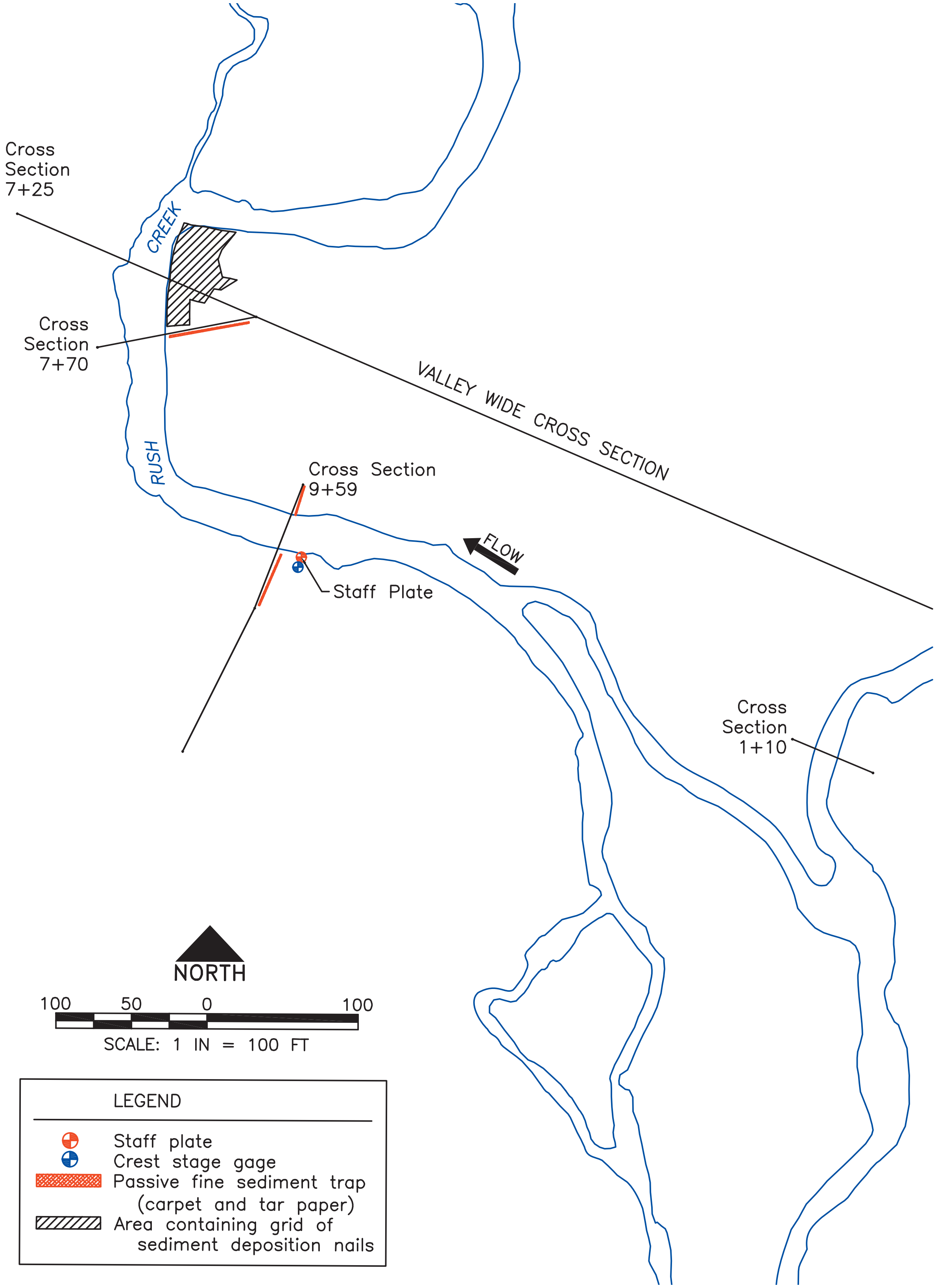

Figure 33. Floodplain deposition monitoring experiments at Lower Rush Creek natural floodplain monitoring site.

Figure 34. The 3-D constructed floodplain monitoring site on 6/11/04 (approximately 384 cfs) showing virtually clear water on passive fine sediment traps on floodplain.

floodplain (Figure 39) and corresponding local D_{95} of deposited sediment and velocities during the peak flow are shown on Figures 39 and 40. Sediment deposition traps were not placed on cross sections 1+10 and -25+00; therefore, only velocity data during the peak flow is available (Figures 41 and 42). However, the velocity field follows the same pattern (rapid reduction at channel margin) as the other cross sections.

- The duration of the June 2004 SRF releases was too short to evaluate the effect of peak flow duration on sediment transport or deposition rates.
- Field observations at numerous sites on Lower Rush Creek confirmed that the primary depositional process during incipient floodplain development is bedload deposition rather than suspended sediment deposition (Figure 35), which supports the conceptual model illustrated in Figure 27A.

Based on these preliminary observations, and anticipating that RY 2005 will be wetter than RY 2004 (resulting in a larger magnitude and or duration of SRF releases), we recommend the following experiments and monitoring tasks for the RY 2005 SRF releases:

- Bedload and suspended sediment samples in the mainstem Rush Creek should occur at three locations between the Mono Ditch and Mono Lake confluence. Recommended locations include the 3D reconstructed floodplain site, Lower Rush Creek (where Streamwise [2004] conducted bedload sampling), and the County Road site. The 3D site would represent a site with a small sediment supply (upstream of Walker Creek, but beginning to have sediment supply from eroding glacial outwash fan), while the County Road monitoring site would represent a site with a large sediment supply (downstream of Walker and Parker creeks, and substantial sediment supply from erosion of terraces and the glacial outwash fan). Additionally, the methodology should be expanded to have at least 3 passes at each sampled discharge to reduce within-sample variability. These results will help frame realistic expectations of deposition rates and time-scales of floodplain confinement as a result of local sediment supply.

Figure 35. The natural floodplain on XS 1+10 at the Rush Creek 10-Channel monitoring site on 6/11/04 (approximately 384 cfs), showing higher suspended sediment concentrations, sand bedload transport on floodplain, and deposition on vegetated floodplain.

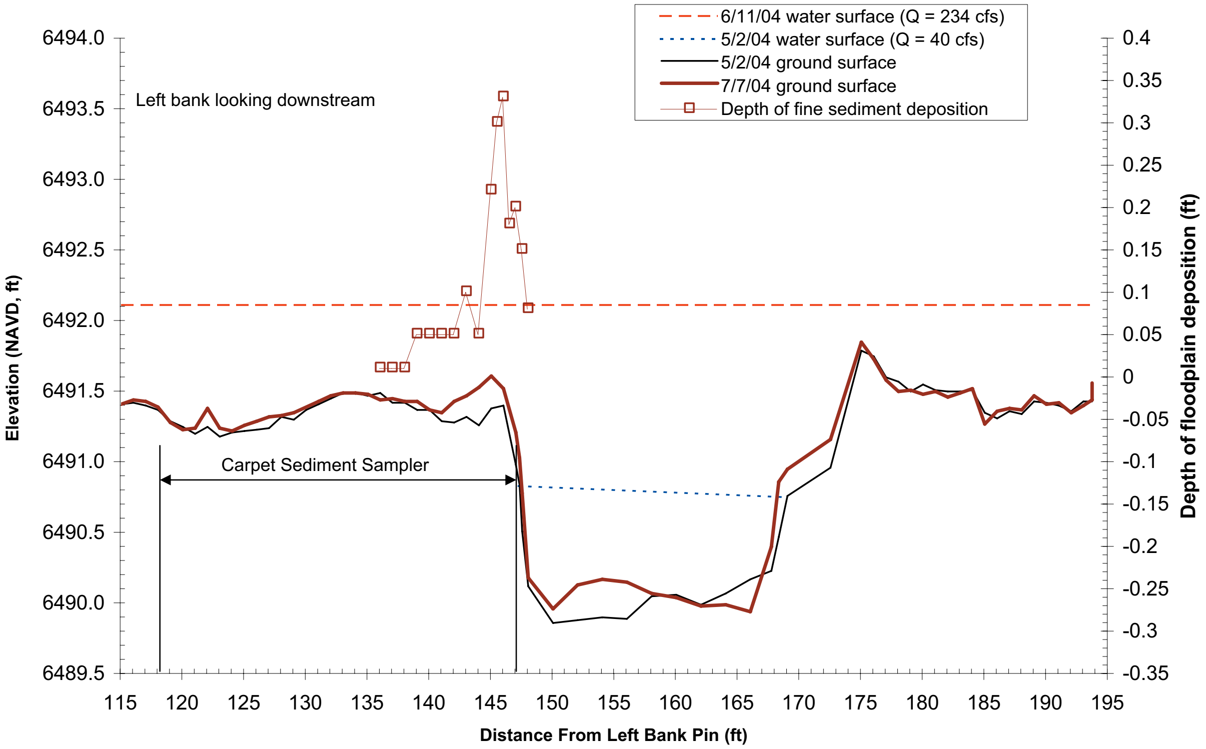

Figure 36. Sediment deposition patterns on the natural left bank floodplain on lower Rush Creek cross section 9+59.

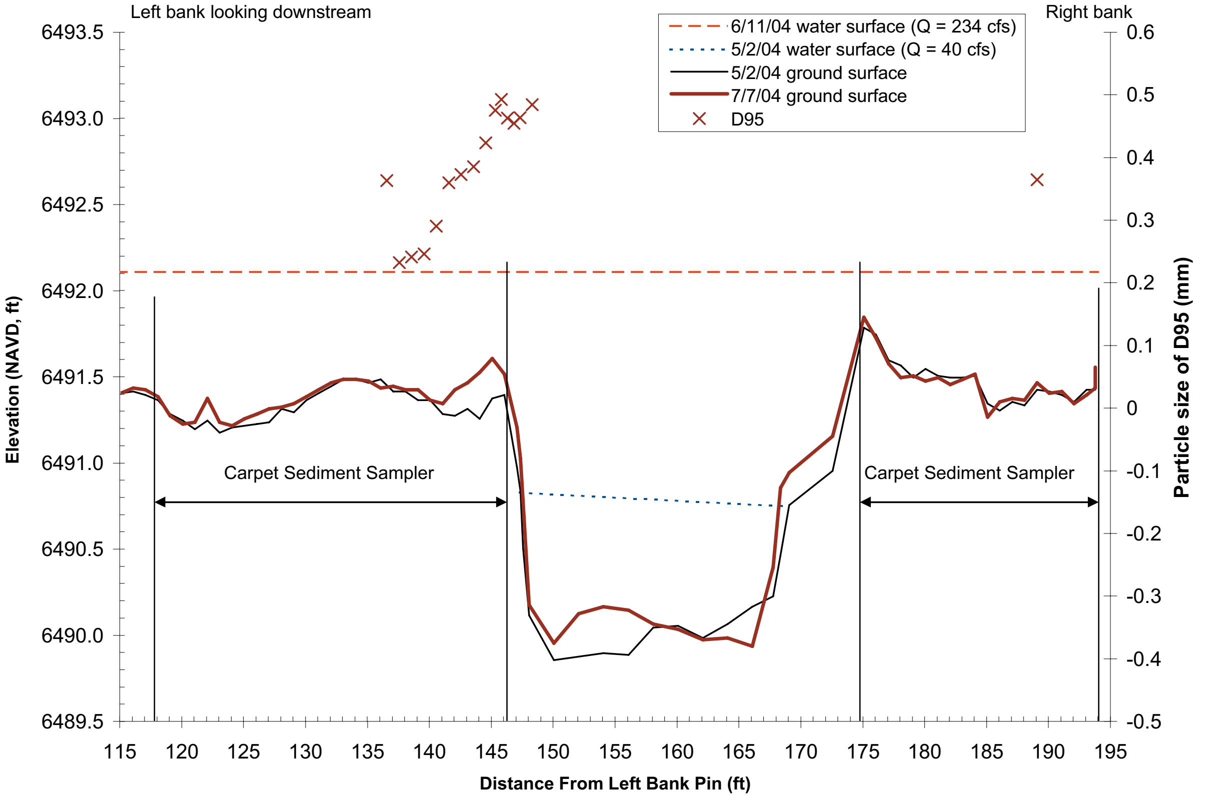

Figure 37. Near-maximum particle size (D_{95}) deposited on the natural left bank floodplain on lower Rush Creek cross section 9+59 during 6/11/04 peak flow.

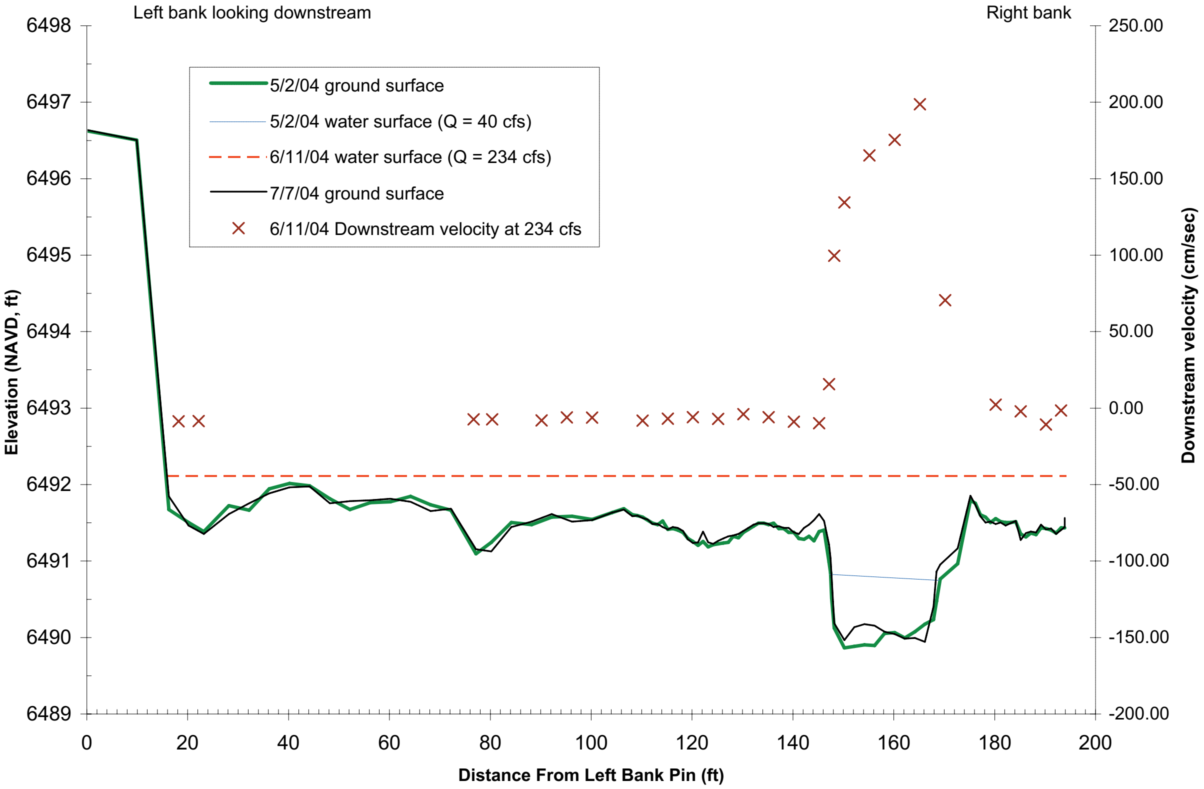

Figure 38. Floodplain velocity patterns on the natural left bank floodplain on lower Rush Creek cross section 9+59 during 6/11/04 peak flow

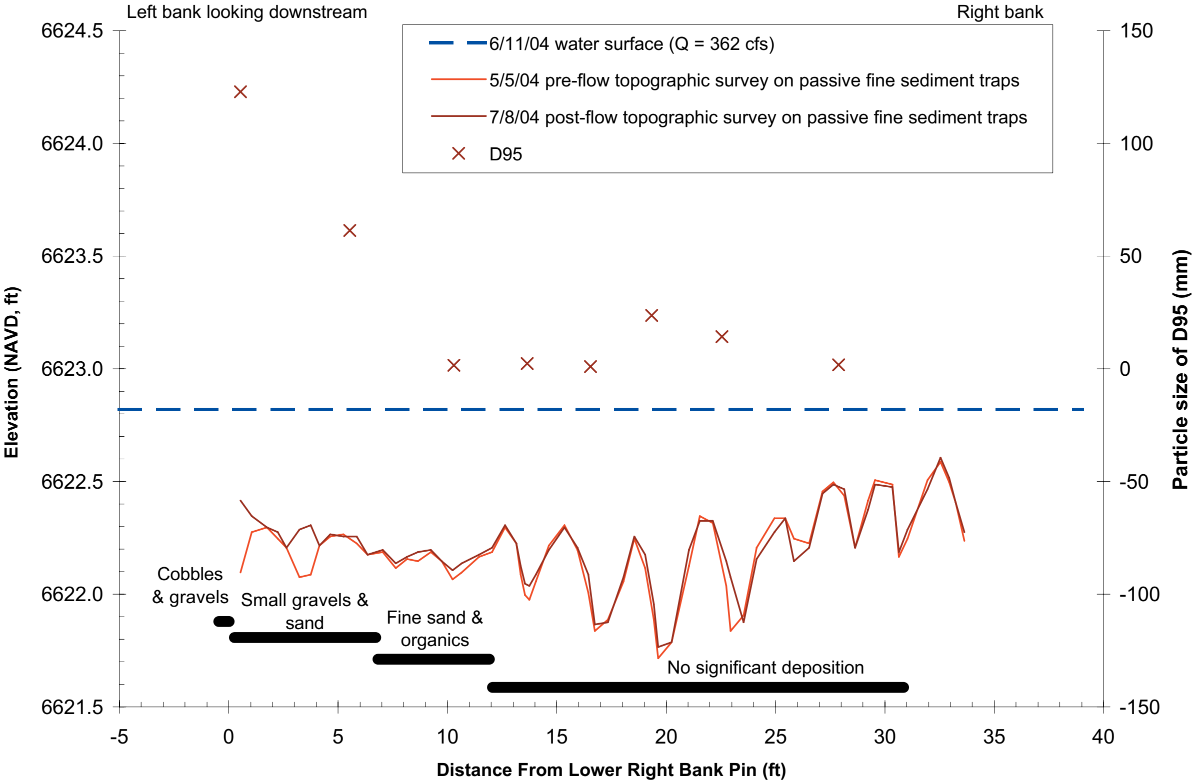

Figure 39. Cross section changes and near-maximum particle size (D_{95}) deposited on the reconstructed right bank floodplain on lower Rush Creek cross section 239+00 during 6/11/04 peak flow.

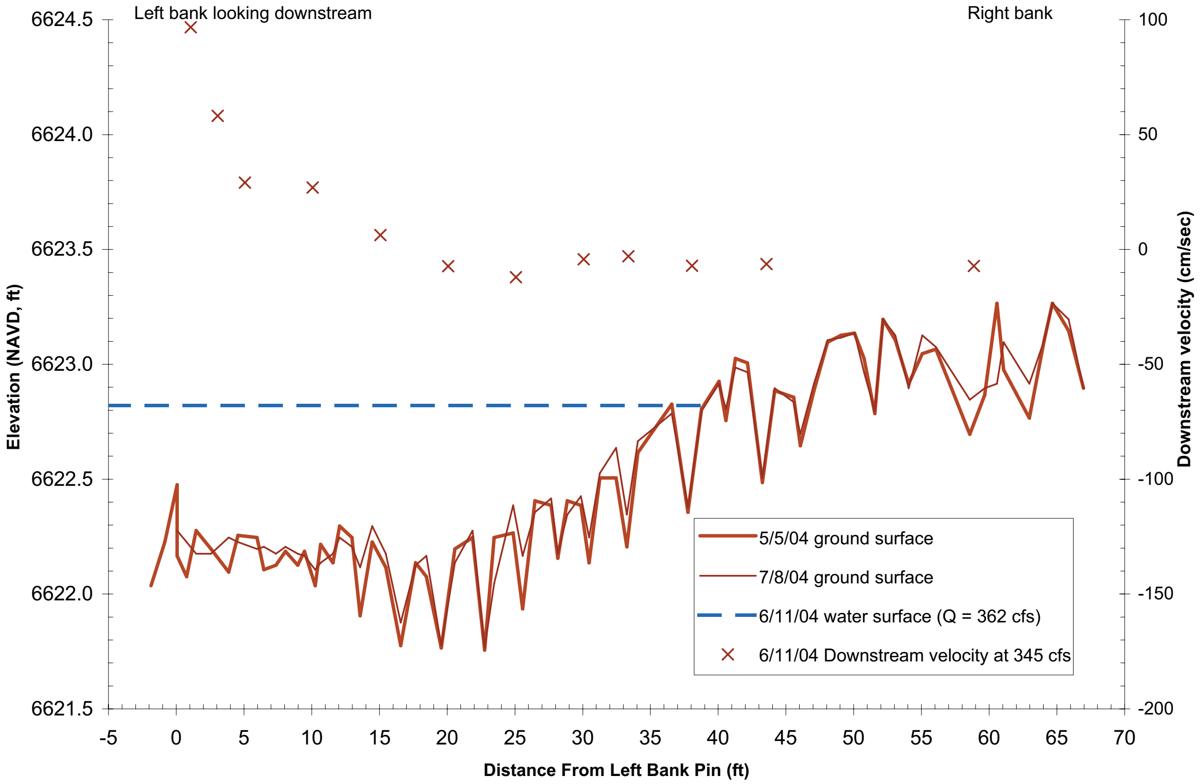

Figure 40. Floodplain velocity patterns on the reconstructed right bank floodplain on lower Rush Creek cross section 239+00 during 6/11/04 peak flow

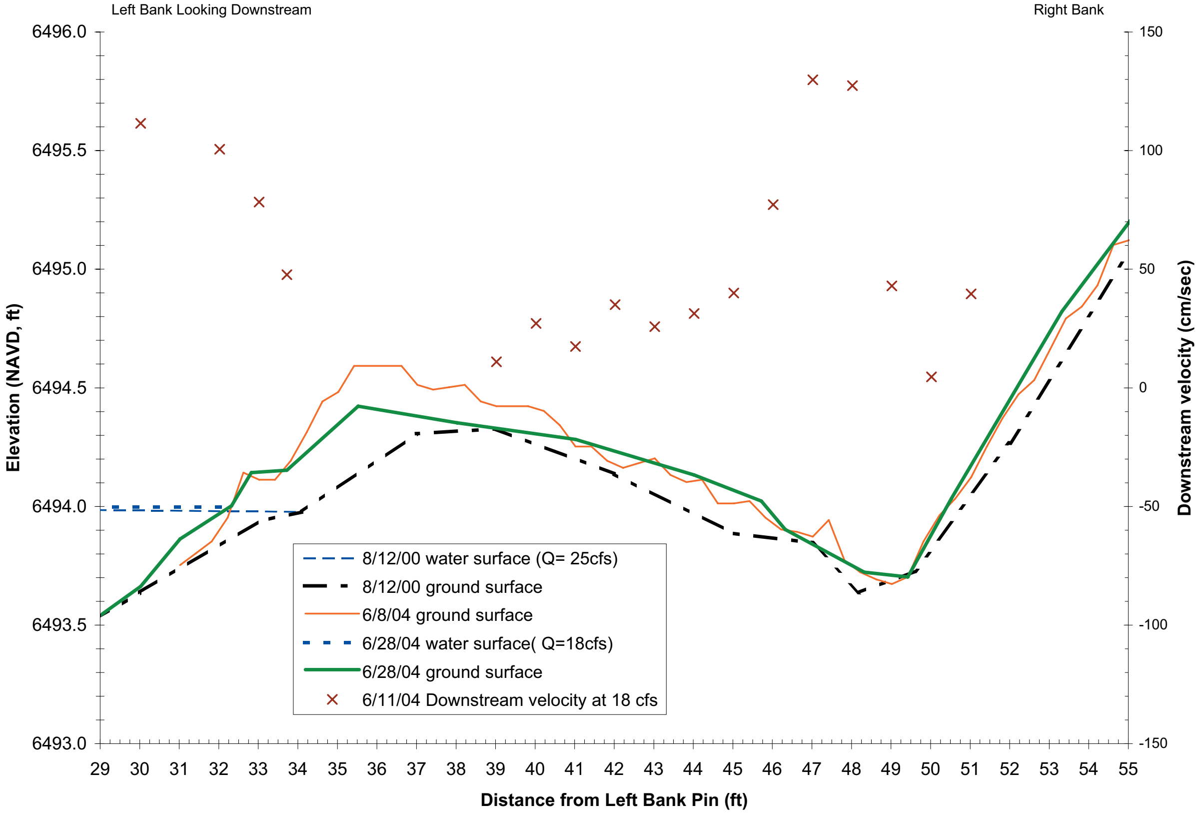

Figure 41. Floodplain velocity patterns on the right bank point bar and incipient floodplain on lower Rush Creek cross section 1+10 (on 10 Channel entrance) during 6/11/04 peak flow

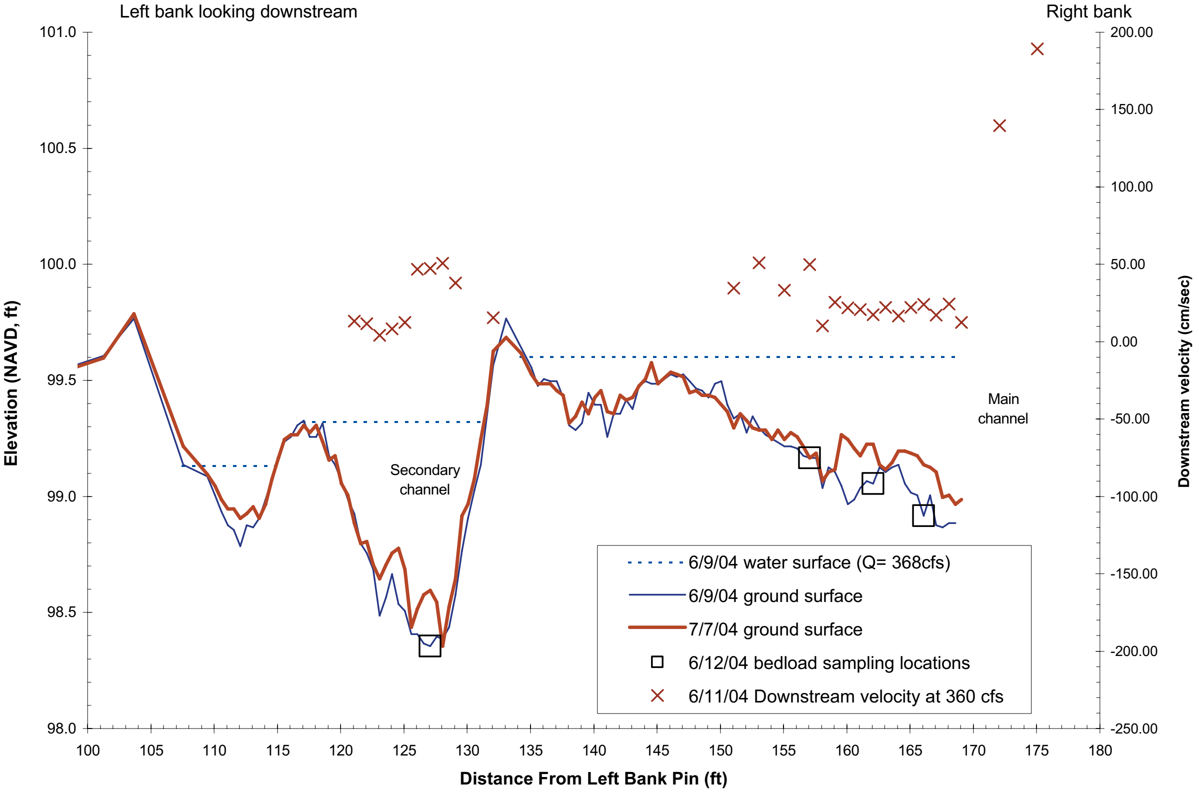

Figure 42. Floodplain velocity patterns on the natural left bank floodplain on lower Rush Creek cross section 25+00 during 6/11/04 peak flow

- Continue monitoring fine sediment deposition at cross sections 239+00, 1+10, 9+59, and -25+00. If flows in spring 2005 are higher than 500 cfs, then monitoring cross sections 7+70 and 7+25 may be feasible. If spring flows are lower than 500 cfs, cross sections 239+00 and 9+59 should not be monitored. Monitoring should employ passive fine sediment traps (carpet) and deposition nails, as they provide more precise measures of fine sediment deposition than cross section surveys (e.g., compare surveys with carpet data on Figure 36). To isolate the effect of duration, the traps could be measured and cleaned each day to assess how daily deposition depths change with time through the release hydrograph. Constructing mini scour cores from brightly colored aquarium gravel could help quantify scour and redeposition depths on developing floodplains.
- The 2003 aerial photographs provide an opportunity to map zones and depths of fine sediment deposition along the entire length of lower Rush Creek, to better characterize confinement rates along the entire stream length. As mentioned above, the 2004 monitoring sites were chosen because they are at incipient floodplain elevations (low surfaces slowly evolving into floodplains), and thus do not fully represent stream-wide floodplain processes. Corridor-wide mapping would extend our predictive capabilities to a broader spectrum of floodplain conditions.
- Using the 2004 monitoring sites, attempt to refine the minimum inundation depth on floodplains of varying roughness for sediment deposition (bedload). Inundation depth may not be the causal mechanism for fine bedload deposition (actually due to sweeps and rapid decrease in shear stress as shown in Figure 28B); however, it may be a reasonable approximation of the causal mechanisms providing a rough rule-of-thumb to estimate inundation depth thresholds that initiate fine bedload deposition.

- The literature shows that sediment transport rates typically decrease with duration of a given flow; however, the short duration of the spring 2004 release did not allow us to quantify the effect of duration on sediment transport rates or fine sediment deposition rates at our floodplain monitoring sites. The Streamwise (2004) data show a rapid drop in transport rates at two of their three sites during the peak flow. This unexpected result may have been caused by the drop in flow on June 10, 2004 as suggested in their report, but it is difficult to pinpoint whether this observation is real or a function of small sample size of the single pass method used. Additionally, bedload transport measurements on the receding limb of the hydrograph would illustrate the degree of hystoresis. Increasing the number of passes from one to at least three would improve predictions of bedload transport rate for each given flow. Lastly, plotting the fine component of bedload (finer than 8 mm) would likely remove potential biasing of total sample weight by a single large particle in a bedload sample.

As mentioned in Section 3.1.2, a numerical model is available (Cui and Parker 1999) that could be developed to predict floodplain aggradation rates on Rush and Lee Vining creeks. The model could help predict tradeoffs in deposition rates as a function of flow magnitude, duration, and frequency, and predict changes in deposition rates with varying fine sediment supplies. The data collected in 2004 provide important calibration data for the model. Determining whether a numerical model is needed depends on our ability to collect empirical data. Evaluating the magnitude of flow needed to promote floodplain aggradation could be conducted strictly with empirical data, assuming SRF releases are higher than the June 2004 releases. The frequency of flow will be largely determined by the natural frequency of wetter and drier water years. Duration of flow is a more difficult variable; a higher magnitude, longer duration SRF release (up to 8 days) would allow daily monitoring of deposition rates to evaluate the decaying benefit of duration. At this time we recommend not applying the model. If we do not get higher flow magnitudes and duration during the next two monitoring seasons, then we recommend reconsidering developing the model to evaluate future high flow magnitudes and durations.

3.4 Geomorphic Termination Criteria

SWRCB Order 98-07 established three geomorphic Termination Criteria – main channel length, gradient, and sinuosity – that have numeric targets for each reach of Rush and Lee Vining creeks. These numeric targets were intended to represent pre-1941 conditions. Specific reaches were established by Trihey (1993) based on contour breaks in the May 1991 aerial survey. The 2003 low-altitude aerial photographs were orthorectified and had photogrammetry developed with contour accuracy of ±1ft. This digital terrain model is thus ideally suited to quantify the geomorphic Termination Criteria.

We replicated the geomorphic Termination Criteria values for main channel length, gradient, and sinuosity from the 2003 aerial photographs and compared them to the Order 98-07 Termination Criteria values. The latest values for length, gradient, and sinuosity are presented separately for Rush Creek and Lee Vining Creek in Tables 14 and 15. The criteria were calculated in the following manner:

- Main Channel Length: The main channel for each reach of Rush and Lee Vining creeks was identified on the 2003 aerial photographs, the left and right edges of water were digitized in AutoCAD, and a centerline was established in the middle of the low-flow channel. Locations of reach boundaries established by Trihey (1993) using contour breaks derived from the May 1991 aerial photogrammetry were imported onto the 2003 photos. Length of the main channel centerline was then measured in AutoCAD.

- Channel Gradient: The channel gradient for each reach of Rush and Lee Vining creeks was calculated using elevations from the 2004 aerial photogrammetry at the Trihey (1993) reach boundary locations, calculating the change in elevation from top to bottom of each reach, and dividing elevation change by the reach length.
- Channel Sinuosity: Channel sinuosity for each reach of Rush and Lee Vining creeks was calculated as the ratio of main channel length to valley length. Valley length was estimated by establishing a valley longitudinal profile line running mid-way between the riparian corridor boundary lines.

3.4.1 Rush Creek

The Rush Creek Termination Criteria and updated 2003 quantities are presented in Table 14. Because main channel length is an independent Termination Criteria *and* is used in the derivation of gradient and sinuosity, our evaluation focused initially on this criterion. Five reaches have equaled or exceeded the Termination Criteria in channel length, including Reaches 2, 3A and 3C where valley confinement is high and the channel has been static over the past several decades, and Reaches 4A and 4B in the bottomlands that have either maintained or recovered a relatively sinuous channel. We overlaid the 1929 and 2003 channels to compare their locations (Figure 43). Reaches 2 and 3A have had little or no change in channel location, so the 2003 channel lengths should match the Termination Criteria values. Using the reach 2-3A boundary reported in Ridenhour et al. (1995), we reproduced identical main channel lengths in reaches 2 and 3A. The remainder of Reach 3 had 2003 main channel lengths close to the Termination Criteria, and overall the Reach 3 2003 channel length total was within 256 ft of the Termination Criteria Reach 3 total. Reaches 4A and 4B also have exceeded the Termination Criteria by 199 ft. Reaches 4C and 5A had the greatest discrepancy between the Termination Criteria and 2003 channel lengths, falling short by 967 ft and 326 ft, respectively. When all reaches were combined, the 2003 channel length was 1,350 ft shorter than the Termination Criteria, a 3% difference.

We examined the four reaches that have not attained the Termination Criteria to determine the feasibility or likelihood those lengths would eventually be attained.

- In Reach 3B, a side-channel was re-opened along the left floodplain in 2000 We have not studied the proportion of flow in this side-channel. The side-channel length is 1,444 ft. The surrounding surfaces are floodplain and there is reasonable opportunity for the main channel to migrate across these surfaces to increase in length by 144 ft. Channel migration rates are low in this reach, however, due to the steep gradient and coarse substrates.
- In Reach 3D, the 2002 construction project lowered the right bank floodplain elevation and excavated a side-channel. The initial flow was less than 5 cfs in the side-channel, and the June 2004 peak flows plugged the entrance to the side-channel. The side-channel length is 347 ft longer than the main channel, so if the main channel avulsed or migrated to the side channel location along the south valley wall, Reach 3D would exceed the Termination Criteria by 212 ft. The reconstructed right bank floodplain elevation will allow channel migration to increase main channel length to meet the Termination Criteria, but the steep gradient and coarse substrates in this reach make migration rates low.
- In Reach 4C, the 1929 14 Channel located upstream of the Lower Rush Creek ford was a long meander across a broad south-bank floodplain. This 2,205 ft long meander was abandoned and the main channel downcut through this reach during past floods. The straightened channel length is currently 451 ft long, thus reducing overall channel length by 1,754 ft. The scale of channel incision in this reach prevents the channel from re-occupying the historic 14 Channel location in the foreseeable future. Main channel length is therefore unlikely to meet the Termination Criteria in this reach.

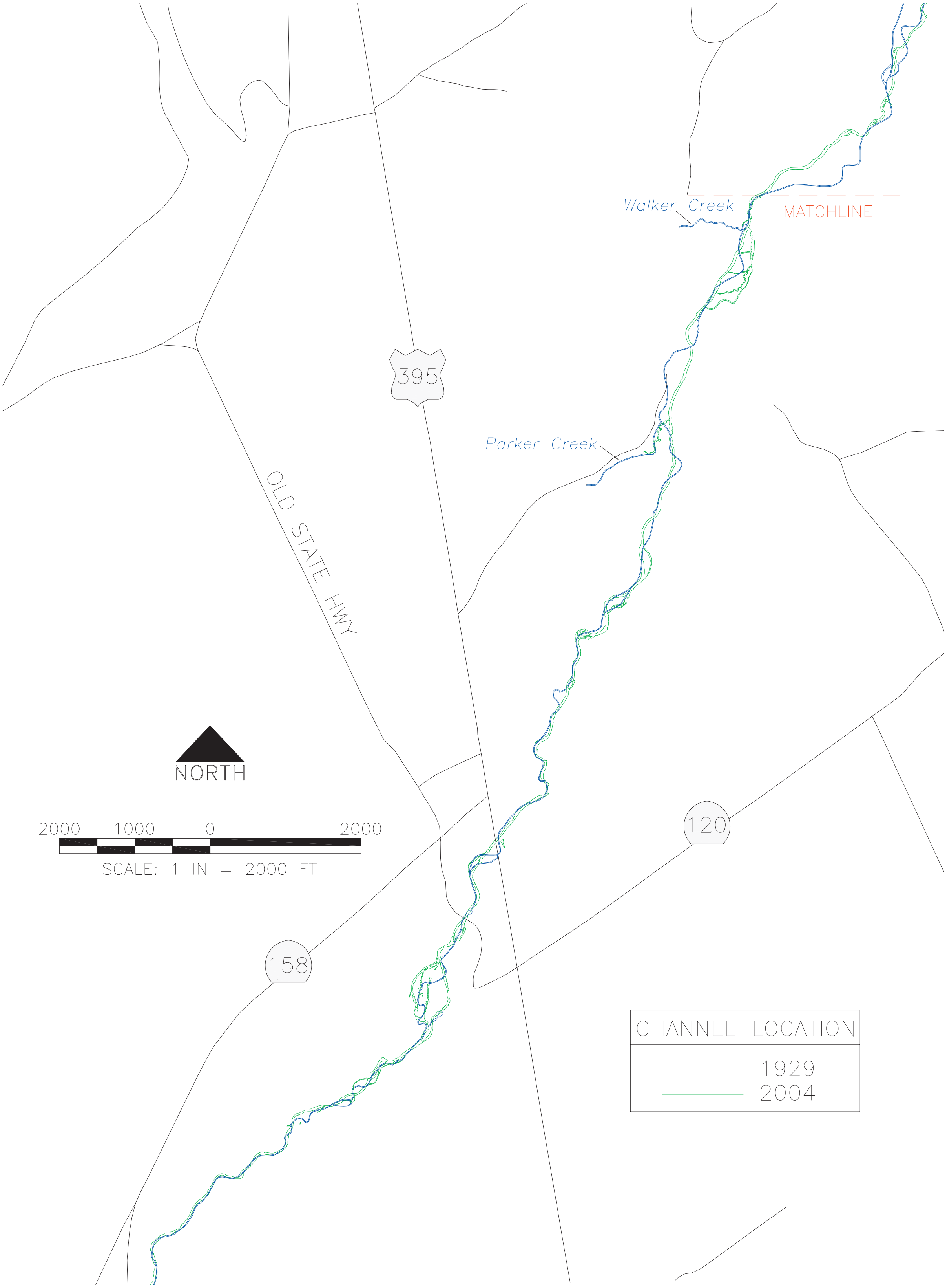

Figure 43. Rush Creek main channel locations from 1929 and 2003 aerial photographs.

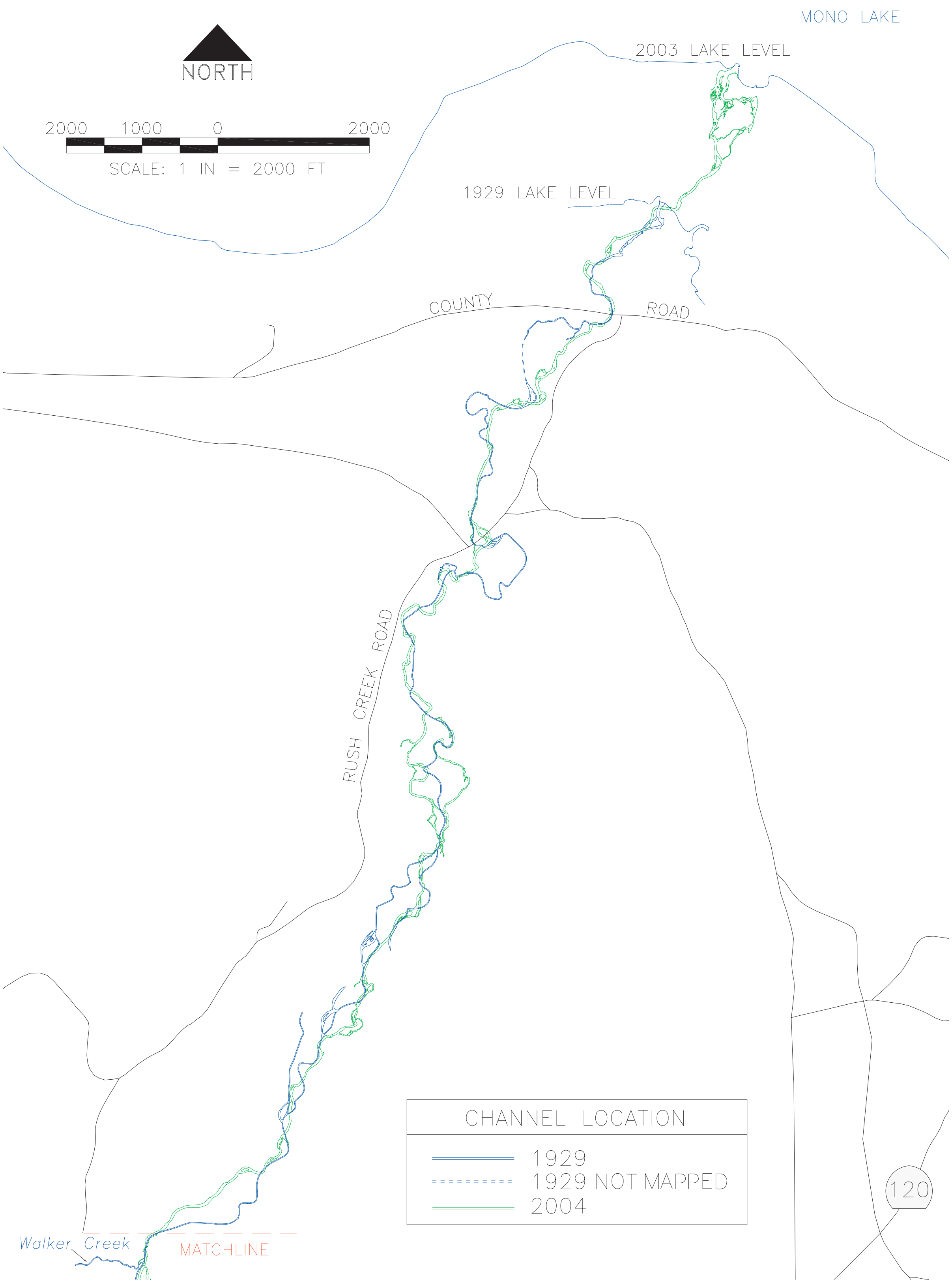

Figure 43. Rush Creek main channel locations from 1929 and 2003 aerial photograph; continued.

- In Reach 5A, the large meander across the left bank floodplain within the County Road study site was also cut off by large floods and channel downcutting. The channel length was reduced from 1,642 ft in 1929 to 628 ft in 2003 (1,014 ft difference). The 2004 geomorphic mapping labeled this surface a Low Terrace (geomorphically active surface), and several monitoring cross sections show the channel actively migrating into this terrace (see Appendix B, County Road XS 6+85). The main channel length could increase 326 ft to meet the Termination Criteria.

The Termination Criteria for channel gradient and sinuosity are more complicated to evaluate. If the main channel length Termination Criteria were met for all reaches, the gradient and sinuosity criteria would still not be met for several reaches. Because gradient and sinuosity are a function of channel length, the only way to attain these criteria is to increase channel length. We therefore determined the additional main channel length necessary to meet the gradient and sinuosity Termination Criteria (Table 14). This results in three values for "additional main channel length needed to achieve Termination Criteria", one for each of the three criteria. The maximum of these three values is therefore the additional length needed to meet all three geomorphic Termination Criteria (Table 14). A total of 3,974 ft of additional channel length (a 9.2% increase) are required on Rush Creek to allow all Termination Criteria to be met. Most of this length (2,656 ft) is needed in the lowermost two reaches (4C and 5A). Several Termination Criteria have been met for specific reaches of Rush Creek, and are indicated in Table 14.

3.4.2 Lee Vining Creek

We evaluated the Lee Vining Creek geomorphic Termination Criteria in a similar manner as Rush Creek. The 2003 values for main channel length, gradient, and sinuosity were computed from the 2003 aerial photographs for Lee Vining Creek Reaches 3A, 3B, and 3C (Table 15). We do not have aerial photographs that include Reaches 1 and 2, so these Termination Criteria were not re-quantified. We assume these reaches are unchanged in main channel length, gradient, and sinuosity.

Lee Vining Creek has not exceed the Termination Criteria in channel length for any of the three reaches evaluated, and is cumulatively 915 ft short of main channel length targets (Table 15). As with Rush Creek, we computed the additional channel length required to meet the gradient and sinuosity Termination Criteria. Only Reach 3A required additional channel length beyond the length Termination Criteria to meet the sinuosity Termination Criteria. This changed the cumulative channel length required to allow all Termination Criteria to be met to 1,144 ft, more than half of which is in Reach 3A. The Termination Criteria for gradient is met for Reaches 3A and 3C and for sinuosity is met for Reach 3C.

Table 14. Summary of the Geomorphic Termination Criteria values for each reach of Rush Creek, and updated values obtained from the 2003 aerial photographs.

RUSH CREEK TERMINATION CRITERIA		**Reach (1)**											**Combined Reaches**	
		2	**3A**	**3B**	**3C**	**3D**	**4A**	**4B**	**4C**	**5A**	**5B**	**Total**	**2-3**	**4-5**
Length (ft)	Termination Criteria	4,820	3,800	3,100	6,940	3,370	3,070	7,810	4,360	7,320		44,590	22,030	22,560
	2003	4,820	3,800	2,956	6,964	3,235	3,078	8,001	3,393	6,994		43,240	21,775	21,466
	Additional main channel length needed to achieve termination criteria	0	0	144	0	135	0	0	967	326		1,572	279	1,293
Gradient (ft/ft)	Termination Criteria	0.024	0.016	0.0140	0.023	0.022	0.014	0.010	0.005	0.0070		0.0150	average TC gradient	
	2003	0.026	0.017	0.016	0.023	0.021	0.017	0.010	0.007	0.008		0.0161	average 2003 gradient	
	Additional gradient needed to meet termination criteria	0.002	0.001	0.002	0	0	0.003	0	0.002	0.001				
	Additional main channel length needed to meet gradient termination criteria	159	200	258	0	0	565	0	1,507	1,149		2,656.1571		
Sinuosity (ft/ft)	Termination Criteria	1.04	1.06	1.19	1.07	1.04	1.19	1.23	2.11	1.39		1.258	average TC sinuosity	
	2003	1.08	1.07	1.27	1.09	1.03	1.17	1.27	1.57	1.27		1.204	average 2003 sinuosity	
	Additional sinuosity needed to meet termination criteria	0	0	0	0	0.01	0.02	0	0.54	0.12				
	Additional main channel length needed to meet sinuosity termination criteria	0	0	0	0	28	54	0	1,172	644				
	Additional main channel length needed to achieve ALL termination criteria	159	200	258	0	135	565	0	1,507	1,149		**3,974**		
	2003 Valley Length	4,469	3,540	2,322	6,370	3,137	2,632	6,276	2,163	5,495		36,404	total valley length	
	2003 Elevations (top of reach)	7,060.5	6,941	6,877	6,832	6,672	6,603	6,552	6,471	6,447	6,390	671.0	change in total elevation 2003	
	Pre-1941 RTC Elevations (top of reach)	7,059.0	6,941	6,879	6,833	6,671	6,597	6,553	6,471	6,450	6,395 #	664.0	change in total elevation Pre-41	

(1) Stream Reach Description
Reach 1: Extends ~0.8 miles from Grant Lake to the beginning of the cut through the glacial moraine
Reach 2: Flows through a narrow canyon cut through the glacial moraine (Elevation 7,059 to 6,941)
Reach 3A: Begins where the stream exits the glacial moraine and the floodplain broadens.
Reach 3B: Begins where the stream was diverted into B ditch and extends downstream to HWY 395
Reach 3C: Extends from HWY 395 to the confluence with Parker Creek (Elevation 6,833 to 6,671)
Reach 3D: At the confluence of Parker Creek extending to and inclusive of the Narrows
Reach 4A: Extends just below the Narrows to the start of Indian Ditch (Elevation 6,597 to 6,553)
Reach 4B: Extends from Indian Ditch to 600' downstream from the start of the last meander bend above the Ford.
Reach 4C: Reach 4C extends from 600' downstream from the start of the last meander bend in Reach 4B to the Ford
Reach 5A: Extends from the Ford ~1800' downstream to the County Road
Reach 5B: Extends from elevation 6,395 to approx. 6,376'.

Table 15. Summary of the Geomorphic Termination Criteria values for each reach of Lee Vining Creek, and updated values obtained from the 2003 aerial photographs.

LEE VINING CREEK TERMINATION CRITERIA		***Reach*** (1)					
		3A	***3B***	***3C***	***3D***	***Total (excluding Reaches 1-2)***	
Length (ft)	Termination Criteria	3,500	4,200	1,360		9,060	
	2003	3139	3795	1210		8,145	
	Additional main channel length needed to achieve termination criteria	361	405	150		915	
Gradient (ft/ft)	Termination Criteria	0.037	0.025	0.021		0.028	average TC gradient
	2003	0.037	0.026	0.019		0.028	average 2003 gradient
	Additional gradient needed to meet termination criteria	0	0.001	0		0.000	
	Additional main channel length needed to meet gradient termination criteria	0	215	0			
Sinuosity (ft/ft)	Termination Criteria	1.33	1.15	1.2		1.23	average TC sinuosity
	2003	1.12	1.04	1.23		1.13	average 2003 sinuosity
	Additional sinuosity needed to meet termination criteria	0.21	0.11	0		0.10	
	Additional main channel length needed to meet sinuosity termination criteria	589	387	0			
	Additional main channel length needed to achieve ALL termination criteria	589	405	150		**1,144**	
	2003 Valley Length	2,803	3,637	986	1,497	8,924	total valley length (3A-3C)
	2003 Elevations (top of reach)	6,647	6,531	6,431	6,408	240	change in total elevation 2003 (3A-3C)
	Pre-1941 RTC Elevations (top of reach)	6,665	6,537	6,433	6,404	261	change in total elevation Pre-41 (3A-3C)

(1) Stream Reach Description
Reach 1: Begins at the Lee Vining Diversion facility and extends to HWY 120
Reach 2: Begins at the end of the meadows where HWY 120 crosses the stream to just below HWY 395 and the SCE substation
Reach 3A: Begins 1,500 below HWY 395 and moves downward to a point just below where the main channel goes eastward across the floodplain
Reach 3B: Begins where the present main channel swings to the east away from the westside of the floodplain and extends to the County Road Crossing
Reach 3C: Begins at County Road crossing and extending to the shoreline of Mono Lake.
Reach 3D: Extends from the 1941 lake shore of Mono Lake to the present shoreline of Mono Lake

4 RIPARIAN VEGETATION MONITORING

4.1 Riparian Vegetation Termination Criteria

The riparian corridors of Lee Vining, Rush, Walker, and Parker creeks were mapped in summer and fall of 2004 to determine riparian woody acreage. The mapping protocol used in 1999 was repeated. The riparian acreages derived from map analysis were the basis for evaluating riparian vegetation recovery. The riparian acreage estimates were also used for comparison to the Termination Criteria (Table 16). Walker and Parker creeks were mapped to evaluate vegetation recovery, though no Termination Criteria exist for these creeks (Table 17).

The vegetation maps developed from 1929, 1999, and 2004 aerial photographs were transformed into a riparian atlas (Appendix G). We combined the detailed cover types previously mapped (McBain and Trush 2001, *ibid* 2003, *ibid* 2004) into three broader cover type categories to make between-year comparisons easier, to reflect the categories used the Termination Criteria, and to make overlays between years easier to interpret. The three general categories were:

- Desert- These patches are typically pinion pine, sagebrush or sagebrush/bitterbrush dominated;
- Riparian herb- These patches are typically grasslands, wet meadows, herbs growing on cobble bars, etc.;
- Riparian woody- These patches are typically aspen, black cottonwood, willows, Jeffery pine, white fir, lodgepole, rose, or mixed rose.

4.1.1 Sources and Significance of Mapping Errors

Vegetation acreage estimates may be affected by several potential sources of error (Table 18). The affect of most sources of error on our estimates could not be quantified. The riparian Termination Criteria have defined acreages to the tenth of an acre for every reach along Rush and Lee Vining creeks, suggesting that the accuracy of acreage estimates is +/- 0.1 acre. We suggest the error between mapping periods in any given reach is more likely on the order of 0.5 acres (+/-).

The greatest unquantifiable source of mapping error is likely field determination of cover types, which relies on identifying the cover type for each vegetation patch, then isolating each patch as a polygon drawn on aerial photographs. The primary goal of drawing polygons is to isolate vegetation patches that exhibit the greatest homogeneity. The mapping is done independent of previous mapping, so the vegetation polygons may be different each time vegetation is mapped. The degree to which the plant species in a polygon are homogenous often dictates which cover type is assigned. For example, in one year a patch might be mapped as mixed willow, but the next time it may be identified as narrowleaf willow, even if the vegetation composition has not changed. Regardless, both of these cover types fall within the broader category of riparian woody vegetation, so this source of error does not affect interpretation of riparian acreages in relation to the Termination Criteria.

One source of error we can evaluate is the accuracy associated with using ink pens and aerial photographs in the field to isolate a vegetation patch, then later digitizing that patch in the office. We intend to compare this mapping method to the “real” perimeter mapped by surveying with Kinematic GPS (Table 18), which is presumed to be more accurate. We identified several large, medium, and small patches along Walker and Parker creeks that will be used to assess the variation in vegetation patch perimeters, and these patches will be surveyed using the GPS device. We will then compare the mapped area with the field survey of the same perimeter. Results of the perimeter comparison will be reported in the RY 2005 annual report.

Table 16. Rush Creek and Lee Vining Creek woody riparian vegetation coverage established in the Termination Criteria, compared to 1989 acreages quantified by JSA, and 1999 and 2004 acreages quantified by McBain and Trush.

RUSH CREEK							
	Woody Riparian Vegetation (Acres)						
Stream Segment	***Termination Criteria (SWRCB D1631)***	***Pre-diversion (McBain and Trush 2004)***	***1989 Vegetation (JSA 1993)***	***1999 Vegetation (McBain & Trush)***	***2004 Vegetation (McBain & Trush)***	***Acreage Change Between 1999 and 2004***	***Acreage needed to meet Termination Criteria***
1	6.2	N/A	1.7	N/A	1.9	N/A	4.3
2	5.0	5.6	5.9	5.6	6.5	0.9 acres	CRITERIA MET
3a	21.5	25.5	12.7	13.2	14.3	1.1 acres	7.2 acres
3b	2.9	3.5	0.1	1.3	2.8	1.5 acres	0.1 acres
3c	11.2	17.3	4.1	8.4	9.7	1.3 acres	1.5 acres
3d	10.0	10.3	4.0	4.0	5.2	1.2 acres	4.8 acres
4a	26.0	37.4		22.5	26.2	3.7 acres	CRITERIA MET
4b	80.0 144.7	73.0 138.6	90.0	61.4 113.4	66.8 124.3	5.4 acres +10.9	13.2 acres -20.4
4c	38.7	28.2		29.5	31.3	1.8 acres	7.4 acres
5a	37.8	33.0	11.0	26.4	29.3	2.9 acres	8.5 acres
5b	N/A	N/A	*combined with 5a*	4.6	7.7	N/A	N/A

LEE VINING CREEK							
	Woody Riparian Vegetation (Acres)						
Stream Segment	***Termination Criteria (SWRCB D1631)***	***Pre-diversion (McBain and Trush 2004)***	***1989 Vegetation (JSA 1993)***	***1999 Vegetation (McBain & Trush)***	***2004 Vegetation (McBain & Trush)***	***Acreage Change Between 1999 and 2004***	***Acreage needed to meet Termination Criteria***
1	20.0	N/A	19.8	N/A	27.9	N/A	CRITERIA MET
2a	30.0	N/A	13.4	N/A	16.7	N/A	3.1 acres
2b	*Combined with 2a*	9.8	10.9	10.6	10.2	-0.4 acres	*Combined with 2a*
3a	22.2	18.5	6.9	12.5	12.5	0.0 acres	9.7 acres
3b	32.9	36.8	7.5	24.6	25.0	0.4 acres	7.9 acres
3c	4.0	4.5	3.3	5.5	5.7	0.2 acres	CRITERIA MET
3d	N/A	0.0	8.6	12.8	13.2	N/A	N/A

Table 17. Parker and Walker Creek 1929 woody riparian vegetation coverage quantified by McBain and Trush, compared to 1989 acreages quantified by JSA, and 1999 and 2004 acreages quantified by McBain and Trush.

PARKER CREEK				
	Woody Riparian Vegetation (Acres)			
Stream Segment	**Pre-Diversion Vegetation (McBain & Trush)**	**1989 Vegetation (Jones & Stokes 1993)**	**1999 Vegetation (McBain & Trush)**	**2004 Vegetation (McBain & Trush)**
1	6.0	15.2	14.0	14.6
2	36.4	31.3	22.1	24.0
3	2.8	0.5	0.7	1.0
4	4.3	2.2	1.4	2.2

WALKER CREEK				
	Woody Riparian Vegetation (Acres)			
Stream Segment	**Pre-Diversion Vegetation (McBain & Trush)**	**1989 Vegetation (Jones & Stokes 1993)**	**1999 Vegetation (McBain & Trush)**	**2004 Vegetation (McBain & Trush)**
1 combined with 4	22.5	13.1	12.5	11.9
2 combined with 5	6.9	1.3	0.3	0.7
3	9.3	2.8	6.2	5.9

4.1.2 Comparison of 1999 to 2004 Vegetation Acreage

The area of riparian woody vegetation is still increasing since 1999 when the riparian corridors were last mapped. However, the rate of recovery has slowed between the 1999-2004 mapping episodes when compared to the rate of recovery between 1989 and 1999. Areas available for colonization in 1989 have now been re-colonized; riparian woody species that survived the 1940-1981 de-watering that were not evident in 1989 have re-sprouted. Future recovery will result from increases in canopy area and stand perimeters, or from channel migration creating new sites where riparian hardwood species can colonize.

Highway 395 was expanded where it crosses Lee Vining, Rush, Walker, and Parker creeks. Areas of riparian woody vegetation permanently converted to human disturbance (i.e., highway) were analyzed using the 1929, 1999, and 2004 vegetation maps (Table 19).

Two reaches in Rush Creek were impacted by the Highway 395 expansion between 1999 and 2004. Rush Creek Reach 3b was 0.1 acre from meeting the Termination Criteria in 2004, (within the +/- 0.5 acre inter-mapping variation). However, 0.1 acres of riparian woody vegetation were permanently lost to highway expansion between 1999 and 2004. Rush Creek Reach 3c was 1.5 acre from meeting the Termination Criteria in 2004. Permanent conversion of riparian woody vegetation mapped in 1999 to human disturbance in 2004 was 0.5 acres. In spite of impacts associated with highway expansion, Reach 3c recovered 1.3 acres of riparian woody vegetation between 1999 and 2004. Although the recovery rate in the reached slowed compared to the 1989-1999 period, the 1.3 acre increase enables us to predict continued riparian woody vegetation recovery in this reach. Even with the permanent conversion of 0.5 acres of riparian woody revegetation, this reach will likely recover the remaining 1.5 acres needed to meet the Termination Criteria within the next two mapping episodes (2009 or 2014).

Lee Vining Creek Reach 2 was the only area impacted by Highway 395 expansion between 1999 and 2004. We did not map the riparian woody revegetation above the SCE substation in 1999. Instead, our impact analysis utilized 1929 riparian woody acres in Reach 2 that would have been impacted by Highway 395 expansion (Table 19). Highway expansion did not impact riparian woody vegetation northwest of the highway, (Reach 2b). However, highway expansion did impact 1.1 acres of 1929 riparian woody vegetation on the southeast side; 1999 riparian woody vegetation acreage might have been less had we mapped it.

Table 18. Errors that could affect acreage estimates during, or between, corridor-wide vegetation mapping episodes.

Errors caused by	***Error Source***	***Affects Accuracy***	***Errors effect on accuracy of area measures***	***Description***
Photo	Orthorectification vs. Rubbersheeting	Between mapping	Low	This shifts the locations of objects and the overlay between mapping periods. Using a riparian corridor boundary derived with one method and overlaying it onto a map created using another method could cause small shifts in acreages within the boundary
Photo	Original aerial photo scale and resolution for enlargement	Between mapping	Moderate	The higher the scale the poorer the enlargements. Digital images have a better enlargement capacity than contact prints enlarged using a copier; changing between the two types of images (digital vs. photocopier enlargements) can create errors
Photo	Time of year aerial photos are taken	Between mapping	High	Shadows and color differences affect where polygons are drawn and patch type identification
Photo	Degree of enlargement	Between mapping	Negligible	Enlargement can obscure the patch bounday lines in the photos making it difficult to draw the polygon line
User	Field pen width	Within the mapping	Low	The thicker the pen width the more likely the union of polygon lines will be unclear when the line is interpreted during digitization
User	Degradation of pen	Within the mapping	Negligible	Pen tips break and grow wider; the line width is interpreted during digitization
User	Interpretation of patch type	Between mapping	None	Smaller mapping units can be defined with better aerial photos; if a stand type that was desert or riparian is changed that could affect woody riparian vegetation acreage estimates
User	Interpretation of patch boundary vs. the real patch boundary	Within the mapping	Moderate	Fatigue, field conditions, perspective, and mapping experience affect hand drawn lines
User	Interpretation of patch boundary	Between mapping	Moderate	Professional experience, perspective, and landscape change affect how and where the boundary lines are drawn
User	Digitization pen width	Between and Within mapping	Negligible	Another person follows the polygon lines drawn in the field, centering the digitizing pen over the lines, the width of the digitizing pen should be less than the field pen
User	Digitization	Between and Within mapping	Moderate	Another person follows the polygon lines drawn in the field possibly causing local wiggles in polygon lines; this error could compound the errors associated with drawing polygons in the field
Method	Extrapolation from originals to laminated photos (1929)	Within the mapping	Negligible	The extrapolation occurred onto the same images so interpretation between images was negligible
Method	Extrapolation from originals to 1991 photogrammetry maps	Within the mapping	Moderate	Extrapolation from high scale aerial photographs onto a topographic maps is difficult
Method	Synthesis of 1929-30 and 1987-89 photos onto 1991 photogrammetry	Within the mapping	High	Extrapolation from high scale aerial photographs onto a topographic maps is difficult

Table 19. Area of riparian woody vegetation that would have been impacted in 1929 and the area impacted between 1999 and 2004 by Highway 395 expansion.

LEE VINING CREEK	***Reach 2a (acres)***	***Reach 2b (acres)***	***Total (acres)***
1929 Riparian Woody Vegetation in expansion area that would have been impacted if HWY395 had been expanded at its current location in 1929	1.1	0.0	1.1

RUSH CREEK	***Reach 3a (acres)***	***Reach 3b (acres)***	***Total (acres)***
1929 Riparian Woody Vegetation in expansion area that would have been impacted if HWY395 had been expanded at its current location in 1929	0.5	0.8	1.3
1999 Riparian Woody Vegetation in expansion area that was actually converted to human disturbance as a result of expansion	0.1	0.5	0.6

4.1.3 Termination Criteria

Some reaches along Rush and Lee Vining creeks have met Termination Criteria, other reaches are recovering or show promise of recovery in the near future (i.e., by 2025), while several reaches still have not shown much recovery since 1989 (Table 16). Our results indicate that riparian recovery is becoming asymptotic and we have passed the steepest recovery trajectory. Future riparian woody vegetation will not increase at the same rate as between 1989 and 1999. The following summarizes observations recorded during the 2004 vegetation mapping and from subsequent data analyses:

Rush Creek Recovery

- Recovery of riparian woody vegetation along Rush Creek has been generally swift. Termination Criteria have been met in Reach 2 and Reach 4a. Some reaches are still recovering, and others have not changed since 1989 (e.g., Reach 1).
- Reach 1 riparian woody vegetation acreage has increased 0.9 acres since 1989 but is still 4.3 acres from meeting the Termination Criteria. Because Rush Creek Reach 1 is permanently dewatered, this reach will not recover woody riparian vegetation.
- Reach 2 has met the Termination Criteria for riparian woody vegetation.
- Reach 3a riparian woody vegetation recovery was greater between 1999 and 2004 than between 1989 and 1999. However, 7.2 acres are still needed in this reach to meet the Termination Criteria. Without channel migration or scour and deposition on current surfaces adjacent to the main channel, it is unlikely that this reach will recover the riparian woody acreage needed to meet the Termination Criteria within the next two mapping episodes (i.e., by 2014).
- Reach 3b riparian woody vegetation needs 0.1 acre to meet the Termination Criteria. Channel rewatering in 1999 will likely help achieve this remaining acreage, likely by the next mapping episode.

- Reach 3c is 1.5 acres from meeting the Termination Criteria. The rate of recovery slowed in this reach between 2004 and 1999 compared to the 1989-1999 period. Even at the current rate of recovery, this reach will likely meet the Termination Criteria within the next two mapping episodes (i.e., by 2014)
- Reach 3D needs 4.5 acres of riparian woody vegetation to meet the Termination Criteria. Floodplain reconstruction, side-channel construction, and gravel mine reclamation have all occurred in this reach within the last three years. As the restored areas recruit riparian woody species, the Termination Criteria will not only be met, but will likely be exceeded (by 2025).
- Reach 4a has met the Termination Criteria for riparian woody vegetation.
- Reach 4b riparian woody vegetation acreage increased between 1999 and 2004, but the acreage increase between 1989 and 1999 for this reach is unknown. However, 13.2 acres are still needed in this reach to meet the Termination Criteria. With future migration, scour and deposition on surfaces adjacent to the main channel, and channel reopening projects (8 Channel in this reach) riparian woody acreage will likely meet the Termination Criteria within the next two mapping episodes (i.e., by 2014).
- Reach 4c riparian woody vegetation recovery has been slow since 1989 and 7.4 acres are needed to meet the Termination Criteria. Channel downcutting resulting from drops in Mono Lake level have incised this reach and abandoned floodplains before riparian woody plant species can colonize and establish on them. Without channel migration or scour and deposition on current surfaces adjacent to the main channel, recovery of riparian woody acreage needed to meet the Termination Criteria will not occur within the next two mapping episodes (i.e., by 2014).
- Reach 5a riparian woody vegetation recovery has been slow since 1989 and 8.5 acres are needed to meet the Termination Criteria. Channel downcutting resulting from drops in Mono Lake level have incised this reach and abandoned floodplains before riparian woody plant species can colonize and establish on them. Without channel migration into incised terraces and reconstruction of floodplains throughout this reach, it is unlikely the riparian woody acreage needed to meet the Termination Criteria will be recovered within the next two mapping episodes (i.e., by 2014).
- Reach 5b did not exist before diversion and has no Termination Criteria.

Lee Vining Creek Recovery

- Lee Vining riparian woody vegetation recovery was initially rapid between 1989-1999, but has slowed considerable between 1999 and 2004. Two reaches meet the Termination Criteria (Reach 1 and Reach 3c), but others have not increased in acreage since 1999 (e.g., Reach 3a).
- Reach 1 has met the Termination Criteria for riparian woody vegetation.
- Reach 2 riparian woody vegetation recovery has been difficult to estimate between 1989 and 2004 because our mapping was not extended past HWY395 in 1999 (only sub-Reach 2b was mapped). In sub-Reach 2b there has been no change in riparian vegetation acreage since 1999, and 3.1 acres are still needed in this reach (2a and 2b combined) to meet the Termination Criteria. Because there has been no change in acreage in subreach 2b since 1999, there has likely been no change in acreage in sub reach 2a either. It is not expected that woody riparian acreage recovery will meet the Termination Criteria within the next two mapping episodes (i.e., by 2014).
- Reach 3a riparian woody acreage has not changed since 1999 and 9.7 acres are needed to meet the Termination Criteria. Recovery of the riparian woody acreage needed to meet the Termination Criteria is not expected within the next two mapping episodes (i.e., by 2014) without channel migration or avulsion.

- Reach 3b riparian woody acreage increased only 0.4 acres since 1999 and 7.9 acres are needed to meet the Termination Criteria Without channel migration, or scour and deposition on surfaces adjacent to the main channel, it is unlikely the riparian woody acreage needed to meet the Termination Criteria will be recovered within the next two mapping episodes (i.e., 2014).
- Lee Vining Creek Reach 3c has met the Termination Criteria for riparian woody vegetation.
- Lee Vining Creek Reach 3D did not exist before diversion and has no Termination Criteria.

5 SIDE CHANNEL AND CONSTRUCTION SITE MONITORING

5.1 3D and 8 Channel Riparian Vegetation Response Monitoring

In summer 2002, the 8 Channel entrance was reopened and a functional floodplain/side channel complex was constructed at the 3D Channel site. The vegetation response monitoring seeks to quantify the response of riparian and desert plant species to the channel re-opening and floodplain construction. In 2004, we assessed the riparian hardwood species composition and density as a function of geomorphic setting, phenology, and magnitude and timing of SRF releases. Specific monitoring objectives were:

- Evaluate the composition and abundance of plant species growing on or near recent channel rehabilitation projects;
- Estimate the composition and density of riparian woody plant species in different geomorphic settings at project sites (e.g., channel edges, shallow depressions, floodplains, and low terraces).

5.1.1 Methods

Overall the protocols we used borrowed heavily from the nested frequency methods employed to describe vegetation patch types (i.e., plant alliances) in the Mono Basin (see the McBain and Trush annual reports for 2002 and 2003, and the White and Blue Books). The methods used in the past can be conducted quickly and provide quantitative estimates of vegetation characteristics (e.g., composition, abundance, spatial arrangement, density, structure, etc.).The nested frequency method uses fifteen 1 m^2 plots (n=15) placed side-by-side along a 15 m transect placed parallel to streamflow. A 0.5 m^2 and a 0.25 m^2 plots are nested inside of the 1 m^2 plot.

We modified the nested frequency sampling protocol for monitoring riparian vegetation response to channel rehabilitation projects. One significant change was to distribute plots around the site, rather than to sample along a 15 m transect. We also increased the number of plots sampled from 15 to 16 (n=16).

As vegetation develops, we anticipate that a 1m^2 plot may be too small to adequately sample tree and shrub distribution at the site. When this occurs (in the next ~5 yrs) our plots will be expanded to 10 m^2, with 5 m^2 and 2.5 m^2 plots nested inside.

Sixteen plot locations have been identified at each monitoring site (Figures 11 and 19), with four plots allocated to each different geomorphic settings. Specific tasks conducted at each plot were as follows:

- The center of each plot was monumented with a rebar pin and the monument location marked on the 2003 aerial photograph;
- The 1 m^2 plot (with the 0.5 m^2 and 0.25 m^2 plots nested within it) was centered over the rebar monument;

- All plant species found within the 0.25 m^2, the 0.50 m^2 and 1.0 m^2 were listed;
- The plant species cover was estimated for all species within the 1 m^2;
- All riparian woody plant species were listed starting in the 0.25 m^2 plot, and the number of stems counted. If the number of stems counted in the 0.25 m^2 plot was less than 100, then the number and species of woody plants in the 0.5 m^2 plot were counted and if the number of total stems counted was less than 100, the same process was repeated in the 1.0 m^2 plot.

In addition to the quantitative plot data, we qualitatively followed the flowering and seed dispersal periods for three riparian hardwood species to better evaluate the response of riparian hardwood recruitment at the 3D and 8 Channel restoration sites. Male and female cottonwoods were identified on the field maps and observations were made opportunistically throughout the seed dispersal periods for yellow willow, narrowleaf willow, and black cottonwood during the 2004 field season.

5.1.2 Nested Plot Results

We monitored vegetation response before and after the 2004 SRF releases at the 3D and 8 Channels. Our analysis and results included:

- Riparian and desert plant species and the total number of each in the geomorphic settings sampled at each site (Tables 20, 21, and 22).
- Percent frequency in plots of desert, riparian herbaceous and riparian woody vegetation types. Estimates of riparian woody plant seedling density as a function of geomorphic setting (Figure 44).
- Predictions of future woody species composition in different geomorphic settings at each site.

5.1.3 Phenology Results

From our site mapping, ratios of male and female black cottonwoods differed between the 8 Channel and the 3D Channel. At both sites, *female trees out-numbered male trees*. The 3D Channel site showed the greatest difference: we mapped 19 female trees and 7 male trees, whereas the sex ratio at the 8 Channel site was more evenly distributed, with 15 male trees and 17 female trees. While the male: female ratios derived from these maps cannot be generalized corridor-wide, they suggest female cottonwoods within the Rush Creek riparian corridor are numerous and that seed source for future recruitment is locally abundant.

We observed a lag in black cottonwood seed dispersal in Rush Creek populations compared to Lee Vining Creek populations, while the yellow willow seed dispersal timing was similar between the two creeks (Figures 45 and 46). The timing of the seed dispersal periods for these two species coincides with the peak and recession of snowmelt floods. The coincidence of seed dispersal with streamflow recession helps explain why yellow willow and black cottonwood were the most abundant riparian woody species sampled on bars and channel margins at the 3D Channel.

Accurately predicting the peak seed dispersal timing of dominant riparian woody plant species will be an important management tool for selectively recruiting species in different water year types and sequences (e.g., black cottonwood). The sex ratios, flower, and seed dispersal observations on Lee Vining and Rush creeks have been helpful in interpreting riparian woody vegetation response to streamflows and geomorphic setting.

5.1.4 Discussion

Riparian plant species did not respond to 2004 peak streamflows within the four geomorphic settings sampled at the 8 Channel (Table 21). Two riparian species were sampled at the 8 Channel: narrowleaf willow and mugwort. There were two occurrences of narrowleaf willow root sprouts in plots adjacent

Table 20. Species sampled during vegetation response monitoring, spring and fall 2004.

	Family	Genus, species, variety and/or subspecies	Common Name	Habit	Hydric Code
1	Asteraceae	*Artmesia douglasii*	mugwort	Herb	FAC+
2	Asteraceae	*Artmesia tridentata*	sage brush	Shrub	NA
3	Asteraceae	*Chaenactis douglasii var. douglasii*	dusty maidens	Herb	NA
4	Asteraceae	*Chrysothamnus nauseosus*	rubber rabbitbrush	Shrub	NA
5	Asteraceae	*Chrysothamnus visidiflorus*	yellow rabbitbrush	Shrub	NA
6	Boraginaceae	*Cryptantha circumscissa*		Herb	NA
7	Boraginaceae	*Cryptantha watsonii*		Herb	NA
8	Boraginaceae	*Tiquilia nuttallii*		Herb	UPL
9	Chenopodiaceae	*Chenopodium nevadens*		Herb	NA
10	**Chenopodiaceae**	***Salsola tragus***	**russian thistle**	**Herb**	**NA**
11	Cyperaceae	*Cyperus squarrosus*	nutsedge	Em Herb	OBL
12	Hydrophyllaceae	*Phacelia bicolor var. bicolor*		Herb	NA
13	Juncaceae	*Juncus covilleii var. obtustatus*		Em Herb	FACW
14	Juncaceae	*Juncus mexicanus*		Em Herb	FACW
15	Juncaceae	*Juncus phaeocephalus*		Em Herb	FACW
16	Loasaceae	*Mentzelia congesta*		Herb	NA
17	Onagraceae	*Epilobium ciliatum*		Herb	FACW
18	Onagraceae	*Gayophytum ramosissimum*	many flowered smoke weed	Herb	NA
19	Onagraceae	*Oenothera elata ssp. hirstuissima*	evening primrose	Herb	FACW
20	Poaceae	*Achnatherum hymenoides*	Indian rice grass	Grass	UPL
21	**Poaceae**	***Bromus tectorum***	**cheat grass**	**Grass**	**NA**
22	Poaceae	*Elymus elymoides ssp. elymoides*	squirrel tail	Grass	FACU-
23	**Poaceae**	***Poa pratensis ssp. pratensis***	**kentucky bluegrass**	**Grass**	**FAC**
24	Poaceae	*Poa sp.*		Grass	NA
25	Polemoniaceae	*Eriastrum sparsiflorum*		Herb	NA
26	Polemoniaceae	*Gilia cana ssp. speciosa*		Herb	NA
27	Polygonaceae	*Eriogonum ampullaceum*	Mono buckwheat	Herb	NA
28	Polygonaceae	*Oxytheca dendroidea ssp. dendrodea*		Herb	NA
29	Portulaceae	*Calyptridium roseum*		Herb	FACU
30	Rosaceae	*Potentilla gracilis var. elmeri*		Herb	FAC
31	Rosaceae	*Purshia tridentata*	bitterbush	Shrub	NA
32	Salicaceae	*Populus balsamifera ssp. trichocarpa*	black cottonwood	Tree	FACW
33	Salicaceae	*Salix exigua*	narrowleaf willow	Shrub	FACW
34	Salicaceae	*Salix geyeriana*	Geyer's willow	Tree	OBL
35	Salicaceae	*Salix lucida ssp. lasiandra*	shiny willow	Tree	OBL
36	Salicaceae	*Salix lutea*	yellow willow	Tree	OBL
37	**Scrophulariaceae**	***Verbascum thapsus***	**wooley mullien**	**Herb**	**NI**
38	Scrophulariaceae	*Veronica serpyllifolia ssp. humifusa*		Herb	NI*

to the 8 channel where existing mature plants roots could quickly re-colonized areas disturbed by construction. We did not present changes in riparian woody plant density for this site due to the low number of stems sampled.

Species richness at the 3D Channel is much higher than the 8 Channel because overbank flows across the 3D site have delivered the seeds of new species to geomorphic settings appropriate to their life history strategies (compare Tables 21 and 22).

The four geomorphic settings sampled at the 3D Channel showed predictable trends in response to 2004 peak streamflows (Table 22). Black cottonwood seedlings were present in 100% of the plots sampled on bar surfaces at the 3D Channel in the spring 2004. During the fall sample we observed that riparian plant species were abundant on bar surfaces and on the edge of the main side channel, though riparian woody plant species desiccated in both these geomorphic settings. In spite of desiccation mortality, many seedlings survived and initiated on bars and along channel margins (Figure 44). Riparian plant species were not consistently found within depressions, presumably

Table 21. Desert and riparian plant species response to the re-opening of the 8 Channel entrance and 2004 SRF releases.

		Upstream in 8-Channel (n=4)	***Adjacent to the 8-Channel (n=4)***	***Downstream in the 8-Channel (n=4)***	***Terrace Surface between the 8-Channel and mainstem Rush Creek (n=4)***
SPRING 2004	Total Number of Desert Species	4	9	1	8
	Total Number of Riparian Species	0	2	0	1
	Frequency of Desert Species in Plots	50%	50%	17%	92%
	Frequency of Riparian Herb Species in Plots	0%	17%	0%	17%
	Frequency of Riparian Hardwood Species in Plots	0%	25%	0%	0%
FALL 2004	Total Number of Desert Species	4	8	1	4
	Total Number of Riparian Species	0	2	0	1
	Frequency of Desert Species in Plots	75%	33%	50%	67%
	Frequency of Riparian Herb Species in Plots	0%	17%	0%	17%
	Frequency of Riparian Hardwood Species in Plots	0%	25%	0%	0%

because some are isolated from overbank flows and others are not. This result suggests the importance of overbank flows in transporting new species to recently exposed surfaces through *hydrochory* (i.e., seeds delivered by water). High spots in the constructed surface are recruiting desert species and functioning as high terraces.

Peak streamflows in spring 2004 caused the side-channel to re-adjust at the 3D Channel site, completely scouring and re-depositing a bar in the lower end where one of the bar plots was located. A head-cut has left another bar and edge plot high above the current side-channel water surface. Two gravel bars in the 3D side-channel were scour and re-deposited as a result of the side-channel re-adjustment. Plant species sampled in plots located on those bars were completely scoured away (plots B-1 and B-4). Channel adjustments are expected, and the riparian plant species that had initiated on the bar surfaces will likely again initiate adjacent to and on bars within the re-adjusted channel.

Table 22. Desert and riparian plant species response to the re-opening of the 3D Channel entrance and 2004 SRF releases.

		Bars on Main Side Channel (n=4)	***Edges of Main Side Channel (n=-4)***	***Depressions in Constructed Surface (n=4)***	***High Spots on Constructed Surface (n=4)***
SPRING 2004	Total Number of Desert Species	3	3	2	0
	Total Number of Riparian Species	16	9	11	0
	Frequency of Desert Species in Plots	33%	58%	8%	0%
	Frequency of Riparian Herb Species in Plots	83%	42%	75%	0%
	Frequency of Riparian Hardwood Species in Plots	100%	100%	100%	0%
FALL 2004	Total Number of Desert Species	2	1	0	4
	Total Number of Riparian Species	8	7	13	0
	Frequency of Desert Species in Plots	25%	25%	0%	75%
	Frequency of Riparian Herb Species in Plots	42%	42%	50%	0%
	Frequency of Riparian Hardwood Species in Plots	50%	75%	75%	0%

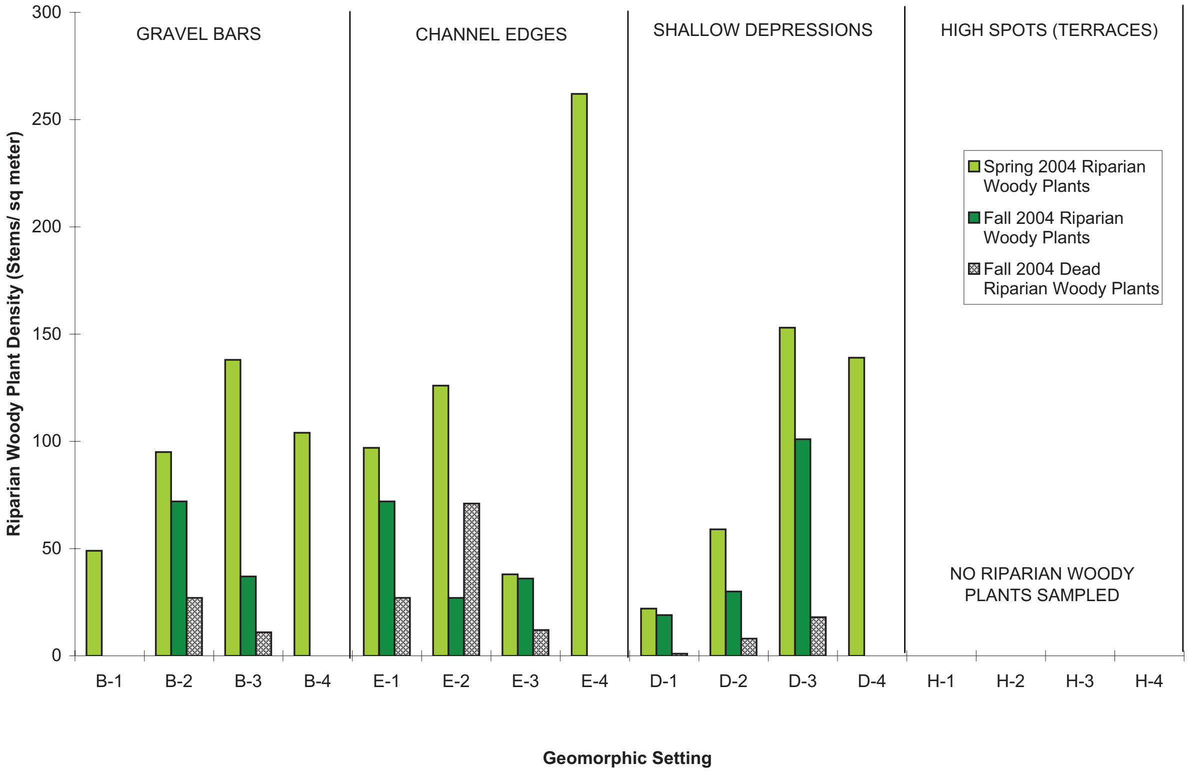

Figure 44. Hardwood seedling density at vegetation monitoring plots at the 3D Floodplain site.

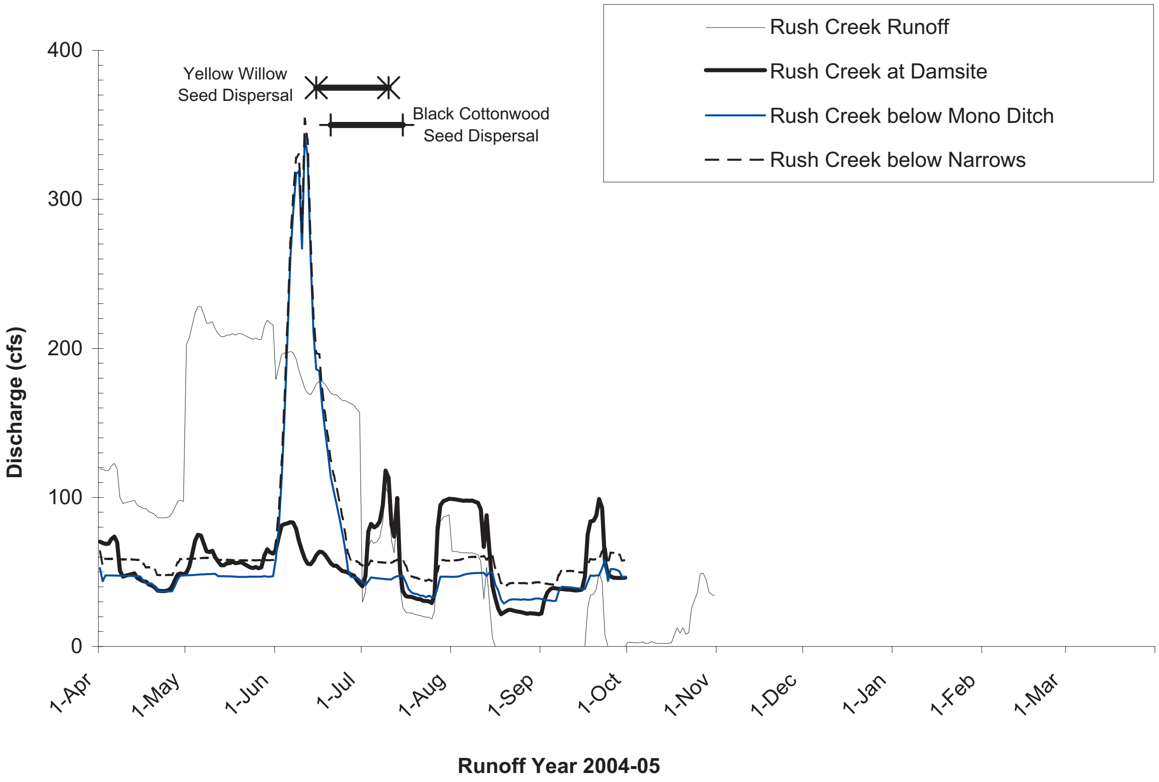

Figure 45. Lee Vining Creek RY 2004 hydrograph with seed dispersal periods for black cottonwood and yellow willow.

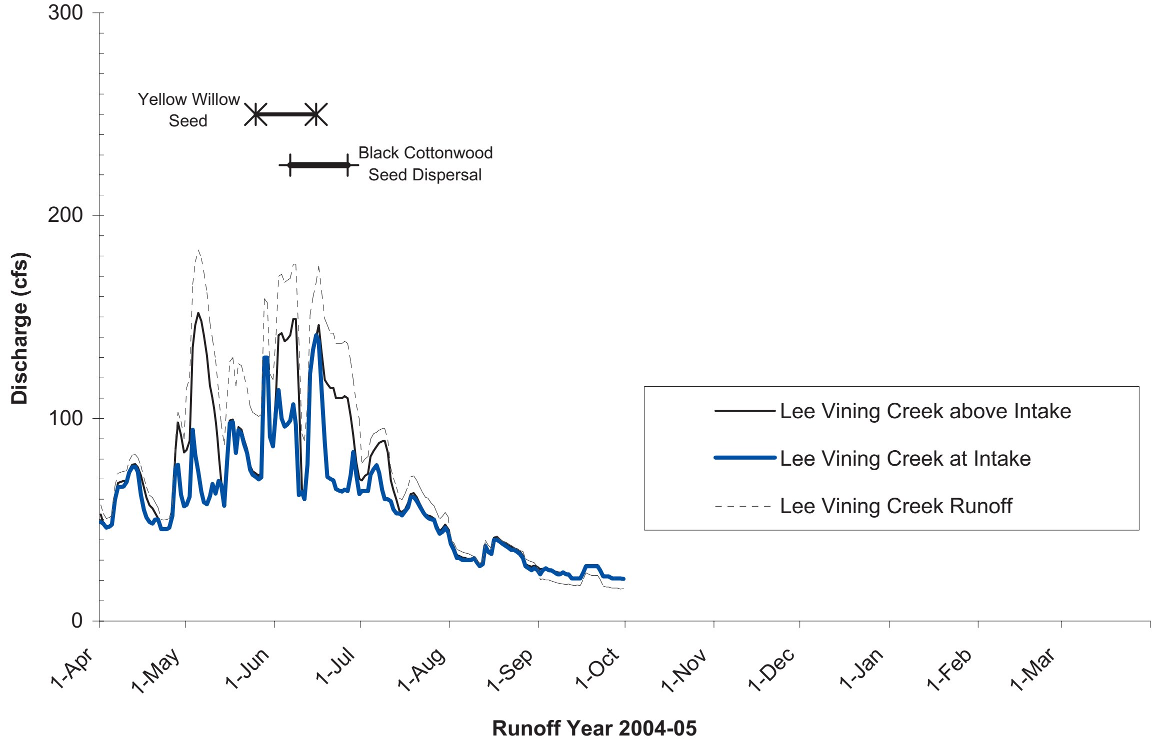

Figure 46. Rush Creek RY 2004 hydrograph with seed dispersal periods for black cottonwood and yellow willow.

6 2005-06 MONITORING SEASON

- Complete planmapping at Lee Vining, Parker and Walker creek planmap sites prior to 2005 snowmelt; conduct comparisons of the 2004 planmaps with the 1999 planmaps;

- Re-install painted tracer rocks and scour cores on Rush and Lee Vining creeks in anticipation of a large-magnitude snowmelt event;

- Continue groundwater and soil moisture data collection at the 3D and 8 Floodplains, with emphasis on the 8 Floodplain as greater flow enters the 8-Channel. Observations will continue to contrast the 8 Floodplain with the 4bii-Floodplain. Dataloggers will be re-installed in piezometers to collect continuous data. Several sites for anecdotal soil moisture data will be included across the 8 Floodplain. We are contemplating an additional piezometer at the downstream extent of the 8 Floodplain.

- Refine floodplain deposition monitoring methods, primarily to quantify rates of fine sediment transported as bedload and deposited on floodplains and along channel margins (more detailed recommendations are provided in Section 3.3.4).

- Replicate riparian vegetation nested frequency transect and band transect sampling conducted in 1999 on Rush and Lee Vining creeks;

- Re-operate the Rush Creek County Road gaging station, developing an updated stage-discharge rating curve, and collecting 15-minute data during the Rush Creek SRF releases for comparisons to LADWP gage data. Maintain gaging dataloggers at the 3D Channel and Lower Rush Creek floodplain monitoring sites for additional 15 minute discharge data. Continue synoptic discharge measurements during the SRF releases.

- Continue large woody debris mobility and transport experiment, adding additional marked wood pieces in Upper Rush Creek and in Lee Vining Creek.

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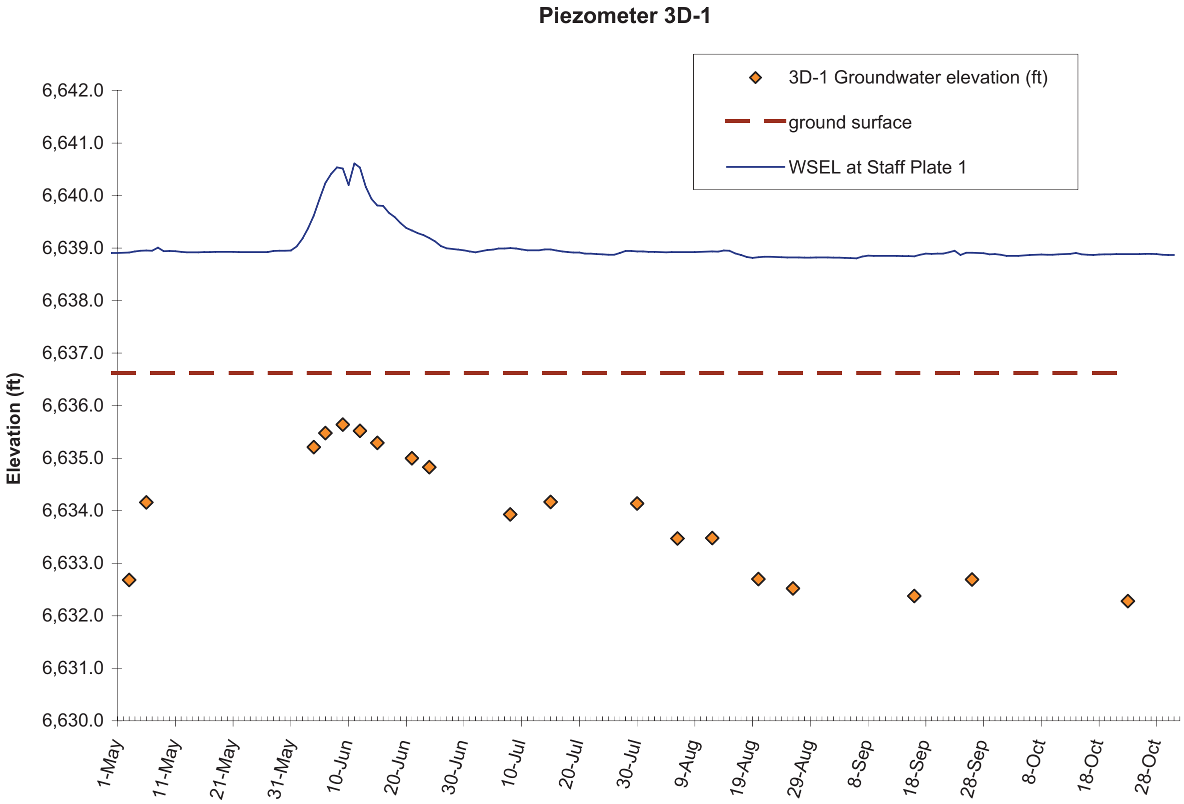
APPENDIX A
Groundwater Monitoring Data for Rush Creek 3D and 8 Floodpains


Piezometer 3D-1
3D-1 Groundwater elevation (ft)
ground surface
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Elevation (ft)
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6,641.0
6,640.0
6,639.0
6,638.0
6,637.0
6,636.0
6,635.0
6,634.0
6,633.0
6,632.0
6,631.0
6,630.0
1-May
11-May
21-May
31-May
10-Jun
20-Jun
30-Jun
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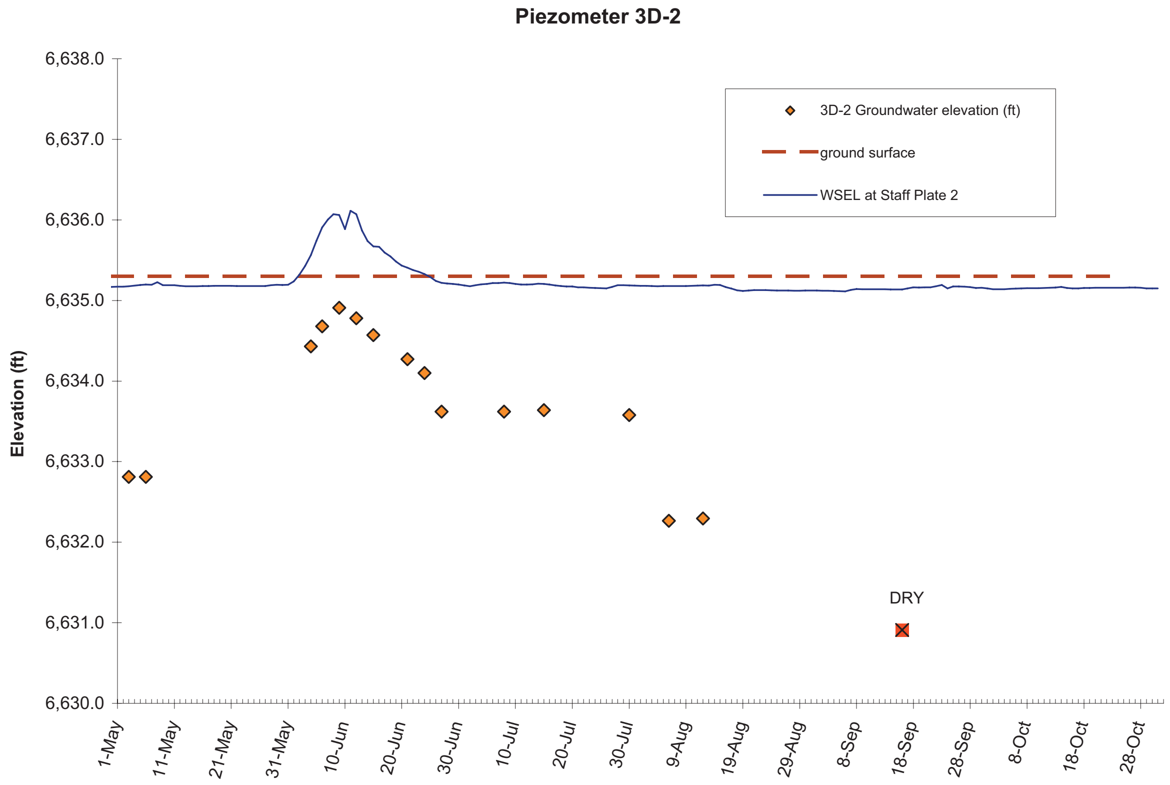
8-Oct
18-Oct
28-Oct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3D-2 Groundwater elevation (ft)
ground surface
WSEL at Staff Plate 2
Elevation (ft)
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6,637.0
6,636.0
6,635.0
6,634.0
6,633.0
6,632.0
6,631.0
6,630.0
DRY
1-May
11-May
21-May
31-May
10-Jun
20-Jun
30-Jun
10-Jul
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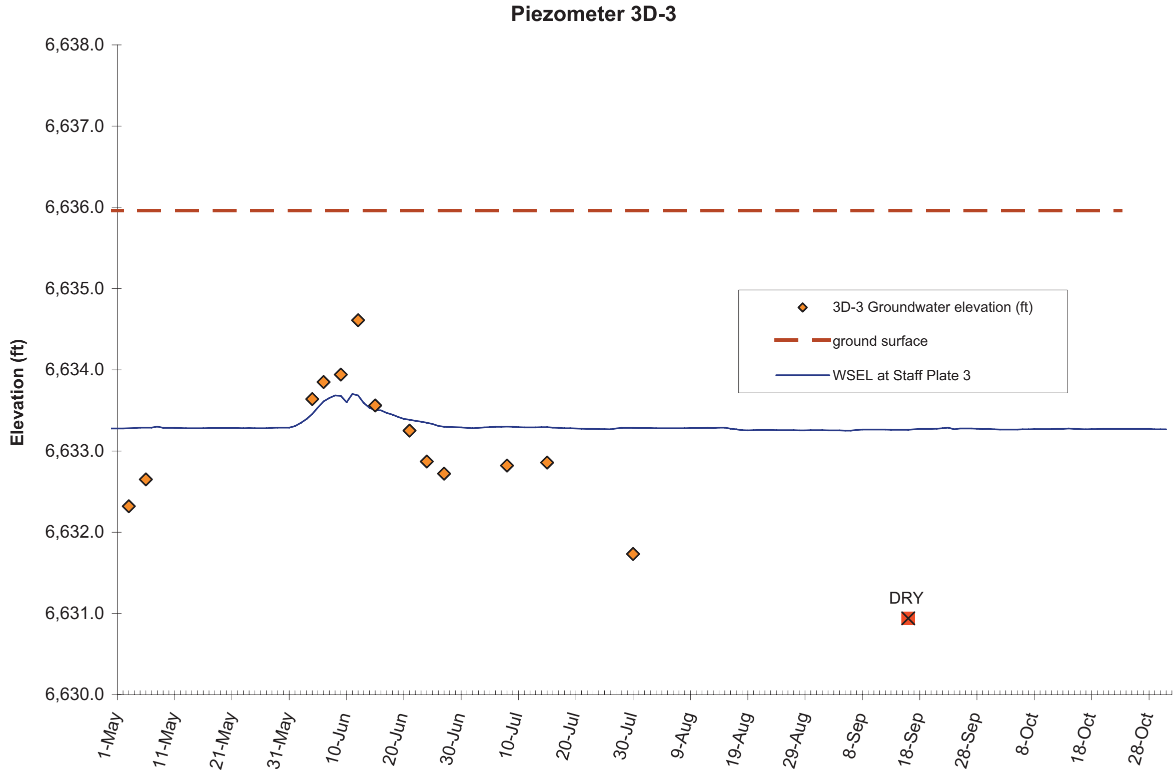
28-Sep
8-Oct
18-Oct
28-Oct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6,635.0
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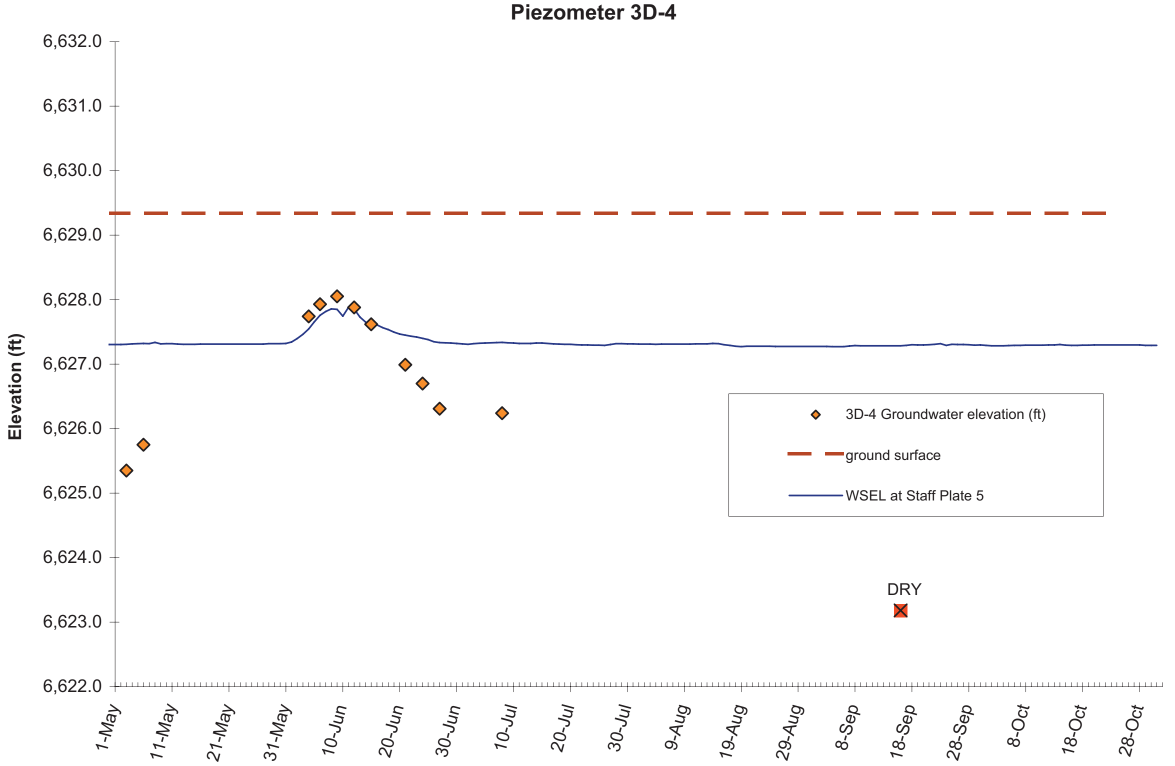
6,631.0
6,630.0
1-May
11-May
21-May
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
19-Aug
29-Aug
8-Sep
18-Sep
28-Sep
8-Oct
18-Oct
28-Oct
3D-3 Groundwater elevation (ft)
ground surface
WSEL at Staff Plate 3
DRY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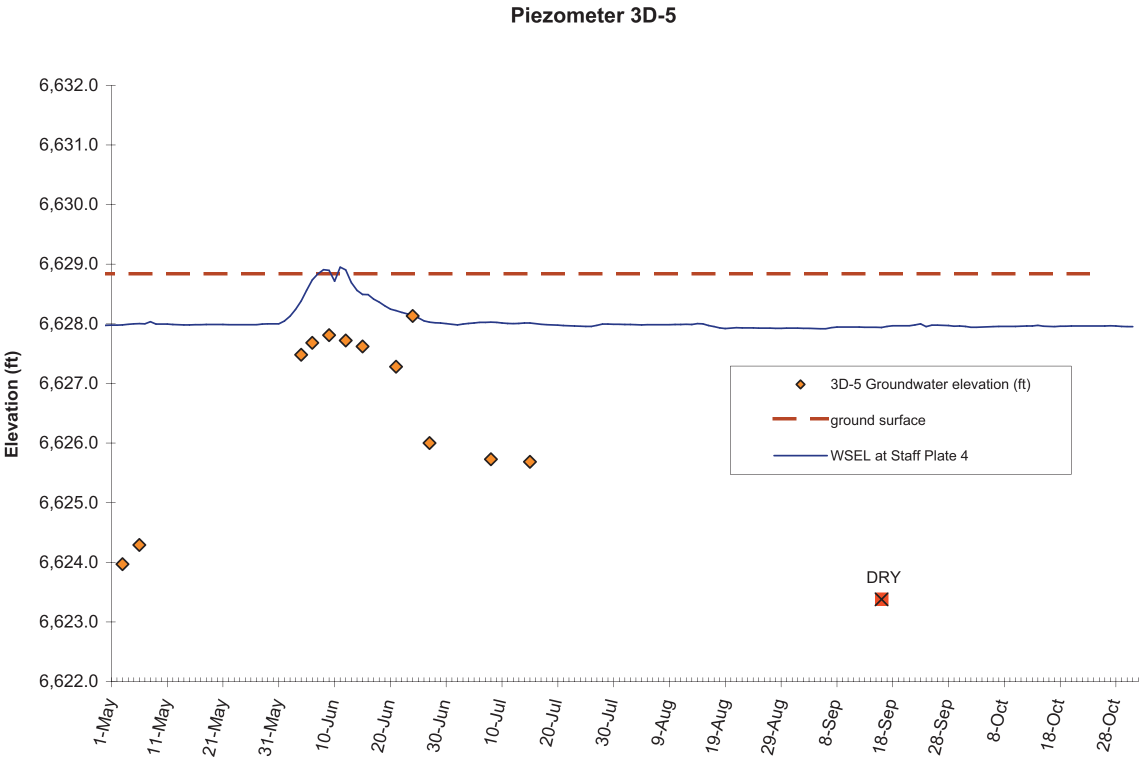
6,623.0
6,622.0
1-May
11-May
21-May
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
19-Aug
29-Aug
8-Sep
18-Sep
28-Sep
8-Oct
18-Oct
28-Oct
3D-4 Groundwater elevation (ft)
ground surface
WSEL at Staff Plate 5
DRY


Piezometer 3D-5
Elevation (ft)
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6,631.0
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6,629.0
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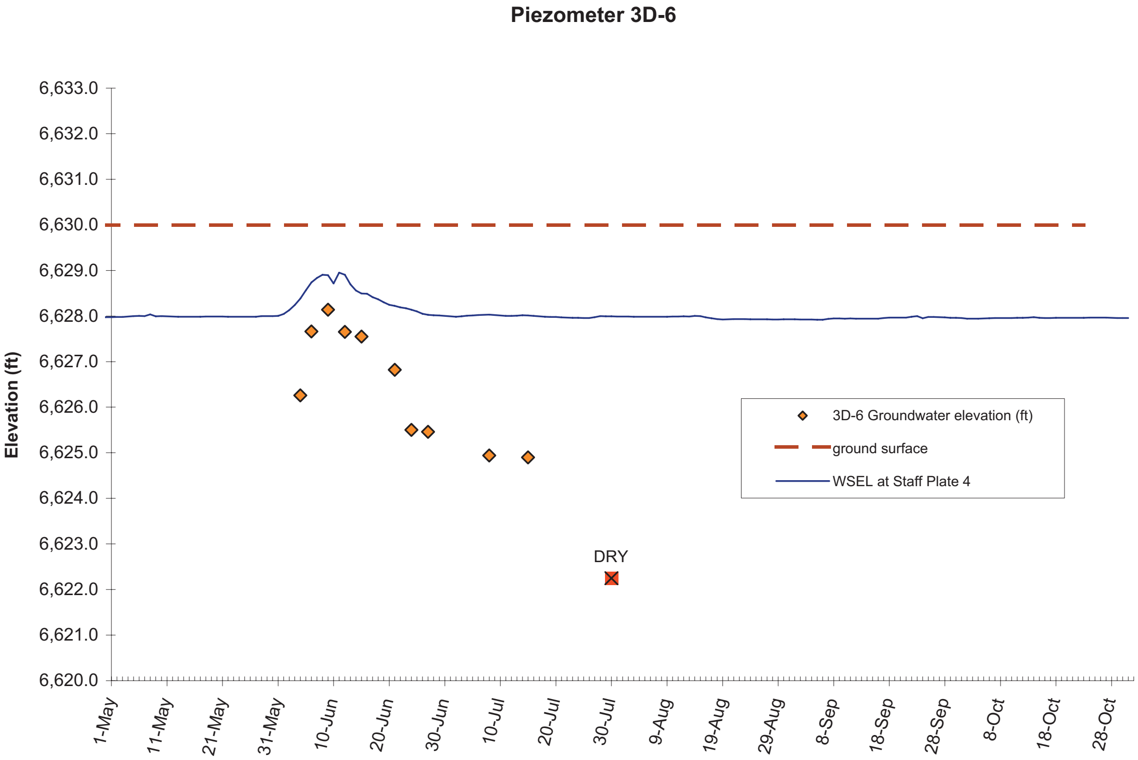
6,625.0
6,624.0
6,623.0
6,622.0
1-May
11-May
21-May
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
19-Aug
29-Aug
8-Sep
18-Sep
28-Sep
8-Oct
18-Oct
28-Oct
3D-5 Groundwater elevation (ft)
ground surface
WSEL at Staff Plate 4
DRY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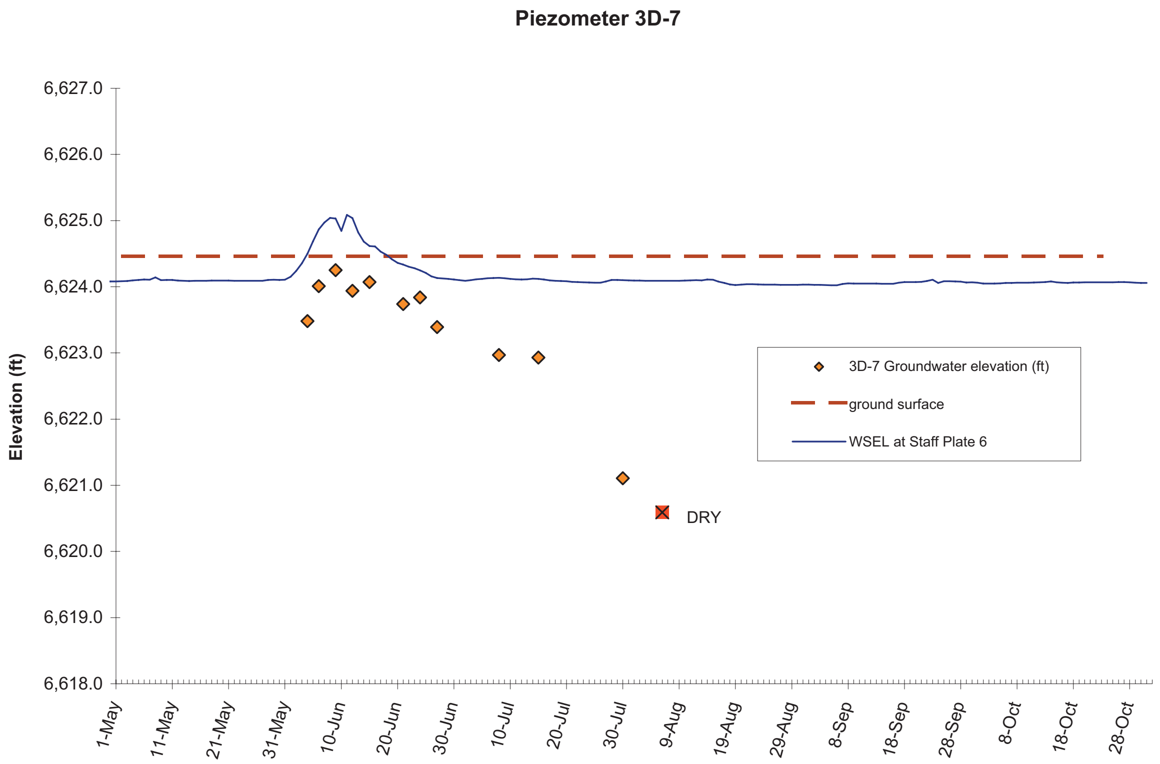
6,630.0
6,629.0
6,628.0
6,627.0
6,626.0
6,625.0
6,624.0
6,623.0
6,622.0
6,621.0
6,620.0
1-May
11-May
21-May
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
19-Aug
29-Aug
8-Sep
18-Sep
28-Sep
8-Oct
18-Oct
28-Oct
3D-6 Groundwater elevation (ft)
ground surface
WSEL at Staff Plate 4
DRY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6,621.0
6,620.0
6,619.0
6,618.0
1-May
11-May
21-May
31-May
10-Jun
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30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
19-Aug
29-Aug
8-Sep
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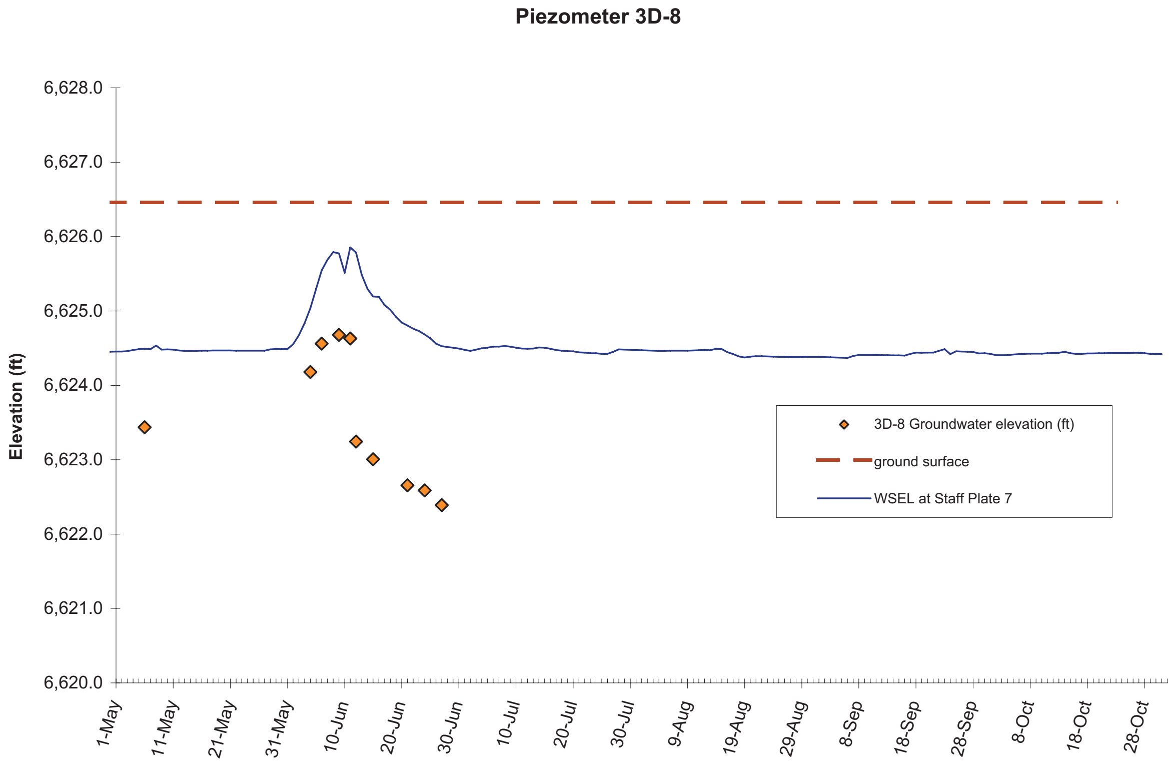
28-Sep
8-Oct
18-Oct
28-Oct
3D-7 Groundwater elevation (ft)
ground surface
WSEL at Staff Plate 6
DRY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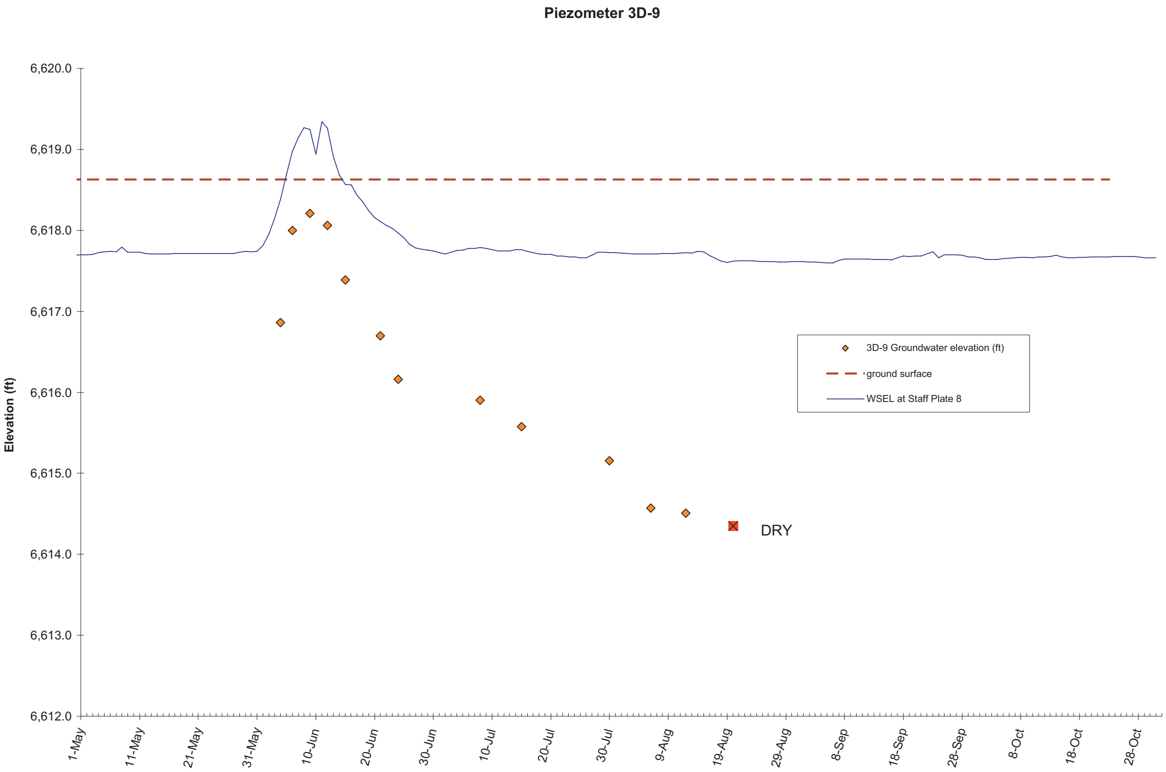
6,621.0
6,620.0
1-May
11-May
21-May
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
19-Aug
29-Aug
8-Sep
18-Sep
28-Sep
8-Oct
18-Oct
28-Oct
3D-8 Groundwater elevation (ft)
ground surface
WSEL at Staff Plate 7


Piezometer 3D-9
Elevation (ft)
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6,618.0
6,617.0
6,616.0
6,615.0
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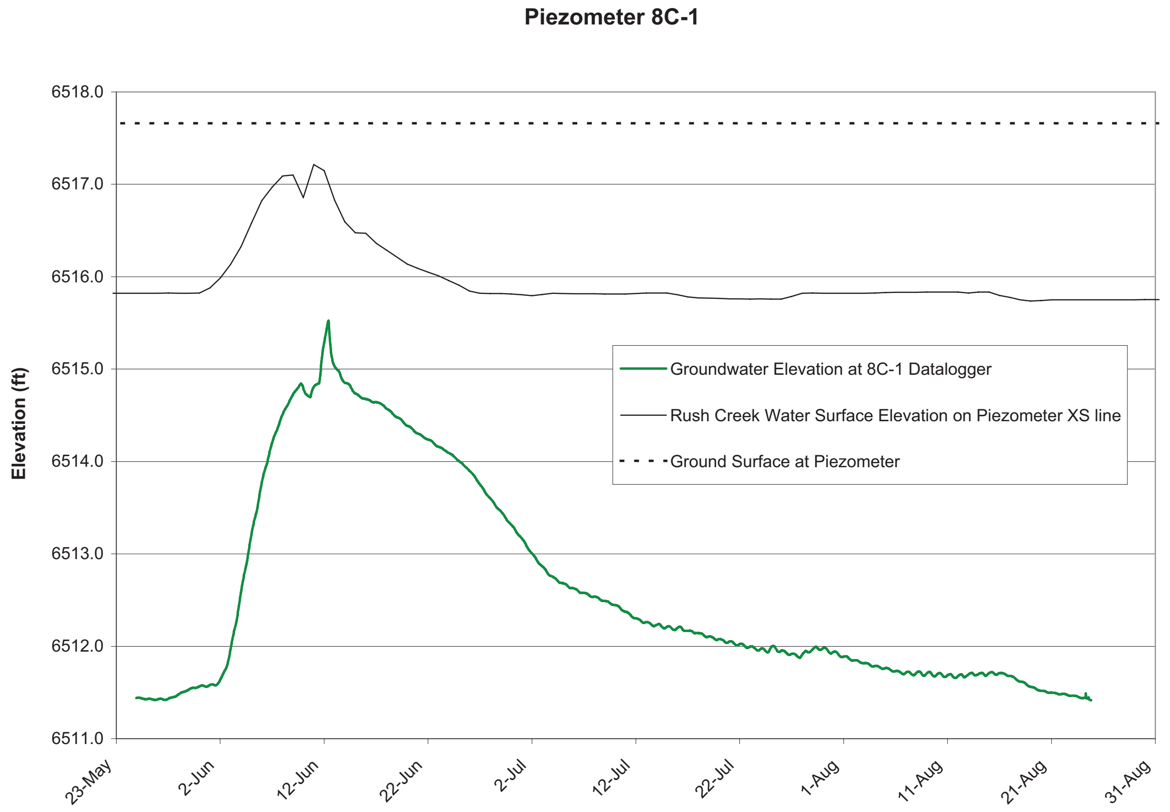
6,613.0
6,612.0
1-May
11-May
21-May
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
19-Aug
29-Aug
8-Sep
18-Sep
28-Sep
8-Oct
18-Oct
28-Oct
3D-9 Groundwater elevation (ft)
ground surface
WSEL at Staff Plate 8
DRY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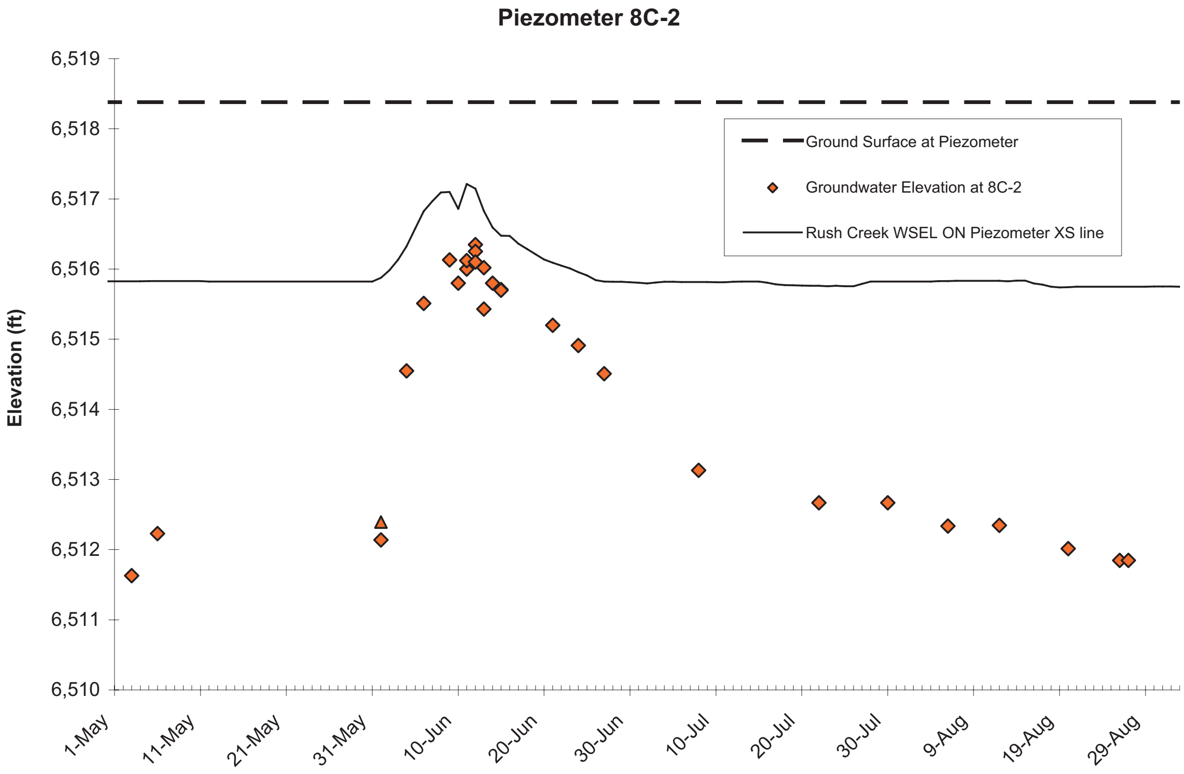
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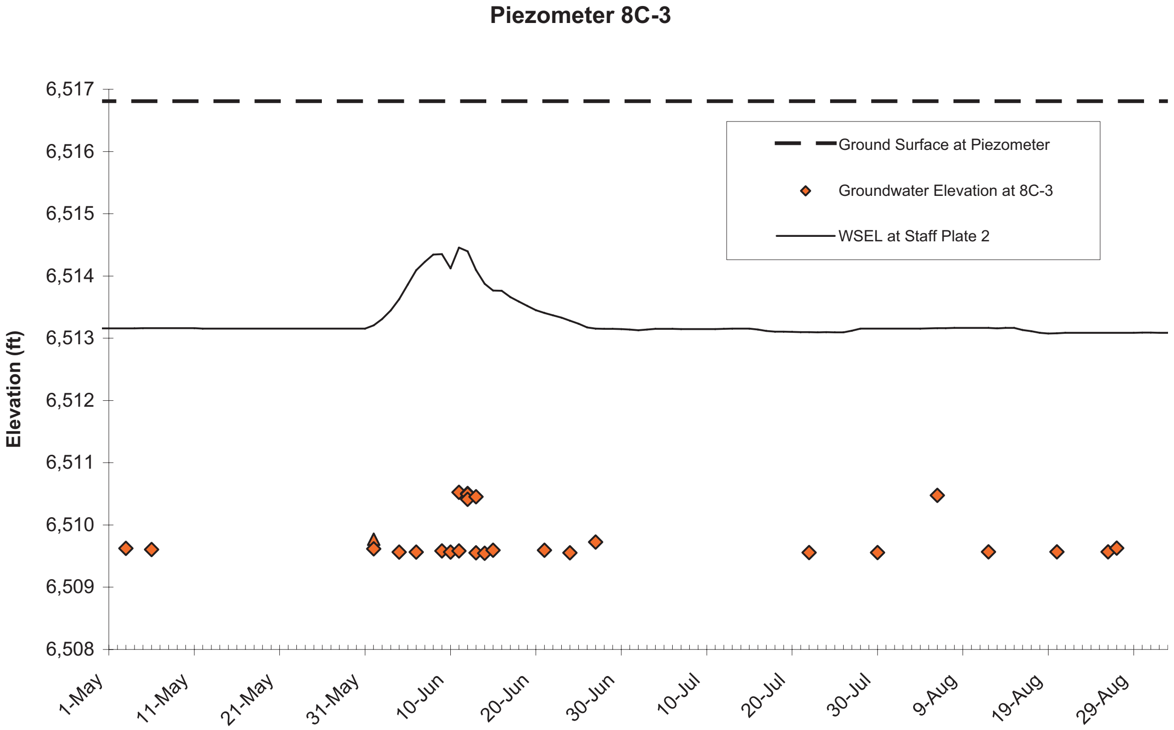
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Elevation (ft)
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6,516
6,515
6,514
6,513
6,512
6,511
6,510
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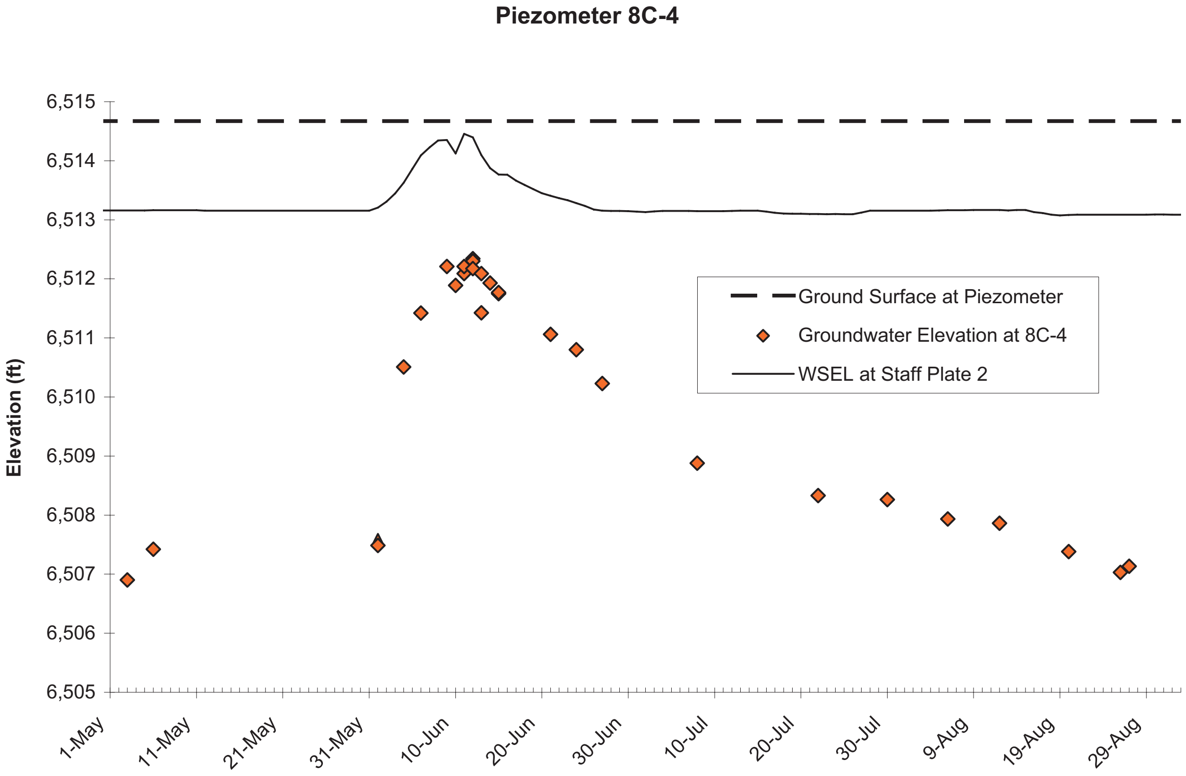
6,508
1-May
11-May
21-May
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
19-Aug
29-Aug
Ground Surface at Piezometer
Groundwater Elevation at 8C-3
WSEL at Staff Plate 2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6,511
6,510
6,509
6,508
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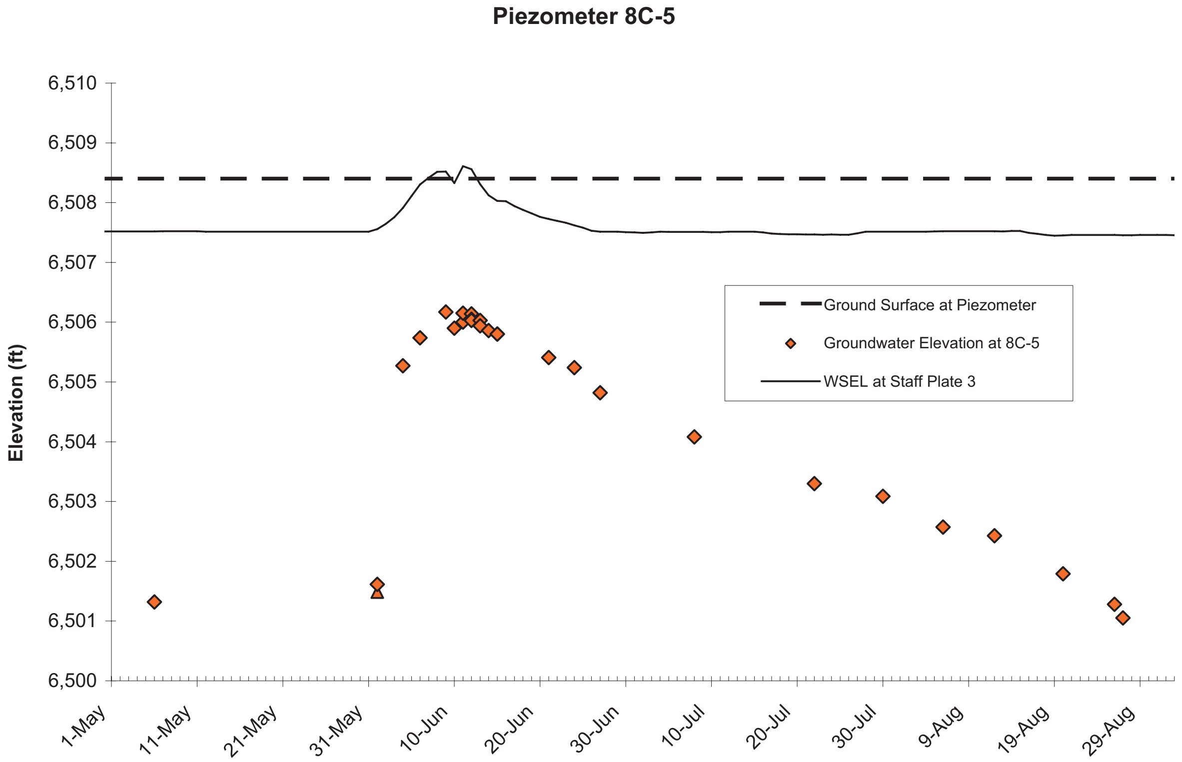
6,506
6,505
1-May
11-May
21-May
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
19-Aug
29-Aug
Ground Surface at Piezometer
Groundwater Elevation at 8C-4
WSEL at Staff Plate 2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6,508
6,507
6,506
6,505
6,504
6,503
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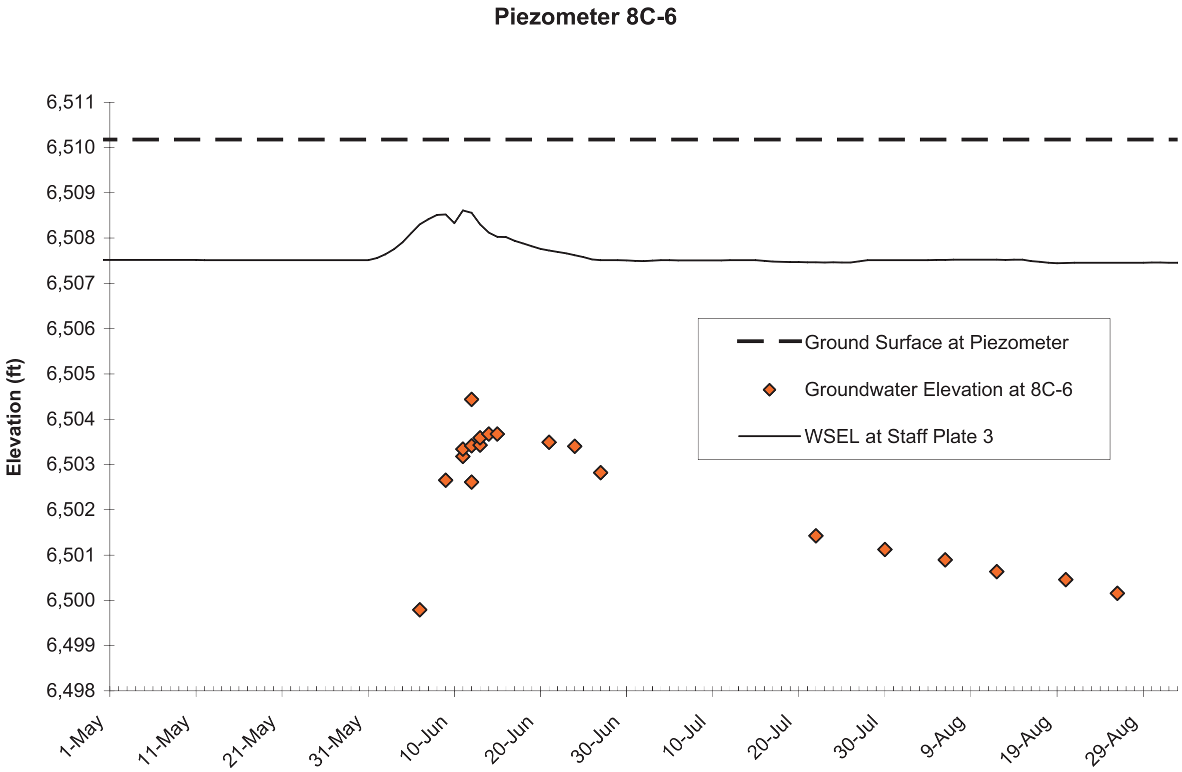
6,500
1-May
11-May
21-May
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
19-Aug
29-Aug
Ground Surface at Piezometer
Groundwater Elevation at 8C-5
WSEL at Staff Plate 3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6,508
6,507
6,506
6,505
6,504
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6,501
6,500
6,499
6,498
1-May
11-May
21-May
31-May
10-Jun
20-Jun
30-Jun
10-Jul
20-Jul
30-Jul
9-Aug
19-Aug
29-Aug
Ground Surface at Piezometer
Groundwater Elevation at 8C-6
WSEL at Staff Plate 3

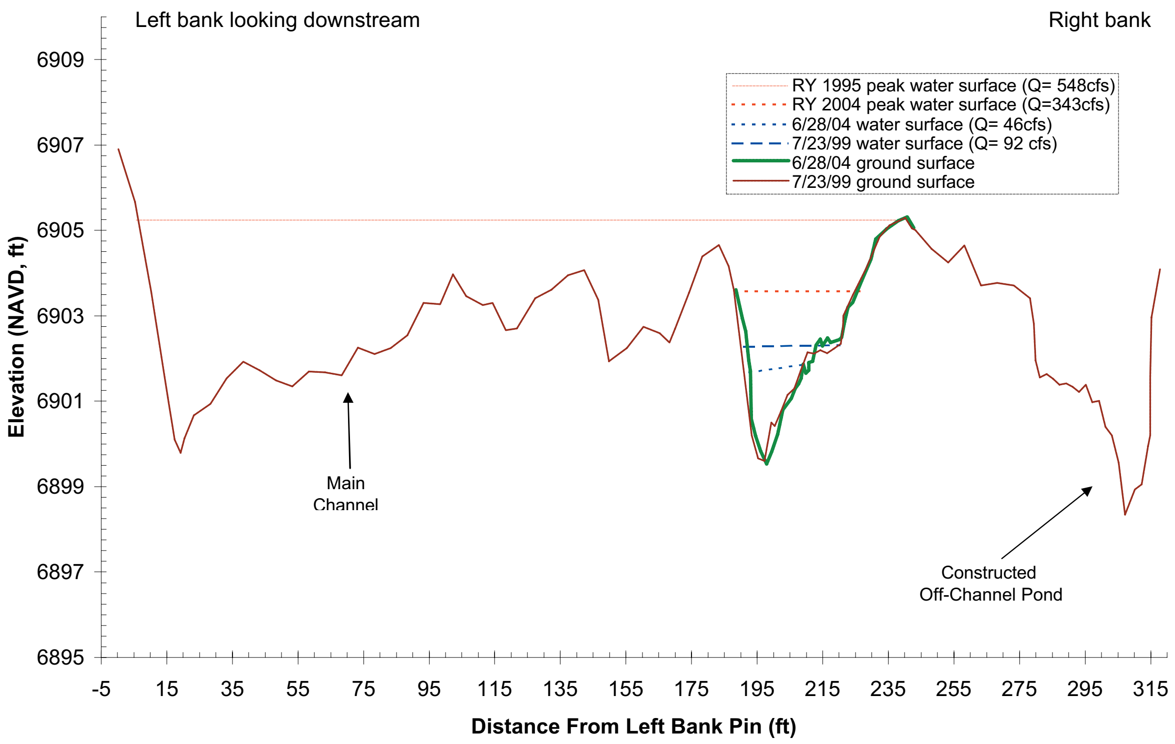
APPENDIX B

Cross Sections for Mono Lake Tributaries: Rush, Parker, Walker, and Lee Vining Creeks

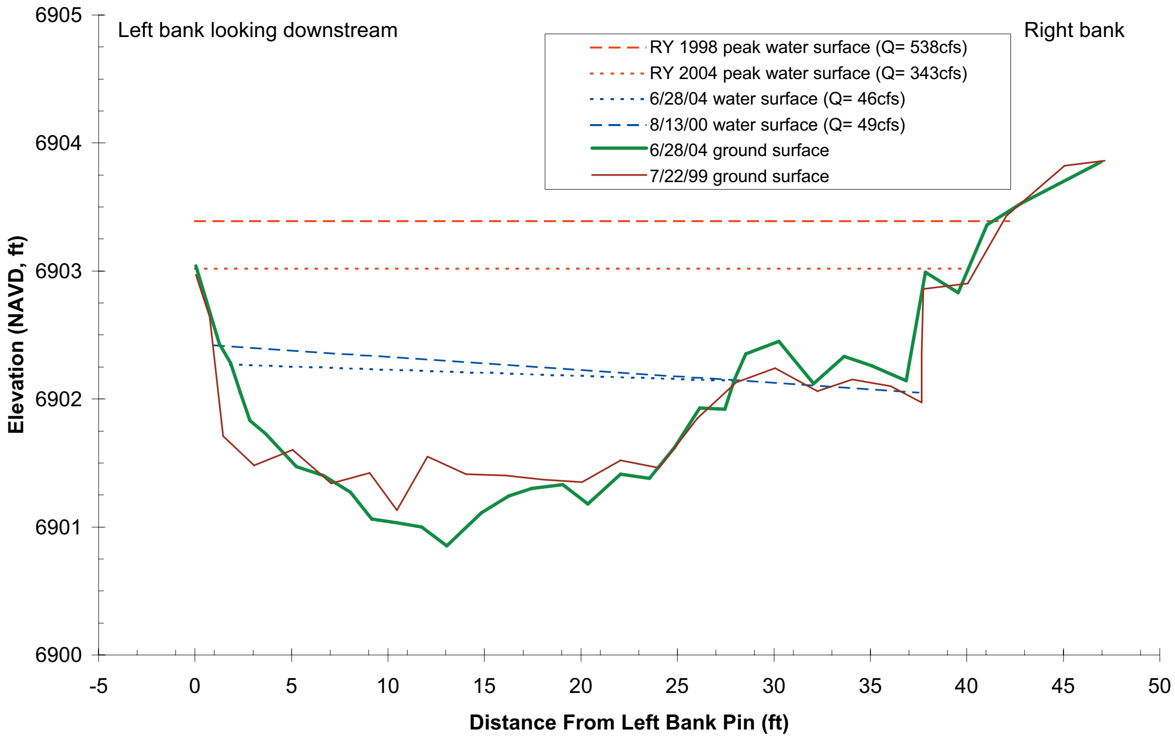
TABLE OF CONTENTS

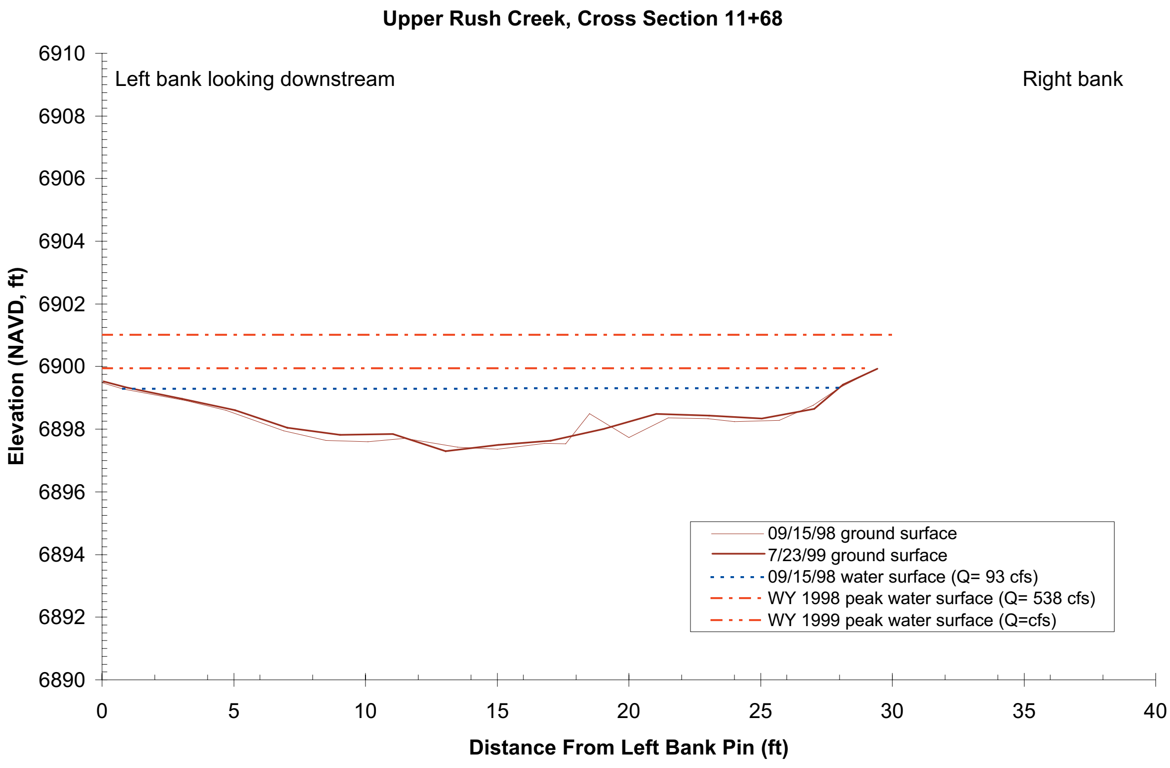
Rush Creek

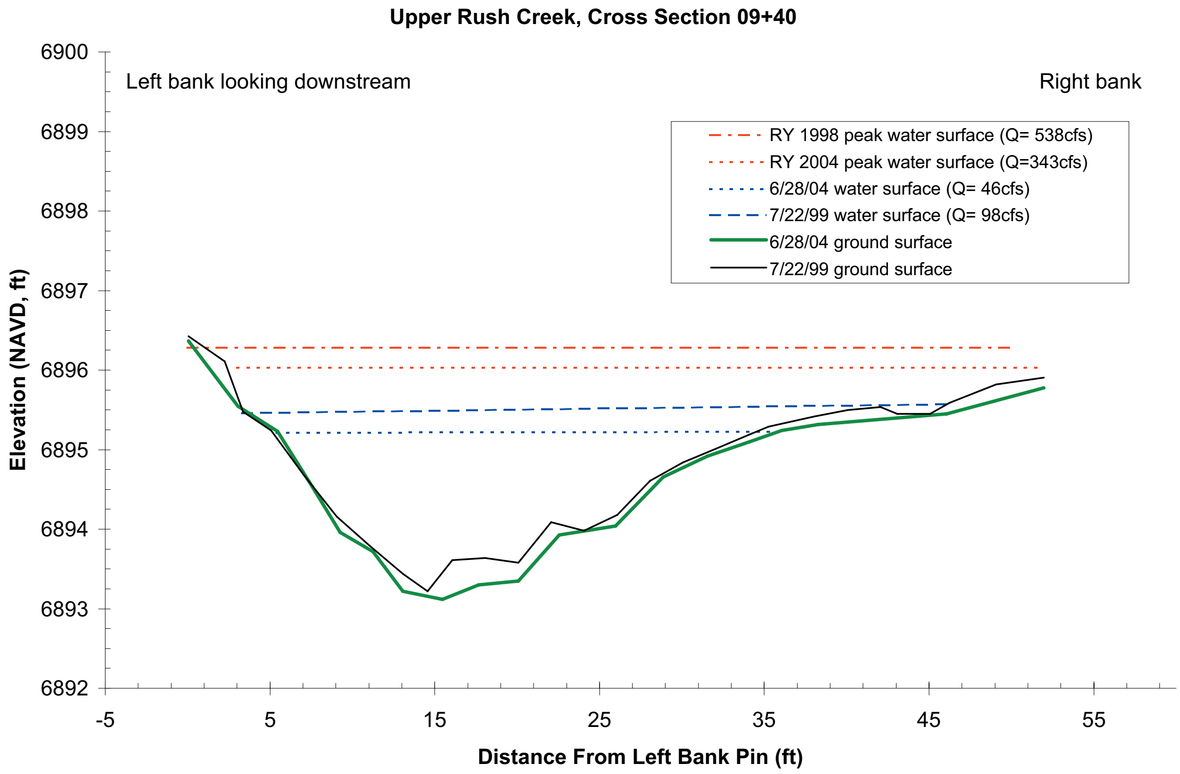
Upper Rush Creek, Valley-Wide Cross Section 13+36

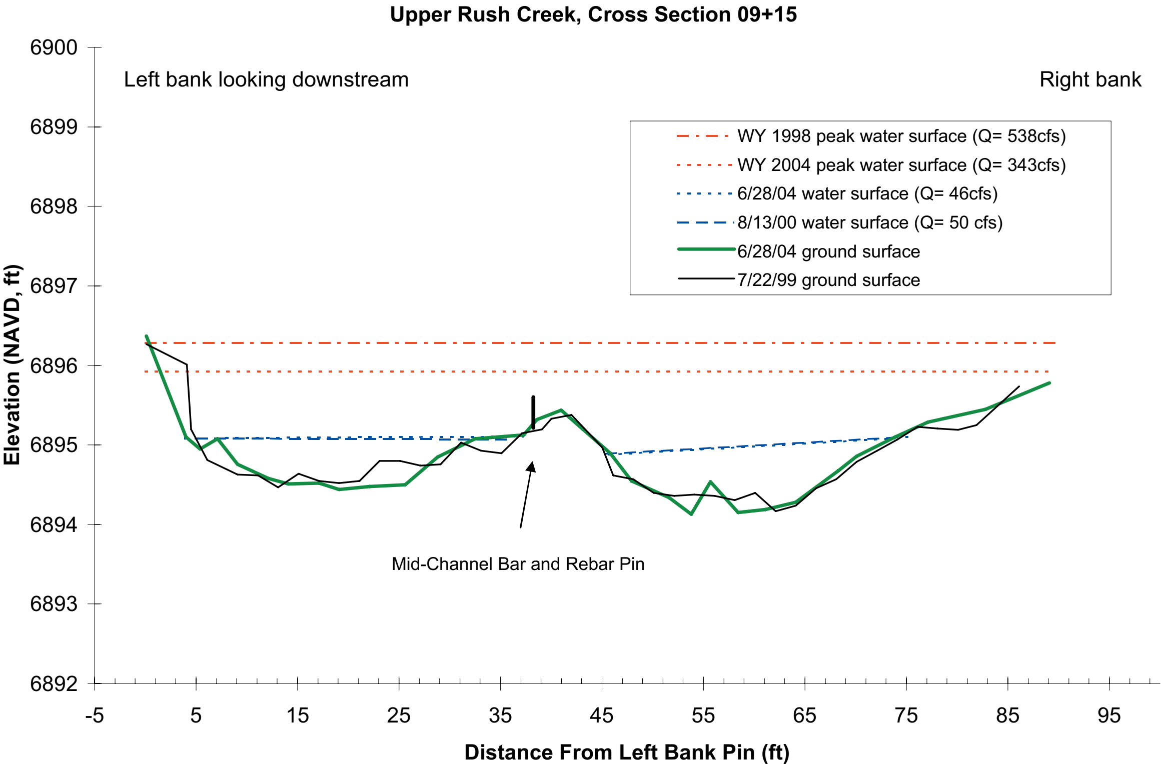


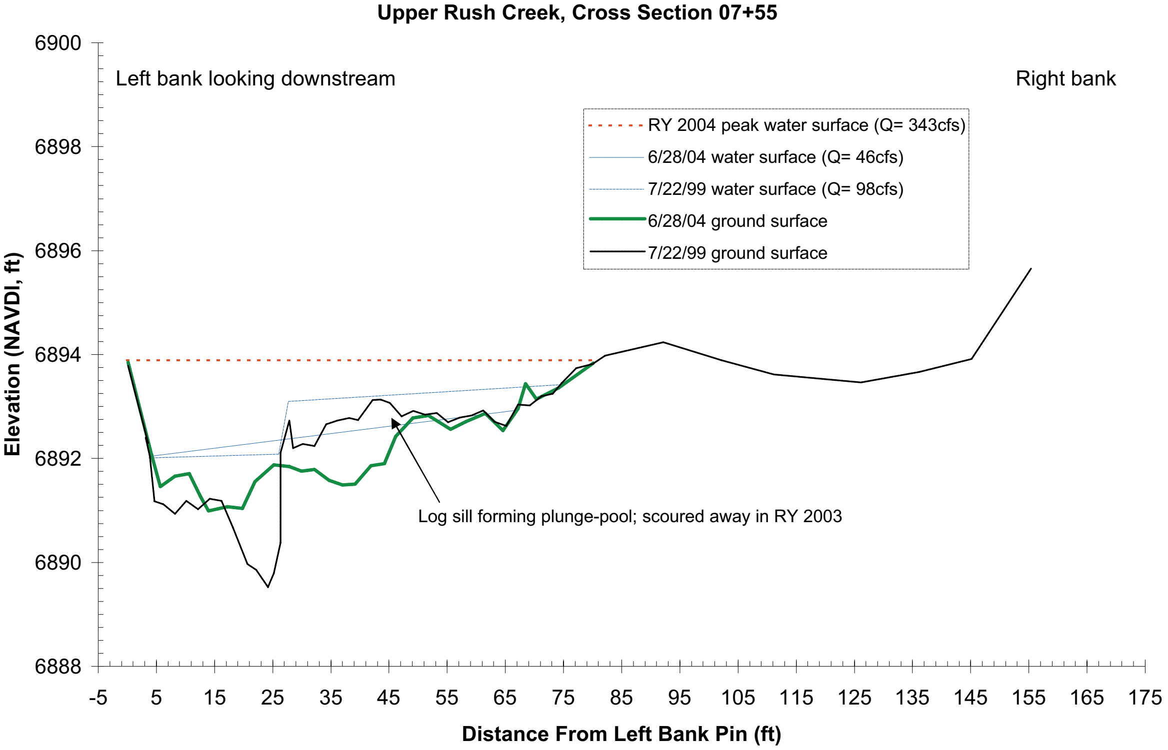
Upper Rush Creek, Cross Section 12+95

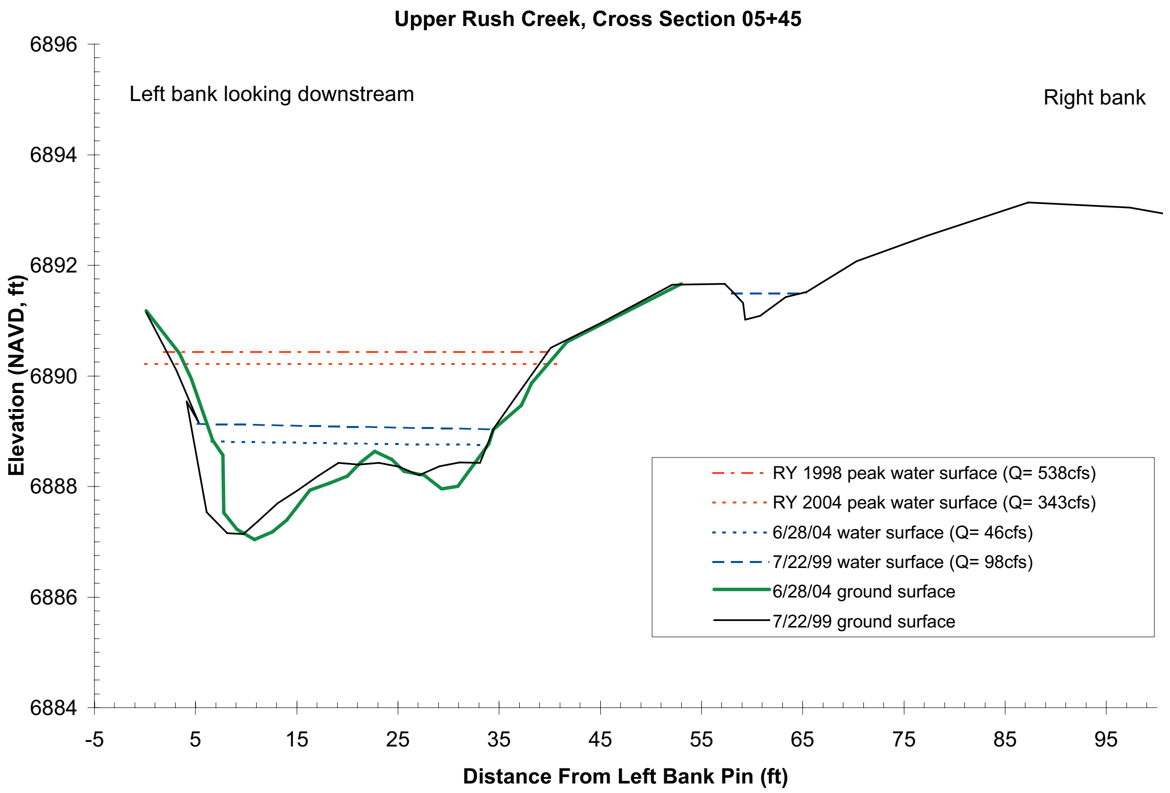


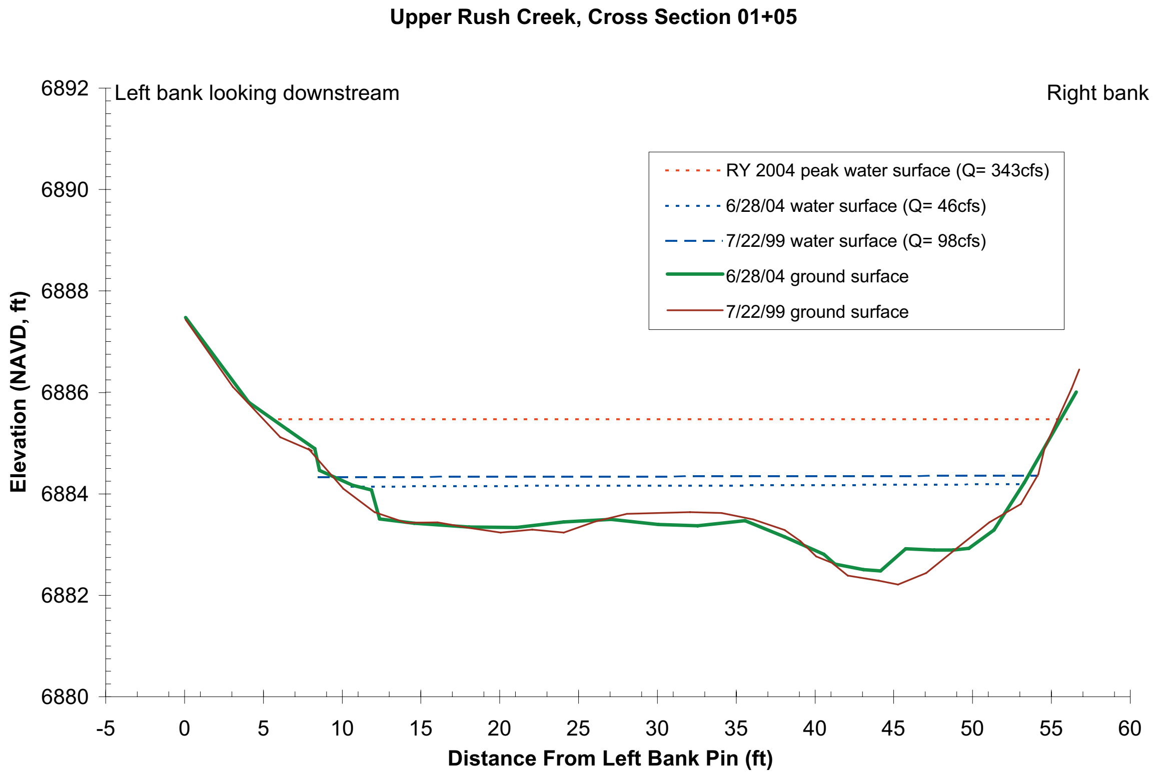

Upper Rush Creek, Cross Section 11+68
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6910
6908
6906
6904
6902
6900
6898
6896
6894
6892
6890
0
5
10
15
20
25
30
35
40
Distance From Left Bank Pin (ft)
09/15/98 ground surface
7/23/99 ground surface
09/15/98 water surface (Q= 93 cfs)
WY 1998 peak water surface (Q= 538 cfs)
WY 1999 peak water surface (Q=cfs)

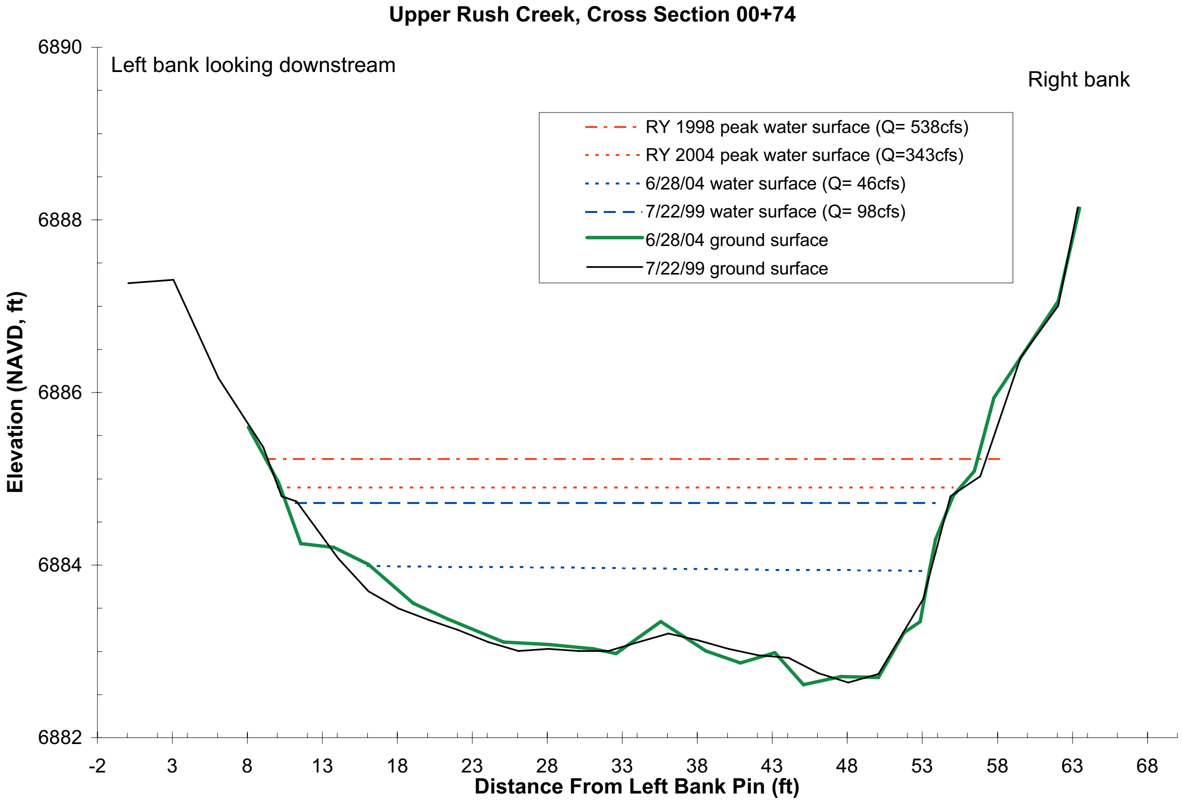

Upper Rush Creek, Cross Section 09+40
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6900
6899
6898
6897
6896
6895
6894
6893
6892
-5
5
15
25
35
45
55
Distance From Left Bank Pin (ft)
RY 1998 peak water surface (Q= 538cfs)
RY 2004 peak water surface (Q=343cfs)
6/28/04 water surface (Q= 46cfs)
7/22/99 water surface (Q= 98cfs)
6/28/04 ground surface
7/22/99 ground surface

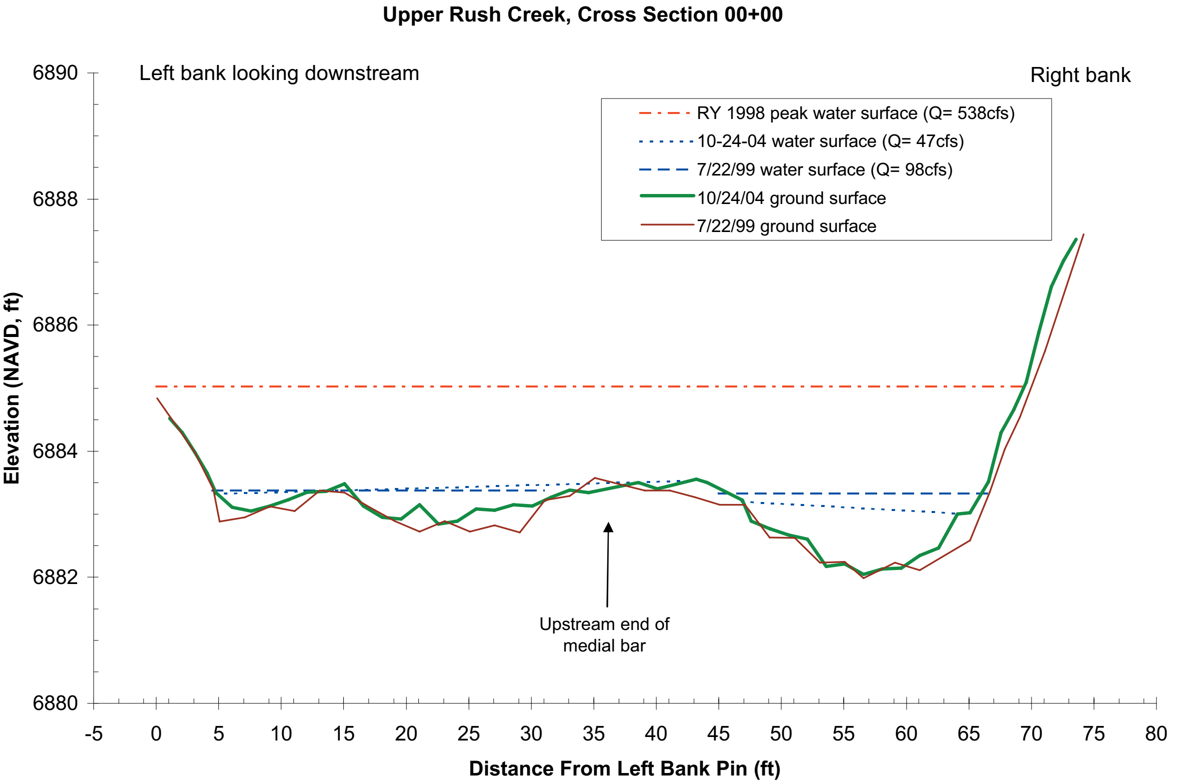

Upper Rush Creek, Cross Section 09+15
Left bank looking downstream
Right bank
WY 1998 peak water surface (Q= 538cfs)
WY 2004 peak water surface (Q= 343cfs)
6/28/04 water surface (Q= 46cfs)
8/13/00 water surface (Q= 50 cfs)
6/28/04 ground surface
7/22/99 ground surface
Mid-Channel Bar and Rebar Pin
Elevation (NAVD, ft)
6900
6899
6898
6897
6896
6895
6894
6893
6892
-5
5
15
25
35
45
55
65
75
85
95
Distance From Left Bank Pin (ft)

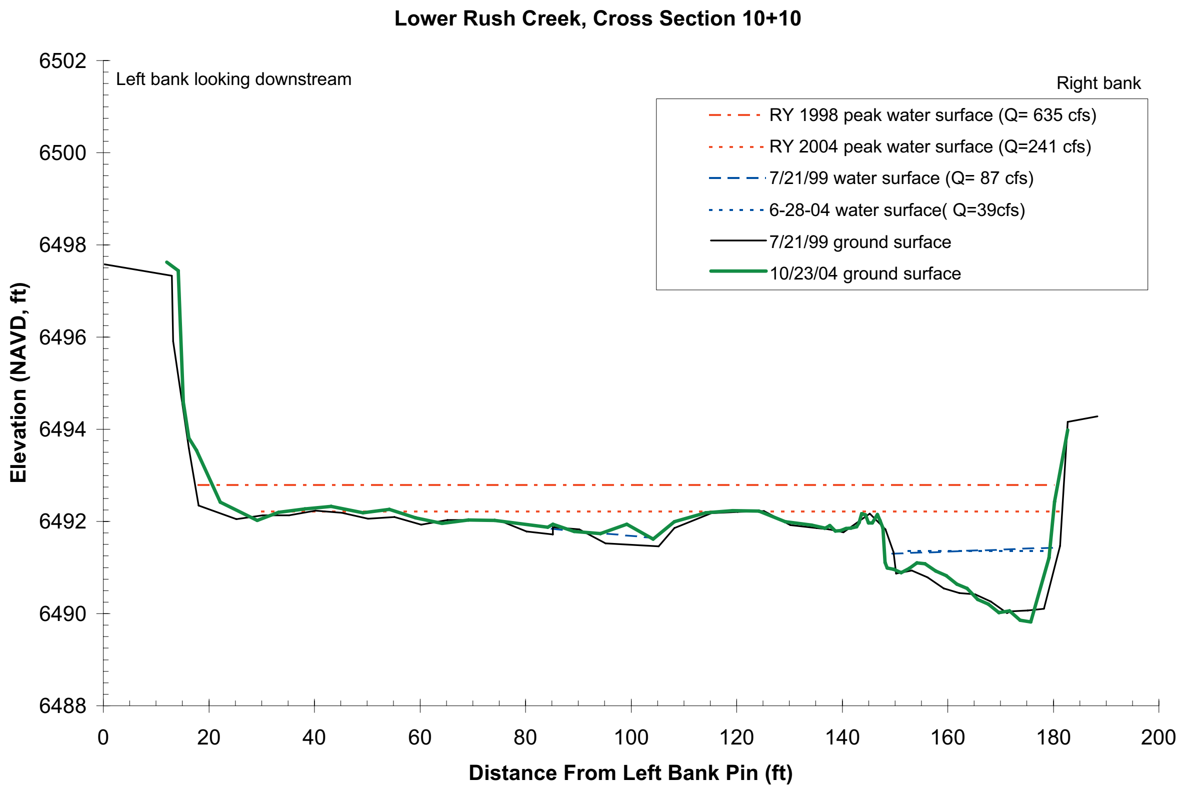

Upper Rush Creek, Cross Section 07+55
Left bank looking downstream
Right bank
RY 2004 peak water surface (Q= 343cfs)
6/28/04 water surface (Q= 46cfs)
7/22/99 water surface (Q= 98cfs)
6/28/04 ground surface
7/22/99 ground surface
Log sill forming plunge-pool; scoured away in RY 2003
Elevation (NAVDI, ft)
6900
6898
6896
6894
6892
6890
6888
-5
5
15
25
35
45
55
65
75
85
95
105
115
125
135
145
155
165
175
Distance From Left Bank Pin (ft)

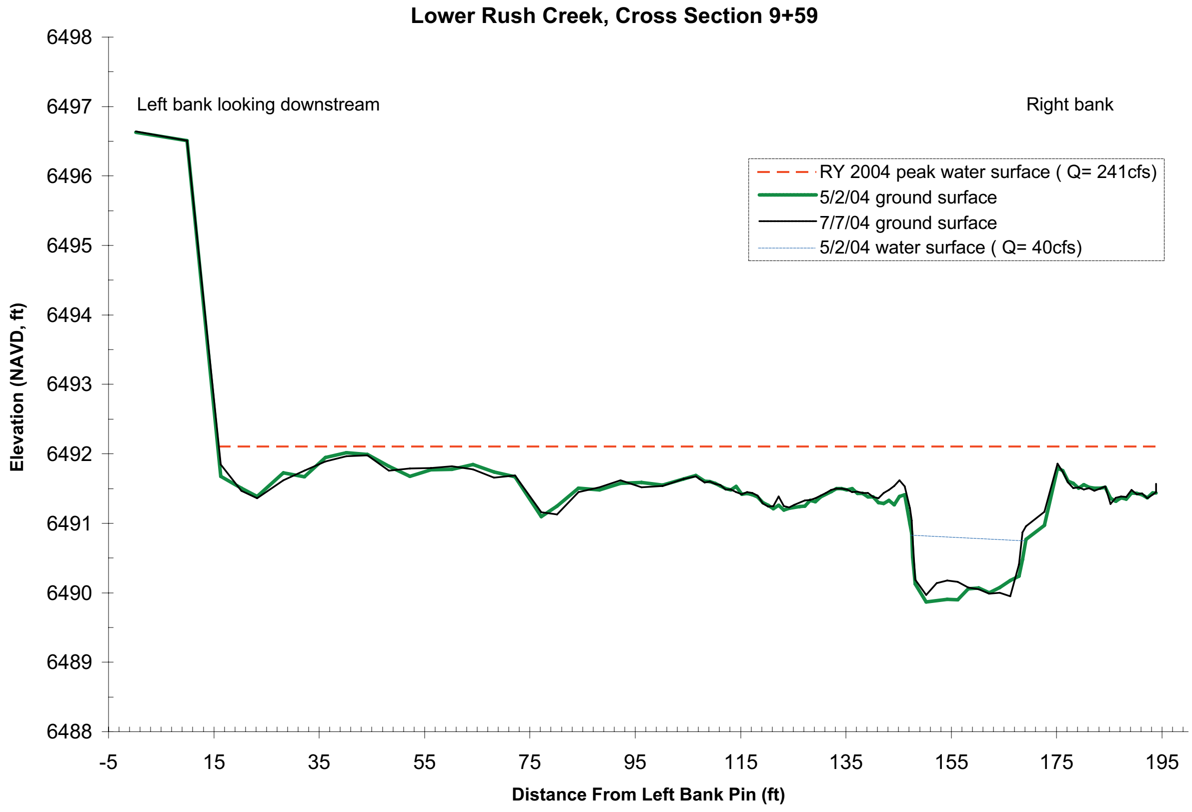

Upper Rush Creek, Cross Section 05+45
Left bank looking downstream
Right bank
RY 1998 peak water surface (Q= 538cfs)
RY 2004 peak water surface (Q= 343cfs)
6/28/04 water surface (Q= 46cfs)
7/22/99 water surface (Q= 98cfs)
6/28/04 ground surface
7/22/99 ground surface
Elevation (NAVD, ft)
6896
6894
6892
6890
6888
6886
6884
Distance From Left Bank Pin (ft)
-5
5
15
25
35
45
55
65
75
85
95

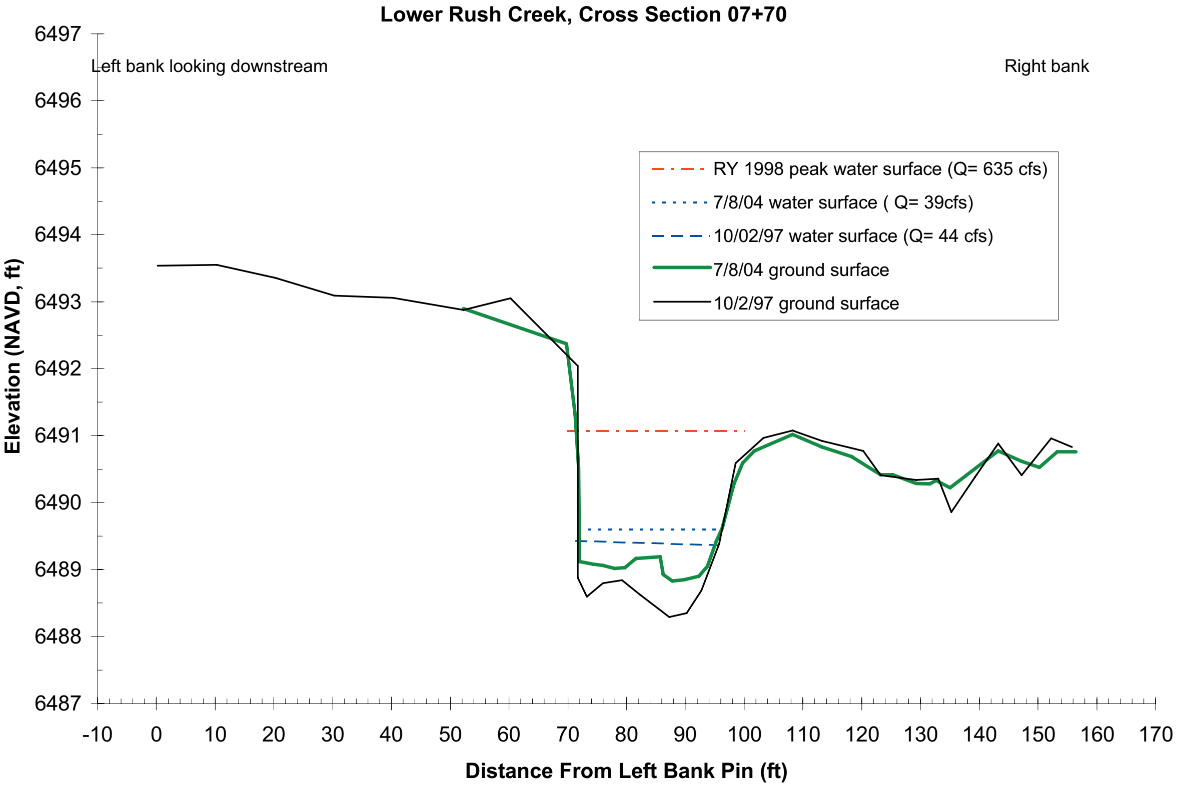

Upper Rush Creek, Cross Section 01+05
Left bank looking downstream
Right bank
RY 2004 peak water surface (Q= 343cfs)
6/28/04 water surface (Q= 46cfs)
7/22/99 water surface (Q= 98cfs)
6/28/04 ground surface
7/22/99 ground surface
Elevation (NAVD, ft)
6892
6890
6888
6886
6884
6882
6880
Distance From Left Bank Pin (ft)
-5
0
5
10
15
20
25
30
35
40
45
50
55
60

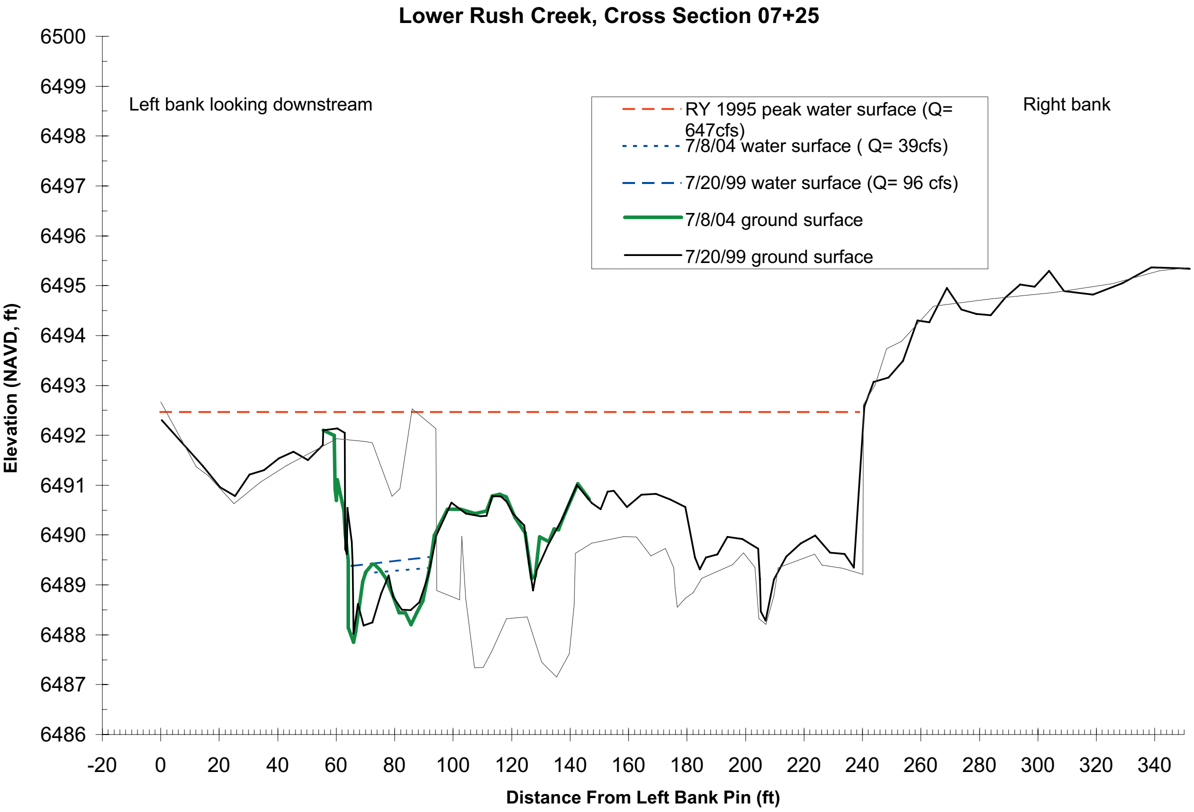

Upper Rush Creek, Cross Section 00+74
Left bank looking downstream
Right bank
RY 1998 peak water surface (Q= 538cfs)
RY 2004 peak water surface (Q=343cfs)
6/28/04 water surface (Q= 46cfs)
7/22/99 water surface (Q= 98cfs)
6/28/04 ground surface
7/22/99 ground surface
Elevation (NAVD, ft)
6890
6888
6886
6884
6882
-2
3
8
13
18
23
28
33
38
43
48
53
58
63
68
Distance From Left Bank Pin (ft)

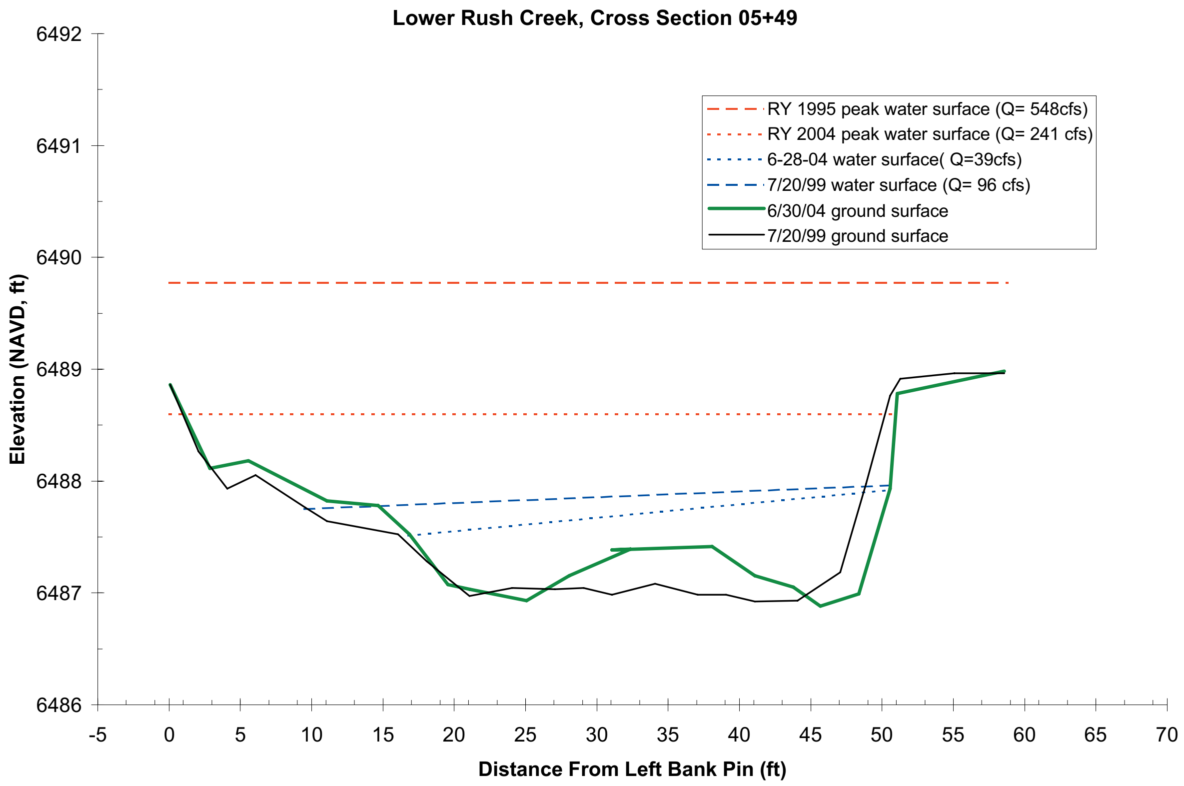

Upper Rush Creek, Cross Section 00+00
Left bank looking downstream
Right bank
RY 1998 peak water surface (Q= 538cfs)
10-24-04 water surface (Q= 47cfs)
7/22/99 water surface (Q= 98cfs)
10/24/04 ground surface
7/22/99 ground surface
Upstream end of medial bar
Elevation (NAVD, ft)
6890
6888
6886
6884
6882
6880
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
Distance From Left Bank Pin (ft)

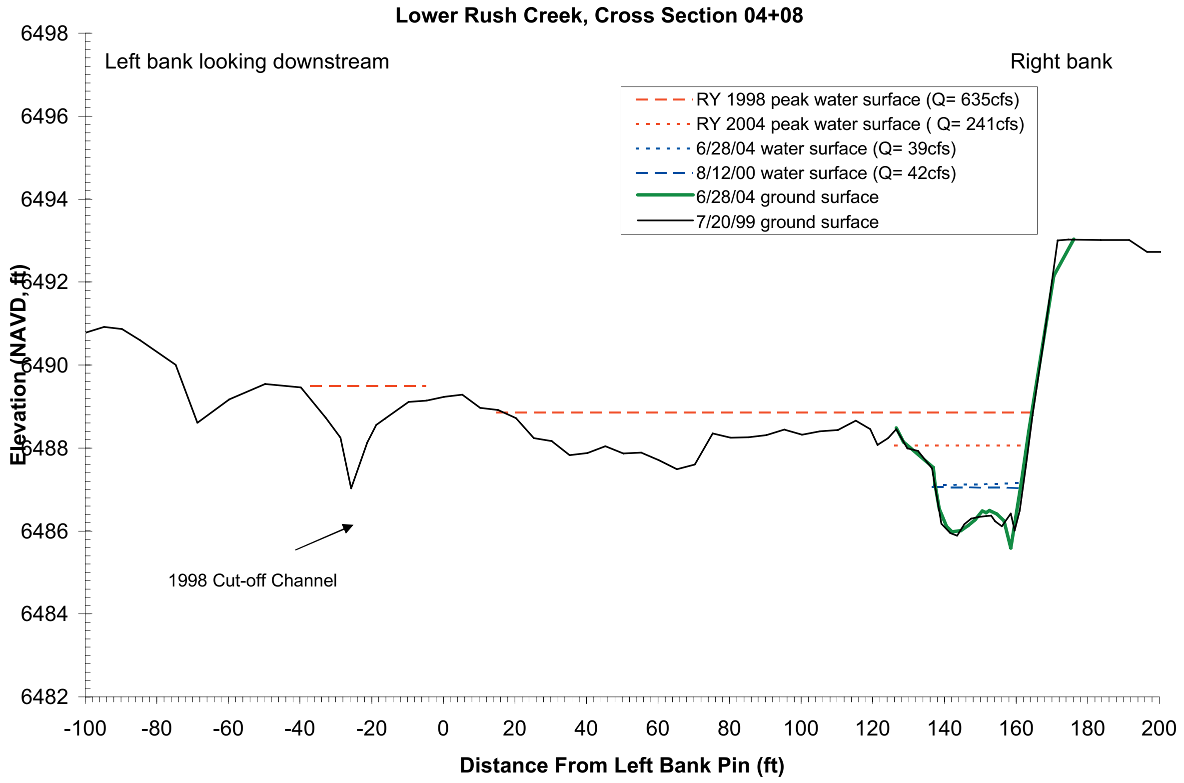

Lower Rush Creek, Cross Section 10+10
Left bank looking downstream
Right bank
RY 1998 peak water surface (Q= 635 cfs)
RY 2004 peak water surface (Q=241 cfs)
7/21/99 water surface (Q= 87 cfs)
6-28-04 water surface(Q=39cfs)
7/21/99 ground surface
10/23/04 ground surface
Elevation (NAVD, ft)
6502
6500
6498
6496
6494
6492
6490
6488
0
20
40
60
80
100
120
140
160
180
200
Distance From Left Bank Pin (ft)

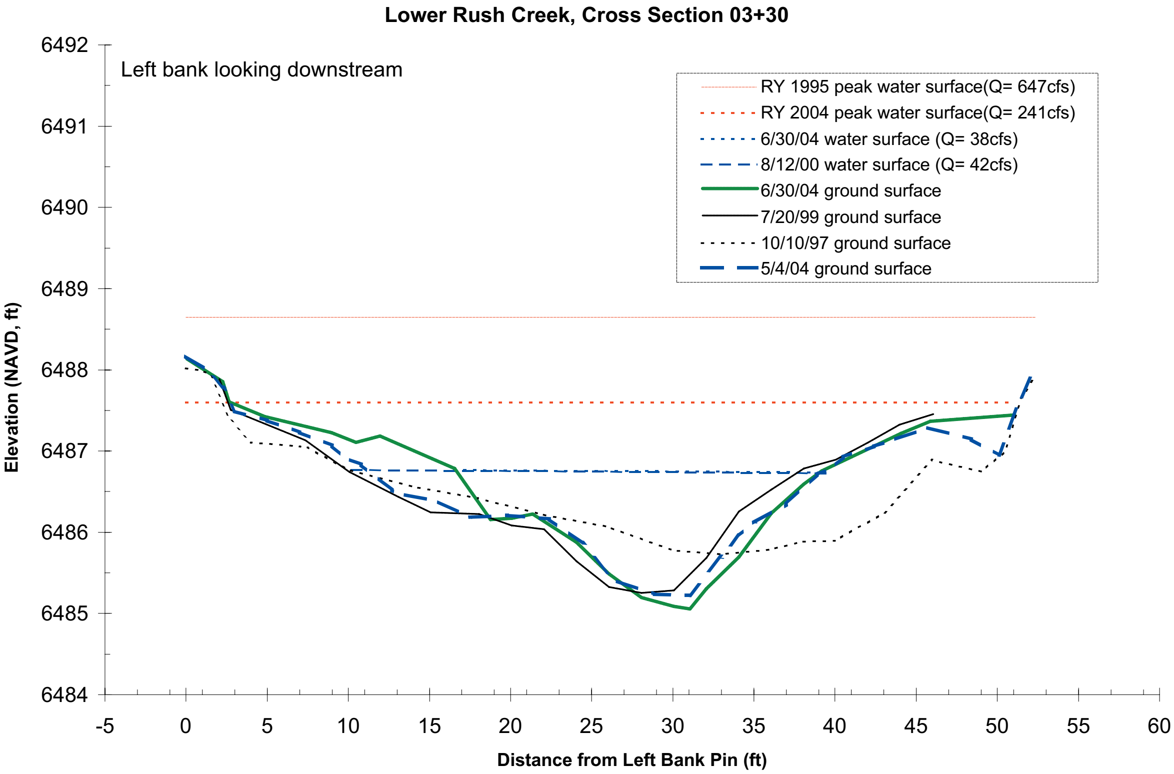

Lower Rush Creek, Cross Section 9+59
Left bank looking downstream
Right bank
RY 2004 peak water surface (Q= 241cfs)
5/2/04 ground surface
7/7/04 ground surface
5/2/04 water surface (Q= 40cfs)
Elevation (NAVD, ft)
6498
6497
6496
6495
6494
6493
6492
6491
6490
6489
6488
-5
15
35
55
75
95
115
135
155
175
195
Distance From Left Bank Pin (ft)

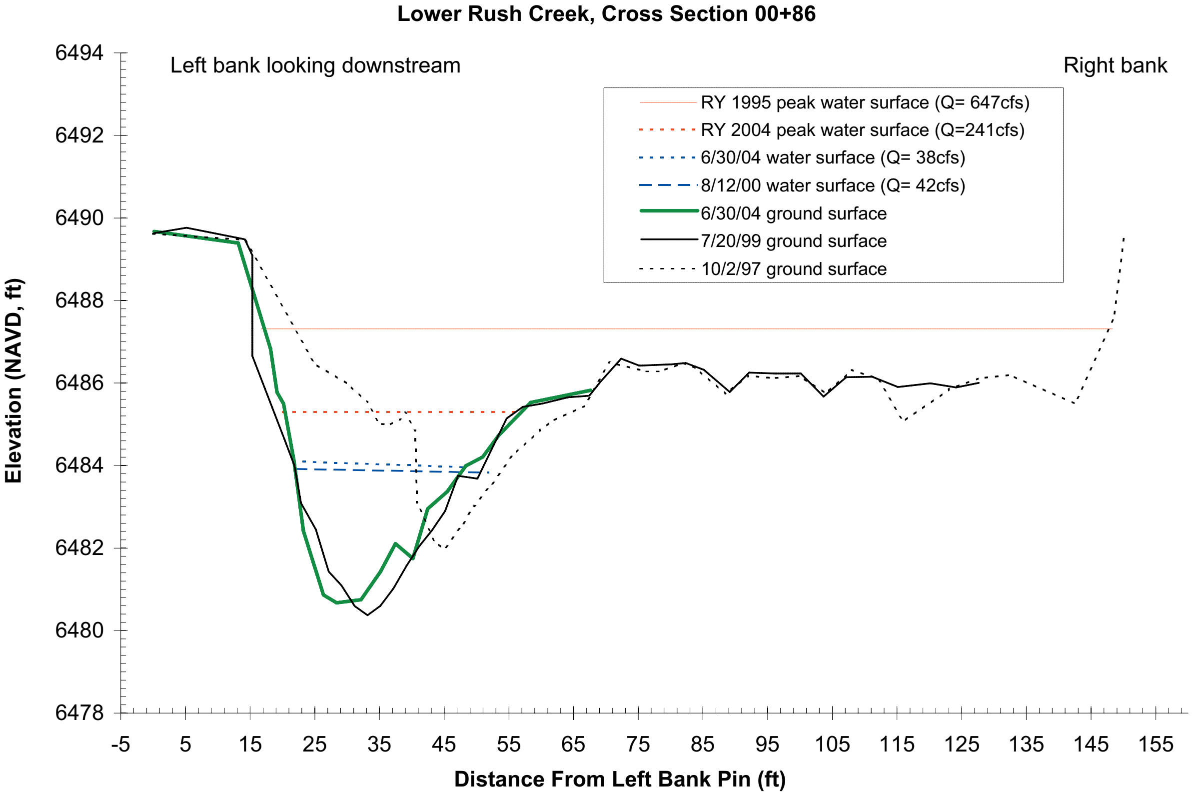

Lower Rush Creek, Cross Section 07+70
Left bank looking downstream
Right bank
RY 1998 peak water surface (Q= 635 cfs)
7/8/04 water surface (Q= 39cfs)
10/02/97 water surface (Q= 44 cfs)
7/8/04 ground surface
10/2/97 ground surface
Elevation (NAVD, ft)
6497
6496
6495
6494
6493
6492
6491
6490
6489
6488
6487
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
Distance From Left Bank Pin (ft)

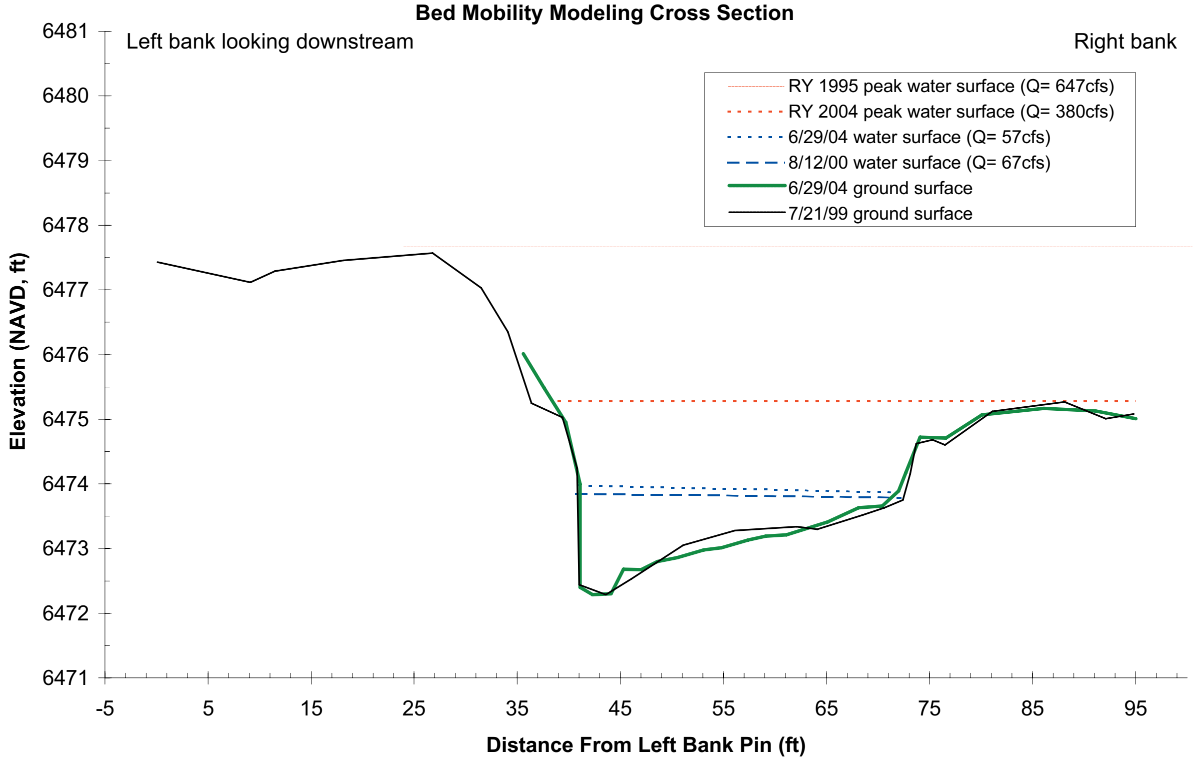

Lower Rush Creek, Cross Section 07+25
Left bank looking downstream
Right bank
RY 1995 peak water surface (Q= 647cfs)
7/8/04 water surface (Q= 39cfs)
7/20/99 water surface (Q= 96 cfs)
7/8/04 ground surface
7/20/99 ground surface
Elevation (NAVD, ft)
6500
6499
6498
6497
6496
6495
6494
6493
6492
6491
6490
6489
6488
6487
6486
-20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
Distance From Left Bank Pin (ft)

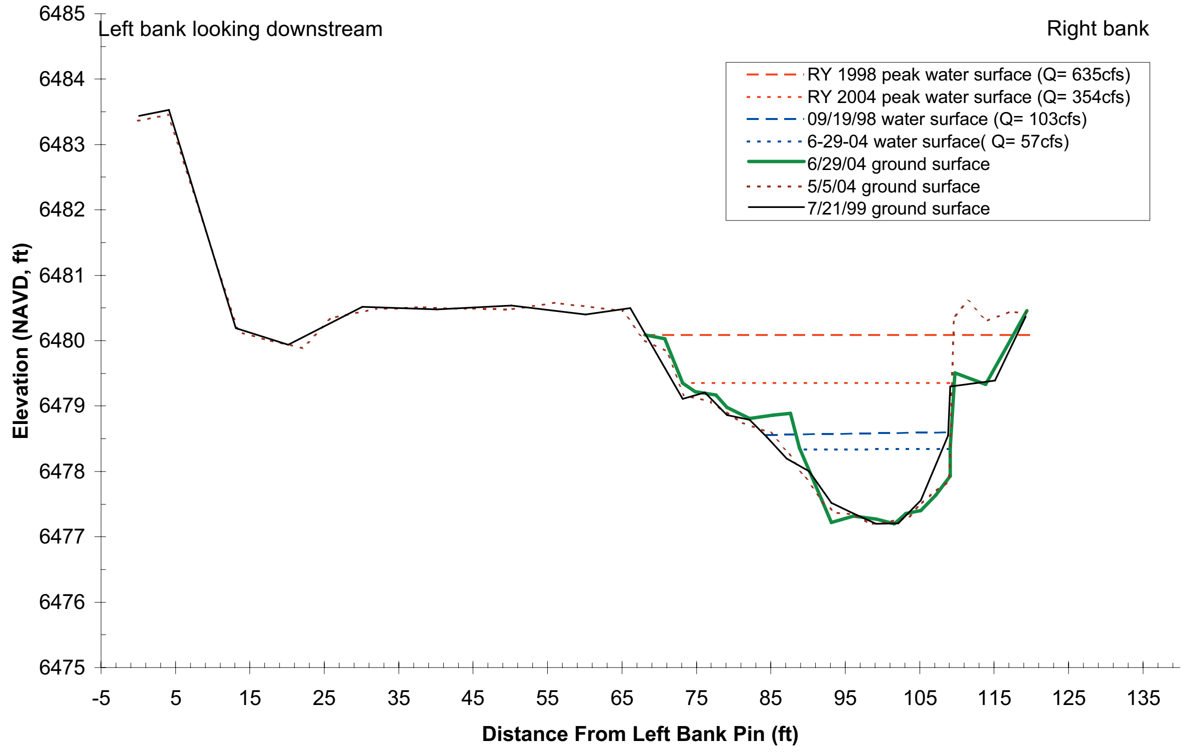

Lower Rush Creek, Cross Section 05+49

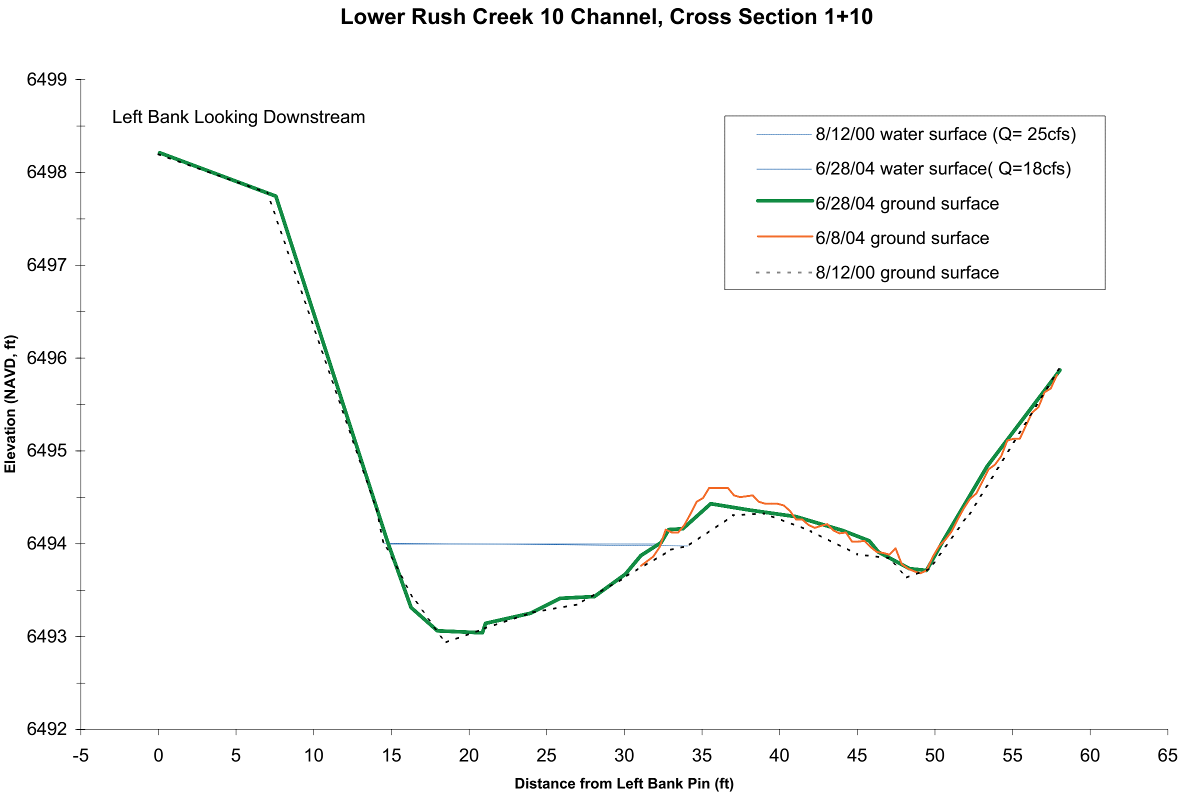

Lower Rush Creek, Cross Section 04+08

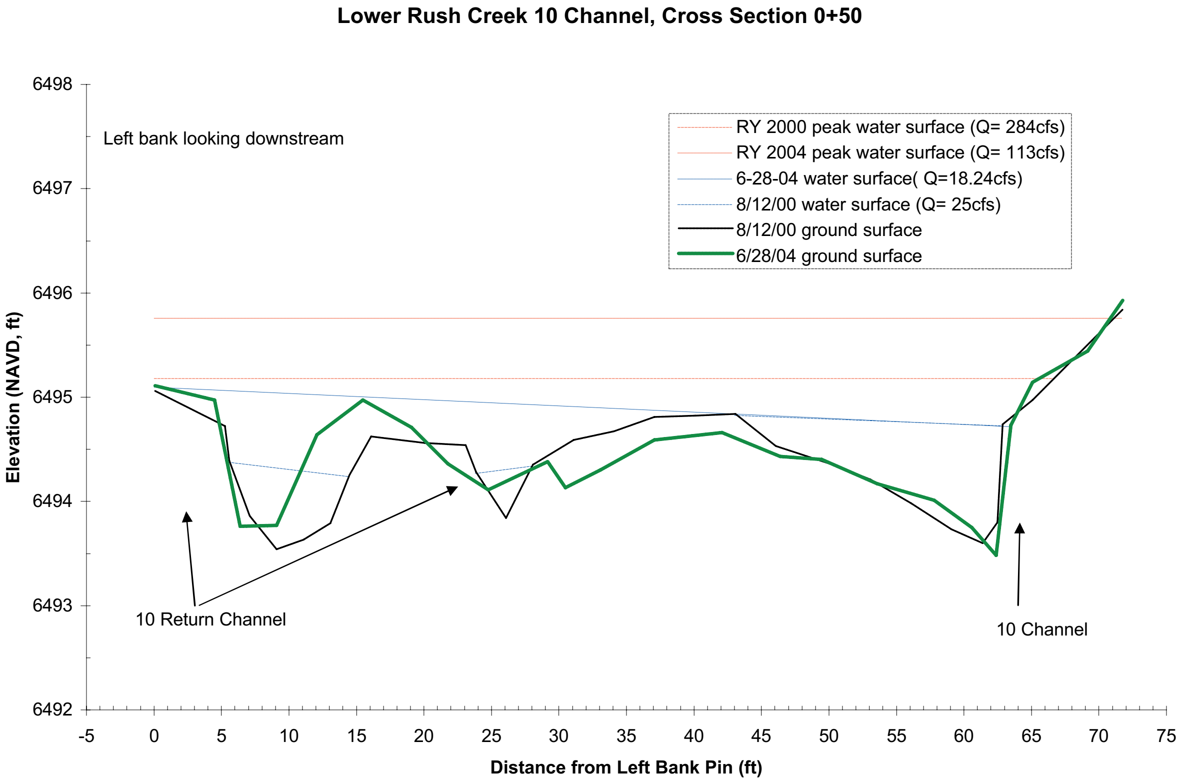

Lower Rush Creek, Cross Section 03+30
Left bank looking downstream
RY 1995 peak water surface(Q= 647cfs)
RY 2004 peak water surface(Q= 241cfs)
6/30/04 water surface (Q= 38cfs)
8/12/00 water surface (Q= 42cfs)
6/30/04 ground surface
7/20/99 ground surface
10/10/97 ground surface
5/4/04 ground surface
Elevation (NAVD, ft)
6492
6491
6490
6489
6488
6487
6486
6485
6484
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
Distance from Left Bank Pin (ft)

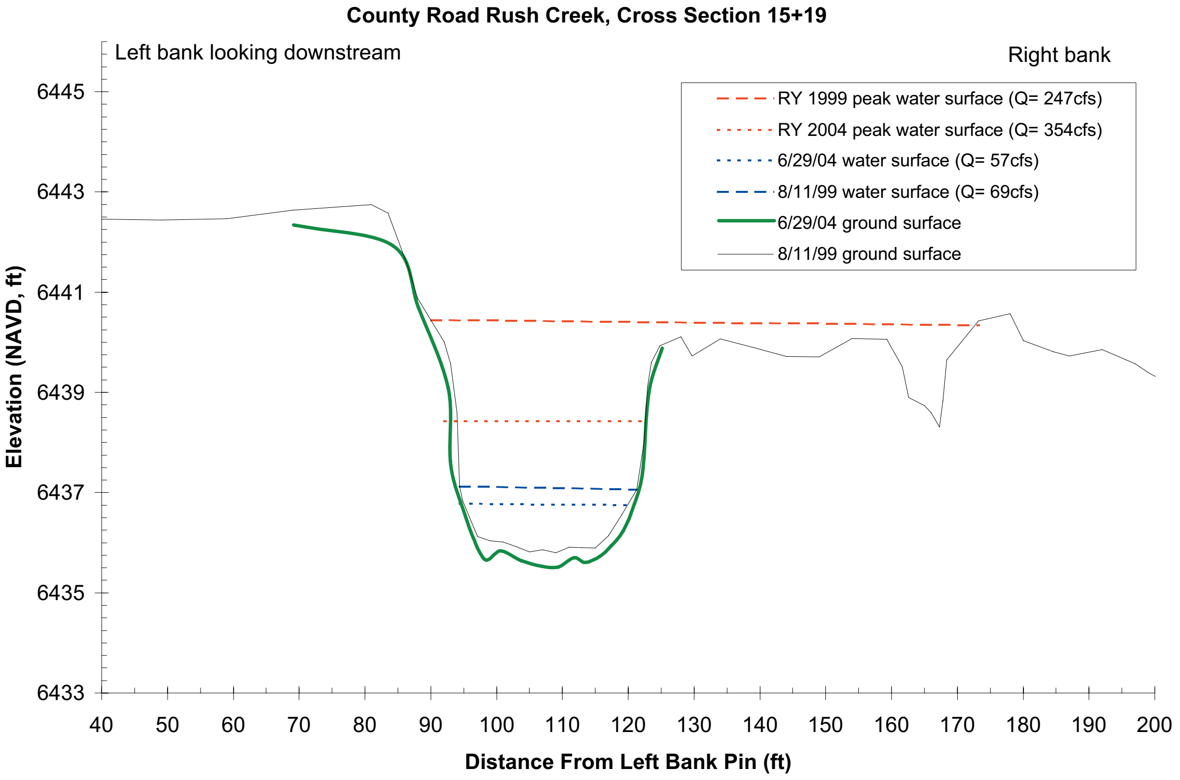

Lower Rush Creek, Cross Section 00+86
Left bank looking downstream
Right bank
RY 1995 peak water surface (Q= 647cfs)
RY 2004 peak water surface (Q=241cfs)
6/30/04 water surface (Q= 38cfs)
8/12/00 water surface (Q= 42cfs)
6/30/04 ground surface
7/20/99 ground surface
10/2/97 ground surface
Elevation (NAVD, ft)
6494
6492
6490
6488
6486
6484
6482
6480
6478
-5
5
15
25
35
45
55
65
75
85
95
105
115
125
135
145
155
Distance From Left Bank Pin (ft)

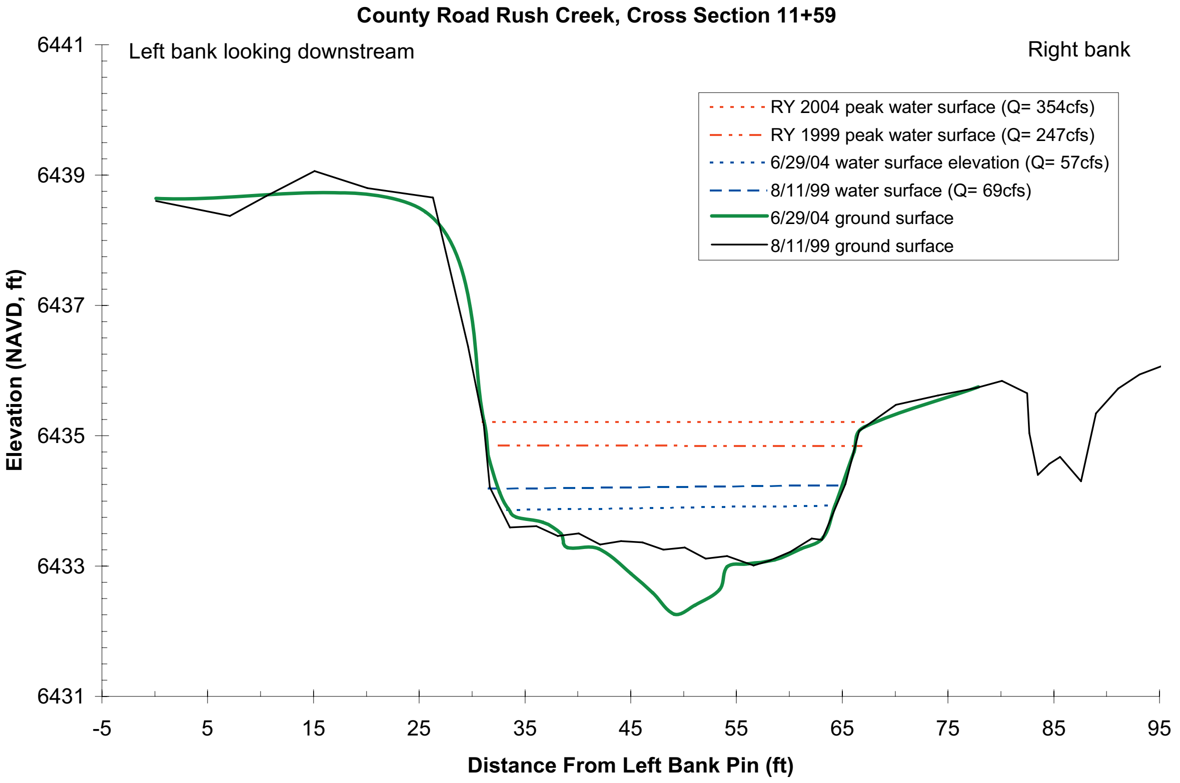

Lower Rush Creek, Cross Section -09+82
Bed Mobility Modeling Cross Section

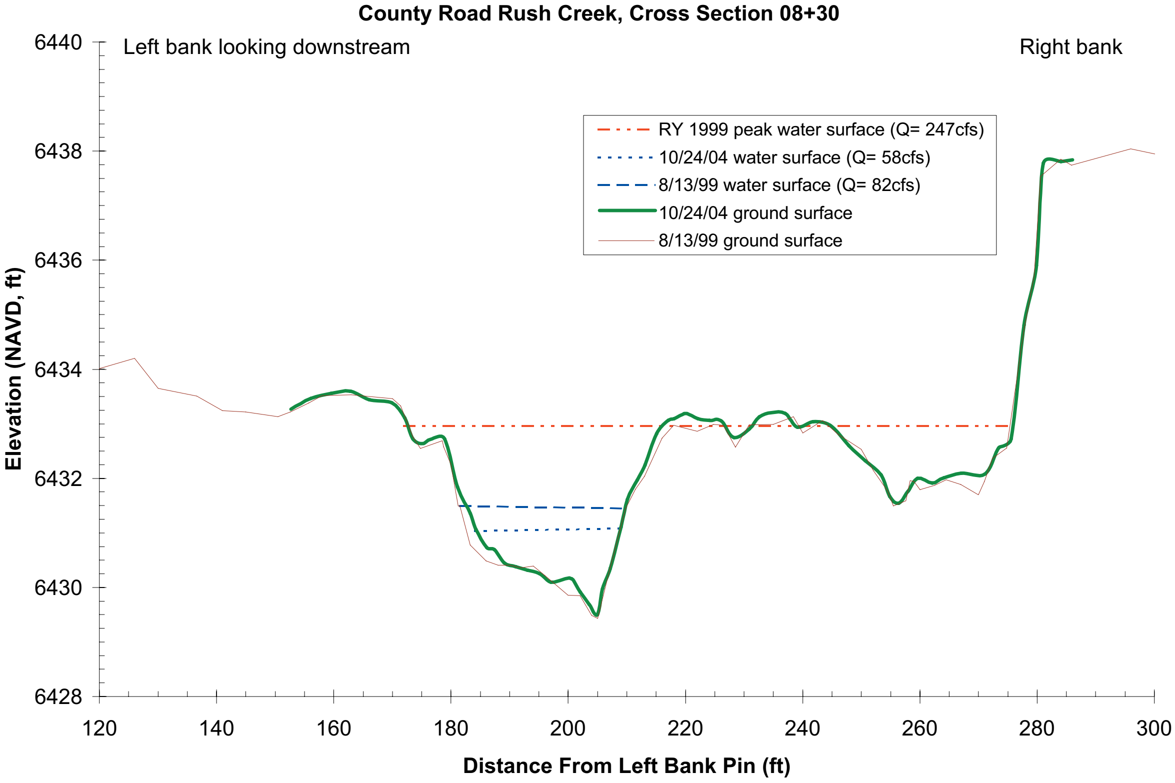

Lower Rush Creek, Cross Section -05+07

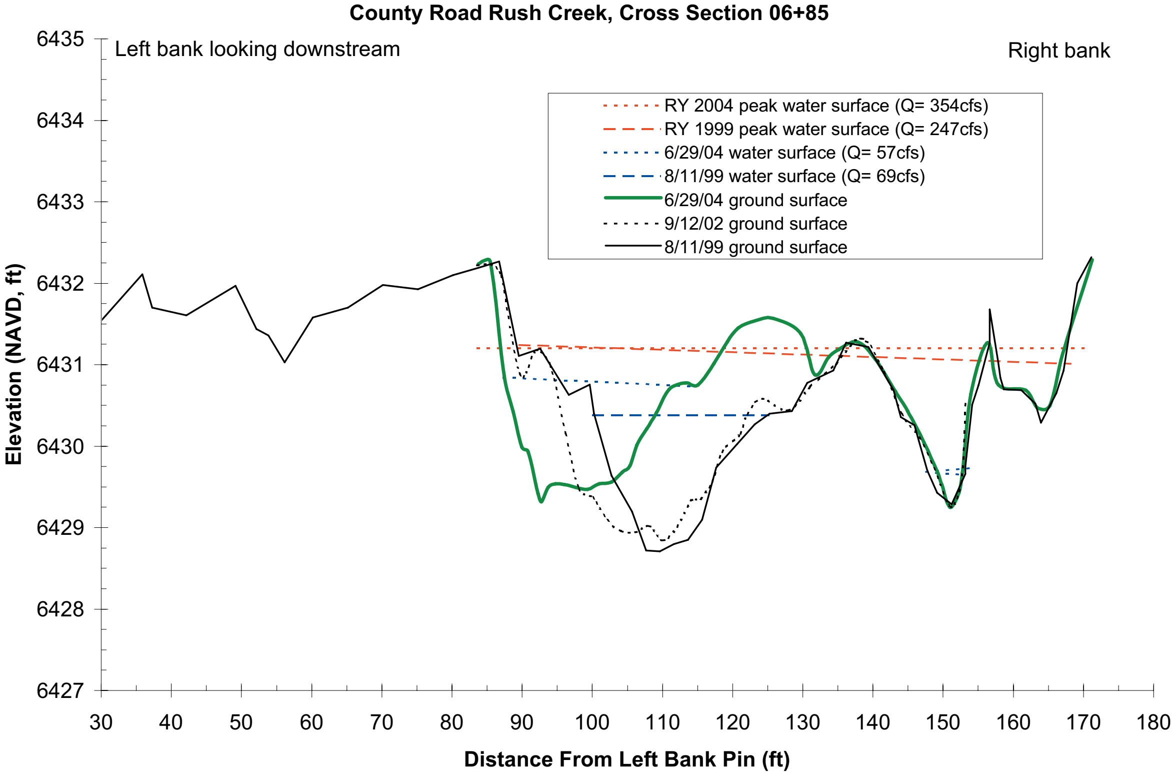

Lower Rush Creek 10 Channel, Cross Section 1+10
Left Bank Looking Downstream
8/12/00 water surface (Q= 25cfs)
6/28/04 water surface(Q=18cfs)
6/28/04 ground surface
6/8/04 ground surface
8/12/00 ground surface
Elevation (NAVD, ft)
6499
6498
6497
6496
6495
6494
6493
6492
Distance from Left Bank Pin (ft)
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65

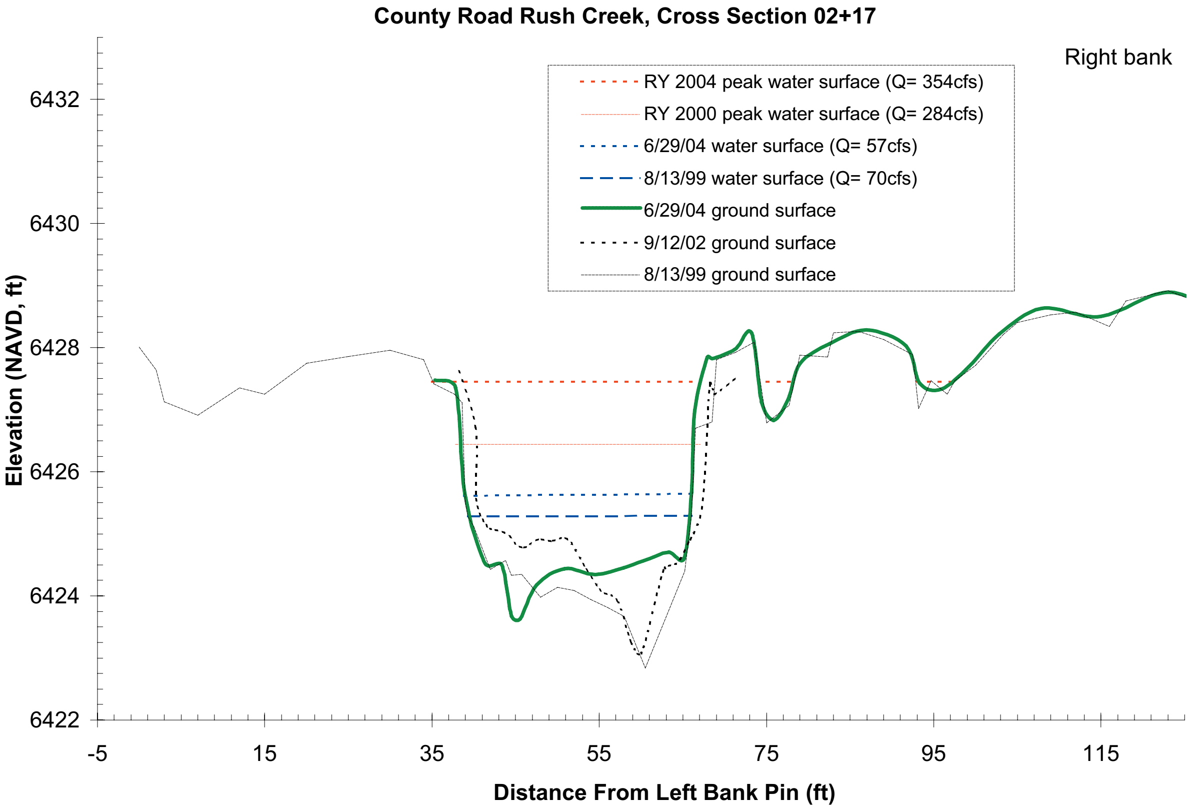

Lower Rush Creek 10 Channel, Cross Section 0+50
Left bank looking downstream
RY 2000 peak water surface (Q= 284cfs)
RY 2004 peak water surface (Q= 113cfs)
6-28-04 water surface(Q=18.24cfs)
8/12/00 water surface (Q= 25cfs)
8/12/00 ground surface
6/28/04 ground surface
10 Return Channel
10 Channel
Elevation (NAVD, ft)
6498
6497
6496
6495
6494
6493
6492
Distance from Left Bank Pin (ft)
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75


County Road Rush Creek, Cross Section 15+19
Left bank looking downstream
Right bank
RY 1999 peak water surface (Q= 247cfs)
RY 2004 peak water surface (Q= 354cfs)
6/29/04 water surface (Q= 57cfs)
8/11/99 water surface (Q= 69cfs)
6/29/04 ground surface
8/11/99 ground surface
Elevation (NAVD, ft)
6445
6443
6441
6439
6437
6435
6433
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance From Left Bank Pin (ft)

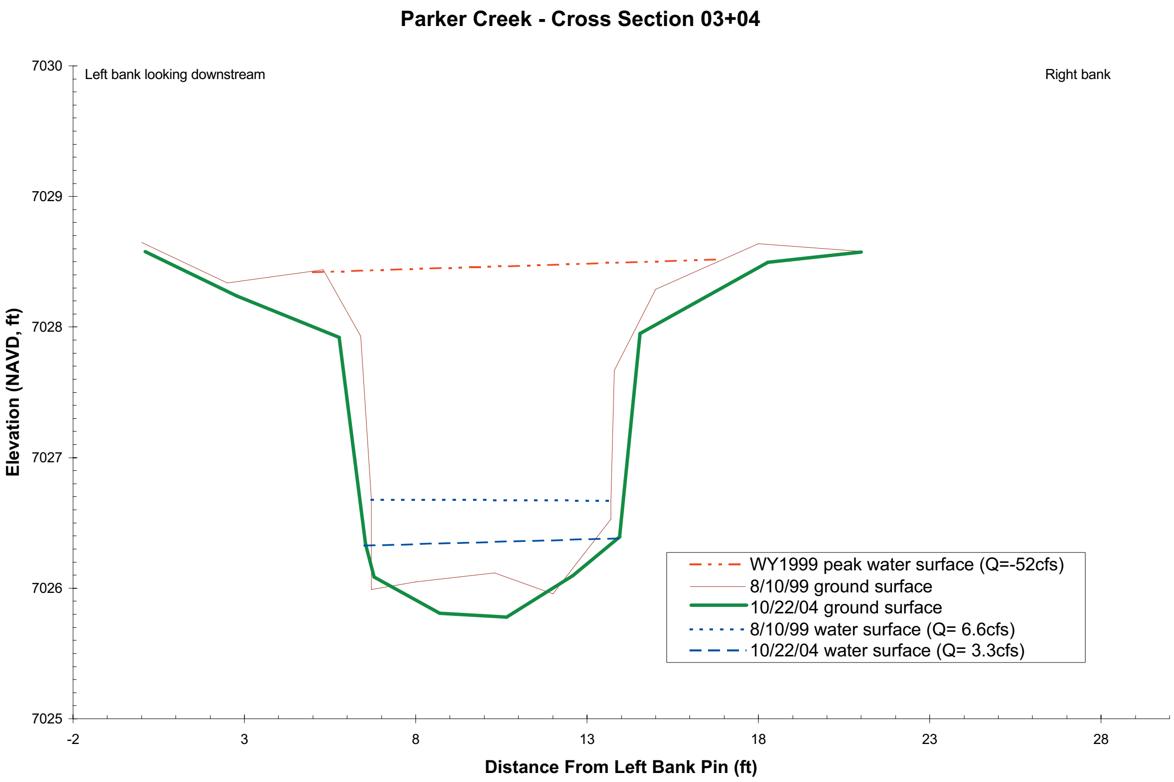

County Road Rush Creek, Cross Section 11+59
Left bank looking downstream
Right bank
RY 2004 peak water surface (Q= 354cfs)
RY 1999 peak water surface (Q= 247cfs)
6/29/04 water surface elevation (Q= 57cfs)
8/11/99 water surface (Q= 69cfs)
6/29/04 ground surface
8/11/99 ground surface
Elevation (NAVD, ft)
6441
6439
6437
6435
6433
6431
-5
5
15
25
35
45
55
65
75
85
95
Distance From Left Bank Pin (ft)

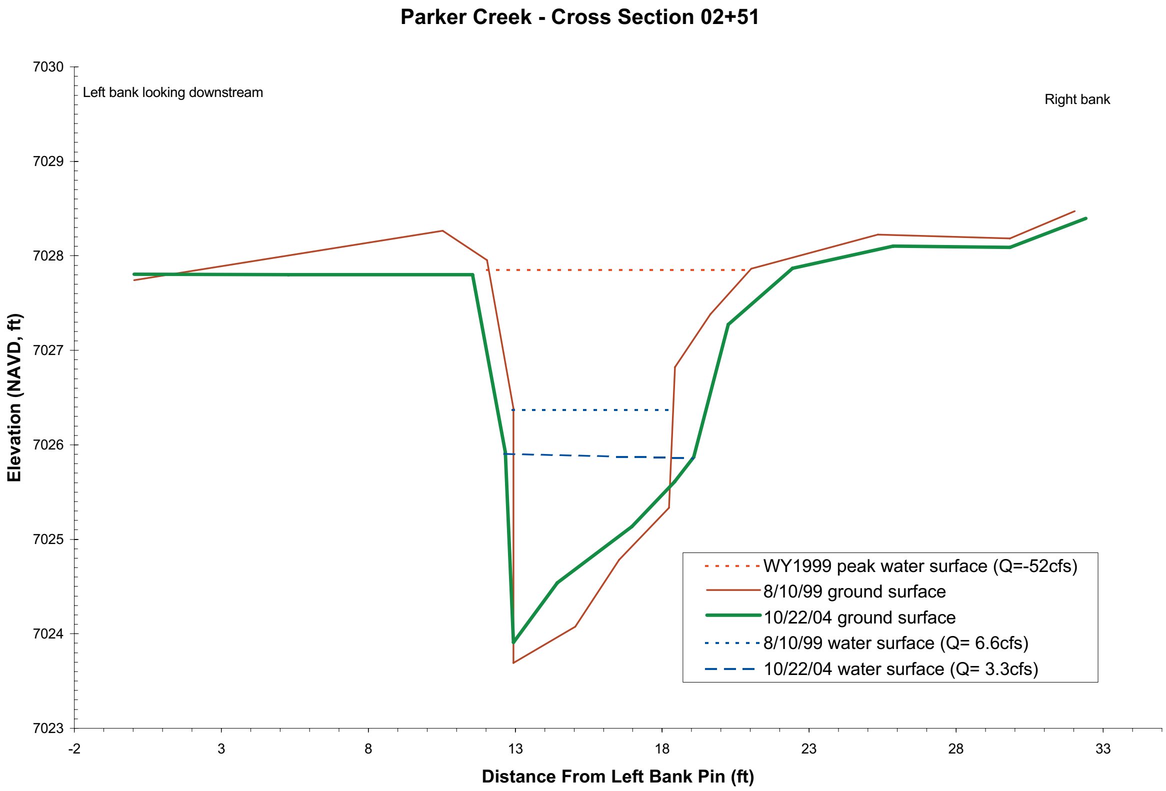

County Road Rush Creek, Cross Section 08+30
Left bank looking downstream
Right bank
RY 1999 peak water surface (Q= 247cfs)
10/24/04 water surface (Q= 58cfs)
8/13/99 water surface (Q= 82cfs)
10/24/04 ground surface
8/13/99 ground surface
Elevation (NAVD, ft)
6428
6430
6432
6434
6436
6438
6440
Distance From Left Bank Pin (ft)
120
140
160
180
200
220
240
260
280
300

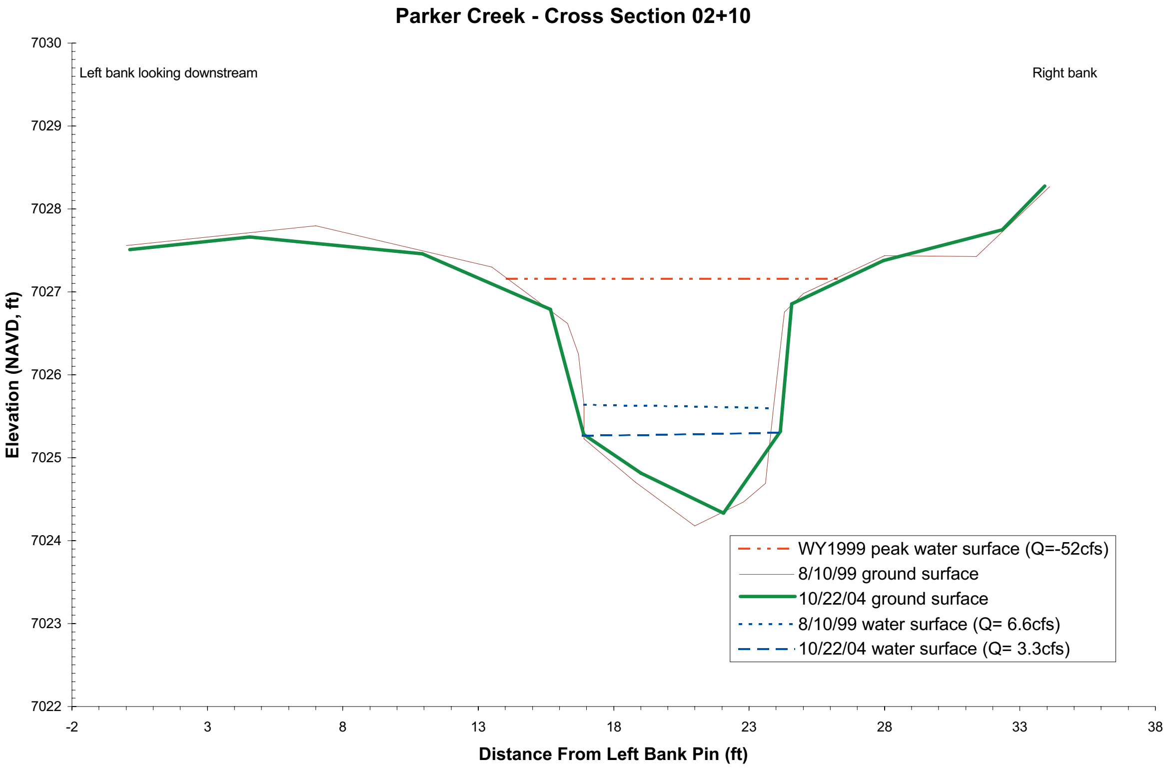

County Road Rush Creek, Cross Section 06+85
Left bank looking downstream
Right bank
RY 2004 peak water surface (Q= 354cfs)
RY 1999 peak water surface (Q= 247cfs)
6/29/04 water surface (Q= 57cfs)
8/11/99 water surface (Q= 69cfs)
6/29/04 ground surface
9/12/02 ground surface
8/11/99 ground surface
Elevation (NAVD, ft)
6427
6428
6429
6430
6431
6432
6433
6434
6435
Distance From Left Bank Pin (ft)
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180

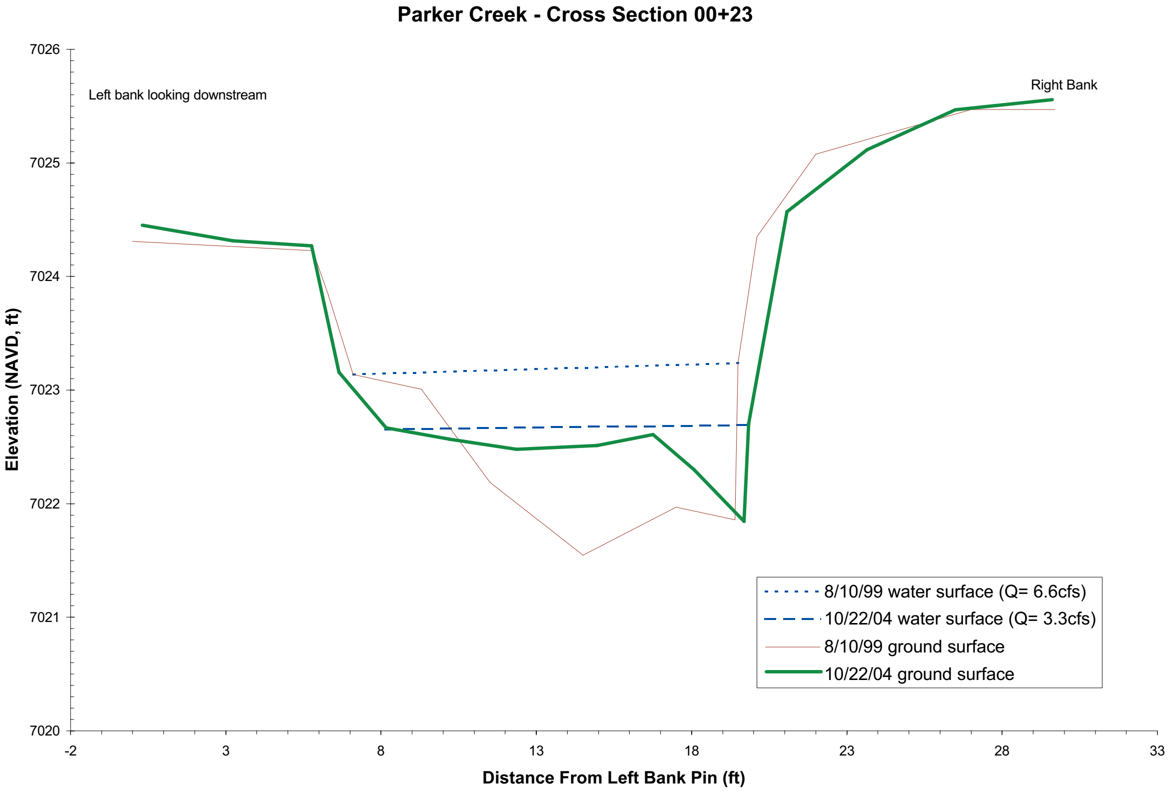

County Road Rush Creek, Cross Section 02+17
Right bank
RY 2004 peak water surface (Q= 354cfs)
RY 2000 peak water surface (Q= 284cfs)
6/29/04 water surface (Q= 57cfs)
8/13/99 water surface (Q= 70cfs)
6/29/04 ground surface
9/12/02 ground surface
8/13/99 ground surface
Elevation (NAVD, ft)
6432
6430
6428
6426
6424
6422
-5
15
35
55
75
95
115
Distance From Left Bank Pin (ft)

Parker Creek

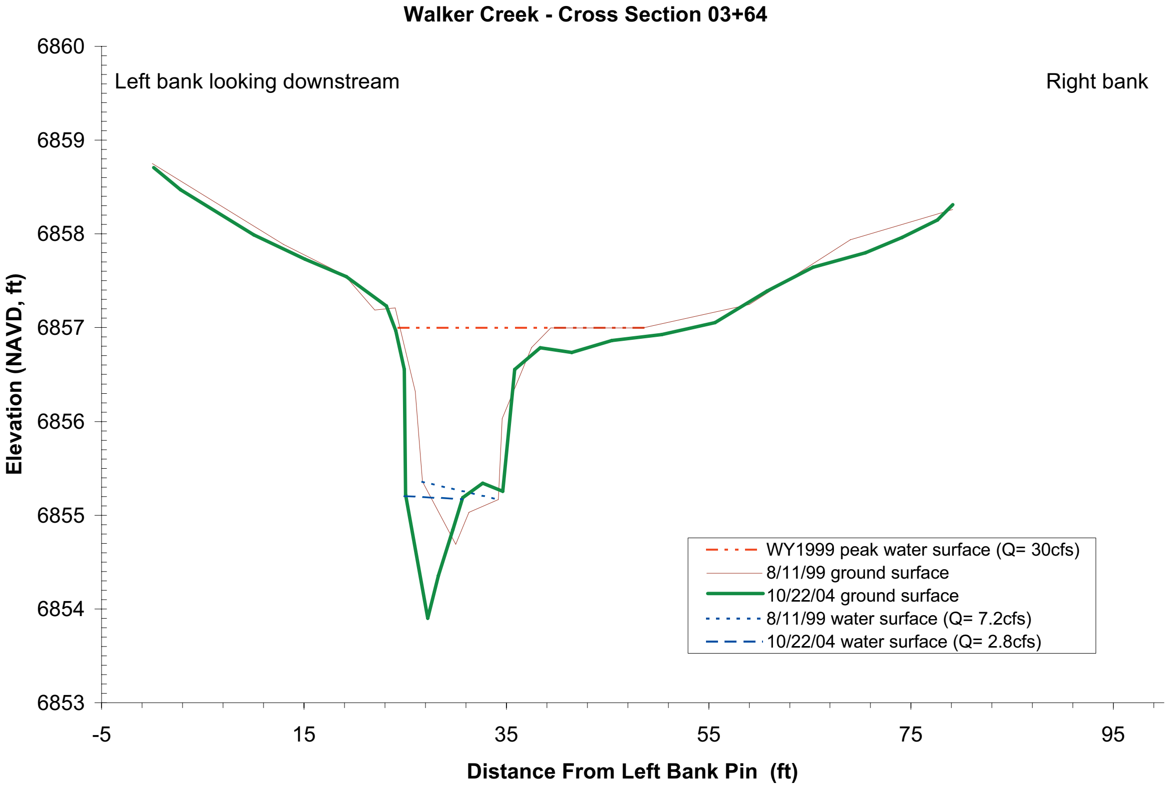

Parker Creek - Cross Section 03+04
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
7030
7029
7028
7027
7026
7025
-2
3
8
13
18
23
28
Distance From Left Bank Pin (ft)
WY1999 peak water surface (Q=-52cfs)
8/10/99 ground surface
10/22/04 ground surface
8/10/99 water surface (Q= 6.6cfs)
10/22/04 water surface (Q= 3.3cfs)

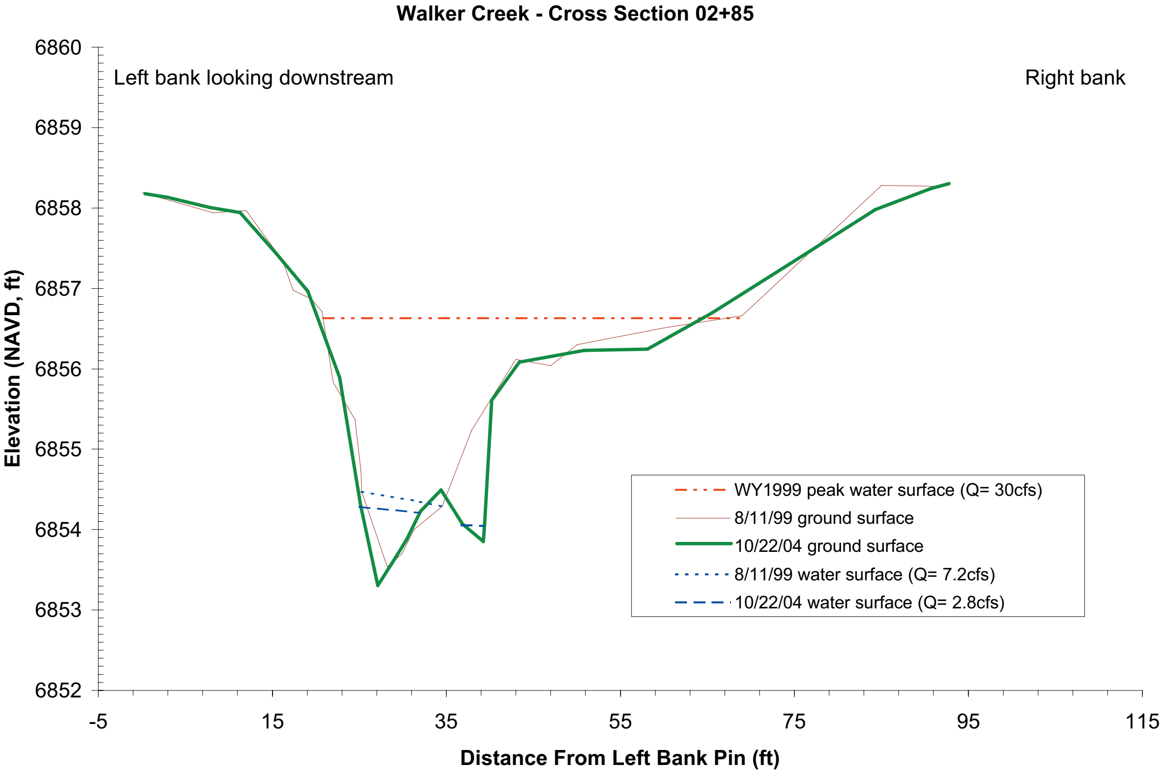

Parker Creek - Cross Section 02+51
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
7030
7029
7028
7027
7026
7025
7024
7023
-2
3
8
13
18
23
28
33
Distance From Left Bank Pin (ft)
WY1999 peak water surface (Q=-52cfs)
8/10/99 ground surface
10/22/04 ground surface
8/10/99 water surface (Q= 6.6cfs)
10/22/04 water surface (Q= 3.3cfs)

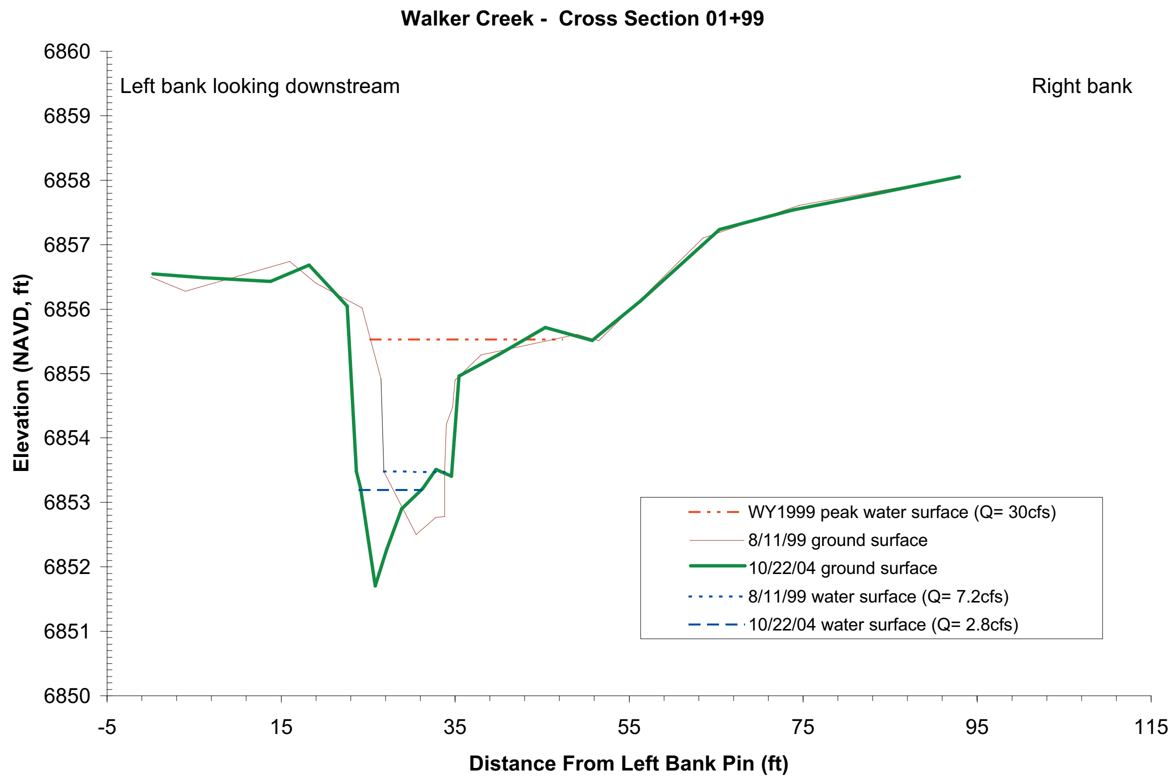

Parker Creek - Cross Section 02+10
Elevation (NAVD, ft)
Distance From Left Bank Pin (ft)
7030
7029
7028
7027
7026
7025
7024
7023
7022
-2
3
8
13
18
23
28
33
38
Left bank looking downstream
Right bank
WY1999 peak water surface (Q=-52cfs)
8/10/99 ground surface
10/22/04 ground surface
8/10/99 water surface (Q= 6.6cfs)
10/22/04 water surface (Q= 3.3cfs)

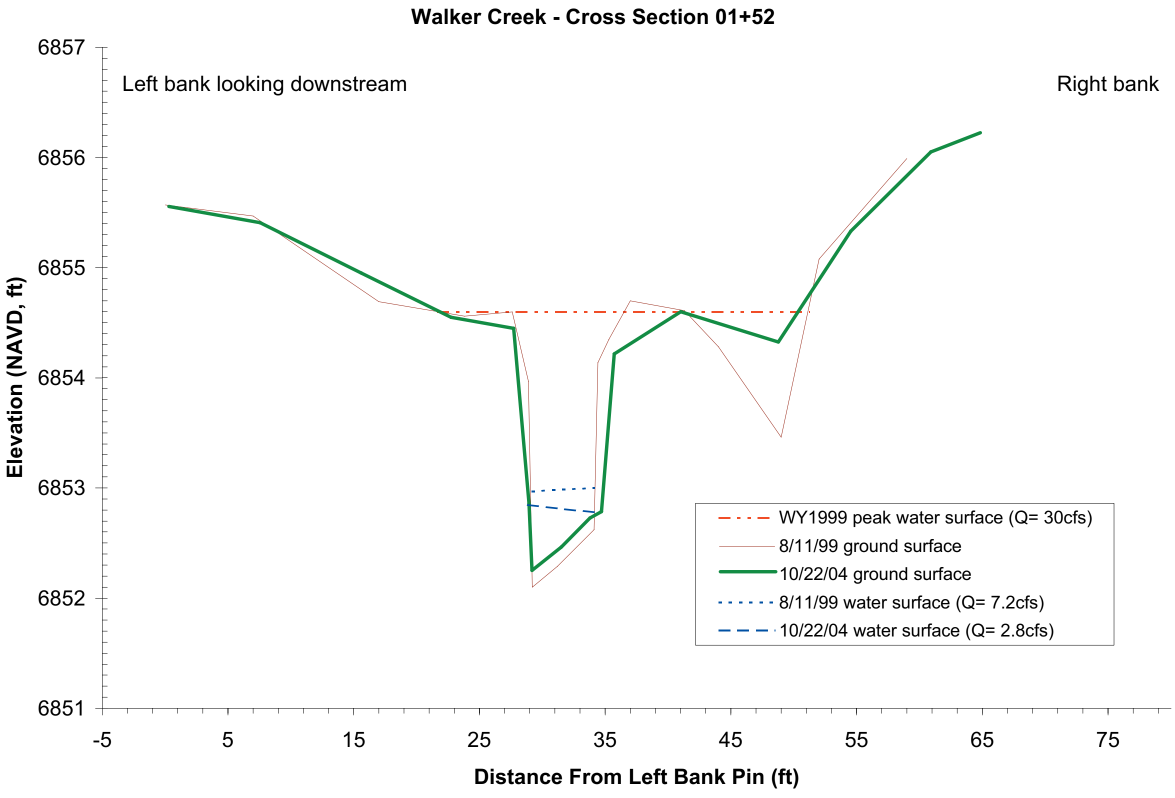

Parker Creek - Cross Section 00+23
Elevation (NAVD, ft)
Distance From Left Bank Pin (ft)
7026
7025
7024
7023
7022
7021
7020
-2
3
8
13
18
23
28
33
Left bank looking downstream
Right Bank
8/10/99 water surface (Q= 6.6cfs)
10/22/04 water surface (Q= 3.3cfs)
8/10/99 ground surface
10/22/04 ground surface

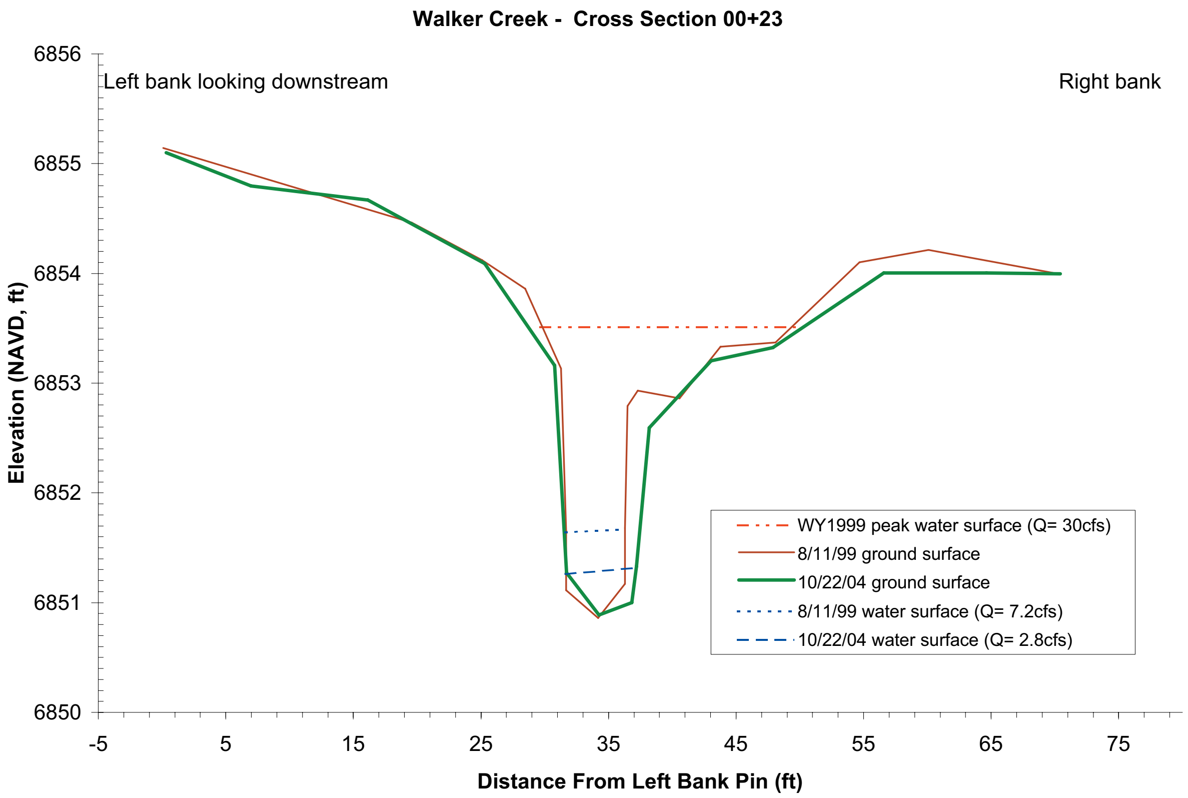
Walker Creek


Walker Creek - Cross Section 03+64
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6860
6859
6858
6857
6856
6855
6854
6853
-5
15
35
55
75
95
Distance From Left Bank Pin (ft)
WY1999 peak water surface (Q= 30cfs)
8/11/99 ground surface
10/22/04 ground surface
8/11/99 water surface (Q= 7.2cfs)
10/22/04 water surface (Q= 2.8cfs)

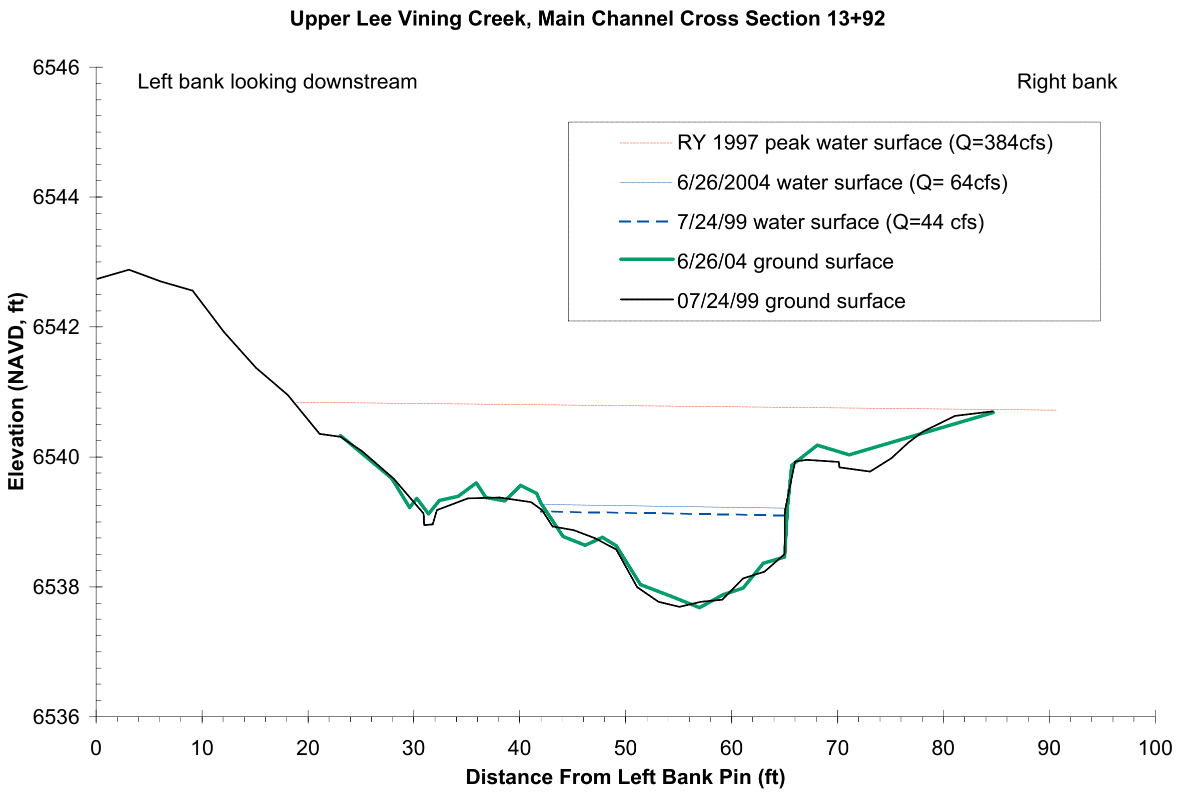

Walker Creek - Cross Section 02+85
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6860
6859
6858
6857
6856
6855
6854
6853
6852
-5
15
35
55
75
95
115
Distance From Left Bank Pin (ft)
WY1999 peak water surface (Q= 30cfs)
8/11/99 ground surface
10/22/04 ground surface
8/11/99 water surface (Q= 7.2cfs)
10/22/04 water surface (Q= 2.8cfs)

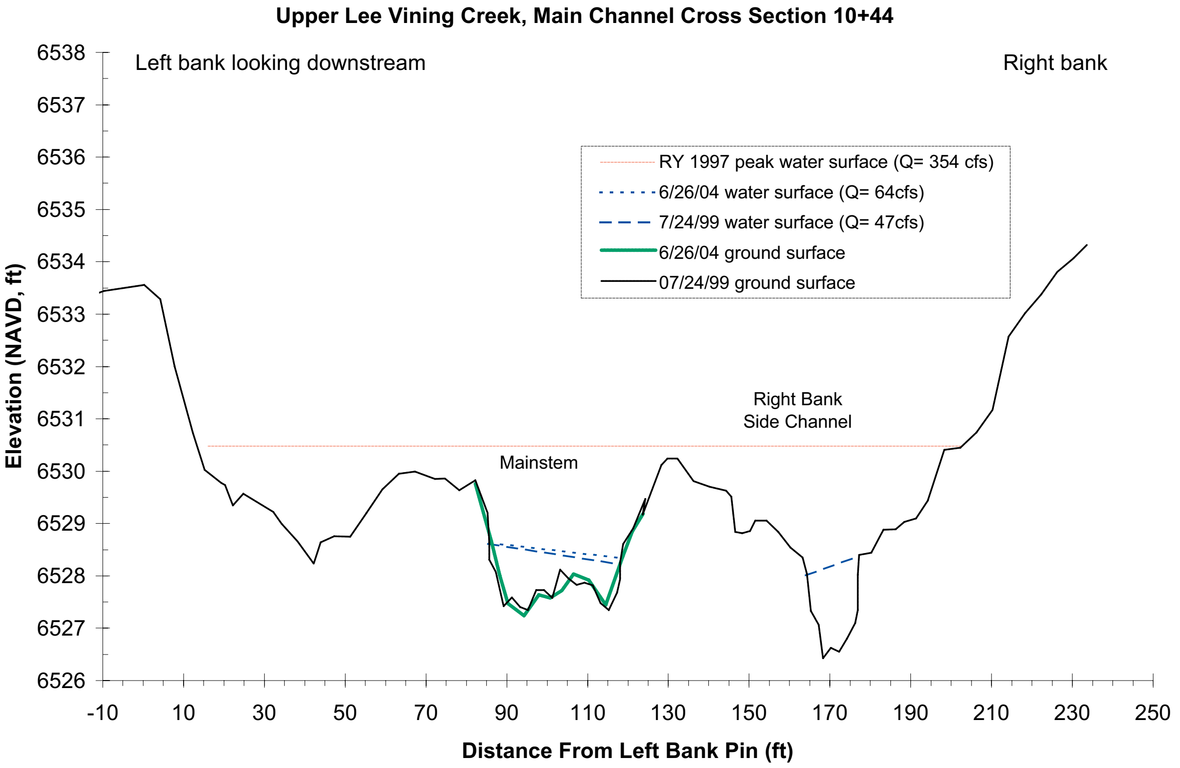

Walker Creek - Cross Section 01+99
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6860
6859
6858
6857
6856
6855
6854
6853
6852
6851
6850
-5
15
35
55
75
95
115
Distance From Left Bank Pin (ft)
WY1999 peak water surface (Q= 30cfs)
8/11/99 ground surface
10/22/04 ground surface
8/11/99 water surface (Q= 7.2cfs)
10/22/04 water surface (Q= 2.8cfs)

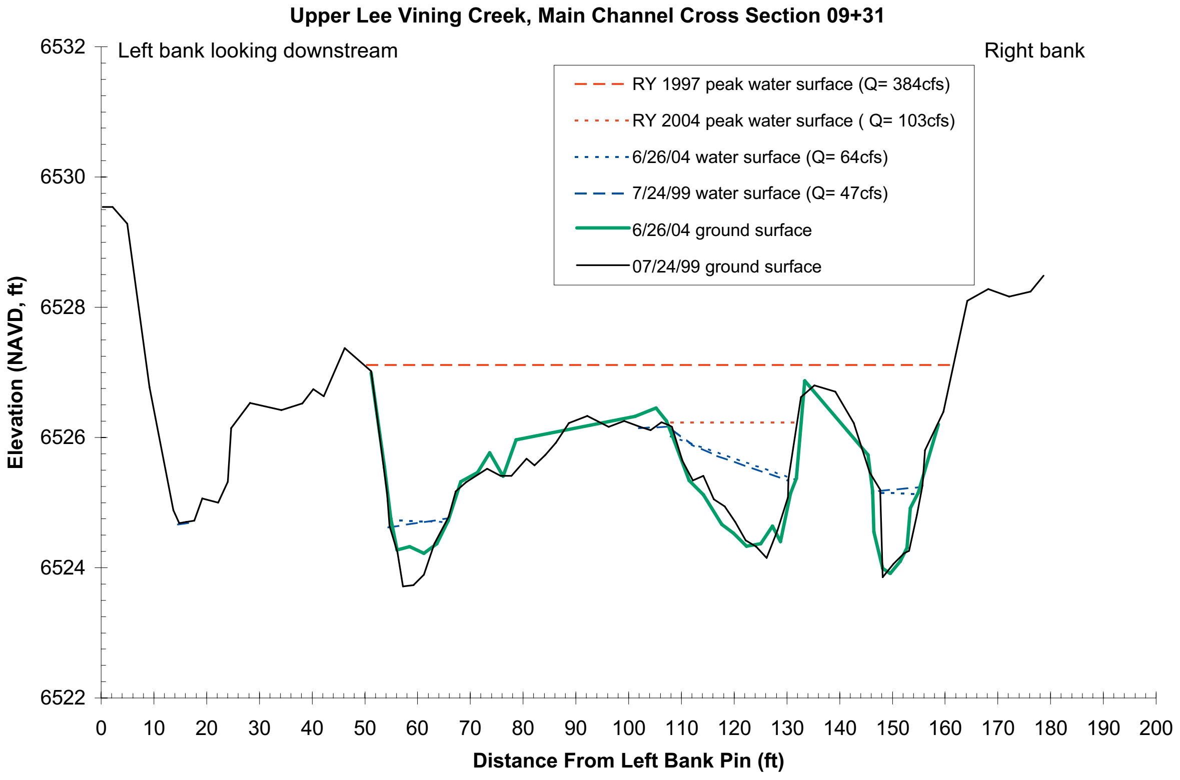

Walker Creek - Cross Section 01+52
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6857
6856
6855
6854
6853
6852
6851
-5
5
15
25
35
45
55
65
75
Distance From Left Bank Pin (ft)
WY1999 peak water surface (Q= 30cfs)
8/11/99 ground surface
10/22/04 ground surface
8/11/99 water surface (Q= 7.2cfs)
10/22/04 water surface (Q= 2.8cfs)

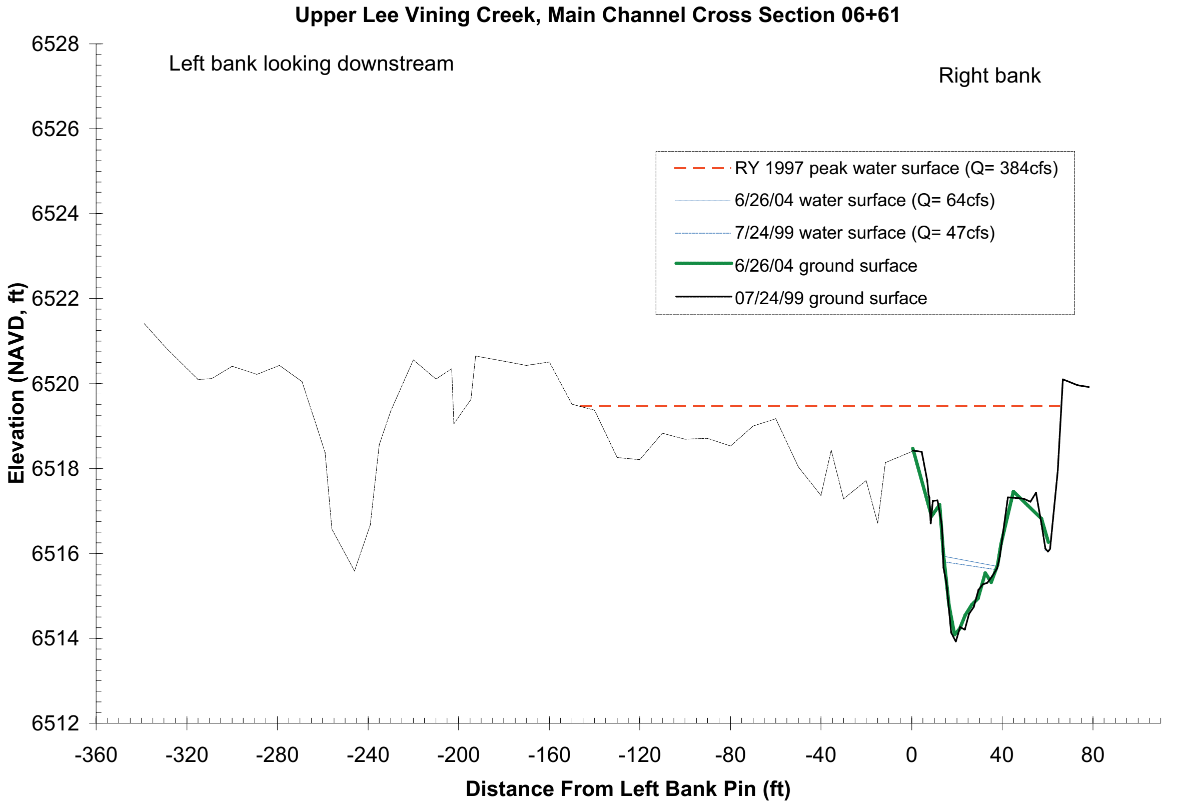

Walker Creek - Cross Section 00+23
Left bank looking downstream
Right bank
Elevation (NAVD, ft)
6856
6855
6854
6853
6852
6851
6850
-5
5
15
25
35
45
55
65
75
Distance From Left Bank Pin (ft)
WY1999 peak water surface (Q= 30cfs)
8/11/99 ground surface
10/22/04 ground surface
8/11/99 water surface (Q= 7.2cfs)
10/22/04 water surface (Q= 2.8cfs)

Lee Vining Creek

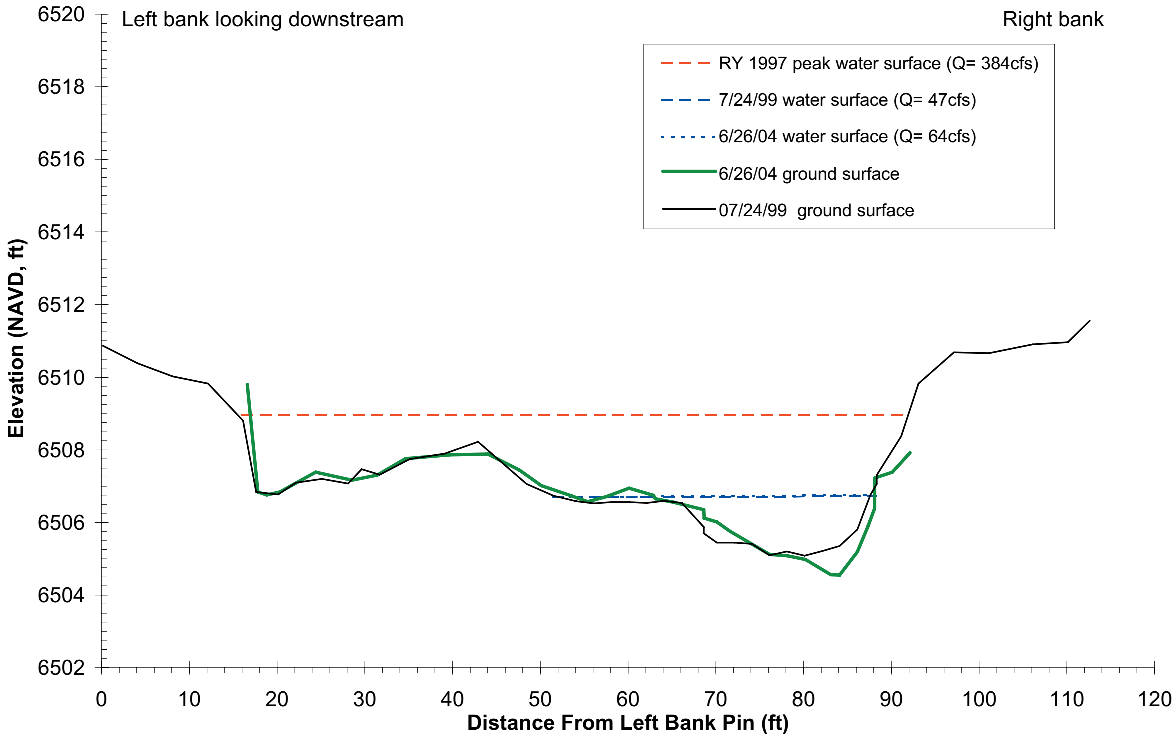

Upper Lee Vining Creek, Main Channel Cross Section 13+92
Left bank looking downstream
Right bank
RY 1997 peak water surface (Q=384cfs)
6/26/2004 water surface (Q= 64cfs)
7/24/99 water surface (Q=44 cfs)
6/26/04 ground surface
07/24/99 ground surface
Elevation (NAVD, ft)
6546
6544
6542
6540
6538
6536
0
10
20
30
40
50
60
70
80
90
100
Distance From Left Bank Pin (ft)


Upper Lee Vining Creek, Main Channel Cross Section 10+44
Left bank looking downstream
Right bank
RY 1997 peak water surface (Q= 354 cfs)
6/26/04 water surface (Q= 64cfs)
7/24/99 water surface (Q= 47cfs)
6/26/04 ground surface
07/24/99 ground surface
Right Bank
Side Channel
Mainstem
Elevation (NAVD, ft)
6538
6537
6536
6535
6534
6533
6532
6531
6530
6529
6528
6527
6526
-10
10
30
50
70
90
110
130
150
170
190
210
230
250
Distance From Left Bank Pin (ft)

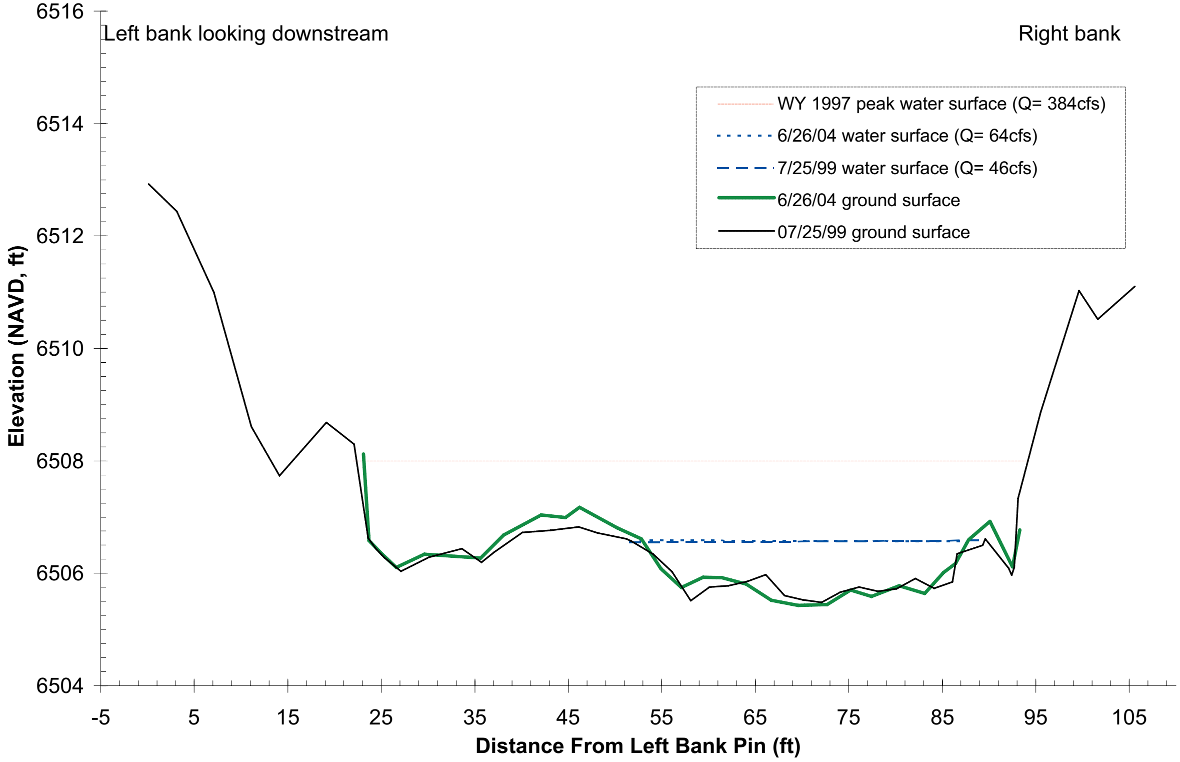

Upper Lee Vining Creek, Main Channel Cross Section 09+31
Left bank looking downstream
Right bank
RY 1997 peak water surface (Q= 384cfs)
RY 2004 peak water surface (Q= 103cfs)
6/26/04 water surface (Q= 64cfs)
7/24/99 water surface (Q= 47cfs)
6/26/04 ground surface
07/24/99 ground surface
Elevation (NAVD, ft)
6532
6530
6528
6526
6524
6522
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Distance From Left Bank Pin (ft)

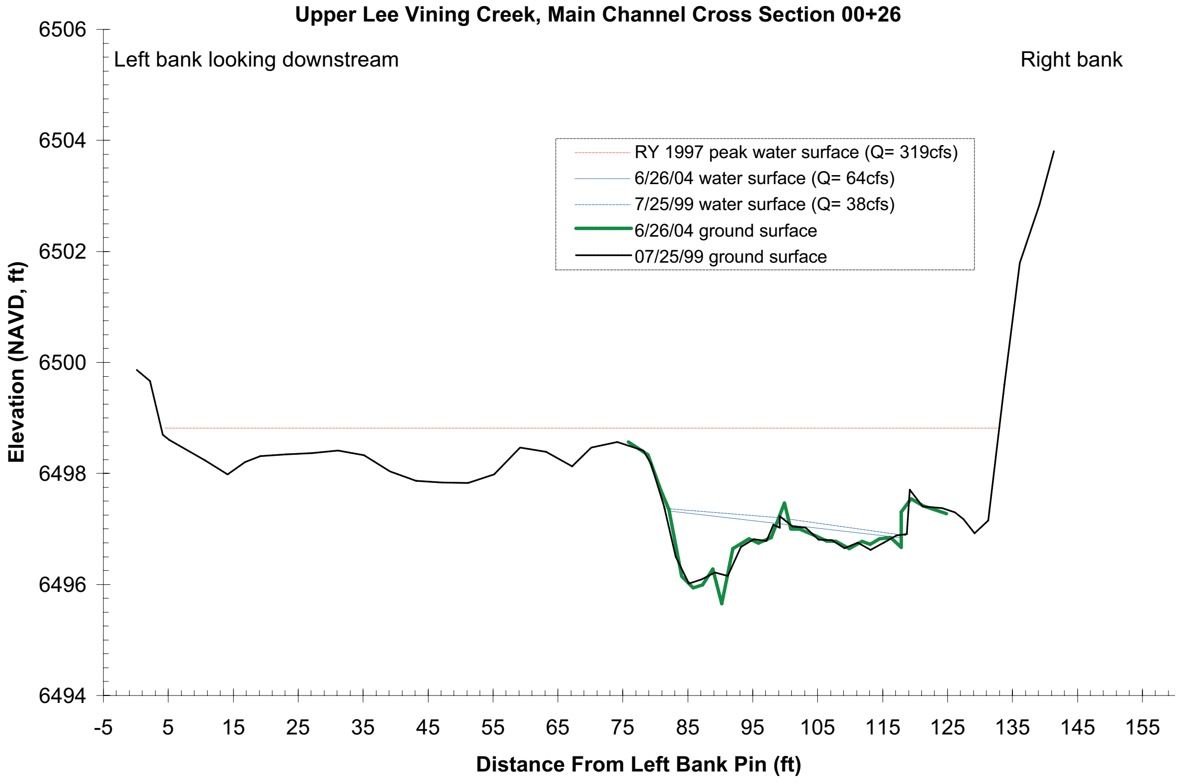

Upper Lee Vining Creek, Main Channel Cross Section 06+61
Left bank looking downstream
Right bank
RY 1997 peak water surface (Q= 384cfs)
6/26/04 water surface (Q= 64cfs)
7/24/99 water surface (Q= 47cfs)
6/26/04 ground surface
07/24/99 ground surface
Elevation (NAVD, ft)
6528
6526
6524
6522
6520
6518
6516
6514
6512
-360
-320
-280
-240
-200
-160
-120
-80
-40
0
40
80
Distance From Left Bank Pin (ft)

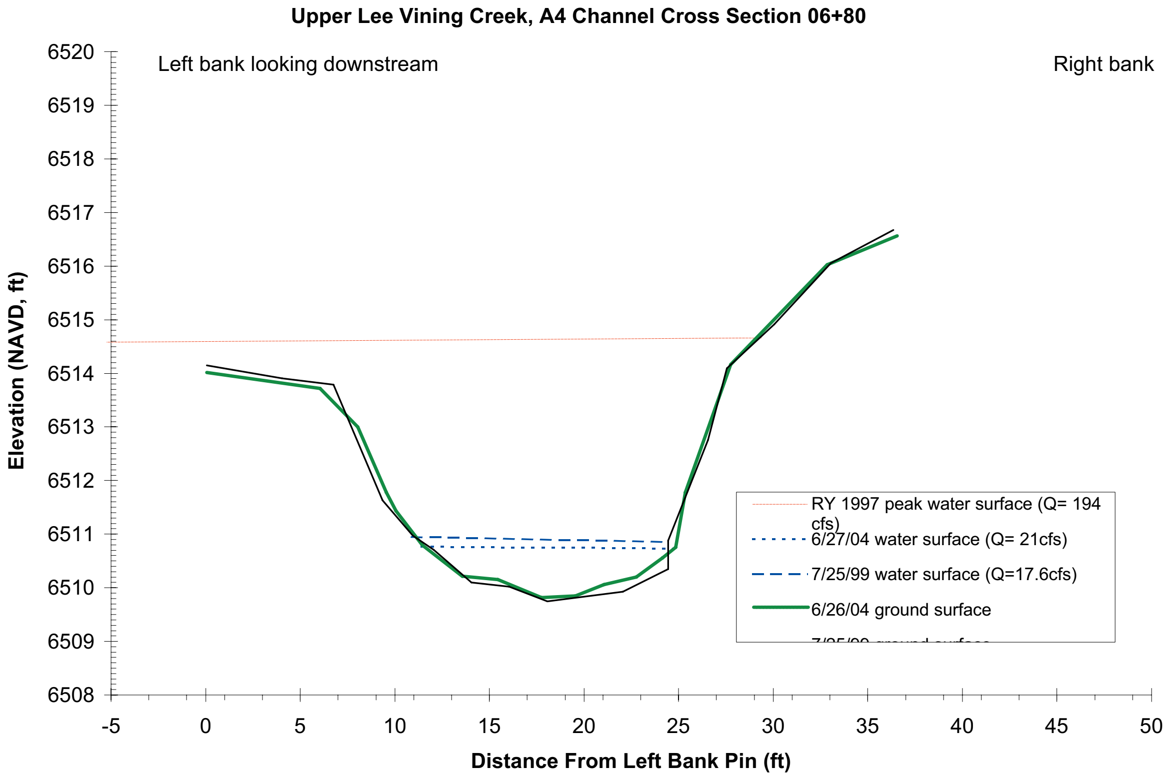
Upper Lee Vining Creek - Main Channel Cross Section 03+73

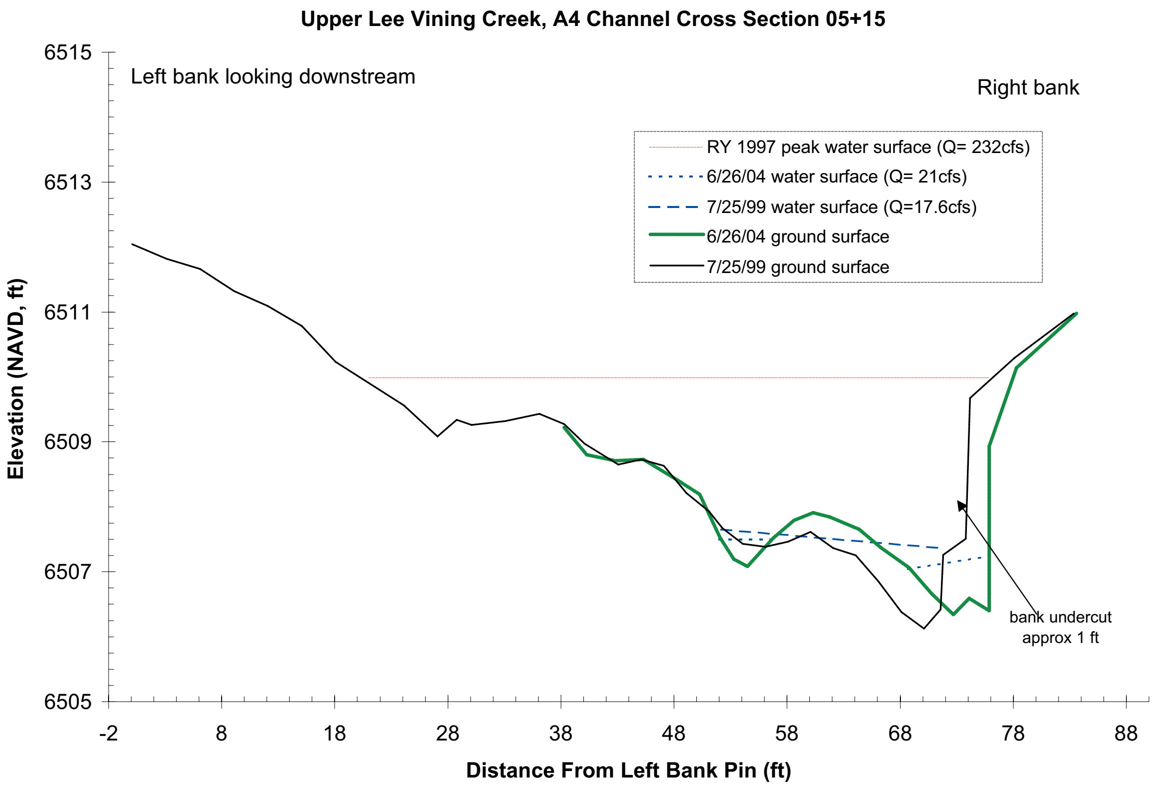


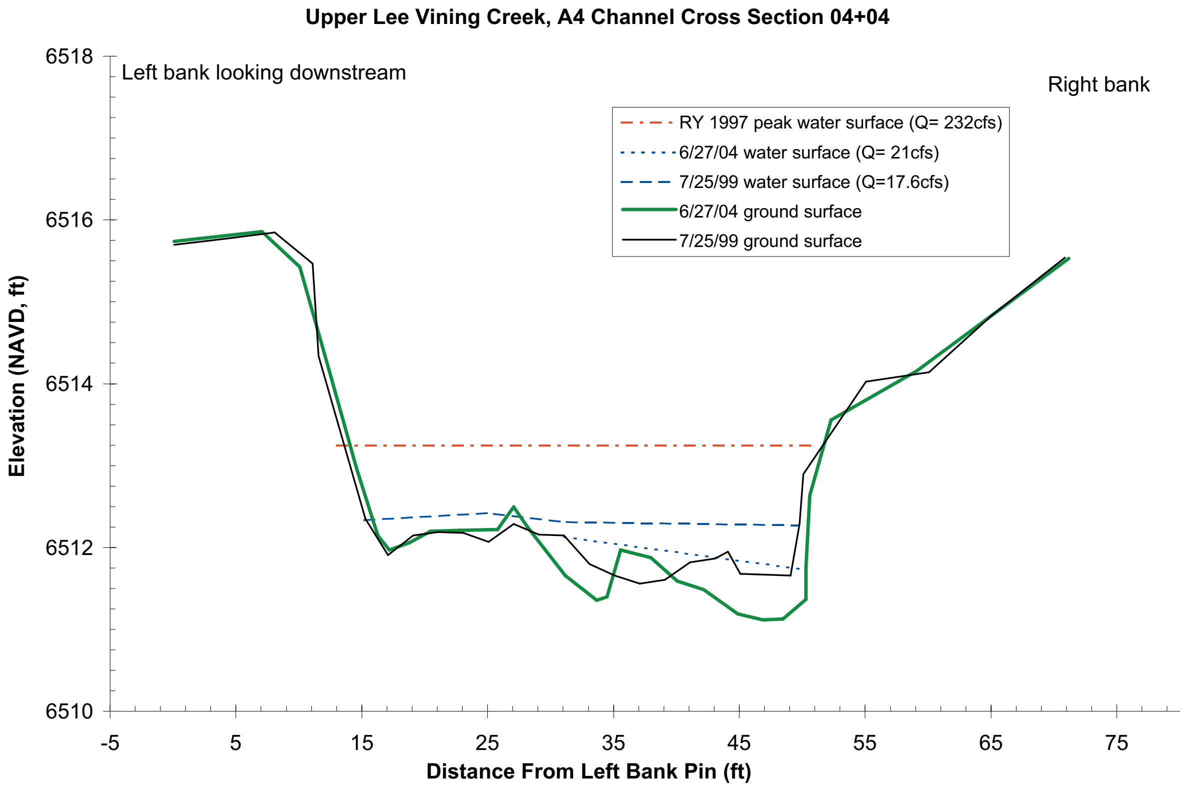
Upper Lee Vining Creek - Main Channel Cross Section 03+45

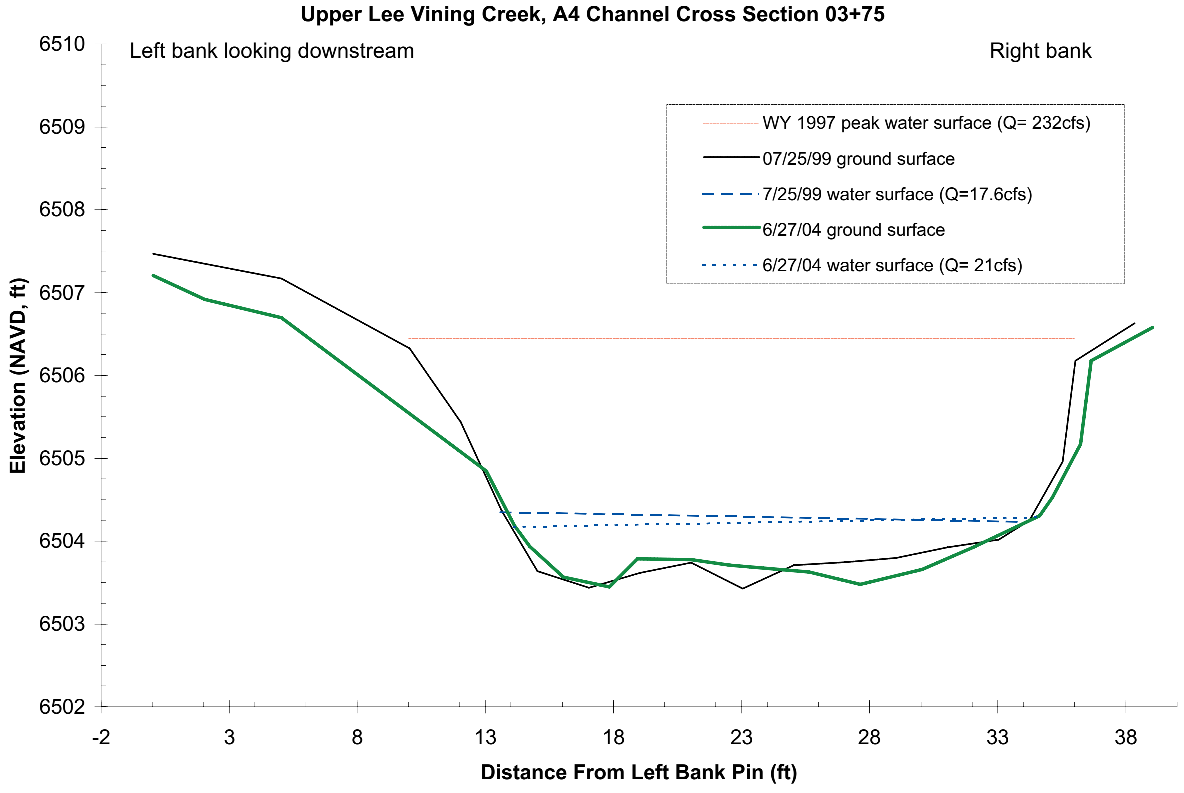


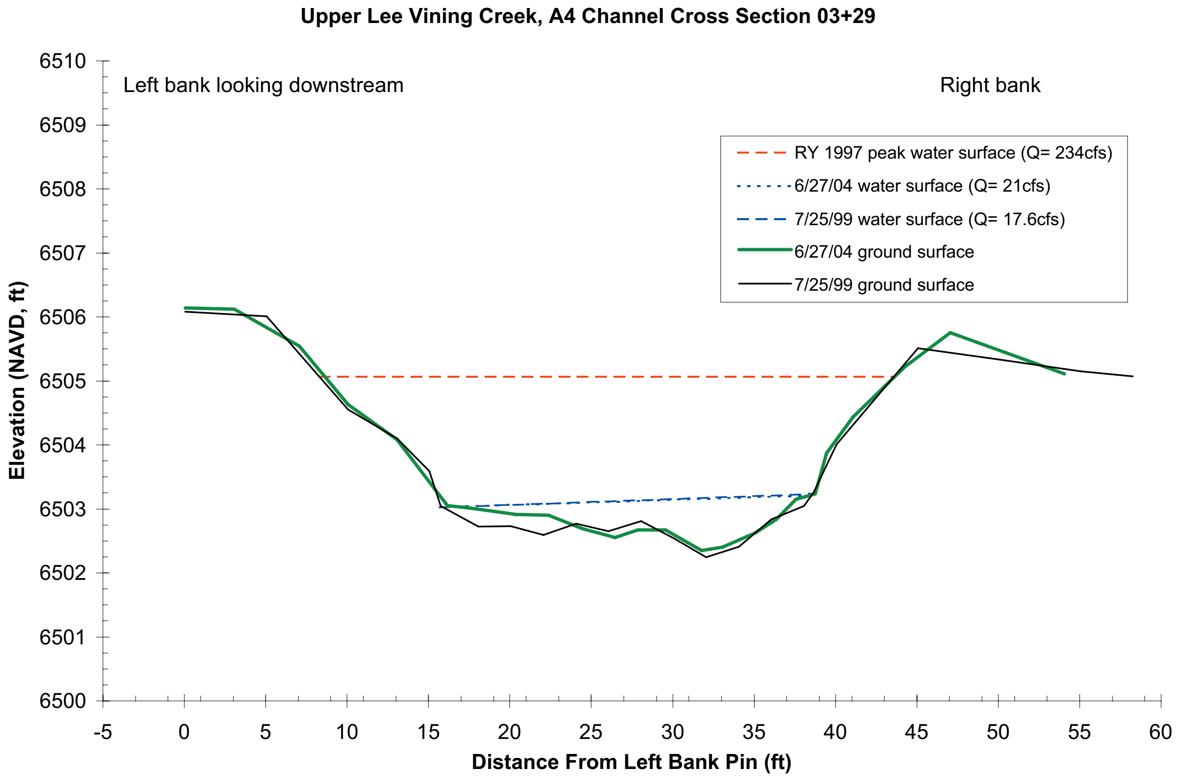

Upper Lee Vining Creek, Main Channel Cross Section 00+26
Left bank looking downstream
Right bank
RY 1997 peak water surface (Q= 319cfs)
6/26/04 water surface (Q= 64cfs)
7/25/99 water surface (Q= 38cfs)
6/26/04 ground surface
07/25/99 ground surface
Elevation (NAVD, ft)
6506
6504
6502
6500
6498
6496
6494
-5
5
15
25
35
45
55
65
75
85
95
105
115
125
135
145
155
Distance From Left Bank Pin (ft)

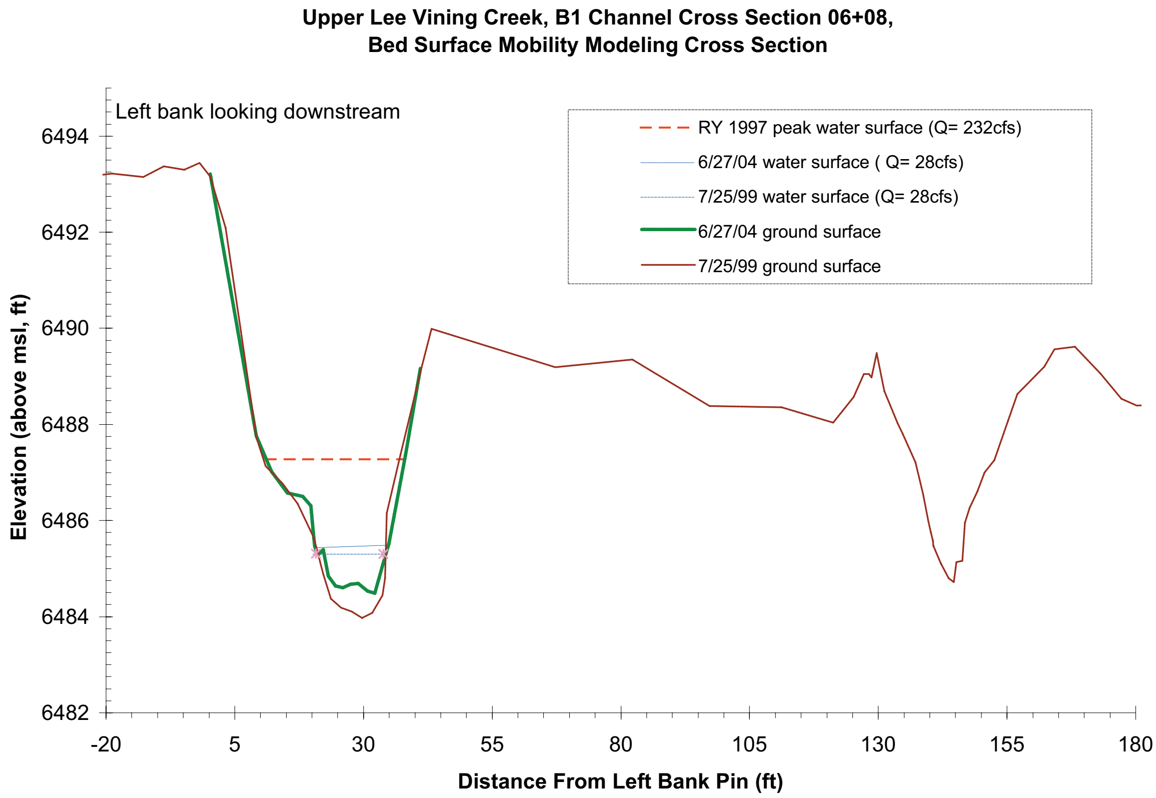

Upper Lee Vining Creek, A4 Channel Cross Section 06+80
Left bank looking downstream
Right bank
RY 1997 peak water surface (Q= 194 cfs)
6/27/04 water surface (Q= 21cfs)
7/25/99 water surface (Q=17.6cfs)
6/26/04 ground surface
Elevation (NAVD, ft)
6520
6519
6518
6517
6516
6515
6514
6513
6512
6511
6510
6509
6508
-5
0
5
10
15
20
25
30
35
40
45
50
Distance From Left Bank Pin (ft)


Upper Lee Vining Creek, A4 Channel Cross Section 05+15

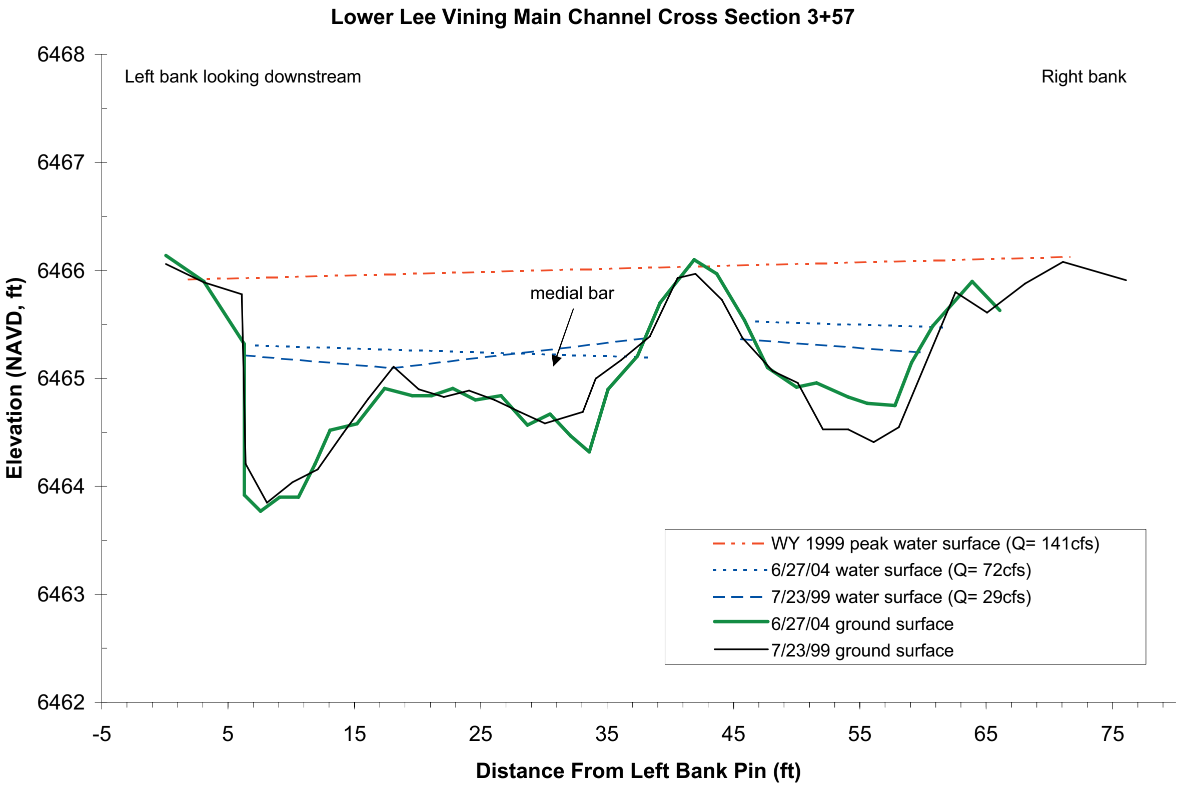

Upper Lee Vining Creek, A4 Channel Cross Section 04+04


Upper Lee Vining Creek, A4 Channel Cross Section 03+75
Left bank looking downstream
Right bank
WY 1997 peak water surface (Q= 232cfs)
07/25/99 ground surface
7/25/99 water surface (Q=17.6cfs)
6/27/04 ground surface
6/27/04 water surface (Q= 21cfs)
Elevation (NAVD, ft)
6510
6509
6508
6507
6506
6505
6504
6503
6502
-2
3
8
13
18
23
28
33
38
Distance From Left Bank Pin (ft)

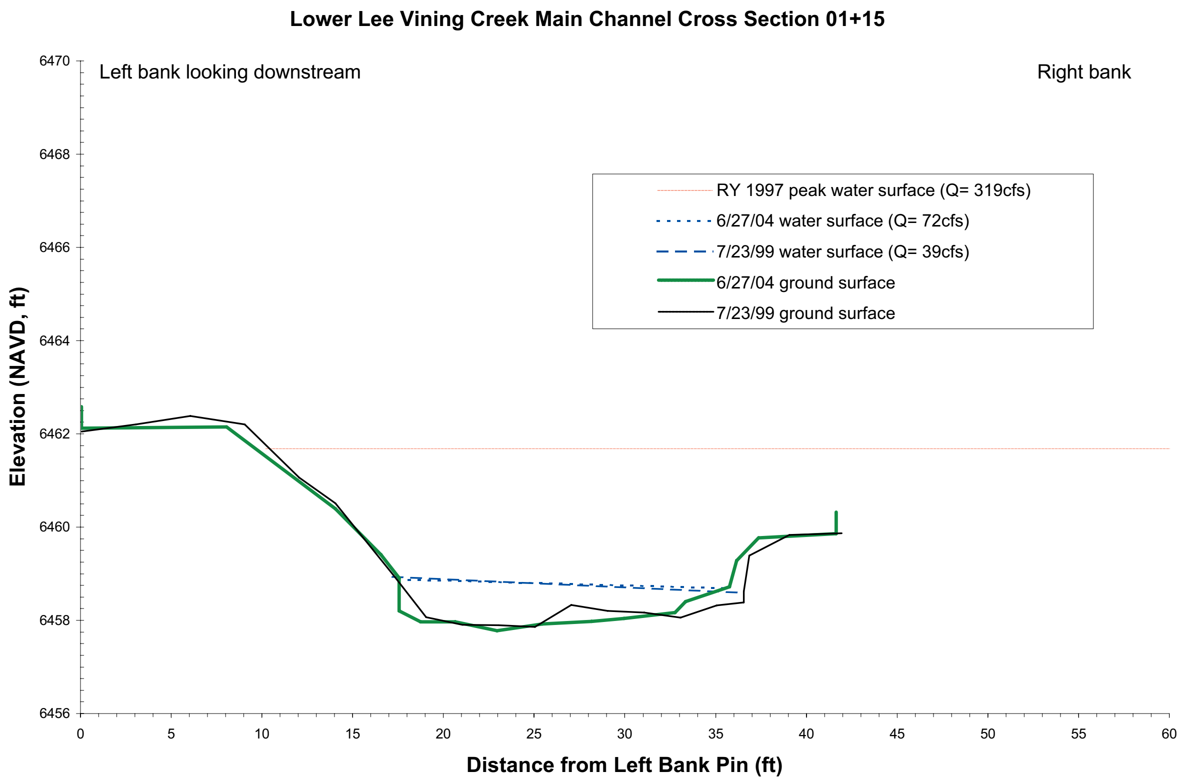

Upper Lee Vining Creek, A4 Channel Cross Section 03+29
Left bank looking downstream
Right bank
RY 1997 peak water surface (Q= 234cfs)
6/27/04 water surface (Q= 21cfs)
7/25/99 water surface (Q= 17.6cfs)
6/27/04 ground surface
7/25/99 ground surface
Elevation (NAVD, ft)
6510
6509
6508
6507
6506
6505
6504
6503
6502
6501
6500
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
Distance From Left Bank Pin (ft)

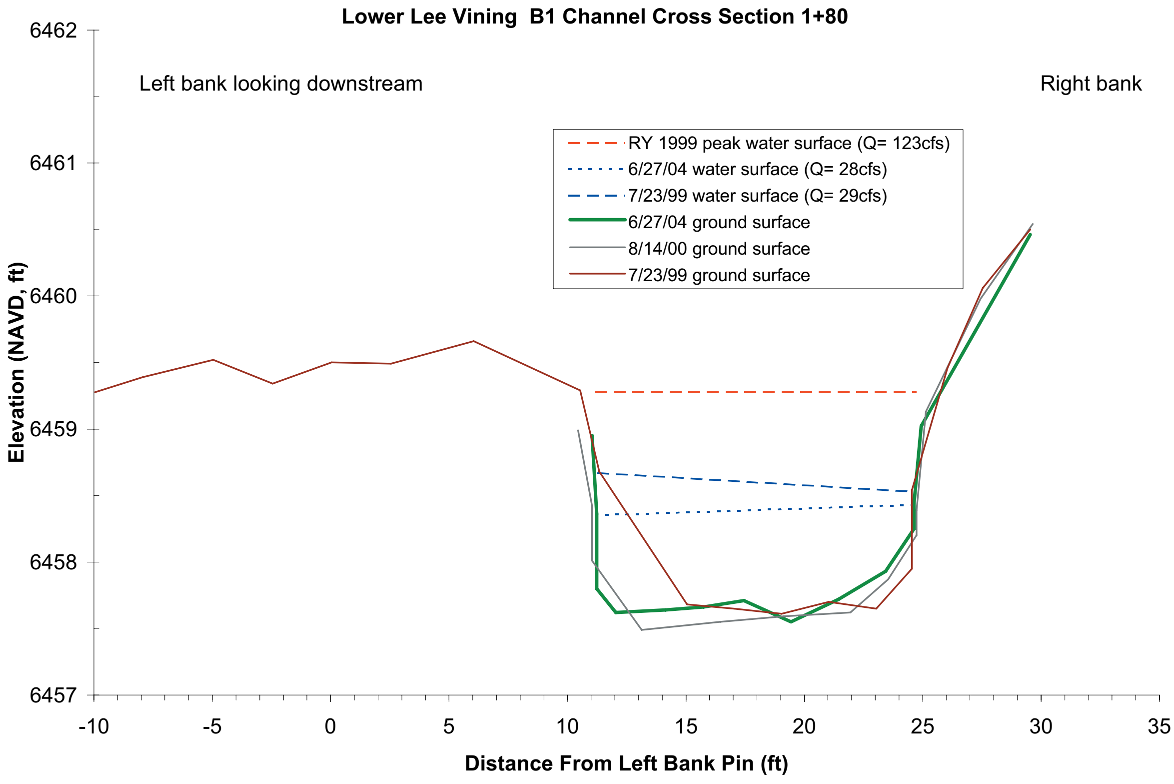


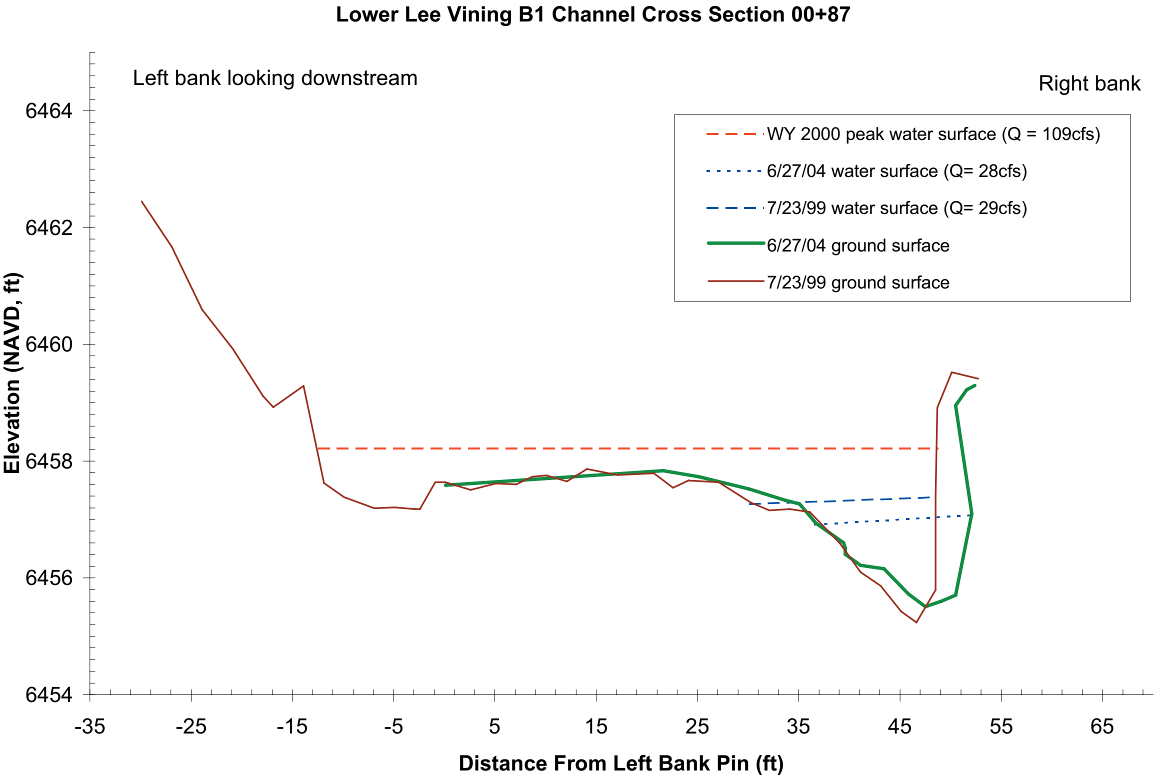
Upper Lee Vining Creek, B1 Channel Cross Section 06+08,
Bed Surface Mobility Modeling Cross Section



Lower Lee Vining Main Channel Cross Section 3+57


Lower Lee Vining Creek Main Channel Cross Section 01+15
Left bank looking downstream
Right bank
RY 1997 peak water surface (Q= 319cfs)
6/27/04 water surface (Q= 72cfs)
7/23/99 water surface (Q= 39cfs)
6/27/04 ground surface
7/23/99 ground surface
Elevation (NAVD, ft)
6470
6468
6466
6464
6462
6460
6458
6456
0
5
10
15
20
25
30
35
40
45
50
55
60
Distance from Left Bank Pin (ft)


Lower Lee Vining B1 Channel Cross Section 1+80
Left bank looking downstream
Right bank
RY 1999 peak water surface (Q= 123cfs)
6/27/04 water surface (Q= 28cfs)
7/23/99 water surface (Q= 29cfs)
6/27/04 ground surface
8/14/00 ground surface
7/23/99 ground surface
Elevation (NAVD, ft)
6462
6461
6460
6459
6458
6457
-10
-5
0
5
10
15
20
25
30
35
Distance From Left Bank Pin (ft)

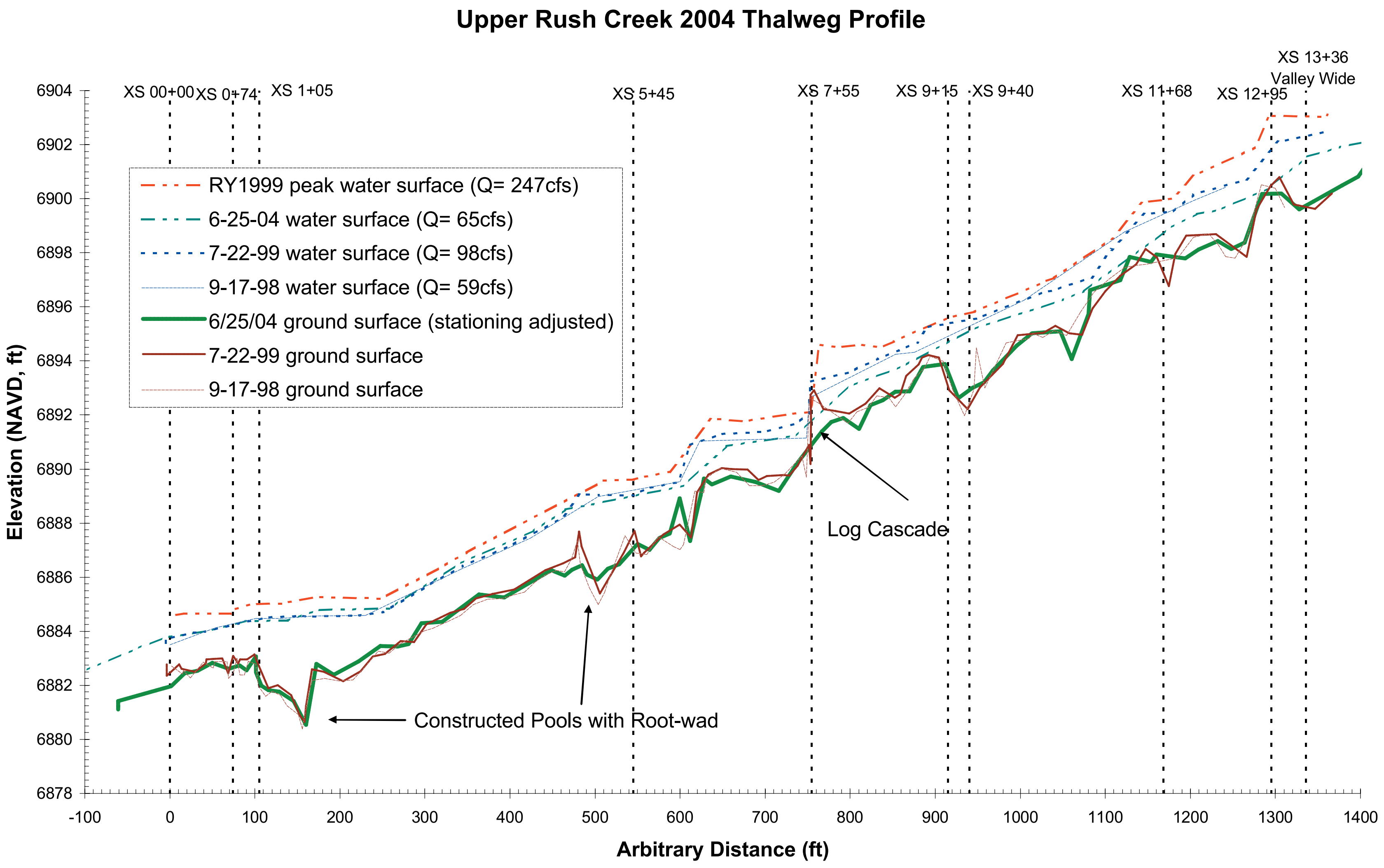

Lower Lee Vining B1 Channel Cross Section 00+87
Left bank looking downstream
Right bank
WY 2000 peak water surface (Q = 109cfs)
6/27/04 water surface (Q= 28cfs)
7/23/99 water surface (Q= 29cfs)
6/27/04 ground surface
7/23/99 ground surface
Elevation (NAVD, ft)
6464
6462
6460
6458
6456
6454
-35
-25
-15
-5
5
15
25
35
45
55
65
Distance From Left Bank Pin (ft)

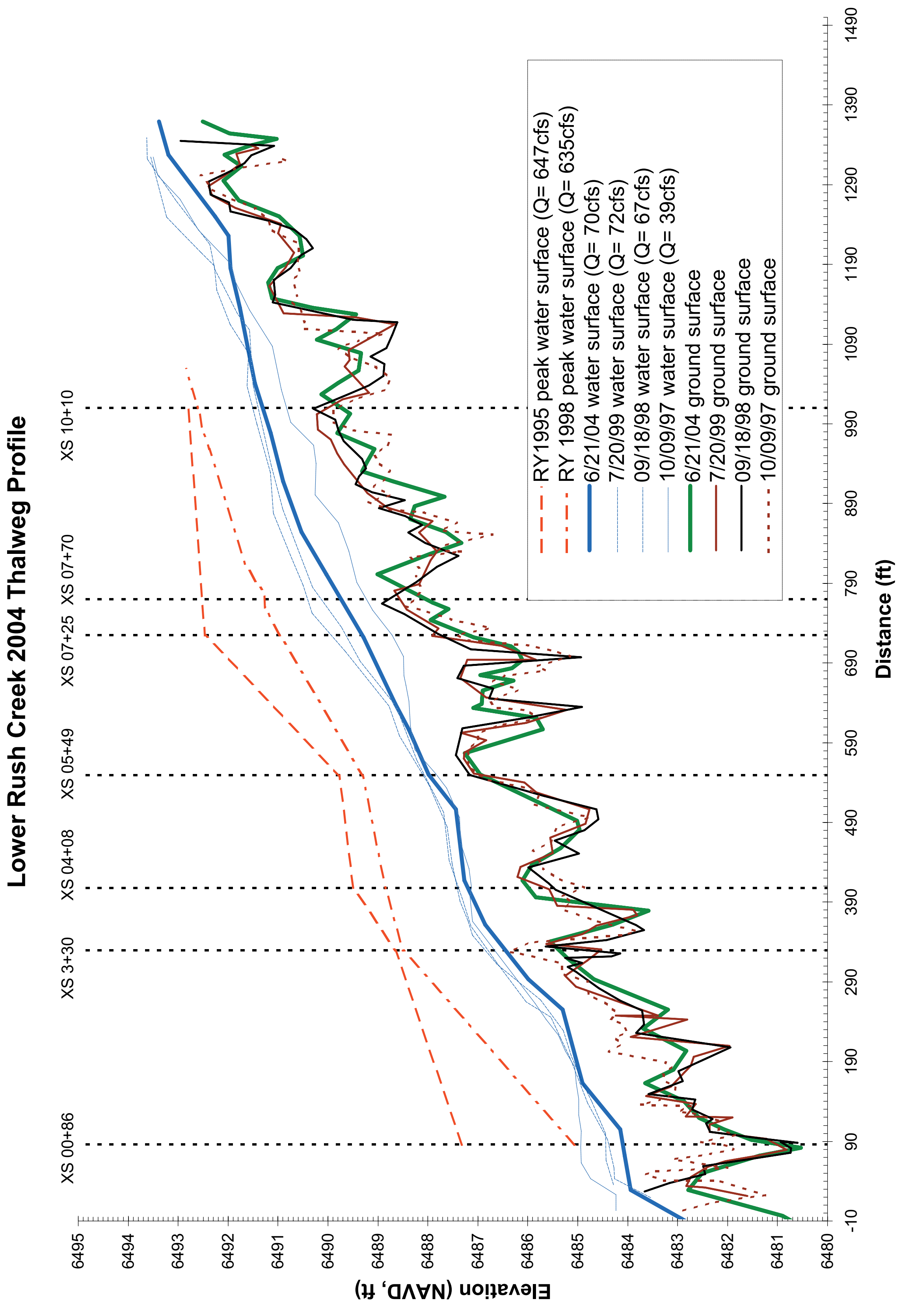
APPENDIX C

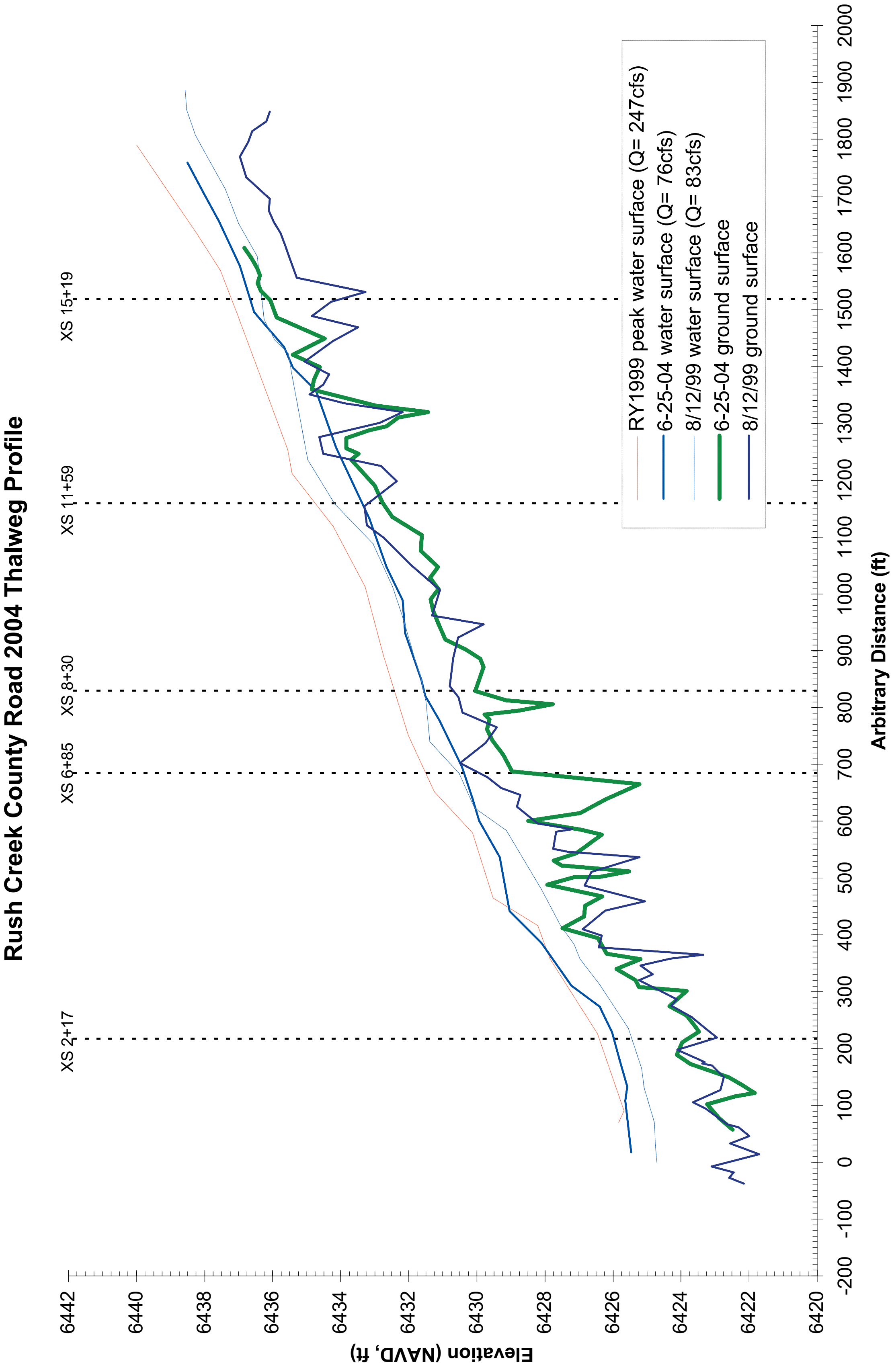
Long Profiles for Mono Lake Tributaries: Rush, Parker, Walker, and Lee Vining Creeks

TABLE OF CONTENTS

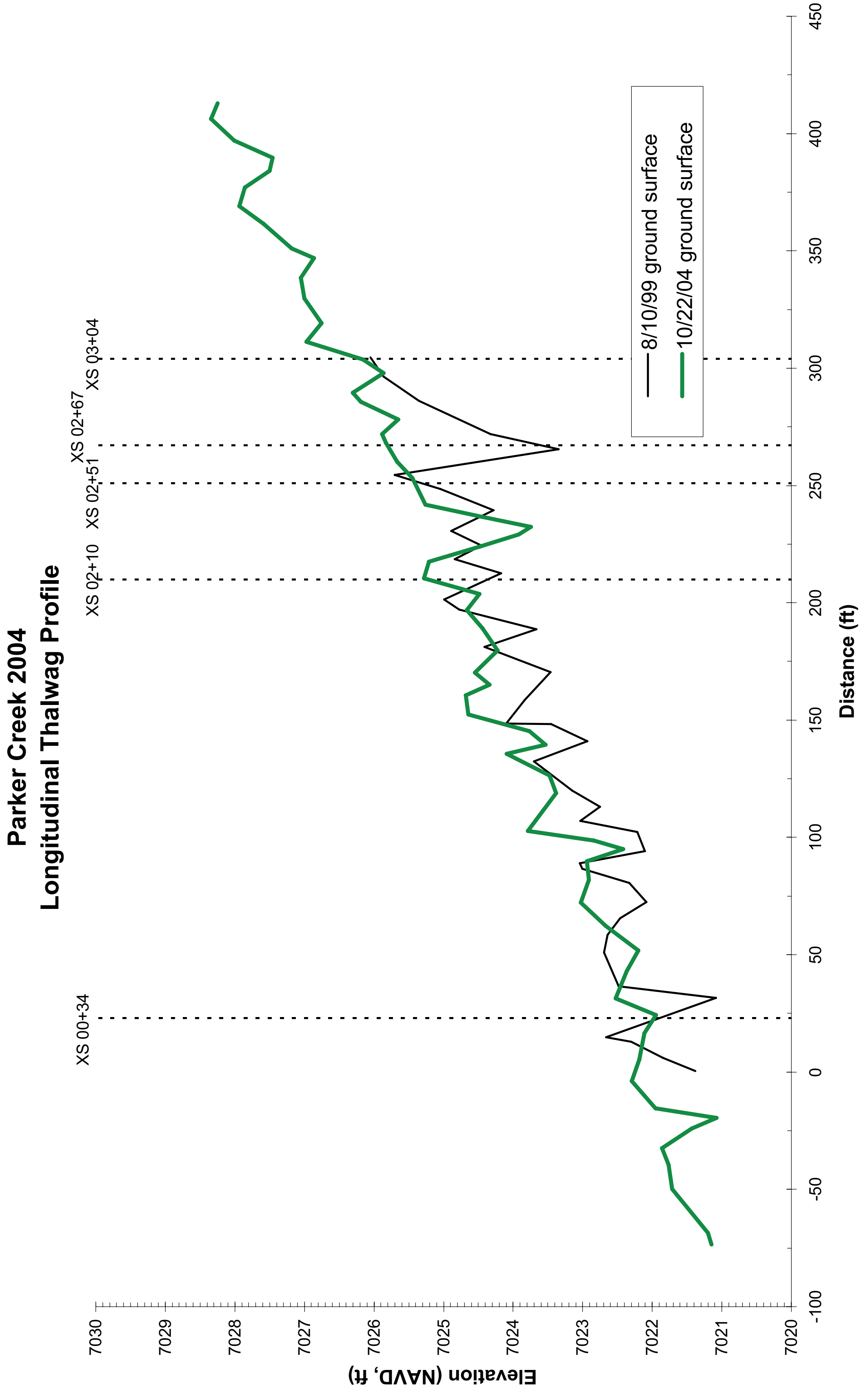
Rush Creek


Upper Rush Creek 2004 Thalweg Profile
XS 00+00
XS 0+74
XS 1+05
XS 5+45
XS 7+55
XS 9+15
XS 9+40
XS 11+68
XS 12+95
XS 13+36 Valley Wide
RY1999 peak water surface (Q= 247cfs)
6-25-04 water surface (Q= 65cfs)
7-22-99 water surface (Q= 98cfs)
9-17-98 water surface (Q= 59cfs)
6/25/04 ground surface (stationing adjusted)
7-22-99 ground surface
9-17-98 ground surface
Log Cascade
Constructed Pools with Root-wad
Elevation (NAVD, ft)
6878
6880
6882
6884
6886
6888
6890
6892
6894
6896
6898
6900
6902
6904
Arbitrary Distance (ft)
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400


Lower Rush Creek 2004 Thalweg Profile
XS 00+86
XS 3+30
XS 04+08
XS 05+49
XS 07+25
XS 07+70
XS 10+10
RY1995 peak water surface (Q= 647cfs)
RY 1998 peak water surface (Q= 635cfs)
6/21/04 water surface (Q= 70cfs)
7/20/99 water surface (Q= 72cfs)
09/18/98 water surface (Q= 67cfs)
10/09/97 water surface (Q= 39cfs)
6/21/04 ground surface
7/20/99 ground surface
09/18/98 ground surface
10/09/97 ground surface
Elevation (NAVD, ft)
6480
6481
6482
6483
6484
6485
6486
6487
6488
6489
6490
6491
6492
6493
6494
6495
Distance (ft)
-10
90
190
290
390
490
590
690
790
890
990
1090
1190
1290
1390
1490

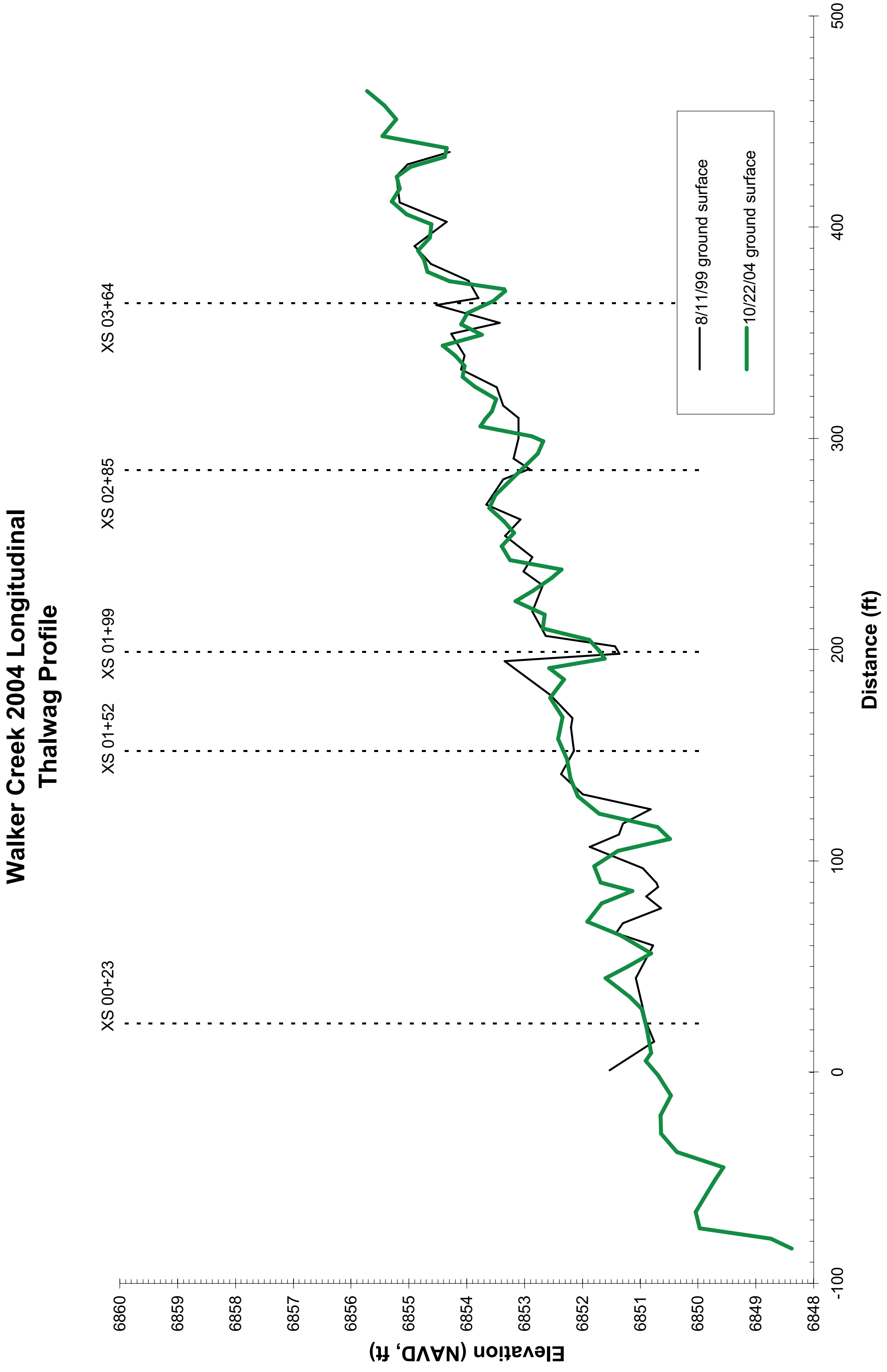

Rush Creek County Road 2004 Thalweg Profile
XS 2+17
XS 6+85
XS 8+30
XS 11+59
XS 15+19
Elevation (NAVD, ft)
6442
6440
6438
6436
6434
6432
6430
6428
6426
6424
6422
6420
Arbitrary Distance (ft)
-200
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
RY1999 peak water surface (Q= 247cfs)
6-25-04 water surface (Q= 76cfs)
8/12/99 water surface (Q= 83cfs)
6-25-04 ground surface
8/12/99 ground surface

Parker Creek

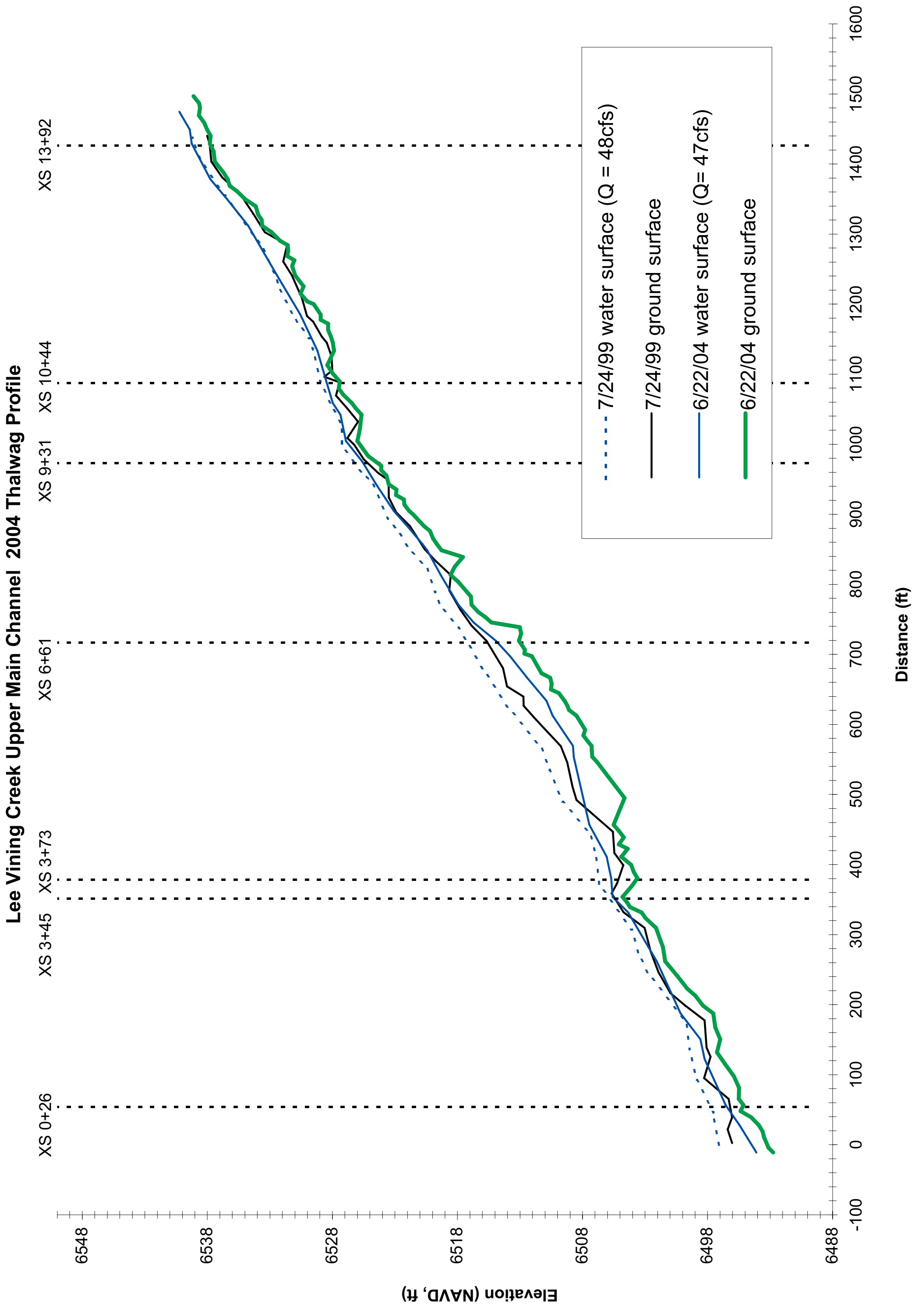


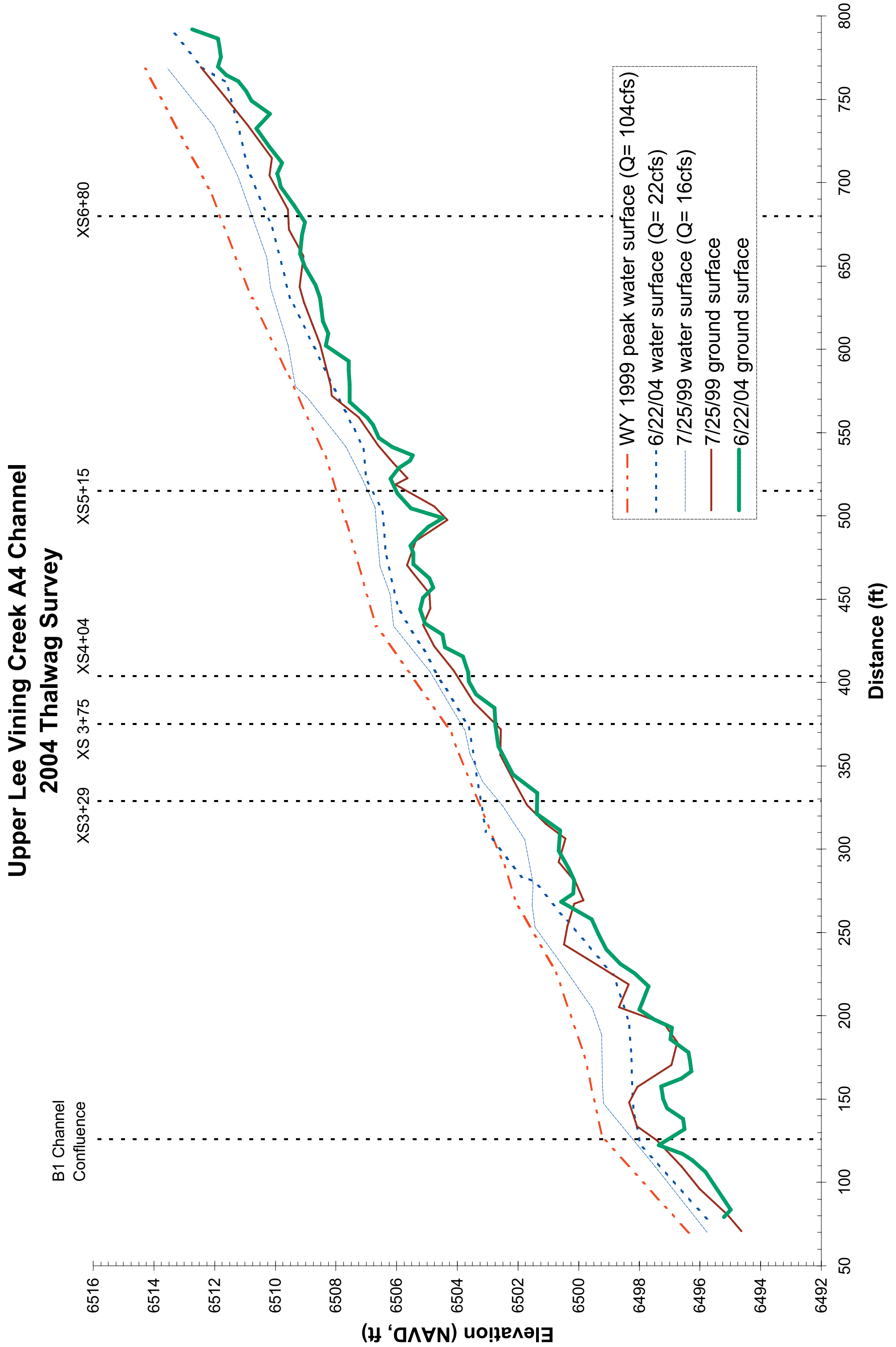
Parker Creek 2004
Longitudinal Thalwag Profile

Walker Creek

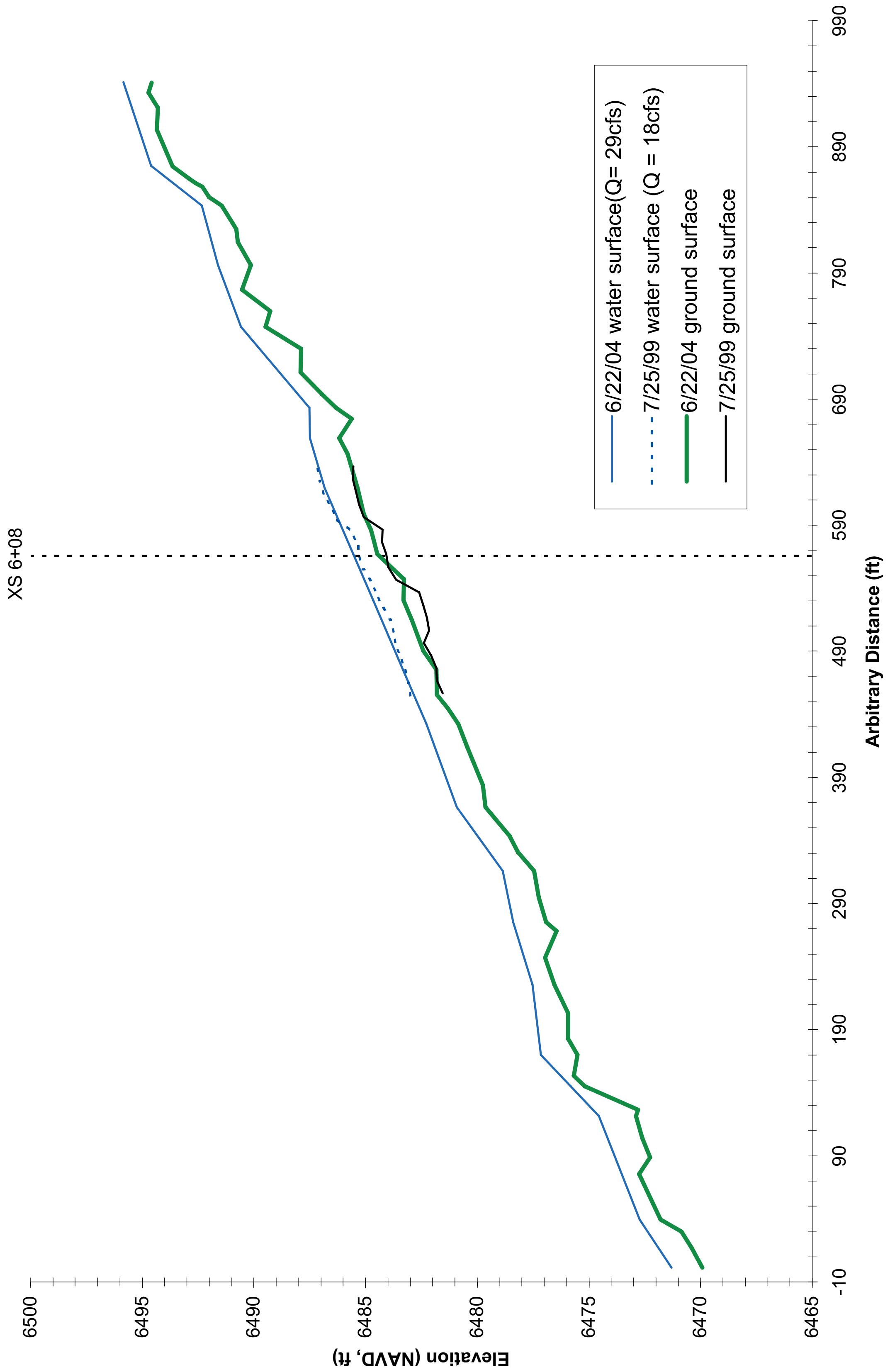

Walker Creek 2004 Longitudinal
Thalwag Profile
XS 00+23
XS 01+52
XS 01+99
XS 02+85
XS 03+64
8/11/99 ground surface
10/22/04 ground surface
Elevation (NAVD, ft)
6860
6859
6858
6857
6856
6855
6854
6853
6852
6851
6850
6849
6848
Distance (ft)
-100
0
100
200
300
400
500

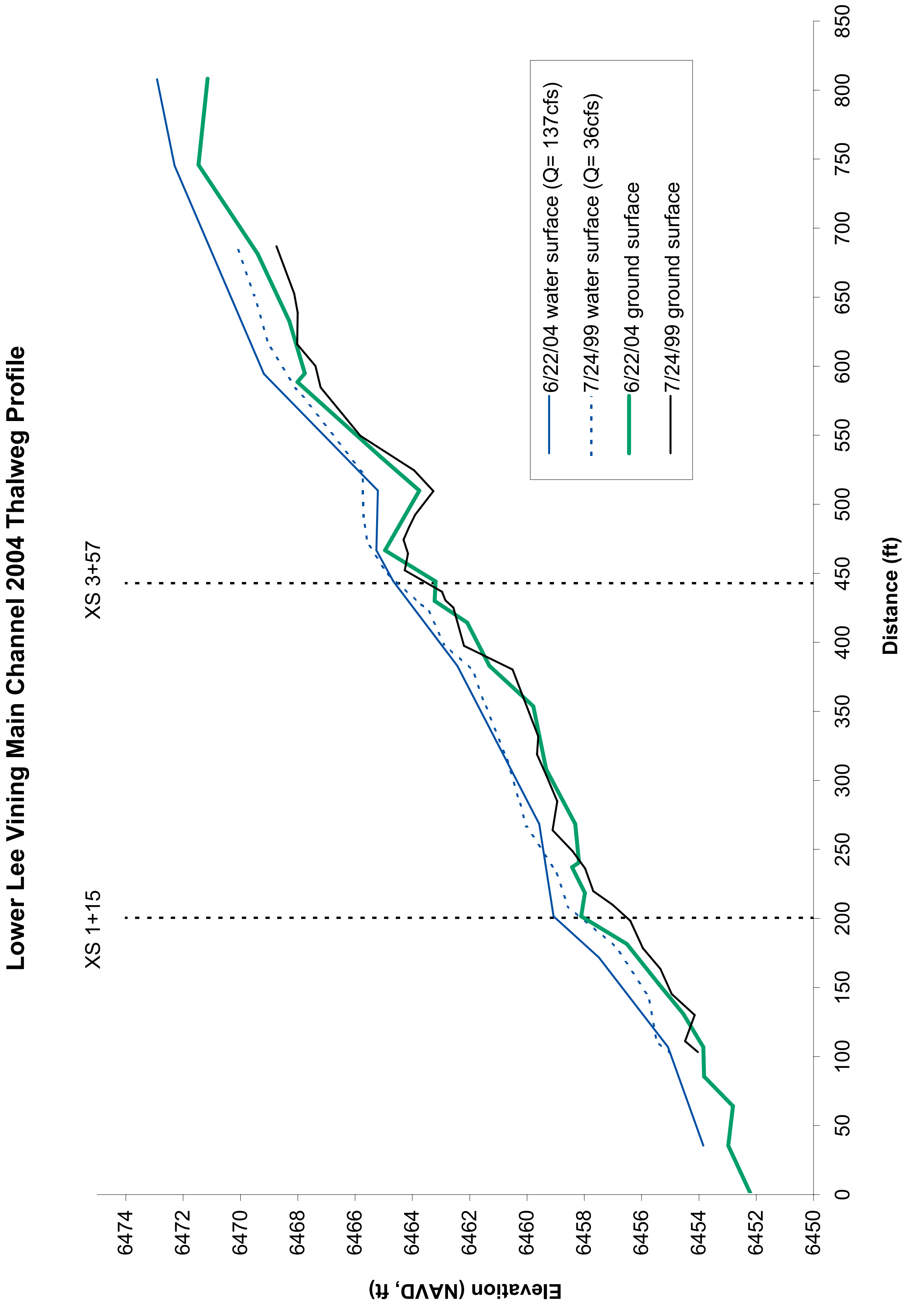
Lee Vining Creek


Lee Vining Creek Upper Main Channel 2004 Thalwag Profile
XS 0+26
XS 3+45
XS 3+73
XS 6+61
XS 9+31
XS 10+44
XS 13+92
Elevation (NAVD, ft)
6548
6538
6528
6518
6508
6498
6488
Distance (ft)
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
7/24/99 water surface (Q = 48cfs)
7/24/99 ground surface
6/22/04 water surface (Q= 47cfs)
6/22/04 ground surface

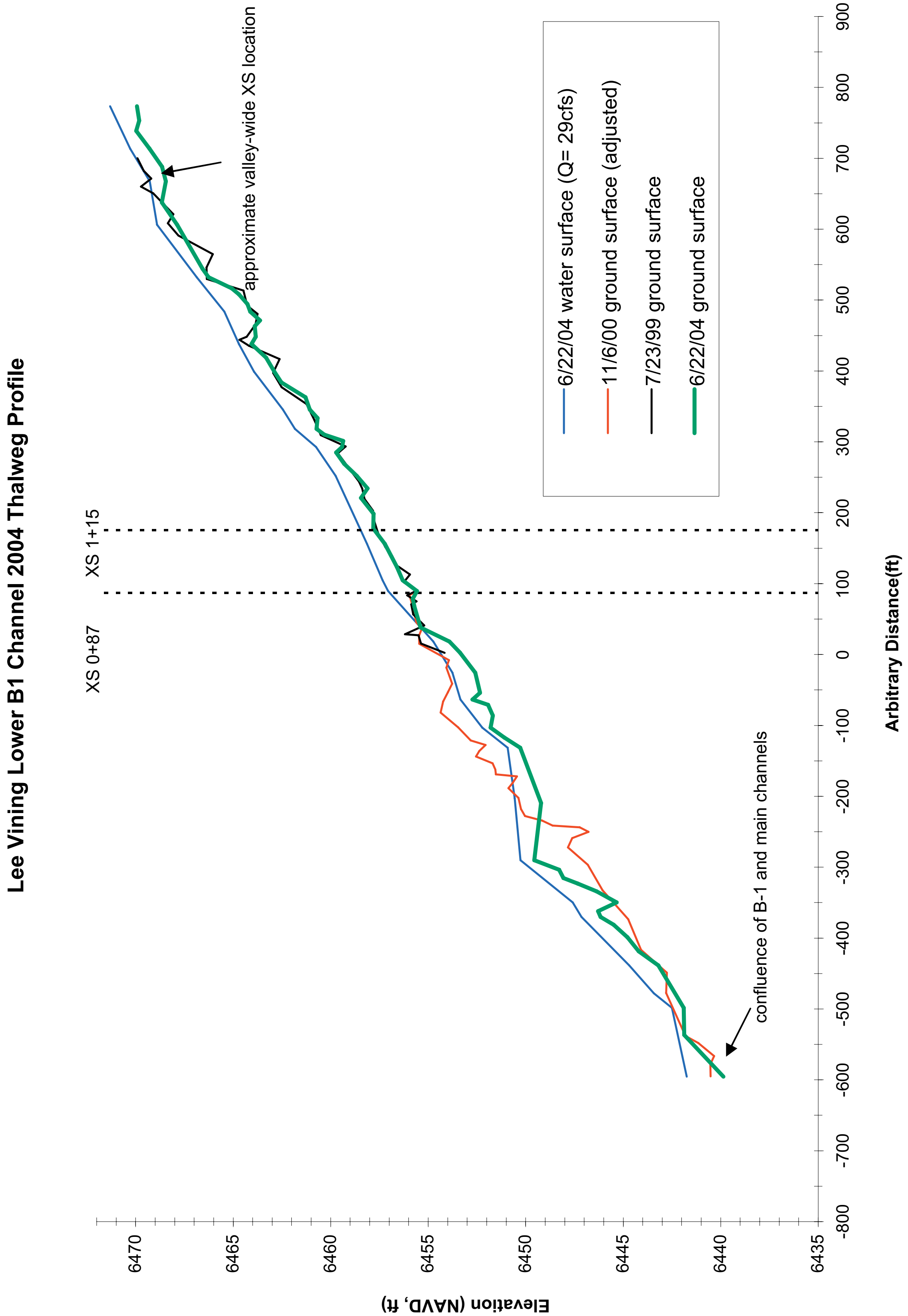

Upper Lee Vining Creek A4 Channel
2004 Thalwag Survey

Lee Vining Upper B1 Channel 2004 Longitudinal Thalweg Profile





Lower Lee Vining Main Channel 2004 Thalweg Profile

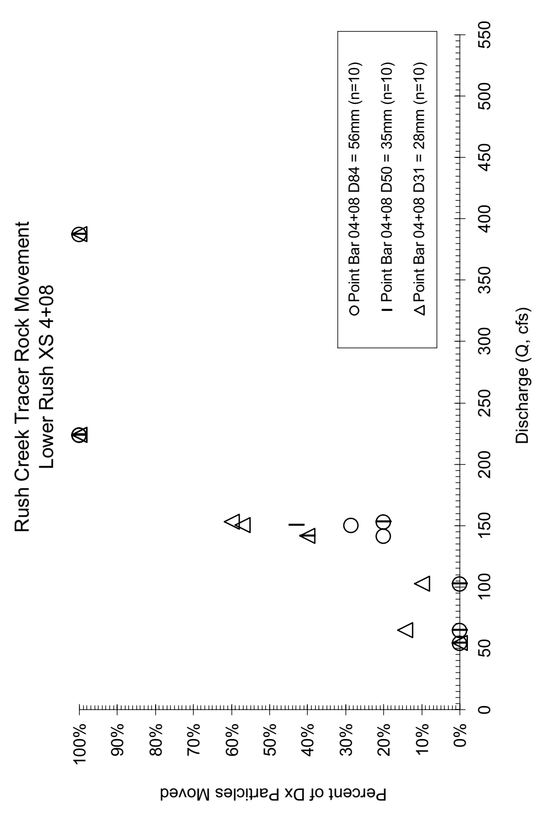

Lee Vining Lower B1 Channel 2004 Thalweg Profile
XS 0+87
XS 1+15
approximate valley-wide XS location
confluence of B-1 and main channels
6/22/04 water surface (Q= 29cfs)
11/6/00 ground surface (adjusted)
7/23/99 ground surface
6/22/04 ground surface
Elevation (NAVD, ft)
6435
6440
6445
6450
6455
6460
6465
6470
Arbitrary Distance(ft)
-800
-700
-600
-500
-400
-300
-200
-100
0
100
200
300
400
500
600
700
800
900

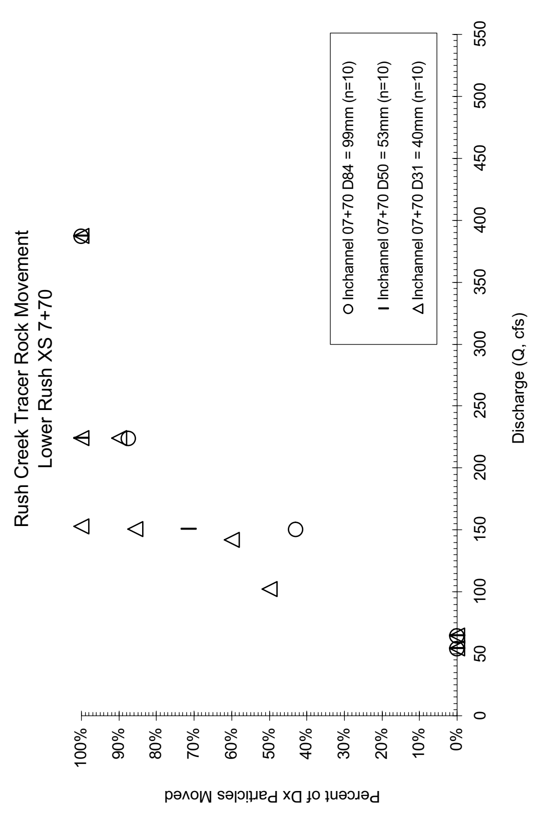
APPENDIX D

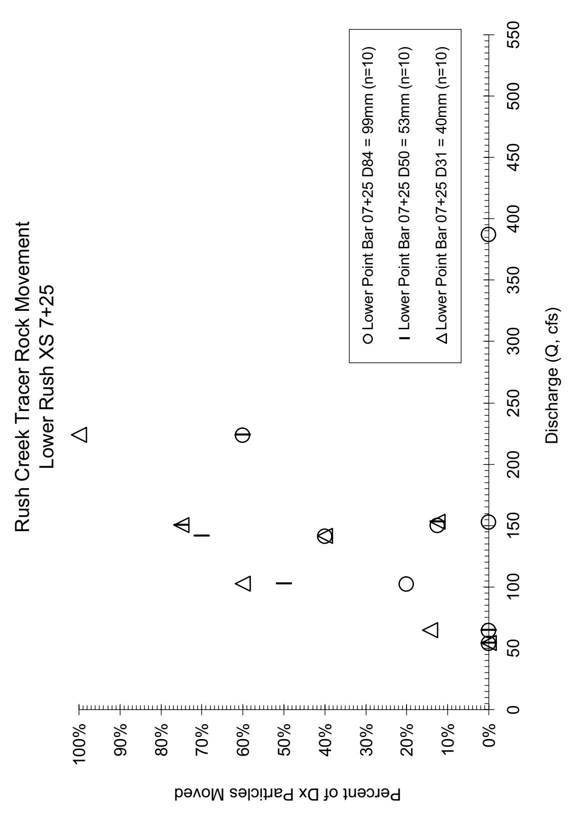
Tracer Rock Movement for Mono Lake Tributaries: Rush and Lee Vining Creeks

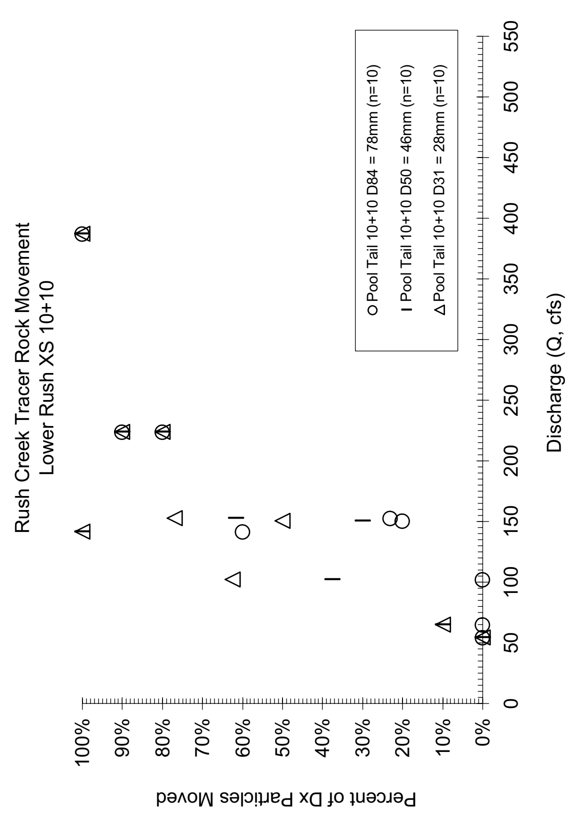
TABLE OF CONTENTS

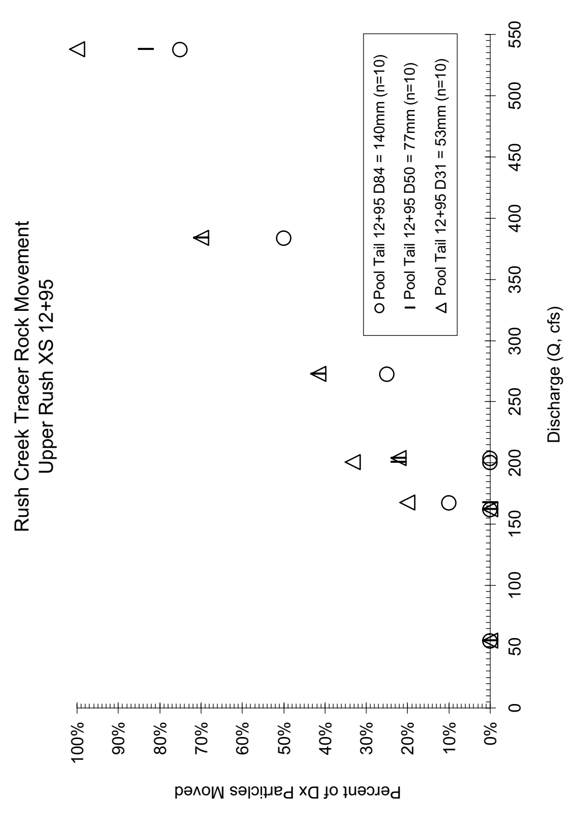
Rush Creek

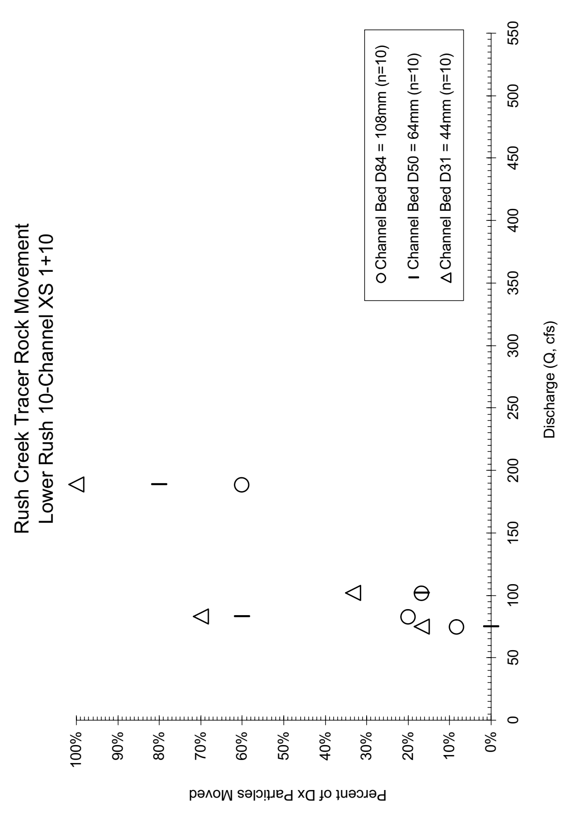

Rush Creek Tracer Rock Movement
Lower Rush XS 4+08
Percent of Dx Particles Moved
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
50
100
150
200
250
300
350
400
450
500
550
Discharge (Q, cfs)
O Point Bar 04+08 D84 = 56mm (n=10)
I Point Bar 04+08 D50 = 35mm (n=10)
Δ Point Bar 04+08 D31 = 28mm (n=10)

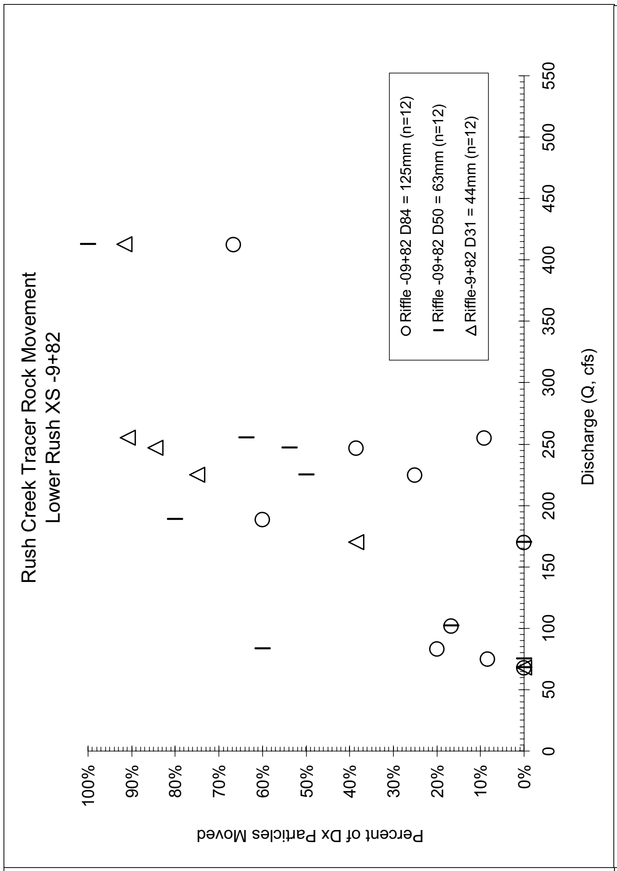

Rush Creek Tracer Rock Movement
Lower Rush XS 7+70
Percent of Dx Particles Moved
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
50
100
150
200
250
300
350
400
450
500
550
Discharge (Q, cfs)
O Inchannel 07+70 D84 = 99mm (n=10)
I Inchannel 07+70 D50 = 53mm (n=10)
Δ Inchannel 07+70 D31 = 40mm (n=10)

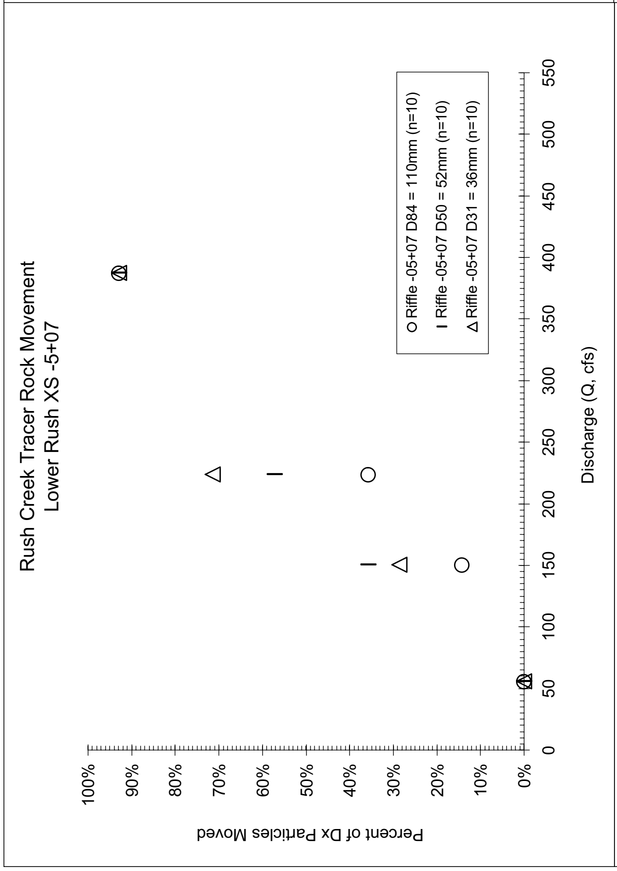

Rush Creek Tracer Rock Movement
Lower Rush XS 7+25
Percent of Dx Particles Moved
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
50
100
150
200
250
300
350
400
450
500
550
Discharge (Q, cfs)
O Lower Point Bar 07+25 D84 = 99mm (n=10)
I Lower Point Bar 07+25 D50 = 53mm (n=10)
Δ Lower Point Bar 07+25 D31 = 40mm (n=10)

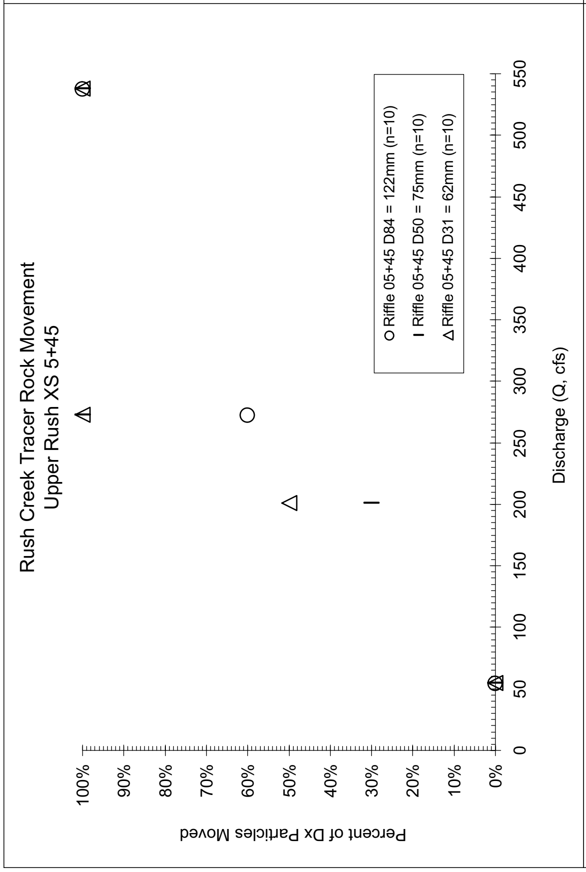

Rush Creek Tracer Rock Movement
Lower Rush XS 10+10
Percent of Dx Particles Moved
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
50
100
150
200
250
300
350
400
450
500
550
Discharge (Q, cfs)
O Pool Tail 10+10 D84 = 78mm (n=10)
I Pool Tail 10+10 D50 = 46mm (n=10)
Δ Pool Tail 10+10 D31 = 28mm (n=10)

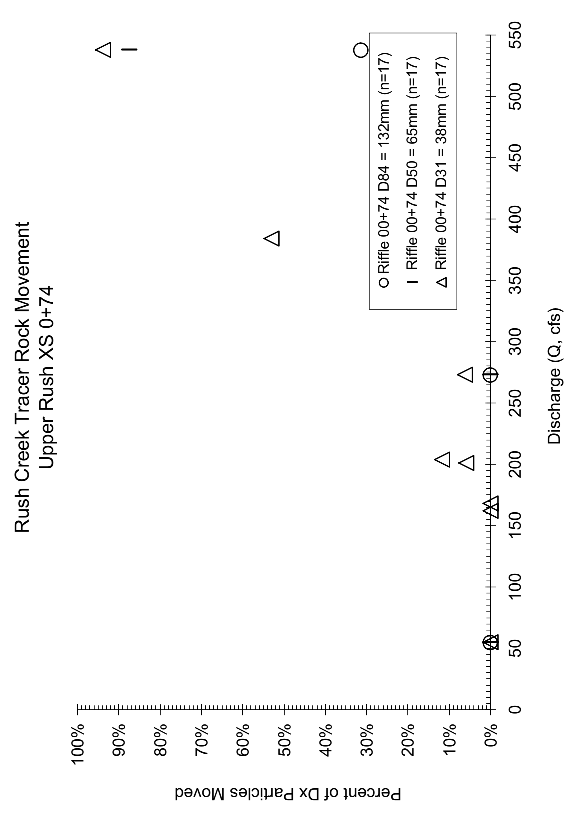

Rush Creek Tracer Rock Movement
Upper Rush XS 12+95
Percent of Dx Particles Moved
Discharge (Q, cfs)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
0 50 100 150 200 250 300 350 400 450 500 550
O Pool Tail 12+95 D84 = 140mm (n=10)
I Pool Tail 12+95 D50 = 77mm (n=10)
Δ Pool Tail 12+95 D31 = 53mm (n=10)

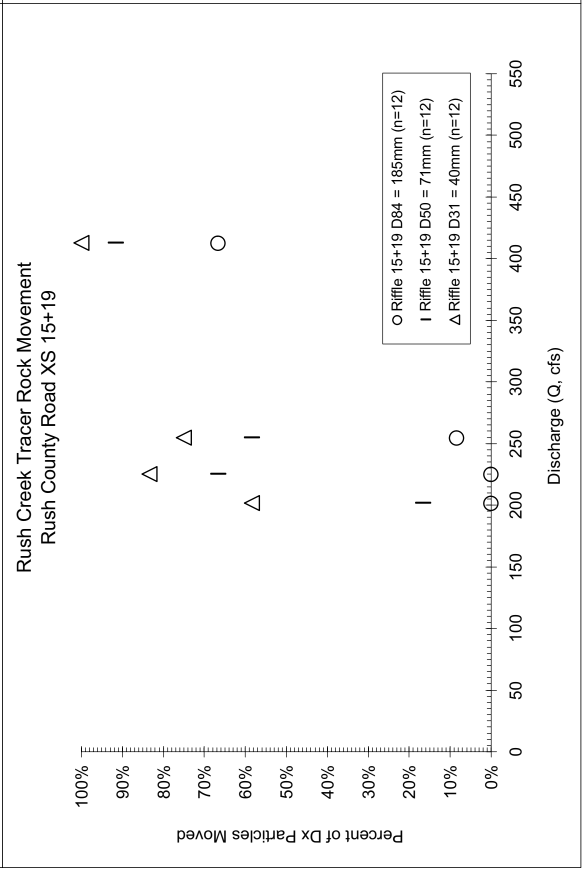

Rush Creek Tracer Rock Movement
Lower Rush 10-Channel XS 1+10
Percent of Dx Particles Moved
Discharge (Q, cfs)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
0 50 100 150 200 250 300 350 400 450 500 550
O Channel Bed D84 = 108mm (n=10)
I Channel Bed D50 = 64mm (n=10)
Δ Channel Bed D31 = 44mm (n=10)

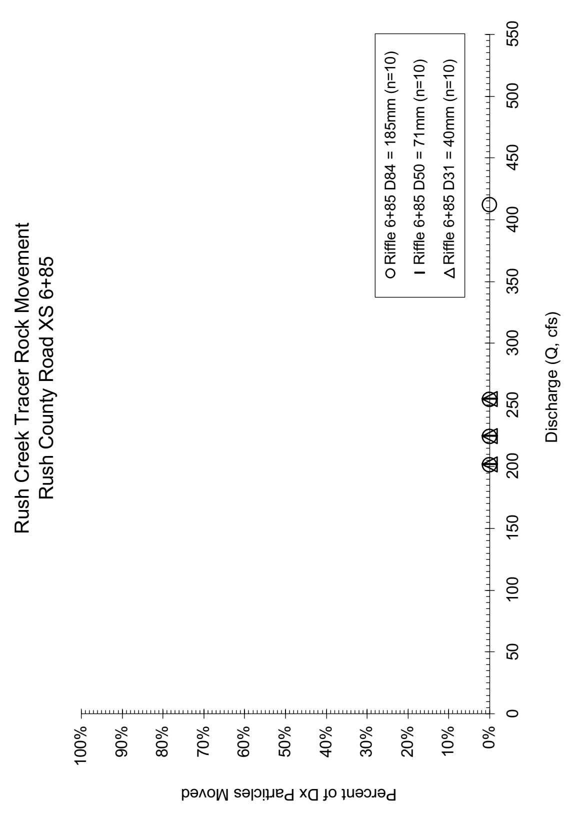

Rush Creek Tracer Rock Movement
Lower Rush XS -9+82
Percent of Dx Particles Moved
Discharge (Q, cfs)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
0 50 100 150 200 250 300 350 400 450 500 550
O Riffle -09+82 D84 = 125mm (n=12)
I Riffle -09+82 D50 = 63mm (n=12)
Δ Riffle-9+82 D31 = 44mm (n=12)


Rush Creek Tracer Rock Movement
Lower Rush XS -5+07
Percent of Dx Particles Moved
Discharge (Q, cfs)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
0 50 100 150 200 250 300 350 400 450 500 550
O Riffle -05+07 D84 = 110mm (n=10)
I Riffle -05+07 D50 = 52mm (n=10)
Δ Riffle -05+07 D31 = 36mm (n=10)

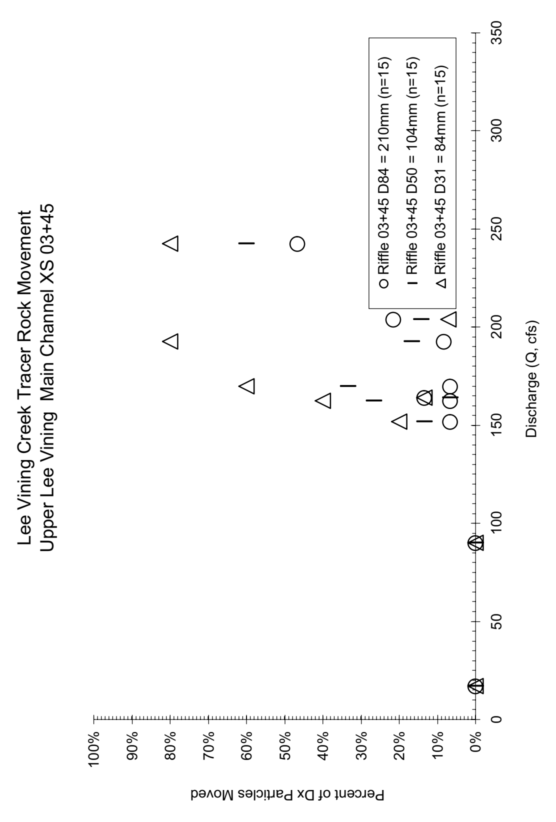

Rush Creek Tracer Rock Movement
Upper Rush XS 5+45
O Riffle 05+45 D84 = 122mm (n=10)
I Riffle 05+45 D50 = 75mm (n=10)
Δ Riffle 05+45 D31 = 62mm (n=10)
Percent of Dx Particles Moved
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Discharge (Q, cfs)
0
50
100
150
200
250
300
350
400
450
500
550

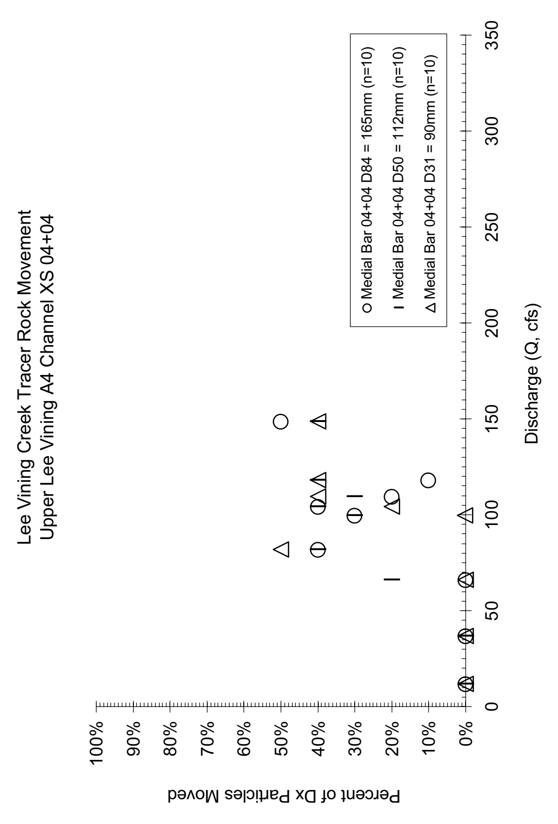

Rush Creek Tracer Rock Movement
Upper Rush XS 0+74
O Riffle 00+74 D84 = 132mm (n=17)
I Riffle 00+74 D50 = 65mm (n=17)
Δ Riffle 00+74 D31 = 38mm (n=17)
Percent of Dx Particles Moved
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Discharge (Q, cfs)
0
50
100
150
200
250
300
350
400
450
500
550

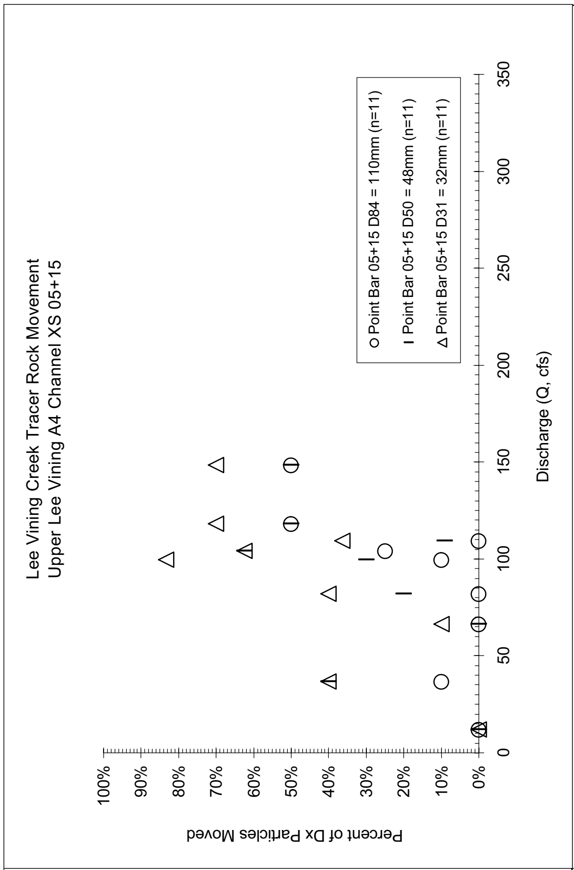

Rush Creek Tracer Rock Movement
Rush County Road XS 15+19
O Riffle 15+19 D84 = 185mm (n=12)
I Riffle 15+19 D50 = 71mm (n=12)
Δ Riffle 15+19 D31 = 40mm (n=12)
Percent of Dx Particles Moved
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Discharge (Q, cfs)
0
50
100
150
200
250
300
350
400
450
500
550

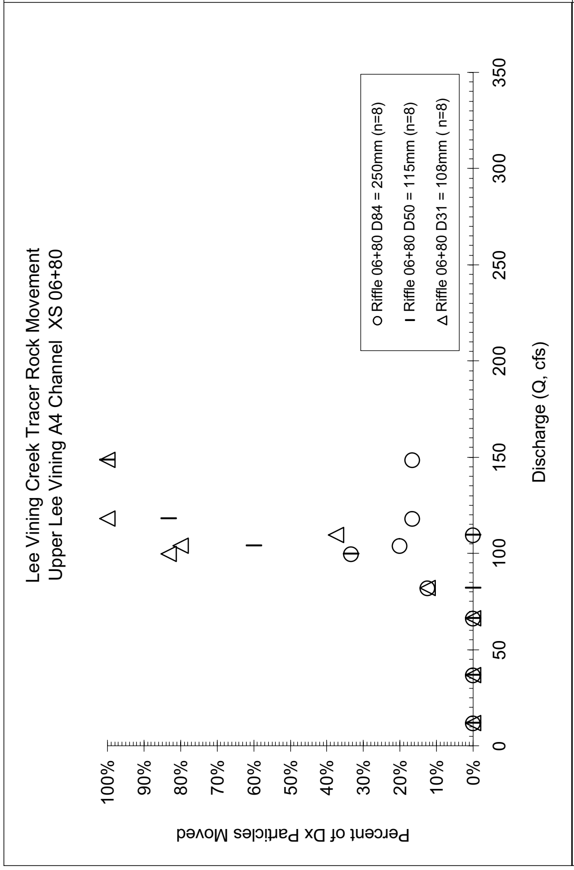

Rush Creek Tracer Rock Movement
Rush County Road XS 6+85
O Riffle 6+85 D84 = 185mm (n=10)
I Riffle 6+85 D50 = 71mm (n=10)
Δ Riffle 6+85 D31 = 40mm (n=10)
Percent of Dx Particles Moved
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Discharge (Q, cfs)
0
50
100
150
200
250
300
350
400
450
500
550

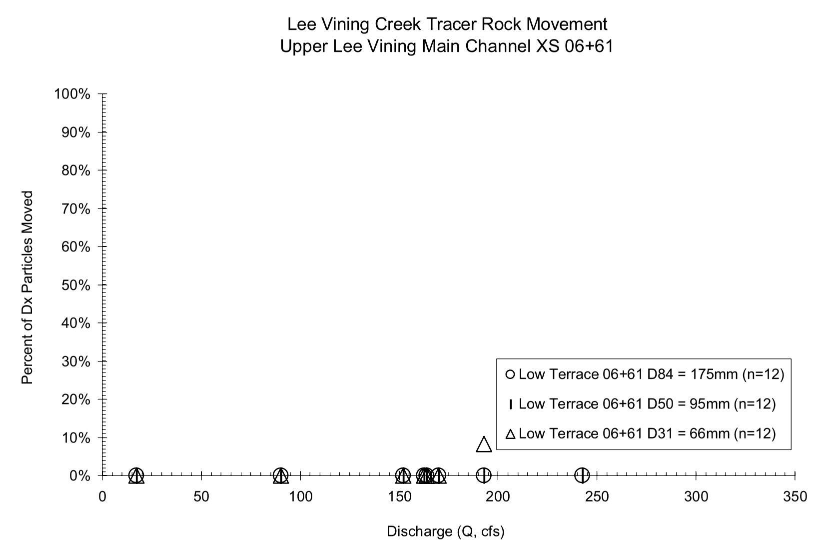
Lee Vining Creek

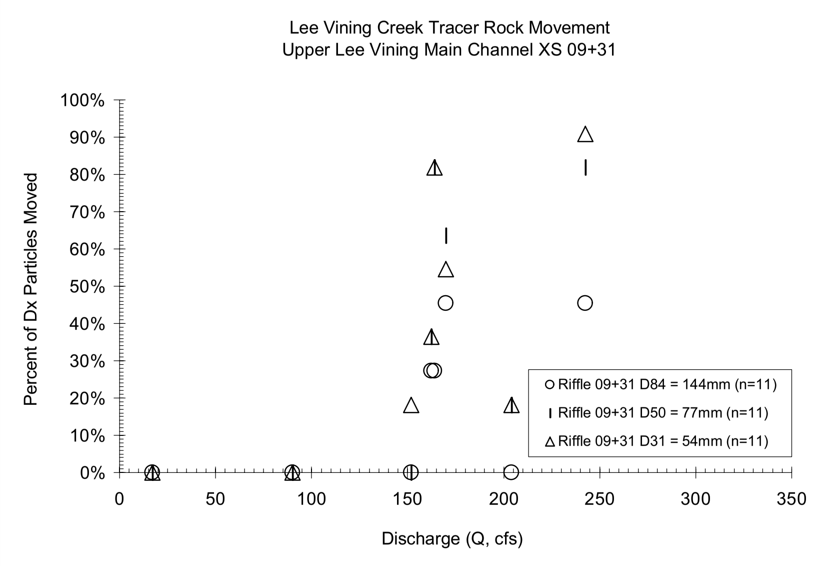

Lee Vining Creek Tracer Rock Movement
Upper Lee Vining Main Channel XS 03+45
○ Riffle 03+45 D84 = 210mm (n=15)
I Riffle 03+45 D50 = 104mm (n=15)
Δ Riffle 03+45 D31 = 84mm (n=15)
Percent of Dx Particles Moved
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Discharge (Q, cfs)
0
50
100
150
200
250
300
350

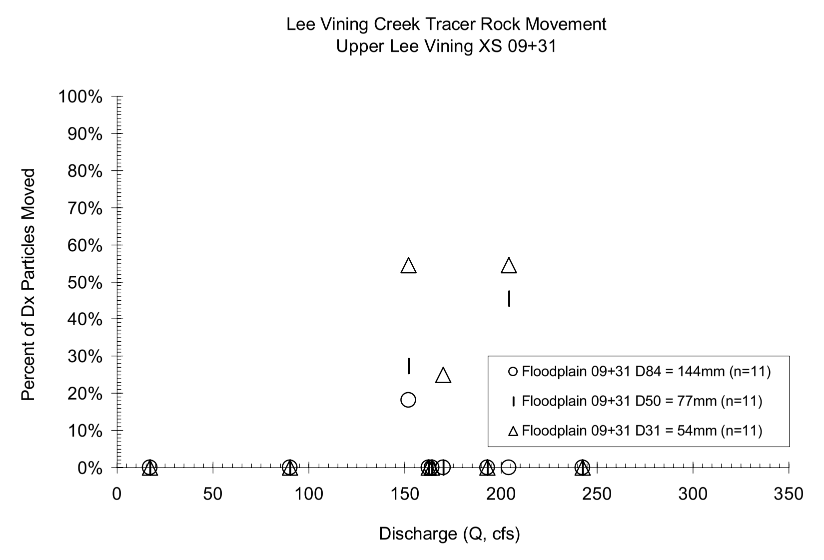

Lee Vining Creek Tracer Rock Movement
Upper Lee Vining A4 Channel XS 04+04
○ Medial Bar 04+04 D84 = 165mm (n=10)
I Medial Bar 04+04 D50 = 112mm (n=10)
Δ Medial Bar 04+04 D31 = 90mm (n=10)
Percent of Dx Particles Moved
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Discharge (Q, cfs)
0
50
100
150
200
250
300
350

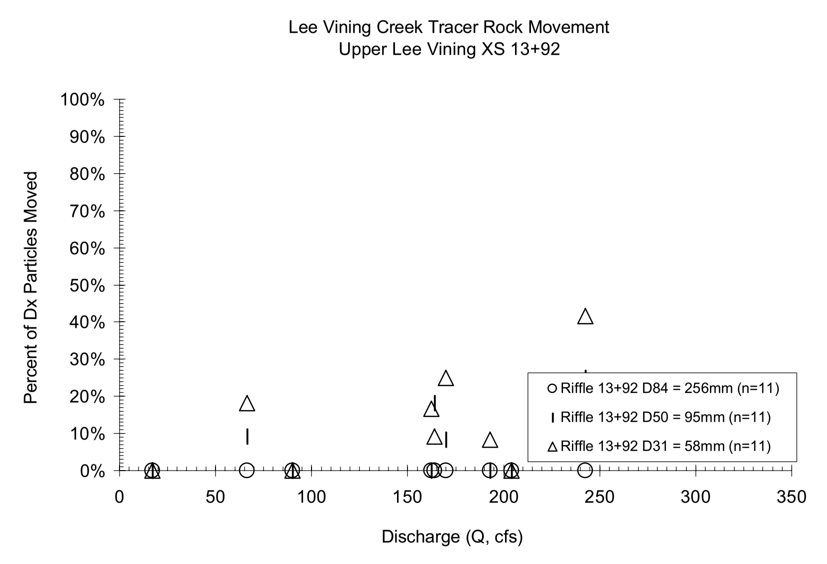

Lee Vining Creek Tracer Rock Movement
Upper Lee Vining A4 Channel XS 05+15
○ Point Bar 05+15 D84 = 110mm (n=11)
I Point Bar 05+15 D50 = 48mm (n=11)
Δ Point Bar 05+15 D31 = 32mm (n=11)
Percent of Dx Particles Moved
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Discharge (Q, cfs)
0
50
100
150
200
250
300
350

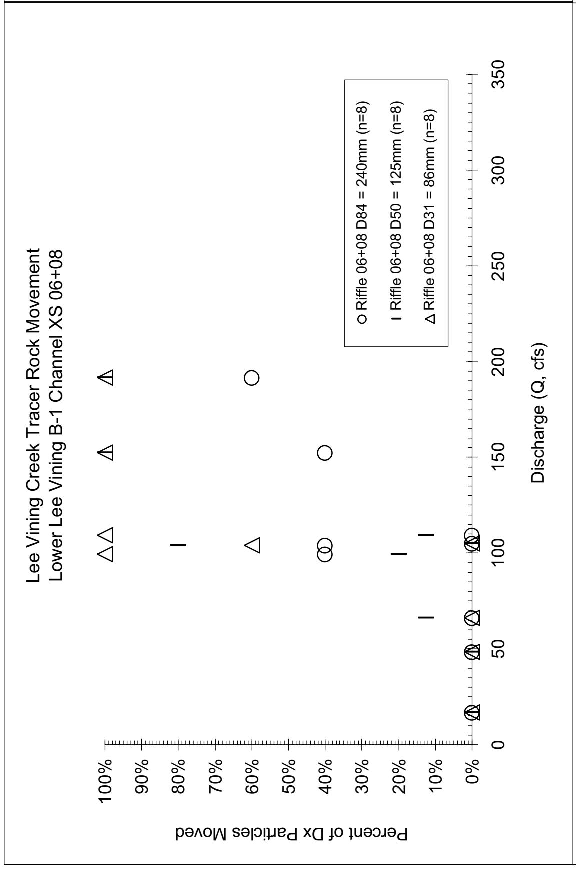

Lee Vining Creek Tracer Rock Movement
Upper Lee Vining A4 Channel XS 06+80
○ Riffle 06+80 D84 = 250mm (n=8)
I Riffle 06+80 D50 = 115mm (n=8)
Δ Riffle 06+80 D31 = 108mm (n=8)
Percent of Dx Particles Moved
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Discharge (Q, cfs)
0
50
100
150
200
250
300
350

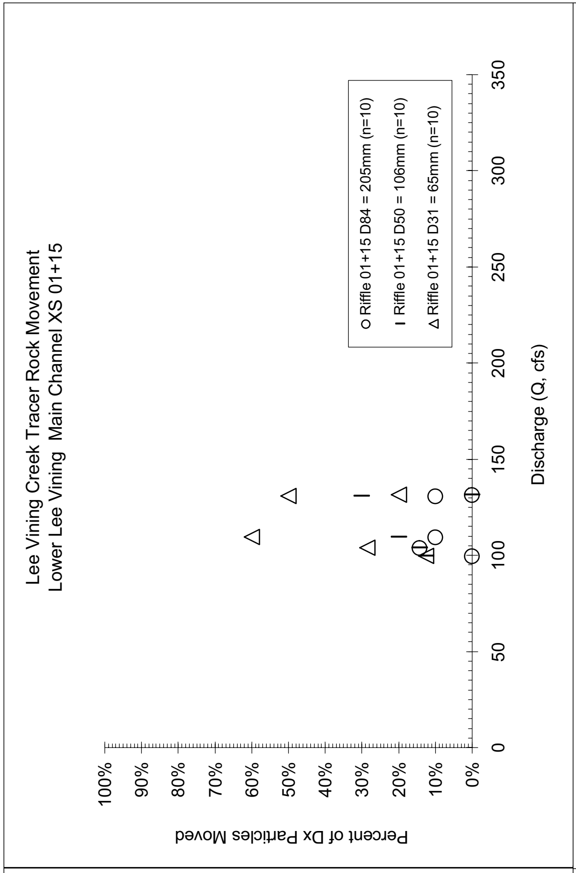

Lee Vining Creek Tracer Rock Movement
Upper Lee Vining Main Channel XS 06+61

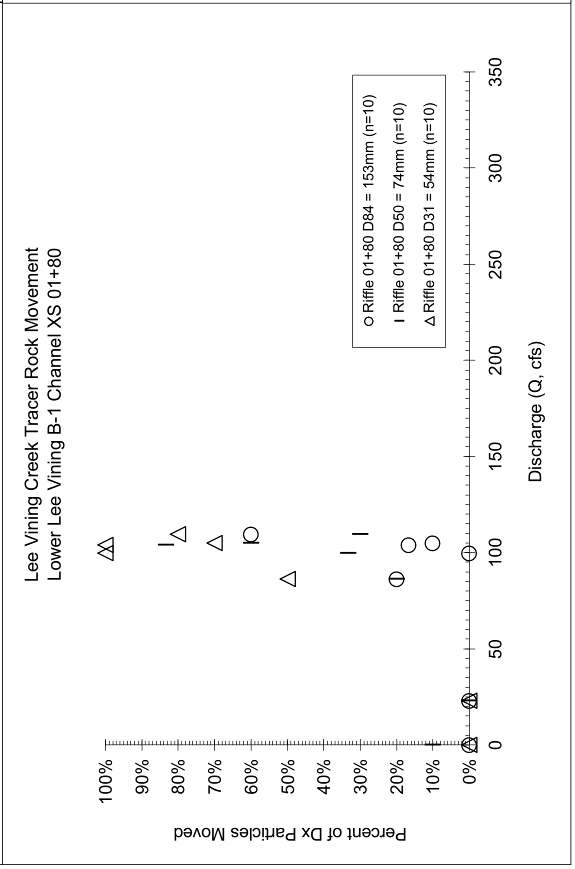

Lee Vining Creek Tracer Rock Movement
Upper Lee Vining Main Channel XS 09+31

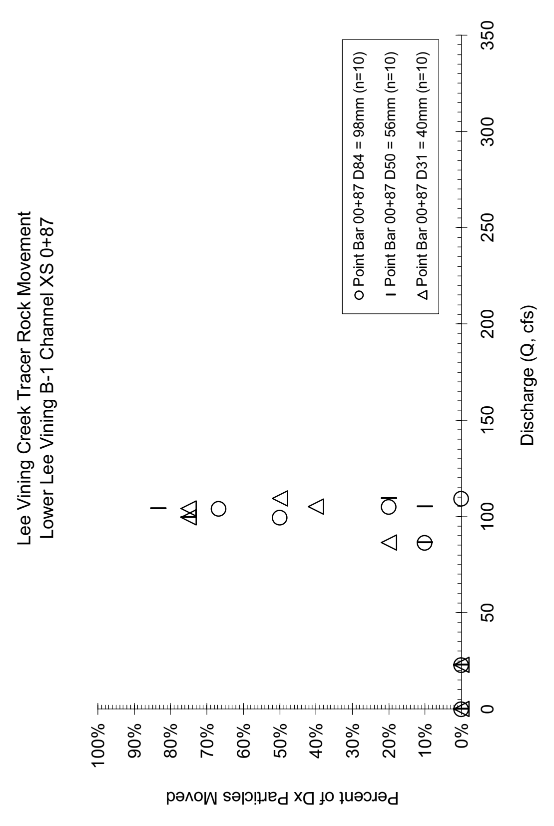

Lee Vining Creek Tracer Rock Movement
Upper Lee Vining XS 09+31


Lee Vining Creek Tracer Rock Movement
Upper Lee Vining XS 13+92


Lee Vining Creek Tracer Rock Movement
Lower Lee Vining B-1 Channel XS 06+08


Lee Vining Creek Tracer Rock Movement
Lower Lee Vining Main Channel XS 01+15


Lee Vining Creek Tracer Rock Movement
Lower Lee Vining B-1 Channel XS 01+80


Lee Vining Creek Tracer Rock Movement
Lower Lee Vining B-1 Channel XS 0+87

APPENDIX E
Plan Mapping for Mono Lake Tributary: Rush Creek

Table D1. Planmapping units, with mapping symbols and definitions.

Group	Map Unit	Symbol (upper case)	Definition
Geomorphology			
Bar	Point Bar	PB	One of a series of low, arcuate ridges of sediment (commonly sand and gravel) developed on the inside of growing meander by the addition of individual accretions accompanying migration of the channel along the outer bank.
	Medial Bar	MB	Similar to a point bar, only developed mid-channel, and oriented parallel with the direction of streamflow with water conveyed on both sides of the bar during summer baseflows.
Floodplain	Mature floodplain	MFP	Contemporary floodplain adjacent to low-water channel. Unit is located below lowest terrace surface and is characterized by one or more of the following features: surface flow patterns, scour channels, loose substrate, and fine sediment deposition. Use sedimentation qualifier if an aggradational floodplain.
	Developing floodplain	DFP	Similar to mature floodplain; however, surface is "younger", as characterized by initiating riparian vegetation that facilitates fine sediment deposition for future floodplain growth. Use sedimentation qualifier if an aggradational floodplain.
Terrace	Low Terrace	LTE	Fluvial geomorphically active surface. Lowest terrace or suite of terraces relative to the contemporary floodplain. This surface is influenced by contemporary floods, as evidenced by one or more of the following features: surface flow patterns, scour channels, fresh and/or loose substrate with little to no soil development (i.e., fluvial processes such as surface mobility, scour, and deposition, are common).
	Middle Terrace	MTE	Fluvial geomorphically semi-active surface. Terrace surface or suite of terrace surfaces where geomorphic influence by contemporary flow regime is generally limited to fine sediment overbank deposition, with little to no bed surface mobilization (deposition >> scour). Other features include isolated scour channels resulting from infrequent high flow events (e.g., 1997), embedded or densely-packed substrate, possible soil development.
	High Terrace	HTE	Fluvial geomorphically inactive surface. Terrace surface or suite of terrace surfaces that are rarely to never accessed by contemporary flows and therefore not fluvial geomorphically influenced.
Bank features	Eroding Bank	EB	Bank being actively eroded by the present channel.
Hillslope features	Hillslope	HILL	Slope extending up and away from the channel that is not a part of another geomorphic unit described in this table.
	Arroyo	ARY	A small channel or gully of an ephemeral or intermittent stream.
	Fan	FAN	Alluvial or colluvial fan.
Channel features	Headcut	HC	Abrupt break in channel bed slope eroding upstream.
Fish Habitat			
Pool	Constructed pool	CP	Constructed pool (upper Rush Creek only)
	Scour pool	SCP	CDFG: Formed by flow impinging against a partial channel obstruction; the associated scour is generally confined to < 60% of the wetted channel width.
	Main channel pool	MCP	CDFG: Large pools formed by mid-channel scour. The scour hole encompasses more than 60% of the wetted channel. Water velocity is slow, and the substrate is highly variable. (this is for DFG mid-channel pool" but use for main channel pool in this instance).
	Step pool	STP	CDFG: A series of pools separated by short riffles or cascades. Generally found in high gradient, confined mountain streams dominated by boulder substrate.
	Pool Tail	PT	Transition area connecting the deepest portion of a pool with the downstream riffle crest.
Riffle	Low gradient riffle	LGR	CDFG: Shallow reaches with swiftly flowing, turbulent water with some partially exposed substrate. Gradient < 4%, substrate is usually cobble dominated.
	High gradient riffle	HGR	CDFG: Steep reaches of moderately deep, swift, and very turbulent water. Amount of exposed substrate is relatively high. Gradient is > 4%, and substrate is boulder dominated.
Flatwater	Glide	GL	CDFG: A wide, uniform channel bottom. Flow with low to moderate velocities, lacking pronounced turbulence. Substrate usually consists of cobble, gravel, and sand.
	Pocket water	PW	CDFG: A section of swift-flowing stream containing numerous boulders or other large obstructions which create eddies or scour holes (pockets) behind the obstructions.
	Run	R	CDFG: Swiftly flowing reaches with little surface agitation and no major flow obstructions. Often appears as flooded riffles. Typical substrate consists of gravel, cobble, and boulders.
	Step Run	SR	CDFG: A sequence of runs separated by short riffle steps. Substrate is usually cobble and boulder dominated.
Cascade	Cascade	CAS	CDFG: The steepest riffle habitat, consisting of alternating small waterfalls and shallow pools. Substrate is usually bedrock and boulders.
Backwater	Alcove	AL	Calm-water located on lateral edge of channel, commonly at downstream end of point bars.
Other			
Wood	Large woody debris	LWD	White Book: LWD greater than 2 m long (approx. 6.5 ft) and 10 cm (approx 4 inches) in smallest diameter. If species cannot be identified, identify as either hardwood or softwood.
Debris	Debris jam	DJ	Debris jams will be mapped separately only if they're not included in the wood mapping (i.e., if the jam is composed of woody debris outside the LWD mapping criteria). White Book says to map only woody debris accumulations that appear to influence local hydraulics.
Off-channel water	Seepage	SEEP	Water seeping from a free face (e.g., bank, hillslope)
	Pond water	POND	A perennial pond or wetland
	Standing water	WET	Non-pond wet area (e.g., wet ground)
Channel features	Wetted Channel	No symbol will be used. Lines will delineate limits of each channel class	Summer baseflow wetted edge of stream. Because the wetted channel is visible on the orthophoto base maps, its boundaries will only be mapped when canopy cover blocks its appearance.
	Bankfull channel		Wetted edge of channel when water surface elevation begins to inundate floodplains. Contact is at back edge of floodplain or at terrace toe.
	Thalweg	x	Thalweg location delineated with an "x" at intervals no greater than 50 feet.
	Undercut bank	UCB	White Book: Location plotted and undercut measured as the distance from the farthest point of protrusion on the bank to the farthest undercut of the bank.
	Cutoff channel	CO	Former side channel either completely abandoned or functioning as a high flow scour channel.
	Boulder weir	WEIR	A man-made weir constructed of boulders.

Table D2. Planmapping unit qualifiers, with mapping symbols and definitions.

Group	Qualifier	Symbol (lower case)	Definition
Texture and stratigraphy	Sand and silt	s	Dominant surface texture is < 2mm
	Gravel and cobble	gc	Dominant surface texture ranges from 2 mm to 256 mm
	Spawning gravel	sg	Discrete patches of gravel ranging from 6 mm to 76 mm
	Boulder	b	Dominant surface texture is > 256mm
Sedimentation	Aggradational	agg	Surface dominantly aggradational under contemporary flow regime
	Degradational	deg	Surface dominantly degradational (scoured) under contemporary flow regime
Vegetation	Aquatic	aq	Plants growing entirely under water
	Aquatic emergent	aqem	Plants rooted under water but
	Tree	ripw or dw	Riparian Tree or Desert Tree
	Shrub	rips or ds	Riparian Shrub or Sesert Shrub
	Herbaceous	riph or dh	Riparian Herbaceous or Desert Herbaceous

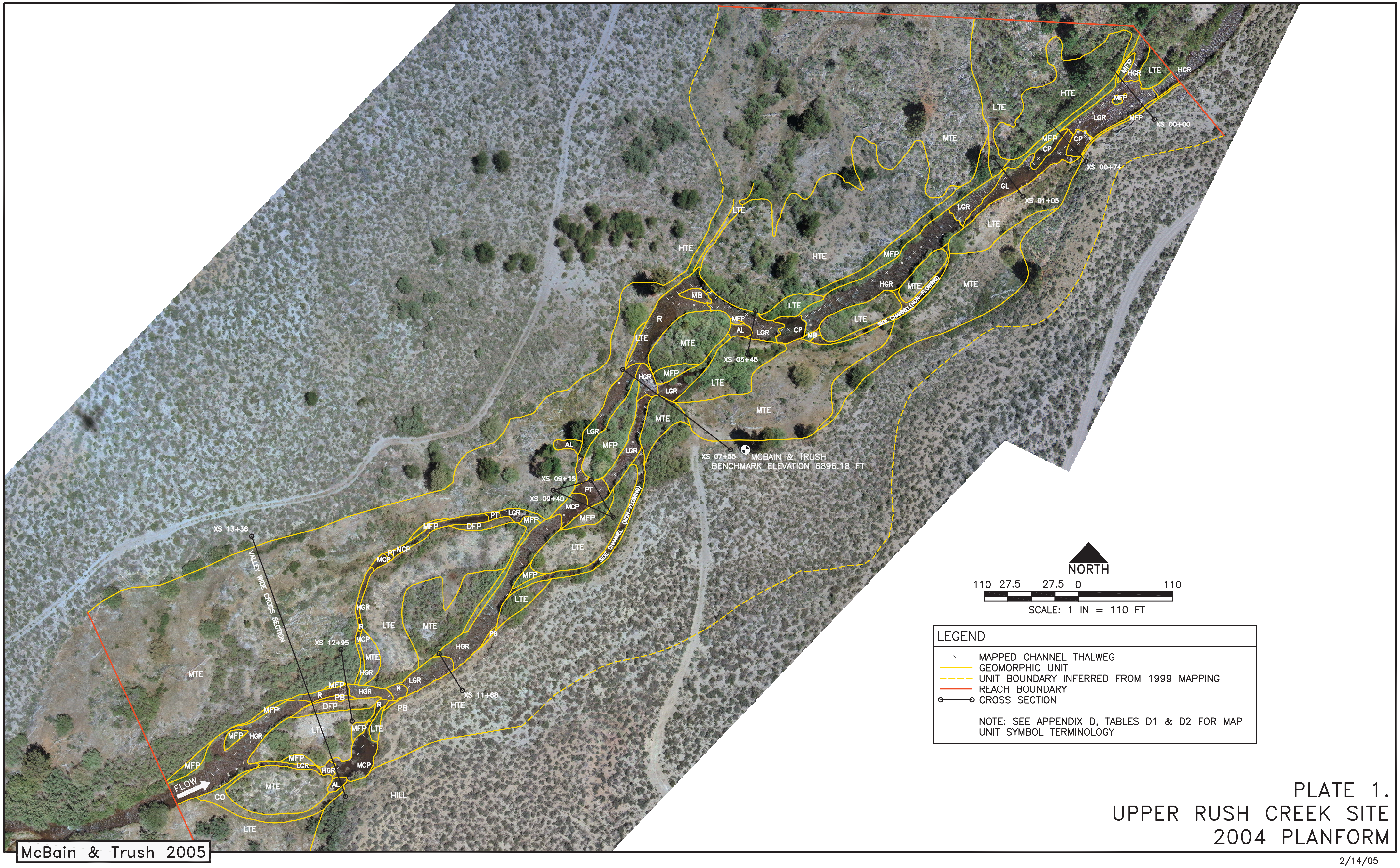


PLATE 1.
UPPER RUSH CREEK SITE
2004 PLANFORM


PLATE 2.
LOWER RUSH CREEK SITE MAIN CHANNEL
2004 PLANFORM
2/14/05
LEGEND
× MAPPED CHANNEL THALWEG
GEOMORPHIC UNIT BOUNDARY
REACH BOUNDARY
CROSS SECTION
NOTE: SEE APPENDIX D, TABLES D1 & D2 FOR MAP UNIT SYMBOL TERMINOLOGY
NORTH
SCALE 1"=75'
25 0 25 50 75
McBain & Trush 2005
MCBAIN & TRUSH BENCHMARK
ELEVATION 6491.41 FEET
VALLEY WIDE CROSS SECTION
FLOW
XS 00+86
XS 03+30
XS 04+08
XS 05+49
XS 07+25
XS 07+70
XS 10+10
HTE
MTE
LTE
MFP
DFP
FP
CO
R
PB
HGR
LGR
PT
MCP
SCP
AL
EB
MB
WET
UCB


PLATE 3.
LOWER RUSH CREEK SITE 10–CHANNEL
2004 PLANFORM
2/14/05
LEGEND
MAPPED CHANNEL THALWEG
GEOMORPHIC UNIT BOUNDARY
REACH BOUNDARY
CROSS SECTION
NOTE: SEE APPENDIX D, TABLES D1 & D2 FOR MAP UNIT SYMBOL TERMINOLOGY
NORTH
40 20 0 40
SCALE: 1 IN = 40 FT
McBain & Trush 2005
FLOW
XS 07+25 VALLEY WIDE CROSS SECTION
XS 01+10
XS 0+50
HILL
MTE
HTE
EB
R
PB
PT
MCP
PB
LTE
MCP
HGR
PT
MCP
LTE
PB
LGR
PB
LTE
LGR
R
DFP
AL
LGR
MFP
HGR
MB
R
PT
MCP

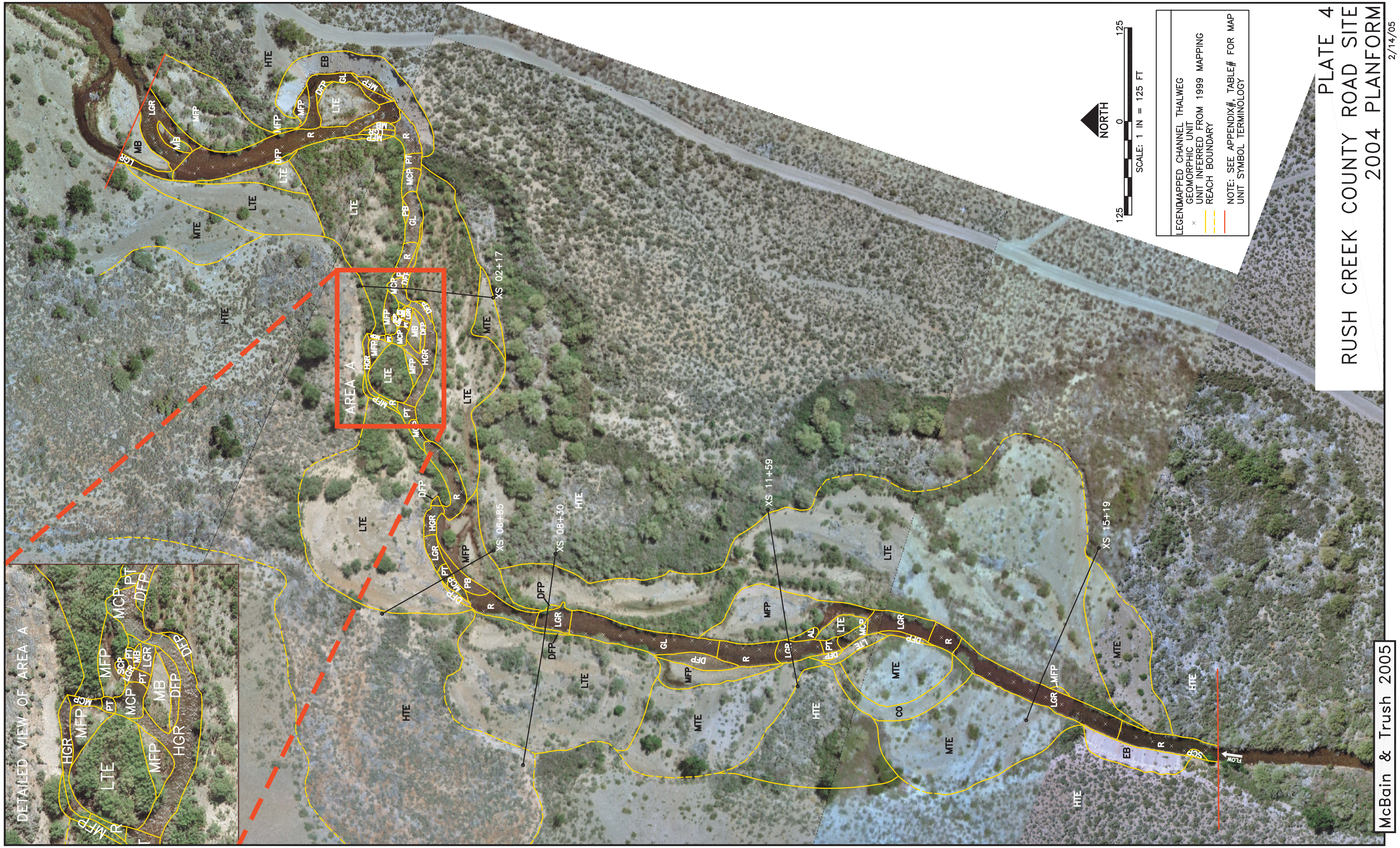


PLATE 4
RUSH CREEK COUNTY ROAD SITE
2004 PLANFORM
2/14/05
LEGEND
MAPPED CHANNEL THALWEG
GEOMORPHIC UNIT
UNIT INFERRED FROM 1999 MAPPING
REACH BOUNDARY
NOTE: SEE APPENDIX#, TABLE# FOR MAP UNIT SYMBOL TERMINOLOGY
NORTH
125
0
125
SCALE: 1 IN = 125 FT
McBain & Trush 2005
DETAILED VIEW OF AREA A
AREA A
XS 02+17
XS 06+85
XS 08+30
XS 11+59
XS 15+19
FLOW
LGR
MB
MFP
DFP
LTE
MTE
HTE
EB
GL
R
MCP
PT
HGR
PB
SCP
CO
AL
LCP

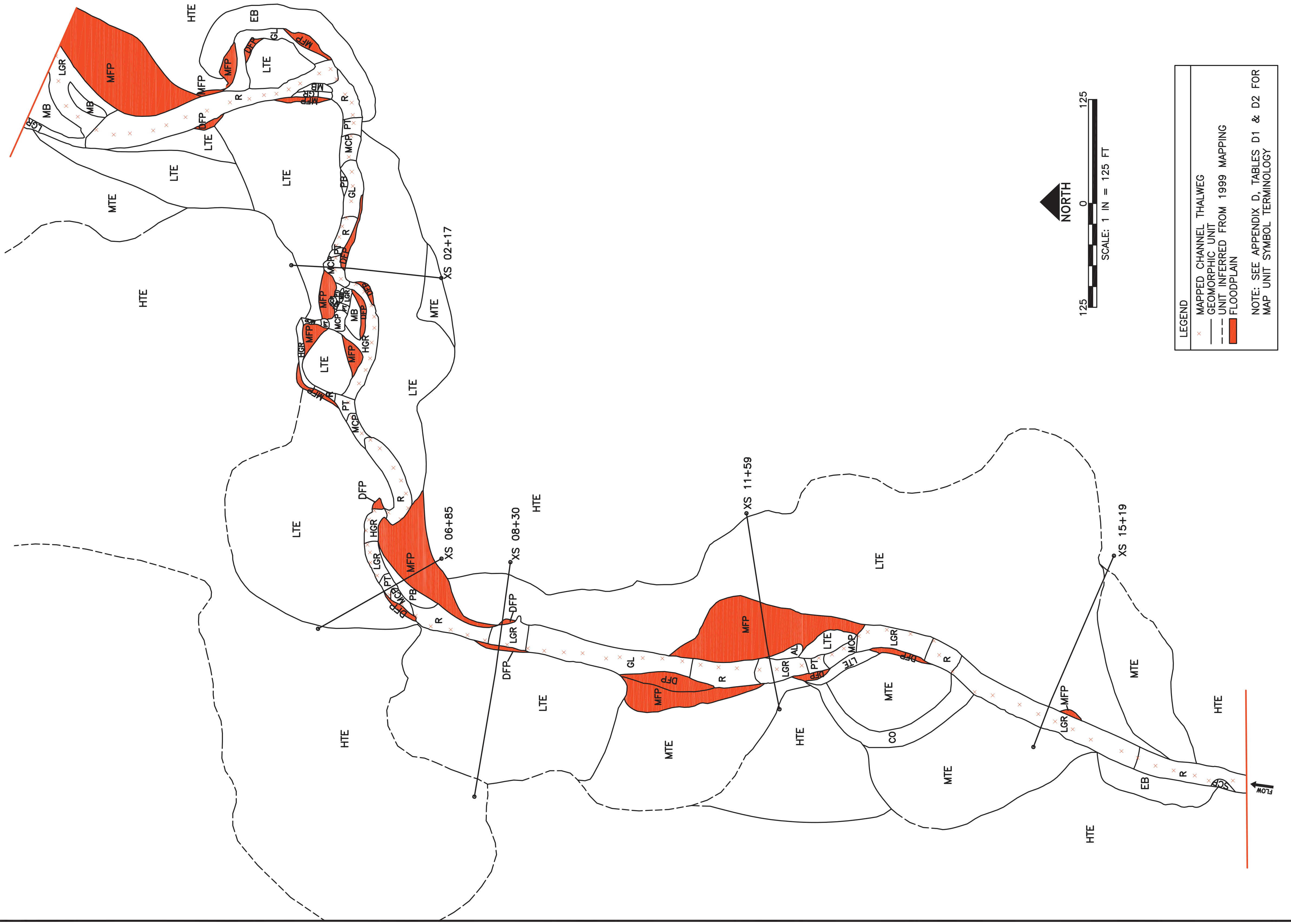


PLATE 5.
RUSH CREEK COUNTY ROAD SITE
2004 PLANFORM WITH HIGHLIGHTED FLOODPLAIN AREAS

2/14/05

McBain & Trush 2005

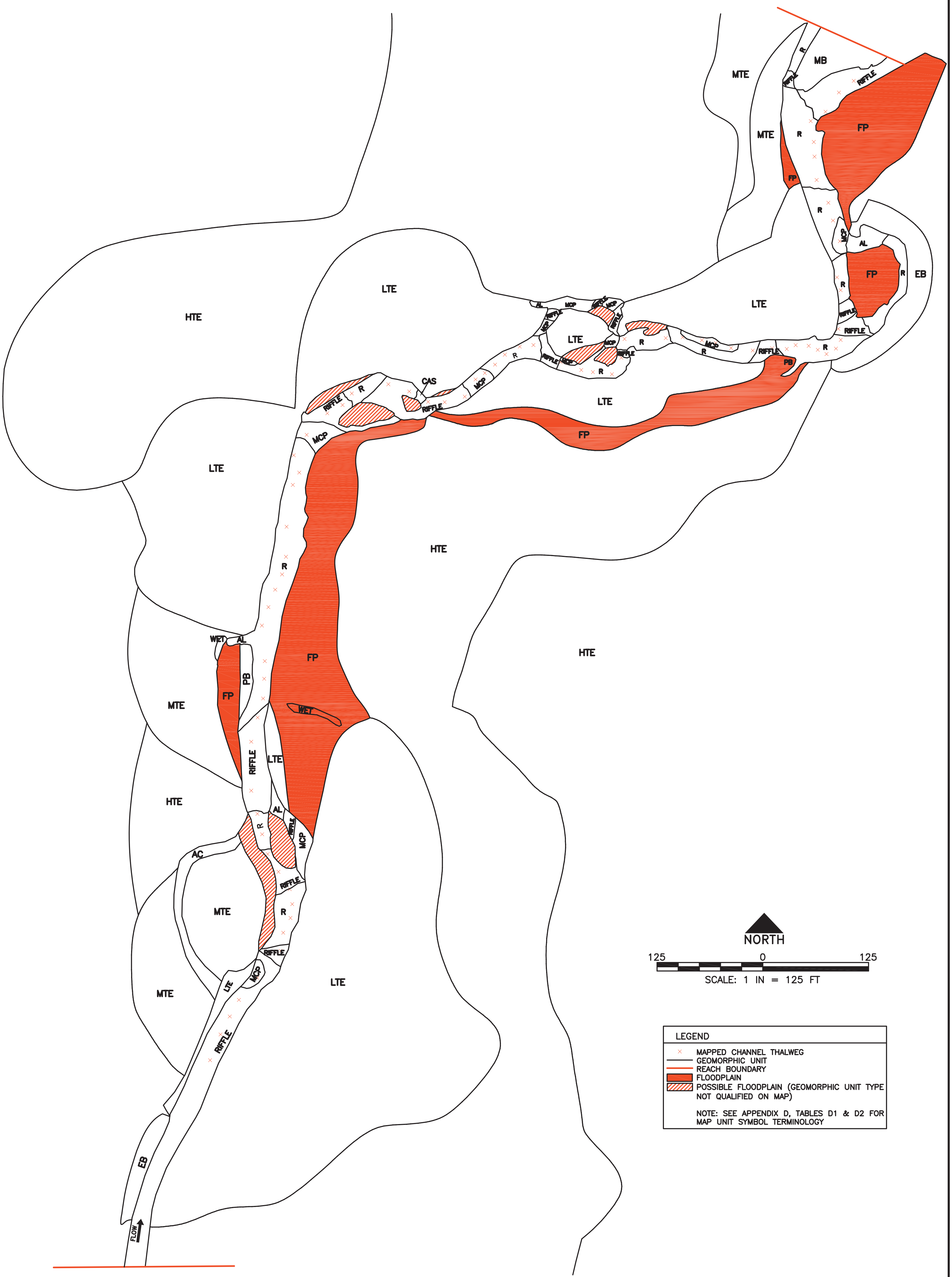
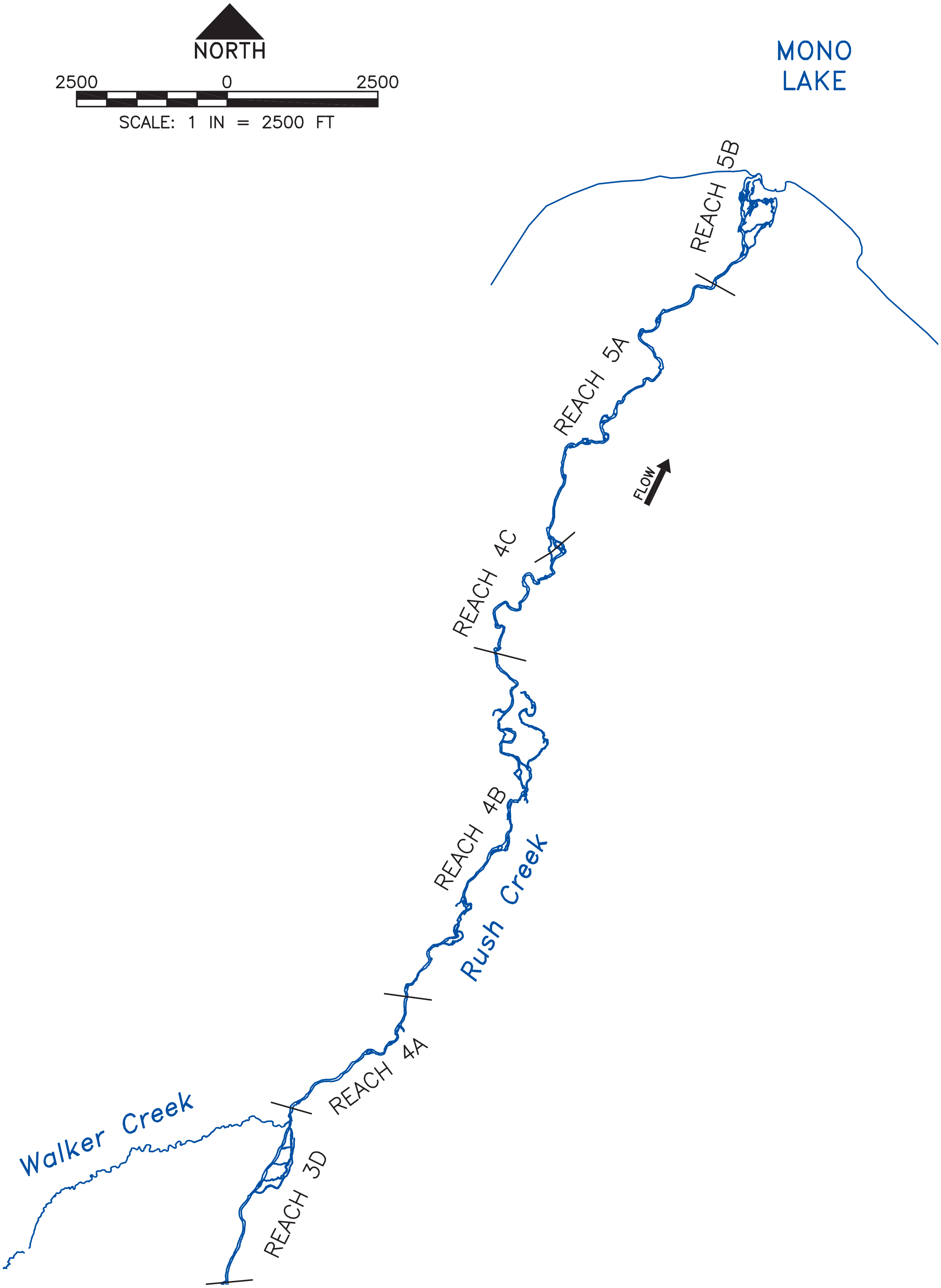


PLATE 6.
RUSH CREEK COUNTY ROAD SITE
1999 PLANFORM WITH HIGHLIGHTED FLOODPLAIN AREAS

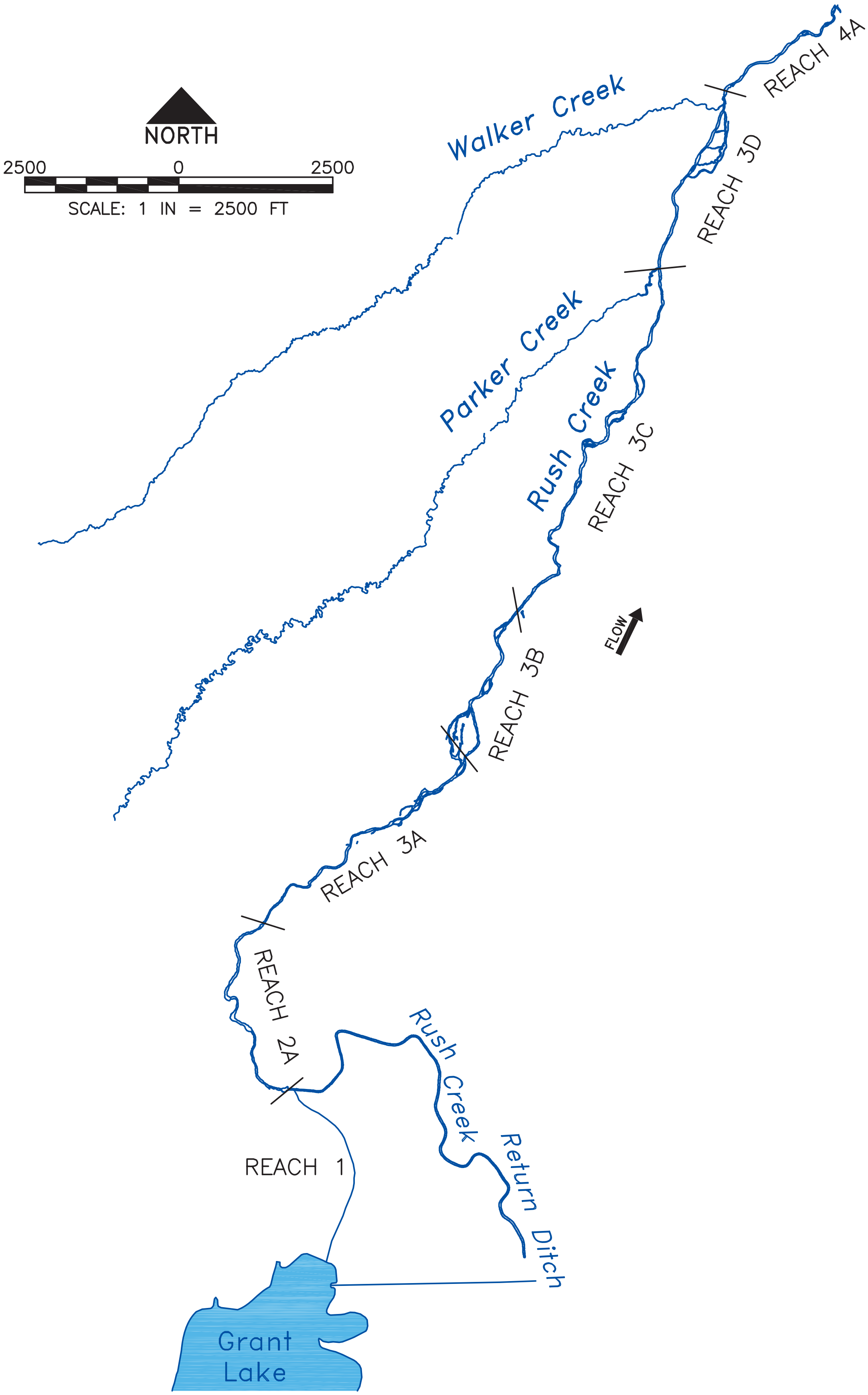
McBain & Trush 2005

2/14/05

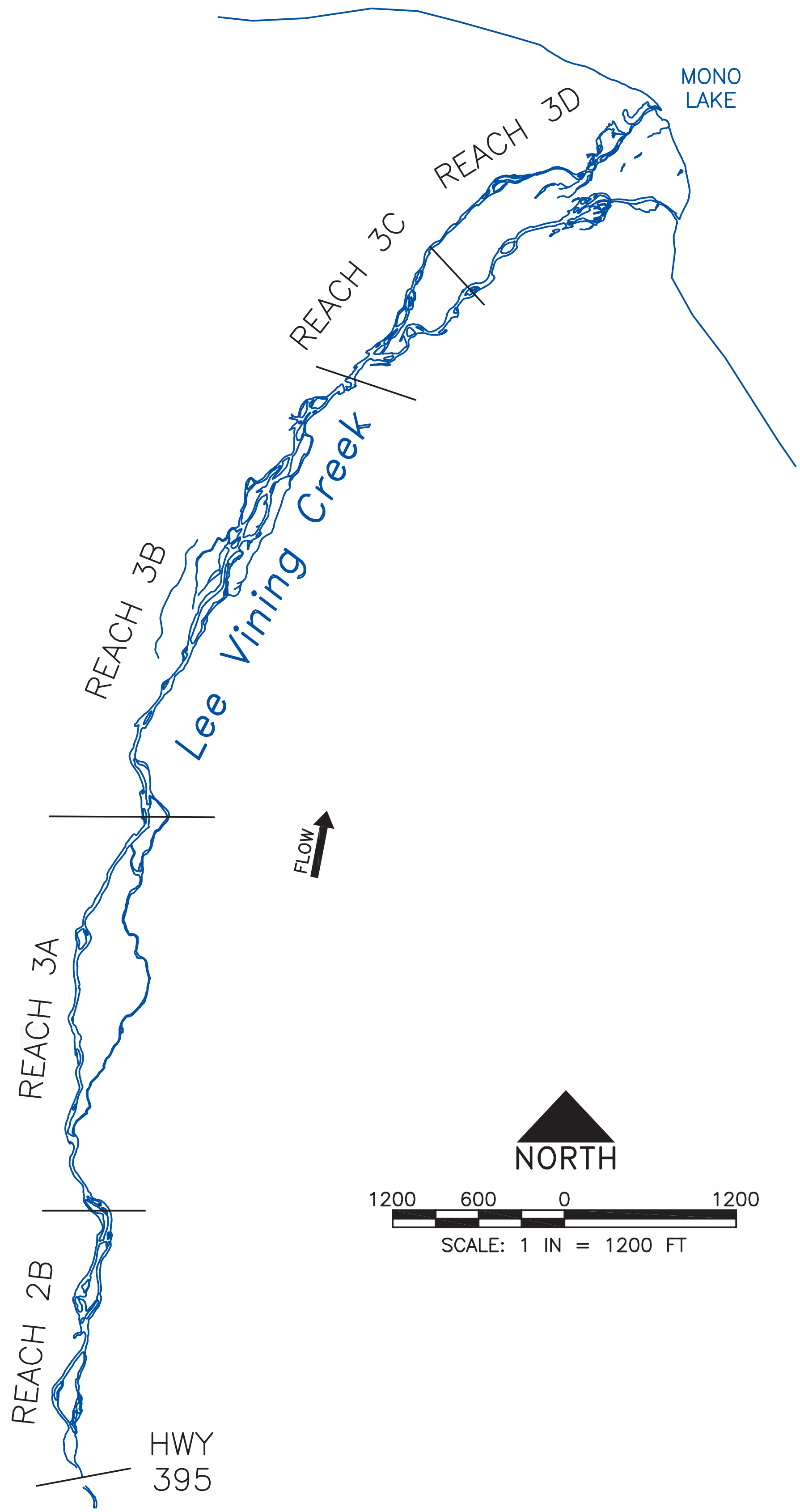
APPENDIX F
Reach Map and Termination Criteria for Mono Lake Tributaries: Rush and Lee Vining Creeks



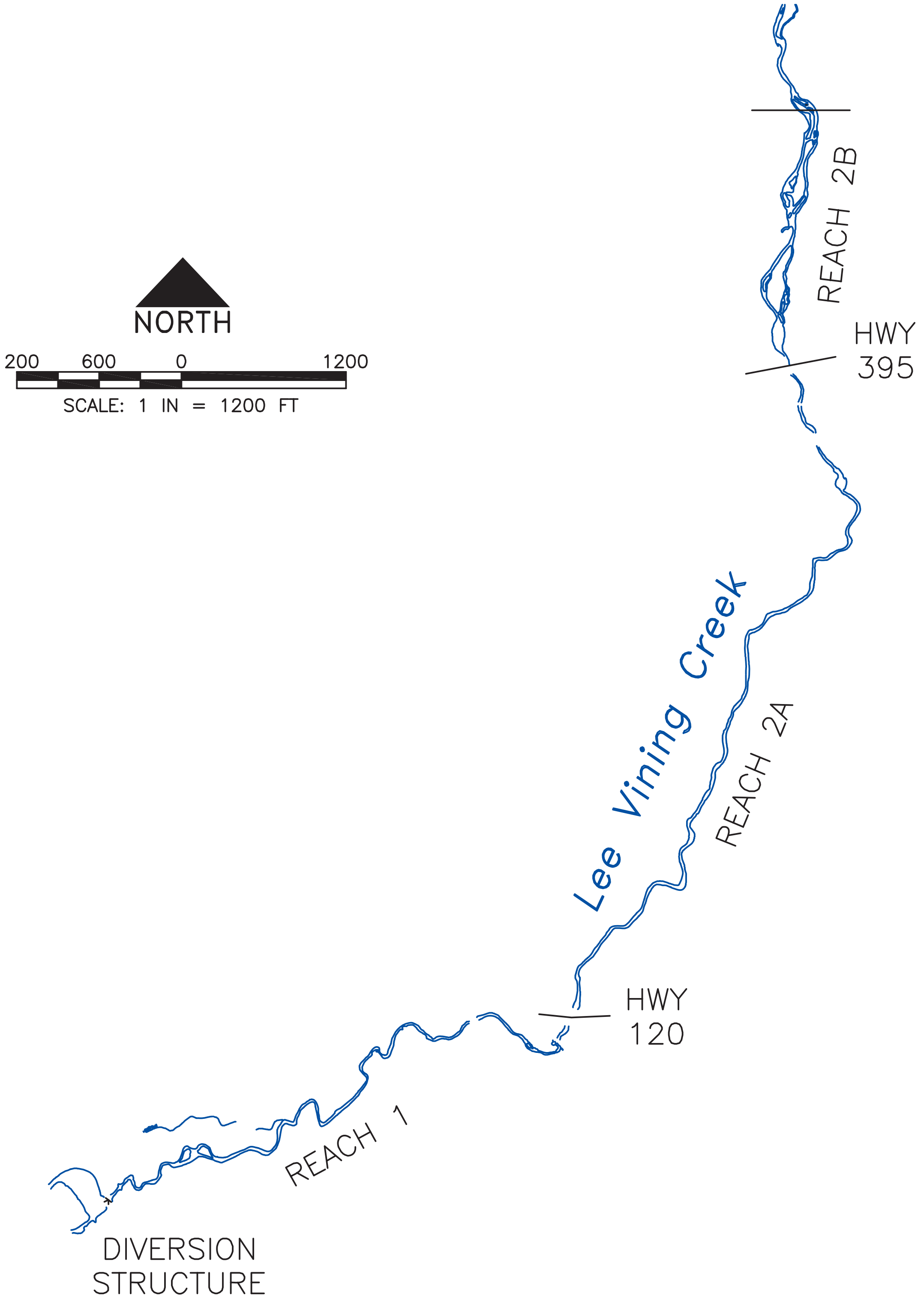
Rush Creek reach map (1 of 2)



Rush Creek reach map (2 of 2)



Lee Vining Creek reach map (1 of 2)



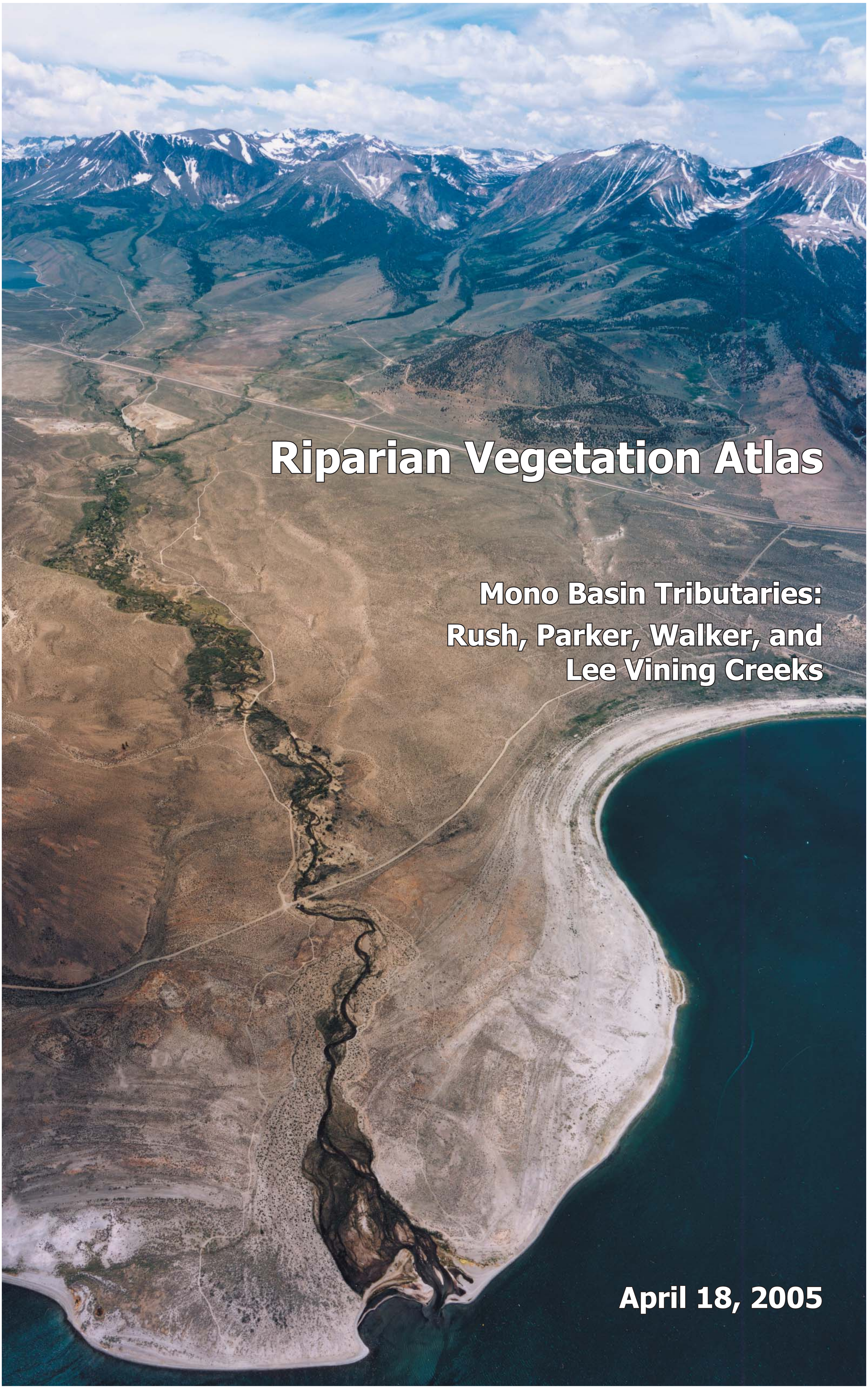
Lee Vining Creek reach map (2 of 2)

RUSH CREEK TERMINATION CRITERIA		Stream Reach(1)										
		1	2A	3A	3B	3C	3D	4A	4B	4C	5A	5B
Riparian Vegetation (acres)	Termination Criteria	6.2	5.0	21.5	2.9	11.2	10.0	26.0	80.0	38.7	37.8	N/A
	Pre-Diversion	N/A	5.6	25.5	3.5	17.3	10.3	37.4	73.0	28.2	33.0	N/A
	1989	1.7	5.9	12.7	0.1	4.1	4.0	90.0			11.0	Combined with 5A
	1999	N/A	5.6	13.2	1.3	8.4	4.0	22.5	61.4	29.5	26.4	4.6
	2004	1.9	6.5	14.3	2.8	9.7	5.2	26.2	66.8	31.3	29.3	7.7
Main Channel Length (ft)	Termination Criteria		4,820	3,800	3,100	6,940	3,370	3,070	7,810	4,360	7,320	
	1995 RTC Report		4,820	3,800	2,700	7,040	3,300	2,910	7,930	2,610	5,950	
	2003		4,820	3,800	2,956	6,964	3,235	3,078	8,001	3,393	6,994	
Main Channel Gradient (ft/ft)	Termination Criteria		0.024	0.016	0.014	0.023	0.022	0.014	0.01	0.005	<0.007	
	1995 RTC Report		0.024	0.016	0.012	0.023	0.023	0.015	0.01	0.008	0.009	
	2003		0.026	0.017	0.016	0.023	0.021	0.017	0.010	0.007	0.008	
Main Channel Sinuosity (ft/ft)	Termination Criteria		1.04	1.06	1.19	1.07	1.04	1.19	1.23	2.11	1.39	
	1995 RTC Report		1.04	1.06	1.03	1.09	1.02	1.08	1.24	1.27	1.11	
	2003		1.08	1.07	1.27	1.09	1.03	1.17	1.27	1.57	1.27	
Fish		REPORTED BY CHRIS HUNTER										

(1) Stream Reach Description
Reach 1: Extends ~0.8 miles from Grant Lake to the beginning of the cut through the glacial moraine
Reach 2A: Flows through a narrow canyon cut through the glacial moraine (Elevation 7,059 to 6,941)
Reach 3A: Begins where the stream exits the glacial moraine and the floodplain broadens.
Reach 3B: Begins where the stream was diverted into B ditch and extends downstream to HWY 395
Reach 3C: Extends from HWY 395 to the confluence with Parker Creek (Elevation 6,833 to 6,671)
Reach 3D: At the confluence of Parker Creek extending to and inclusive of the Narrows
Reach 4A: Extends just below the Narrows to the start of Indian Ditch (Elevation 6,597 to 6,553)
Reach 4B: Extends from Indian Ditch to 600' downstream from the start of the last meander bend above the Ford.
Reach 4C: Reach 4C extends from 600' downstream from the start of the last meander bend in Reach 4B to the Ford
Reach 5A: Extends from the Ford ~1800' downstream to the County Road
Reach 5B: Extends from elevation 6,395 to approx. 6,376'.

LEE VINING CREEK TERMINATION CRITERI		**Stream Reach** (1)						
		1	**2A**	**2B**	**3A**	**3B**	**3C**	**3D**
Riparian Vegetation (acres)	Termination Criteria	20.0	30.0	Combined with 2A	22.2	32.9	4.0	N/A
	Pre-Diversion	N/A	N/A	9.8	18.5	36.8	4.5	0.0
	1989	19.8	13.4	10.9	6.9	7.5	3.3	8.6
	1999	N/A	N/A	10.6	12.5	24.6	5.5	12.8
	2004	27.9	16.7	10.2	12.5	25.0	5.7	13.2
Main Channel Length (ft)	Termination Criteria	4,500	7,400	Combined with 2A	3,500	4,200	1,360	
	1995 RTC Report	4,500	7,400	Combined with 2A	3,150	3,620	1,330	
	2003	N/A	N/A	N/A	3139	3795	1210	1880
Main Channel Gradient (ft/ft)	Termination Criteria	0.011	0.062	Combined with 2A	0.037	0.025	0.021	
	1995 RTC Report	0.011	0.062	Combined with 2A	0.041	0	0.019	
	2003	N/A	N/A	N/A	0.037	0.026	0.019	0.014
Main Channel Sinuosity (ft/ft)	Termination Criteria	1.42	1.38/1.16 (above/belowHWY395)	Combined with 2A	1.33	1.15	1.2	
	1995 RTC Report	1.42	1.38/1.16 (above/belowHWY395)	Combined with 2A	1.21	1.06	1.17	
	2003	N/A	N/A	N/A	1.12	1.04	1.23	1.26
Fish		REPORTED BY CHRIS HUNTER						

(1) Stream Reach Description
Reach 1: Begins at the Lee Vining Diversion facility and extends to HWY 120
Reach 2: Begins at the end of the meadows where HWY 120 crosses the stream to just below HWY 395 and the SCE substation
Reach 3A: Begins 1,500 below HWY 395 and moves downward to a point just below where the main channel goes eastward across the floodplain
Reach 3B: Begins where the present main channel swings to the east away from the westside of the floodplain and extends to the County Road Crossing
Reach 3C: Begins at County Road crossing and extending to the shoreline of Mono Lake.
Reach 3D: Extends from the 1941 lake shore of Mono Lake to the present shoreline of Mono Lake



Riparian Vegetation Atlas

Mono Basin Tributaries:
Rush, Parker, Walker, and Lee Vining Creeks

April 18, 2005

Atlas of Riparian Vegetation Mapping Conducted by McBain and Trush, Including Pre-Diversion Conditions, and Mapping Conducted in 1999 and 2004.

Mono Basin Tributaries:
Rush, Parker, Walker, and Lee Vining Creeks

Prepared for:

Los Angeles Department of Water and Power

Prepared by:

McBain & Trush
P.O. Box 663
Arcata, CA 95518
(707) 826-7794

April 18, 2005

2005 RIPARIAN ATLAS TABLE OF CONTENTS

Comparison of the Rush and Lee Vining Creek woody riparian vegetation coverage established in the termination criteria to 1989 acreages quantified by JSA, 1999 acreages and 2004 acreages quantified by McBain and Trush.

RUSH CREEK							
Stream Segment	***Woody Riparian Vegetation (Acres)***						
	Termination Criteria (SWRCB D1631)	***Pre-diversion (McBain and Trush 2004)***	***1989 Vegetation (JSA 1993)***	***1999 Vegetation (McBain & Trush)***	***2004 Vegetation (McBain & Trush)***	***Acreage Change Between 1999 and 2004***	***Acreage needed to meet Termination Criteria***
1	6.2	N/A	1.7	N/A	1.9	N/A	4.3
2	5.0	5.6	5.9	5.6	6.5	0.9 acres	CRITERIA MET
3a	21.5	25.5	12.7	13.2	14.3	1.1 acres	7.2 acres
3b	2.9	3.5	0.1	1.3	2.8	1.5 acres	0.1 acres
3c	11.2	17.3	4.1	8.4	9.7	1.3 acres	1.5 acres
3d	10.0	10.3	4.0	4.0	5.2	1.2 acres	4.8 acres
4a	26.0 $\boxed{144.7}$	37.4 $\boxed{138.6}$		22.5 $\boxed{113.4}$	26.2 $\boxed{124.3}$	3.7 acres $\boxed{+10.9}$	CRITERIA MET $\boxed{-20.4}$
4b	80.0	73.0		61.4	66.8	5.4 acres	13.2 acres
4c	38.7	28.2	90.0	29.5	31.3	1.8 acres	7.4 acres
5a	37.8	33.0	11.0	26.4	29.3	2.9 acres	8.5 acres
5b	N/A	N/A	*combined with 5a*	4.6	7.7	N/A	N/A

LEE VINING CREEK							
Stream Segment	***Woody Riparian Vegetation (Acres)***						
	Termination Criteria (SWRCB D1631)	***Pre-diversion (McBain and Trush 2004)***	***1989 Vegetation (JSA 1993)***	***1999 Vegetation (McBain & Trush)***	***2004 Vegetation (McBain & Trush)***	***Acreage Change Between 1999 and 2004***	***Acreage needed to meet Termination Criteria***
1	20.0	N/A	19.8	N/A	27.9	N/A	CRITERIA MET
2a	30.0	N/A	13.4	N/A	16.7	N/A	3.1 acres
2b	*Combined with 2a*	9.8	10.9	10.6	10.2	-0.4 acres	*Combined with 2a*
3a	22.2	18.5	6.9	12.5	12.5	0.0 acres	9.7 acres
3b	32.9	36.8	7.5	24.6	25.0	0.4 acres	7.9 acres
3c	4.0	4.5	3.3	5.5	5.7	0.2 acres	CRITERIA MET
3d	N/A	0.0	8.6	12.8	13.2	N/A	N/A

Comparison of the Parker and Walker Creek 1929 woody riparian vegetation coverage quantified by McBain and Trush to 1989 acreages quantified by JSA, 1999 acreages and 2004 acreages quantified by McBain and Trush.

PARKER CREEK				
Stream Segment	***Woody Riparian Vegetation (Acres)***			
	Pre-Diversion Vegetation (McBain & Trush)	***1989 Vegetation (Jones & Stokes 1993)***	***1999 Vegetation (McBain & Trush)***	***2004 Vegetation (McBain & Trush)***
1	6.0	15.2	14.0	14.6
2	36.4	31.3	22.1	24.0
3	2.8	0.5	0.7	1.0
4	4.3	2.2	1.4	2.2

WALKER CREEK				
Stream Segment	***Woody Riparian Vegetation (Acres)***			
	Pre-Diversion Vegetation (McBain & Trush)	***1989 Vegetation (Jones & Stokes 1993)***	***1999 Vegetation (McBain & Trush)***	***2004 Vegetation (McBain & Trush)***
1 combined with 4	22.5	13.1	12.5	11.9
2 combined with 5	6.9	1.3	0.3	0.7
3	9.3	2.8	6.2	5.9

1929, 1999, AND 2004 RUSH CREEK RIPARIAN VEGETATION MAPS

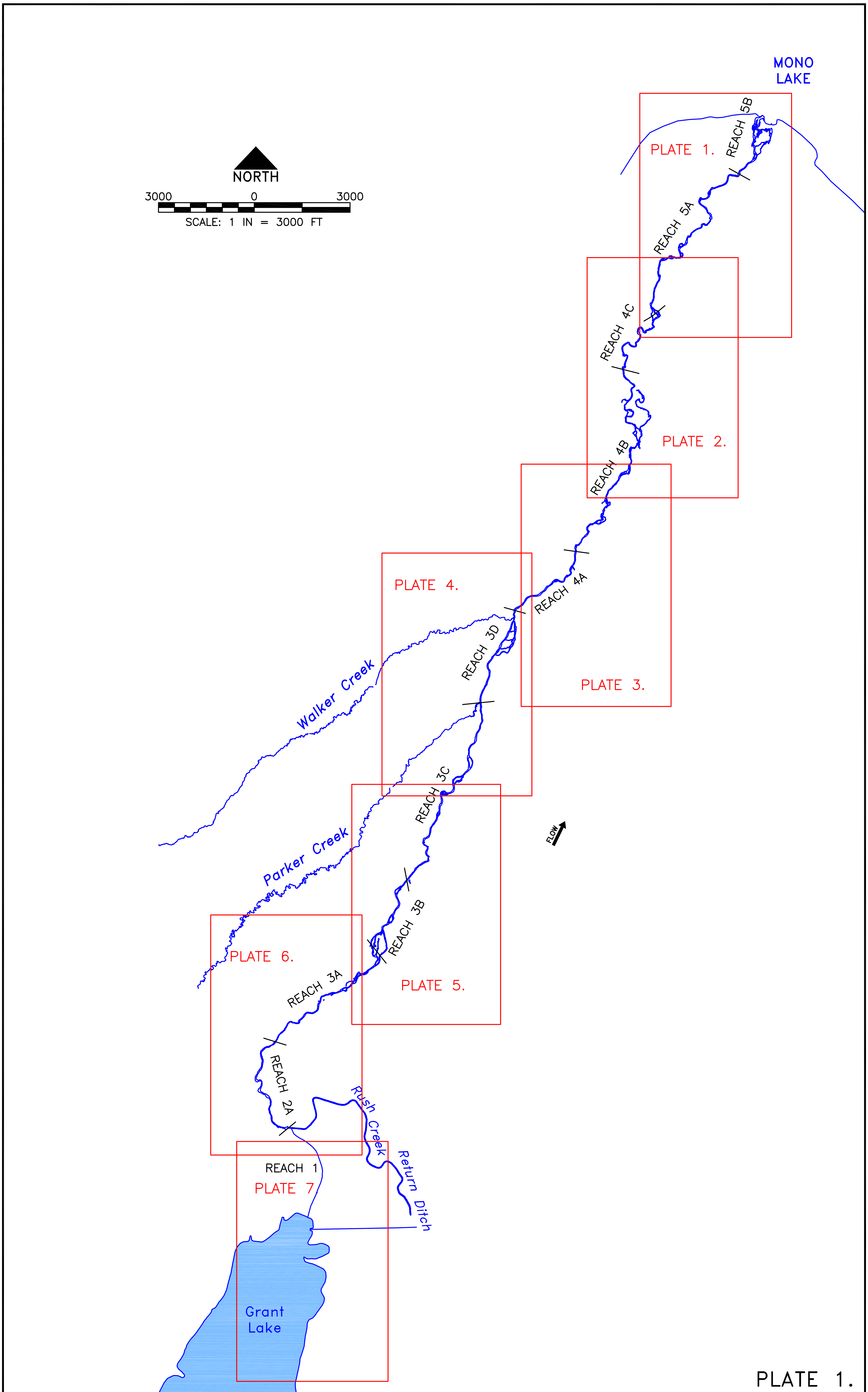
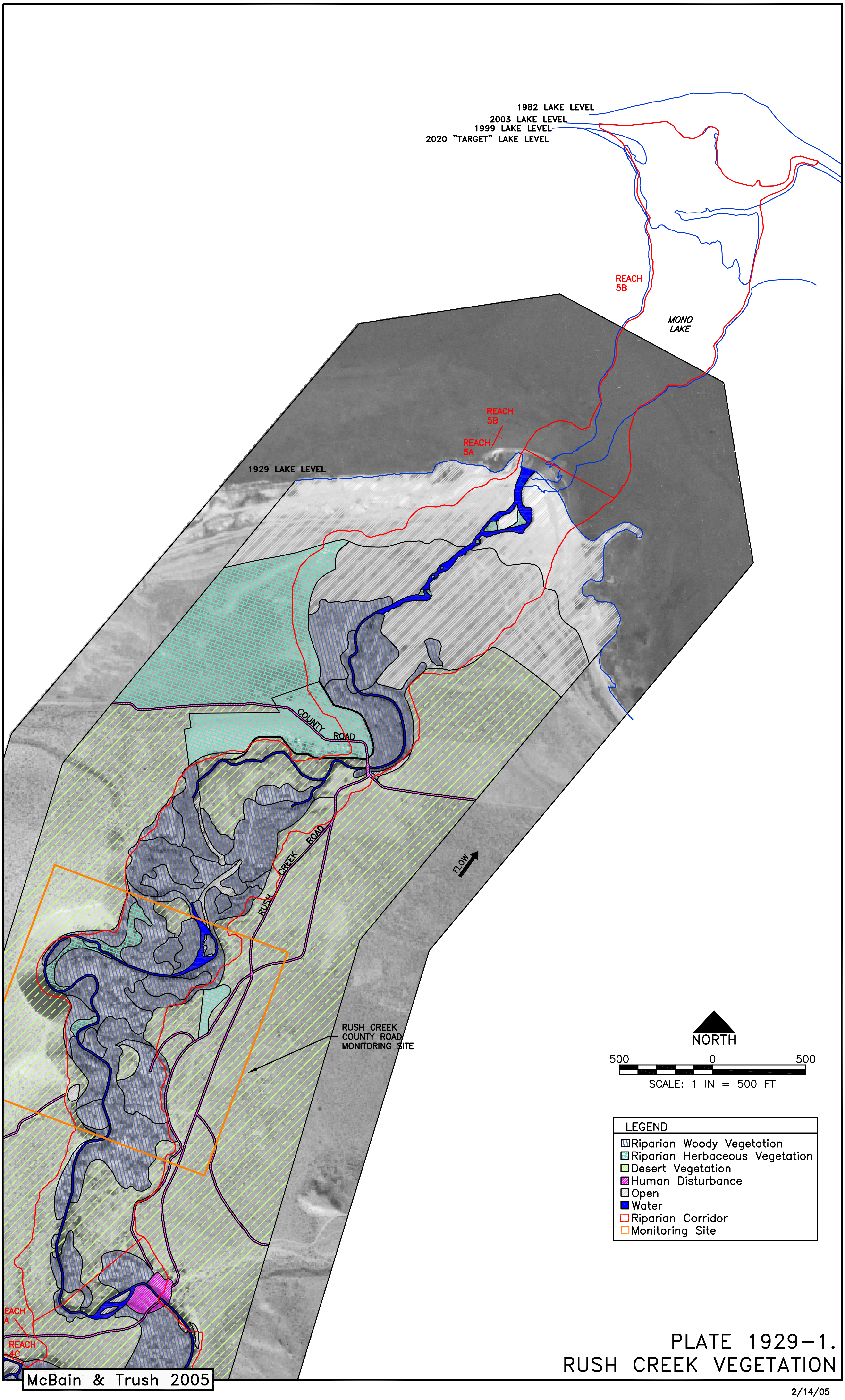


PLATE 1.
RUSH CREEK VEGETATION MAP INDEX

2/14/05

McBain & Trush 2005



LEGEND
- ▨ Riparian Woody Vegetation
- ▨ Riparian Herbaceous Vegetation
- ▨ Desert Vegetation
- ▨ Human Disturbance
- ☐ Open
- ■ Water
- ☐ Riparian Corridor
- ☐ Monitoring Site

PLATE 1929–1.
RUSH CREEK VEGETATION

2/14/05

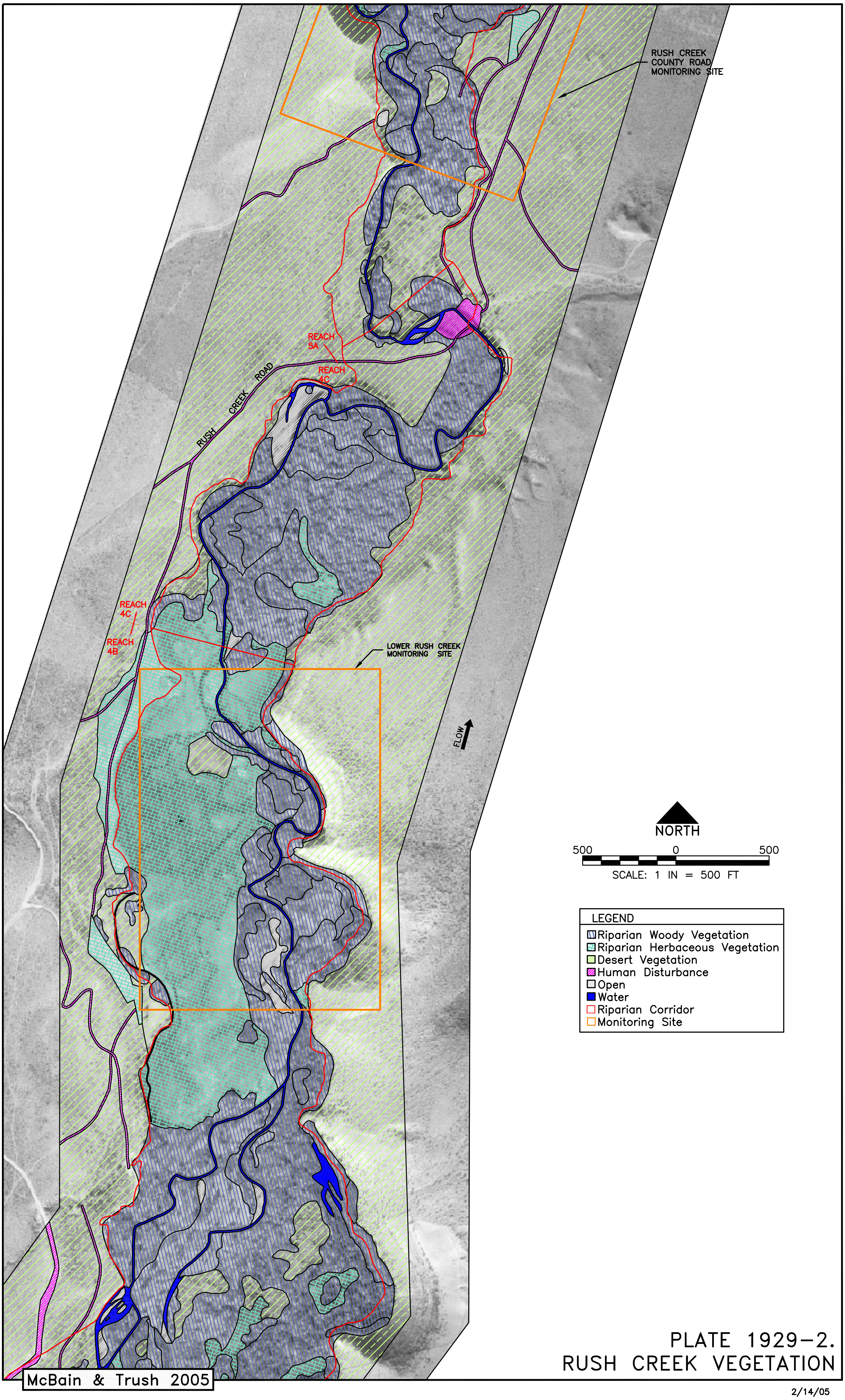


PLATE 1929–2.
RUSH CREEK VEGETATION

2/14/05

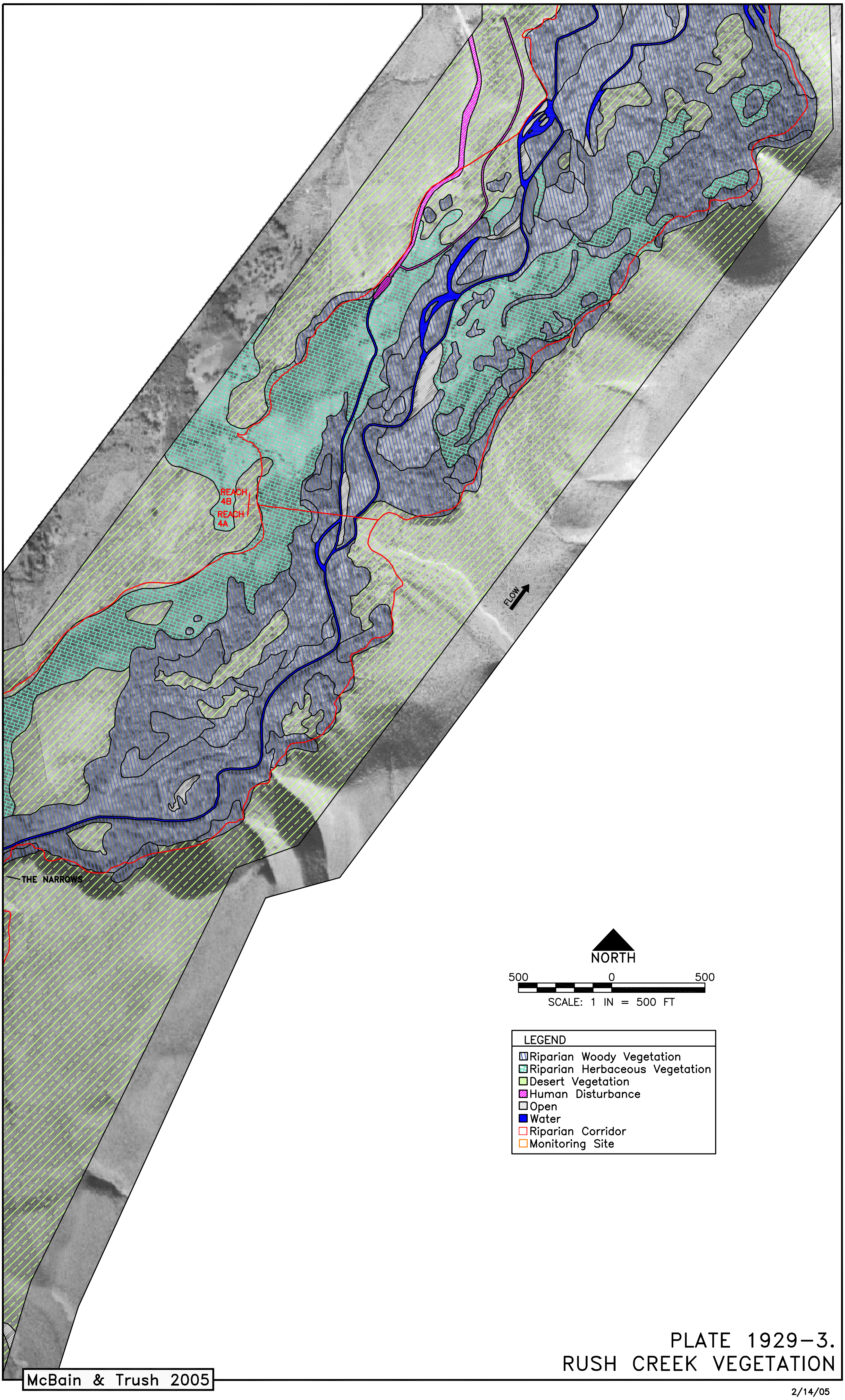


PLATE 1929-3.
RUSH CREEK VEGETATION

2/14/05

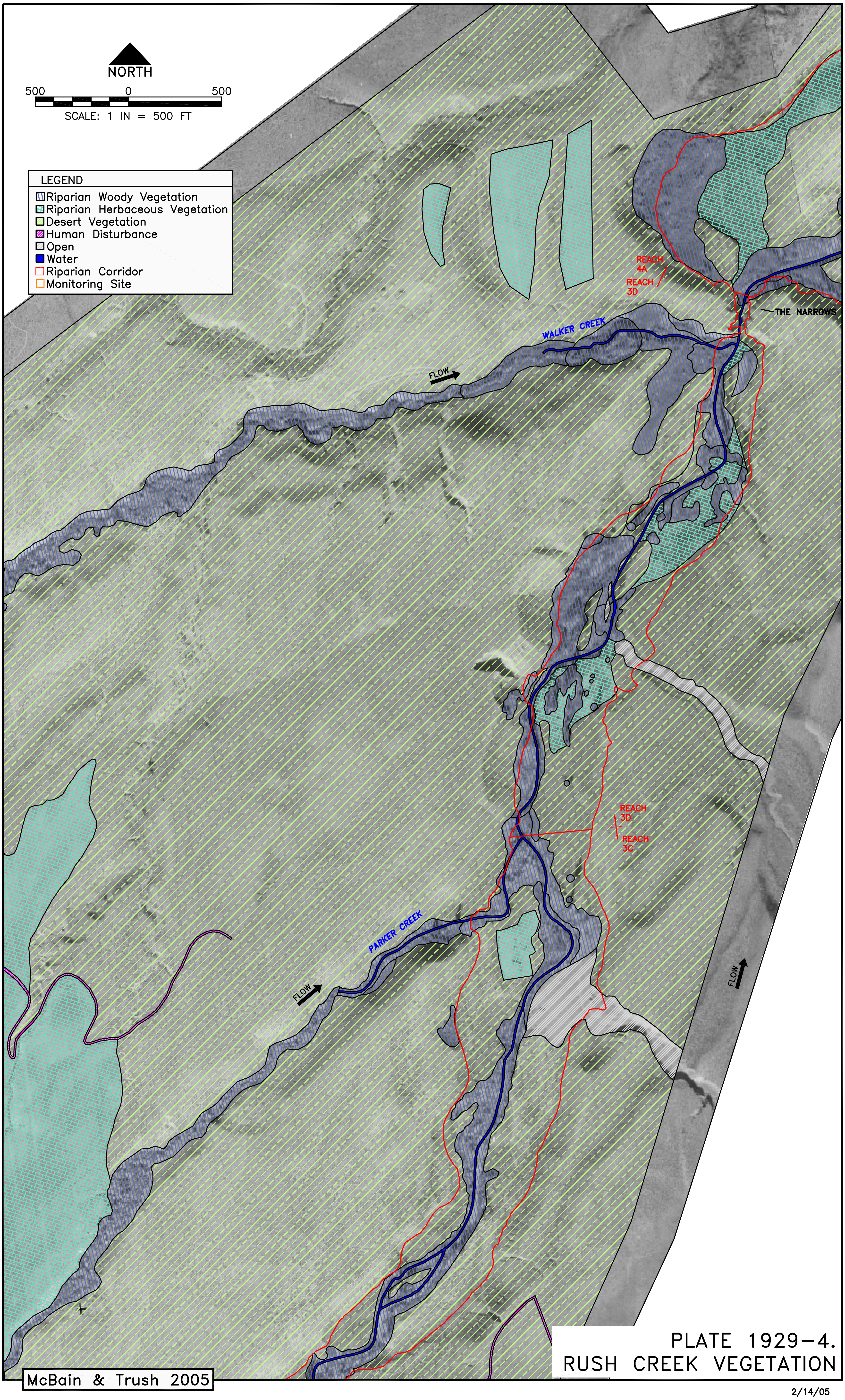


PLATE 1929-4.
RUSH CREEK VEGETATION

2/14/05

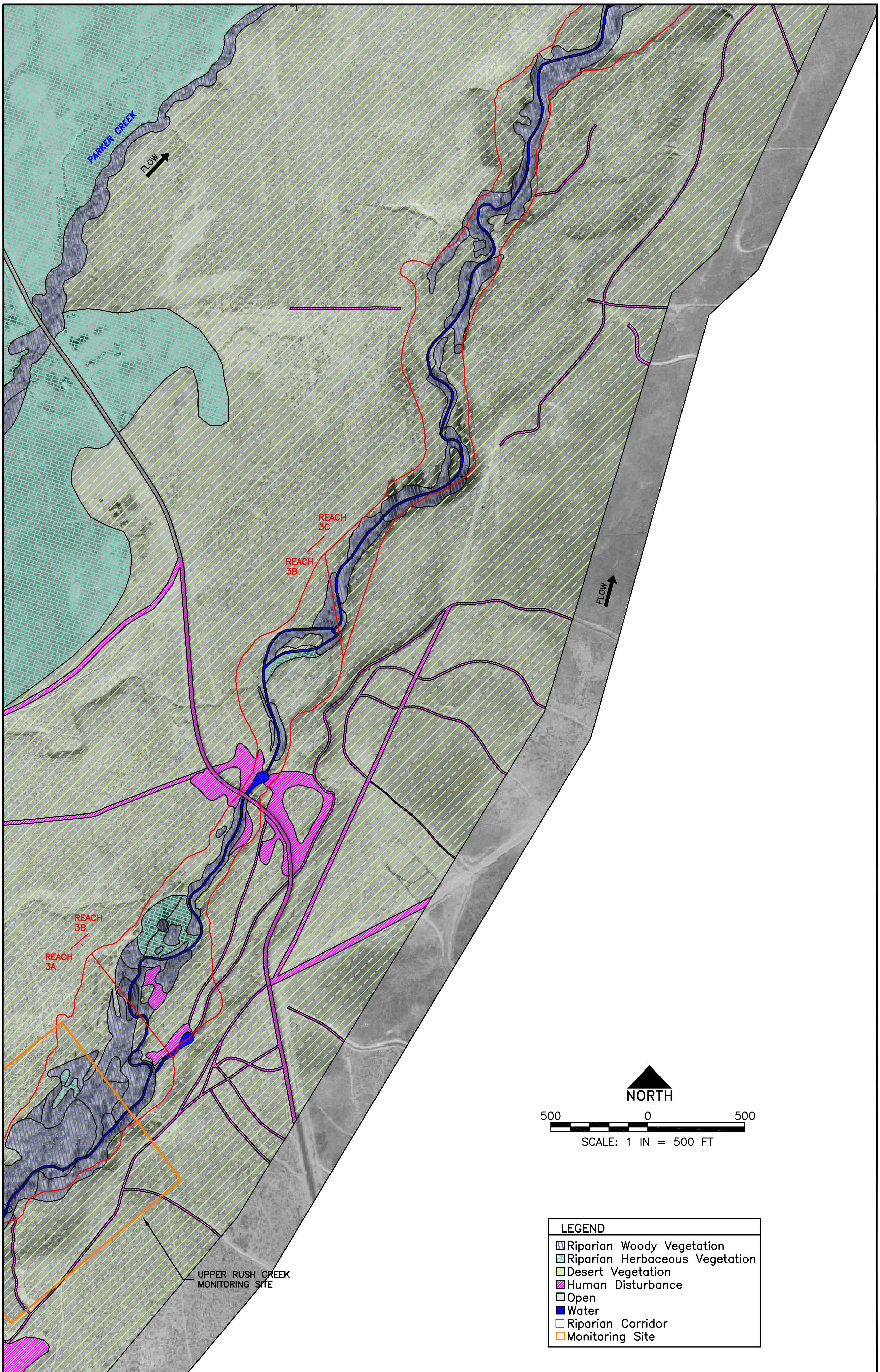


PLATE 1929–5.
RUSH CREEK VEGETATION

McBain & Trush 2005

2/14/05

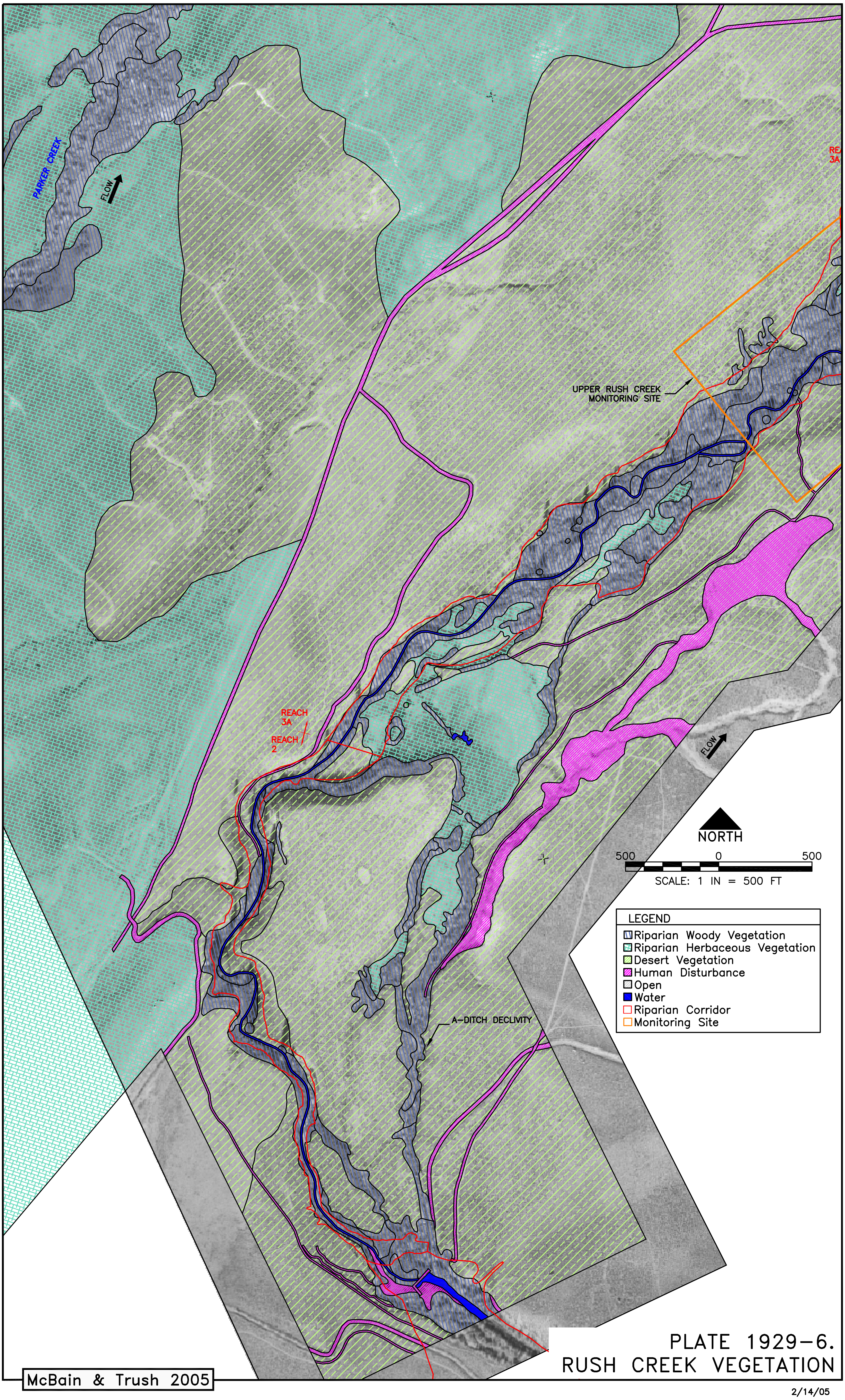


PLATE 1929-6.
RUSH CREEK VEGETATION

2/14/05

Rush Creek Reach 1

1929

Not Mapped

No PLATE 1929-7

PLATE 1929-7.
RUSH CREEK VEGETATION

McBain & Trush 2005

2/14/05

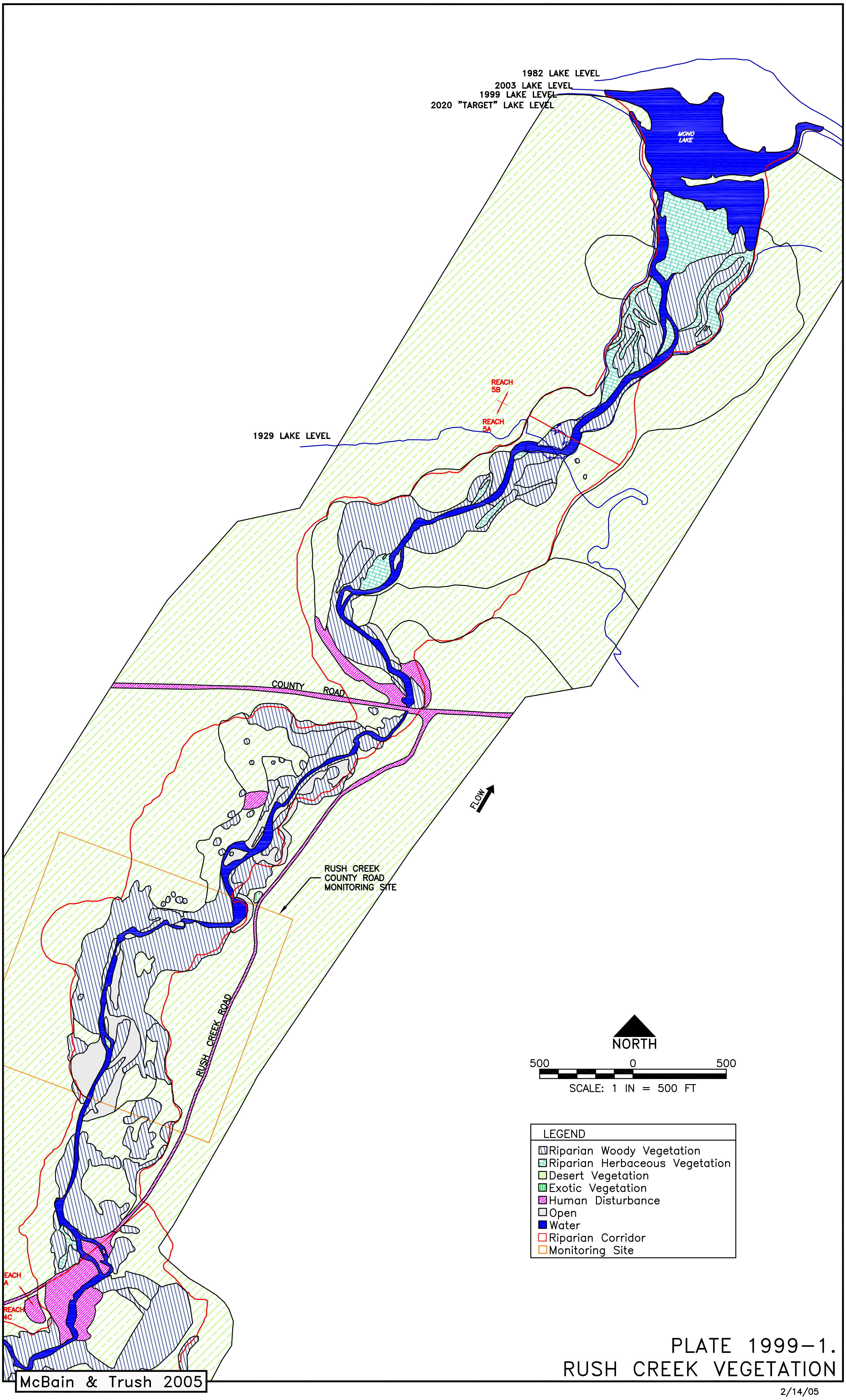


PLATE 1999-1.
RUSH CREEK VEGETATION

2/14/05

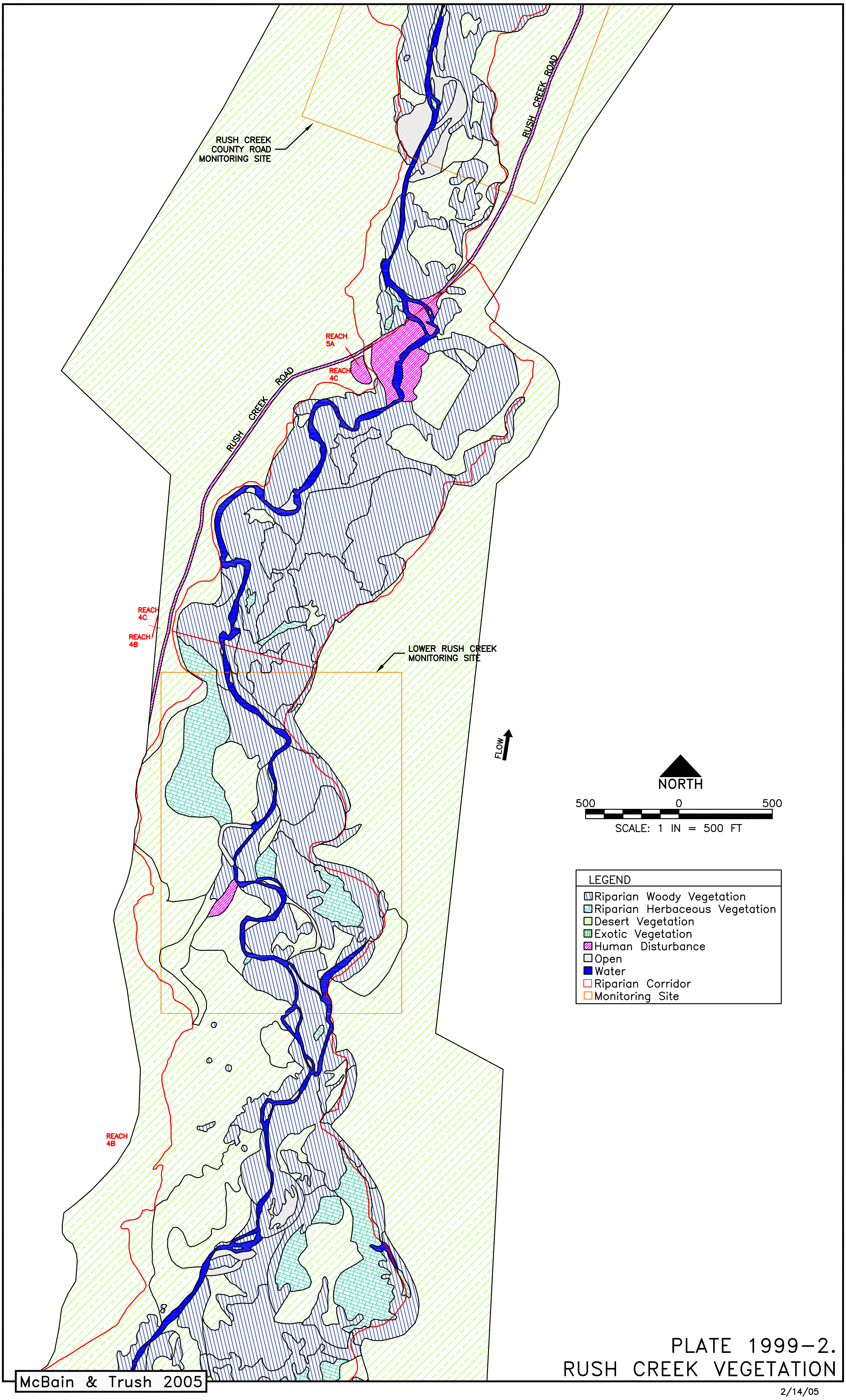


PLATE 1999–2.
RUSH CREEK VEGETATION

2/14/05

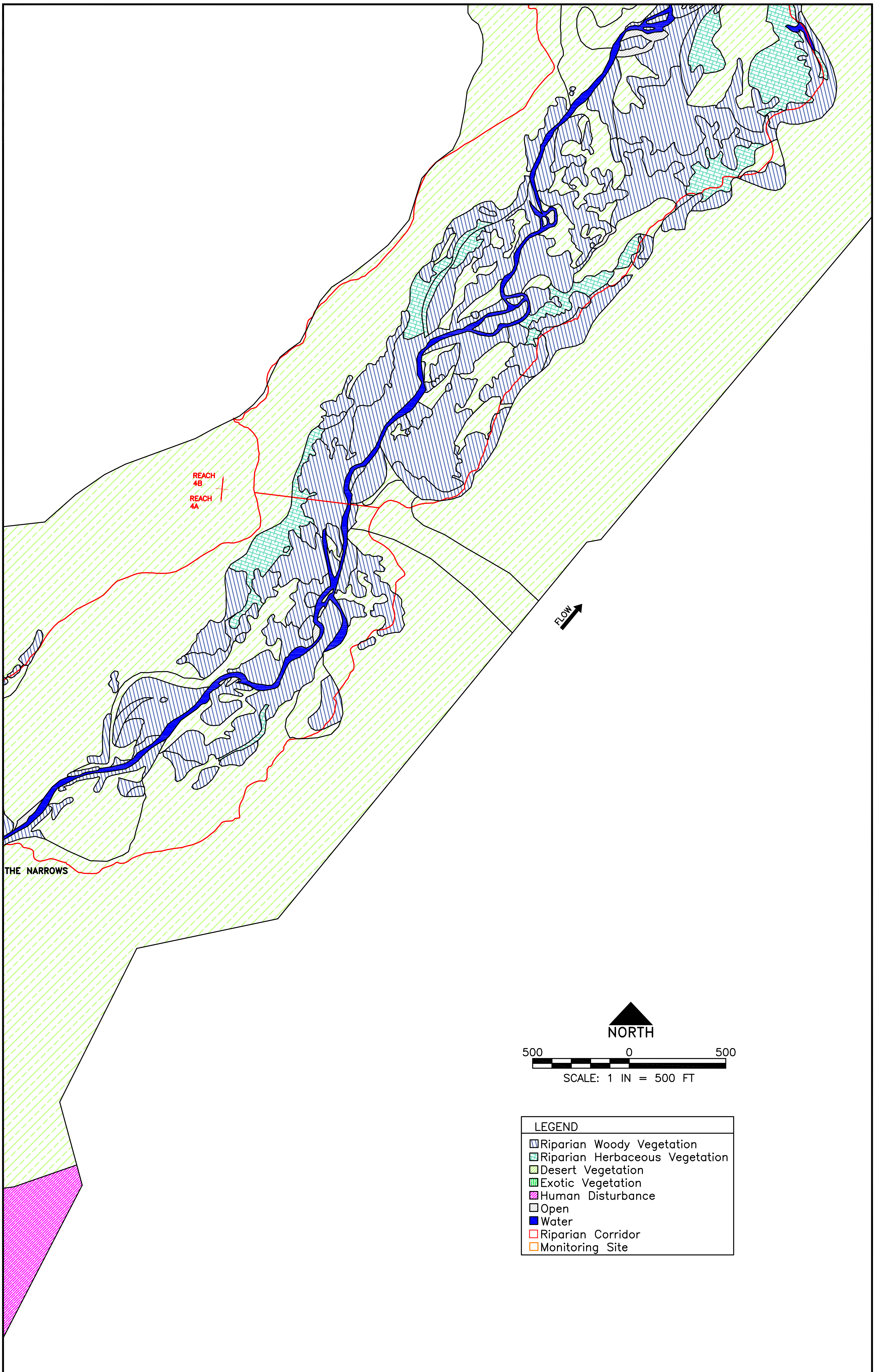


PLATE 1999–3.
RUSH CREEK VEGETATION

2/14/05

McBain & Trush 2005

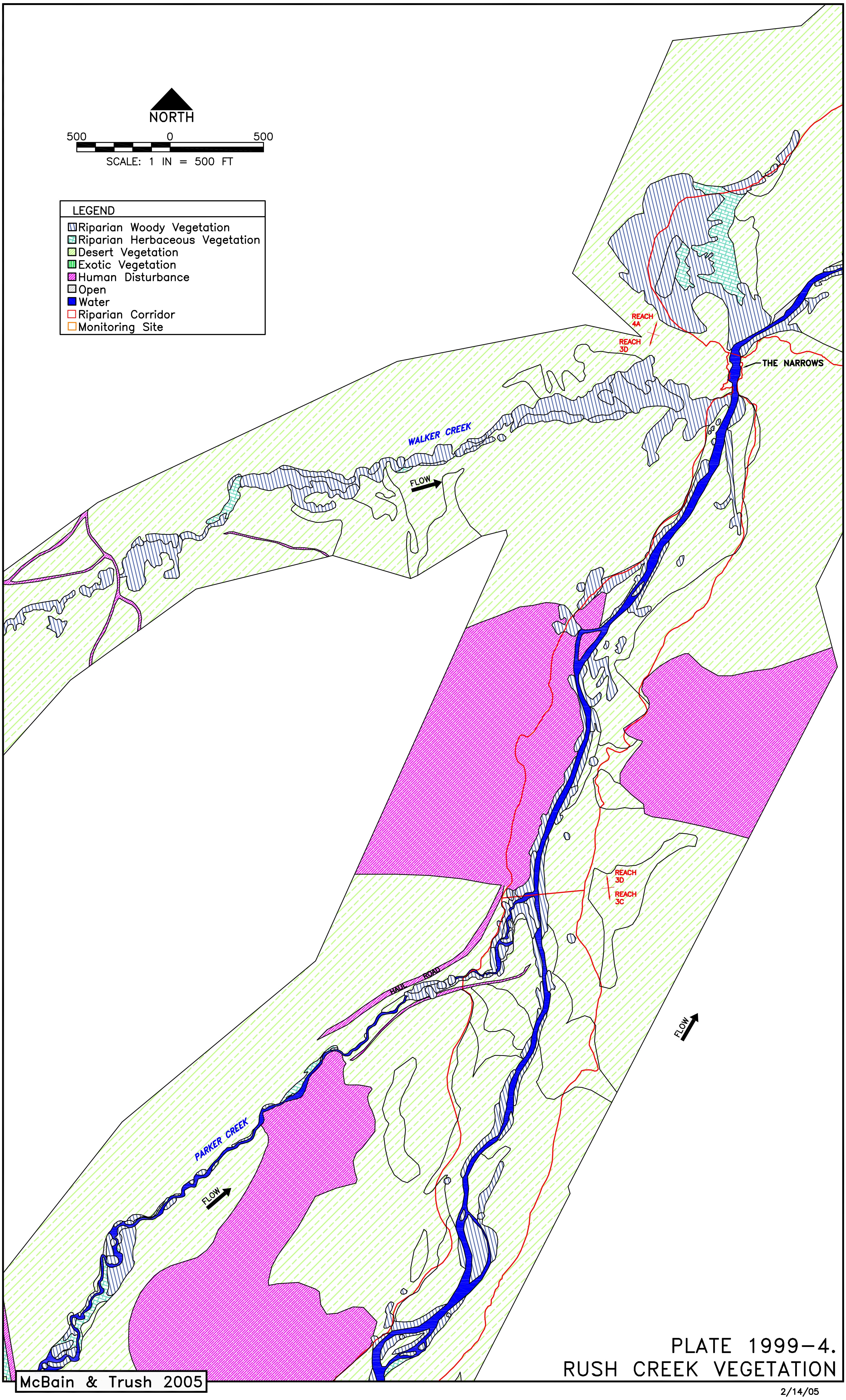


PLATE 1999–4.
RUSH CREEK VEGETATION

2/14/05

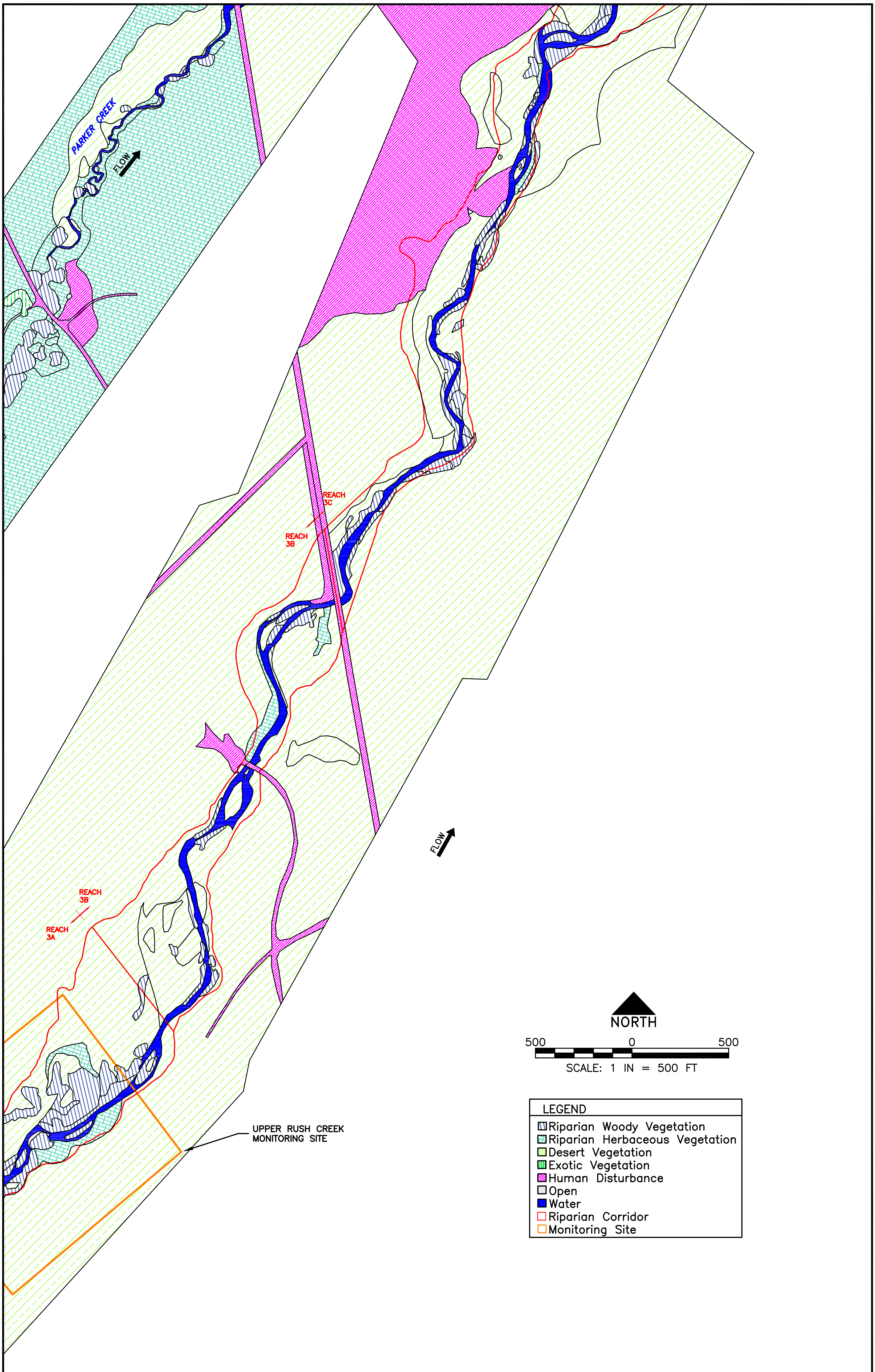


PLATE 1999–5.
RUSH CREEK VEGETATION

2/14/05

McBain & Trush 2005

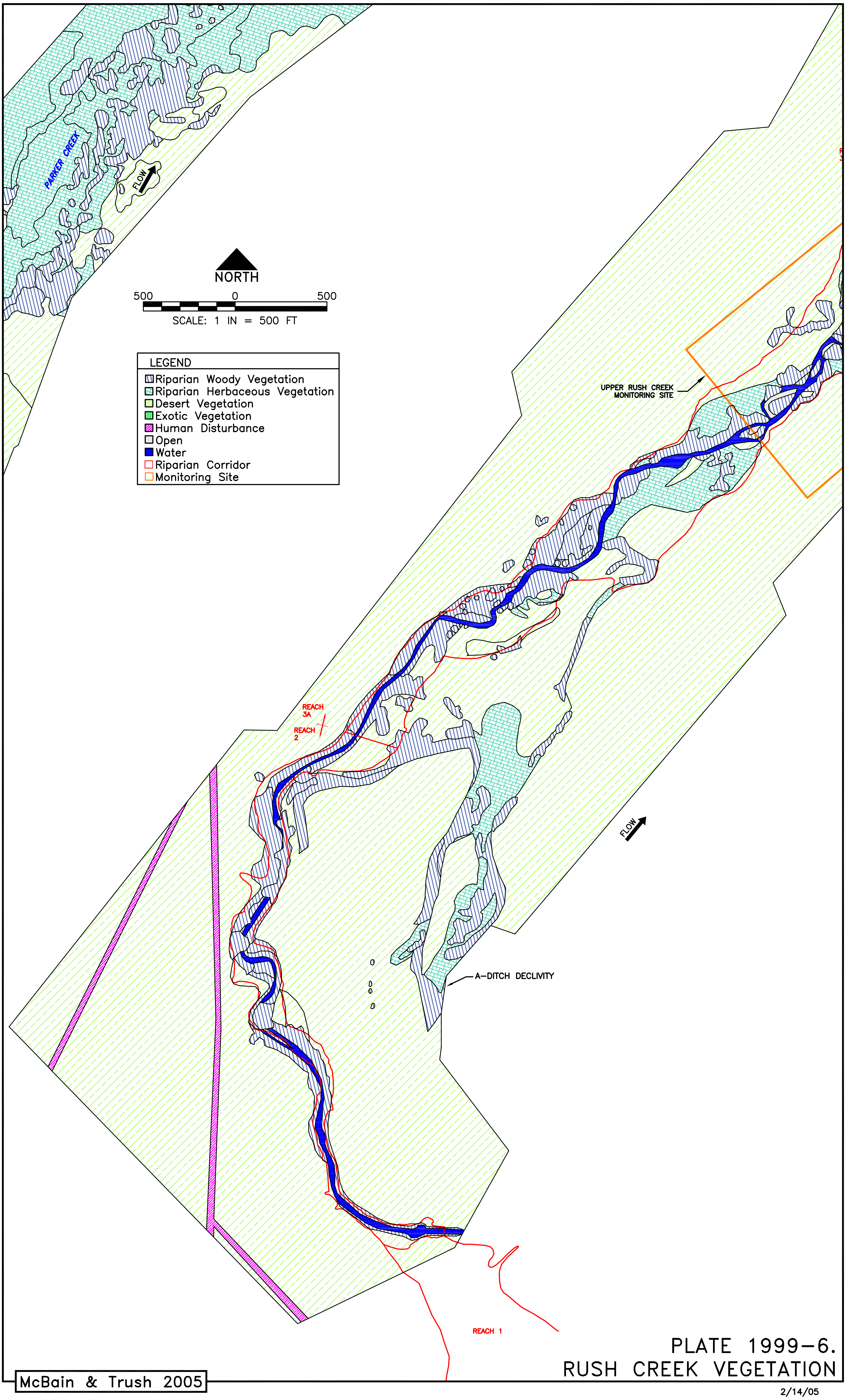


PLATE 1999-6.
RUSH CREEK VEGETATION

2/14/05

Rush Creek Reach 1

1999

Not Mapped

No PLATE 1999-7

PLATE 1999-7.
RUSH CREEK VEGETATION

McBain & Trush 2005

2/14/05

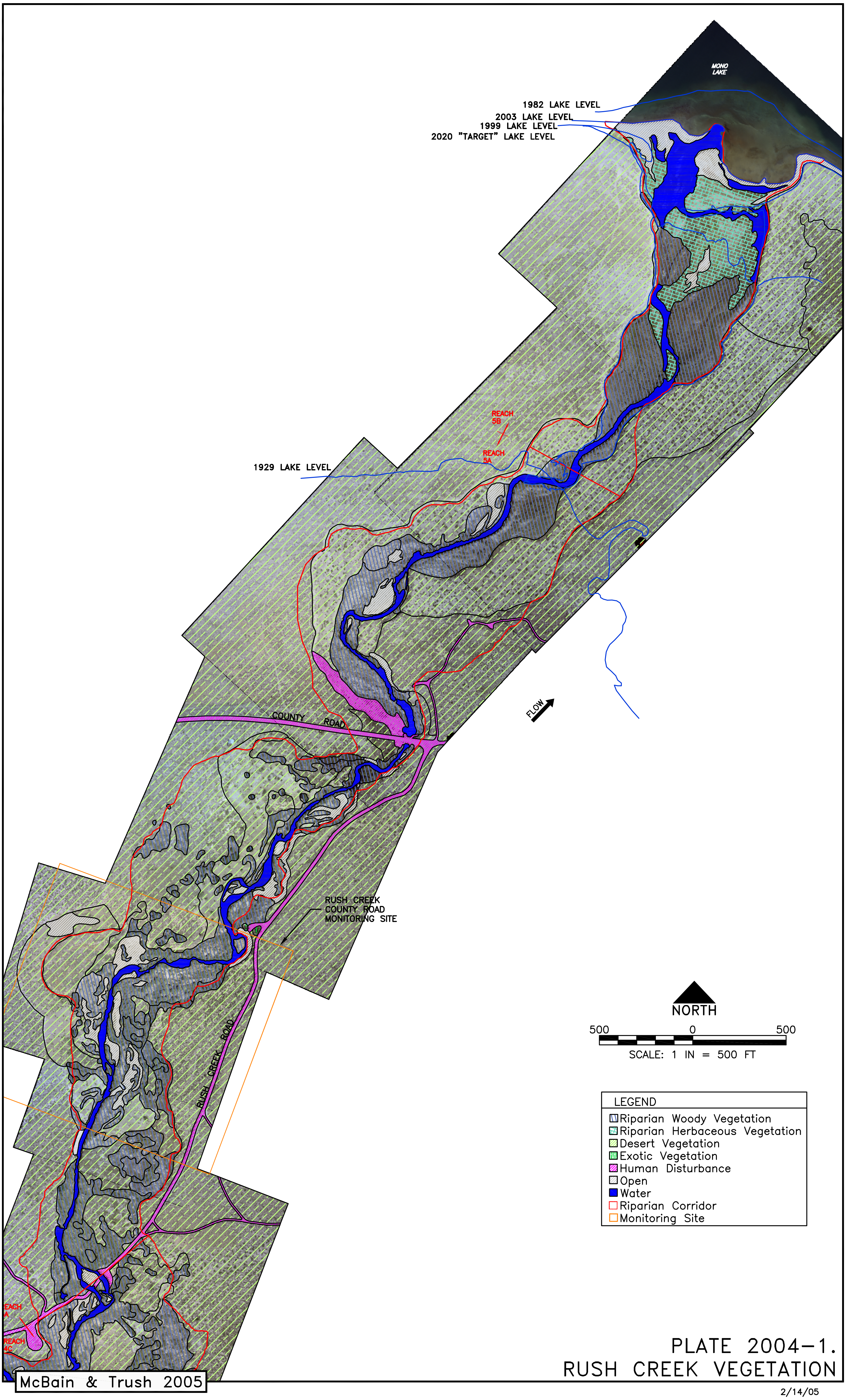


PLATE 2004–1.
RUSH CREEK VEGETATION

2/14/05

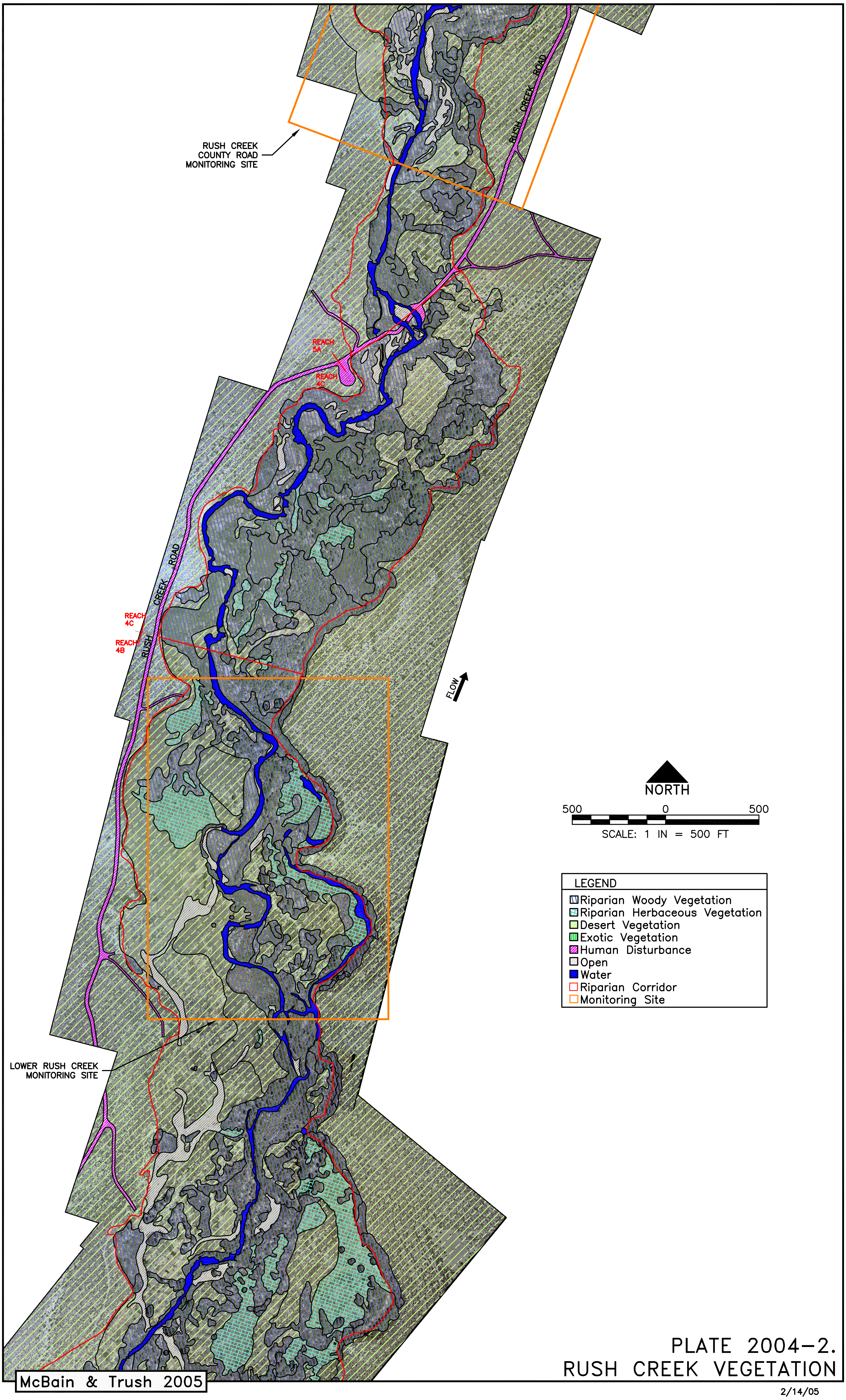


PLATE 2004–2.
RUSH CREEK VEGETATION

2/14/05

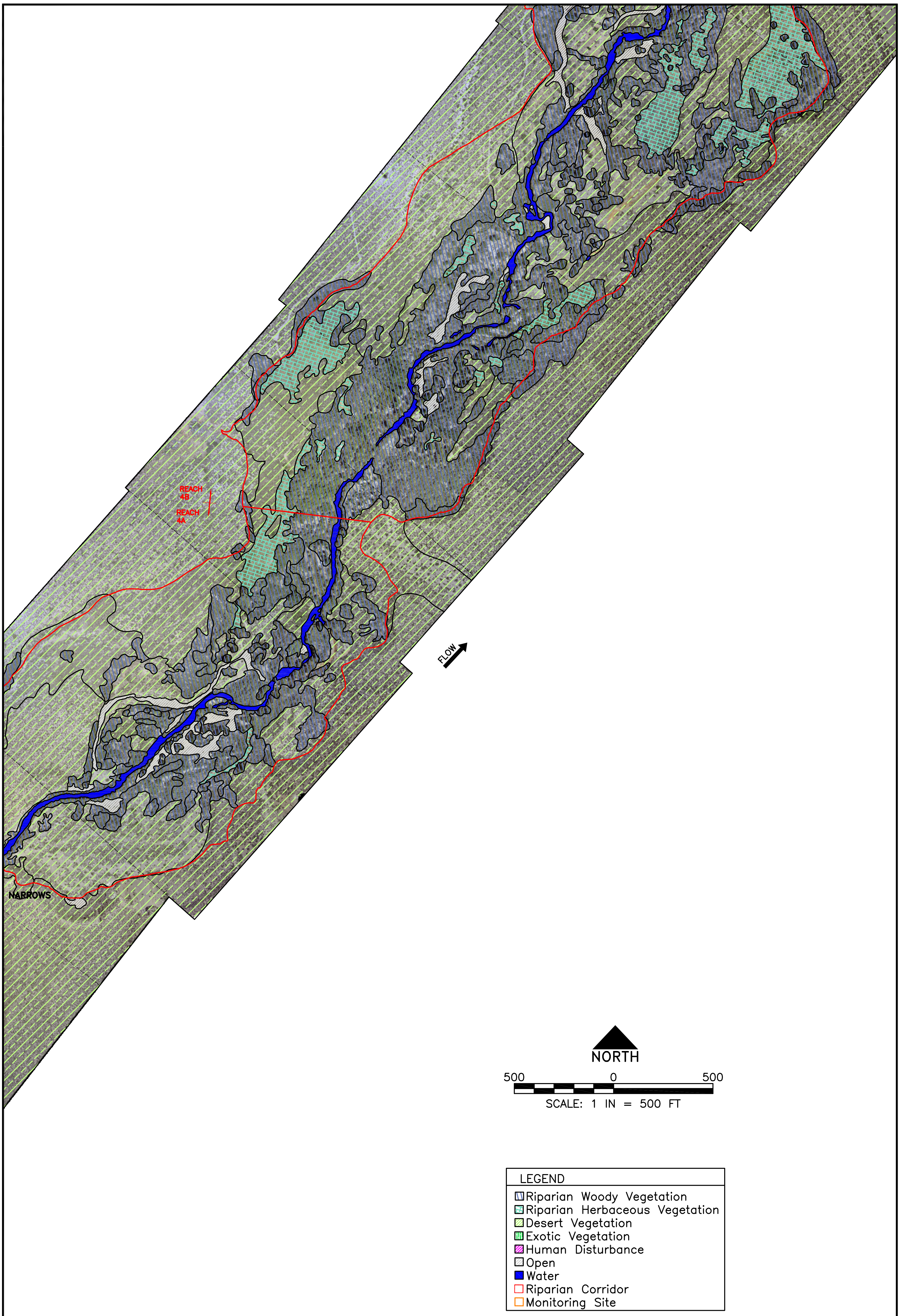


PLATE 2004–3.
RUSH CREEK VEGETATION

McBain & Trush 2005

2/14/05

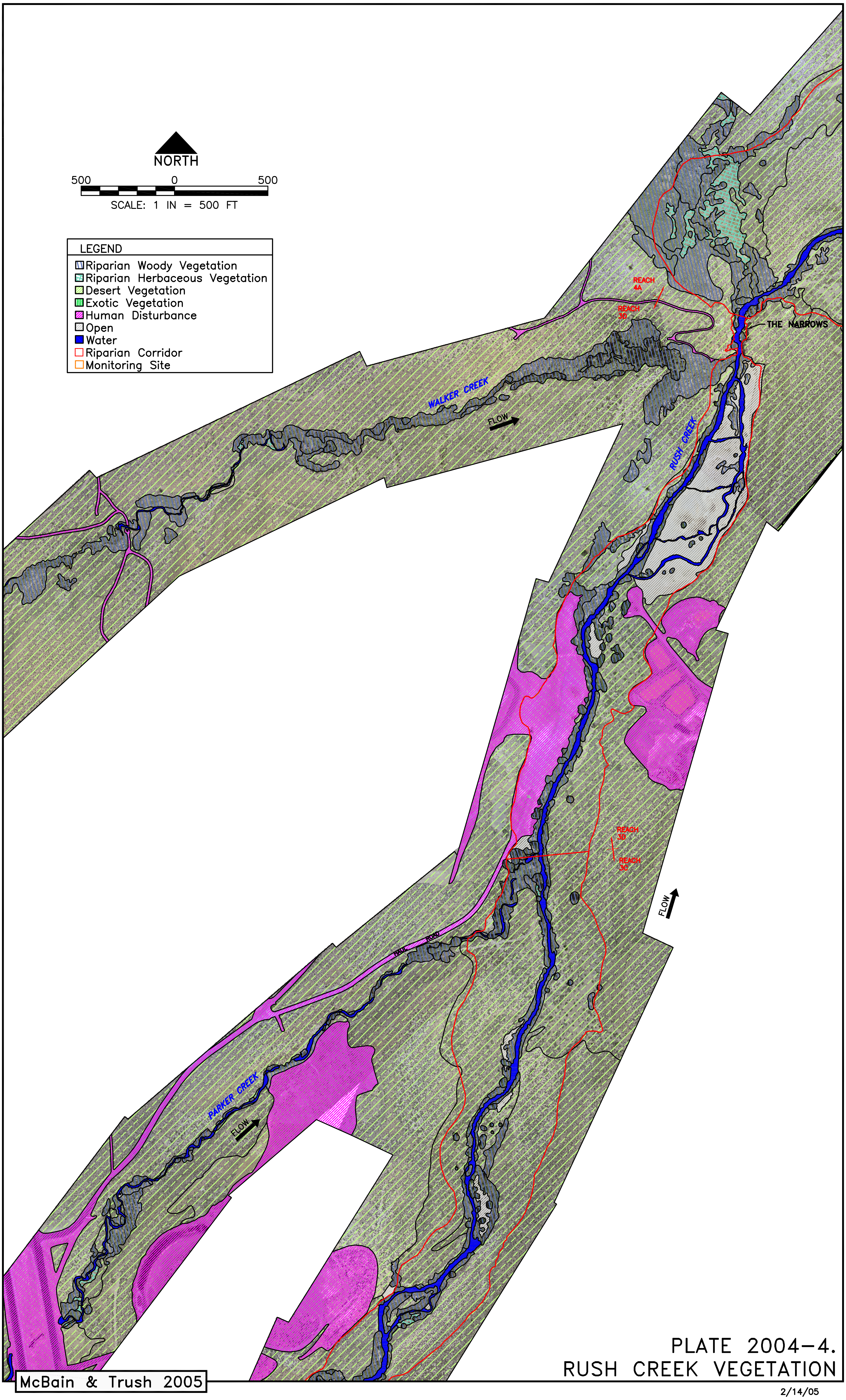


PLATE 2004–4.
RUSH CREEK VEGETATION

2/14/05

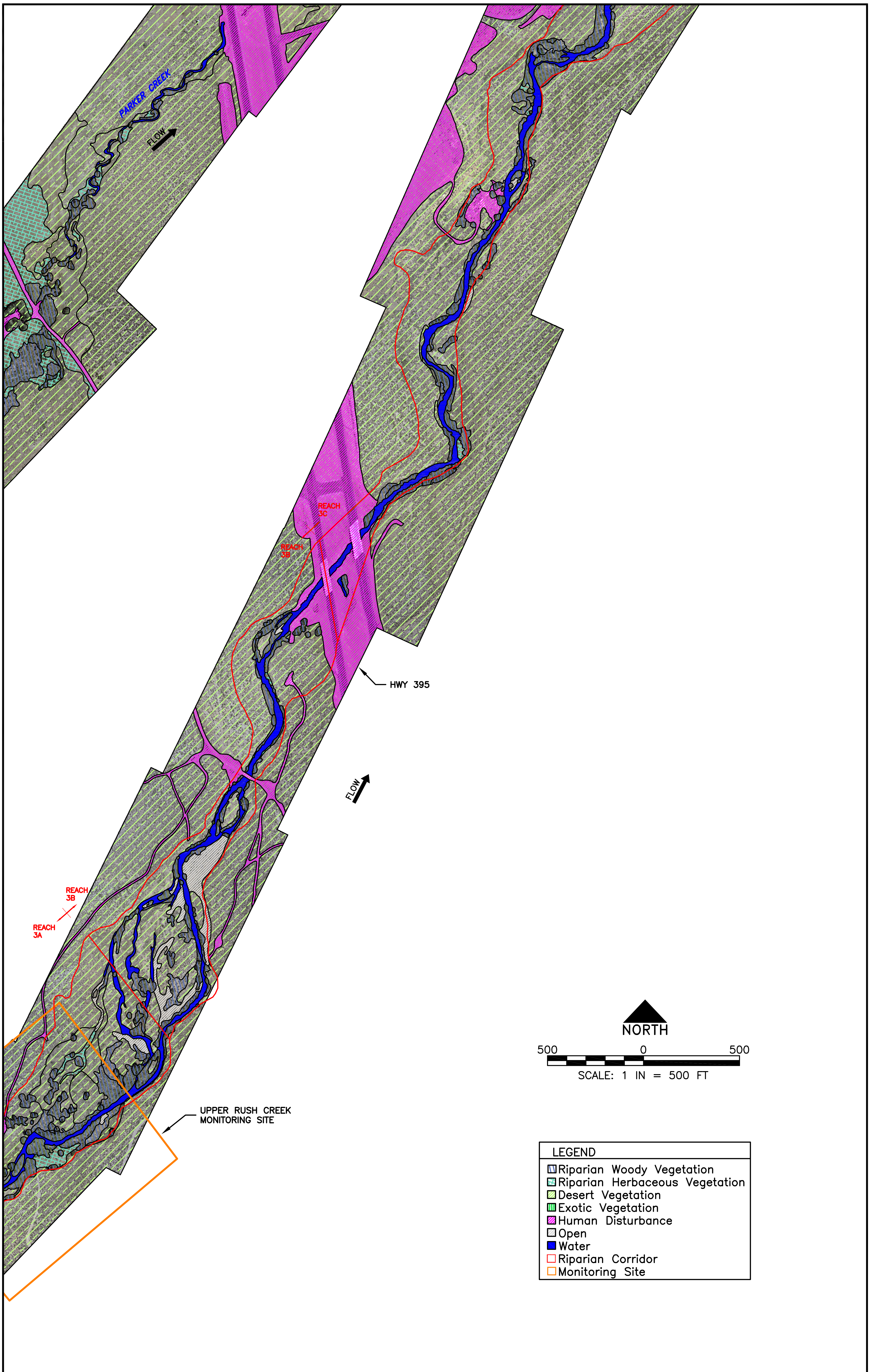


PLATE 2004–5.
RUSH CREEK VEGETATION

2/14/05

McBain & Trush 2005

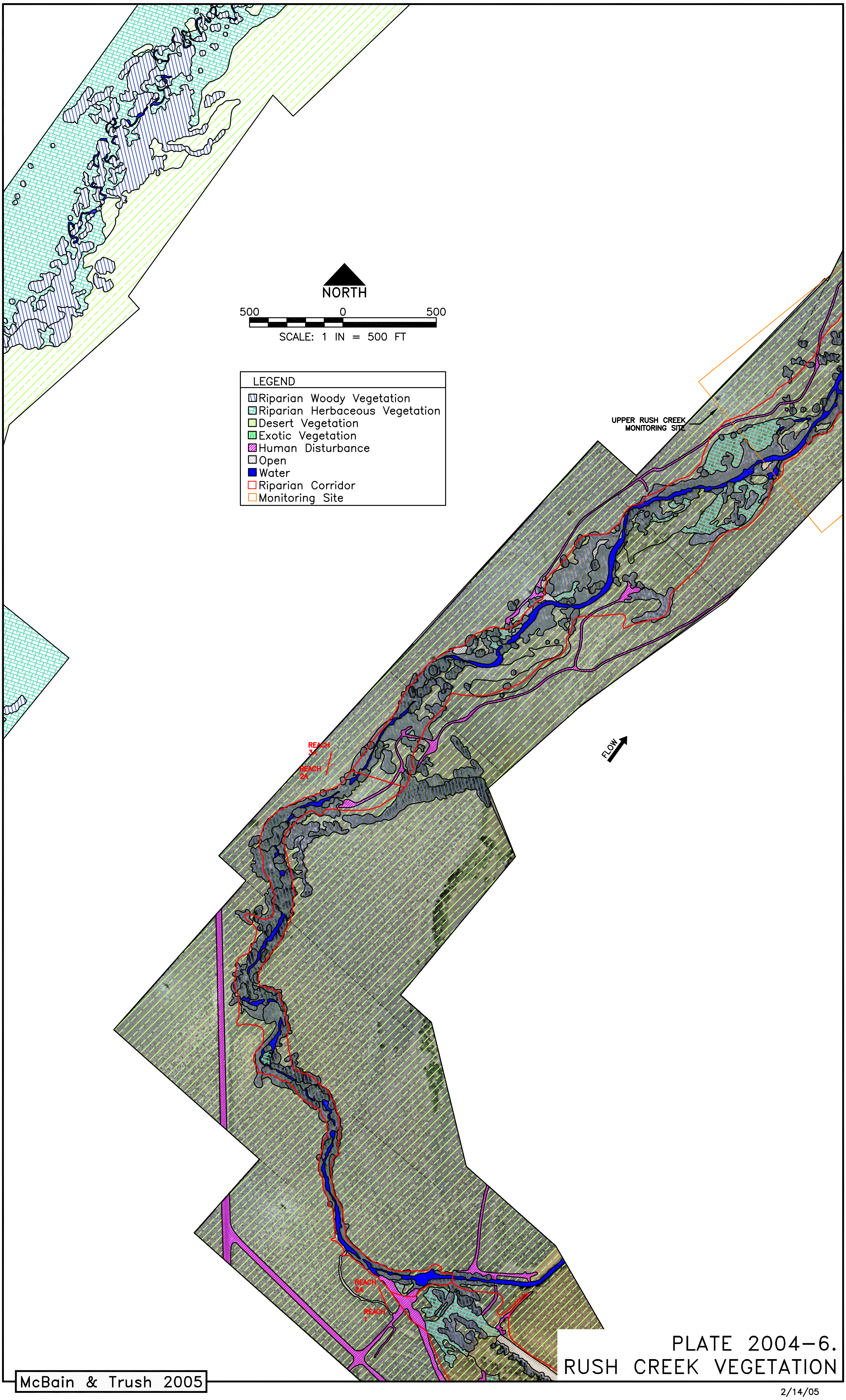


PLATE 2004–6.
RUSH CREEK VEGETATION

2/14/05

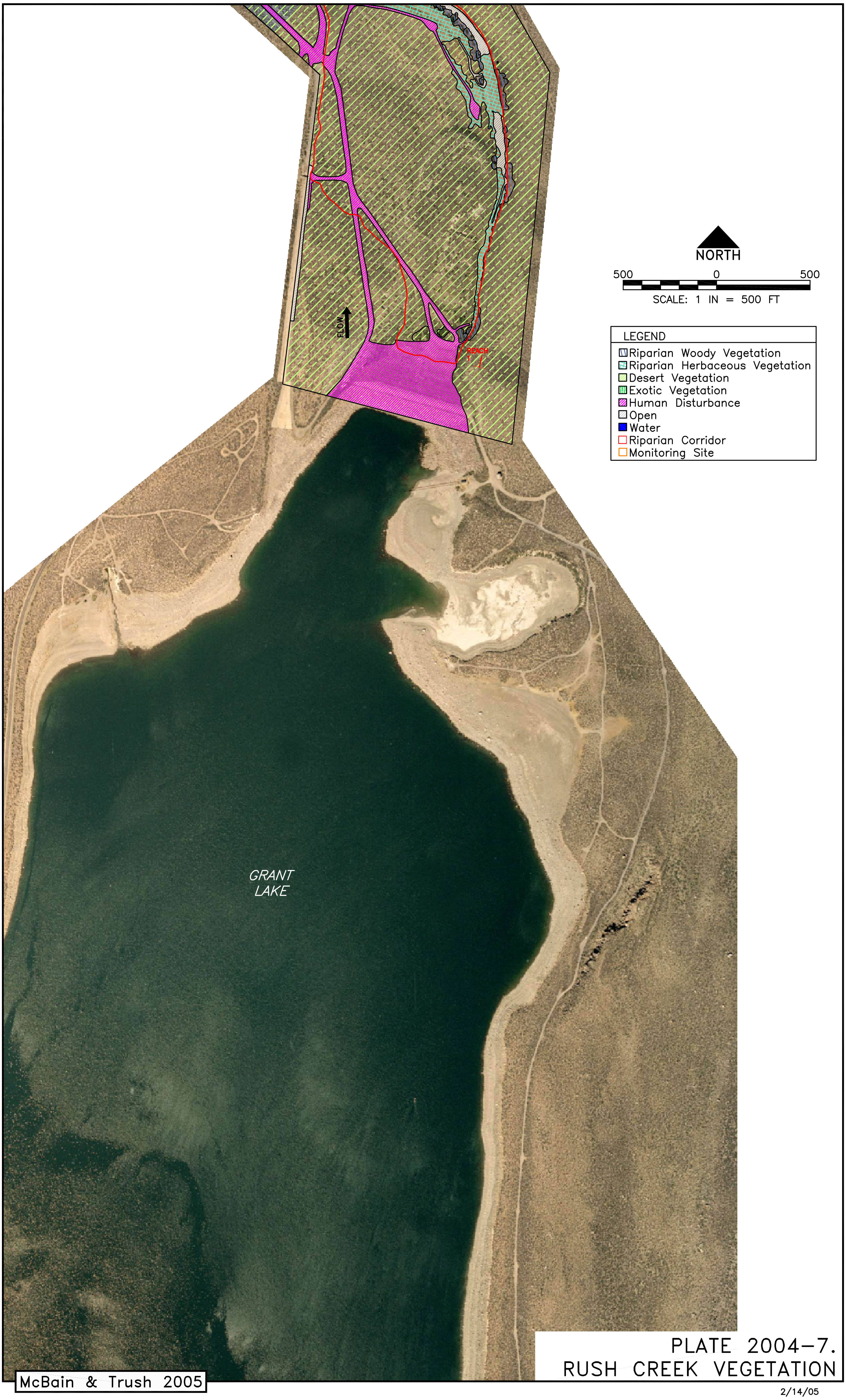


PLATE 2004–7.
RUSH CREEK VEGETATION

2/14/05

1929, 1999, AND 2004 PARKER CREEK RIPARIAN VEGETATION MAPS

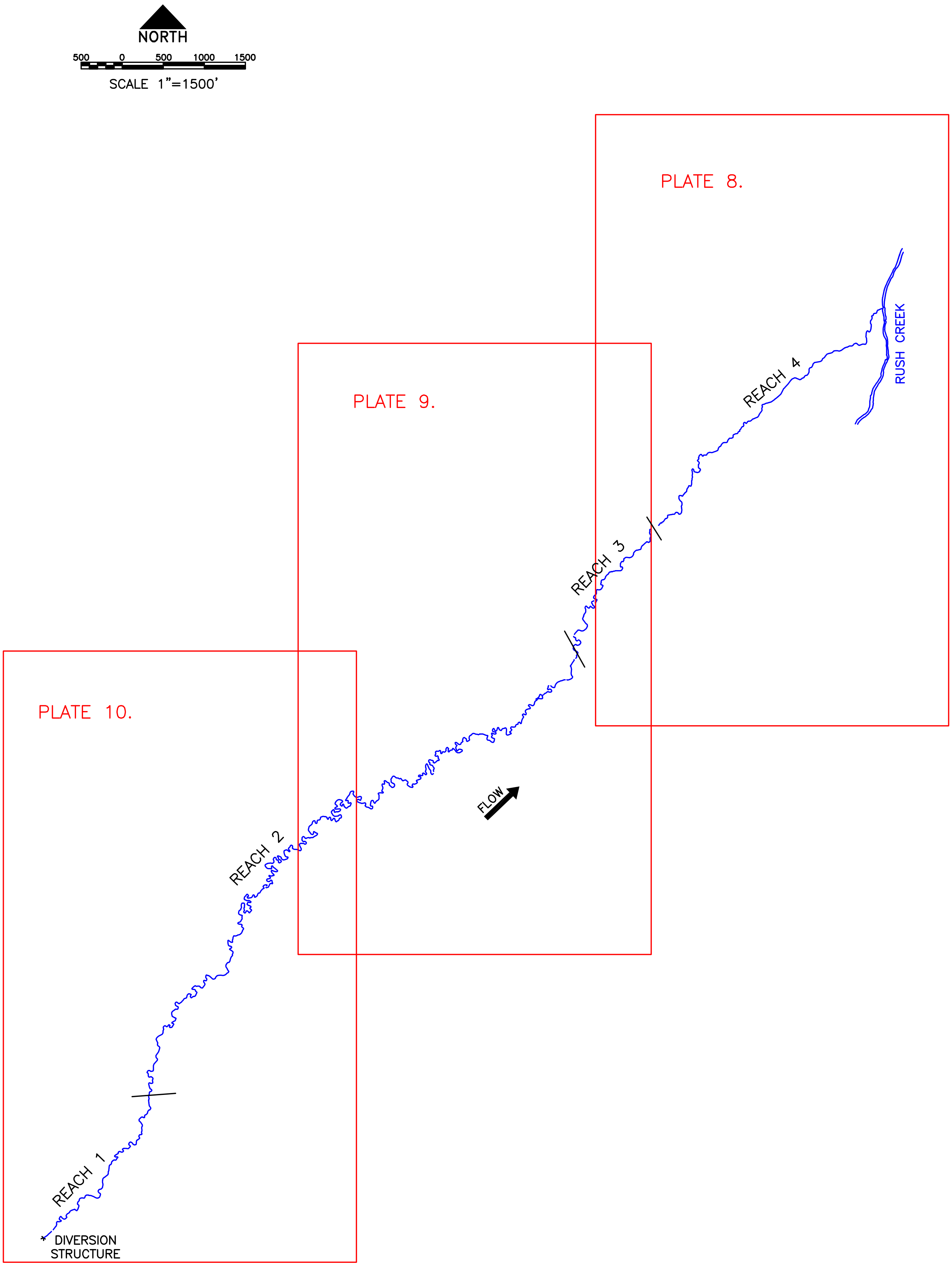


PLATE 2.
PARKER CREEK VEGETATION MAP INDEX

2/14/05

McBain & Trush 2005

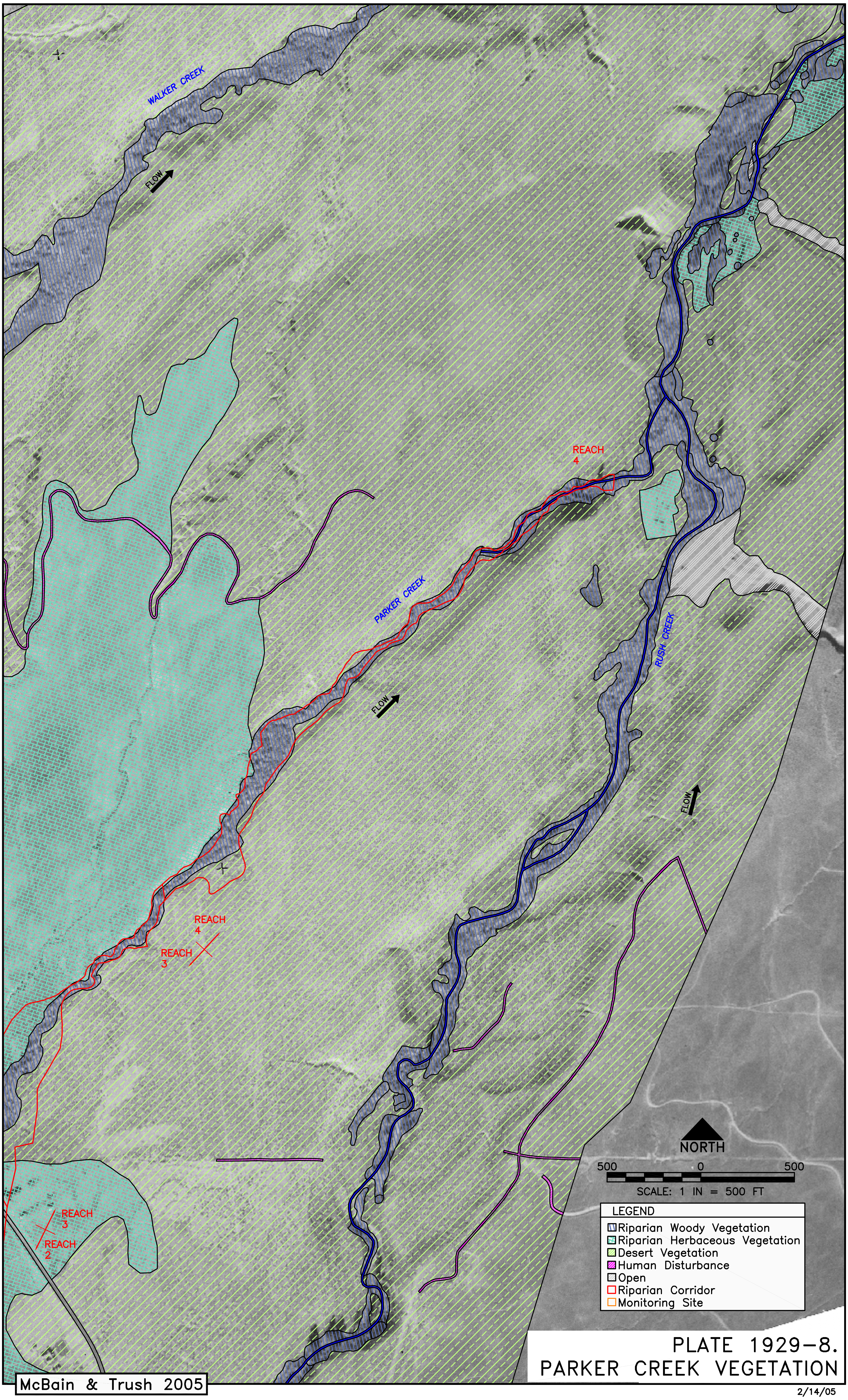


PLATE 1929–8.
PARKER CREEK VEGETATION

2/14/05

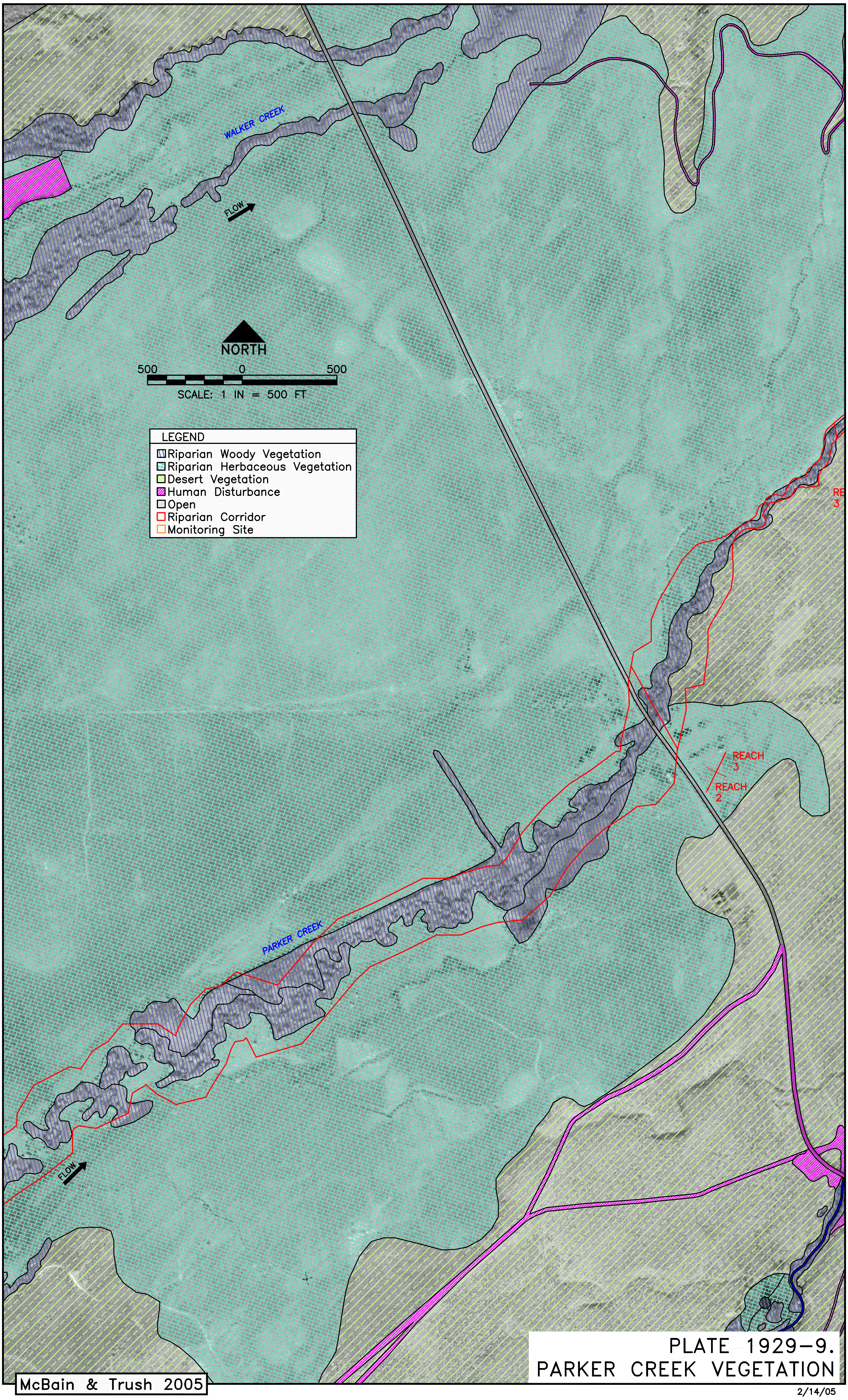


PLATE 1929-9.
PARKER CREEK VEGETATION

2/14/05

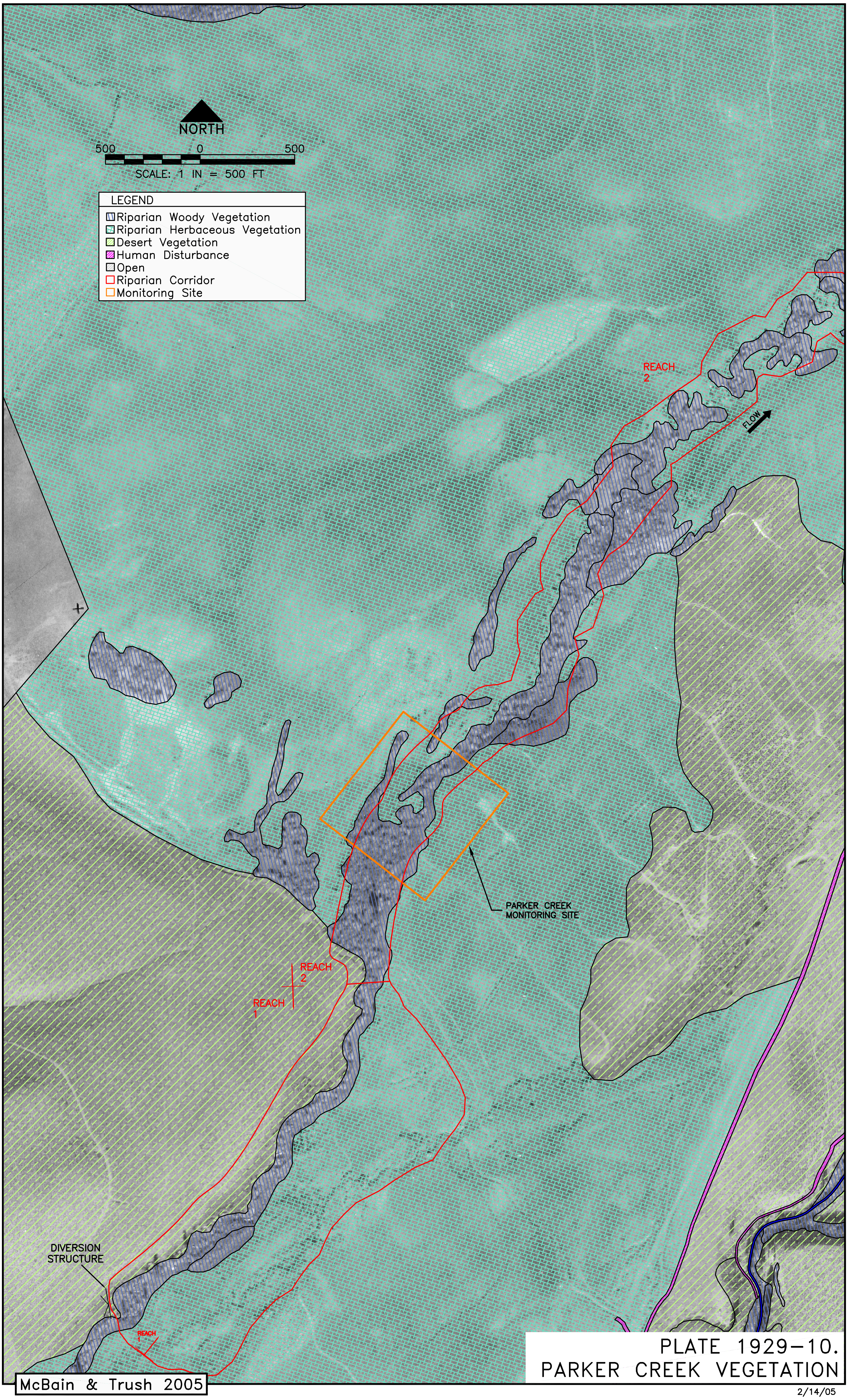


PLATE 1929–10.
PARKER CREEK VEGETATION

2/14/05

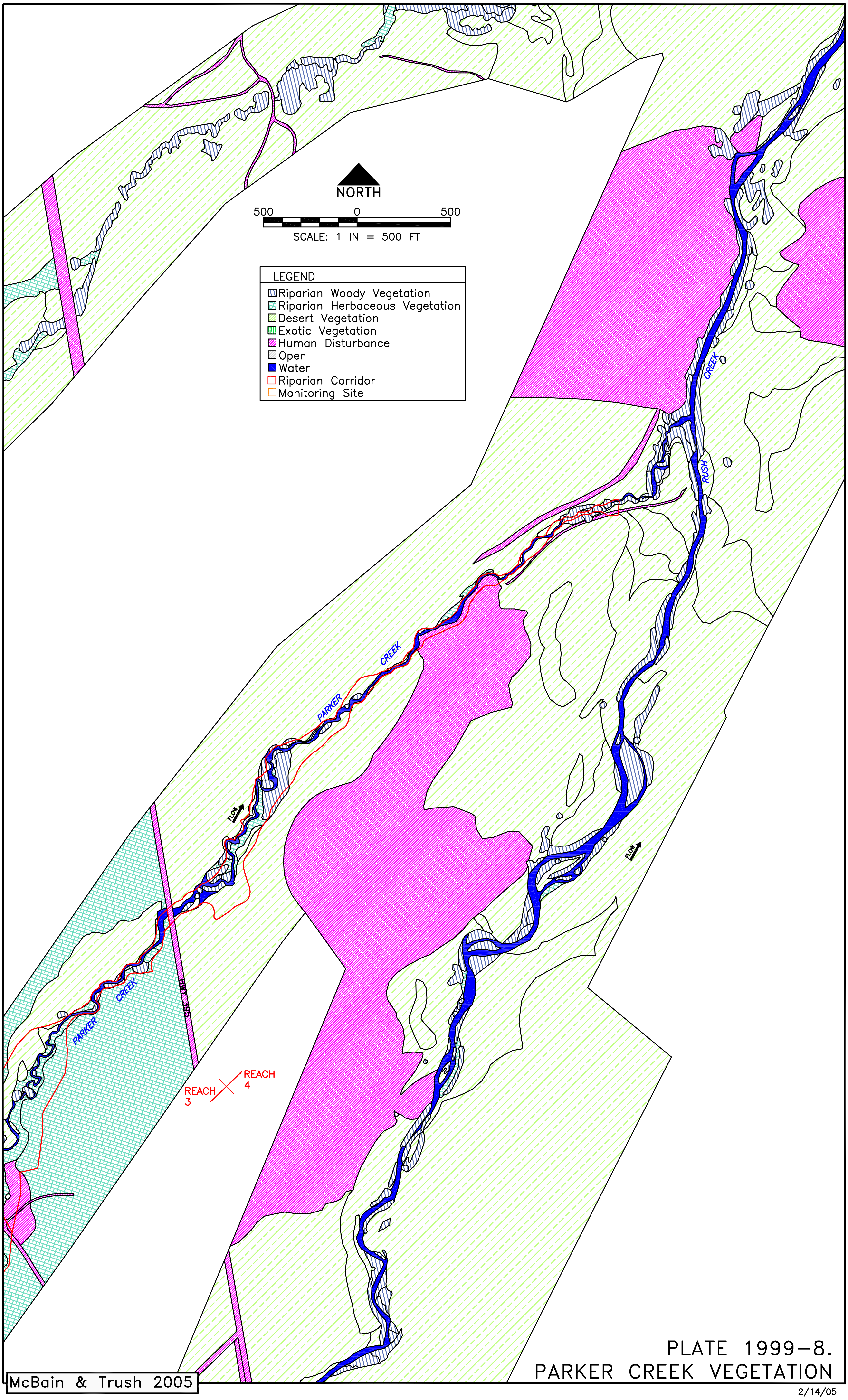


PLATE 1999–8.
PARKER CREEK VEGETATION

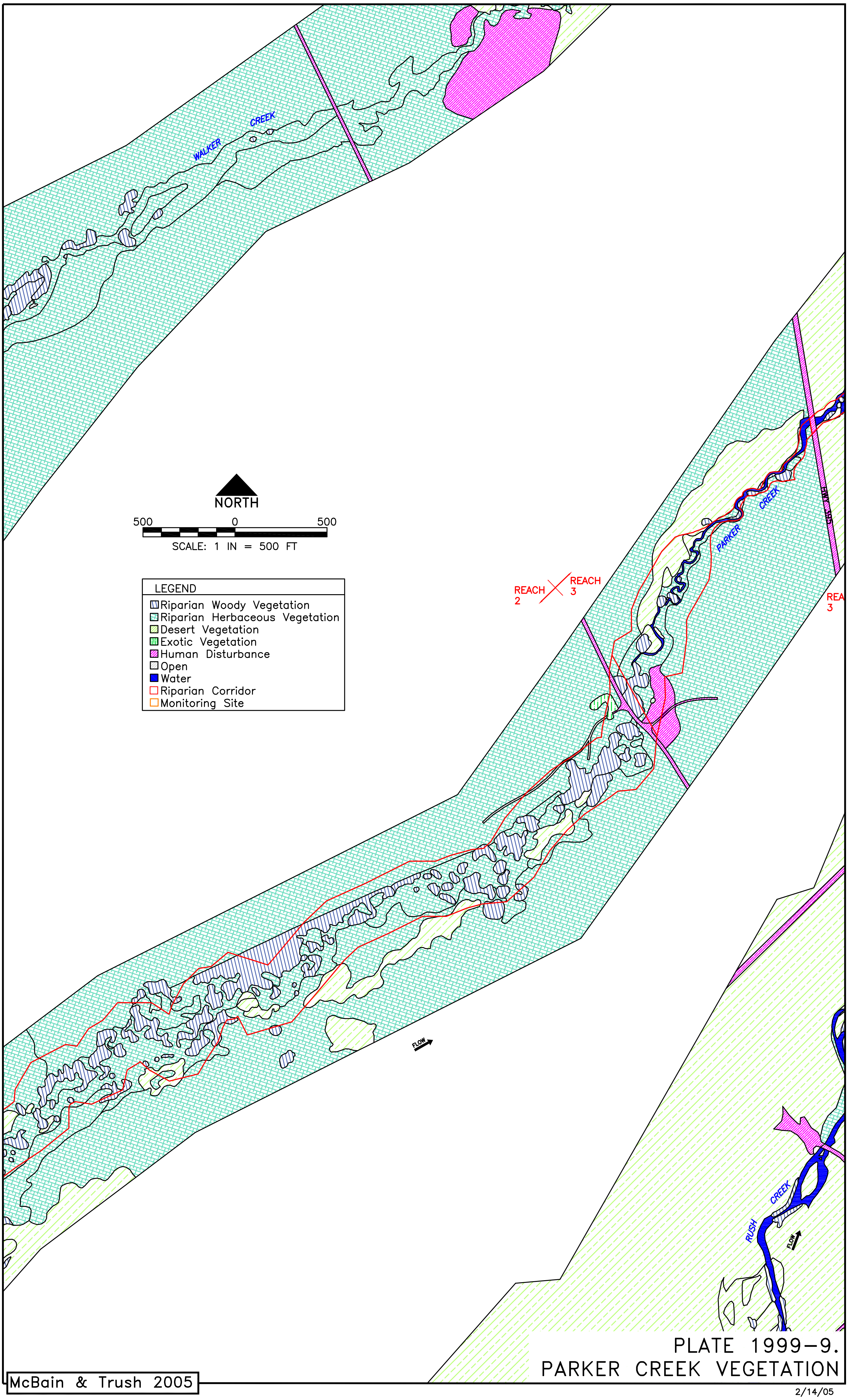
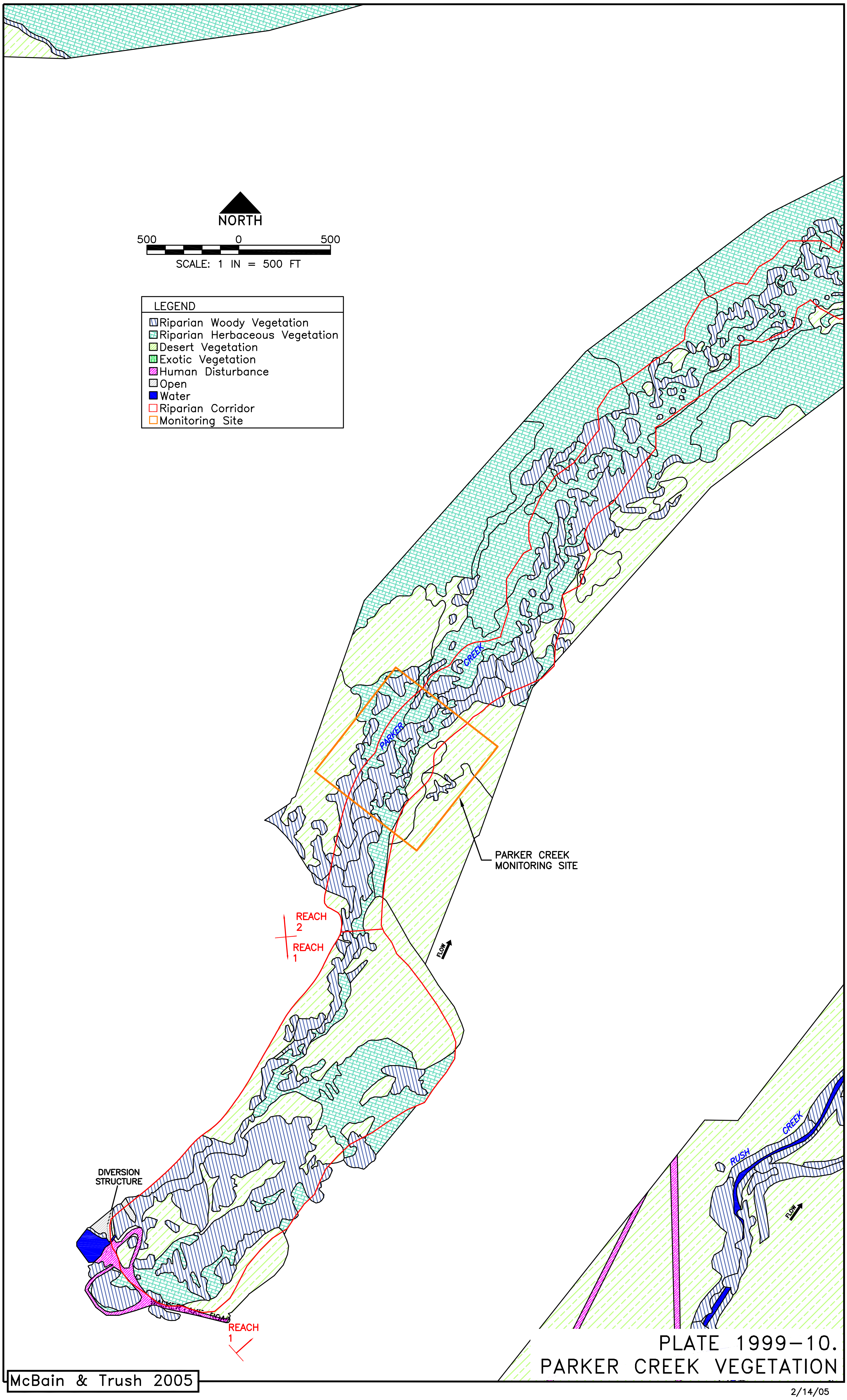


PLATE 1999–9.
PARKER CREEK VEGETATION

2/14/05

PLATE 1999-10.
PARKER CREEK VEGETATION



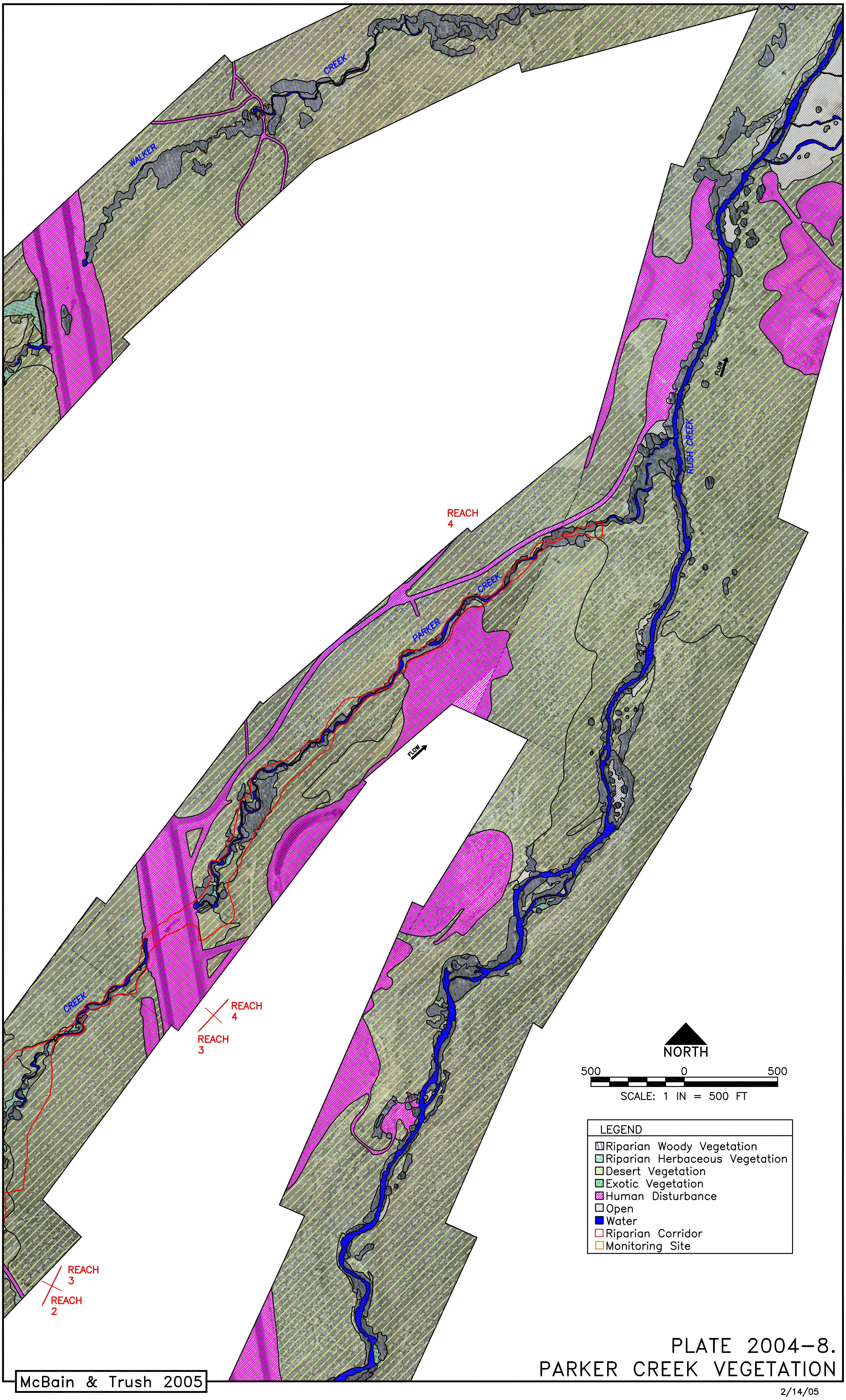


PLATE 2004–8.
PARKER CREEK VEGETATION

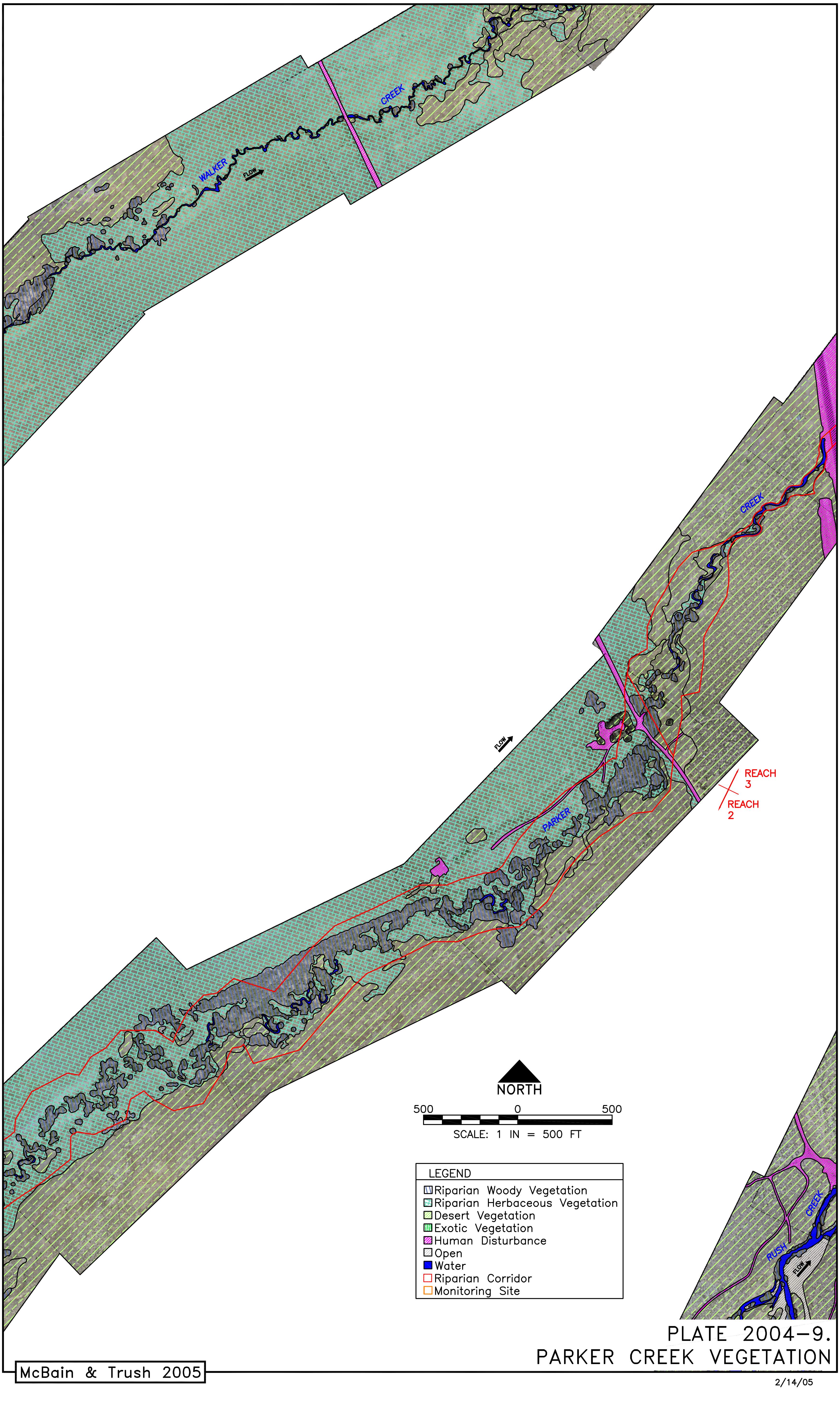


PLATE 2004–9.
PARKER CREEK VEGETATION

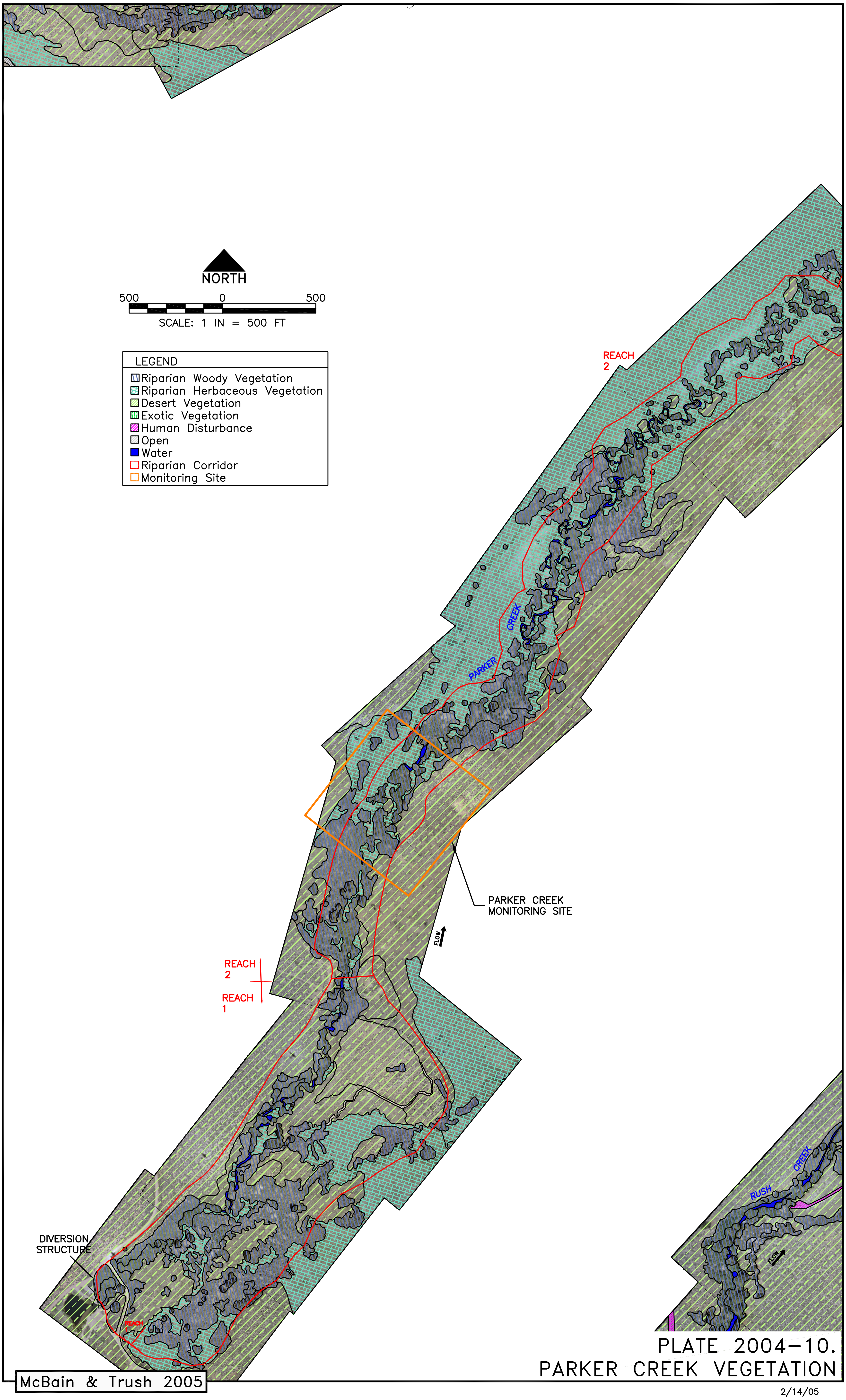


PLATE 2004–10.
PARKER CREEK VEGETATION
2/14/05

1929, 1999, AND 2004 WALKER CREEK RIPARIAN VEGETATION MAPS

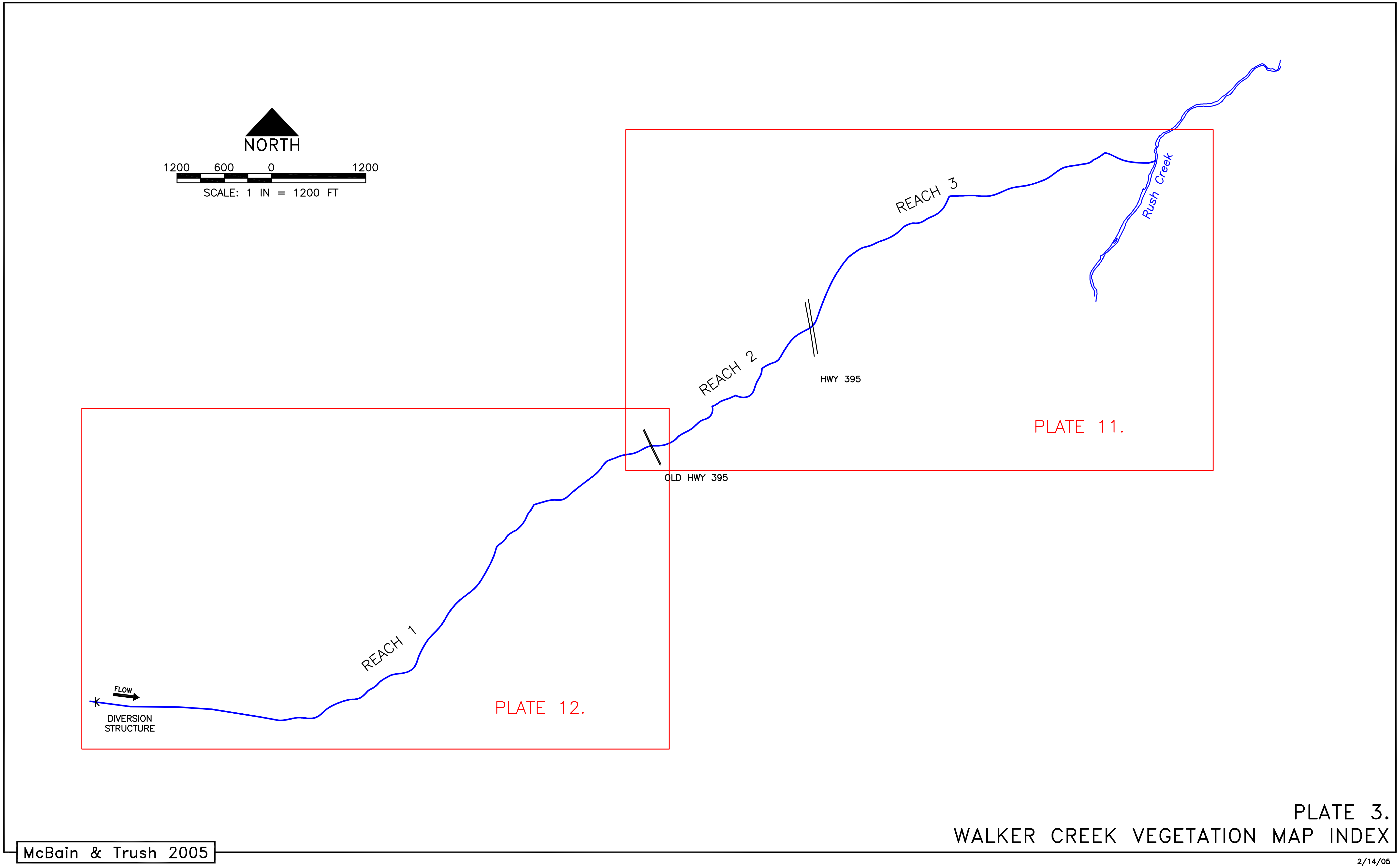


PLATE 3.
WALKER CREEK VEGETATION MAP INDEX

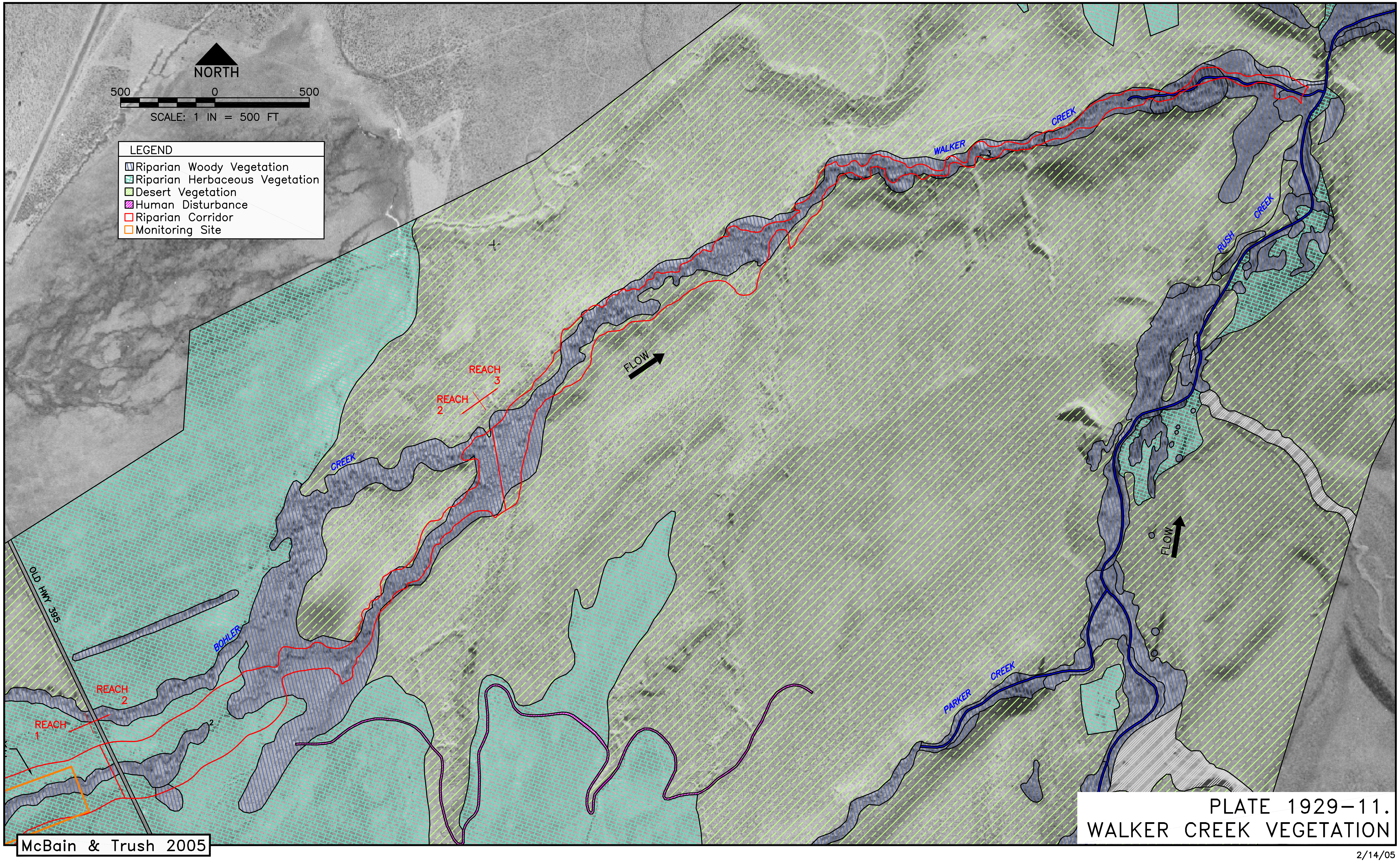


PLATE 1929–11.
WALKER CREEK VEGETATION

2/14/05

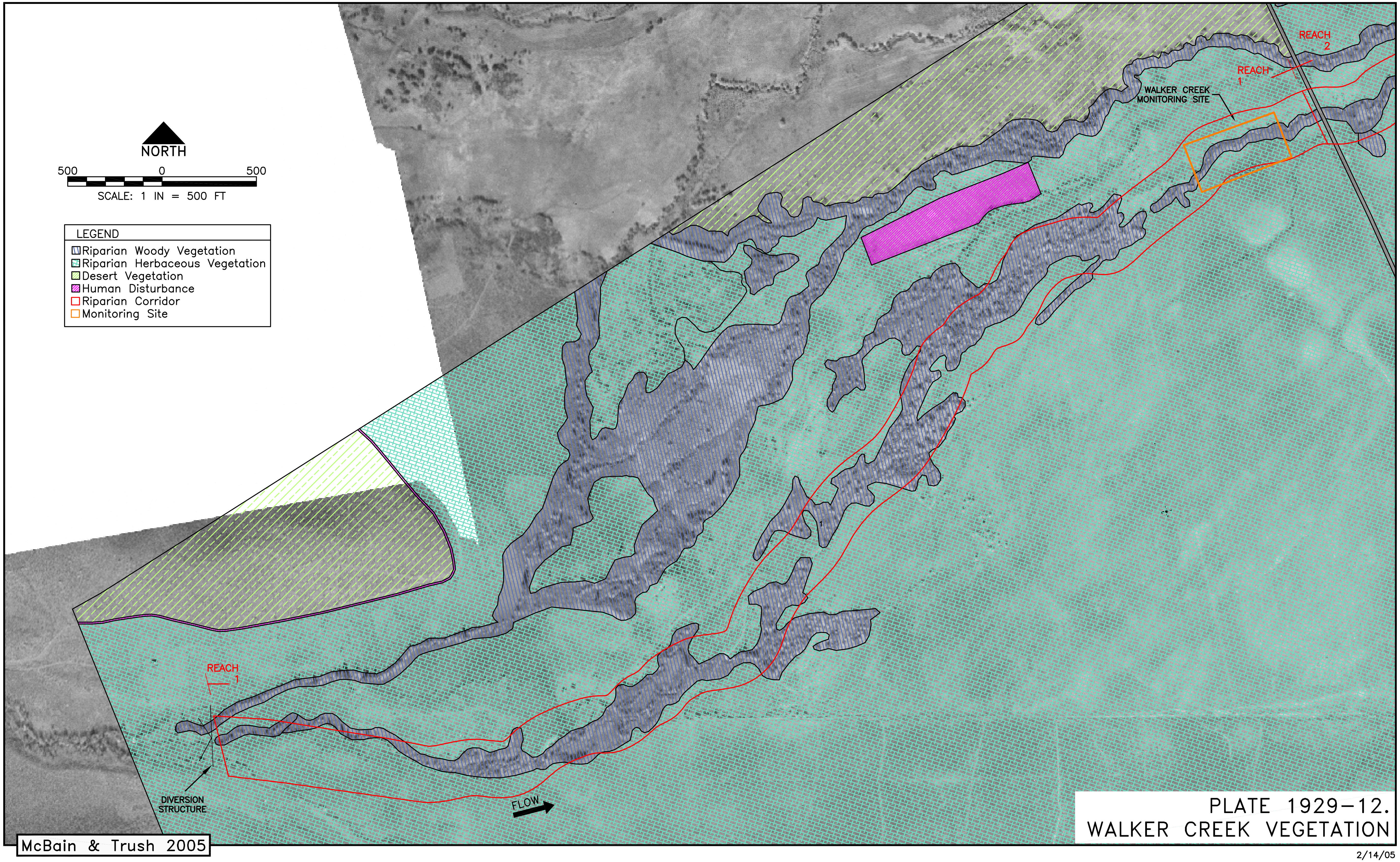


PLATE 1929-12.
WALKER CREEK VEGETATION

2/14/05

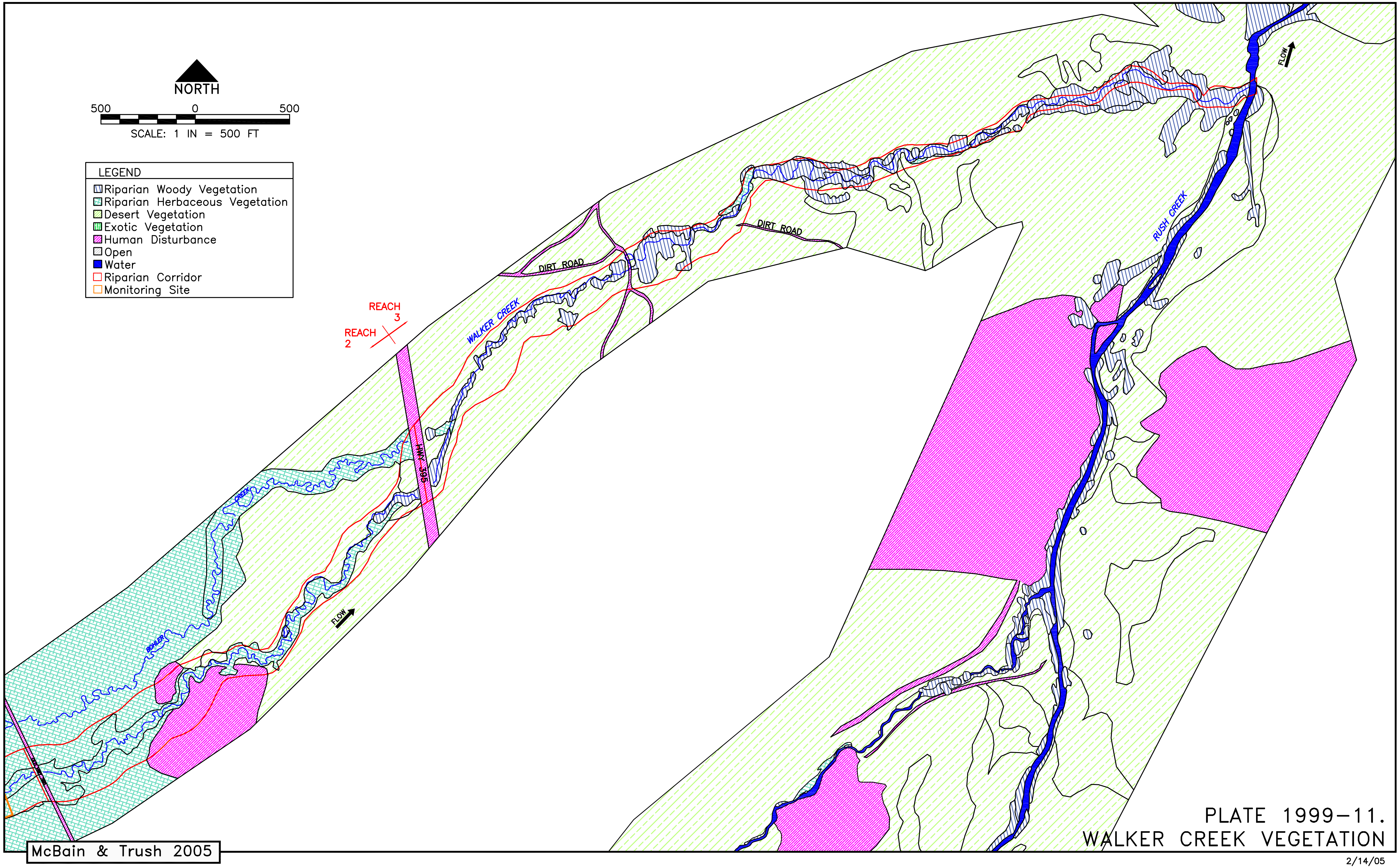


PLATE 1999–11.
WALKER CREEK VEGETATION

2/14/05

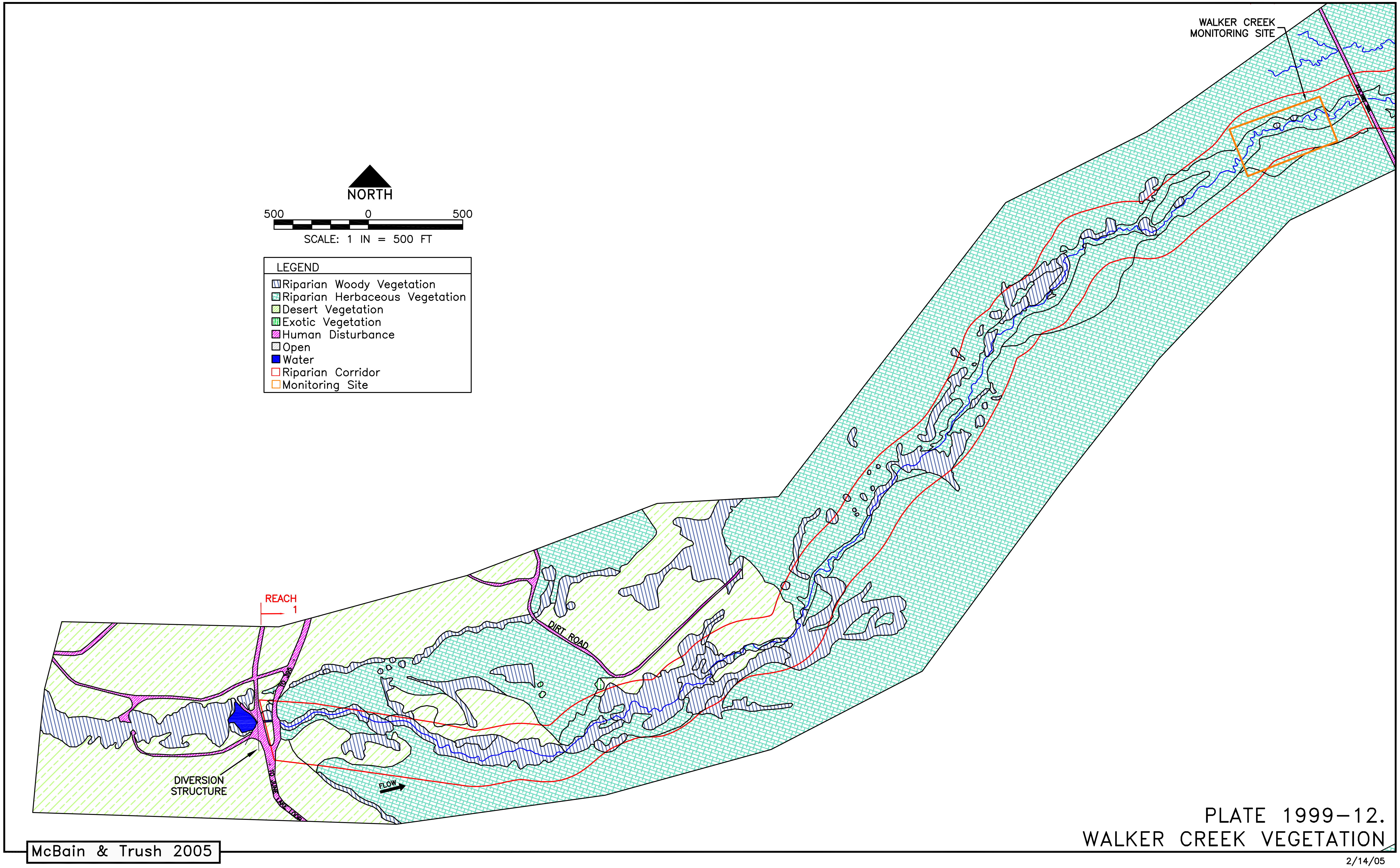


PLATE 1999–12.
WALKER CREEK VEGETATION

2/14/05

McBain & Trush 2005

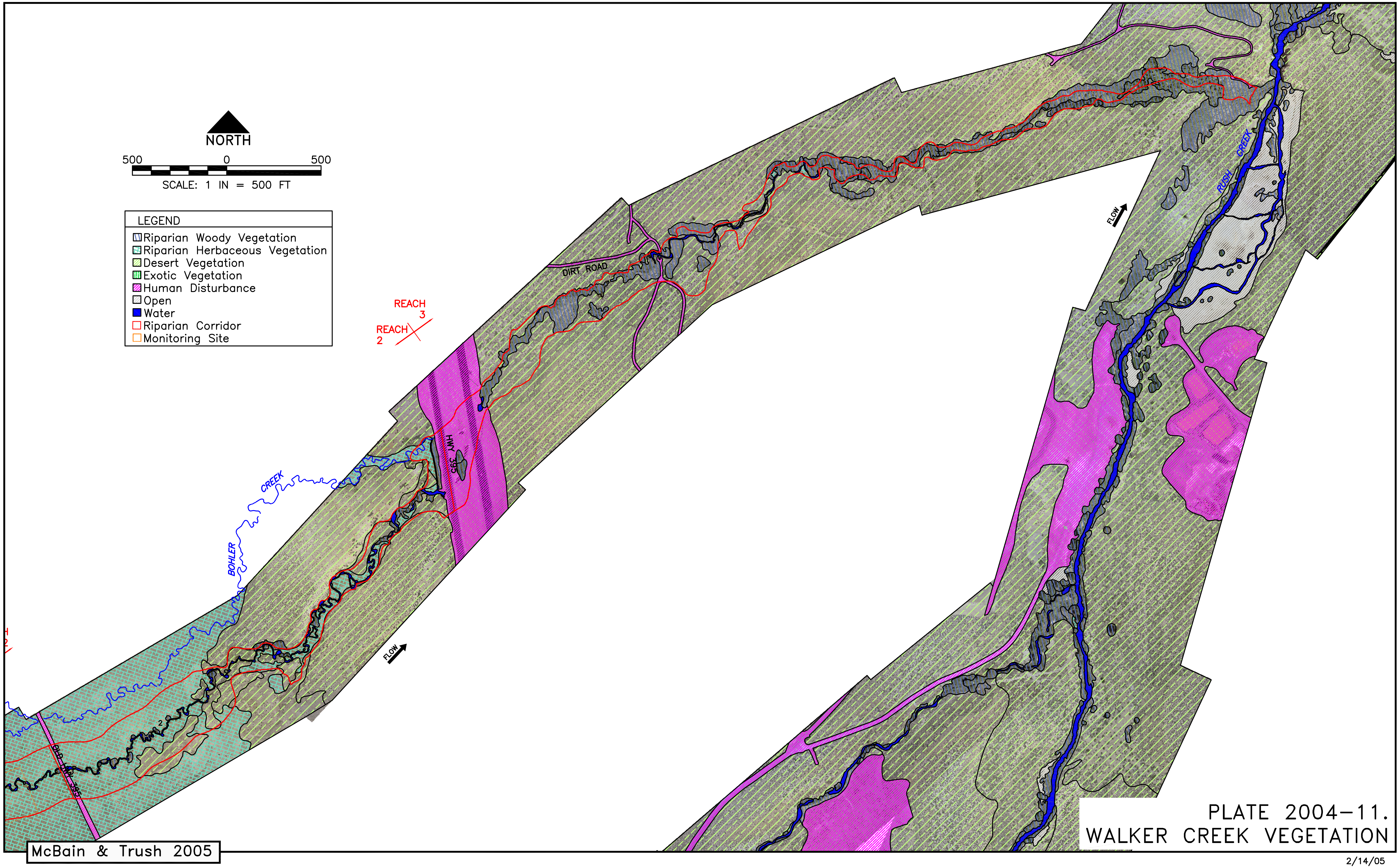


PLATE 2004-11.
WALKER CREEK VEGETATION

2/14/05

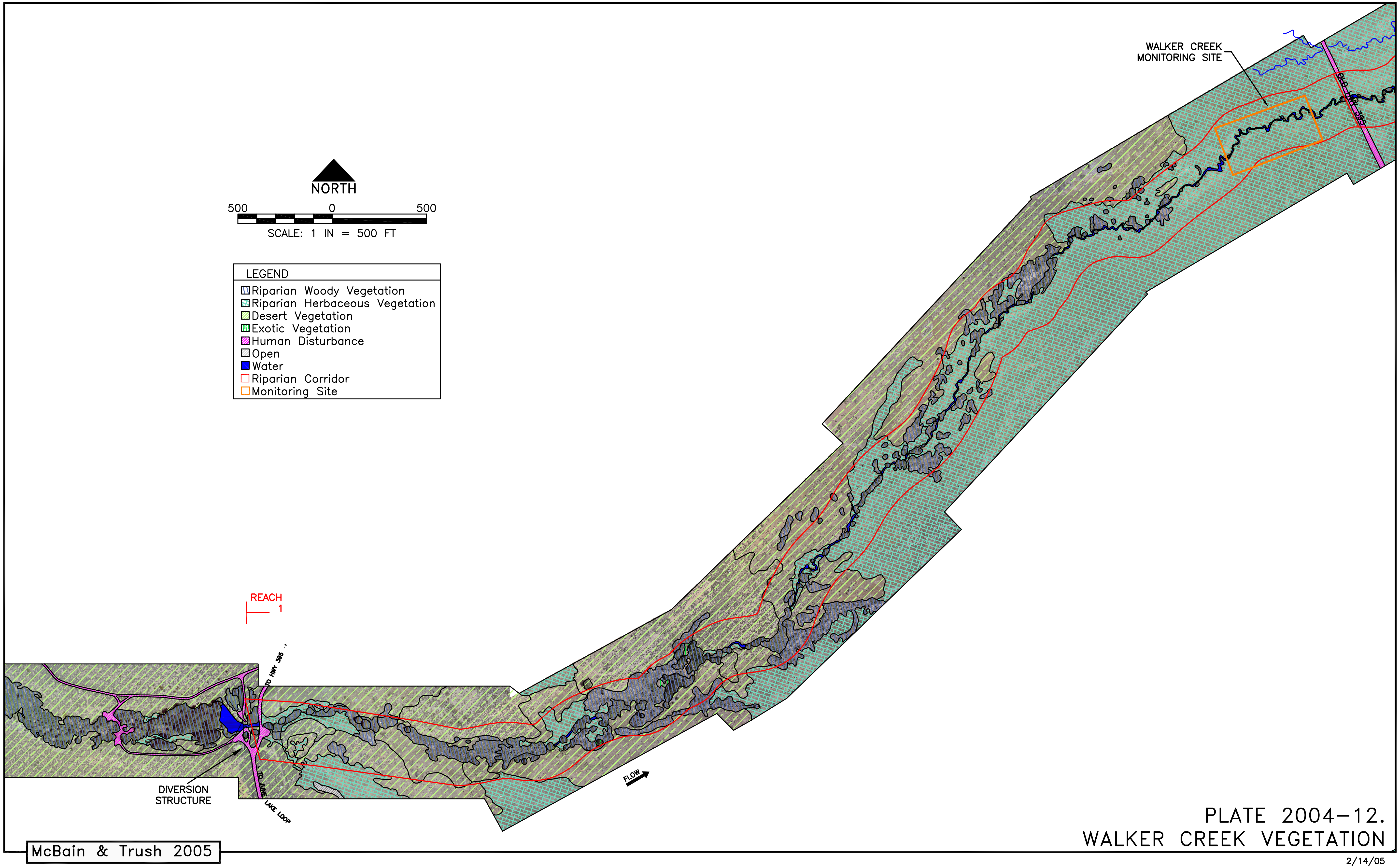


PLATE 2004-12.
WALKER CREEK VEGETATION

2/14/05

1929, 1999, AND 2004 LEE VINING CREEK RIPARIAN VEGETATION MAPS

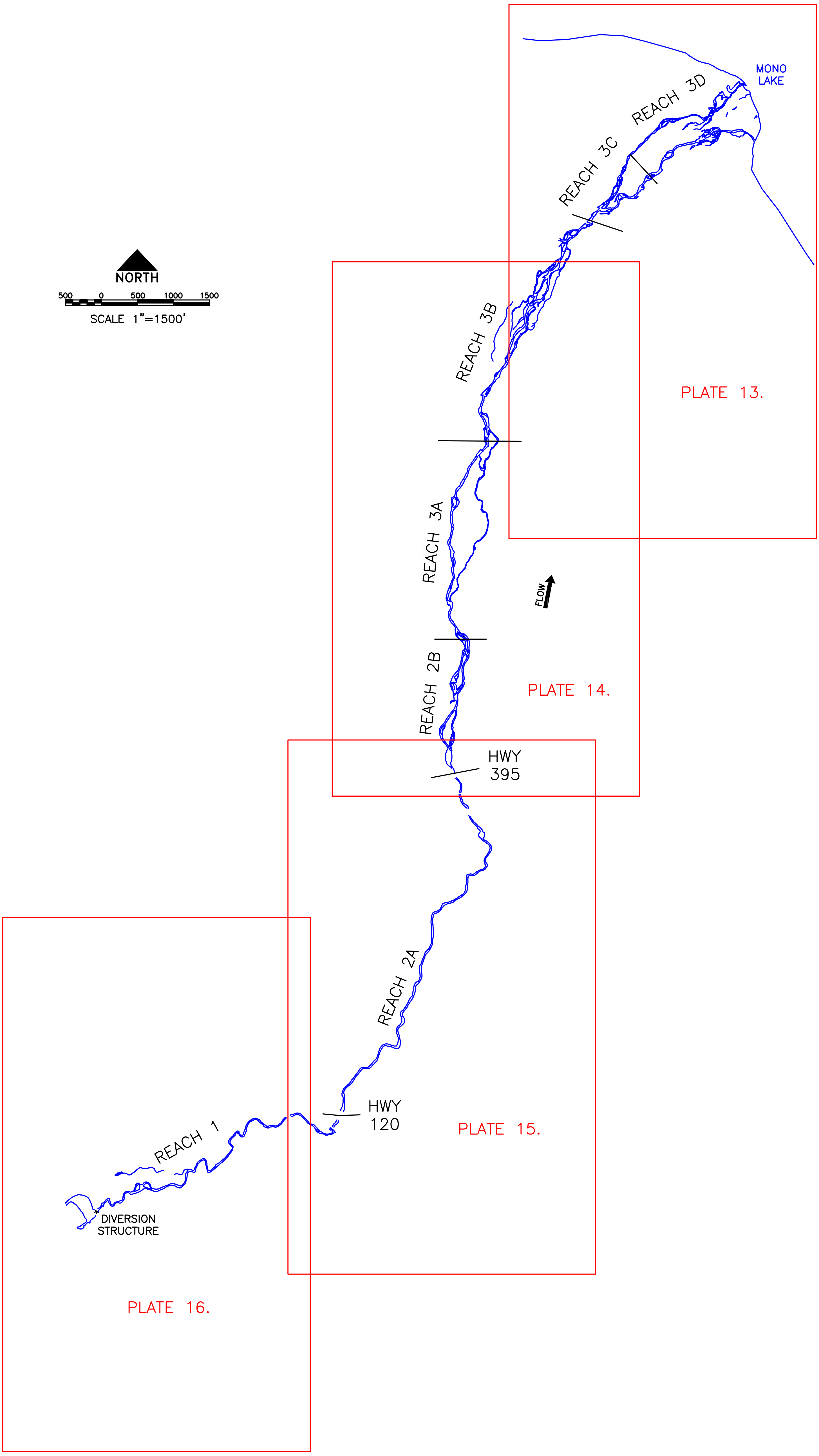


PLATE 4.
LEE VINING CREEK VEGETATION MAP INDEX

2/14/05

McBain & Trush 2005

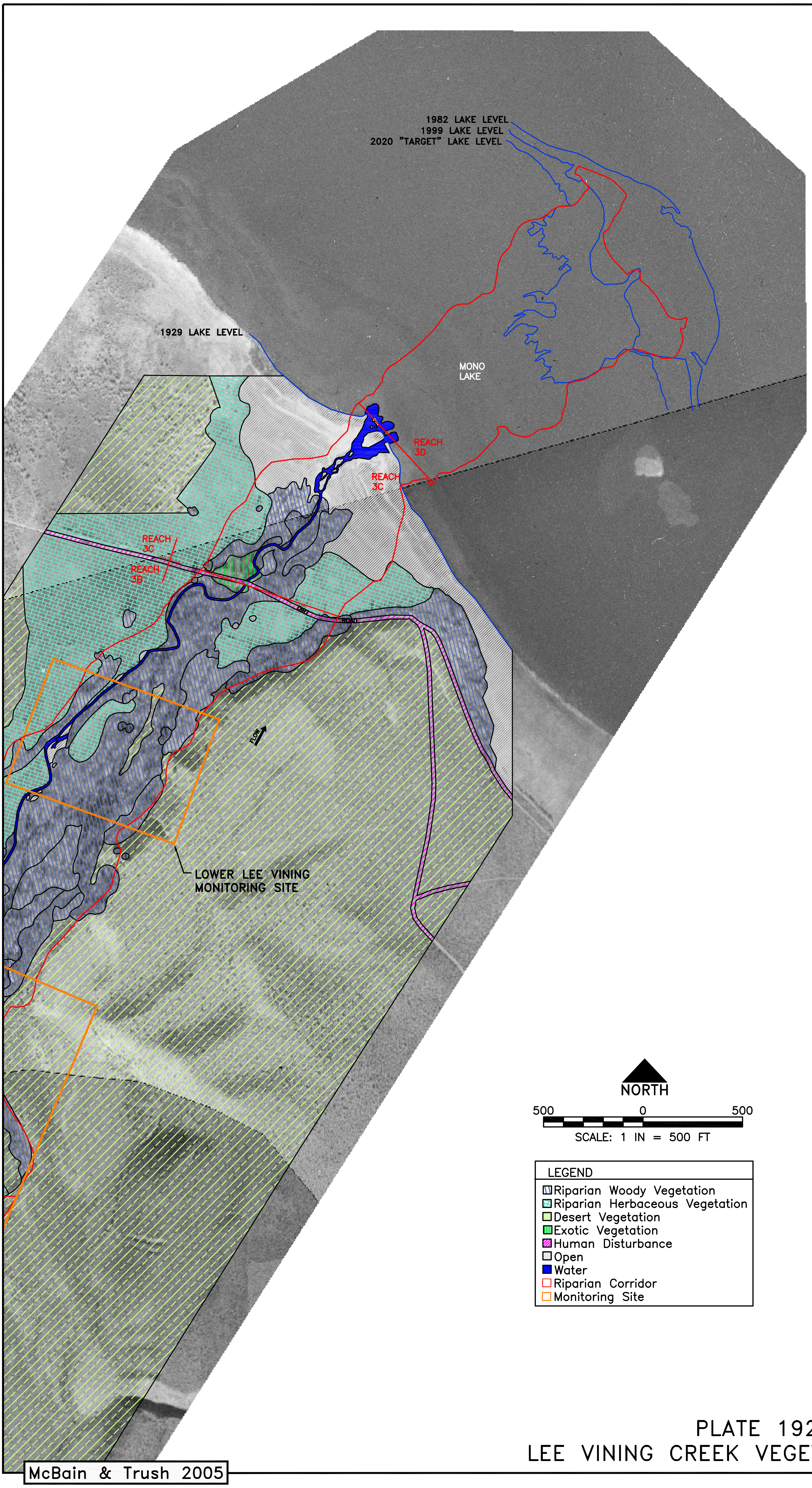


PLATE 1929–13.
LEE VINING CREEK VEGETATION

2/14/05

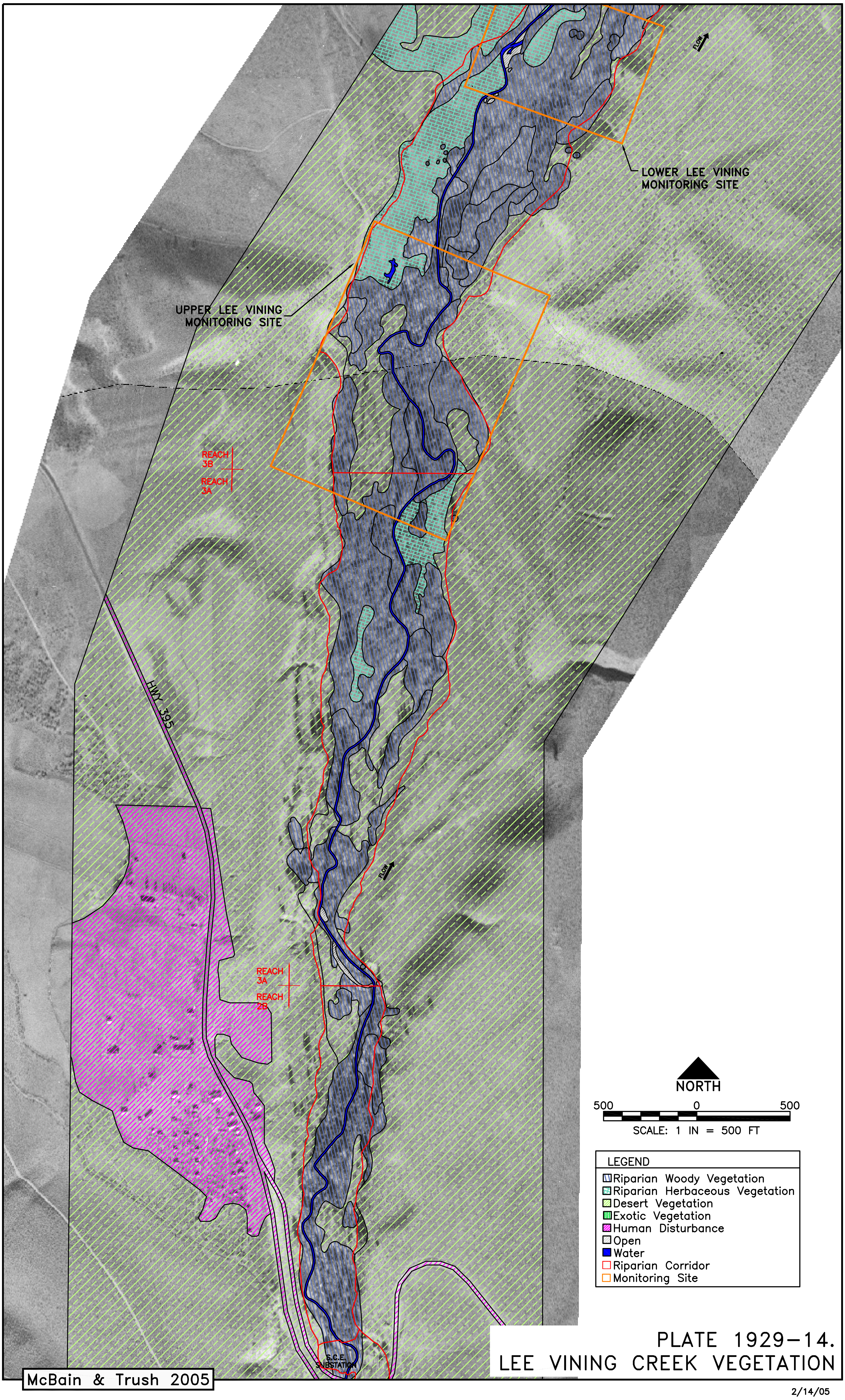


PLATE 1929-14.
LEE VINING CREEK VEGETATION

2/14/05

Lee Vining Creek Reach 2A

1929

Not Mapped

No PLATE 1929–15

PLATE 1929–15.
LEE VINING CREEK VEGETATION

McBain & Trush 2005

2/14/05

Lee Vining Creek Reach 1

1929

Not Mapped

No PLATE 1929-15

PLATE 1929-16.
LEE VINING CREEK VEGETATION

McBain & Trush 2005

2/14/05

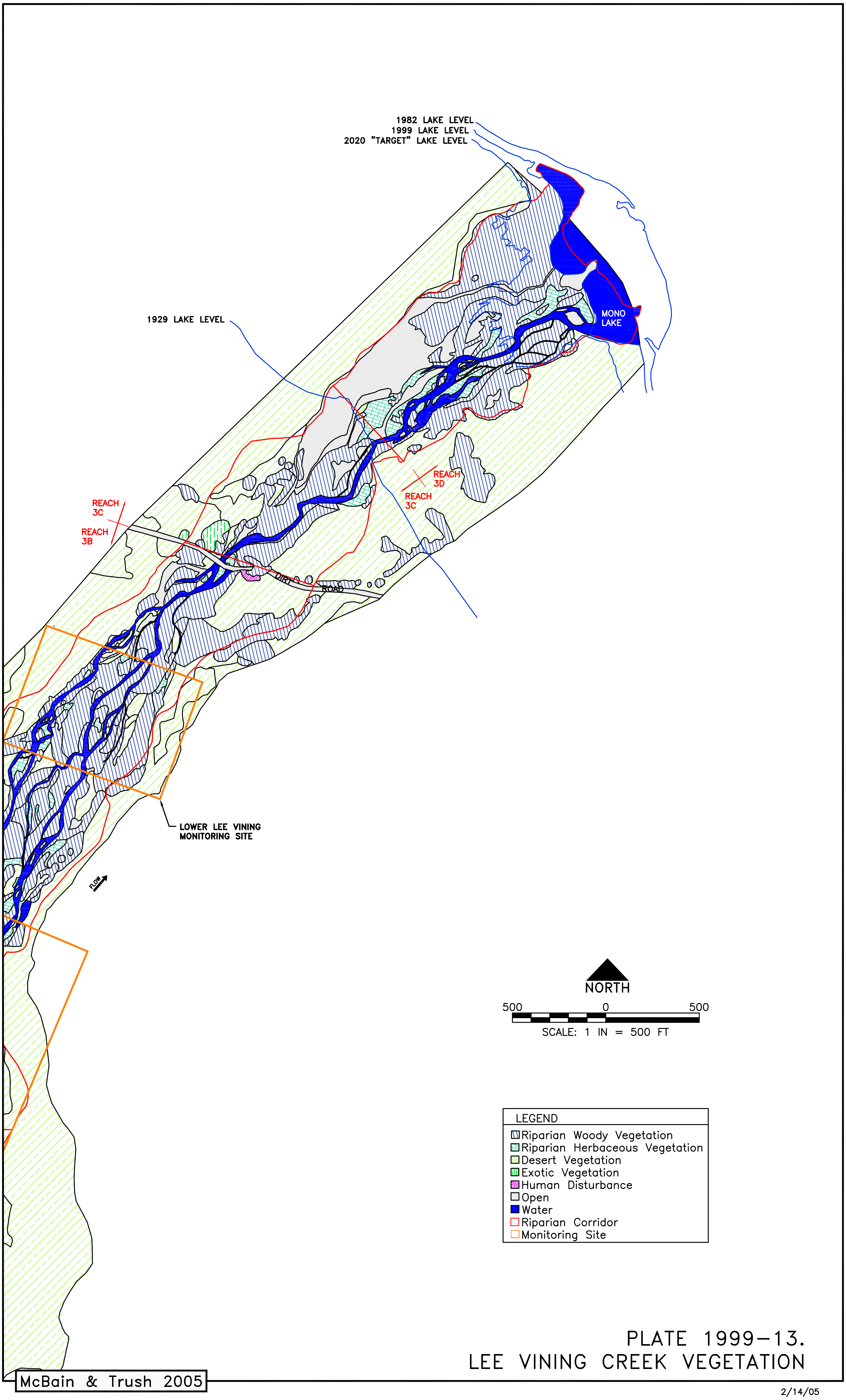


PLATE 1999–13.
LEE VINING CREEK VEGETATION

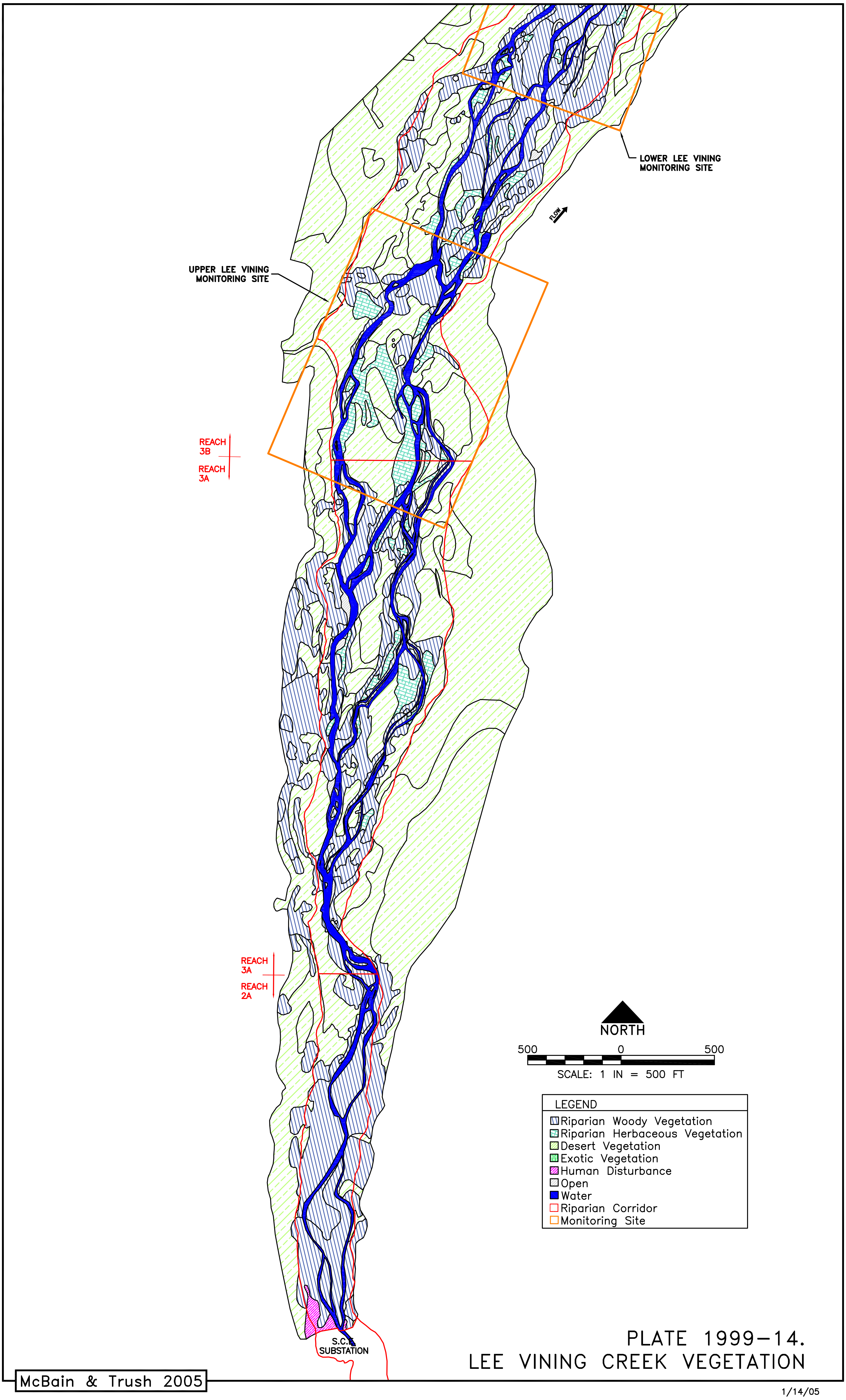


PLATE 1999–14.
LEE VINING CREEK VEGETATION

McBain & Trush 2005

1/14/05

Lee Vining Creek Reach 2A

1999

Not Mapped

No PLATE 1999–15

PLATE 1999–15.
LEE VINING CREEK VEGETATION

McBain & Trush 2005

2/14/05

Lee Vining Creek Reach 1

1999

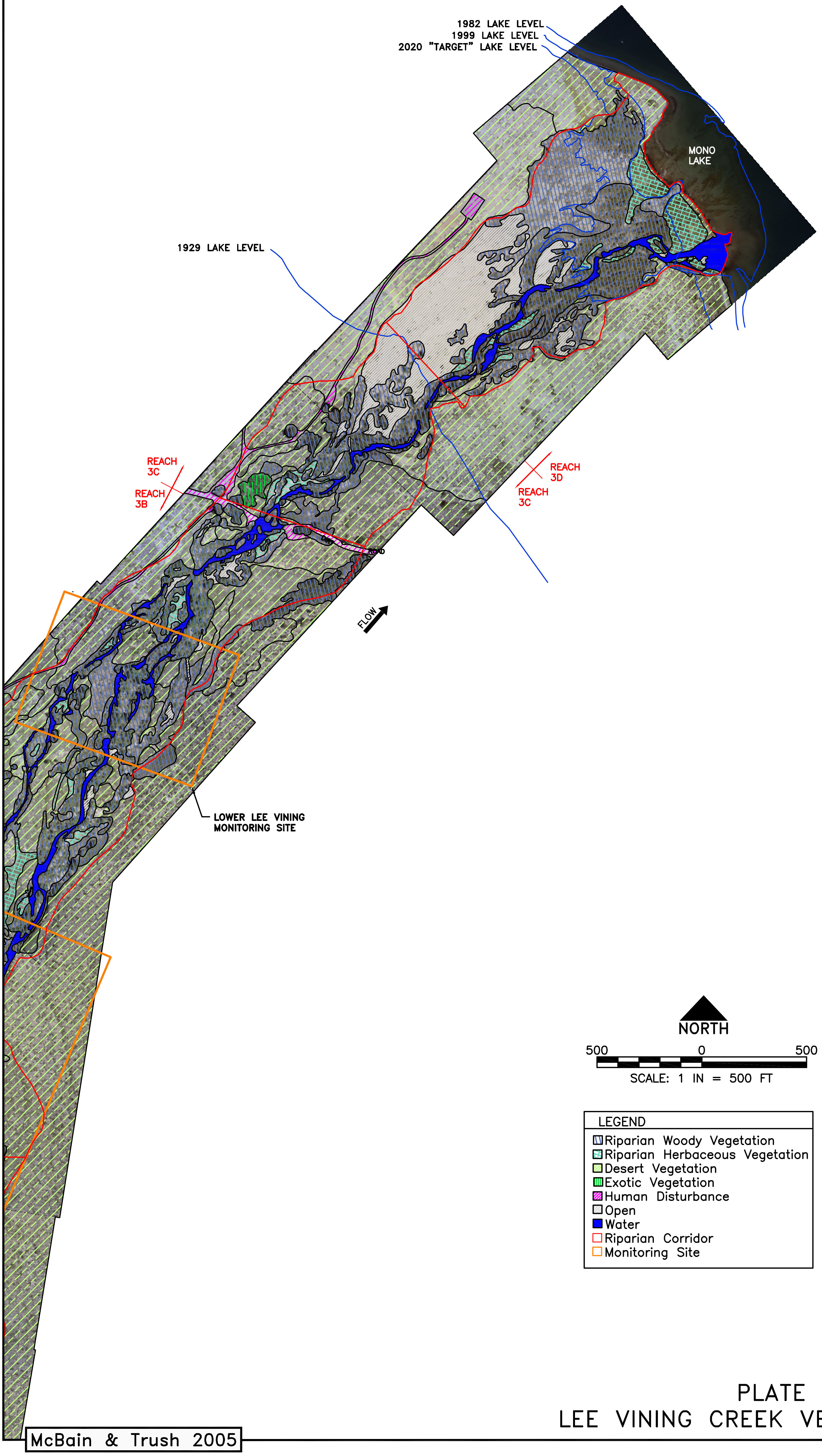
Not Mapped

No PLATE 1999–16

PLATE 1999–16.
LEE VINING CREEK VEGETATION

McBain & Trush 2005

2/14/05



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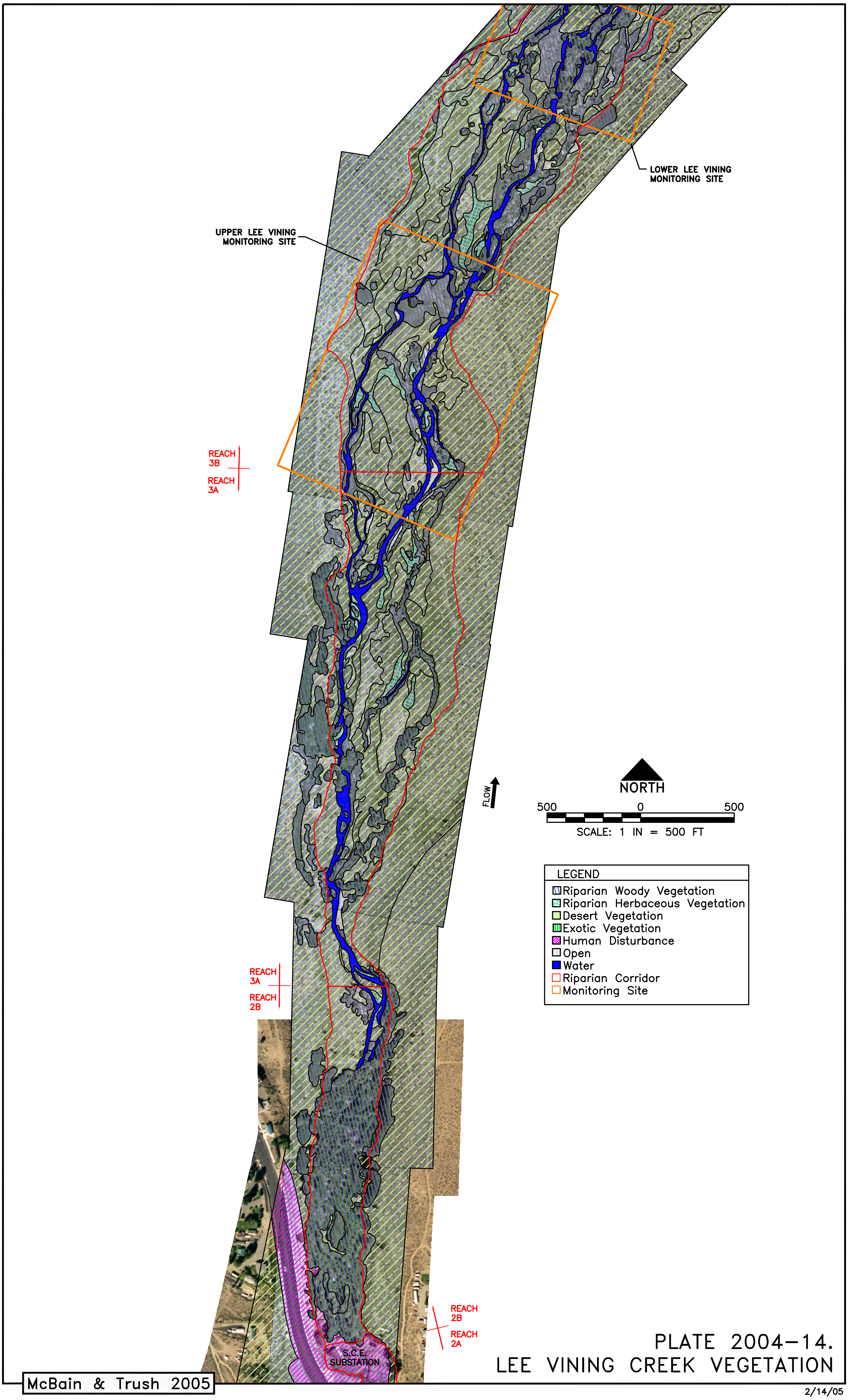
LEE VINING CREEK VEGETATION

McBain & Trush 2005

2/14/05



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LEE VINING CREEK VEGETATION

2/14/05

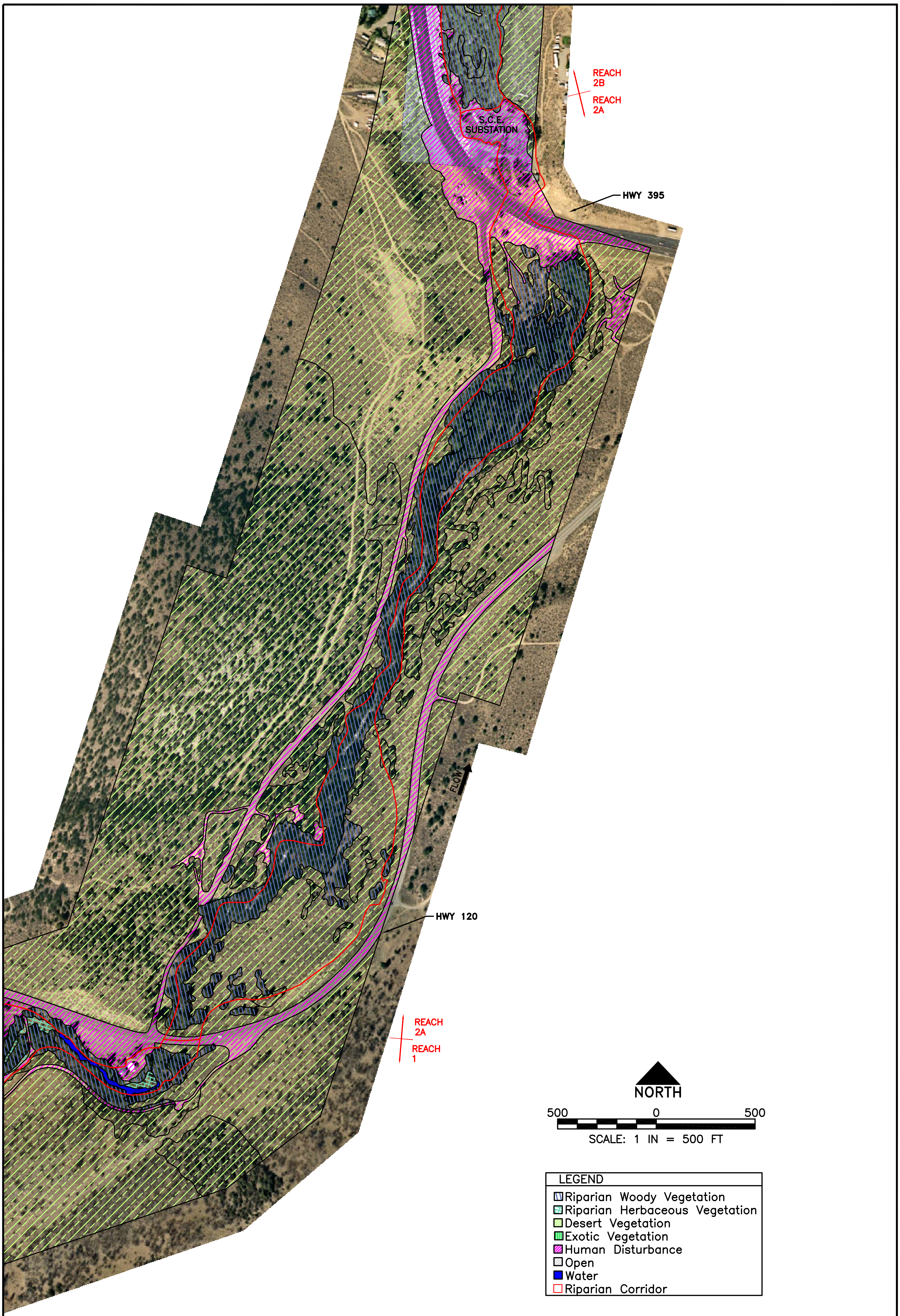


PLATE 2004–15.
LEE VINING CREEK VEGETATION

McBain & Trush 2005

2/14/05

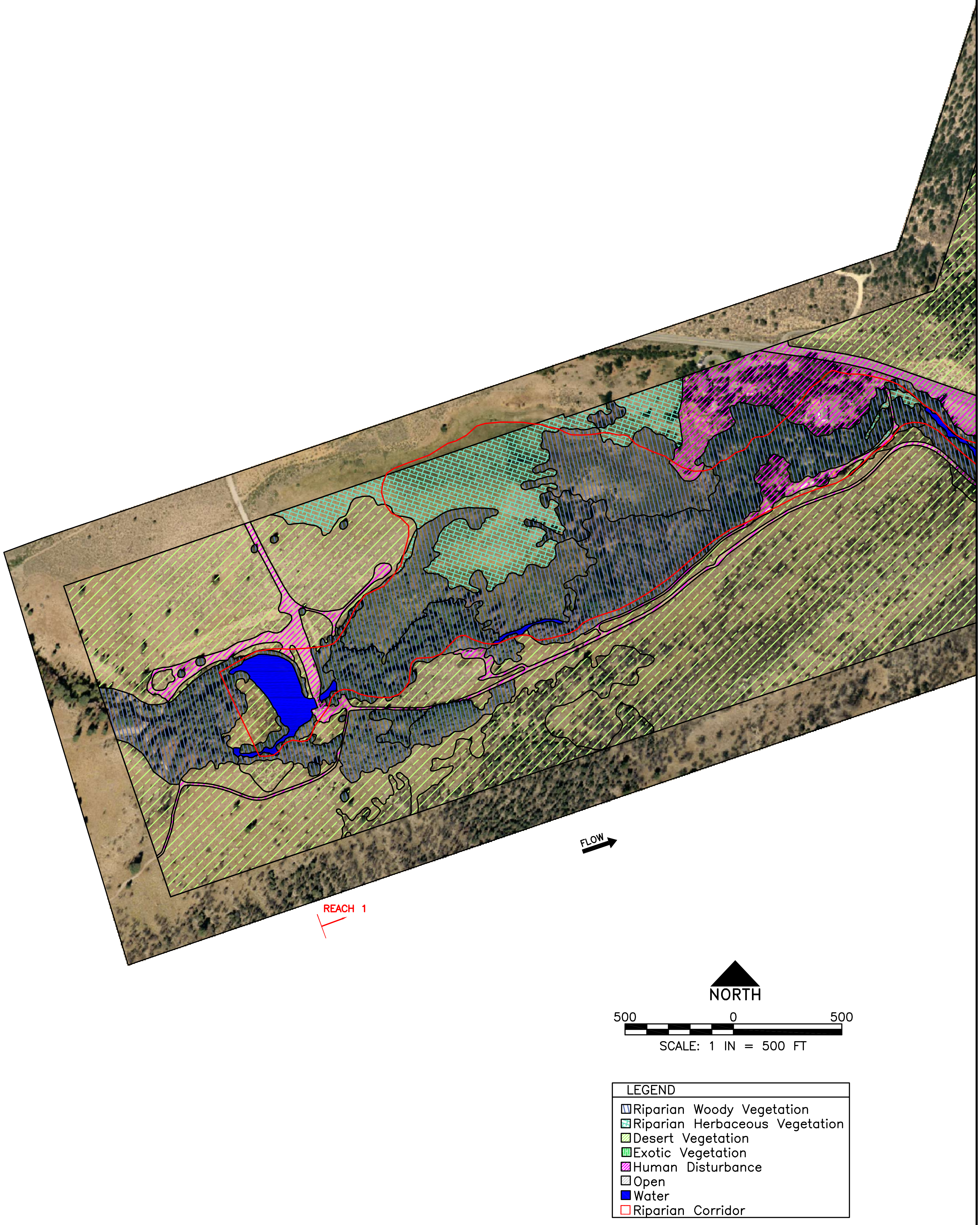
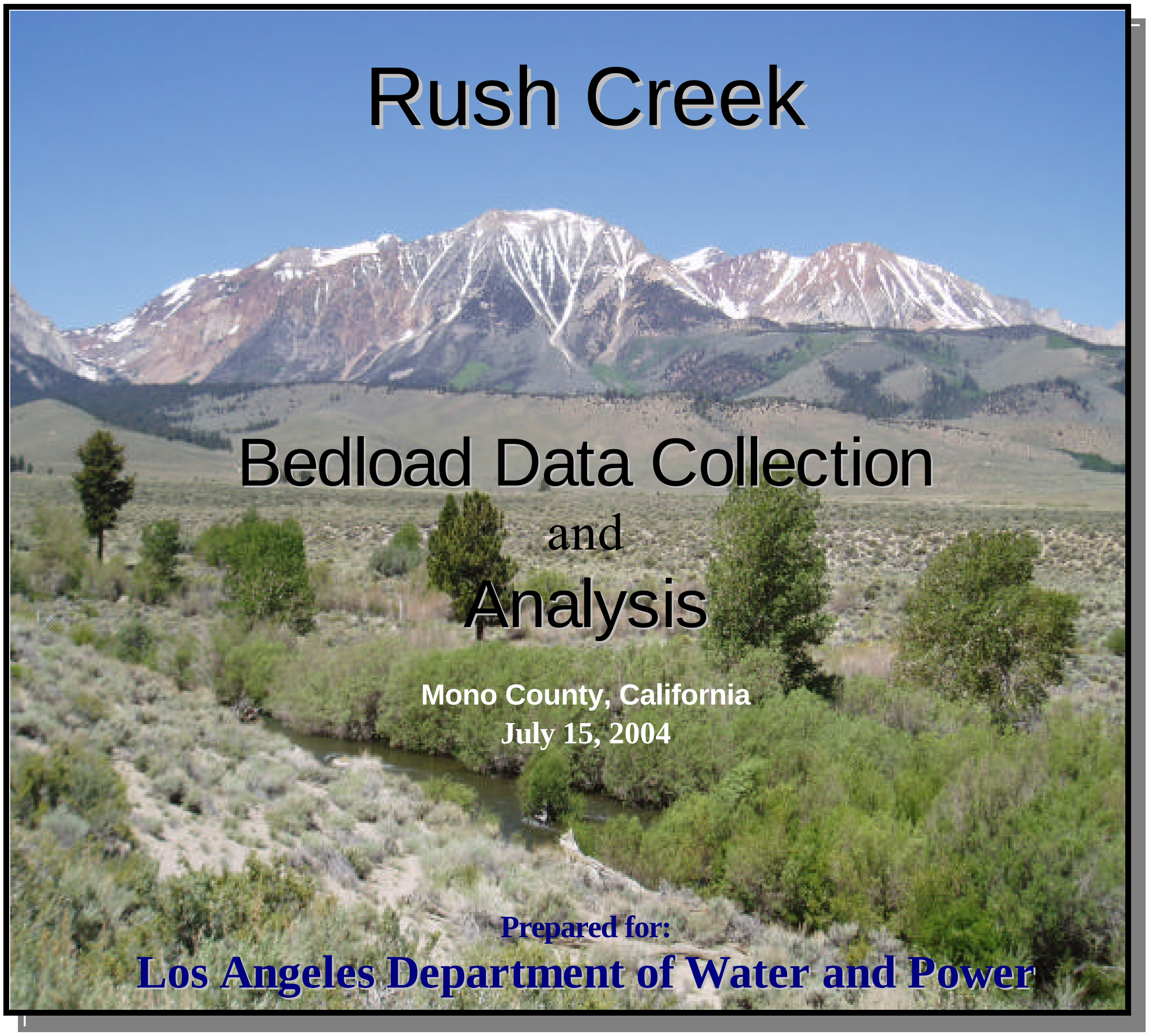


PLATE 2004–16.
LEE VINING CREEK VEGETATION

McBain & Trush 2005

2/14/05

Streamwise Bedload Report



Rush Creek

Bedload Data Collection
and
Analysis

Mono County, California
July 15, 2004

Prepared for:
Los Angeles Department of Water and Power

STREAMWISE
Stream Assessment and Restoration
Achieving restoration goals with natural
stream form, processes, and function.

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CONTENTS

Executive Summary

The Los Angeles Department of Water and Power (LADWP) controls flows in Lower Rush Creek, Mono County, California, by scheduling releases from Grant Lake Dam through the return ditch to the creek. In spring of 2004 the State Water Resources Control Board encouraged LADWP to flow test the newly refurbished return ditch, requiring the development of a "test" hydrograph. The "test" hydrograph and resulting controlled flood on Lower Rush Creek provided the opportunity to monitor the effects of the hydrograph on some of the Lower Rush Creek stream functions. One stream function monitored was bed material mobility. Bed material mobility is beneficial to a stream system because it refreshes the channel bed substrate critical to spawning trout, avails entrained nutrients and sediment to building point bars and floodplains, and maintains the geomorphic character (width, depth, sinuosity) of the channel.

StreamWise, a stream restoration and assessment company from Mt. Shasta, California, was contacted by LADWP to monitor bed material mobility through the rising limb of the hydrograph and estimate several important features for Rush Creek. These features include determination of the point when the important bed material began to mobilize (point of incipient motion); the size class distribution of the bed material; and create a rating curve for flow versus bed load transport volume.

Results show that although it is difficult to determine exactly when the point of incipient mobility occurs as it happens in a continuum, data suggest that it occurs somewhere between 275 and 300 cfs. The size class distribution shows that D_{31} is 10 mm, D_{50} is 30 mm, and D_{80} is 80 mm. Finally, a series of bedload to discharge rating curves were generated for the three different monitoring locations and are presented in the text.

In addition, StreamWise was asked to observe daily changes in Rush Creek noting the behavior of the stream channel and determine at what point, or flow rate, important stream functions occurred in Rush Creek in 2004. These points included bankfull conditions, floodplain inundation, side channel flow, and large woody debris mobilization. Through observation, StreamWise determined that bankfull and floodplain inundation and side channel flow all occurred between 275 and 300 cfs, while large woody debris mobilization occurred around 350 cfs.

This report minimizes the background discussion of Setting and Background, as these topics are well documented and additional detail would not offer further support of the report content. The sediment data collection and analysis were done using standard methods and careful measurements. There is no question that further study would shed additional light on the subject and that more stringent methodology may help refine the estimates to some degree. However, we feel the data presented here is based on good science and offers valuable insights into the characteristics of bedload sediment transport in Rush Creek.

I. Setting

Rush Creek originates from eastern slopes of the Sierra Nevada Mountain Range above the June Lake area, and passes through a series of high-altitude lakes before flowing through the broad glacial moraines and terraces above Mono Lake. The Los Angeles Department of Water and Power (LADWP) diverts a portion of the Rush Creek flow collected at Grant Lake. Water is also released into Rush Creek downstream of Grant Lake for purposes of maintaining a viable fishery and stream ecosystem.

II. Background

LADWP was encouraged by the State Water Resources Control Board (SWRCB) to "flow test" the Rush Creek return ditch, their water conveyance facility used to supply water to lower Rush Creek from Grant Lake Reservoir. The requirements of this flow test were to: 1) test the ability of the recently upgraded return ditch to pass 380 cfs; 2) use approximately 7,000 acre-feet of water for the peak flow operation (above that which is required for daily base flows of 47 cfs); and 3) provide the flows to lower Rush Creek in such a way as to provide the maximum possible benefit to the fishery and stream ecosystem. LADWP proposed an experimental release schedule for June of 2004 to meet the requirements stated above. Because of the requirements stated, the experimental release schedule was different than that which is required by the SWRCB. This provided LADWP with the opportunity to study channel and floodplain response to an altered flow release. Part of this study involves further investigation into the movement of bedload sediment. When arranging for the release schedule, consideration was given to the duration of flood flow volume and ramping rates on the ascending and descending limbs of the hydrograph.

Considerable study has already been accomplished along Rush Creek to document the biological and physical condition of the stream. For LADWP, these studies were primarily conducted by:

1. McBain & Trush, an environmental consulting firm based in Arcata, California;
2. Chris Hunter, a fisheries specialist from Montana; and
3. LADWP personnel.

McBain & Trush conducted additional data collection during the recent June 2004 release.

StreamWise was contacted by LADWP staff to assist with bedload collection protocols using alternative methods to assist in identifying the nature and volume of bedload movement during such discharges. StreamWise was selected to conduct the data collection due to knowledge of streams in various stages of restoration, and their prior experience with bedload data collection in high-velocity streams.

III. Objectives

Overall Objectives

In addition to testing the Rush Creek return ditch, the June 2004 Rush Creek release was intended to meet the following objectives:

- Provide a large peak spring snowmelt release to Lower Rush Creek;
- Provide ascending and descending limb ramping rates that are beneficial to the fishery and riparian ecosystem;
- Inundate sections of the floodplain recently graded to allow for flood access;
- Facilitate the vegetative recovery of the riparian ecosystem;
- Afford the opportunity to document channel response to the release;
- Provide the opportunity to collect data for a host of environmental disciplines during a controlled and predictable release schedule; and
- Allow for a series of sediment measurements as flows increase to gain better understanding of channel dynamics.

StreamWise was asked to focus on the final objective, analysis of the channel dynamics during the release.

Study Objectives

The study objectives of the investigation were divided into four main categories:

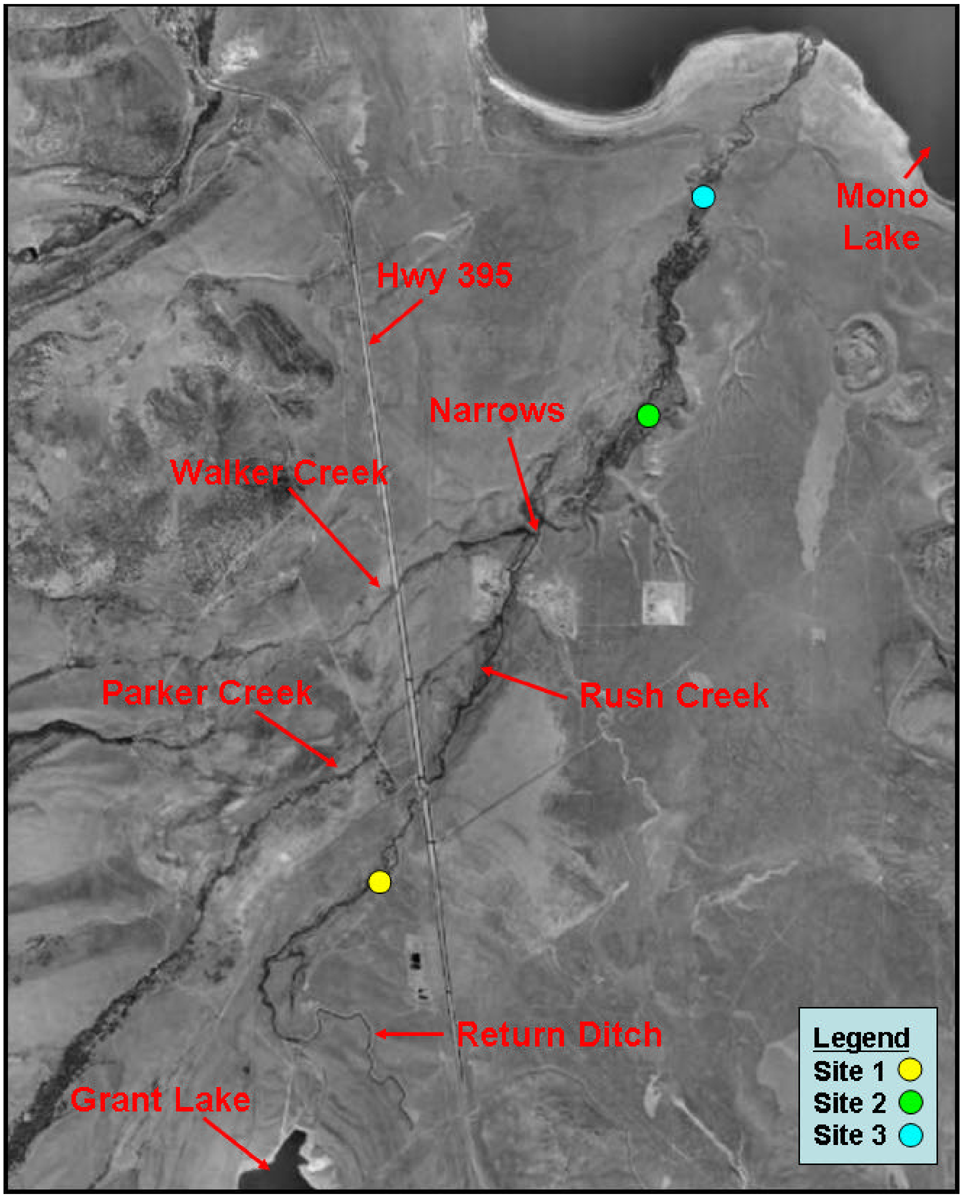
- Point of incipient movement of bedload;
- Size distribution of bedload samples;
- Bedload volume estimates; and
- Points of observed stream functions, including
    - Bankfull observations;
    - Floodplain inundation and side channel flow; and
    - Large woody debris (LWD) mobilization.

Previous work by McBain & Trush (McBain & Trush, 2000; McBain & Trush, 2001) has provided a good foundation. Some of the data collection and analyses by McBain & Trush have performed regarding channel dynamics include painted rock movement studies and scour core studies. The painted rock studies measure rock movements after flood events, and conclusions can then be drawn regarding flow levels at which the bed is mobilized and what percentage of the bed width becomes mobile somewhere below or at peak flow levels. The scour core experiments, pits filled with bright rock, help approximate scour and fill depth after peak events. Other experiments are ongoing that measure floodplain deposition, groundwater exchange, and other topics dealing with the geomorphology of the stream ecosystem.

IV. Methods

Scheduling of the sample collection follows a top to bottom order of the three sampling stations. As the release changes were made at 8:00 am each morning, it was necessary to allow for each new release volume to equilibrate to the sample site before initiating sampling protocol. Figure 1 below shows the locations of the three sites chosen for monitoring. It was estimated that starting at 12:00 noon or later at the uppermost sampling site, Site 1, would afford adequate equilibration. The time required for sampling at Site 1 allowed flows to propagate and equalize downstream prior to initiating sampling at Sites 2 and 3. Sampling at highest flows required considerably more time at each station due to the necessity of using boat equipment. Data entry and sieve analysis was conducted in the mornings before data collection ensued.

Figure 1 – Rush Creek Monitoring Sites



The protocols outlined below are a reasonable and feasible method to collect the data necessary to meet the objectives of the LADWP. It is our intention to produce reliable data, using efficient and responsible methods that will compliment the current efforts to restore the health and function of the Rush Creek ecosystem.

Protocol for Bedload Sediment Collection

The basic data collection techniques are contained in the USGS Open file Report 86-531, Field Methods for Measurement of Fluvial Sediment. Although rich in detail regarding specifications for measurement, much is left to the practitioner regarding the means of maintaining the proper position in mid-stream during large release events.

According to the USGS report, bedload should be sampled using the Single Equal Width Increment method. Using this method, bedload material is collected in approximately 20 equal increments across a stream. An equal time interval is assigned to each cell. Once across the channel, a return trip is made, collecting another 20 cells at an equal time interval. These 40 sample locations represent a composite collection of a portion of the total bedload for the stream at a given flow volume with the duration of the sample interval.

The width of the sampler orifice is multiplied by the number of samples to give the total sampled width. Dividing stream width by sampled width gives a ratio required to adjust the sample volume to match total estimated bedload transport over the interval. To convert this sediment volume to a more useful figure, multiply the interval by the appropriate factor to yield volume by weight per day (or hour). This sampling method was developed by William Emmett, USGS, and has been calibrated in the field and determined to be statistically accurate (*Leopold, 1994*).

For Rush Creek, a six inch Helley-Smith Model 8025 handheld bedload sampler (152.4 mm) was used to capture the large bedload material that often exceeds 100 mm (McBain & Trush, 2000). By using the larger sampler, a greater proportion of the channel bed was sampled. If the channel width averages approximately 30 feet, 40, six inch samples would yield sampling of 2/3 of the streambed. This is in excess of the needed sample proportion. Using the large sampler in a narrow streambed allows us to sample a more appropriate proportion of the total bed width. For this reason, StreamWise collected a single pass of 20 samples at each transect. This represents approximately 1/3 of the channel width and is considered representative of the condition at each site.

The challenge lies in sampling for the given interval without the sample-taker being entrained in the flow. Initial attempts indicated that wading the channel at higher flow volumes was ill advised. A cable marked in 1.5 foot increments was placed across two metal stakes. During the peak release schedule, an inflatable boat was affixed to the cable and the sampling procedure managed from the boat. Once the samples were taken, they were transferred to plastic containers and labeled with the appropriate data for future analysis.

Protocol for Sieve Analysis

To accurately portray the bedload transport conditions, some samples were passed through a stack of sieves and each size class weighed to allow a size distribution to be plotted. Site #3 was analyzed over the full flow range to offer insights into differences in incipient movement for various sizes of bedload. The total weight of a sample can be converted, as mentioned above, into a volume per day estimate. More importantly, such measurements allow for a regression curve to be plotted that estimates bedload volume versus flow release. This can be useful in future estimates of total work accomplished by the stream in a given release duration. While error is inherent with such estimates, the resulting data offers considerable insight into potential changes in channel and floodplain morphology with variable peak discharge regimes. The bedload measurement data from the June release is expected to compliment existing measurements of incipient movement by offering additional understanding of bedload transport conditions.

V. Results

The study results are divided into same four main categories:

- Point of incipient movement of bedload;
- Size distribution of bedload samples;
- Bedload volume estimates; and
- Points of observed stream functions, including
  - Bankfull observations;
  - Floodplain inundation and side channel flow; and
  - Large woody debris (LWD) mobilization.

As mentioned above, LADWP would make the flow release changes at 8 AM. As these flow changes would propagate downstream, flows would decrease due to bank storage losses, and increase from tributary inputs (Parker and Walker Creeks). Table 1 below shows flow releases, measurements, and estimations for Rush Creek. Site 1 was located in Upper Rush Creek and Sites 2 and 3 were located in Lower Rush Creek.

Table 1 – Flow Releases, Measurements, and Estimations for Rush Creek, June-04

	LADWP Flow Measurements				McBain & Trush		model	Estimate
Date	Upper Rush Creek	Parker Creek	Walker Creek	Lower Rush Creek (URC+PC +WC)	Measured, Lower Rush Creek	% Lost to Floodplain	% Lost to Floodplain	Lower Rush Creek
5/31/04	47	18	12	77			0.0%	77
6/1/04	66	21	12	99			0.0%	99
6/2/04	91	25	15	131			0.0%	131
6/3/04	126	28	18	172			3.0%	167
6/4/04	169	31	19	219			5.0%	208
6/5/04	230	34	20	284			7.0%	264
6/6/04	277	34	20	331	303	9.2%	9.3%	300
6/7/04	298	31	20	349			10.7%	312
6/8/04	325	25	17	367			11.2%	326
6/9/04	350	20	15	385	339	13.6%	13.6%	333
6/10/04	297	17	13	327			0.0%	327
6/11/04	380	16	12	408	375	8.8%	8.8%	372
6/12/04	295	18	11	324			0.0%	324

Point of incipient movement of bedload

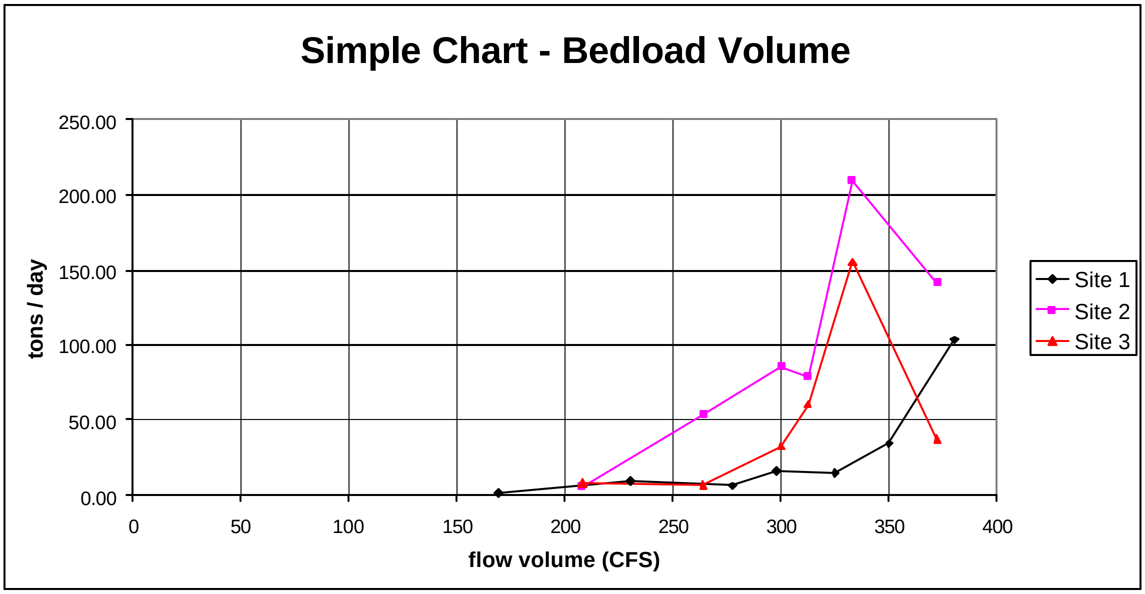
To determine an exact point at which the bed of a stream becomes mobile is not feasible, as that point occurs along a continuum as flow increases. Therefore, such determination is open to the subjectivity of the observer. There are, however, data that helps us make sense of this, and allows for some understanding of the threshold for bed mobilization, within a certain range of variability.

The primary factors that influence bed mobility are the depth of water and the water surface slope (velocity). These factors combine to increase bed shear stress as flow volume increases. At some point, this shear stress exceeds the resistance of the substrate, and the bed particles become entrained in the flow. This is somewhat oversimplified, as a host of variables enter into the equation at any given point along the stream channel. Some additional factors may include:

- Turbulence of the water column;
- Bed armoring (degree to which the substrate is imbedded into a finer matrix);
- Entrainment of sediment from upstream sources;
- Lateral bank erosion upstream of site;
- Vertical channel incision upstream of site;
- Availability of coarse sediment from flow across to the floodplain; and
- Many other factors.

To depict the interaction of flow and sediment movement we plot sediment volume versus flow and present it in Figure 2, below.

Figure 2 – Bedload Volume vs. Flowrate, Sites 1, 2, and 3.



Site 1 appears to mobilize sediment at significant volumes between 325 and 350 cfs. Site 2 begins to rise sharply between 210 and 260 cfs. Site 3 appears to begin bedload transport between 275 and 325 cfs. However, this simple method of viewing volume lacks important details regarding many aspects sediment transport.

Size Distribution of Bedload Samples

Sieve analyses were performed to determine the size distribution of the captured bedload sediment. From these distributions we are able to learn more about what sizes of bedload are moving at what flow levels.

Often, when discussing the critical shear stress required for mobilization of bed material, we use a reference to the size of sediment at which 84% of the sediment, by weight, is finer than that diameter particle. (Diameter is measured in the secondary axis.) This is referred to as the D_{84} size class of the bed material.

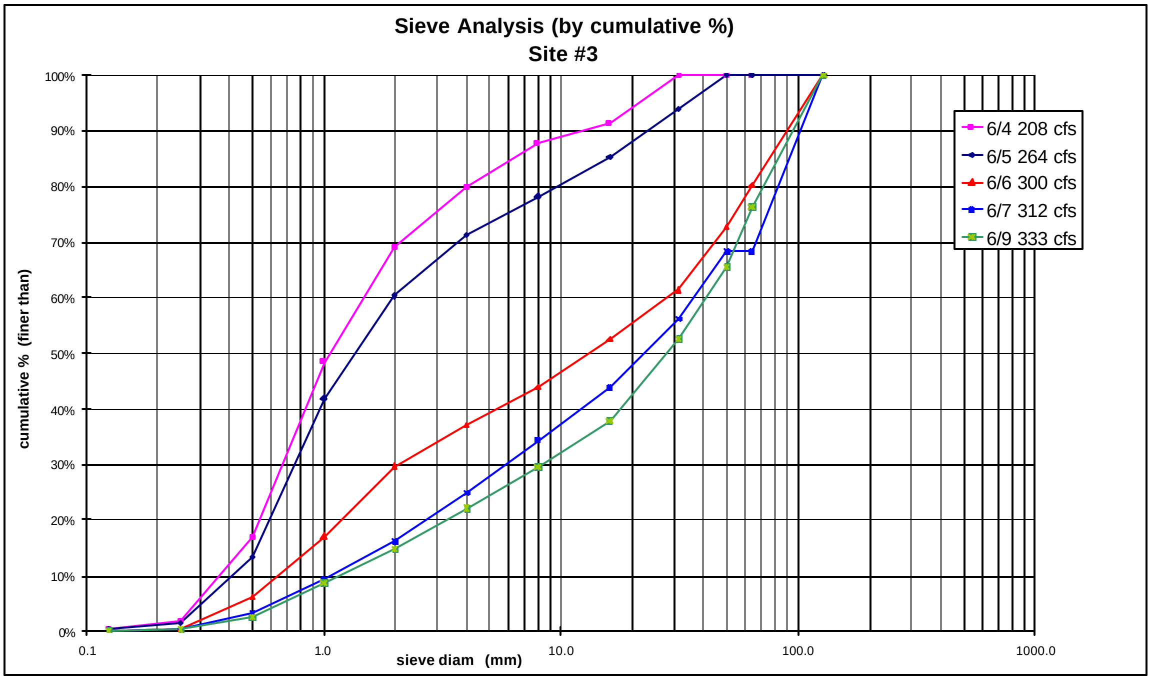
There are several methods of determining this D_{84} size, but one of the more reliable is to physically sample the bedload being transported at flow volumes above bankfull stage and perform a sieve analysis on that sample. Other methods, such as pebble counts, often tend to overestimate size distribution due to natural coarsening of the stream bed. Bar samples along the lower third of active point bars, sampled at the downstream face are more accurate representations of bedload distribution than pebble counts (Rosgen, 1996). For the purposes of this report, we rely on sieve analysis of bedload samples.

In-depth sieve analysis at Site 3 was chosen for several reasons:

- There was major floodplain grading work immediately upstream from Site 2, making bedload volume estimate suspect for that site;
- Site 1 is immediately below Grant Lake bypass channel and may not represent the general character of bedload transport in Rush Creek; and
- The main focus for restoration is on the Lower Rush Creek reaches where fish habitat values are deemed most valuable.

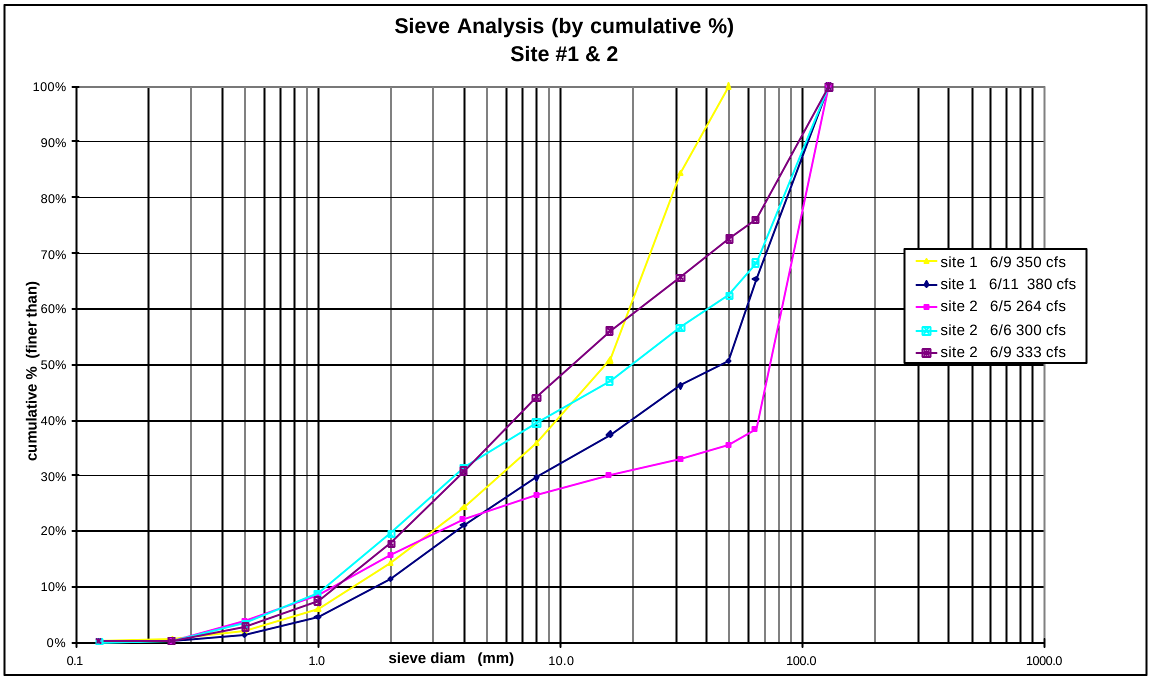
Figure 3 shows data from Site 3, where bedload samples from several collection days were analyzed for size distribution.

Figure 3 – Site 3 Sieve Analysis



Now that the bedload transport is viewed in relation to size of particles being moved, it is more clear at which point the D_{84} size class is being mobilized. The chart shows a large difference in size class mobilization between June 5 and 6. This represents a range of 264 to 300 cfs. Sieve samples for Sites 1 and 2 were also examined, but not in as great a detail as Site 3. Several bedload samples were sieved to provide clues as to the differences, if any, in size distribution of the bedload particles. Figure 4 represents the sieve analysis of several samples from Sites 1 and 2.

Figure 4 – Sieve Analyses for Sites 1 and 2



Bedload Volume Estimates

A final consideration in our investigation of bedload characteristics is to examine bedload volumes and compare these samples to stream flow. If we are able to estimate sediment volume at a range of flow levels, then we can predict future sediment transport capacities of the channel, at least within the range of discharges measured. This is useful when discussing such factors as floodplain and channel maintenance.

The bed material mobility data for the full range of flows is contained in Table 2, on the following page.

Table 2 – Bedload Volume Estimates (tons/day)

date	site	width	HS width	# cells	interval	total wt	cont. wt	net wt	dry wt	Q est	Site 1 tons/day
6/4/2004	**1**	28.5	0.25	19	1.0	190.5	8.8	181.7	145.4	169	1.38
6/5/2004	**1**	30.0	0.50	20	0.5	1226.9	8.8	1218.1	974.5	230	9.26
6/6/2004	**1**	30.5	0.50	20	0.5	1061.3	194.6	866.7	693.4	277	6.59
6/7/2004	**1**	30.5	0.50	20	0.5	2070	0	2070	1656.0	298	15.74
6/8/2004	**1**	32.0	0.50	21	0.5	2295.2	349.2	1946	1556.8	325	14.80
6/9/2004	**1**	33.5	0.50	22	0.25	2600	349.3	2250.7	1800.6	350	34.23
6/11/2004	**1**	33.0	0.50	22	0.25	7000	190.9	6809.1	5447.3	380	103.54

date	site	width	HS width	# cells	interval	total wt	cont. wt	net wt	dry wt	Q est	Site 2 tons/day
6/4/2004	**2**	30.0	0.25	20	1.0	698.7	8.8	689.9	551.9	208	5.25
6/5/2004	**2**	31.5	0.50	21	0.5	7200.2	167.4	7032.8	5626.2	264	53.47
6/6/2004	**2**	33.0	0.50	22	0.5	11249.1	0	11249.1	8999.3	300	85.53
6/7/2004	**2**	33.0	0.50	22	0.5	10700	384.5	10315.5	8252.4	312	78.43
6/9/2004	**2**	32.5	0.50	22	0.3	14100	348.4	13751.6	11001.3	333	209.11
6/11/2004	**2**	35.0	0.50	23	0.3	9600	349.2	9250.8	7400.6	372	140.67

date	site	width	HS width	# cells	interval	total wt	cont. wt	net wt	dry wt	Q est	Site 3 tons/day
6/4/2004	**3**	34.0	0.25	23	1.0	1015.7	8.8	1006.9	805.5	208	7.66
6/5/2004	**3**	34.5	0.50	23	0.5	1161.4	194.2	967.2	773.8	264	7.35
6/6/2004	**3**	35.0	0.50	23	0.5	4500	194.2	4305.8	3444.6	300	32.74
6/7/2004	**3**	35.0	0.50	23	0.5	8100	166.7	7933.3	6346.6	312	60.32
6/9/2004	**3**	35.0	0.50	23	0.25	10900	695.8	10204.2	8163.4	333	155.17
6/11/2004	**3**	36.5	0.50	24	0.25	2800	349.2	2450.8	1960.6	372	37.27

As mentioned above, inaccuracies exist in the measurement of bedload volume, and the figures presented here are meant only to offer some general insight into potential sediment volumes at the relatively narrow range of flows released in the June 2004 study. Figures 5, 6, and 7 depict the rating curves developed for the three sites over the course of the release.

Figure 5 – Bedload vs. Flow, Site 1

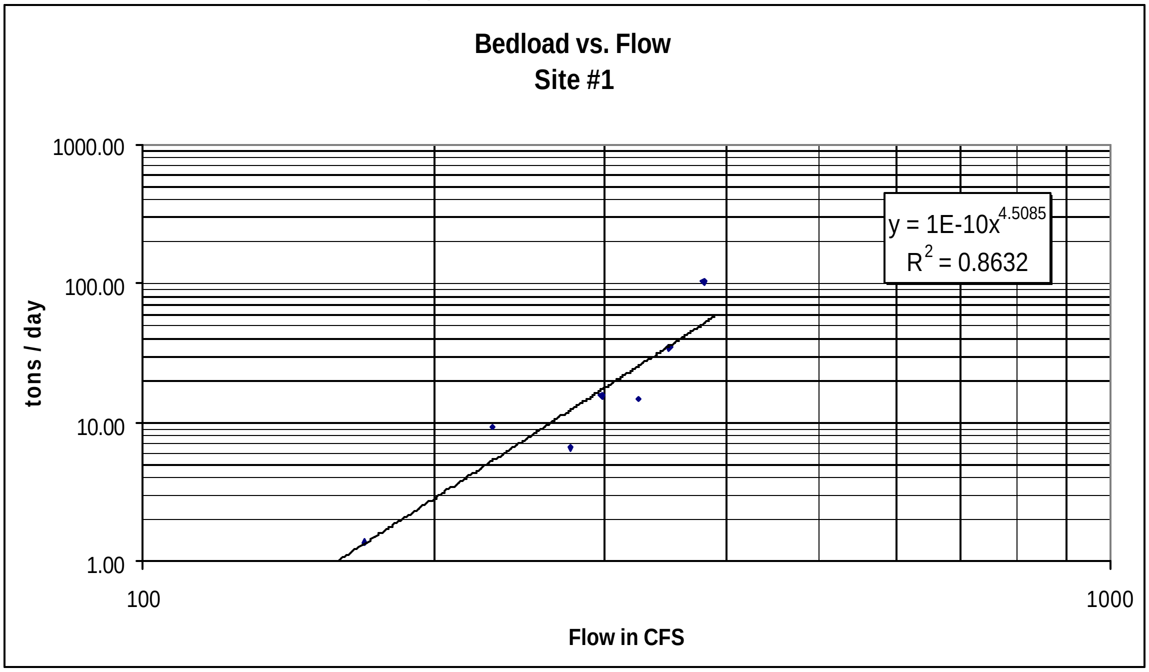


Figure 6 – Bedload vs. Flow, Site 2

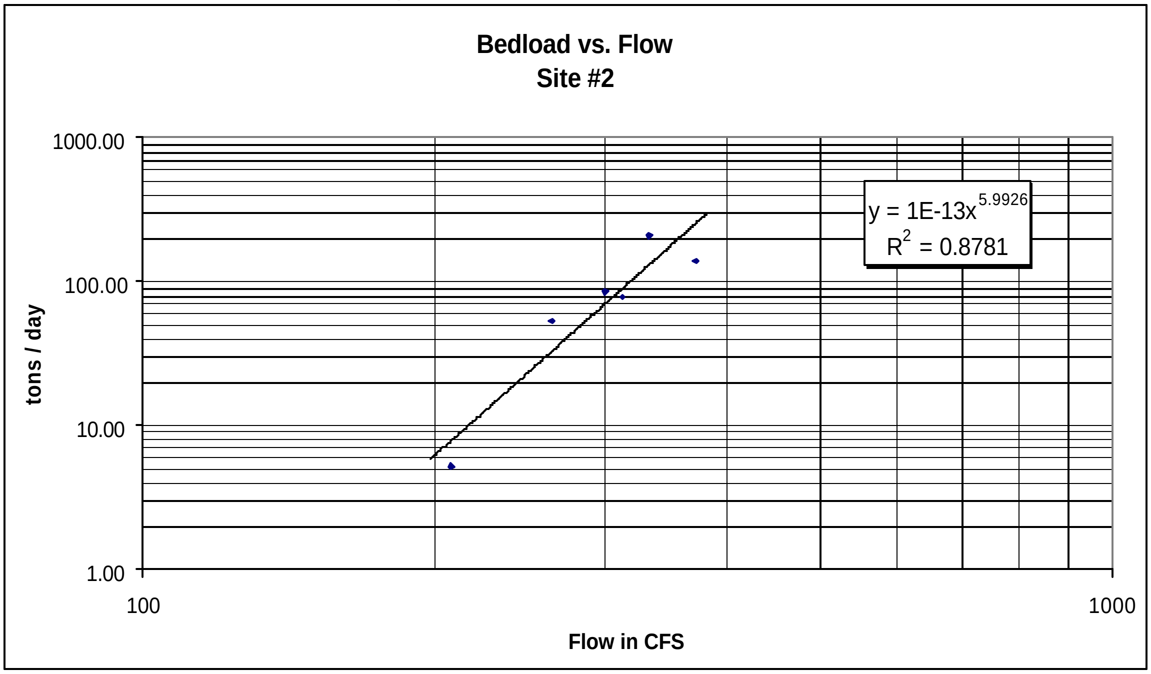
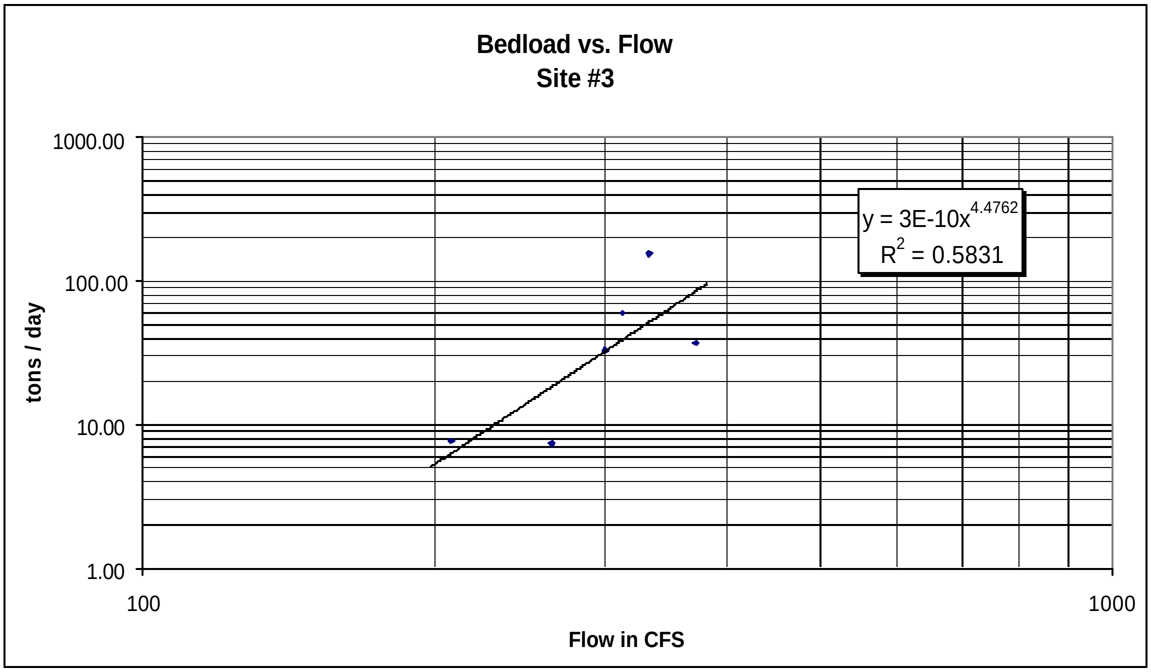


Figure 7 – Bedload vs. Flow, Site 3



Sites 1 and 2 show a strong correlation of flow to sediment volume despite a drop in sediment weight at the highest flow volume. This unexpected drop in volume is mirrored by Site 3. During the peak release of 380 cfs, (372 cfs in the Lower Rush Creek reach) the bedload volumes actually decreased at the lower two sites.

While this does not affect our ability to estimate the point of incipient bed mobility, it does complicate our ability to predict sediment transport as a function of flow volume.

Several factors may contribute to the low sediment anomaly seen at higher flows. These factors include:

- The release schedule was interrupted on June 9th and 10th to inspect the return ditch integrity. This rapid decrease in volume, followed by a return to higher flows could have caused a temporary dip in the sediment transport rates at the lower sites.
- The interruption in the release schedule could have lowered the storage in the surrounding banks and floodplain, causing a larger than estimated loss to recharge on June 11. This would result in lower than reported flow volumes in Lower Rush Creek.
- Delivery of loose sediment from the disturbed floodplain and overflow channels above Site 2 could have slowed after several days of contribution to the system.

It is important to remember that that the decrease in sediment transport measured at the peak release is represented by a single data point from each lower site. This single point may not be representative of the bedload transport rate for that discharge and would require expanded sampling times and discharge levels to verify the trend at higher release levels. To project bedload transport trends above the current release volumes requires additional bedload sampling and sieve analysis at higher flood levels, beyond the capacity of the return ditch. This data collection would need to be timed with infrequent natural flood events that overtop the storage capacity of the lake.

For consistency, we will focus on the bedload rating curve at Site 3 as most representative of Lower Rush Creek conditions. Whether or not this rating curve is consistent from year to year is in doubt. Most of lower Rush Creek is well vegetated, but channel and floodplain adjustments continue in response to the changes in hydrologic regime. Physical manipulation of the channels and floodplain to facilitate restoration of the riparian corridor also contribute to fluctuations in the sediment budget. Just as each sediment sample represents only a point in time, the release schedule represents a point in the recovery of Rush Creek.

Figure 8 below, depicting the particle size distribution that was reviewed in the section above (*Size Distribution of Bedload Material*), can help refine the bedload rating curves.

Figure 8 – Sieve Analyses for Various Flows, Site 3

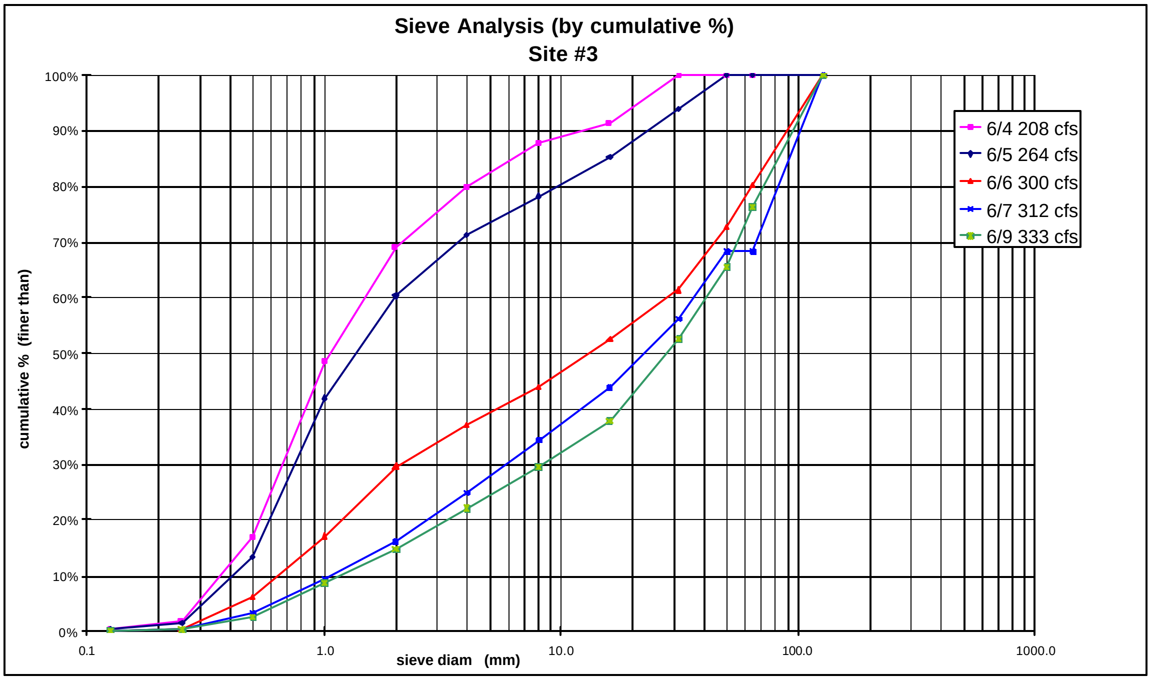


Figure 8 indicates that the D_{84} particle size representative of the streambed begins to mobilize between 264 and 300 cfs. The three lines to the right side represent the larger particle sizes being moved at higher flow levels. If we plot only the data points that represent the mobilization of the D84 of the streambed, then the bedload rating curve more accurately reflects true bedload material. To accomplish this, Figure 9 below was created by removing the sample points at the bottom of the release that contained primarily coarse sand and did not represent the size distribution of the bed.

Figure 9 –Bedload Material vs. Flow, Site 3

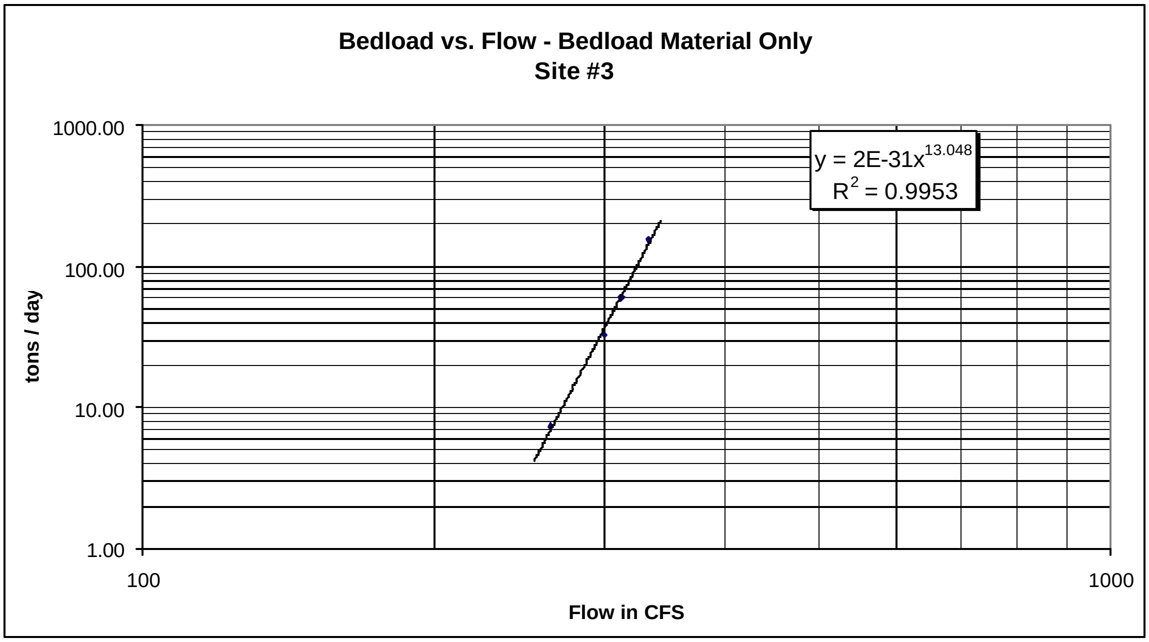


Figure 9 above shows that the data points are tightly aligned with an excellent coefficient of correlation and are likely to represent the approximate bedload sediment transport in the range of 264 to 333 cfs.

Points of Important Stream Functions

While walking to and from each site, standing or riding in a boat during the preparation and monitoring period, and visiting other areas of Rush Creek, daily observations were made and noted in a field notebook. The areas where Rush Creek was observed at close range, other than in the immediate areas of the three monitoring sites, include much of the 3A-channel, parts of the 3D-channel, and several stretches of the 4B-channel. Additional observations of Rush Creek were made from vantage points overlooking the 2-channel, much of the 3B-channel, 3C-channel and the 3D-channel, portions of the 4A-channel, much of the 4B-channel, and portions of the 4C-channel.

Bankfull

Bankfull, the point when flood flows begin to access the active floodplain, is an important indicator for several reasons. The flow at this stage determines the dimensions and capacity of the channel. This is due to the duration of flows at the bankfull stage that are capable of moving bedload sediment. Because of the long duration of flows near bankfull stage, more work is accomplished at bankfull than at higher flows that occur less often. Bankfull is the stage at which most of the work is done most of the time. Lower flows occur more often, but are less capable of moving sediment. Higher flows move greater volumes of bedload, but occur too infrequently to be considered the dominant force in forging the channel morphology.

Bankfull can be calculated several ways, but one of the most reliable is through field observation during known flowrates. Various portions of Rush Creek showed bankfull characteristics anywhere from 210 to 350 cfs, but in general it seemed that this point was met at the expected locations at 300 cfs.

Point of Floodplain Inundation and Side Channel Flow

The point when the floodplain becomes inundated is important because it is when water begins to escape the main channel, replenish the building banks with nutrients and fresh substrate for new vegetation, build bars, and distribute seeds from riparian vegetation. Floodplain inundation can be calculated several ways, but one of the most reliable is through field observation during known flows. Various portions of Rush Creek showed floodplain inundation characteristics at flows similar to those needed for bankfull, but in general it seemed the this point was met at the expected locations at 300 cfs.

Point of Large Woody Debris Mobilization

Woody debris was observed throughout the flow test, however the point when LWD was regularly observed, and subsequent care needed to be taken during bed load sampling, was at a flow rate of approximately 350 cfs.

VI. Conclusions

Point of incipient movement of bedload

Site 1 shows a tendency toward a later mobilization of bedload (350 cfs), perhaps as much as 50 cfs higher than Site 3 (300cfs). It is not known why this tendency exists. The bed may be more stable or imbedded than the lower reaches or have larger surface particles. All sites have similar widths and entrenchment. The difference is not great and may be due simply to natural variations in bedload mobilization as the stream continues to adjust to changes in the hydrologic regime.

Site 2 shows earlier bedload mobilization (264 cfs), but these data are suspect due to floodplain disturbances immediately upstream of the sampling station.

Site 3 data shows that the bed material of Lower Rush Creek first becomes mobilized at approximately 300 cfs discharge. This site was deemed to be the most representative of Lower Rush Creek.

Initial Floodplain Access

Floodplain access at Site 1 was noted to be close to inundation of the surface on June 8 with discharge estimated at 325 cfs. The floodplain surface area was somewhat elevated at the sampling transect, and flood flows inundated most of the rest of the floodplain much earlier. Field notes from June 7 indicate, "*No water behind stake. FP access above and below.*" The June 7 release was estimated at 298 cfs, making initial floodplain access equivalent at all three sites.

Flows at Site 2 began to appear in low volume (< 1 cfs) along the overflow channels west of the main channel (left bank) on June 6 with release discharge estimated at 300 cfs. This initial floodplain access correlates with Site 3.

Of additional interest are observations of flows beginning to access the floodplain and overflow channel on the right bank at approximately this discharge.

In natural alluvial systems, initial floodplain access is an indicator of bankfull stage. The point at which significant volumes of all size classes within the streambed are mobilized (point of incipient movement) can also serve as an indicator of the bankfull stage. These data tend to agree within the scope of this investigation. The bankfull discharge is typically the dominant influence in channel morphology (Leopold, 1994). It appears that that the Rush Creek channel morphology is largely controlled by release discharge levels of approximately 300 cfs. This does not imply that peak flows of 300 cfs are or are not sufficient to maintain channel morphology. It does appear that the channel has responded to a discharge regime in recent years, as the current dimensions tend to correspond with estimations of bankfull discharge.

The resiliency of the channel to forces of change (erosion) is largely based in the strength of the riparian ecosystem. As the riparian corridor continues to recover from past disturbances, the channel will respond with equal tendency toward stability and improvement of fishery habitat.

Size distribution of bedload samples

Samples analyzed at Site 1 indicate the D_{84} ranges from 32 to 84 mm. Observation of the bed materials and previous size distribution work indicate that the sample from the higher flow on June 11 contains bedload material more representative of the true size distribution. It is concluded that 84 mm is more representative of the D_{84} size class at Site 1.

At Site 2 the D_{84} ranges from 80 to 105mm. The larger particles were actually sampled at lower flow volumes, but with large components of coarse sand, and relatively little material from the medium size classes. Once the entire bed became mobilized on subsequent days, (i.e. June 9), the largest size particles no longer skew the results toward a higher D_{84}. Therefore, it is concluded that the approximate D_{84} of the bedload measured at Site 1 is best represented by the June 9 sample of 80 mm.

Site 3 data points during significant bedload movement are grouped closely within the range of 72 to 92 mm. If the June 9 sample is used, as it was at Site 2 as representative of mobilization of the entire bedload, then a D_{84} figure of 80 mm for Site 3 is indicated.

Bedload Volume Estimates

Bedload volume typically increases in proportion to stream flow in most alluvial systems. This trend is documented at each site for most flow levels. At Sites 2 and 3, however, bedload volume dropped during sampling at the highest flow release on June 11, 2004. This was an unexpected result and not typical of natural systems in unregulated flood events.

It would be useful to have further data points above the June 11 sampling to determine if the point was low due to changes in the release schedule (the flows were reduced on June 10 to facilitate levee repairs), or if the decrease continued through higher flow levels. The release schedule peaked on June 11 at 380 cfs, yielding approximately 372 cfs in the lower reaches once floodplain absorption and tributary contribution are included in the calculations.

It is not known what volume of bedload sediment at the lower sites was contributed from floodplain grading work above Site 2. The only clue as to the source of the bedload comes from staining found on the larger cobbles at Site 3. The bright red stains on many rocks seem to underlie a brighter, more recent depositional layer. Site 3 cobble may have come from older layers or from the bed material that shows dark staining.

Site 2 cobbles did not contain such stained rocks, but seemed to be sourced from more recent deposits. It is not known whether these brighter rock sampled at Site 2 was sourced from bed, bank, or upstream floodplain entrainment.

Site 1 followed a more typical path of bedload volume, even on the June 11 sample date. Given the anomaly at the upper flow levels at Sites 2 and 3, the data collected along Rush Creek should not be used to project sediment volumes beyond the range of flow releases actually measured.

At the highest transport rates, the following sediment volumes were measured:

Site	**Date**	**Flow (cfs)**	**Bedload (tons/day)**
1	6/11/04	380	103.5
2	6/9/04	333	209.1
3	6/9/04	333	155.1

There is not a typical figure for bedload production at a given discharge. However, the sediment volumes listed above do not indicate symptoms of excessive bedload. The bedload samples at peak discharge are representative of the bed material and fall within the range of transport volumes expected in an Eastern Sierra stream of this type. For a full data set from all measured discharge levels, see the data table in the Bedload Volume Estimates section of the results section above.

Other studies are underway to determine the interaction of bedload transport with floodplain and channel maintenance. It is our hope that these measurements will assist with determination of discharge peaks and duration required to maintain and enhance the Rush Creek ecosystem.

VII. References

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Section 5

Mono Basin Waterfowl
Habitat and Population Monitoring
2004-2005

Waterfowl Habitat Restoration Project
Annual Report
2004

Mono Basin Hydrology

Water exports for the Mono Basin are reported in Appendix 1.

The elevation of Mono Lake was measured on 43 occasions during Runoff Year 2004-2005. The reads are reported in Appendix 1.

Lake Limnology

Dr. Robert Jellison of the University of California Santa Barbara conducted eleven limnological surveys on Mono Lake. The results are reported in Appendix 2.

Waterfowl Surveys

Ms. Debbie House, Range and Wildlife Biologist with the Los Angeles Department of Water and Power, conducted three summer ground counts and six fall aerial surveys. The Mono Lake Waterfowl Population Monitoring 2004 Annual Report is presented in Appendix 3.

Mr. Robert McKernan reviewed the Mono Lake Waterfowl Population Monitoring 2003 Annual Report prepared by Ms. House. His comments are presented in Appendix 4. McKernan's proposed changes were incorporated in the 2004 Annual Report.

Vegetation

The next regularly scheduled vegetation surveys are set for 2005.

Mono Lake Waterfowl Restoration Project
Compliance Checklist
2004

Hydrology	**Appendix 1**
Mono Lake Elevation	☑
Walker Creek Flows	☑
Parker Creek Flows	☑
Lee Vining Creek Flows	☑
Rush Creek Flows	☑
Mono Basin Exports	☑
Limnology	**Appendix 2**
Meteorology	☑
Physicochemical Variables	☑
Primary Producers	☑
Secondary Producers	☑
Ornithology	**Appendix 3**
Population Surveys	☑
Aerial Photography	☑
Time Activity Budget	Required at Stabilization
Vegetation	Required 2005

Brian White

Brian White
Waterfowl Coordinator

APPENDIX 1

Hydrology

May 11, 2005

Ms. Victoria Whitney, Chief
Division of Water Rights
State Water Resources Control Board
1001 I Street
Sacramento, California 95812

Dear Ms. Whitney:

Subject: Update on Mono Basin Operations During Runoff Year 2004-05

This letter is being submitted to the State Water Resources Control Board (SWRCB) and Mono Basin parties as an update to the Los Angeles Department of Water and Power's (LADWP) preliminary Mono Basin operations plan for Runoff Year 2004-05. The preliminary operations plan was submitted to the SWRCB and the Mono Basin parties in a letter submitted on April 29, 2004, and again in the "Compliance Reporting" submitted on May 15, 2004.

The April through March runoff for Mono Basin Runoff Year 2004-05 (RY2004-05) was typical in some regards, and atypical in others. In general, peak flows and total runoff were lower than predicted. The peak flowrate for Rush Creek entering Grant Lake Reservoir occurred when expected however it was approximately one-half the predicted magnitude (see Table 1 – Mono Basin Runoff Summary). Similarly, peak flows for Walker and Parker Creeks occurred when expected, yet were roughly two-thirds the predicted magnitude (Table 1). The real annomally this year was Lee Vining Creek. Flows on Lee Vining Creek peaked on five separate occasions, from early May through mid-June, and none were of any significant magnitude.

The following is a summary of LADWP's operations for the Mono Basin for the RY2004-05, April 2004 through March 2005:

- Mono Basin Exports: As during the previous runoff year, exports were delayed to help maintain Grant Lake Reservoir Elevations through the recreation season. Exports began in late September 2004 and continued through March 31, 2005, when a total of 15,965 acre-feet had been exported from the Mono Basin. This value is less than the 16,000 acre-feet allowed under Decision 1631.

- Rush Creek: Grant Lake Reservoir's elevation on April 1, 2004 was approximately 7,104.9 ft above mean sea level, 25.1 feet below the lip of the spillway. The low elevation of the reservoir provided no opportunity to spill. A peak inflow into Grant Lake Reservoir (Rush Creek at Damsite) of 216 cubic feet per second (cfs) was forecasted to occur on June 9, 2004. Rush Creek at Damsite experienced its peak on June 10 with a magnitude of 121 cfs.

  Rush Creek below the confluence of the return ditch experienced a flow of approximately 380 cfs for 21 hours on June 11, 2004. The 380 cfs was achieved during the testing for the maximum capacity of the newly refurbished return ditch.

- Parker Creek: There have been no diversions for export during the year. Parker Creek experienced its peak of a magnitude of 34 cfs on June 7, 2004. The peak was less than the forecasted magnitude of 47 cfs, and it occurred 11 days earlier than the forecasted date of June 18.

- Walker Creek: There have been no diversions for export during the year. Walker Creek experienced its peak of a magnitude of 20 cfs from June 6 to 8. The peak was less than the forecasted magnitude of 33 cfs, and it occurred 5 days earlier than the forecasted date of June 13.

- Lee Vining Creek: Lee Vining Creek experienced several peak flows ranging from 145 to 155 cfs. The absolute peak was 155 cfs, 85 cfs less than the predicted peak of 240 cfs, and it occurred 32 days earlier than predicted. The peak that was passed through the diversion facility occurred on May 28 with a magnitude of 151 cfs. This peak occurred 9 days earlier than the predicted date of June 6, and was 89 cfs lower than the predicted peak of 240 cfs.

  As of March 31, 2005, diversions from Lee Vining Creek to Grant Lake Reservoir totaled approximately 3,900 acre-feet.

- Runoff – Actual vs. Forecasted: The forecasted runoff for the period April 1, 2004 through March 31, 2005 was 97,400 acre-feet while the actual runoff was measured at 93,800 acre-feet; a difference of approximately 3,600 acre-feet.

The table below compares May 1 forecasted values to those actually measured.

Table 1 – Mono Basin Runoff Summary

	Forecasted		Measured	
	Magnitude	Timing	Magnitude	Timing
Rush Creek @ Damsite	216 cfs	June 9	121 cfs	June 10
Parker Creek	47 cfs	June 18	34 cfs	June 7
Walker Creek	33 cfs	June 13	20 cfs	June 8
Lee Vining Creek	240 cfs	June 6	155 cfs	May 5
Runoff (acre-feet), Apr – Mar	97,400	N/A	93,800	N/A

- Grant Lake Reservoir: Flow releases from the reservoir to Rush Creek were maintained slightly above the minimum and exports were suspended until late September to help reduce impacts to recreation at Grant Lake reservoir.

If you have any questions or need additional information, please contact Dr. Mark Hanna of my staff at (213) 367-1289.

Sincerely,

Original signed by
Gene L. Coufal

Gene L. Coufal
Manager
Aqueduct Business Group

Enclosure
c: enclosed mailing list
Dr. Mark Hanna

APPENDIX 2

Limnology

2004 ANNUAL REPORT

MIXING AND PLANKTON DYNAMICS IN MONO LAKE, CALIFORNIA

Robert Jellison, Ph.D.

Marine Science Institute
University of California
Santa Barbara, CA 93106

Submitted: 6 April 2005

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EXECUTIVE SUMMARY

Limnological monitoring of the plankton dynamics in Mono Lake was continued during 2004 following the breakdown of an 8-yr (1995–2003) episode of persistent chemical stratification (meromixis) in late 2003. Chapter 1 describes previous results of limnological studies of the seasonal plankton dynamics observed from 1979 through 2002, a period which encompassed a wide range of varying hydrologic and annual vertical mixing regimes including two periods of persistent chemical stratification or meromixis (1983–88 and 1995–2003). In brief, long-term monitoring has shown that Mono Lake is highly productive compared to other temperate salt lakes, that this productivity is nitrogen-limited, and that year-to-year variation in the plankton dynamics has largely been determined by the complex interplay between varying climate and hydrologic regimes and the resultant seasonal patterns of thermal and chemical stratification which modify internal recycling of nitrogen. The importance of internal nutrient cycling to productivity is highlighted in the years immediately following the onset of persistent chemical stratification (meromixis) when upward fluxes of ammonium are attenuated. These seasonal variations in the physical and nutrient environments have obscured any real or potential impacts due to the effects of changing salinity over the range observed during the period of regular limnological monitoring (1982-present).

Chapter 2 provides a detailed description of the laboratory and field methods employed.

Chapter 3 describes the results of the 2004 limnological monitoring program. The breakdown of an 8-yr period of meromixis in November 2003 mixed nutrient-rich bottom waters throughout the water column. Thus, 2004 began with high ammonia concentrations (10–29 µM) throughout the water column, and a large algal bloom (105 µg chl *a* liter^{-1}) had developed by the February survey. While the upper mixed-layer ammonia concentrations decreased to <1 µM by mid-March, algal biomass remained high (89–95 µg chl *a* liter^{-1}). Dissolved oxygen concentrations in the lake had recovered following low values observed in November 2003 associated with the breakdown of meromixis and hatching of over-wintering *Artemia* cysts began in February as indicated by the presence of abundant (47,324 m^{-2}) 1st instar nauplii on 24 February. Record high

(68,746 m^{-2}) naupliar abundance was observed on the 19 March survey. A large hatch, abundant food, and warmer than average water temperatures led to the largest and earliest 1st generation of adult *Artemia* in Mono Lake observed during the 26-yr period of record (1979-2004). This large 1st generation of adults depleted algal biomass and suppressed fecundity and recruitment into subsequent generations resulting in an early decline in adult abundance.

Artemia grazing maintained low phytoplankton abundance throughout the summer and annual primary production was lower (864 g C m^{-2}) than the record levels (1645 g C m^{-2}) observed in 2003 as meromixis weakened and broke down. However, the mean annual *Artemia* biomass increased 46% from 7.5 g m^{-2} in 2003 to 11.0 g m^{-2} in 2004 and is 18% above the long-term (1983-2004) average of 9.4 g m^{-2}. Total annual cyst production decreased to 2.6 x 10^{6} m^{-2} from the 4.2 x 10^{6} m^{-2} observed in 2003. While this is among the lowest estimates of annual cyst production, there is little correlation between cyst production and the subsequent year's population of *Artemia*.

This year, two additional time series are provided as potential indicators of long-term ecological trends (Figs. 30 & 31). These are seasonally-filtered mixed-layer chlorophyll *a* concentration and adult *Artemia* abundance. These indicators highlight the role of year-to-year changes in the annual mixing regime (meromixis/monomixis), the muted response of *Artemia* relative to phytoplankton, and the absence of any marked long-term trend over the period 1982–2004.

ACKNOWLEDGEMENTS

This work was supported by a grant from the Los Angeles Department of Water and Power to R. Jellison and J. M. Melack at the Marine Science Institute, University of California, Santa Barbara. Laboratory work was performed at the Sierra Nevada Aquatic Research Laboratory, University of California. Sandra Roll and Kimberly Rose assisted with field sampling, laboratory and data analyses. K. Rose and Brian White (LADWP) also provided valuable editing and review of this report.

LIMNOLOGICAL MONITORING COMPLIANCE

This report fulfills the Mono Lake limnological monitoring requirements set forth in compliance with State Water Resources Control Board Order Nos. 98-05 and 98-07. The limnological monitoring program consists of four components: meteorological, physical/chemical, phytoplankton, and brine shimp population data. Meteorological data are collected continuously at a station on Paoha Island, while the other three components are assessed on eleven monthly surveys (every month except January). A summary of previous monitoring is included in Chapter 1, the methodology employed is detailed in Chapter 2, and results and discussion of the monitoring during 2004 presented in Chapter 3. The relevant pages of text, tables, and figures for the specific elements of each of the four required components are given below.

	Text	Tables	Figures
Meteorological			
Wind Speed	21		60
Wind Direction	21		
Air Temperature	21		61
Incident Radiation	21-22		62
Humidity	22		63
Precipitation	22		64
Physical/Chemical			
Water Temperature	22-23	37, 40	66
Transparency	24	41	69-70
Underwater light	24		71
Dissolved Oxygen	25	42	72
Conductivity	23	38, 40	67-68
Nutrients (ammonia and phosphate)	25-26	43	73
Plankton			
Chlorophyll *a*	26	44	74, 88
Primary production	29-31	55	81-85
Artemia Abundance	27-29	45-47	76-77, 89
Artemia Instar distribution	27-29	48	
Artemia Fecundity/Length	27-29	52	
Artemia Reproductive parameters	27-29	49-51	78
Artemia Biomass	31-32	55	86

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CHAPTER 1
INTRODUCTION

Background

Saline lakes are widely recognized as highly productive aquatic habitats, which in addition to harboring unique assemblages of species, often support large populations of migratory birds. Saline lake ecosystems throughout the world are threatened by decreasing size and increasing salinity due to diversions of freshwater inflows for irrigation and other human uses (Williams 1993, 2002); notable examples in the Great Basin of North America include Mono Lake (Patten et al. 1987), Walker Lake (Cooper and Koch 1984), and Pyramid Lake (Galat et al. 1981). At Mono Lake, California, diversions of freshwater streams out of the basin beginning in 1941 led to a 14 m decline in surface elevation and an approximate doubling of the lake's salinity.

In 1994, following two decades of scientific research, litigation, and environmental controversy, the State Water Resources Control Board (SWRCB) of California issued a decision to amend Los Angeles' water rights to "establish fishery protection flows in streams tributary to Mono Lake and to protect public trust resources at Mono Lake and in the Mono Lake Basin" (Decision 1631). The decision restricts water diversions until the surface elevation of the lake reaches 1,948 m and requires long-term limnological monitoring of the plankton dynamics.

Long-term monitoring of the plankton and their physical, chemical, and biological environment is essential to understanding the effects of changing lake levels. Measurements of the vertical distribution of temperature, oxygen, conductivity, and nutrients are requisite for interpreting how variations in these variables affect the plankton populations. Consistent methodologies have been employed during the 25-yr period, 1979–2004, and have yielded a standardized data set from which to analyze seasonal and year-to-year changes in the plankton. The limnological monitoring program at Mono Lake includes the interpretation of a wide array of limnological data collected during monthly surveys conducted during February through December.

Seasonal Mixing Regime and Plankton Dynamics

Limnological monitoring at Mono Lake can be divided into several periods corresponding to two different annual circulation patterns, meromixis and monomixis, and the transition between them.

Monomictic and declining lake levels, 1964–82

The limnology of Mono Lake, including seasonal plankton dynamics, was first documented in the mid 1960s (Mason 1967). During this period Mono Lake was characterized by declining lake levels, increasing salinity, and a monomictic thermal regime. No further limnological research was conducted until summer 1976 when a broad survey of the entire Mono Basin ecosystem was conducted (Winkler 1977). Subsequent studies (Lenz 1984; Melack 1983, 1985) beginning in 1979, further described the seasonal dynamics of the plankton. During the period 1979–81, Lenz (1984) documented a progressive increase in the ratio of peak summer to spring abundances of adult brine shrimp. The smaller spring generations resulted in greater food availability and much higher ovoviviparous production by the first generations, leading to larger second generations. Therefore, changes in the size of the spring hatch can result in large changes in the ratio of the size of the two generations.

In 1982, an intensive limnological monitoring program funded by LADWP was established to monitor changes in the physical, chemical, and biological environments in Mono Lake. This monitoring program has continued to the present. Detailed descriptions of the results of the monitoring program are contained in a series of reports to LADWP (Dana *et al.* 1986, 1992; Jellison *et al.* 1988, 1989, 1990, 1991, 1994, 1995a, 1996a, 1997, 1998a, 1999, 2001, 2002; Jellison and Melack 2000) and are summarized below.

Meromixis, 1983–87

In 1983, a large influx of freshwater into Mono Lake resulted in a condition of persistent chemical stratification (meromixis). A decrease in surface salinities resulted in a chemical gradient of ca. 15 g total dissolved solids l^{-1} between the mixolimnion (the mixed layer) and monimolimnion (layer below persistent chemocline). In subsequent years evaporative concentration of the surface water led to a decrease in this gradient and in November 1988 meromixis was terminated.

Following the onset of meromixis, ammonium and phytoplankton were markedly affected. Ammonium concentrations in the mixolimnion were reduced to near zero during spring 1983 and remained below 5 µM until late summer 1988. Accompanying this decrease in mixolimnetic ammonium concentrations was a dramatic decrease in the algal bloom associated with periods when the *Artemia* are less abundant (November through April). At the same time, ammonification of organic material and release from the anoxic sediments resulted in a gradual buildup of ammonium in the monimolimnion over the six years of meromixis to 600 to 700 µM. Under previous monomictic conditions, summer ammonium accumulation beneath the thermocline was 80–100 µM, and was mixed into the upper water column during the autumn overturn.

Artemia dynamics were also affected by the onset of meromixis. The size of the first generation of adult *Artemia* in 1984 (~31,000 m^{-2}) was nearly ten times as large as observed in 1981 and 1982, while peak summer abundances of adults were much lower. Following this change, the two generations of *Artemia* were relatively constant during the meromictic period from 1984 to 1987. The size of the spring generation of adult *Artemia* only varied from 23,000 to 31,000 m^{-2} while the second generation of adult *Artemia* varied from 33,000 to 54,000 m^{-2}. The relative sizes of the first and second generation are inversely correlated. This is at least partially mediated by food availability as a large first generation results in decreased algal levels for second generation nauplii and vice versa. During 1984 to 1987, recruitment into the first generation adult class was a nearly constant but small percentage (about 1 to 3%) of the cysts calculated to be available (Dana *et al*. 1990). Also, fecundity showed a significant correlation with ambient algal concentrations (r^2, 0.61).

In addition to annual reports submitted to Los Angeles and referenced herein, a number of published manuscripts document the limnological conditions and algal photosynthetic activity during the onset, persistence, and breakdown of meromixis, 1982–90 (Jellison *et al*. 1992; Jellison and Melack 1993a, 1993b; Jellison *et al.* 1993; Miller *et al.* 1993).

Response to the breakdown of meromixis, 1988–89

Although complete mixing did not occur until November 1988, the successive deepening of the mixed layer during the period 1986–88 led to significant changes in the plankton dynamics. By spring 1988, the mixed layer included the upper 22 m of the lake and included 60% of the area and 83% of the lake's volume. In addition to restoring an annual mixing regime to much of the lake, the deepening of the mixed layer increased the nutrient supply to the mixolimnion by entraining water with very high ammonium concentrations (Jellison *et al.* 1989). Mixolimnetic ammonium concentrations were fairly high during the spring (8–10 µM), and March algal populations were much denser than in 1987 (53 vs. 15 µg chl *a* l^{-1}).

The peak abundance of spring adult *Artemia* in 1988 was twice as high as any previous year from 1979 to 1987. This increase could have been due to enhanced hatching and/or survival of nauplii. The pool of cysts available for hatching was potentially larger in 1988 since cyst production in 1987 was larger than in the four previous years (Dana *et al.* 1990) and significant lowering of the chemocline in the autumn and winter of 1987 allowed oxygenated water to reach cysts in sediments which had been anoxic since 1983. Cysts can remain dormant and viable in anoxic water for an undetermined number of years. Naupliar survival may also have been enhanced since chlorophyll *a* levels in the spring of 1988 were higher than the previous four years. This hypothesis is corroborated by the results of the 1988 development experiments (Jellison *et al.* 1989). Naupliar survival was higher in the ambient food treatment relative to the low food treatment.

Mono Lake returned to its previous condition of annual autumnal mixing from top to bottom with the complete breakdown of meromixis in November 1988. The mixing of previously isolated monimolimnetic water with surface water affected biotic components of the ecosystem. Ammonium, which had accumulated to high levels (> 600 µM) in the monimolimnion during meromixis, was dispersed throughout the water column raising surface concentrations above previously observed values (>50 µM). Oxygen was diluted by mixing with the anoxic water and consumed by the biological and chemical oxygen demand previously created in the monimolimnion. Dissolved oxygen concentration immediately fell to zero. *Artemia* populations experienced an immediate and total die-off following deoxygenation. Mono Lake remained anoxic for a few months following the breakdown of meromixis in November 1988. By mid-February 1989, dissolved oxygen concentrations had increased (2–3 mg l^{-1}) but were still below those observed in previous years (4–6 mg l^{-1}). The complete recovery of dissolved oxygen concentrations occurred in March when levels reached those seen in other years.

Elevated ammonium concentrations following the breakdown of meromixis led to high chlorophyll *a* levels in spring 1989. Epilimnetic concentrations in March and April were the highest observed (40–90 µg chl *a* l^{-1}). Subsequent decline to low midsummer concentrations (<0.5–2 µg chl *a* l^{-1}) due to brine shrimp grazing did not occur until late June. In previous meromictic years this decline occurred up to six weeks earlier. Two effects of meromixis on the algal populations, decreased winter-spring concentrations and a shift in the timing of summer clearing are clearly seen over the period 1982–89.

The 1989 *Artemia* population exhibited a small first generation of adults followed by a summer population over one order of magnitude larger. A similar pattern was observed from 1980–83. In contrast, the pattern observed during meromictic years was a larger first generation followed by a summer population of the same order of magnitude. The timing of hatching of *Artemia* cysts was affected by the recovery of oxygen. The initiation of hatching occurred slightly later in the spring and coincided with the return of oxygenated conditions. First generation numbers in 1989 were initially high in March (~30,000 individuals m^{-2}) and within the range seen from 1984–88, but decreased by late spring to ~4,000 individuals m^{-2}. High mortality may have been due to low temperatures, since March lake temperatures (2–6°C) were lower than the suspected lethal limit (ca. 5–6°C) for *Artemia* (Jellison *et al.* 1989). Increased mortality may also have been associated with elevated concentrations of toxic compounds (H_2S, NH_4+, As) resulting from the breakdown of meromixis.

High spring chlorophyll levels in combination with the low first generation abundance resulted in a high level of fecundity that led to a large second generation of shrimp. Spring chlorophyll *a* concentrations were high (30–44 µg chl *a* l^{-1}) due to the elevated ammonium levels (27–44 µM) and are typical of pre-meromictic levels. This abundant food source (as indicated by chlorophyll *a*) led to large *Artemia* brood sizes and high ovigerity during the period of ovoviviparous reproduction and resulted in the large observed summer abundance of *Artemia* (peak summer abundance, ~93,000 individuals m^{-2}). Negative feedback effects were apparent when the large summer population of *Artemia* grazed the phytoplankton to very low levels (<0.5–2 µg chl *a* l^{-1}). The low algal densities led to decreased reproductive output in the shrimp population. Summer brood size, female length, and ovigerity were all the lowest observed in the period 1983–89.

Small peak abundance of first generation adults were observed in 1980–83, and 1989. However, the large (2–3 times the mean) second generations were only observed in 1981, 1982, and 1989. During these years, reduced spring inflows resulted in less than usual density stratification and higher than usual vertical fluxes of nutrients thus providing for algal growth and food for the developing *Artemia* population.

Monomictic conditions with relatively stable lake levels, 1990–94

Mono Lake was monomictic from 1990 to 1994 (Jellison *et al.* 1991, Dana *et al.* 1992, Jellison *et al.* 1994, Jellison *et al.* 1995b) and lake levels (6374.6 to 6375.8 ft asl) were similar to those in the late 1970s. Although the termination of meromixis in November 1988 led to monomictic conditions in 1989, the large pulse of monimolimnetic ammonium into the mixed layer led to elevated ammonium concentrations in the euphotic zone throughout 1989, and the plankton dynamics were markedly different than 1990–94. In 1990–94, ammonium concentrations in the euphotic zone decreased to levels observed prior to meromixis in 1982. Ammonium was low, 0–2 µM, from March through April and then increased to 8–15 µM in July. Ammonium concentrations declined slightly in late summer and then increased following autumn turnover. This pattern of ammonium concentrations in the euphotic zone and the hypolimnetic ammonium concentrations were similar to those observed in 1982. The similarities among the years 1990–94 indicate the residual effects of the large hypolimnetic ammonium pulse accompanying the breakdown of meromixis in 1988 were gone. This supports the conclusion by Jellison *et al.* (1990) that the seasonal pattern of ammonium concentration was returning to that observed before the onset of meromixis.

Spring and summer peak abundances of adult *Artemia* were fairly constant throughout 1990 to 1994. Adult summer population peaks in 1990, 1991, and 1992 were all ~35,000 m^{-2} despite the large disparity of second generation naupliar peaks (~280,000, ~68,000, and ~43,000 m^{-2} in 1990, 1991, and 1992, respectively) and a difference in first generation peak adult abundance (~18,000, ~26,000, and ~21,000 m^{-2} in 1990, 1991, and 1992, respectively). Thus, food availability or other environmental factors are more important to determining summer abundance than recruitment of second generation nauplii. In 1993, when freshwater inflows were higher than usual and thus density stratification enhanced, the summer generation was slightly smaller (~27,000 m^{-2}). Summer abundance of adults increased slightly (~29,000 m^{-2}) in 1994 when runoff was lower and lake levels were declining.

Meromictic conditions with rising (1995-1999) and falling (1999-2002) lake levels

1995

The winter (1994/95) period of holomixis injected nutrients which had previously accumulated in the hypolimnion into the upper water column prior to the onset of thermal and chemical stratification in 1995 (Jellison *et al*. 1996a). During 1995, above normal runoff in the Mono Basin coupled with the absence of significant water diversions out of the basin led to rapidly rising lake levels. The large freshwater inflows resulted in a 3.4 ft rise in surface elevation and the onset of meromixis, a condition of persistent chemical stratification with less saline water overlying denser more saline water. Due to holomixis during late 1994 and early 1995, the plankton dynamics during the first half of 1995 were similar to those observed during the past four years (1991–94). Therefore 1995 represents a transition from monomictic to meromictic conditions. In general, 1995 March mixed-layer ammonium and chlorophyll *a* concentrations were similar to 1993. The peak abundance of summer adult *Artemia* (~24,000 m^{-2}) was slightly lower to that observed in 1993 (~27,000 m^{-2}) and 1994 (~29,000 m^{-2}). The effects of increased water column stability due to chemical stratification only became evident later in the year. As the year continued, a shallower mixed layer, lower mixed-layer ammonium and chlorophyll *a* concentrations, slightly smaller *Artemia,* and smaller brood sizes compared to 1994 were all observed. The full effects of the onset of meromixis in 1995 were not evident until 1996.

1996

Chemical stratification persisted and strengthened throughout 1996 (Jellison *et al*. 1997). Mixolimnetic (upper water column) salinity ranged from 78 to 81 g kg^{-1} while monimolimnetic (lower water column) were 89–90 g kg^{-1}. The maximum vertical density stratification of 14.6 kg m^{-3} observed in 1996 was larger than any year since 1986. During 1996, the annual maximum in Secchi depth, a measure of transparency, was among the highest observed during the past 18 years and the annual minimum was higher than during all previous years except 1984 and 1985 during a previous period of meromixis. While ammonium concentrations were <5 µM in the mixolimnion throughout the year, monimolimnetic concentrations continued to increase. The spring epilimnetic chlorophyll *a* concentrations (5–23 µg chl *a* l^{-1}) were similar to those observed in previous meromictic years, but were much lower than the concentrations observed in March 1995 before the onset of the current episode of meromixis. During previous monomictic years, 1989–94, the spring maximum epilimnetic chlorophyll *a* concentrations ranged between 87–165 µg chl *a* l^{-1}.

A single mid-July peak in adults characterized *Artemia* population dynamics in 1996 with little evidence of recruitment of second generation *Artemia* into the adult population during late summer. The peak abundance of first generation adults was observed on 17 July (~35,000 m^{-2}), approximately a month later than in previous years. The percent ovigery during June 1996 (42%) was lower than that observed in 1995 (62%), and much lower than that observed 1989–94 (83–98%). During the previous meromictic years (1984–88) the female population was also slow to attain high levels of ovigery due to lower algal levels. The maximum of the mean female length on sampling dates through the summer, 10.7 mm, was shorter than those observed during 1993, 1994, and 1995 (11.7, 12.1, and 11.3 mm, respectively). In 1996, brood size ranged from 29 to 39 eggs $brood^{-1}$ during July through November. The summer and autumn brood sizes were smaller than those observed during 1993–95 (40 to 88 eggs $brood^{-1}$), with the exception of September 1995 (34 eggs $brood^{-1}$) when the brood size was of a similar size to September 1996 (33 eggs $brood^{-1}$).

1997

Chemical stratification continued to increase in 1997 as the surface elevation rose an additional 1.6 ft during the year. The midsummer difference in density between 2 and 28 m attributable to chemical stratification increased from 10.4 kg m^{-3} in 1996 to 12.3 kg m^{-3} in 1997. The lack of holomixis during the previous two winters resulted in depleted nutrient levels in the mixolimnion and reduced abundance of phytoplankton. In 1997, the spring (February–April) epilimnetic chlorophyll *a* concentrations at 2 m (2–3 µg chl *a* l^{-1}) were lower than those observed during 1996 (5–8 µg chl *a* l^{-1}), and other meromictic years 1984–89 (1.6–57 µg chl *a* l^{-1}), and much lower than those observed during the spring months in the last period of monomixis, 1989–95 (15–153 µg chl *a* l^{-1}). Concomitant increases in transparency and the depth of the euphotic zone were also observed. As in 1996, a single mid-July peak in adults characterized the *Artemia* population dynamics in 1997 with little evidence of recruitment of second generation *Artemia* into adults. The peak midsummer adult abundance (~27,000 m^{-2}) was slightly lower than 1996 but similar to 1995 (~24,000 m^{-2}). The mean length of adult females was 0.2–0.3 mm shorter than the lengths observed in 1996 and the brood sizes lower, 26–33 eggs $brood^{-1}$ in 1997 compared to 29 to 53 eggs $brood^{-1}$ in 1996.

1998

In 1998 the surface elevation of the lake rose 2.2 ft. The continuing dilution of saline mixolimnetic water and absence of winter holomixis led to increased chemical stratification. The peak summer difference in density between 2 and 28 m attributable to chemical stratification increased from 12.3 kg m^{-3} in 1997 to 14.9 kg m^{-3} in August 1998. The 1998 peak density difference due to chemical stratification was higher than that seen in any previous year, including 1983–84. The lack of holomixis during the previous three winters resulted in depleted nutrient levels in the mixolimnion and reduced abundance of phytoplankton. Chlorophyll *a* concentrations at 2 m generally decreased from 14.3 µg chl *a* l^{-1} in February to 0.3 µg chl *a* l^{-1} in June, when the seasonal chlorophyll *a* concentration minimum was reached. After that it increased to 1–2 µg chl *a* l^{-1} during July–October and to ~8 µg chl *a* l^{-1} in early December. In general, the seasonal pattern of mixolimnetic chlorophyll *a* concentration was similar to that observed during the two previous meromictic years, 1996 and 1997, in which the spring and autumn algal blooms are much reduced compared to monomictic years.

As in 1996 and 1997, a single mid-July peak in adults characterized the Artemia population dynamics in 1998 with little evidence of recruitment of second generation *Artemia* into adults. The peak abundance of adults observed on 10 August (~34,000 m^{-2}) was slightly higher than that observed in 1997 (~27,000 m^{-2}) and, while similar to the timing in 1997, approximately two weeks to a month later than in most previous years. The mean female length ranged from 9.6 to 10.3 mm in 1998 and was slightly shorter than observed in 1996 (10.1–10.7 mm) and 1997 (9.9–10.4 mm). Mean brood sizes in 1998 were 22–50 eggs brood^{-1}. The maximum brood size (50 eggs brood^{-1}) was within the range of maximums observed in 1995–97 (62, 53, and 33 eggs brood^{-1}, respectively), but was significantly smaller than has been observed in any other previous year 1987–94 (81–156 eggs brood^{-1}).

1999

Meromixis continued but weakened slightly in 1999 as the net change in surface elevation over the course of the year was -0.1 ft. The midsummer difference in density between 2 and 28 m attributable to chemical stratification declined from 14.9 kg m^{-3} in 1998 to 12.2 kg m^{-3}. The lack of holomixis during the past four winters resulted in depleted inorganic nitrogen concentrations in the mixolimnion and reduced abundance of phytoplankton. In 1999, the spring (February–April) epilimnetic chlorophyll *a* concentrations at 2 m (10–16 µg chl *a* l^{-1}) were similar to those observed in 1998 but slightly higher than the two previous years of meromixis, 1997 (2–3 µg chl *a* l^{-1}) and 1996 (5–8 µg chl *a* l^{-1}). However, they are considerably lower than those observed during the spring months of the last period of monomixis, 1989–95 (15–153 µg chl *a* l^{-1}). As in all of the three immediately preceding years of meromixis, 1996–98, the *Artemia* population dynamics in 1999 were characterized by a single late-summer peak in adults with little evidence of recruitment of second generation *Artemia* into adults. The peak midsummer adult abundance (~38,000 m^{-2}) was slightly higher than 1996 (~35,000 m^{-2}), 1997 (~27,000 m^{-2}), and 1998 (~34,000 m^{-}2). The mean length of adult females was slightly longer (10.0–10.7 mm) than 1998 (9.6–10.3 mm) and similar to 1996 (10.1–10.7

mm) and 1997 (9.9–10.4 mm), while the range of mean brood sizes (27–48 eggs brood^{-1}) was similar (22–50 eggs brood^{-1}; 1996–98).

2000

In 2000, persistent chemical stratification (meromixis) continued but weakened due to evaporative concentration of the upper mixed layer accompanying a net 0.7 ft annual decline in surface elevation and slight freshening of water beneath the chemocline. The midsummer difference in density between 2 and 28 m attributable to chemical stratification declined from 12.2 kg m^{-3} in 1999 to 10.5 kg m^{-3} in 2000. Most likely of greater significance to the overall plankton dynamics is the marked midwinter deepening (ca. 2 m) of the chemocline. Not only were significant amounts of ammonium-rich monimolimnetic water entrained, but less of the lake is now effectively meromictic; only 38% of the lake's area and 16% of the volume were beneath the chemocline.

Algal biomass, as characterized by the concentration of chlorophyll *a*, was higher in 2000 compared to 1999 and varied in the mixolimnion from a midsummer low of 1.4 µg chl *a* l^{-1} to the December high of 54.2 µg chl *a* l^{-1}. The December value is the highest observed during the entire 21 years of study. Although adult *Artemia* abundance (peak of ~22,000 m^{-2}) was anomalously low (50% of the long-term mean), *Artemia* biomass and total annual cyst production were only slightly below the long-term mean, 12 and 16%, respectively. Thus, while meromixis persisted in 2000, the combined effects of declining lake levels, the reduced proportion of the lake beneath the chemocline, and increased upward fluxes of ammonium due to the large buildup of monimolimnetic ammonium offset, to some degree, the effect of the absence of winter holomixis.

2001

Persistent chemical stratification (meromixis) continued but weakened in 2001 due to evaporative concentration of the upper mixed layer accompanying a net 0.8 ft decline in surface elevation and slight freshening of water beneath the chemocline. Colder than average mixolimnetic temperatures (1.5–2.2ºC) observed in February 2001 enhanced deep mixing. The midsummer difference in density between 2 and 28 m attributable to chemical stratification has declined from 10.5 kg m^{-3} in 2000 to 8.9 kg m^{-3} in 2001. Most likely of greater significance to the overall plankton dynamics was the marked midwinter deepening (ca. 2 m) of the chemocline. Not only were significant amounts of ammonium-rich monimolimnetic water entrained, but less of the lake was effectively meromictic. At the end of 2001, only 33% of the lake's area and 12% of the volume were beneath the chemocline. Ammonium concentrations in the monimolimnion continued their 6-year increase with concentrations at 28 and 35 m generally 900–1200 µM.

Algal biomass, as characterized by chlorophyll *a* concentration, was similar to that observed during 2000 except that the autumn bloom was somewhat later as adult *Artemia* were more abundant in September and October compared to 2000.

As in 2000, the 2001 *Artemia* population was characterized by fairly rapid development of the 1st generation, a pulse of ovoviviparous reproduction in June, peak of adult abundance in July at ~38,000 m^{-2}, followed by a decline to very low numbers by November. In 2000, the autumn decline was very rapid and resulted in the lowest seasonal mean abundance of any year studied. In 2001 the autumn decline was less rapid and resulted in a seasonal mean abundance identical to the long-term mean of ~20,000 m^{-2}. The 2001 mean annual *Artemia* biomass was 8.8 g m^{-2} or 9 % below the long-term mean of 9.7 g m^{-2} and slightly higher than calculated in 2000 (8.2 g m^{-2}).

In Mono Lake, oviparous (cyst) reproduction is always much higher than ovoviviparous (live-bearing) reproduction. Although adult *Artemia* were more abundant in 2001 compared to 2000, total annual cyst production was lower, 3.02×10^6 m^{-2} compared to 4.03×10^6 m^{-2} in 2000. While this is 37% below the long-term mean of 4.77×10^6 m^{-2}, it is not expected to have a significant impact on 2002 abundance as food availability is a much stronger determinant of the spring generation of *Artemia.*

2002

Meromixis continued but weakened due to evaporative concentration of the upper mixed layer accompanying a net 0.8 ft decline in surface elevation and slight freshening of water beneath the chemocline. The peak difference in density between 2 and 28 m attributable to chemical stratification declined from 10.5 kg m^{-3} in 2000 to 8.9 kg m^{-3} in 2001 to 5.5 kg m^{-3} in 2002. More importantly the chemical stratification between 2 and 32 m decreased to ~1 kg m^{-3} and the chemocline was eroded downward several meters to ~30 m. Not only were significant amounts of ammonium-rich monimolimnetic water entrained, but only 14% by area and 3% by volume of the lake is below the chemocline.

Algal biomass, as characterized by chlorophyll *a* concentration, was high during both spring (60-78 µg chl *a* l^{-1}, February and March) and autumn (60-80 µg chl *a* l^{-1}, November). Annual estimates of lakewide primary production were 723 g C m^{-2} y^{-1} and continued the consistent upward trend from the lowest value of 149 g C m^{-2} y^{-1} in 1997.

As in 2000 and 2001, the *Artemia* population was characterized by fairly rapid development of the 1st generation, a pulse of ovoviviparous reproduction in June, adult abundance peak in August at ~26,000 m^{-2}, followed by a decline to very low numbers by November. In 2002, the mean annual *Artemia* biomass was 4.9 g m^{-2} almost 50% below the long-term mean of 9.7 g m^{-2}. Recent analysis of seasonal *Artemia* dynamics indicates small changes in algal biomass immediately following maturation of the 1st generation, dramatically affects recruitment into the summer generation. In 2002, a larger spring hatch and spring adult generation lowered algal biomass and led to decreased recruitment into the summer adult population. This inter-generational compensatory interaction is a dominant feature of the seasonal and annual variation of adult abundance observed in the long-term monitoring (1982-present).

Total annual cyst production (2.5×10^6 m^{-2}), along with abundance of ovigerous females, was less than in the previous three years ($3.0\text{-}4.2 \times 10^6$ m^{-2}), though the size of ovigerous females was larger than in these years. Annual cyst production was the same as in 1997, and was 53% below the long term mean of 4.77×10^6 m^{-2}.

Response to the breakdown of an 8-yr period of meromixis

2003

The persistent chemical stratification (meromixis) initiated in 1995 nearly broke down early in the year (February-March) prior to the onset of seasonal thermal stratification. This resulted in an upward pulse of nutrients (ammonia) into the upper mixed layer early in the year. Following a small rise in surface elevation and slight freshening of the mixed layer due to snowmelt runoff, decreased inflow and evaporative concentration led to an inverse chemical gradient with slightly more saline mixolimnetic water overlying the monimolimnion (region beneath the chemocline). Thus, autumn cooling led to holomixis (complete mixing of the lake) in mid-November and the end of an 8-yr period of meromixis (1995-2003).

Algal biomass, as characterized by chlorophyll *a* concentration, was high throughout the winter and spring (50-96 µg chl *a* l^{-1}, January through May) and autumn (50-62 µg chl *a* l^{-1}, October through November). While *Artemia* grazing and nutrient limitation normally result in low summer algal biomass (~1µg chl *a* l^{-1}), values in summer 2003 never fell below 3 µg chl *a* l^{-1} despite near average *Artemia* abundance. Thus, primary production was unusually high. The 2003 estimated annual primary production was 1,645 g C m^{-2} y^{-1}, more than twice that observed in 2002 (763 g C m^{-2} y^{-1}), and the highest of any year from 1982-2003.

In 2003, the *Artemia* population was characterized by early development of a moderate 1st generation (18 June, 24,600 m^{-2}) followed by recruitment balancing mortality through the summer (13 August, 27,300 m^{-2}). Mean annual *Artemia* biomass increased 53% from 4.9 g m^{-2} in 2002 to 7.5 g m^{-2} in 2003, although it was still slightly below the long-term (1983-2003) average of 9.2 g m^{-2}. Recruitment of ovoviviparous (live-bearing) reproduction into the 2nd generation was low and accounts for below average mean annual biomass. Recent analysis of seasonal *Artemia* dynamics indicates small changes in algal biomass immediately following maturation of the 1st generation dramatically affects recruitment into the summer generation. A detailed cohort analysis of 2003 stage-specific *Artemia* data is being conducted. Total annual cyst production also increased over 2002 and was 4.2×10^6 m^{-2}, close to the long-term (1983-2003) mean of 4.5×10^6 m^{-2}.

Long-term integrative measures: annual primary productivity, mean annual *Artemia* biomass and egg production

The availability of dissolved inorganic nitrogen or phosphorus has been shown to limit primary production in a wide array of aquatic ecosystems. Soluble reactive phosphorus concentrations are very high (>400 µM) in Mono Lake and thus will not limit growth. However, inorganic nitrogen varies seasonally, and is often low and potentially limiting to algal growth. A positive response by Mono Lake phytoplankton in ammonium enrichments performed during different periods from 1982 to 1986 indicates inorganic nitrogen limits the standing biomass of algae (Jellison 1992, Jellison and Melack 2001). In Mono Lake, the two major sources of inorganic nitrogen are brine shrimp excretion and vertical mixing of ammonium-rich monimolimnetic water.

Algal photosynthetic activity was measured from 1982 to 1992 (Jellison and Melack, 1988, 1993a; Jellison *et al.* 1994) and clearly showed the importance of variation in vertical mixing of nutrients to annual primary production. Algal biomass during the spring and autumn decreased following the onset of meromixis and annual photosynthetic production was reduced (269–462 g C m^{-2} yr^{-1}; 1984 to 1986) compared to non-meromictic conditions (499–641 g C m^{-2} yr^{-1}; 1989 and 1990) (Jellison and Melack 1993a). Also, a gradual increase in photosynthetic production occurred even before meromixis was terminated because increased vertical fluxes of ammonium accompanied deeper mixing with ammonium-rich monimolimnetic water. Annual production was greatest in 1988 (1,064 g C m^{-2} yr^{-1}) and 2003 (1,645 g C m^{-2} y^{-1}) when the weakening of chemical stratification and eventual breakdown of meromixis in November resulted in large fluxes of ammonium into the euphotic zone.

Estimates of annual primary production integrate annual and seasonal changes in photosynthetic rates, algal biomass, temperature, and insolation. Although measurements of photosynthetic rates were discontinued after 1992, most of the variation in photosynthetic rates can be explained by regressions on environmental covariates (i.e. temperature, nutrient, and light regimes) (Jellison and Melack 1993a, Jellison *et al.* 1994). Therefore, estimates of annual primary production using previously derived regressions and current measurements of algal biomass, temperature, and insolation were made during 1993-2001. These estimates of annual primary production indicate a period of declining productivity (1994–1997) associated with the onset of meromixis and increasing chemical stratification, followed by continually increasing estimates of annual primary production through the breakdown of meromixis in 2003 when the highest estimated annual primary production occurred (1,645 g C m^{-2} y^{-1}).

The mean annual biomass of *Artemia* was estimated from instar-specific abundance and length-weight relationships for the period 1983–99 and by direct weighing from 2000 to the present. The mean annual biomass has varied from 5.3 to 17.6 g m^{-2} with a 22-yr (1983-2004) mean of 9.4 g m^{-2}. The highest estimated mean annual biomass (17.6 g m^{-2}) occurred in 1989 just after the breakdown of meromixis during a period of elevated phytoplankton nutrients (ammonium) and phytoplankton. The lowest annual estimate was in 1997 following two years of meromixis and increasing density stratification. Mean annual biomass was somewhat below the long-term mean during the first 3 years of the 1980s episode of meromixis and then above the mean the next 3 years as meromixis weakened and ended. The lowest annual biomass of *Artemia* (5.3 g m^{-2}) was observed in 1997, the second year of the 1990s episode of meromixis. However, mean annual *Artemia* biomass increased in 2003 as meromixis weakened to 7.5 g m^{-2}, and further to 11.0 g m^{-2} in 2004 following the breakdown of meromixis in late 2003.

Scientific publications

In addition to the long-term limnological monitoring, the City of Los Angeles has partially or wholly funded a number of laboratory experiments, analyses, and analytical modeling studies resulting in the following peer-reviewed research publications by University of California, Santa Barbara (UCSB) researchers.

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CHAPTER 2

METHODS

Meteorology

Continuous meteorological data is collected at the Paoha station located on the southern tip of Paoha Island. The station is approximately 30 m from the shoreline of the lake with the base located at 1948 m asl, several meters above the current surface elevation of the lake. Sensor readings are made every second and stored as either ten minute or hourly values. A Campbell Scientific CR10 datalogger records up to 3 weeks of measurements and radio frequency telemetry is used to download the data weekly.

Wind speed and direction (RM Young wind monitor) are measured at a height of 3 m above the surface of the island and are averaged over a 10-minute interval. The maximum wind speed during the ten-minute interval is also recorded. The 10-minute wind vector magnitude, wind vector direction, and the standard deviation of the wind vector direction are computed from the measurements of wind speed and wind direction and stored. Hourly measurements of average photosynthetically available radiation (PAR, 400 to 700 nm, Li-Cor 192-S) and total rainfall (Qualimetrics 601 I-B tipping bucket), and ten minute averages of relative humidity (Vaisalia HMP35C) and air temperature (Vaisalia HNV35C and Omnidata ES-060) are also made and stored.

The Cain Ranch meteorological station is located approximately 7 km southwest of the lake at an elevation of 2088 m. Throughout the 1980s, LADWP measured wind and temperature at this station. Currently UCSB maintains and records hourly averages of incoming shortwave (280 to 2800 nm; Eppley pyranometer), longwave radiation (3000 to 50000 nm; Eppley pyrgeometer) and PAR (400 to 700 nm; Li-Cor 192-S) at this site.

Sampling Regime

The limnological monitoring program for Mono Lake specifies eleven monthly surveys from February through December. In 2004, the lake was surveyed on 6 January 2003 (as weather did not permit a December 2003 sampling) and approximately mid-month February through December. An extra spring survey (2 June) and two extra September surveys were conducted due to the timing of maturation of the 1st generation of *Artemia* and interest in the interaction between grebe migration and autumn *Artemia* abundance, respectively. *Artemia*, temperature, conductivity, oxygen, ammonium, chlorophyll *a* and Secchi depth were sampled during every survey. During most summer surveys, the sampling was conducted on two consecutive days, with lakewide *Artemia* sampling conducted one day and the detailed profiles and algal productivity conducted the other.

Field Procedures

In situ profiles

Water temperature and conductivity were measured at nine buoyed, pelagic stations (2, 3, 4, 5, 6, 7, 8, 10 and 12) (Fig. 1). Profiles were taken with a high-precision, conductivity-temperature-depth profiler (CTD) (Seabird Electronics model Seacat 19) (on loan from the University of Georgia) equipped with sensors to additionally measure photosynthetically available radiation (PAR) (LiCor 191S), fluorescence (695 nm) (WETLabs WETStar miniature fluorometer), and transmissivity (660 nm) (WETlabs C-Star Transmissometer). The CTD was deployed by lowering it at a rate of ~0.25 m s^{-1}. An analysis of salinity spiking from the mismatch in the time response of the conductivity and temperature sensors indicated a 1.7 s displacement of the temperature data provided the best fit. The pumped fluorometer data required a 3.7 s shift, and other sensors (pressure, PAR, transmissivity) required a distance offset based on their relative placement. As density variations in Mono Lake can be substantial due to chemical stratification, pressure readings were converted to depth by integrating the mass of the water column above each depth.

Conductivity readings at in situ temperatures (C_t) were standardized to 25°C (C_{25}) using

$$C_{25} = \frac{C_t}{1 + 0.02124(t - 25) + 9.16 \times 10^{-5}(t - 25)^2}$$

where t is the in situ temperature. To describe the general seasonal pattern of density stratification, the contributions of thermal and chemical stratification to overall density stratification were calculated based on conductivity and temperature differences between 2 and 28 m at station 6 and the following density equation:

$$\begin{aligned}\rho(t, C_{25}) = 1.0034 + 1.335 \times 10^{-5} t - 6.20 \times 10^{-6} t^2 + 4.897 \times 10^{-4} C_{25} \\ + 4.23 \times 10^{-6} C_{25}^2 - 1.35 \times 10^{-6} t C_{25}\end{aligned}.$$

The relationship between total dissolved solids and conductivity for Mono Lake water was given by:

$$TDS(g\ kg^{-1}) = 3.386 + 0.564 \times C_{25} + 0.00427 \times C_{25}^2 .$$

To obtain TDS in grams per liter, the above expression was multiplied by the density at 25°C for a given standardized conductivity given by:

$$\rho_{25}(C) = 0.99986 + 5.2345 \times 10^{-4} C + 4.23 \times 10^{-6} C^2$$

A complete description of the derivation of these relationships is given in Chapter 4 of the 1995 Annual Report.

Dissolved oxygen was measured at one centrally located station (Station 6). Dissolved oxygen concentration was measured with a Yellow Springs Instruments temperature-oxygen meter (YSI, model 58) and probe (YSI, model 5739). The oxygen electrode is calibrated at least once each year against Miller titrations of Mono Lake water (Walker *et al.* 1970).

Water samples

Chlorophyll and nutrient samples were collected from seven to eleven depths at one centrally located station (Station 6). In addition, 9-m integrated samples for chlorophyll *a* determination and nutrient analyses were collected with a 2.5 cm diameter tube at seven stations (Station 1, 2, 5, 6, 7, 8, and 11) (Fig. 1). Samples for nutrient analyses were filtered immediately upon collection through Gelman A/E glass-fiber filters, and kept chilled and dark until returned to the lab. Water samples used for the analysis of chlorophyll *a* were filtered through a 120-µm sieve to remove all stages of *Artemia*, and kept chilled and dark until filtered in the laboratory.

Artemia samples

The *Artemia* population was sampled by one net tow from each of twelve, buoyed stations (Fig. 1). Samples were taken with a plankton net (1 m x 0.30 m diameter, 120 µm Nitex mesh) towed vertically through the water column. Samples were preserved with 5% formalin in lake water. Two additional samples were collected at Stations 1, 6, and 8, to analyze for presence of rotifers, and to archive a representative of the population. One unpreserved sample was collected at Stations 1, 2, 5, 6, 7, 8 and 11 during June - October to measure fecundity.

Laboratory Procedures

Water samples

Upon return to the laboratory samples were immediately processed for ammonium and chlorophyll determinations. Ammonium concentrations were measured immediately, while chlorophyll samples were filtered onto 47 mm Whatman GF/F filters and kept frozen until the pigments were analyzed within two weeks of collection.

Chlorophyll *a* was extracted and homogenized in 90% acetone at room temperature in the dark. Following clarification by centrifugation, absorption was measured at 750 and 663 ηm on a spectrophotometer (Milton Roy, model Spectronics 301), calibrated once a year by Milton Roy Company. The sample was then acidified in the cuvette, and absorption was again determined at the same wavelengths to correct for phaeopigments. Absorptions were converted to phaeophytin-corrected chlorophyll *a* concentrations with the formulae of Golterman (1969). During periods of low phytoplankton concentrations (<5 µg chl *a* l^{-1}), the fluorescence of extracted pigments was measured on a fluorometer (Turner Designs, model TD-700) which was calibrated using a fluorometer solid standard and an acetone blank.

Ammonium concentrations were measured using the indophenol blue method (Strickland and Parsons 1972). In addition to regular standards, internal standards were analyzed because the molar extinction coefficient is less in Mono Lake water than in distilled water. Oxygen gas was bubbled into Mono Lake water and used for standards and sample dilutions. Oxygenating saline water may help reduce matrix effects that can occur in the spectrophotometer (S. Joye, pers. comm.) When calculating concentration, the proportion of ammonium in the Mono Lake dilution water in diluted (deep) samples was subtracted from the total concentration.

Artemia samples

Artemia abundances were counted under a stereo microscope (6x or 12x power). Depending on the density of shrimp, counts were made of the entire sample or of subsamples made with a Folsom plankton splitter. Samples were split so that a count of >100 animals was obtained. Shrimp were classified into adults (instars > 12), juveniles (instars 8–11), and nauplii (instar 1–7) according to Heath's classification (Heath 1924). Adults were sexed and the adult females were divided into ovigerous and non-ovigerous. Ovigerous females included egg-bearing females and females with oocytes. Adult ovigerous females were further classified according to their reproductive mode, ovoviviparous or oviparous. A small percentage of ovigerous females were unclassifiable if eggs were in an early developmental stage. Nauplii at seven stations (Stations 1, 2, 5, 6, 7, 8, and 11) were further classified as to instars 1–7.

Live females were collected for brood size and length analysis from seven buoyed stations (Stations 1, 2, 5, 6, 7, 8, and 11) with 20-m vertical net tows and kept cool and in low densities during transport to the laboratory. Immediately on return to the laboratory, females were randomly selected, isolated in individual vials, and preserved. Brood size was determined by counting the number of eggs in the ovisac including those dropped in the vial, and egg type and shape were noted. Female length was measured from the tip of the head to the end of the caudal furca (setae not included).

Long-term integrative measures of productivity

Primary Production

Photosynthetically available radiation (PAR, 400-700 nm) was recorded continuously at Cain Ranch, seven kilometers southwest of the lake, from 1982 to 1994 and on Paoha Island in the center of the lake beginning in 1991 with a cosine-corrected quantum sensor. Attenuation of PAR within the water column was measured at 0.5-m intervals with a submersible quantum sensor. Temperature was measured with a conductivity-temperature-depth profiler (Seabird, SB19) (see Methods, Chapter 2). Phytoplankton samples were filtered onto glass fiber filters and extracted in acetone (see above).

Photosynthetic activity was measured using the radiocarbon method. Carbon uptake rates were measured in laboratory incubations within five hours of sample collection. Samples were kept near lake temperatures and in the dark during transport. Samples were incubated in a “photosynthetron”, a temperature-controlled incubator in which 28 20-ml samples are exposed to a range of light intensities from 0 to 1500 μE m^{-2} s^{-1}. After a 4-h incubation, samples were filtered through a Whatman GF/F filter at a pressure not exceeding 125 mm of Hg and rinsed three times with filtered Mono Lake water. Filters were then soaked for 12 h in 1 ml of 2.0 N HCl, after which 10 ml of scintillation cocktail were added and activity measured on a liquid scintillation counter. Chlorophyll-normalized light-limited (α^B) and saturated ($P_m{}^B$) parameters were determined via non-linear least-squared fitting to a hyperbolic tangent equation: $P^B = P_m{}^B \tanh\left(\dfrac{\alpha^B I}{P_m{}^B}\right)$ where I is the light intensity and P^B is the measured chlorophyll-specific uptake of carbon.

Estimates of daily integral production were made using a numerical interpolative model (Jellison and Melack 1993a). Inputs to the model include the estimated photosynthetic parameters, insolation, the vertical attenuation of photosynthetically available irradiance and vertical water column structure as measured by temperature at 1 m intervals and chlorophyll a from samples collected at 4–6 m intervals. Chlorophyll-specific uptake rates based on temperature were multiplied by ambient chlorophyll a concentrations interpolated to 1-m intervals. The photosynthetically available light field was calculated from hourly-integrated values at Paoha meteorological station, measured water column attenuation, and a calculated albedo. The albedo was calculated based on hourly solar declinations. All parameters, except insolation that was recorded continuously, were linearly interpolated between sampling dates. Daily integral production was calculated by summing hourly rates over the upper 18 m.

Artemia biomass and reproduction

Average daily biomass and annual cyst and naupliar production provide integrative measures of the *Artemia* population allowing simple comparison among years. Prior to 2000, *Artemia* biomass was estimated from stage specific abundance and adult length data, and weight-length relationship determined in the laboratory simulating in situ conditions of food and temperature (see Jellison and Melack 2000 for details). Beginning in 2000, biomass was determined directly by drying and weighing of *Artemia* collected in vertical net tows.

The resulting biomass estimates are approximate because actual instar-specific weights may vary within the range observed in the laboratory experiments. However, classifying the field samples into one of the three categories will be more accurate than using a single instar-specific weight-length relationship. Because length measurements of adult females are routinely made, they were used to further refine the biomass estimates. The adult female weight was estimated from the mean length on a sample date and one of the three weight-length regressions determined in the laboratory development experiments. As the lengths of adult males are not routinely determined, the average ratio of male to female lengths determined from individual measurements on 15 dates from 1996 and 1999 was used to estimate the average male length of other dates.

Naupliar and cyst production was calculated using a temperature-dependent brood interval, ovigery, ovoviviparity versus oviparity, fecundity, and adult female abundance data from seven stations on each sampling date.

CHAPTER 3

RESULTS AND DISCUSSION

The breakdown of an 8-yr period of persistent chemical stratification was concluded with holomixis (complete vertical mixing) in mid-November 2003. Even though enhanced vertical mixing during 2003 had reduced the amount of nutrients still remaining beneath the chemocline, holomixis resulted in heightened upper mixed-layer concentrations of nitrogen in early 2004. High concentration of nitrogen, the limiting nutrient in Mono Lake, resulted in high primary productivity and unusual *Artemia* dynamics. Thus, both 2003 and 2004 represent transition years between meromictic (persistent chemical stratification) and monomictic (annual mixing regime with one period of holomixis) mixing regimes.

Here, we describe the limnological conditions observed during 2004, analyze the causes of the observed unusual brine shrimp (*Artemia*) dynamics, and calculate and compare several long-term integrative measures of ecosystem productivity.

Meteorological Data

Wind Speed and Direction

Mean daily wind speed varied from 0.1 – 9.6 m s^{-1} over the year, with an overall annual mean of 3.1 m s^{-1} (Fig. 2). This annual mean is nearly identical to the 3.2 m s^{-1} annual mean observed in 2001, 2002, and 2003. The daily maximum 10-min averaged wind speeds averaged 2.6 times mean daily wind speeds. The maximum recorded gust (35.5 m s^{-1}, 80 mph) was during an afternoon storm on 28 June with sustained winds (10-min mean) of 23.8 m s^{-1}(Fig. 2). The mean monthly wind speed varied from 2.1 to 4.1 m s^{-1} (coefficient of variation, 18%). This was similar to 2002 when the mean monthly wind speed varied only from 2.2 to 3.5 m s^{-1}, and less than observed in 2003 when it varied from a low of 1.4 m s^{-1} in January to 5.1 m s^{-1} in April (coefficient of variation, 66%). As observed in the past, winds were predominately from the southwest.

Air Temperature

Mean daily air temperatures ranged from a minimum of –9.5°C on 4 January to a maximum of 22.5°C on 24 July and 11 August (Fig. 3). Air temperatures ranged from 0°C to 33°C during the summer (June through August) with a mean daily range of 8.5°C to 22.5°C and from –12°C to 13°C during the winter (December through February) with a mean daily range of -9.5°C to 6.4°C.

Incident Photosynthetically Available Radiation

Photosynthetically available radiation (400-700 nm) exhibits a regular sinusoidal curve dictated by the temperate latitude (38°N) of Mono Lake. Maximum daily values typically range from about ~15 Einsteins m^{-2} day^{-1} at the winter solstice to ~65 Einsteins m^{-2} day^{-1} in mid-June (Fig. 4). Daily values that diverge from the curve indicate overcast or stormy days. During 2004, the annual mean was 37.5 Einsteins m^{-2} day^{-1}, with daily values ranging from 2.0 Einsteins m^{-2} day^{-1} on 28 December to 65.5 Einsteins m^{-2} day^{-1}

on 8 June. The 2004 annual mean was between those observed in 2002 (39.9 Einsteins m^{-2} day^{-1}) and 2003 (35.0 Einsteins m^{-2} day^{-1}).

Relative Humidity and Precipitation

Mean daily relative humidity followed a general pattern of high values (mostly 60-80%) in January, decreasing to lows (mostly 30-50%) in April through August, and increasing to 60-80% through December (Fig. 5). Several periods of increased relative humidity occurred during the summer, most notably during mid-August. The yearly mean was 54.3%, almost identical to the 54% observed in 2003.

During 2004, annual precipitation, collected at Paoha meteorological station was 102.7 mm (4.04 in) (Fig. 6), almost identical to 2003 (101.1 mm). Total precipitation was higher than in 2001 and 2002 (87.9 mm and 69.1 mm, respectively). The largest precipitation events occurred in February and October-November. The largest events occurred on 8 November (11.9 mm) and 19 October (10.3 mm). The week long period of lower daily insolation (PAR) observed in August corresponded to five minor precipitation events totaling 3.9 mm. The detection limit for the tipping bucket gage is 1 mm of water. As the tipping bucket is not heated, the instrument is less accurate during periods of freezing due to sublimation of ice and snow.

Surface Elevation

In 2004, the surface elevation of Mono Lake rose ~0.5 ft from the winter low of 6381.3 ft asl (USGS datum) in early January 2004 to 6381.8 ft asl in early March (Fig. 7). The surface elevation fluctuated less than 0.1 ft from March through early July, after which it gradually declined to 6380.7 ft in December. Thus, a net annual decline of 0.6 ft in surface elevation occurred in 2004, similar to previous declines of 0.7, 0.8, 0.8, and 0.7 ft observed in 2000, 2001, 2002, and 2003, respectively.

Temperature

The annual pattern of thermal stratification in Mono Lake results from seasonal variations in climatic factors (e.g. air temperature, solar radiation, wind speed, humidity) and their interaction with density stratification arising from the timing and magnitude of freshwater inputs. The annual pattern of seasonal thermal stratification observed during 1990–94 is typical of large temperate lakes, with the lake being vertically isothermal during holomixis in the late autumn through early winter. This pattern was altered during two episodes of meromixis (1982–88 and 1995–03) due to the lack of mixing associated with vertical salinity gradients and the absence of winter holomixis (Fig. 7). Following the breakdown of meromixis in late 2003, the annual pattern of thermal stratification returned to that associated with a monomictic annual mixing regime.

January represents a period of low biological activity due to cold water temperatures, low light levels, and absence of *Artemia*. January surveys are only conducted when unusual circumstances warrant it and weather permitting. This year, we conducted a reduced survey on 20 January, primarily to monitor oxygenation of the lake and *Artemia* hatching following the breakdown of meromixis in late 2003. Following the episode of meromixis in the 1980s, the spring hatch of *Artemia* was delayed due to low oxygen concentrations extending into February 1989.

On 20 January 2004 the water column was well-mixed and water column temperatures had cooled from 5.7 °C in mid-December to 2.8-3.3 °C (Fig. 8, Table 1). On the survey date, slight stratification and marginally cooler (2.8-3.0 °C) temperatures existed in the upper 5 m. The lake continued to cool through late winter with water temperatures reaching 2.6–3.0 °C by 24 February. These annual minimum temperatures are within the range observed in recent years: 3.3, 1.5, 2.2, and 3.6 °C in February 2000, 2001, 2002, 2003, respectively.

A seasonal thermocline was beginning to form by the 19 March survey with near surface waters (0–2.5 m) warming to 7.2–8.5 °C. Beneath this shallow thermocline water temperatures decreased to 3.0 °C at 7.5 m and remained between 2.6 and 3.0 °C near the bottom. Epilimnetic (mixed-layer) temperatures increased through summer reaching just over 20°C by mid-August. April (8–10.5°C) and May (12.2–12.8°C) epilimnetic temperatures were slightly above normal and contributed to rapid development of the 1st generation of *Artemia* (see later section).

A pronounced summer thermocline existed between 11 and 13 m through the summer. This thermocline deepened to 14 m in September and further to 16 m by mid-October. Autumn “turnover” or holomixis occurred between the 14 October and 19 November surveys as indicated by near isothermal conditions (8.0-8.8°C) observed throughout most of the water column (6 m to the bottom) on the November survey. Slightly cooler temperatures were present in the upper 5 m. Water temperatures continued to decline to 5.0-5.3°C on 14 December.

Conductivity and Salinity

Salinity, expressed as total dissolved solids, can be calculated from conductivity measurements corrected to a reference temperature (25 °C, see Methods). Because total dissolved solids are conservative at the current salinities in Mono Lake, salinity fluctuates with volume due to changes in the balance between freshwater inputs (streams and precipitation) and evaporative losses.

In January 2004, conductivity was uniform at 83.3–83.4 mS cm^{-1} below 10 m depth and slightly less and variable (83.0-83.3 mS cm^{-1}) above 10 m (Fig. 9, Table 2). Early winter and spring freshwater inputs as reflected by the 0.5-ft increase surface elevation resulted in a slight decrease throughout the water column which persisted through summer. Evaporative concentration during the second half of the year resulted in epilimnetic conductivities increasing to 83.9–84.0 mS cm^{-1} by October. Holomixis in November diluted the mixolimnetic conductivities with slightly less saline hypolimnetic water resulting in the uniform conductivity of 83.7-83.8 mS cm^{-1} in December. Thus, there was a small (0.5 mS cm^{-1}) increase over the year from ~83.3 to 83.8 mS cm^{-1}or from ~80.0 to 80.6 g kg^{-1}. There has been an overall decrease in salinity from 89.4 g kg^{-1} in December 1994 to 80.6 g kg^{-1} in December 2004 or ~10% decline.

Density Stratification: Thermal and Chemical

The large seasonal variation in freshwater inflows associated with a temperate climate and year-to-year climatic variation have led to complex patterns of seasonal density stratification over the last 25 years. Much of the year-to-year variation in the plankton dynamics observed at Mono Lake can be attributed to marked differences in chemical stratification resulting from variation in freshwater inflows.

Given the winter period of holomixis and low runoff in 2004, the density stratification was predominately due to seasonal thermal stratification. Maximum density stratification occurred in June when excess density increased from 68.1 g l^{-1} in the surface water to 72.6 g l^{-1} in the hypolimnion (Table 3). A comparison of the density differences between 2 and 32 m due to thermal versus chemical stratification indicates that the magnitude of density stratification due to temperature was approximately 2.5 times larger than those due to chemical stratification (Fig. 10, Table 4). Chemical stratification contributed to water column stability during the first half of the year and lessened overall stability during late summer as upper waters became more saline than those below.

Transparency and Light Attenuation

In Mono Lake, variation in transparency is predominately due to changes in algal biomass. Standing algal biomass reflects the balance between all growth and loss processes. Thus, variation in transparency as measured by Secchi depth often reflects the detailed development of the *Artemia* population as much as any changes in nutrient availability and primary productivity.

In 2004, average lakewide transparency during winter and autumn were among the lowest observed (Fig. 11, Table 5). The average lakewide Secchi depth was 0.7–0.8 m from January through April and 0.9 m during October through December. The high algal biomass present during these periods reflects ample nutrients (e.g. ammonia) and low grazing pressure. Development of the large spring generation of *Artemia* led to a sharp decrease in phytoplankton and an increase in transparency during late May when Secchi depth increased from 2.1 m on 15 May to 10 m on 12 June. The 2004 midsummer Secchi depths lie between the extremes observed during the past 25 years.

Secchi depth is an integrative measure of light attenuation within the water column. Because absorption is exponential with depth, the long-term variation in Secchi depth is most appropriately viewed on a logarithmic scale. The annual pattern of Secchi depths during 2004 was within the range observed during the past 25 years (Fig. 12).

The attenuation of PAR within the water column varies seasonally, primarily as a function of changes in algal biomass. In 2004, the depth of the euphotic zone, operationally defined as the depth at which only 1% of the surface insolation is present, varied from a low of 3-4 m during the spring and autumn phytoplankton blooms to 16 m during midsummer (Fig. 13).

Dissolved Oxygen

Dissolved oxygen concentrations are primarily a function of salinity, temperature, and the balance between photosynthesis and overall community respiration. In the euphotic zone of Mono Lake, dissolved oxygen concentrations are typically highest during the spring algal bloom. As the water temperature and *Artemia* population increase through the spring, dissolved oxygen concentrations decline. Beneath the euphotic zone, bacterial and chemical processes deplete the oxygen once the lake stratifies. During meromictic periods, the monimolimnion (the region beneath the persistent chemocline) remains anoxic throughout the year.

Holomixis following extended periods of meromixis in both 1988 and 2003 resulted in complete de-oxygenation of the water column. By December 2003, dissolved oxygen concentrations had increased to 1.7 mg l^{-1} throughout the water column. We conducted a January survey in 2004 to determine whether oxygenation had proceeded to a degree which would not impact the spring hatching of *Artemia.* Dissolved oxygen concentrations were above 3 mg l^{-1} in the lower water column and increased to above 6 mg l^{-1} above 5 m depth (Table 6). Thus, there was unlikely to have been any measurable impact on hatching.

Dissolved oxygen concentrations in the upper water column increase further to above 11 mg l^{-1} by mid March (Fig. 14, Table 6). Midsummer epilimnetic concentrations were 2.1 to 5.4 mg l^{-1} with the lowest values observed during the mid-June survey when an exceptionally large spring population of *Artemia* matured. Mixolimnetic concentrations were somewhat higher (4.0–5.7 mg l^{-1}) during October–December.

The anoxic zone (depth below which dissolved oxygen concentrations are <0.5 mg l^{-1}) varied from below 30 m in March and April to 17 m during summer and 15 m during September. The deep water dissolved oxygen concentrations were above 3 mg l^{-1} on the December survey and up to 5.7 mg l^{-1} in the upper mixed-layer.

Nutrients (ammonium)

Nitrogen is the primary limiting macronutrient in Mono Lake as phosphate is in super-abundance (350-450 µM) throughout the year (Jellison *et al.* 1994). External inputs of nitrogen are low relative to recycling within the lake (Jellison and Melack 1993). Ammonium concentrations in the euphotic zone reflect the dynamic balance between excretion by shrimp, uptake by algae, upward vertical fluxes through thermo- and chemocline(s), release from sediments, ammonia volatilization, and small external inputs. Because a large portion of particulate nitrogen, in the form of algal debris and *Artemia* fecal pellets, sink to the bottom and are remineralized to ammonium in the hypolimnion (or monimolimnion during meromixis), vertical mixing controls much of the internal recycling of nitrogen.

During the breakdown of an extended period of meromixis in November 2003, large amounts of ammonia were mixed uniformly throughout the water column resulting in a concentration of ~25 µM. In January 2004, ammonia concentrations were still high (20.6-29.3 µM) throughout much of the water column but had decreased to 9.8 µM near the surface reflecting uptake by active phytoplankton growth (Fig. 15, Table 7). By

March, a large spring bloom of phytoplankton reduced ammonia concentrations to 0.5–1.1 µM in the upper 9-m integrated samples. While beneath the mixed-layer, ammonia increased near linearly from 15.8 µM at 12 m to 36.4 µM at 35 m. Epilimnetic ammonia concentrations were further reduced to near zero at 2 and 8 m at the central station 6 by mid-April, but varied from 1.4-2.3 µM in 9-m integrated samples taken across the lake.

Higher euphotic zone ammonium concentrations during June through August result from *Artemia* ammonium excretion and decreased algal uptake accompanying *Artemia* grazing and lower standing algal biomass. While this seasonal feature is observed during both meromictic and monomictic conditions, it is generally larger during monomictic periods. During 2004, epilimnetic (upper mixed-layer) ammonia concentrations increased markedly (8.1–24.4 µM) during May through July as an exceptionally large 1st generation of *Artemia* reduced the algal biomass effectively converting particulate N to ammonia via excretion. Epilimnetic concentrations then decreased as the *Artemia* population declined and the autumn phytoplankton bloom developed.

Deep water (24, 28, and 35 m) concentrations of ammonia increased from 25.4–29.3 µM in January to 80-97 µM by late summer (September-October) prior to autumn holomixis. Following holomixis, ammonia concentrations at station 6 were 10.5 µM near surface increasing to 25.7 µM at the bottom.

Soluble reactive phosphate concentrations remain several orders of magnitude above those that are saturating for phosphate uptake by phytoplankton. Thus, seasonal variation is not expected to significantly affect the plankton dynamics.

Phytoplankton (algal biomass and fluorescence)

The phytoplankton community, as characterized by chlorophyll *a* concentration, shows pronounced seasonal variation (Table 8, Fig. 16). In January 2004, chlorophyll *a* concentration was 73.3 µg chl *a* liter^{-1} at 2 m at station 6 and averaged 61 µg chl *a* liter^{-1} in the 9-m integrated samples taken at seven stations across the lake. At the centrally located station 6, chlorophyll concentrations ranged from 43.1–54 µg chl *a* liter^{-1} between 8 m and the bottom. Chlorophyll *a* increased in February and March. On the March survey chlorophyll concentration was 95-110 µg liter^{-1} in the upper 9-m integrated samples of the water column, except at the shallow station 11 where it was lower, 67 µg liter^{-1}. The lower value at station 11 likely reflects *Artemia* grazing as spring hatching of *Artemia* is most pronounced in the shallow gently sloping sediments of the lake.

As the spring *Artemia* population matured, algal biomass decreased. April concentrations ranged from 54 to 71 µg chl *a* liter^{-1} in the upper 9-m integrated samples and were high (47.7–66.9 µg liter^{-1}) throughout the water column at the central station 6. Algal biomass then declined abruptly in May and June. May lakewide mean chlorophyll *a* concentration, in the upper 9 m was 15 µg liter^{-1}, much lower than observed in May 2003 (78 µg liter^{-1}). Algal biomass was higher (24-26 µg liter^{-1}) at the northwest stations (1 and 2), but otherwise ranged from 8 to 15 µg liter^{-1} across the lake. Algal biomass increased with depth: 28.7 µg liter^{-1} at 12 m, 49.1 µg liter^{-1} at 16 m, and 67.2–76.1 µg liter^{-1} at 20 to 28 m.

June and July algal biomass, as measured by chlorophyll *a*, in the upper water column (<9 m) was only 0.5–2.1 µg liter^{-1}. The lessening of grazing pressure in August and September led to small increases in algal biomass prior to a large bloom in October. The autumn phytoplankton bloom reached ~50 µg liter^{-1} in October and increased further to 69.6 and 75.5 µg liter^{-1} in November and December, respectively. On the December survey, chlorophyll exceeded 56 µg liter^{-1} throughout the water column. In December, 83% of chlorophyll was from the <5 µm size class or the small green alga, *Picocystis salinarum*. Deep (20–28 m) chlorophyll concentrations were high throughout the year ranging from 37.2 to 76.1 µg liter^{-1}.

Prominent mid-depth chlorophyll maxima observed during the previous episode of meromixis were largely absent in 2004. However, i*n situ* fluorescence profiles indicated minor peaks at 16-18 m during July and August profiles (Fig. 17).

Artemia Population Dynamics

Hatching of over-wintering cysts, and maturation and decline of 1st generation

A small number (815 ±221 m^{-2}) of 1st instar nauplii were present on the 20 January survey. However, abundant 1st-instar *Artemia* nauplii present on the 24 February survey indicated spring hatching had begun and suffered no delay due to lowered oxygen concentrations following the breakdown of meromixis (Table 9a, Fig. 18). The February lakewide mean naupliar *Artemia* abundance was 47,324 (±37,826) m^{-2}, all 1st naupliar instars. The large standard error on this date arises from the very high abundance observed at the only eastern stationed sampled on this date (station 7). Threatening winter weather conditions prevented sampling other eastern stations. Winter Hatching is usually more pronounced on the eastern side of the lake and abundance at station 7 was 197,666 m^{-2}. Naupliar abundance in March 2004 was the highest March value observed (68,746 m^{-2}) since sampling began in 1979. Nauplii abundance was exceptionally high at the eastern nearshore stations 11 and 12 (>140,000 m^{-2}) and overall eastern sector abundance was 101,569 (±21280) m^{-2}. Instars 1 (32.4%), 2 (58.3%), and 3 (9.3 %) were present (Table 10).

Above normal water temperatures and abundant food led to high survivorship and rapid maturation of the 1st generation of *Artemia*. By April, adult lakewide abundance was 22,052 (±4416) m^{-2} and higher than ever observed during April (Fig. 19). During 2003, no adults were present in April and only 1715 (±415) m^{-2} adults were present a month later in May. Adult abundance increased to 63,528 (±7289) m^{-2} on 14 May and 75,466 (±6321) m^{-2} on 2 June before declining slightly to 72,300 (±5966) m^{-2} on the 15 June survey. Although adult males and females were present in approximately equal abundance in mid-May, the proportion of females declined to 39% of adults by 15 June. This decline in the proportion of females is typical as female mortality is usually higher than male mortality.

Beginning in June, adult numbers declined throughout July–August at an average rate of 2.2% d^{-1}. In late August, we were notified (T. Hansen, pers. commun.) of bloom conditions at the lake. We therefore conducted a supplemental survey on 1 September to investigate. A sudden decrease in adult *Artemia* accompanied by a pronounced algal bloom had occurred. Lakewide mean algal biomass had increased to 21 µg liter^{-1} and the transparency dropped to 1.64 (±0.07) m. On 14 September only 8,303 (±1127) m^{-2} adults remained. Another supplemental survey was conducted on 29 September to further examine this autumn decline. From mid-August onwards the rate of decline was faster (6% d^{-1}) with virtually no adults remaining in November and December.

Ovoviviparous reproduction and the second generation

In April, although adult females were abundant, there were no ovigerous (egg-bearing) females (Table 11a, b). Even later on the 14 May survey, only 4.4 % of adult females were carrying eggs. As so many females appeared to be ready to begin reproduction, an additional survey was conducted on 2 June to determine the magnitude of the expected pulse of ovoviviparous (live-bearing) reproduction. However, only 13.8% of adult females were ovigerous on 2 June and all these were producing cysts. Two weeks later on the 15 June survey, ovigerity had still only increased to 13.3% (Table 11c, Fig. 20) with just 1.6% of ovigerous females reproducing ovoviviparously (carrying live young). Ovigerity increased to 32% in July and then to above 82% during August and September before declining in autumn. Ovoviviparity remained low (<2%) throughout the summer with only a brief increase to 7.3% in mid-September.

Ovoviviparous reproduction depends on the ambient food levels and the age of the individual. *Artemia* produce multiple broods and ovoviviparous reproduction occurs, if at all, almost exclusively with the first brood, rarely occurring in an individual's second brood. The low rates of ovoviviparous reproduction observed through most of the summer correspond with low food levels accompanying an exceptionally abundant first generation of adults. Only following the pronounced early September algal bloom was there a significant pulse of ovoviviparous reproduction. Although low rates of ovoviviparous reproduction are more typical of low food conditions found during meromictic years, a similar pattern was observed in 1988 when an exceptionally large 1st generation of adults was also observed.

Individual fecundity (eggs $brood^{-1}$) depends on the size of the individual and ambient food levels. Mean lakewide fecundity ranged from 17 to 35 eggs $brood^{-1}$ throughout June, July, and August before increasing to 90 to 111 as the autumn bloom developed in September and October (Table 12, Fig. 20). These ranges are consistent with observed food levels and lie within the range observed in other years. Lakewide mean adult female size was 9.5–9.9 mm in June and July and increased to 10.0–12.0 mm during August through October.

Although the percentage of females reproducing ovoviviparously in June were very low, the second peak in the abundance of 1st instars observed on 2 June (20,788 ± 3,976 m^{-2}) is indicative of ovoviviparous reproduction. However, the absence of any instars 3–5 during June and July (Table 10) and any second peak in adult *Artemia* indicate few of these individuals were maturing to be recruited into the adult population. The presence of all early instars, albeit at low numbers, during September when algal biomass had increased indicates low levels of recruitment into the adult population despite the overall trend of declining abundance.

Analysis of long-term monitoring data of plankton dynamics reveals a 4-fold variation in summer peak abundance of adult brine shrimp. The summer population consists of overlapping generations of individuals, those hatched in spring from over-wintering cysts and those produced ovoviviparously during June-July. A persistent feature of the seasonal pattern of *Artemia* abundance is that during years with smaller or delayed spring generations much larger summer populations develop. This occurs despite relatively small year-to-year differences in ovoviviparous reproduction. Detailed stage-specific analysis indicates near cessation of development in early instars and increased mortality when algal biomass declines to below 1 µg chlorophyll a l^{-1}. During years with smaller or delayed first generations, algal biomass declines more slowly to these critical concentrations and adult recruitment is markedly enhanced.

The magnitude and temporal pattern of *Artemia* abundance in 2004 expands the range of observed dynamics (Fig.19). The 1st generation was significantly larger and earlier than any other years from 1981 through the present. The large 1st generation depleted food levels resulting in low reproductive output and absence of significant recruitment into the second generation. Thus, while the 1st generation was the largest observed the autumn abundances were among the lowest observed. The early and abundant 1st generation had a significant positive effect on gull reproduction. A significant percentage of nesting gulls on the Negit islets had clutch sizes of three in 2004 (P. Wrege, pers. commun.), an unusual occurrence.

Artemia Population Statistics, 1979-2004

Year to year variation in climate, hydrological conditions, vertical stratification, food availability, and possibly salinity have led to large inter-year differences in *Artemia* dynamics. During years when the first generation was small due to reduced hatching, high mortality, or delayed development, (1981, 1982, and 1989) the second generation peak of adults was 2–3 times the long term average (Table 13, Fig. 21). Seasonal peak abundances were also significantly higher (1.5–2 times the mean) in 1987 and 1988 as the 1980s episode of meromixis weakened and nutrients that had accumulated beneath the chemocline were transported upward and during 2004 following breakdown of the 1990s episode of meromixis. However, in most years the seasonal peaks of adult abundance were similar (30–40,000 m^{-2}) and the seasonal (1 May to November 30) mean of adult abundance is relatively constant (14–37,000 m^{-2}). The overall mean seasonal abundance of adult *Artemia* from 1979 to 2004 was ~19,900 m^{-2}. During this 26-yr record, mean seasonal abundance was lowest in 2000 (~10,500 m^{-2}) and 2002 (~11,600 m^{-2}) and highest in 1982 (~36,600 m^{-2}) and 1989 (~36,400 m^{-2}). In 2004, mean seasonal abundance increased markedly from ~13,800 m^{-2} in 2003 to ~32,000 m^{-2} in 2004.

During most years, the seasonal distribution of adult abundance was roughly normal or lognormal. However, in several years the seasonal abundance was not described well by either of these distributions. Therefore, the abundance-weighted centroid of temporal occurrence was calculated to compare overall seasonal shifts in the timing of adult abundance. The center of the temporal distribution of adults varied from day 180 (28 June) to 252 (9 September) in the 26-yr record from 1979 to 2004 (Table 13, Fig. 22). During five years when there was a small spring hatch (1980–83, and 1989) the overall temporal distribution of adults was much later (24 August – 9 September) and during 2004 the exceptionally large and early 1st generation shifted the seasonal temporal distribution much earlier to 28 June.

Long term integrative measures of productivity

Planktonic primary production

Photosynthetic rates were determined by laboratory radiocarbon uptake measurements from 1982-1992 (Jellison and Melack 1988, 1993b) and combined with an interpolative model of chlorophyll, temperature, and in situ photosynthetically-available light (PAR) to estimate annual productivity. While radiocarbon uptake measurements were not conducted from 1993-2001, a significant fraction of the chlorophyll-specific variance in maximum (P_m^B) and light-limited uptake rates (α^B) is explained by temperature (Jellison and Melack 1988, 1993b) and estimates of primary production in subsequent years were made employing measurements of light, chlorophyll, temperature and estimates of P_m^B and $\alpha^{B.}$ As 1989 and 1990 had elevated ammonia concentrations due to the breakdown of meromixis, regressions were performed on just 1991 and 1992 for use in subsequent years. The exponential equation:

$$P_m^B = 0.237 \text{ x } 1.183^T \qquad n=42,\ r^2=0.86$$

where T is temperature (°C) explained 86% of the overall variation. As found in previous analyses (Jellison and Melack 1993b), there was a strong correlation between light-limited and light-saturated rates. A linear regression on light-saturated rates explained 82% of the variation in light-limited rates:

$$\alpha^B = 2.69 + (1.47 \times P_m^B) \qquad n=42,\ r^2=0.82$$

Both light-limited and light-saturated carbon uptake rates reported here are within the range reported in other studies (Jellison and Melack 1993b).

In 1995, rising lake levels and greater salinity stratification reduced the vertical flux of nutrients and may have affected the photosynthetic rates, but previous regression analyses (Jellison and Melack 1993b) using an extensive data set collected during periods of different nutrient supply regimes indicated little of the observed variance in photosynthetic rates can be explained by simple estimates of nutrient supply. The differences in annual phytoplankton production throughout the period, 1982–1992, resulted primarily from changes in the amount of standing biomass; year to year changes in photosynthetic parameters during the years they were measured (1983–92) were not correlated with annual production. Thus, we suggested the above regressions might explain most of the variance in photosynthetic rates and provide a reasonable alternative to frequent, costly field and laboratory measurements using radioactive tracers.

In 2001, new “photosynthetrons” (see Methods, Chapter 2) were constructed and direct measurements of carbon uptake were resumed to determine photosynthetic parameters. The new “photosynthetrons” provide more light levels and better control and measurement of the incubator’s light and temperature. Thus, more accurate measurements of P_m^B and α^B are possible and carbon uptake experiments are now routinely conducted with a sample from the upper mixed layer (2 m) and a sample from a depth near the bottom of the epilimnion (10-16 m). These measurements enable annual productivity changes associated with varying nutrient regimes or changing phytoplankton composition to be estimated more accurately than during 1993 to 2001 when P_m^B and α^B were estimated from previously derived regressions.

During 2004, fourteen carbon uptake experiments were conducted with natural phytoplankton assemblages from either the mixed-layer or near the bottom of the epilimnion (Table 14). Chlorophyll-specific maximum carbon uptakes (P_m^B) rates and light-limited rates (α^B) were determined for each sample by fitting a hyperbolic tangent curve to the data using least-squares nonlinear estimation. Chlorophyll-specific maximum carbon uptakes (P_m^B) rates ranged from 0.25 g C g Chl a^{-1} h^{-1} on 19 March to 16.7 g C g Chl a^{-1} h^{-1} on 18 August (Table 14, Fig. 23), while light-limited rates (α^B) ranged from 1.0 to 38.7 g C g Chl a^{-1} $Einst^{-1}$ m^2 (Table 14).

Using the interpolative model to integrate the photosynthetic parameters with in situ temperature, chlorophyll, and light resulted in annual productivity estimates of 864 g C m^{-2} during 2004 (Table 15, Fig. 24). The maximum uptakes rates are primary a function of temperature and thus the seasonal pattern and magnitudes were roughly similar during 2002–2004 (Fig. 25A). The most notable differences occurred in August when the maximum uptake rate was much lower in 2002 and higher in 2004. Changes in standing algal biomass are a dominant factor in variation in daily and annual primary productivity (Jellison and Melack 1988, 1993b). While the seasonal trends were similar during 2002–04, the higher algal biomass throughout the summer in 2003 (Fig. 25B, Fig. 26) led to the highest estimates of annual primary productivity in the entire period of record. Daily production rates ranged from 0.4 to 5.3 g C m^{-2} in 2002, 1.4 to 10.8 g C m^{-2} in 2003, and 0.1 to 7.7 g C m^{-2} in 2004. Daily photosynthetic rates were higher during 2003 compared to 2002 throughout January through September.

Annual primary production in 2004 was 57% higher than the long-term mean (1982–2004) of 550 g C m^{-2} (Table 15, Fig. 27). Estimates from previous years ranged from 149 in 1997 to 1645 g C m^{-2} in 2003. In 1988, a 5-yr episode of meromixis was breaking down and nutrients which had accumulated beneath the thermocline were mixed into the euphotic zone leading to higher algal biomass and estimated annual production of 1064 g C m^{-2}. During 2003, an 8-yr period of chemical stratification broke down and significant amounts of ammonia were entrained into the mixed layer. Estimates of planktonic photosynthesis at Mono Lake are generally higher than other hypersaline lakes in the Great Basin: Great Salt Lake (southern basin), 145 g C m^{-2} yr^{-1} (Stephens and Gillespie 1976); Soap Lake, 391 g C m^{-2} yr^{-1} (Walker 1975); and Big Soda, 500 g C m^{-2} yr^{-1} (350 g C m^{-2} yr^{-1} phototrophic production) (Cloern *et al.* 1983).

Artemia biomass and egg production

Artemia biomass was estimated from instar-specific population data and previously derived weight-length relationships for the period 1982–99. Variation in weight-length relationships among sampling dates was assessed from 1996–99 and found to lead to errors of up to 20% in the annual estimates. Thus, in 2000 we implemented direct drying and weighing of vertical net tow samples collected explicitly for biomass determinations.

In 2004, *Artemia* biomass increased from 0.0 during January to 37.3 g dry weight m^{-2} on 2 June before declining to near zero following holomixis in mid-November. The

2004 mean annual biomass of 11.0 g m^{-2} was 46% higher than observed in 2003 and 18% above the long-term (1982-2004) mean of 9.4 g m^{-2} (Table 15, Fig. 28)

The highest estimated mean annual *Artemia* biomass (17.6 g m^{-2}) occurred in 1989 just after the breakdown of meromixis during a period of elevated phytoplankton nutrients (ammonium) and phytoplankton. Mean annual biomass was somewhat below the long-term mean during the first 3 years of the 1980s episode of meromixis and then above the mean during the next 3 years as meromixis weakened and ended. Except for lower values in 2002 and in 1997, *Artemia* biomass has remained relatively constant since 1993 and was only slightly higher during 1990–92. The slightly higher value in 2004 is associated with the largest spring generation observed.

In Mono Lake, oviparous (cyst) reproduction is always much higher than ovoviviparous (live-bearing) reproduction (Fig. 29, Table 15). In 2004, total annual naupliar production (0.04 x 10^6 m^{-2}) was much lower than the long-term mean of 0.24 x 10^6 m^{-2} and among the lowest observed. Total annual cyst production in 2004 (2.62 x 10^6 m^{-2}) was also below the long-term mean of 4.4 x 10^6 m^{-2} cysts.

Long-term trends in inter-year variation in algal biomass and adult Artemia abundance

The long-term record of plankton dynamics in Mono Lake show marked seasonal and inter-year variation (Figs. 30–31). Multi-year episodes of meromixis have markedly increased the inter-year variation compared to periods of monomixis in which an annual winter period of holomixis occurs. The large variations caused by changes in mixing regime preclude the possibility of determining the effects of variation in salinity from any small subset of years. Here, we examine the long-term trends in algal biomass in the upper water column (< 10 m) and adult *Artemia* biomass from 1982 through 2004.

The seasonal trend can be removed by calculating a yearly moving average. Because the intervals between sampling dates varied among years, daily values were derived by linearly interpolating between sample dates prior to calculating a 365-day moving average. Thus, each point represents a moving average of 365 days centered on the point. The seasonally-filtered chlorophyll *a* concentrations (Fig. 30, heavy line) show the marked impact of the two episodes of meromixis. The seasonally-filtered mean chlorophyll ranged from a minimum of 2.8 µg $liter^{-1}$ following the onset of meromixis in 1984 to 50.3 µg $liter^{-1}$ in late 2003 as the longer 1980s episode of meromixis ended. This represents an 18-fold difference. The seasonally-filtered adult *Artemia* abundance show much less inter-year variation (Fig. 31) with mean abundance ranging from 6,200 m^{-2} in 2000 to 24,000 m^{-2} in 1982 or about a 4-fold difference. Thus, inter-year variation in seasonally-filtered adult *Artemia* abundance is much less than that of algal abundance. Also, it is clear that any long-term trend in either measure is either small or obscured by the inter-year variation due to varying mixing regimes.

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Table 1. Temperature (ºC) at Station 6, January – December 2004.

	Dates											
Depth (m)	1/20	2/24	3/19	4/24	5/15	6/16	7/14	8/18	9/15	10/14	11/19	12/14
1	2.93	3.21	8.45	10.55	12.66	17.93	18.51	20.49	18.48	14.48	7.90	-
2	2.89	2.86	7.19	8.61	12.69	17.41	18.99	20.70	18.46	14.36	7.90	5.53
3	2.77	2.94	4.09	8.22	12.81	17.19	19.05	20.74	18.47	14.28	7.82	5.47
4	2.86	2.99	3.85	8.18	12.74	17.28	19.00	20.69	18.47	14.23	7.82	5.43
5	2.97	2.95	3.63	8.08	12.15	17.99	18.98	20.44	18.47	14.22	7.86	5.41
6	3.01	2.86	3.31	8.02	11.62	17.41	18.94	20.27	18.47	14.20	8.04	5.41
7	3.03	2.72	3.04	7.90	11.32	16.71	18.91	20.12	18.48	14.20	8.33	5.41
8	3.11	2.69	2.97	7.72	11.02	15.91	18.90	19.97	18.48	14.23	8.41	5.42
9	3.25	2.67	2.90	7.68	10.72	15.08	18.88	19.73	18.50	14.29	8.53	5.42
10	3.26	2.65	2.82	7.72	10.30	14.43	18.43	19.04	18.52	14.43	8.57	5.36
11	3.25	2.63	2.78	6.95	9.97	13.06	18.27	18.65	18.35	14.45	8.43	5.36
12	3.26	2.62	2.79	6.25	9.61	11.76	15.22	16.96	18.12	14.41	8.44	5.38
13	3.26	2.61	2.77	5.65	8.16	9.47	12.27	14.63	17.90	14.30	8.46	5.38
14	3.21	2.60	2.75	4.73	7.43	8.04	10.29	12.44	16.36	14.30	8.47	5.37
15	3.20	2.60	2.72	4.13	6.79	7.42	8.56	9.31	10.59	14.29	8.46	5.37
16	3.22	2.61	2.69	3.90	5.96	6.63	7.07	7.53	8.39	14.28	8.46	5.36
17	3.22	2.61	2.67	3.48	4.75	6.22	6.64	6.63	7.16	11.11	8.45	5.36
18	3.19	2.63	2.66	3.34	4.17	5.73	6.13	6.29	6.40	8.98	8.43	5.34
19	3.16	2.65	2.65	3.14	3.93	5.06	5.41	5.42	5.81	6.49	8.44	5.32
20	3.15	2.67	2.65	3.02	3.76	4.49	5.15	5.27	5.61	6.38	8.45	5.32
21	3.14	2.67	2.67	2.99	3.66	4.20	4.82	5.13	5.43	6.35	8.46	5.32
22	3.11	2.66	2.70	2.98	3.50	4.09	4.64	4.88	5.28	5.85	8.47	5.32
23	3.10	2.68	2.69	2.97	3.44	4.03	4.53	4.81	5.03	5.82	8.51	5.31
24	3.08	2.70	2.69	2.92	3.35	3.87	4.44	4.81	4.81	5.82	8.54	5.31
25	3.04	2.72	2.69	2.85	3.25	3.79	4.26	4.62	4.70	5.83	8.56	5.32
26	3.02	2.72	2.71	2.82	3.24	3.74	4.25	4.46	4.61	5.81	8.60	5.32
27	3.00	2.72	2.69	2.83	3.12	3.64	4.15	4.36	4.47	5.40	8.71	5.32
28	2.98	2.73	2.69	2.81	3.09	3.60	4.04	4.23	4.43	5.30	8.77	5.32
29	2.96	2.74	2.70	2.81	3.08	3.56	3.98	4.17	4.39	5.22	8.78	5.32
30	2.92	2.70	2.69	2.81	3.07	3.51	3.94	4.15	4.35	5.22	8.79	5.32
31	2.90	2.69	2.71	2.81	3.04	3.47	3.90	4.13	4.31	5.21	8.66	5.32
32	2.90	2.69	2.73	2.81	3.02	3.43	3.88	4.10	4.28	5.21	8.57	5.31
33	2.90	2.68	2.77	2.81	3.01	3.39	3.80	4.08	4.26	5.21	8.51	5.31
34	2.90	2.68	2.78	2.81	2.98	3.37	3.65	4.06	4.25	4.87	8.37	5.30
35	2.90	2.70	2.78	2.81	2.98	3.34	3.62	4.03	4.24	4.97	8.28	5.30
36	2.90	2.72	2.78	-	2.96	3.31	-	4.01	-	4.94	8.18	5.30
37	2.90	2.72	-	-	2.96	3.30	-	-	-	4.86	8.07	5.30

Table 2. Conductivity (mS cm^{-1} at 25ºC) at Station 6, January – December 2004.

	Dates											
Depth (m)	1/20	2/24	3/19	4/24	5/15	6/16	7/14	8/18	9/15	10/14	11/19	12/14
1	83.0	82.7	81.5	82.7	82.3	81.9	82.6	83.0	83.7	83.9	83.4	-
2	83.2	82.7	81.8	82.6	82.5	81.6	82.7	83.1	83.7	83.9	83.4	83.6
3	83.3	82.5	82.6	82.5	82.6	81.8	82.8	83.1	83.7	83.9	83.4	83.6
4	83.1	82.7	82.5	82.6	82.7	82.4	82.8	83.1	83.7	83.9	83.4	83.7
5	83.2	82.9	82.5	82.6	82.6	82.8	82.8	83.2	83.7	83.9	83.5	83.7
6	83.2	83.1	82.5	82.6	82.7	82.7	82.8	83.2	83.7	83.9	83.6	83.7
7	83.2	83.3	82.5	82.5	82.7	82.7	82.8	83.2	83.7	83.9	83.7	83.7
8	83.1	83.2	82.5	82.6	82.6	82.7	82.8	83.3	83.7	84.0	83.7	83.8
9	83.0	83.2	82.6	82.6	82.6	82.6	82.7	83.2	83.7	84.0	83.7	83.8
10	83.1	83.1	82.7	82.6	82.6	82.6	82.7	83.1	83.7	84.1	83.7	83.7
11	83.3	83.0	82.7	82.4	82.6	82.5	82.7	83.0	83.7	84.1	83.7	83.8
12	83.3	83.0	82.7	82.5	82.5	82.4	82.4	82.7	83.7	84.0	83.7	83.8
13	83.4	83.0	82.7	82.6	82.5	82.2	82.3	82.8	83.7	84.0	83.7	83.8
14	83.4	83.0	82.7	82.5	82.6	82.5	82.3	82.7	82.8	84.0	83.7	83.8
15	83.3	83.0	82.8	82.6	82.6	82.6	82.3	82.7	82.4	84.0	83.7	83.8
16	83.3	83.0	82.8	82.6	82.6	82.6	82.3	82.6	82.8	84.0	83.7	83.8
17	83.3	83.0	82.8	82.7	82.6	82.6	82.5	82.7	82.4	83.2	83.7	83.8
18	83.3	83.0	82.8	82.7	82.6	82.6	82.6	82.7	82.4	82.7	83.7	83.8
19	83.3	83.0	82.9	82.8	82.7	82.7	82.6	82.7	82.6	82.9	83.8	83.8
20	83.3	83.0	82.9	82.8	82.8	82.7	82.6	82.7	82.7	83.1	83.8	83.8
21	83.3	83.0	82.9	82.8	82.9	82.7	82.6	82.8	82.7	83.1	83.8	83.8
22	83.3	83.0	82.9	82.9	82.9	82.8	82.6	82.7	82.6	83.1	83.8	83.8
23	83.3	83.1	82.9	82.8	82.9	82.8	82.7	82.8	82.7	83.2	83.8	83.8
24	83.3	83.1	83.0	82.9	82.9	82.8	82.6	82.8	82.7	83.2	83.8	83.8
25	83.3	83.1	83.0	82.9	83.0	82.8	82.6	82.8	82.8	83.2	83.8	83.8
26	83.3	83.1	83.0	82.9	83.0	82.8	82.6	82.8	82.8	83.2	83.8	83.8
27	83.3	83.1	83.0	82.9	83.0	82.8	82.6	82.9	82.8	83.0	83.9	83.8
28	83.3	83.1	83.0	82.9	83.1	82.8	82.7	82.9	82.9	83.0	83.9	83.8
29	83.3	83.1	83.0	82.9	83.1	82.8	82.7	82.9	82.9	83.2	83.9	83.8
30	83.3	83.1	83.0	82.9	83.1	82.8	82.7	82.9	82.9	83.2	83.9	83.8
31	83.3	83.1	83.0	82.9	83.1	82.8	82.7	82.9	82.9	83.2	83.9	83.8
32	83.3	83.1	83.0	82.9	83.1	82.8	82.7	82.9	83.0	83.2	83.9	83.8
33	83.3	83.1	83.0	83.0	83.1	82.9	82.7	82.9	82.9	83.2	83.9	83.8
34	83.3	83.1	83.0	83.0	83.1	82.9	82.8	82.9	83.0	83.2	84.0	83.8
35	83.3	83.1	83.0	83.0	83.1	82.9	82.8	82.9	83.0	83.3	84.0	83.8
36	83.3	83.1	83.0	-	83.1	82.9	-	82.9	-	83.3	84.0	83.8
37	83.3	83.1	-	-	83.1	82.9	-	-	-	83.2	84.0	83.8

Table 3. Excess density (g l^{-1}) at Station 6, January – December 2004.

	Dates											
Depth (m)	1/20	2/24	3/19	4/24	5/15	6/16	7/14	8/18	9/15	10/14	11/19	12/14
1	72.9	72.4	70.1	71.1	70.1	68.1	68.8	68.6	70.0	71.5	72.5	-
2	73.0	72.5	70.7	71.4	70.3	67.9	68.8	68.6	70.0	71.5	72.5	73.2
3	73.2	72.3	72.2	71.4	70.4	68.3	68.8	68.6	70.0	71.6	72.5	73.2
4	73.0	72.5	72.1	71.4	70.5	69.0	68.8	68.6	70.0	71.6	72.6	73.3
5	73.1	72.7	72.1	71.5	70.6	69.2	68.8	68.8	70.0	71.6	72.6	73.3
6	73.0	73.0	72.3	71.5	70.8	69.2	68.8	68.8	70.0	71.6	72.7	73.3
7	73.1	73.2	72.2	71.4	70.9	69.4	68.8	69.0	70.0	71.6	72.7	73.3
8	72.9	73.1	72.2	71.6	70.9	69.7	68.8	69.0	70.0	71.7	72.7	73.4
9	72.8	73.1	72.4	71.6	70.9	69.8	68.8	69.0	70.0	71.7	72.8	73.4
10	72.9	73.1	72.5	71.6	71.1	70.0	68.9	69.1	70.1	71.7	72.7	73.4
11	73.2	72.9	72.5	71.5	71.1	70.3	69.0	69.2	70.1	71.7	72.7	73.4
12	73.2	72.9	72.5	71.7	71.1	70.4	69.6	69.4	70.2	71.7	72.8	73.4
13	73.2	72.9	72.5	71.9	71.3	70.7	70.3	70.2	70.3	71.7	72.8	73.4
14	73.2	72.9	72.6	72.0	71.7	71.4	70.7	70.6	69.7	71.7	72.8	73.4
15	73.2	72.9	72.6	72.2	71.8	71.6	71.1	71.3	70.7	71.7	72.8	73.4
16	73.2	72.9	72.6	72.2	71.9	71.7	71.4	71.6	71.7	71.7	72.8	73.4
17	73.2	72.9	72.7	72.4	72.1	71.8	71.7	71.9	71.4	71.6	72.8	73.4
18	73.2	72.9	72.7	72.5	72.2	71.9	71.8	72.0	71.7	71.4	72.8	73.4
19	73.2	72.9	72.7	72.5	72.4	72.1	72.0	72.1	72.0	72.2	72.8	73.4
20	73.2	72.9	72.8	72.6	72.5	72.3	72.1	72.2	72.1	72.4	72.8	73.4
21	73.2	72.9	72.8	72.6	72.6	72.3	72.1	72.2	72.2	72.4	72.8	73.4
22	73.2	72.9	72.8	72.7	72.6	72.4	72.1	72.3	72.1	72.5	72.8	73.4
23	73.2	72.9	72.8	72.6	72.6	72.4	72.2	72.3	72.2	72.6	72.8	73.4
24	73.2	72.9	72.8	72.7	72.7	72.5	72.2	72.3	72.2	72.6	72.8	73.4
25	73.2	72.9	72.8	72.7	72.8	72.5	72.2	72.3	72.3	72.6	72.8	73.4
26	73.2	72.9	72.8	72.7	72.8	72.5	72.2	72.4	72.4	72.6	72.9	73.4
27	73.2	72.9	72.9	72.7	72.9	72.5	72.2	72.5	72.4	72.5	72.9	73.4
28	73.2	73.0	72.9	72.8	72.9	72.5	72.3	72.5	72.5	72.5	72.9	73.4
29	73.2	73.0	72.9	72.8	72.9	72.5	72.3	72.5	72.5	72.7	72.9	73.4
30	73.2	73.0	72.9	72.8	72.9	72.6	72.3	72.6	72.5	72.7	72.9	73.4
31	73.2	73.0	72.9	72.8	73.0	72.6	72.4	72.6	72.5	72.8	72.9	73.4
32	73.2	73.0	72.9	72.8	73.0	72.6	72.4	72.6	72.6	72.8	73.0	73.4
33	73.2	73.0	72.9	72.8	73.0	72.6	72.4	72.6	72.6	72.8	73.0	73.4
34	73.2	73.0	72.9	72.8	73.0	72.6	72.4	72.6	72.6	72.8	73.1	73.4
35	73.2	73.0	72.9	72.8	73.0	72.6	72.5	72.6	72.6	72.9	73.1	73.4
36	73.2	73.0	72.9	-	73.0	72.6	-	72.6	-	72.9	73.2	73.5
37	73.2	73.0	-	-	73.0	72.6	-	-	-	72.8	73.1	73.5

Table 4. Temperature, conductivity, and density stratification (kg m^{-3}) at Station 6, January – December 2004.

Date	Temperature		Conductivity		Density Difference due to		
	2 m	32 m	2 m	32 m	Temperature	Conductivity	Both
1/20	2.89	2.90	83.20	83.30	-0.001	0.119	0.118
2/24	2.86	2.69	82.70	83.10	0.023	0.475	0.498
3/19	7.19	2.73	81.80	83.00	0.711	1.416	2.127
4/24	8.61	2.81	82.60	82.90	0.981	0.355	1.336
5/15	12.69	3.02	82.50	83.10	1.894	0.708	2.601
6/16	17.41	3.43	81.60	82.80	3.171	1.405	4.576
7/14	18.99	3.88	82.70	82.70	3.628	0.000	3.628
8/18	20.70	4.10	83.10	82.90	4.191	-0.235	3.956
9/15	18.46	4.28	83.70	83.00	3.405	-0.826	2.580
10/14	14.36	5.21	83.90	83.20	2.020	-0.828	1.192
11/19	7.90	8.57	83.40	83.90	-0.135	0.593	0.458
12/14	5.53	5.31	83.60	83.80	0.037	0.238	0.275

Table 5. Secchi Depths (m), January – December 2004.

	Dates											
Station	1-6	2-21	3-19	4-19	5-15	6-12	7-17	8-13	9-18	10-17	11-14	12-16
Western Sector												
1	-	-	0.60	0.75	0.90	10.30	10.8	10.5	3.4	0.8	0.85	-
2	0.80		0.70	0.70	0.90	10.20	11.5	11.6	3.2	0.8	0.9	0.9
3	-	0.80	0.90	-	1.50	9.30	10.5	11.3	3.25	0.8	0.85	0.75
4	-	0.75	0.70	0.85	2.60	9.50	10.5	11.3	3.4	0.9	0.85	0.9
5	-	0.90	0.85	0.70	2.50	10.30	9.5	9.9	2.8	0.95	0.85	-
6	0.80	0.80	0.65	0.70	2.00	9.80	10.2	6.0	2.9	0.9	0.88	0.9
Avg.	0.80	0.82	0.75	0.75	1.68	9.92	10.56	10.92	3.21	0.85	0.86	0.85
S.E.	0.00	0.03	0.05	0.03	0.31	0.18	0.27	0.86	0.10	0.03	0.01	0.04
n	2	4	6	5	6	6	6	6	6	6	6	4
Eastern Sector												
7	0.85	0.90	0.80	0.75	3.30	10.50	9.8	9.3	3.55	0.8	0.88	0.9
8	-	-	0.70	0.80	2.40	10.70	9.9	7.3	3.25	0.9	0.89	-
9	-	-	0.50	0.75	1.90	9.90	11.4	4.2	3	0.9	1	-
10	-	-	0.60	0.80	2.30	10.30	10.5	10.6	2.6	1.1	0.9	-
11	0.90	-	0.60	0.85	2.50	8.40	9.5	-	3	0.85	0.89	0.9
12	-	-	0.85	0.80	2.75	10.20	10.5	10.3	3.4	0.9	0.85	0.9
Avg.	0.88	0.90	0.68	0.79	2.52	10.00	10.27	8.34	3.13	0.91	0.90	0.90
S.E.	0.02	-	0.05	0.02	0.19	0.34	0.28	1.19	0.14	0.04	0.02	0.00
n	2	1	6	6	6	6	6	5	6	6	6	3
Total Lakewide												
Avg.	0.84	0.83	0.70	0.77	2.13	9.95	10.38	9.30	3.15	0.88	0.88	0.88
S.E.	0.02	0.03	0.04	0.02	0.21	0.18	0.19	0.73	0.08	0.02	0.01	0.02
n	4	5	12	11	12	12	12	11	12	12	12	7

Table 6: Dissolved Oxygen (mg l^{-1}) at Station 6, January – December 2004.

	Dates											
Depth (m)	1/20	2/24	3/19	4/24	5/15	6/16	7/14	8/18	9/15	10/14	11/19	12/14
0	7.1	7.9	10.2	5.9	4.6	2.9	3.3	4.7	4.6	4.3	4.7	5.6
1	7.4	8.5	11.5	6.2	4.3	2.7	3.5	4.8	4.8	4.2	4.7	5.7
2	7.6	8.8	11.6	7.4	4.3	2.8	3.6	4.9	4.8	4.1	4.7	4.9
3	7.9	8.8	9.5	6.2	4.0	2.8	3.6	5.0	4.6	4.1	4.2	4.3
4	6.0	8.3	8.9	5.6	2.9	2.5	3.7	5.2	4.6	4.0	4.1	3.9
5	5.9	6.9	7.7	5.2	3.5	2.1	3.6	5.4	4.5	3.8	3.2	3.4
6	5.7	6.3	6.4	5.0	4.0	2.2	3.6	5.0	4.5	3.5	2.1	3.3
7	5.0	5.8	5.7	4.9	4.1	2.1	3.6	4.8	4.5	3.3	1.7	3.1
8	4.6	5.7	5.0	4.8	3.8	2.1	3.6	3.5	4.5	3.6	1.6	2.9
9	4.6	5.6	5.0	4.8	3.4	1.7	3.5	2.9	4.4	3.5	1.4	2.8
10	4.2	5.7	5.0	4.8	3.3	1.1	2.9	2.6	4.3	3.7	1.3	2.9
11	4.2	-	4.9	4.1	3.1	0.7	2.1	1.9	4.1	3.7	2.0	3.1
12	4.0	5.8	4.9	3.7	3.1	0.7	1.0	1.5	3.5	3.6	2.1	3.0
13	3.8	-	4.7	3.2	2.7	0.8	1.0	1.1	3.3	3.5	2.1	3.0
14	4.2	5.8	4.5	2.3	1.9	0.8	0.9	1.0	2.7	3.5	2.1	3.0
15	3.9	-	4.4	2.0	1.5	0.8	0.8	1.1	<0.5	3.5	2.0	3
16	3.6	5.7	4.0	1.6	1.2	0.7	0.8	1.0	<0.5	3.5	2.0	3.0
17	3.4	-	4.0	1.3	0.6	<0.5	<0.5	<0.5	-	1.6	2.0	3.1
18	3.3	4.9	3.9	1.4	<0.5	<0.5	<0.5	<0.5	-	<0.5	2.0	3.1
19	3.3	4.6	3.8	1.4	<0.5	-	<0.5	<0.5	-	<0.5	1.8	3.1
20	3.3	4.4	3.5	1.2	<0.5	-	<0.5	-	-	<0.5	1.8	3.2
21	-	4.2	3.5	1.2	<0.5	-	<0.5	-	-	-	1.8	3.2
22	3.3	4.2	3.1	0.9	-	-	-	-	-	-	1.7	3.1
23	-	4.1	2.9	0.9	-	-	-	-	-	-	1.7	3.1
24	3.3	-	2.9	1.0	-	-	-	-	-	-	1.4	-
25	-	3.8	2.6	1.1	-	-	-	-	-	-	1.4	3.1
26	3.3	-	2.2	1.2	-	-	-	-	-	-	1.3	-
27	-	3.7	2.2	0.9	-	-	-	-	-	-	1.2	3.2
28	3.3	-	2.5	0.7	-	-	-	-	-	-	0.91	-
29	-	3.5	2.3	0.6	-	-	-	-	-	-	0.76	-
30	3.0	-	2.1	<0.5	-	-	-	-	-	-	<0.5	3.2
31	-	3.5	2.3	<0.5	-	-	-	-	-	-	<0.5	-
32	-	-	1.7	<0.5	-	-	-	-	-	-	<0.5	3.2
33	-	3.3	0.6	<0.5	-	-	-	-	-	-	<0.5	-
34	-	-	0.5	0.5	-	-	-	-	-	-	<0.5	-
35	-	2.9	0.5	0.5	-	-	-	-	-	-	-	-
36	-	-	0.5	0.5	-	-	-	-	-	-	-	-

Table 7. Ammonia (µM) at Station 6, January – December 2004.

	Dates											
Depth (m)	1/20	2/24	3/19	4/24	5/15	6/16	7/14	8/18	9/15	10/14	11/19	12/14
1	-	-	-	-	-	-	-	-	-	-	-	-
2	9.8	3.5	0.5	0.0	8.1	19.3	15.7	4.2	0.7	1.1	2.4	10.5
3	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-
8	20.6	13.3	0.8	0.1	12.4	19.1	15.6	8.7	0.6	3.4	16	17
9	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-
12	22.4	13.1	15.8	1.0	10.7	22.7	24.4	19.8	3.3	2.5	13	16.2
13	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-
16	24.3	14.6	19.0	20.2	20.6	25.2	27.1	20.6	48.2	3	13.6	16.6
17	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	40.7	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-	-
20	25.4	17.5	24.8	27.3	33.7	41.1	55.3	66.4	54.9	73.5	26.5	20.2
21	-	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-	-
24	26.5	20.3	28.9	32.9	35.4	48.2	58.9	75.3	65.8	80.3	19.6	21.1
25	-	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-	-
28	24.4	23.4	30.8	35.6	35.9	40.7	58.1	75.3	80.2	80.7	20.8	22.9
29	-	-	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-	-	-	-
35	29.3	24.4	36.4	37.0	37.6	55.8	70.3	83.8	97	87.1	35.1	25.7

Table 8. Chlorophyll *a* (mg/m^3) at Station 6, January – December 2004.

	Dates											
Depth (m)	1/20	2/24	3/19	4/24	5/15	6/16	7/14	8/18	9/15	10/14	11/19	12/14
1	-	-	-	-	-	-	-	-	-	-	-	-
2	73.3	105.2	89.4	47.7	7.0	0.5	2.0	2.8	2.8	51.3	69.6	75.5
3	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-
8	54.0	91.0	94.9	66.9	7.6	0.6	2.1	3.5	2.9	49.3	52.6	65.1
9	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-	-
12	50.5	77.9	66.4	63.4	28.7	3.4	0.8	2.6	4.9	45.3	60.0	60.8
13	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	-
16	49.0	65.2	44.6	64.8	49.1	12.3	7.1	10.2	30.2	45.9	55.4	56.1
17	-	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	33.6	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-	-
20	47.9	62.3	67.3	62.6	75.0	60.7	38.5	42.5	44.5	37.2	58.1	58.9
21	-	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-	-
24	47.8	63.9	60.2	62.8	67.2	66.9	45.5	50.6	49.4	38.2	52.3	58.6
25	-	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-	-
28	43.1	54.2	60.4	57.0	76.1	68.3	41.6	41.2	39.9	36.3	48.3	58.2

Table 9a. *Artemia* lake and sector means, 2004.

	Instars		adult	adult	adult	adult	adult	adult	adult	
	1-7	8-11	male	fem ?	fem e	fem c	fem n	fem tot	total	total
Lakewide Mean:										
1/20	815	0	0	0	0	0	0	0	0	815
2/24	47,324	0	0	0	0	0	0	0	0	47,324
3/18	68,746	0	0	0	0	0	0	0	0	68,746
4/23	49,108	17,559	7163	0	14,889	0	0	14,889	22,052	88,719
5/14	20,711	3,970	33,722	1,207	28,491	107	0	29,805	63,528	88,209
6/2	18,967	3,353	42,495	1,288	28,437	3,246	0	32,971	75,466	97,787
6/15	11,482	1,932	43,810	376	24,708	3,353	54	28,491	72,300	85,714
7/15	5,674	134	28,196	1,771	13,052	4,319	0	19,142	47,338	53,145
8/17	3,427	7	25,312	785	1,878	8,357	81	11,100	36,412	39,846
9/1	2,777	0	10,785	194	161	3,454	47	3,856	14,641	17,418
9/14	2,223	174	6,767	64	90	1,281	101	1,536	8,303	10,701
9/29	2,230	148	3,798	23	162	693	23	902	4,700	7,077
10/13	857	96	1,802	18	195	226	3	443	2,245	3,198
11/18	233	22	77	3	42	0	0	45	122	377
12/14	256	20	20	0	20	0	0	20	40	316
Western Sector Mean:										
1/20	634	0	0	0	0	0	0	0	0	634
2/24	9,738	0	0	0	0	0	0	0	0	9,738
3/18	35,922	0	0	0	0	0	0	0	0	35,922
4/23	47,780	17,089	8,317	0	13,843	0	0	13,843	22,160	87,029
5/14	17,009	3,702	27,579	1,073	25,111	161	0	26,345	53,924	74,634
6/2	22,213	1,932	44,212	1,502	26,828	2,683	0	31,013	75,225	99,370
6/15	13,628	1,502	44,588	215	20,013	2,844	0	23,072	67,659	82,790
7/15	5,687	268	34,179	912	14,433	3,058	0	18,404	52,582	58,538
8/17	2,146	13	36,298	1,006	3,313	6,989	27	11,335	47,632	49,792
9/1	1,664	0	11,469	134	201	2,589	54	2,978	14,447	16,110
9/14	2,388	174	7,713	54	80	1,368	67	1,570	9,282	11,844
9/29	1,771	121	4,078	40	174	758	34	1,006	5,084	6,975
10/13	647	77	2,331	27	201	309	7	543	2,874	3,599
11/18	164	10	44	0	10	0	0	10	54	228
12/14	136	20	10	0	15	0	0	15	25	181
Eastern Sector Mean:										
1/20	996	0	0	0	0	0	0	0	0	996
2/24	197,666	0	0	0	0	0	0	0	0	197,666
3/18	101,569	0	0	0	0	0	0	0	0	101,569
4/23	50,436	18,028	6,009	0	15,936	0	0	15,936	21,945	90,409
5/14	24,413	4,239	39,866	1,341	31,871	54	0	33,266	73,132	101,784
6/2	15,721	4,775	40,778	1,073	30,047	3,810	0	34,930	75,708	96,204
6/15	9,336	2,361	43,032	537	29,403	3,863	107	33,910	76,942	88,638
7/15	5,661	0	22,213	2,629	11,670	5,580	0	19,879	42,093	47,753
8/17	4,708	0	14,326	564	443	9,725	134	10,865	25,191	29,900
9/1	3,890	0	10,101	255	121	4,319	40	4,735	14,836	18,726
9/14	2,059	174	5,822	74	101	1,194	134	1,503	7,324	9,558
9/29	2,689	174	3,518	7	151	627	13	798	4,316	7,180
10/13	1,067	114	1,274	10	188	144	0	342	1,617	2,797
11/18	302	33	111	7	74	0	0	80	191	527
12/14	416	20	33	0	27	0	0	27	60	496

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

Table 9b. Standard errors of *Artemia* sector means (Table 9a), 2004.

	Instars		adult	adult	adult	adult	adult	adult	adult	
	1-7	8-11	male	fem ?	fem e	fem c	fem n	fem tot	total	total
SE of Lakewide Mean:										
1/20	221	0	0	0	0	0	0	0	0	221
2/24	37,826	0	0	0	0	0	0	0	0	37,826
3/18	14,337	0	0	0	0	0	0	0	0	14,337
4/23	5,952	3,234	1,472		3,228	0	0	3,228	4,416	13,138
5/14	2,260	621	4,638	191	2,820	61	0	2,935	7,289	8,949
6/2	2,802	695	3,727	380	2,914	449	0	3,409	6,321	7,299
6/15	1,643	336	3,214	147	3,746	658	54	3,464	5,966	6,142
7/15	943	62	3,652	353	1,650	1,041	0	2,238	4,912	5,236
8/17	946	7	6,570	242	753	2,104	37	2,727	8,115	8,236
9/1	562		996	55	52	485	21	503	1,263	1,602
9/14	237	33	1,084	24	28	144	39	160	1,127	1,146
9/29	425	44	527	9	40	109	12	155	658	1,002
10/13	113	15	309	7	27	42	2	68	363	414
11/18	58	6	21	2	19	0	0	20	40	90
12/14	85	6	11	0	4	0	0	4	15	98
SE of Western Sector Mean:										
1/20	272	0	0	0	0	0	0	0	0	272
2/24	5,496	0	0	0	0	0	0	0	0	5,496
3/18	4,536	0	0	0	0	0	0	0	0	4,536
4/23	7,926	4,408	2,792	0	5,061	0	0	5,061	7,521	19,209
5/14	2,792	826	5,949	307	2,909	110	0	3,181	8,805	10,436
6/2	4,579	470	4,981	756	3,373	421	0	4,144	7,673	10,379
6/15	2,233	318	3,006	215	5,534	1,079	0	5,082	7,753	8,698
7/15	1,189	99	6,340	255	2,791	704	0	3,470	8,635	9,456
8/17	505	13	11,475	412	1,270	2,972	27	4,493	14,032	13,875
9/1	318		827	54	82	338	34	343	926	796
9/14	413	60	1,710	27	29	185	32	215	1,714	1,711
9/29	373	54	844	15	60	151	22	231	1,041	1,283
10/13	128	18	378	13	34	58	4	98	437	539
11/18	81	4	13	0	4	0	0	4	17	88
12/14	43	8	6	0	5	0	0	5	10	43
SE of Eastern Sector Mean:										
1/20	392	0	0	0	0	0	0	0	0	392
2/24	0	0	0	0	0	0	0	0	0	0
3/18	21,280	0	0	0	0	0	0	0	0	21,280
4/23	9,609	5,148	1,099	0	4,450	0	0	4,450	5,408	19,732
5/14	3,032	992	6,646	241	4,687	54	0	4,794	10,924	13,028
6/2	3,059	1,046	5,926	215	4,995	764	0	5,694	10,813	11,211
6/15	2,247	568	6,013	198	4,722	797	107	3,901	9,374	9,321
7/15	1,579	0	2,038	435	1,849	1,906	0	3,126	4,541	4,423
8/17	1,739	0	3,158	262	237	3,144	65	3,538	6,518	8,146
9/1	891	0	1,869	94	68	788	27	830	2,479	3,159
9/14	256	32	1,374	42	51	232	72	258	1,507	1,526
9/29	756	74	691	7	58	166	8	219	873	1,662
10/13	150	23	407	4	45	41	0	84	481	631
11/18	80	10	36	4	35	0	0	36	71	138
12/14	155	12	24	0	7	0	0	7	31	187

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

Table 9c. Percentage in different classes for Artemia sector means (Table 9a), 2004.

	Instars		adult	adult	adult	adult	adult	adult	adult	
	1-7	8-11	male	fem ?	fem e	fem c	fem n	fem tot	total	total
Lakewide (%):										
1/20	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
2/24	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
3/18	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4/23	55.4	19.8	8.1	0.0	100.0	0.0	0.0	16.8	24.9	100.0
5/14	23.5	4.5	38.2	4.1	95.6	0.4	0.0	33.8	72.0	100.0
6/2	19.4	3.4	43.5	3.9	86.2	9.8	0.0	33.7	77.2	100.0
6/15	13.4	2.3	51.1	1.3	86.7	11.8	0.2	33.2	84.4	100.0
7/15	10.7	0.3	53.1	9.3	68.2	22.6	0.0	36.0	89.1	100.0
8/17	8.6	0.0	63.5	7.1	16.9	75.3	0.7	27.9	91.4	100.0
9/1	15.9	0.0	61.9	5.0	4.2	89.6	1.2	22.1	84.1	100.0
9/14	20.8	1.6	63.2	4.1	5.9	83.4	6.5	14.4	77.6	100.0
9/29	31.5	2.1	53.7	2.6	18.0	76.8	2.6	12.7	66.4	100.0
10/13	26.8	3.0	56.4	4.1	43.9	51.1	0.8	13.8	70.2	100.0
11/18	61.8	5.7	20.4	7.4	92.6	0.0	0.0	12.0	32.4	100.0
12/14	80.8	6.3	6.3	0.0	100.0	0.0	0.0	6.3	12.7	100.0
Western Sector (%):										
1/20	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
2/24	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
3/18	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4/23	54.9	19.6	9.6	0.0	100.0	0.0	0.0	15.9	25.5	100.0
5/14	22.8	5.0	37.0	4.1	95.3	0.6	0.0	35.3	72.3	100.0
6/2	22.4	1.9	44.5	4.8	86.5	8.7	0.0	31.2	75.7	100.0
6/15	16.5	1.8	53.9	0.9	86.7	12.3	0.0	27.9	81.7	100.0
7/15	9.7	0.5	58.4	5.0	78.4	16.6	0.0	31.4	89.8	100.0
8/17	4.3	0.0	72.9	8.9	29.2	61.7	0.2	22.8	95.7	100.0
9/1	10.3	0.0	71.2	4.5	6.8	86.9	1.8	18.5	89.7	100.0
9/14	20.2	1.5	65.1	3.4	5.1	87.2	4.3	13.3	78.4	100.0
9/29	25.4	1.7	58.5	4.0	17.3	75.3	3.3	14.4	72.9	100.0
10/13	18.0	2.1	64.8	4.9	37.1	56.8	1.2	15.1	79.9	100.0
11/18	72.1	4.4	19.1	0.0	100.0	0.0	0.0	4.4	23.5	100.0
12/14	74.9	11.0	5.5	0.0	100.0	0.0	0.0	8.3	13.8	100.0
Eastern Sector (%):										
1/20	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
2/24	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
3/18	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4/23	55.8	19.9	6.6	0.0	100.0	0.0	0.0	17.6	24.3	100.0
5/14	24.0	4.2	39.2	4.0	95.8	0.2	0.0	32.7	71.9	100.0
6/2	16.3	5.0	42.4	3.1	86.0	10.9	0.0	36.3	78.7	100.0
6/15	10.5	2.7	48.5	1.6	86.7	11.4	0.3	38.3	86.8	100.0
7/15	11.9	0.0	46.5	13.2	58.7	28.1	0.0	41.6	88.1	100.0
8/17	15.7	0.0	47.9	5.2	4.1	89.5	1.2	36.3	84.3	100.0
9/1	20.8	0.0	53.9	5.4	2.5	91.2	0.8	25.3	79.2	100.0
9/14	21.5	1.8	60.9	4.9	6.7	79.5	8.9	15.7	76.6	100.0
9/29	37.5	2.4	49.0	0.8	18.9	78.6	1.7	11.1	60.1	100.0
10/13	38.1	4.1	45.6	2.9	54.9	42.2	0.0	12.2	57.8	100.0
11/18	57.3	6.3	21.0	8.3	91.7	0.0	0.0	15.2	36.3	100.0
12/14	83.7	4.0	6.7	0.0	100.0	0.0	0.0	5.4	12.2	100.0

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

The fem-?, e, c, n, percentages are of the total females

Table 10. Lakewide *Artemia* instar analysis, 2004

	Instars									
	1	2	3	4	5	6	7	8-11	adults	total
Mean:										
1/20	810	5	0	0	0	0	0	0	0	815
2/24	68,786	0	0	0	0	0	0	0	0	68,786
3/18	18,787	49,049	7,703	0	0	0	0	0	0	75,539
4/23	3,334	4,645	5,772	6,025	10,095	9,336	11,498	18,051	23,409	92,164
5/14	9,060	1,150	2,208	3,035	2,254	2,208	1,656	4,001	58,224	83,794
6/2	20,788	2,208	0	0	46	322	414	3,081	73,538	100,397
6/15	10,532	1,702	0	0	0	92	276	1,564	72,986	87,151
7/15	3,909	1,219	0	0	0	0	46	138	51,164	56,476
8/17	1,725	1,909	0	0	0	0	0	11	26,939	30,583
9/1	322	713	943	736	103	0	0	0	14,176	16,994
9/14	529	299	385	374	299	195	184	195	9,336	11,797
9/29	238	339	310	523	368	210	115	138	4,067	6,309
10/13	95	164	103	158	118	92	86	83	2,481	3,380
11/18	29	17	11	46	49	20	23	14	95	305
12/14	261	30	10	0	5	10	10	15	40	383
Standard error of mean:										
1/20	217	5	0	0	0	0	0	0	0	221
2/24	64,448	0	0	0	0	0	0	0	0	64,448
3/18	4,370	18,915	2,785	0	0	0	0	0	0	23,989
4/23	1,128	628	885	1,511	2,807	1,907	2,883	5,519	7,372	21,900
5/14	2,364	343	672	486	439	638	340	797	8,449	9,504
6/2	3,976	887	0	0	46	157	182	756	9,613	10,287
6/15	2,461	698	0	0	0	59	191	394	8,553	8,106
7/15	1,038	222	0	0	0	0	46	96	7,970	8,585
8/17	737	691	0	0	0	0	0	11	4,998	5,807
9/1	58	172	223	272	29	0	0	0	1,087	1,102
9/14	200	46	108	110	91	39	60	43	1,786	1,823
9/29	62	97	112	176	138	66	37	69	778	1,355
10/13	43	54	34	56	31	21	19	24	486	597
11/18	9	12	9	24	19	8	11	8	29	114
12/14	110	17	10	0	5	6	6	5	27	167
Percentage in different age classes:										
1/20	99.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
2/24	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100
3/18	24.9	64.9	10.2	0.0	0.0	0.0	0.0	0.0	0.0	100
4/23	3.6	5.0	6.3	6.5	11.0	10.1	12.5	19.6	25.4	100
5/14	10.8	1.4	2.6	3.6	2.7	2.6	2.0	4.8	69.5	100
6/2	20.7	2.2	0.0	0.0	0.0	0.3	0.4	3.1	73.2	100
6/15	12.1	2.0	0.0	0.0	0.0	0.1	0.3	1.8	83.7	100
7/15	6.9	2.2	0.0	0.0	0.0	0.0	0.1	0.2	90.6	100
8/17	5.6	6.2	0.0	0.0	0.0	0.0	0.0	0.0	88.1	100
9/1	1.9	4.2	5.5	4.3	0.6	0.0	0.0	0.0	83.4	100
9/14	4.5	2.5	3.3	3.2	2.5	1.7	1.6	1.7	79.1	100
9/29	3.8	5.4	4.9	8.3	5.8	3.3	1.8	2.2	64.5	100
10/13	2.8	4.8	3.1	4.7	3.5	2.7	2.5	2.5	73.4	100
11/18	9.4	5.6	3.7	15.0	16.0	6.6	7.5	4.7	31.1	100
12/14	68.3	7.8	2.6	0.0	1.3	2.6	2.6	3.9	10.5	100

Table 11a. *Artemia* reproductive summary, lake and sector means, 2004.

	Adult Females					
	Total	Ovigery	e	?	c	n
Lakewide Mean:						
4/23	14,889	0	14,889	0	0	0
5/14	29,805	1,315	28,491	1,207	107	0
6/2	32,971	4,534	28,437	1,288	3,246	0
6/15	28,491	3,783	24,708	376	3,353	54
7/15	19,142	6,090	13,052	1,771	4,319	0
8/17	11,100	9,222	1,878	785	8,357	81
9/1	3,856	3,695	161	194	3,454	47
9/14	1,536	1,445	90	64	1,281	101
9/29	902	739	162	23	693	23
10/13	443	248	195	18	226	3
11/18	45	3	42	3	0	0
12/14	20	0	20	0	0	0
Western Sector Mean:						
4/23	13,843	0	13,843	0	0	0
5/14	26,345	1,234	25,111	1,073	161	0
6/2	31,013	4,185	26,828	1,502	2,683	0
6/15	23,072	3,058	20,013	215	2,844	0
7/15	18,404	3,971	14,433	912	3,058	0
8/17	11,335	8,022	3,313	1,006	6,989	27
9/1	2,978	2,777	201	134	2,589	54
9/14	1,570	1,489	80	54	1,368	67
9/29	1,006	831	174	40	758	34
10/13	543	342	201	27	309	7
11/18	10	0	10	0	0	0
12/14	15	0	15	0	0	0
Eastern Sector Mean:						
4/23	15,936	0	15,936	0	0	0
5/14	33,266	1,395	31,871	1,341	54	0
6/2	34,930	4,883	30,047	1,073	3,810	0
6/15	33,910	4,507	29,403	537	3,863	107
7/15	19,879	8,209	11,670	2,629	5,580	0
8/17	10,865	10,423	443	564	9,725	134
9/1	4,735	4,614	121	255	4,319	40
9/14	1,503	1,402	101	74	1,194	134
9/29	798	647	151	7	627	13
10/13	342	154	188	10	144	0
11/18	80	7	74	7	0	0
12/14	27	0	27	0	0	0

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

There were no reproductive females on the first three sampling dates (1/20, 2/24, 3/18).

Table 11b. Standard errors of *Artemia* reproductive summary (Table 11a), 2004.

			Adult Females			
	Total	Ovigery	e	?	c	n
Standard Error of Lakewide Mean:						
4/23	3,228	0	3,228	0	0	0
5/14	2,935	196	2,820	191	61	0
6/2	3,409	668	2,914	380	449	0
6/15	3,464	771	3,746	147	658	54
7/15	2,238	1,308	1,650	353	1,041	0
8/17	2,727	2,247	753	242	2,104	37
9/1	503	518	52	55	485	21
9/14	160	155	28	24	144	39
9/29	155	118	40	9	109	12
10/13	68	50	27	7	42	2
11/18	20	2	19	2	0	0
12/14	4	0	4	0	0	0
Standard Error of Western Sector Mean:						
4/23	5,061	0	5,061	0	0	0
5/14	3,181	357	2,909	307	110	0
6/2	4,144	1,074	3,373	756	421	0
6/15	5,082	1,186	5,534	215	1,079	0
7/15	3,470	882	2,791	255	704	0
8/17	4,493	3,231	1,270	412	2,972	27
9/1	343	328	82	54	338	34
9/14	215	205	29	27	185	32
9/29	231	175	60	15	151	22
10/13	98	75	34	13	58	4
11/18	4	0	4	0	0	0
12/14	5	0	5	0	0	0
Standard Error of Eastern Sector Mean:						
4/23	4,450	0	4,450	0	0	0
5/14	4,794	198	4,687	241	54	0
6/2	5,694	873	4,995	215	764	0
6/15	3,901	997	4,722	198	797	107
7/15	3,126	2,225	1,849	435	1,906	0
8/17	3,538	3,346	237	262	3,144	65
9/1	830	857	68	94	788	27
9/14	258	251	51	42	232	72
9/29	219	166	58	7	166	8
10/13	84	42	45	4	41	0
11/18	36	4	35	4	0	0
12/14	7	0	7	0	0	0

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

There were no reproductive females on the first three sampling dates (1/20, 2/24, 3/18).

Table 11c. *Artemia* percentages in different reproductive categories (Table 11a), 2004.

	Adult Females					
	Total	Ovig	e	?	c	n
Lakewide Mean (%):						
4/23	100		100.0	0.0	0.0	0.0
5/14	100	4.4	95.6	91.8	100.0	0.0
6/2	100	13.8	86.2	28.4	100.0	0.0
6/15	100	13.3	86.7	9.9	98.4	1.6
7/15	100	31.8	68.2	29.1	100.0	0.0
8/17	100	83.1	16.9	8.5	99.0	1.0
9/1	100	95.8	4.2	5.3	98.7	1.3
9/14	100	94.1	5.9	4.4	92.7	7.3
9/29	100	81.9	18.0	3.2	96.7	3.3
10/13	100	56.0	43.9	7.4	98.5	1.5
11/18	100	7.4	92.6	100.0	0.0	0.0
12/14	100	0.0	100.0	0.0	0.0	0.0
Western Sector Mean (%):						
4/23	100	0.0	100.0	0.0	0.0	0.0
5/14	100	4.7	95.3	87.0	100.0	0.0
6/2	100	13.5	86.5	35.9	100.0	0.0
6/15	100	13.3	86.7	7.0	100.0	0.0
7/15	100	21.6	78.4	23.0	100.0	
8/17	100	70.8	29.2	12.5	99.6	0.4
9/1	100	93.2	6.8	4.8	98.0	2.0
9/14	100	94.8	5.1	3.6	95.3	4.7
9/29	100	82.6	17.3	4.8	95.8	4.2
10/13	100	62.9	37.1	7.8	97.9	2.1
11/18	100	0.0	100.0	0.0	0.0	0.0
12/14	100	0.0	100.0	0.0	0.0	0.0
Eastern Sector Mean (%):						
4/23	100	0.0	100.0	0.0	0.0	0.0
5/14	100	4.2	95.8	96.2	100.0	0.0
6/2	100	14.0	86.0	22.0	100.0	0.0
6/15	100	13.3	86.7	11.9	97.3	2.7
7/15	100	41.3	58.7	32.0	100.0	0.0
8/17	100	95.9	4.1	5.4	98.6	1.4
9/1	100	97.4	2.5	5.5	99.1	0.9
9/14	100	93.3	6.7	5.3	89.9	10.1
9/29	100	81.1	18.9	1.0	97.9	2.1
10/13	100	45.1	54.9	6.5	100.0	0.0
11/18	100	8.3	91.7	100.0	0.0	0.0
12/14	100	0.0	100.0	0.0	0.0	0.0

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

Total, ovigery, and e given as percentages of total number of females. ? given as percentage of ovigerous females.

Cyst and naup given as percentages of individuals with differentiated egg masses.

There were no reproductive females on the first three sampling dates (1/20, 2/24, 3/18).

Table 12. *Artemia* fecundity summary, 2004.

	#eggs/brood mean	#eggs/brood SE	%cyst	%intended	female length mean	female length SE	n
Lakewide Mean:							
6/2	32.5	1.0	0.9	0.5	9.9	0.1	7
6/15	17.2	0.5	0.9	0.6	9.6	0.0	7
7/15	21.9	0.8	1.0	0.5	9.5	0.1	7
8/17	34.7	3.8	0.9	0.5	10.3	0.2	7
9/14	90.5	3.1	0.9	0.6	11.2	0.1	7
9/29	95.8	5.7	0.9	0.4	12.1	0.1	7
10/13	110.8	9.5	1.0	0.6	12.0	0.2	6
Western Sector Mean:							
6/2	33.1	1.5	0.9	0.5	9.8	0.1	4
6/15	17.2	0.8	0.9	0.5	9.6	0.1	4
7/15	22.5	1.2	1.0	0.7	9.5	0.1	4
8/17	33.0	6.6	1.0	0.5	10.0	0.3	4
9/14	93.0	2.3	0.9	0.6	11.3	0.1	4
9/29	93.1	9.9	1.0	0.3	12.0	0.2	4
10/13	122.1	8.5	1.0	0.5	12.0	0.3	4
Eastern Sector Mean:							
6/2	31.8	1.2	1.0	0.6	9.9	0.1	3
6/15	17.2	0.6	1.0	0.7	9.6	0.0	3
7/15	21.2	0.9	1.0	0.3	9.4	0.2	3
8/17	37.1	3.0	0.9	0.5	10.5	0.1	3
9/14	87.1	6.7	0.8	0.5	11.1	0.2	3
9/29	99.5	4.4	0.9	0.6	12.1	0.1	3
10/13	88.2	11.8	1.0	0.7	12.0	0.5	2

‘n’ in last column refers to number of stations averaged.
Ten females were collected and measured from each station.

Table 13. Summary Statistics of Adult *Artemia* Abundance from 1 May through 30 November, 1979–2004.

Year	Mean	Median	Peak	Centroid*
1979	14,118	12,286	31,700	216
1980	14,643	10,202	40,420	236
1981	32,010	21,103	101,670	238
1982	36,643	31,457	105,245	252
1983	17,812	16,314	39,917	247
1984	17,001	19,261	40,204	212
1985	18,514	20,231	33,089	218
1986	14,667	17,305	32,977	190
1987	23,952	22,621	54,278	226
1988	27,639	25,505	71,630	207
1989	36,359	28,962	92,491	249
1990	20,005	16,775	34,930	230
1991	18,129	19,319	34,565	226
1992	19,019	19,595	34,648	215
1993	15,025	16,684	26,906	217
1994	16,602	18,816	29,408	212
1995	15,584	17,215	24,402	210
1996	17,734	17,842	34,616	216
1997	14,389	16,372	27,312	204
1998	19,429	21,235	33,968	226
1999	20,221	21,547	38,439	225
2000	10,550	9,080	22,384	210
2001	20,031	20,037	38,035	209
2002	11,569	9,955	25,533	200
2003	13,778	12,313	29,142	203
2004	32,044	36,909	75,466	180

*Centroid calculated as the abundance-weighted mean day of occurrence.

Table 14. Photosynthetic parameters for 2004.

Date	**Depth** (m)	**Temperature** (C)	α^B ($g\ C\ g\ Chl\ a^{-1}\ h^{-1}$)	P_m^B ($g\ C\ g\ Chl\ a^{-1}\ Einst^{-1}\ m^2$)
3/19/2004	2	7.3	1.02	0.25
4/24/2004	2	8.8	8.92	3.14
5/15/2004	2	12.5	8.69	3.25
5/15/2004	12	9.7	8.54	2.45
6/16/2004	2	17.5	38.73	9.39
6/16/2004	16	7.5	4.70	0.97
7/14/2004	2	19.5	17.30	9.11
7/14/2004	18	6	3.82	0.83
8/18/2004	2	20.5	12.69	16.71
8/18/2004	17.5	7.5	4.76	0.77
9/15/2004	2	18	3.77	3.86
10/14/2004	2	14	7.29	3.70
11/19/2004	2	7.7	7.31	2.14
12/14/2004	2	5.4	7.01	1.78

P_m^B: Chlorophyll-specific maximum carbon uptakes rates ($g\ C\ g\ Chl\ a^{-1}\ h^{-1}$)

α^B: Chlorophyll-specific light-limited uptake rates ($g\ C\ g\ Chl\ a^{-1}\ Einst^{-1}\ m^2$)

Table 15. Long term Integrative Measures of Productivity: Annual Primary Production, *Artemia* biomass and egg production (see Chapter 2 for methods), 1982-2004.

Year	**Planktonic Primary Production** (g C m^{-2} y^{-1})	***Artemia*** **Biomass** (g dry weight m^{-2})	***Artemia*** **Naupliar Production** (10^6 m^{-2})	***Artemia*** **Cyst Production** (10^6 m^{-2})
1982	1,107	-	-	-
1983	523	9.3	0.15	4.8
1984	269	7.8	0.08	3.7
1985	399	7.8	0.22	4.6
1986	462	7.7	0.44	3.0
1987	371	12.5	0.23	6.4
1988	1,064	15.2	0.21	4.7
1989	499	17.6	0.11	6.7
1990	641	11.0	1.02	6.1
1991	418	9.7	0.69	5.5
1992	435	10.2	0.26	5.8
1993	602	8.9	0.35	6.3
1994	446	8.7	0.16	5.6
1995	227	8.4	0.40	4.9
1996	221	8.2	0.05	3.6
1997	149	5.3	0.01	2.5
1998	228	8.0	0.01	2.8
1999	297	8.9	0.03	4.2
2000	484	8.2	0.08	4.0
2001	532	8.8	0.10	3.0
2002	763	4.9	0.10	2.5
2003	1,645	7.5	0.60	4.2
2004	864	11.0	0.04	2.6

*Carbon uptake measurements not conducted during 1982, 1993-2001. Estimates in these years are based on temperature, chlorophyll, light, and regressions of photosynthetic rates (P_m^B) and (α^B) versus temperature (see methods).

FIGURE CAPTIONS

Fig. 1. UCSB sampling stations at Mono Lake. Solid circles represent permanently moored buoys. Open circles represent old intermediate stations.

Fig. 2. Wind speed; daily mean and 10-min. maximum, 2004.

Fig. 3. Daily air temperature; mean, maximum, and minimum, 2004.

Fig. 4. Daily photosynthetically available radiation, 2004.

Fig. 5. Mean daily relative humidity, 2004.

Fig. 6. Daily precipitation, 2004.

Fig. 7. Mono Lake surface elevation (ft asl), 1979–04, USGS datum.

Fig. 8. Temperature (°C) at station 6, 2004.

Fig. 9. Conductivity (mS cm^{-1} corrected to 25°C) at station 6, 2004.

Fig.10. Density difference (kg m^{-3}) between 2 and 32 m at station 6 due to temperature and chemical stratification from 1991–2004.

Fig. 11. Transparency as measured by mean lakewide Secchi depth (m), 1994–04. Error bars show standard errors of the lakewide estimate based on 12-20 stations.

Fig. 12. Mean lakewide Secchi depth ($\log_{10}$ m) 1979–04.

Fig. 13. Light attenuation (% of surface) at station 6, 2004.

Fig. 14. Dissolved oxygen concentration (mg O_2 l^{-1}) at station 6, 2004. Dots denote the dates and depths of samples.

Fig. 15. Ammonium concentration (µM) at station 6, 2006. Dots denote the dates and depths of samples.

Fig. 16. Concentration of chlorophyll *a* (µg chl *a* l^{-1}) at station 6, 2004. Dots denote the dates and depths of samples.

Fig. 17. Seasonal fluorescence profiles at station 6, 2004.

Fig. 18. Lakewide *Artemia* abundance during 2004: nauplii (instars 1-7), juveniles (instars 8-11), and adults (instars 12+).

Fig. 19. Lakewide estimates of adult *Artemia* based on 3-20 stations, 1982–04 (see Methods). The mean relative error of the lakewide estimates is 20-25%.

Fig. 20. Reproductive characteristics of *Artemia* during 2004: lakewide mean abundance of total females and ovigerous females (top), percent of females ovoviviparous and ovigerous (middle), and brood size (bottom). Vertical lines are the standard error of the estimate.

Fig. 21. Summary statistics of the seasonal (1 May through 30 November) lakewide abundance of adult *Artemia*, 1979–04. Values are based on interpolated daily abundances.

Fig. 22. Temporal center of abundance-weighted centroid of the seasonal (1 May through 30 November) distribution of adult *Artemia*, 1979–04. Centroid is based on interpolated daily abundances of adult *Artemia*.

Fig. 23. Chlorophyll-specific uptake rates during March and August 2004 for samples collected from the surface mixed layer and the deep chlorophyll maximum.

Fig. 24. Chlorophyll-specific light saturated carbon uptake rate (g C g Chl^{-1} h^{1}), algal biomass (mg m^{-3}), and daily primary production (g C m^{-2}), 2004.

Fig. 25. Comparison of 2002–04 photosynthetic rates and algal biomass. A) Chlorophyll-specific specific light saturated carbon uptake rate (g C g Chl^{-1} h^{1}) B) Mixed-layer (2 m depth) chlorophyll *a* concentrations µg Chl l^{-1}.

Fig. 26. Comparison of 2002–04 daily primary production (g C m^{-2} y^{-1}) calculated with a numerical interpolative model of chlorophyll, temperature, insolation, attenuation, and photosynthetic parameters.

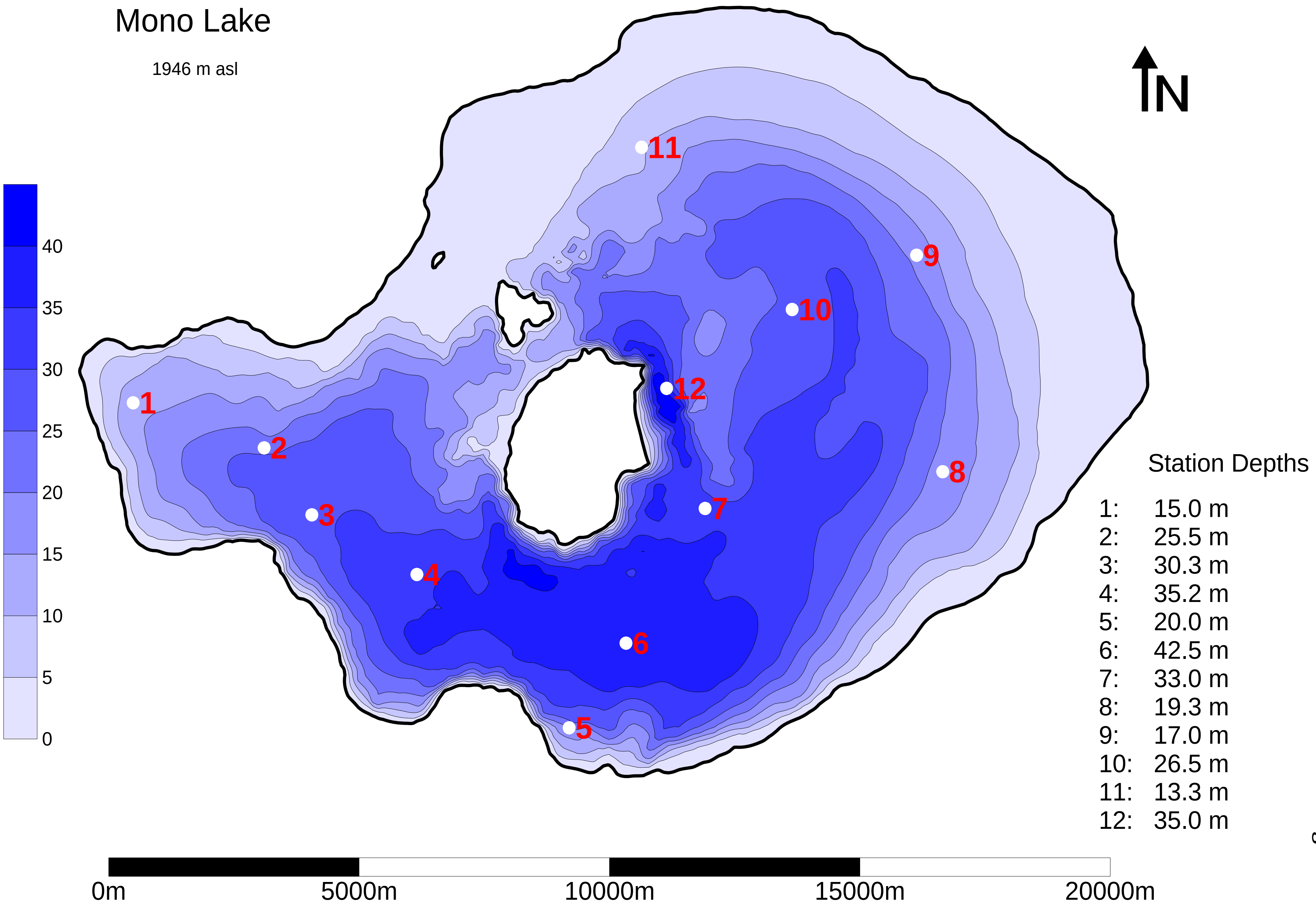
Fig. 27. Annual phytoplankton production estimates (g C m^{-2}), 1982–04.

Fig. 28. Mean annual *Artemia* biomass, 1983–04. Data for the period 1982–99 estimated from instar-specific population data and previously derived weight-length relationships. In 2000–03, *Artemia* biomass was measured directly by determining dry weights of plankton tows.

Fig. 29. Annual *Artemia* reproduction, ovoviviparous (live-bearing) and oviparous (cyst-bearing), 1983–04.

Fig. 30. Lakewide mean of mixolimnetic (<10 m) chlorophyll *a*, 1982–04. Heavy line shows seasonally filtered data formed by linearly interpolating between sampling dates to daily values and then calculating a 365-day running mean.

Fig. 31. Lakewide mean of adult *Artemia* abundance, 1982–04. Heavy line shows seasonally filtered data formed by linearly interpolating between sampling dates to daily values and then calculating a 365-day running mean.



Station Depths

1:	15.0 m
2:	25.5 m
3:	30.3 m
4:	35.2 m
5:	20.0 m
6:	42.5 m
7:	33.0 m
8:	19.3 m
9:	17.0 m
10:	26.5 m
11:	13.3 m
12:	35.0 m

Figure 1

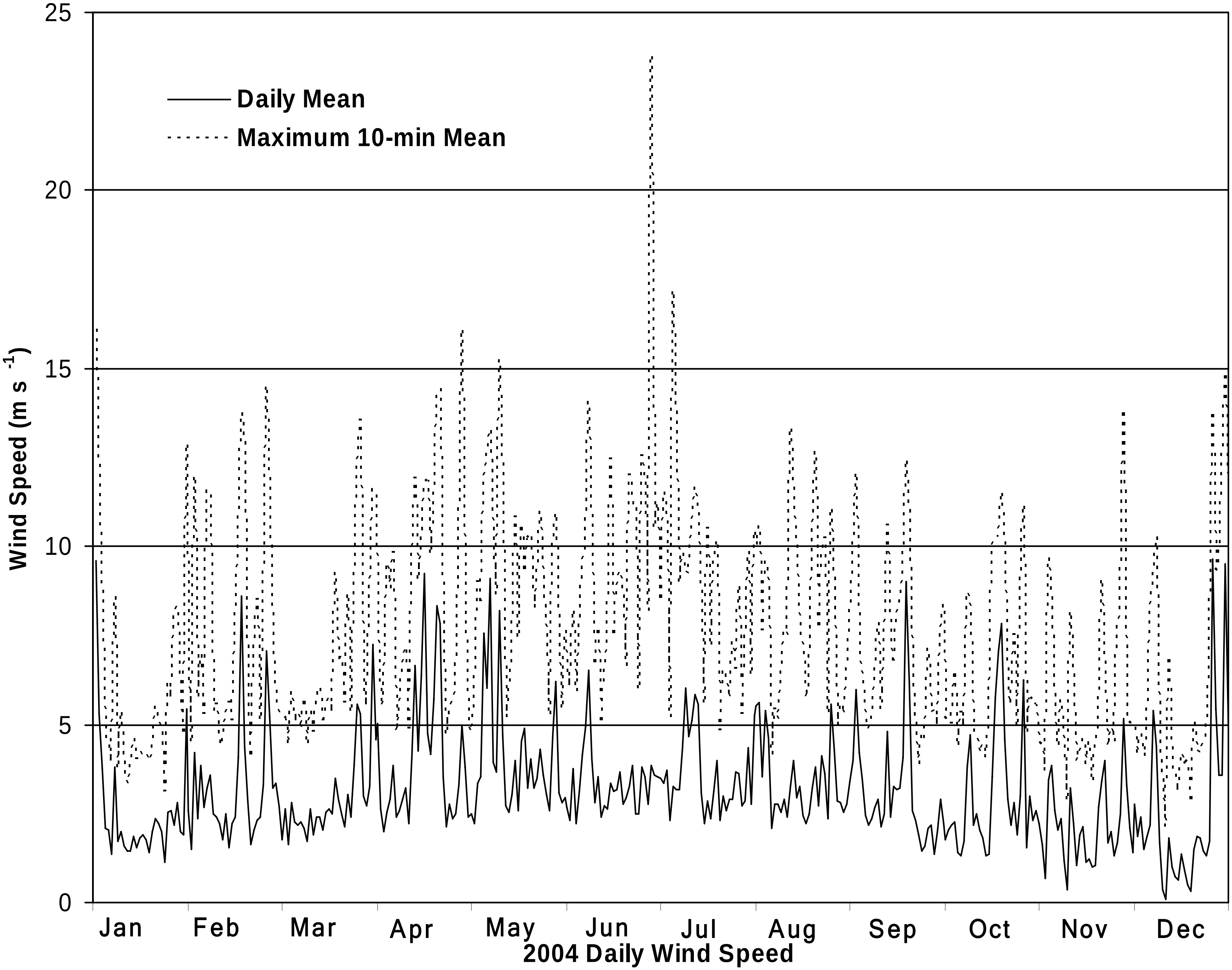

Daily Mean
Maximum 10-min Mean
Wind Speed (m s $^{-1}$)
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2004 Daily Wind Speed

Figure 2

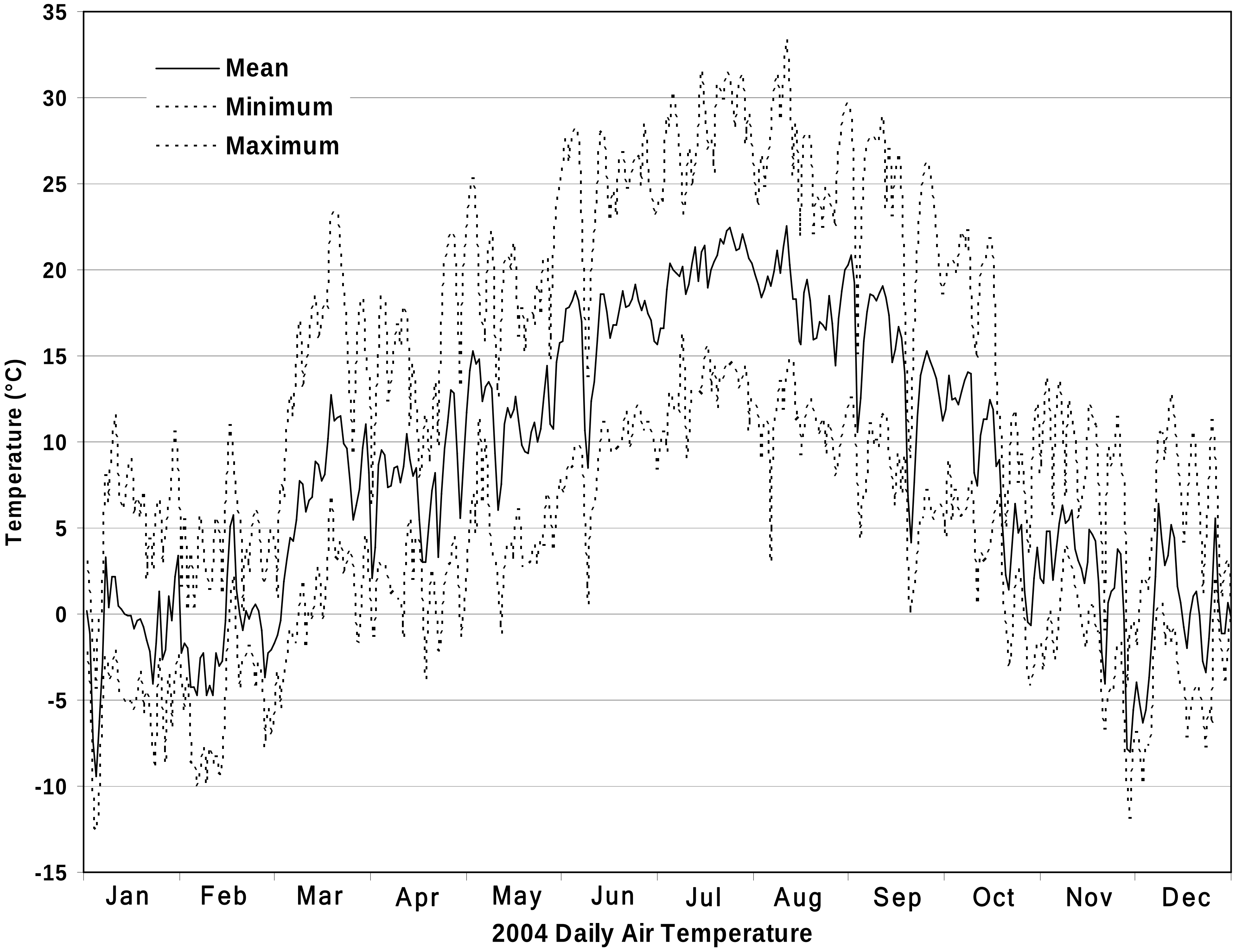

Mean
Minimum
Maximum
Temperature (°C)
35
30
25
20
15
10
5
0
-5
-10
-15
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2004 Daily Air Temperature

Figure 3

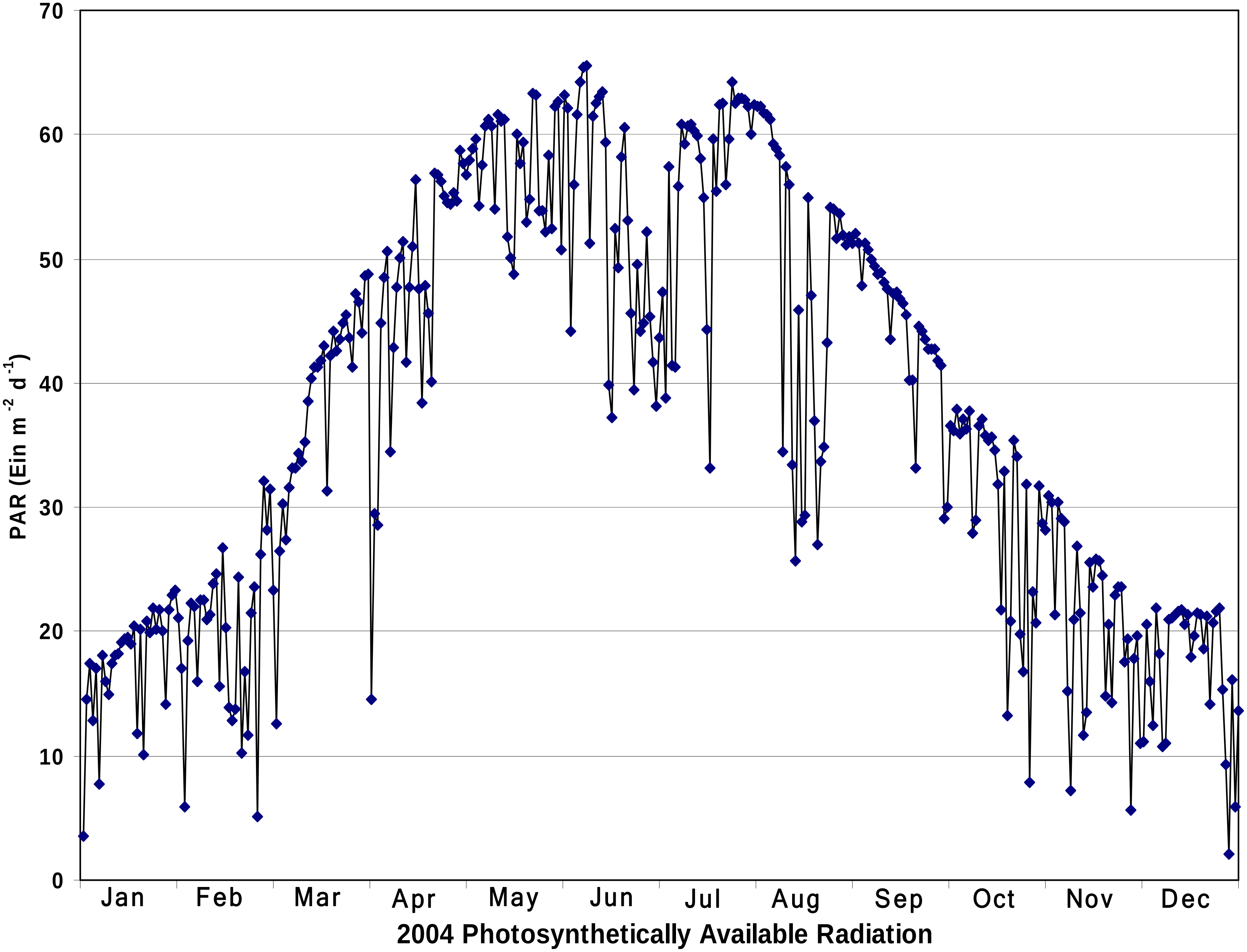
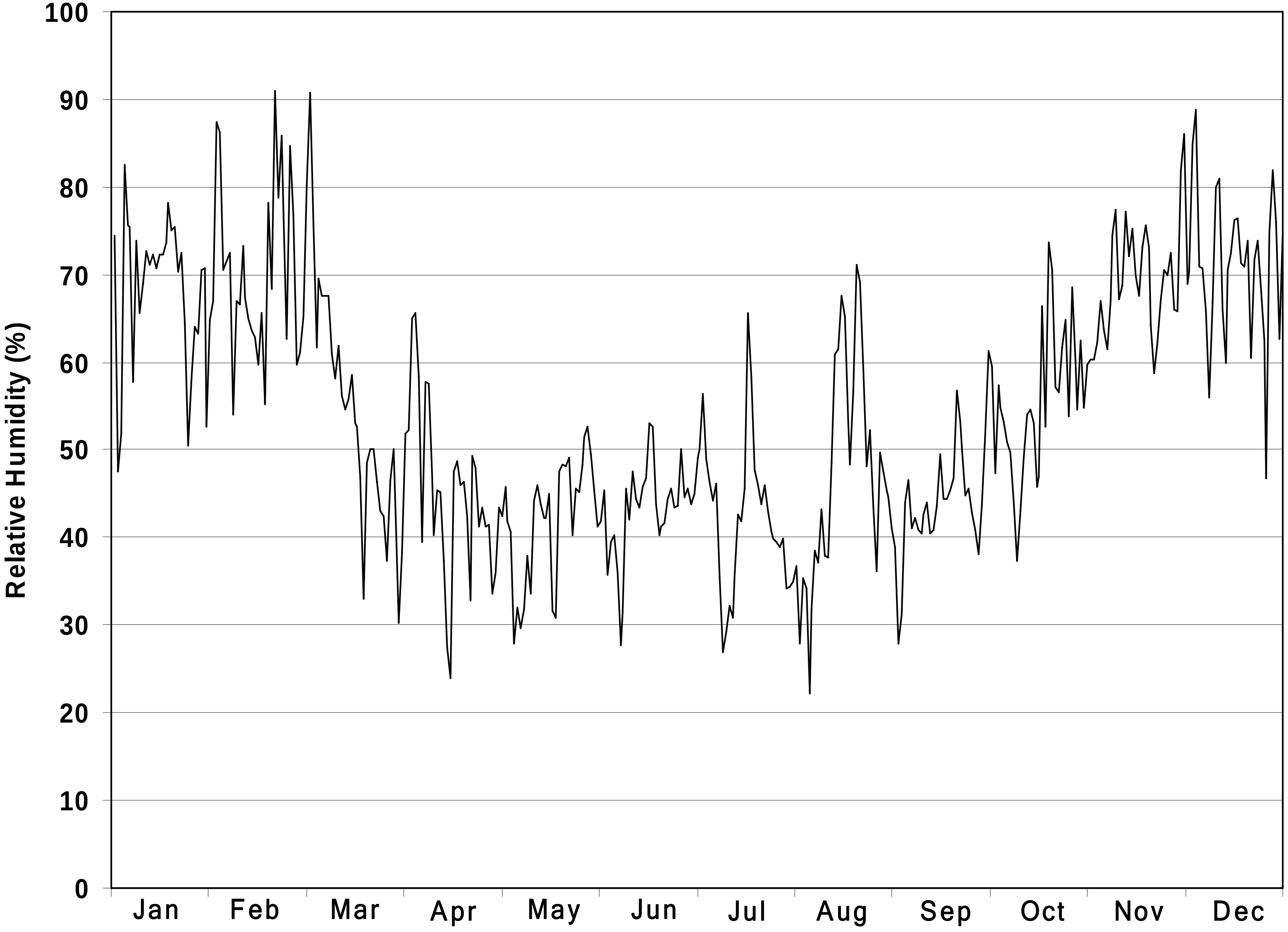
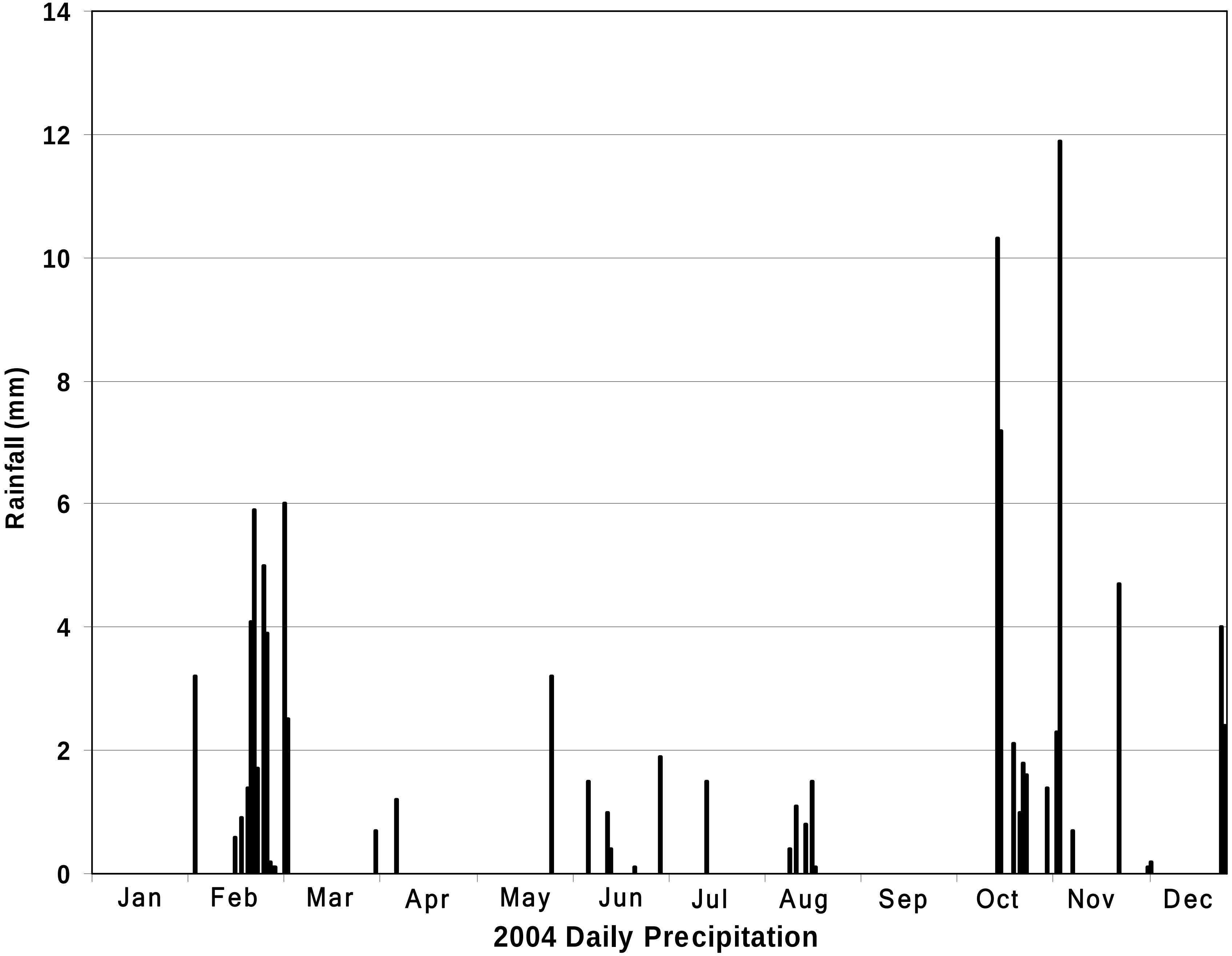

70
60
50
40
30
20
10
0
PAR (Ein m $^{-2}$ d $^{-1}$)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2004 Photosynthetically Available Radiation

Figure 4



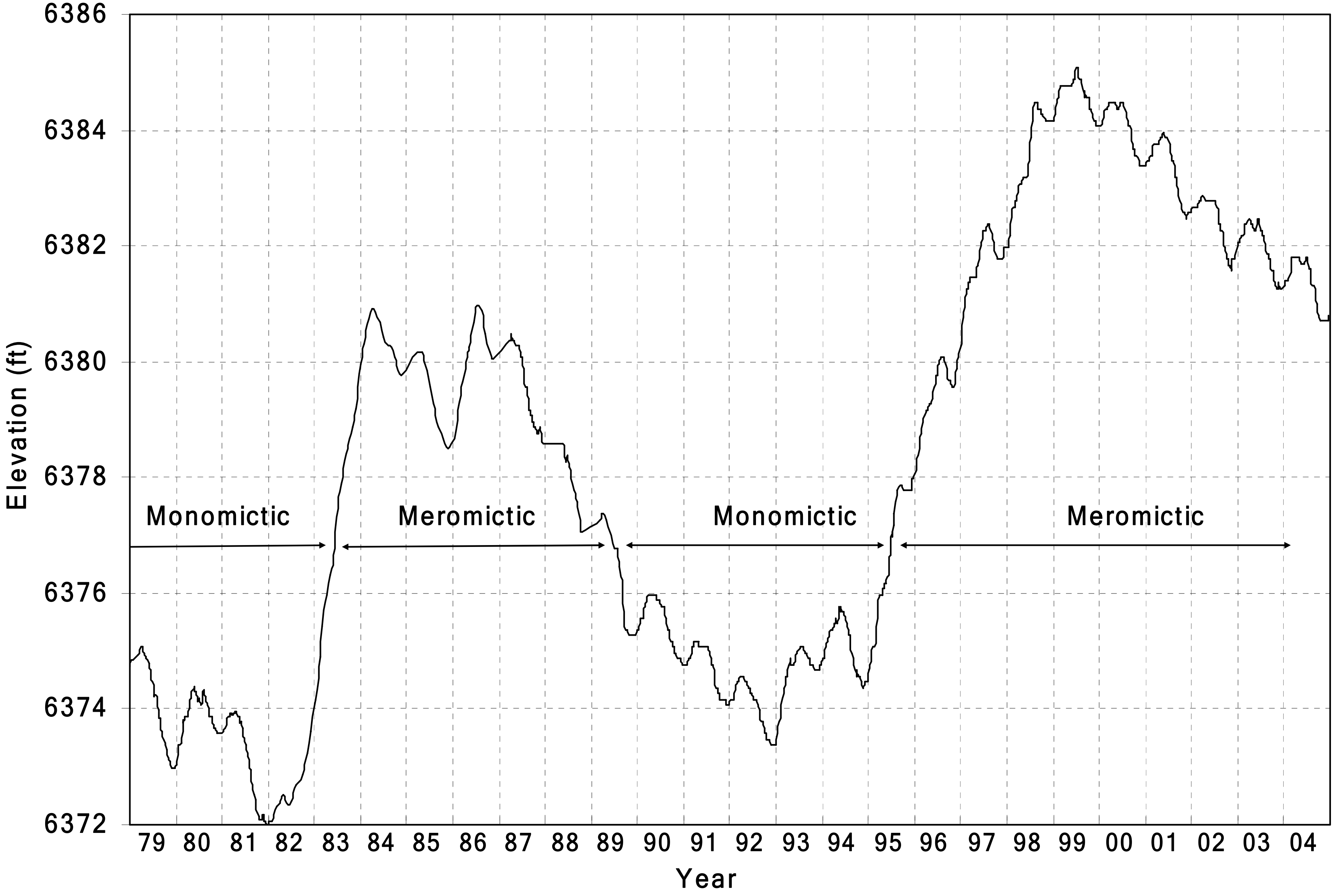
2004 Mean Daily Relative Humidity

Figure 5



Rainfall (mm)
0
2
4
6
8
10
12
14
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2004 Daily Precipitation

Figure 6



Mono Lake Surface Elevation

Figure 7

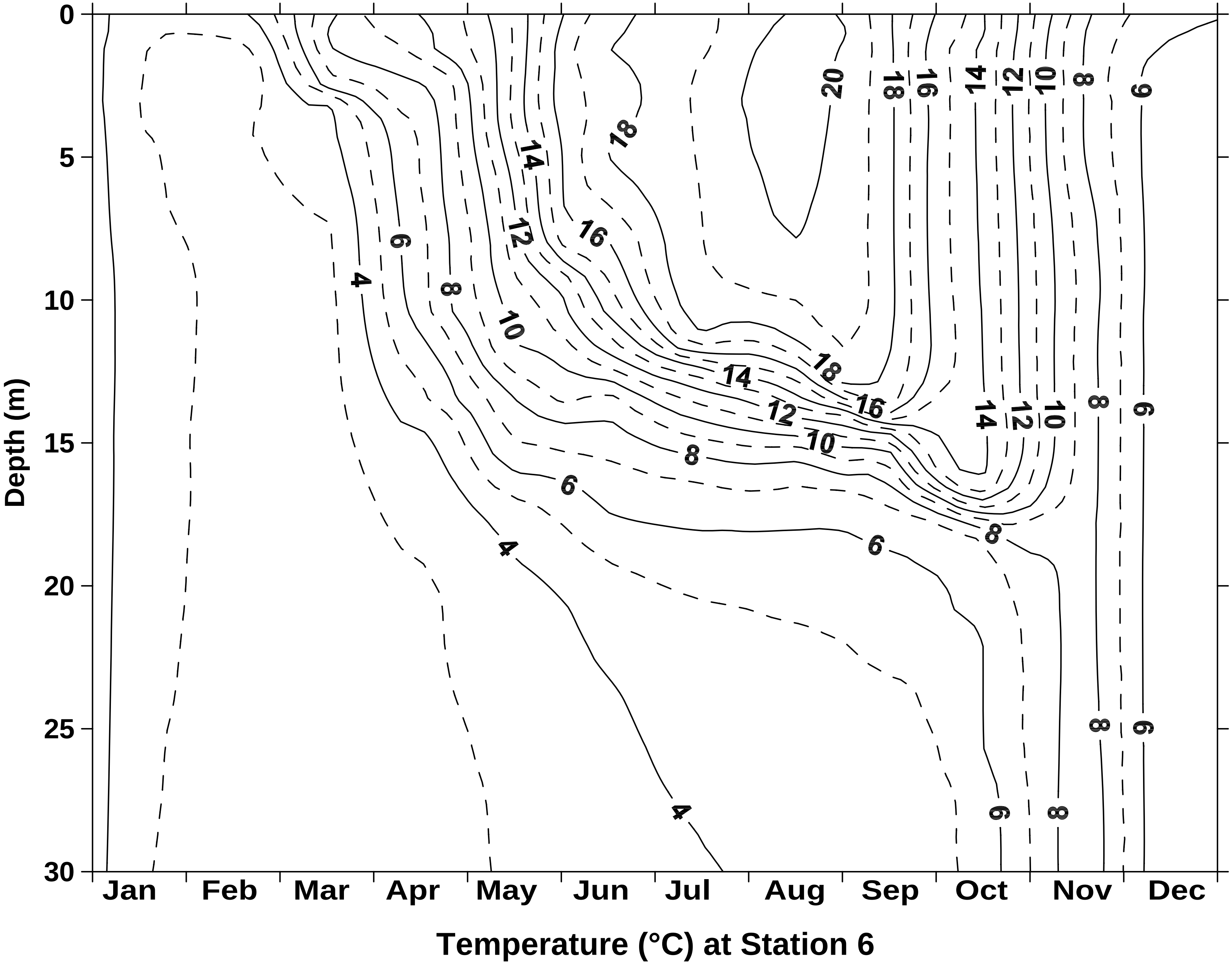
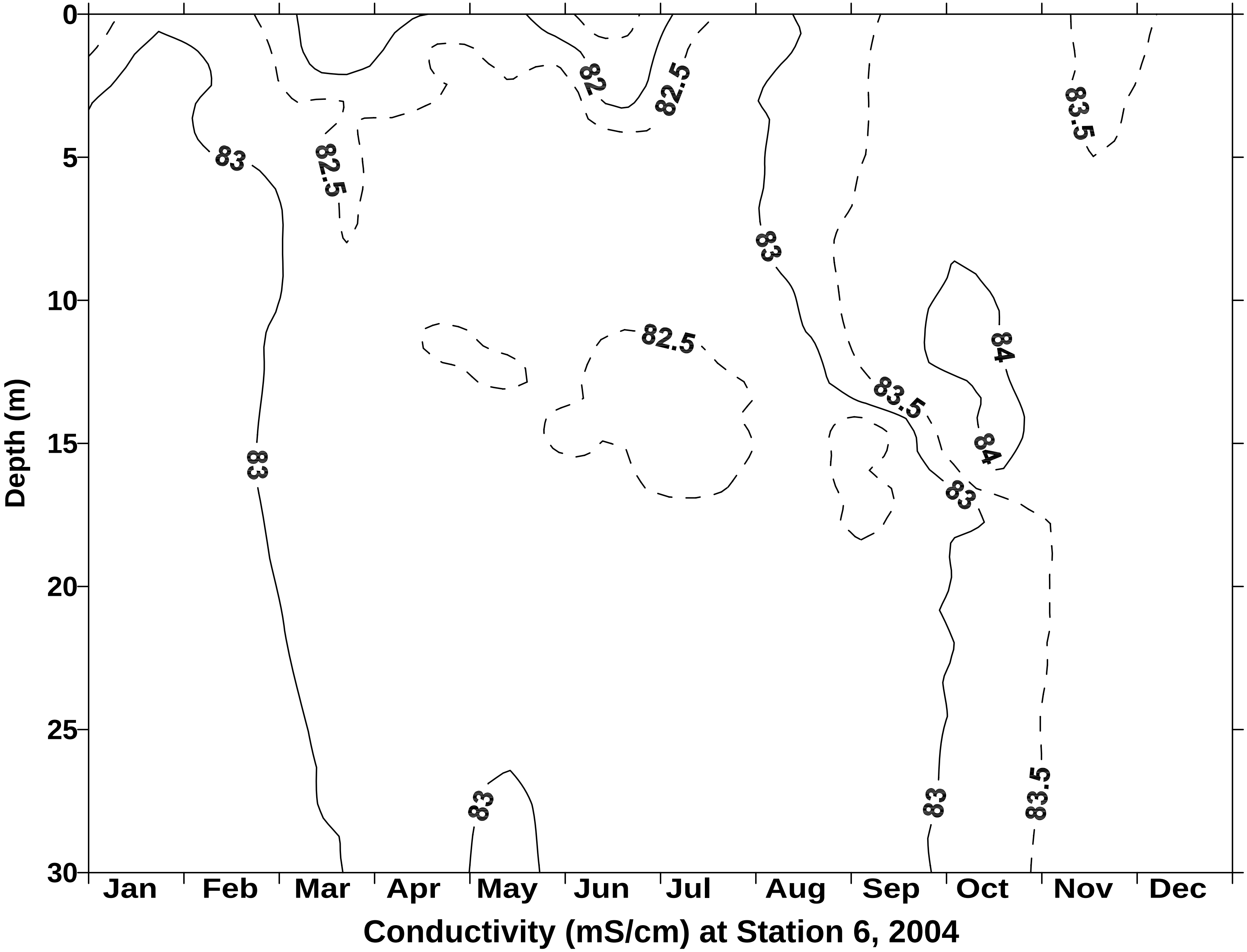
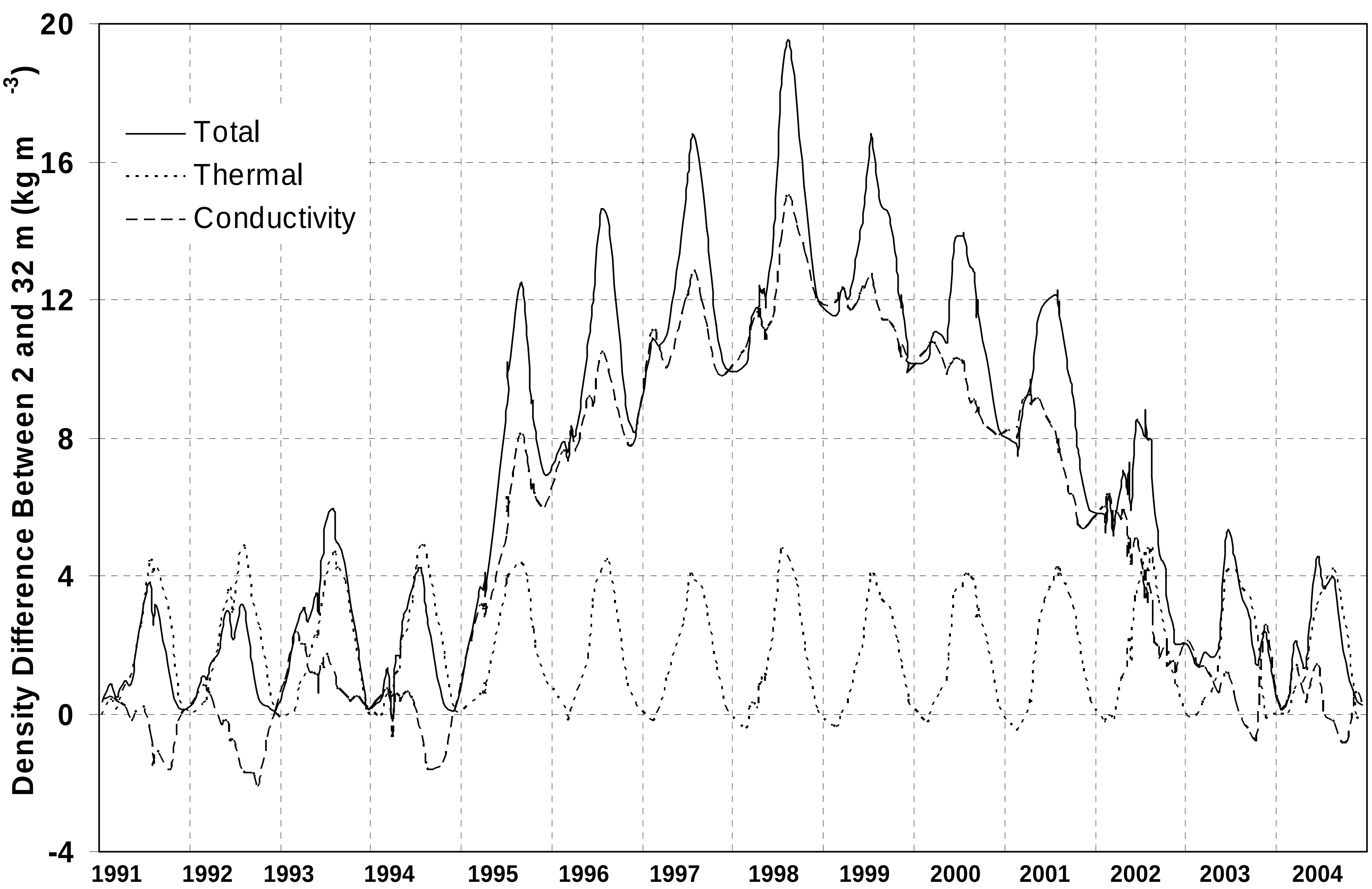

Depth (m)
0
5
10
15
20
25
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Temperature (°C) at Station 6
4
6
8
10
12
14
16
18
20

Figure 8



Depth (m)
0
5
10
15
20
25
30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
83
82.5
82
82.5
83.5
83
82.5
83.5
84
84
83
83
83
83
83.5
Conductivity (mS/cm) at Station 6, 2004

Figure 9



Density Stratification (2-32 m), 1991 - 2004

Figure 10

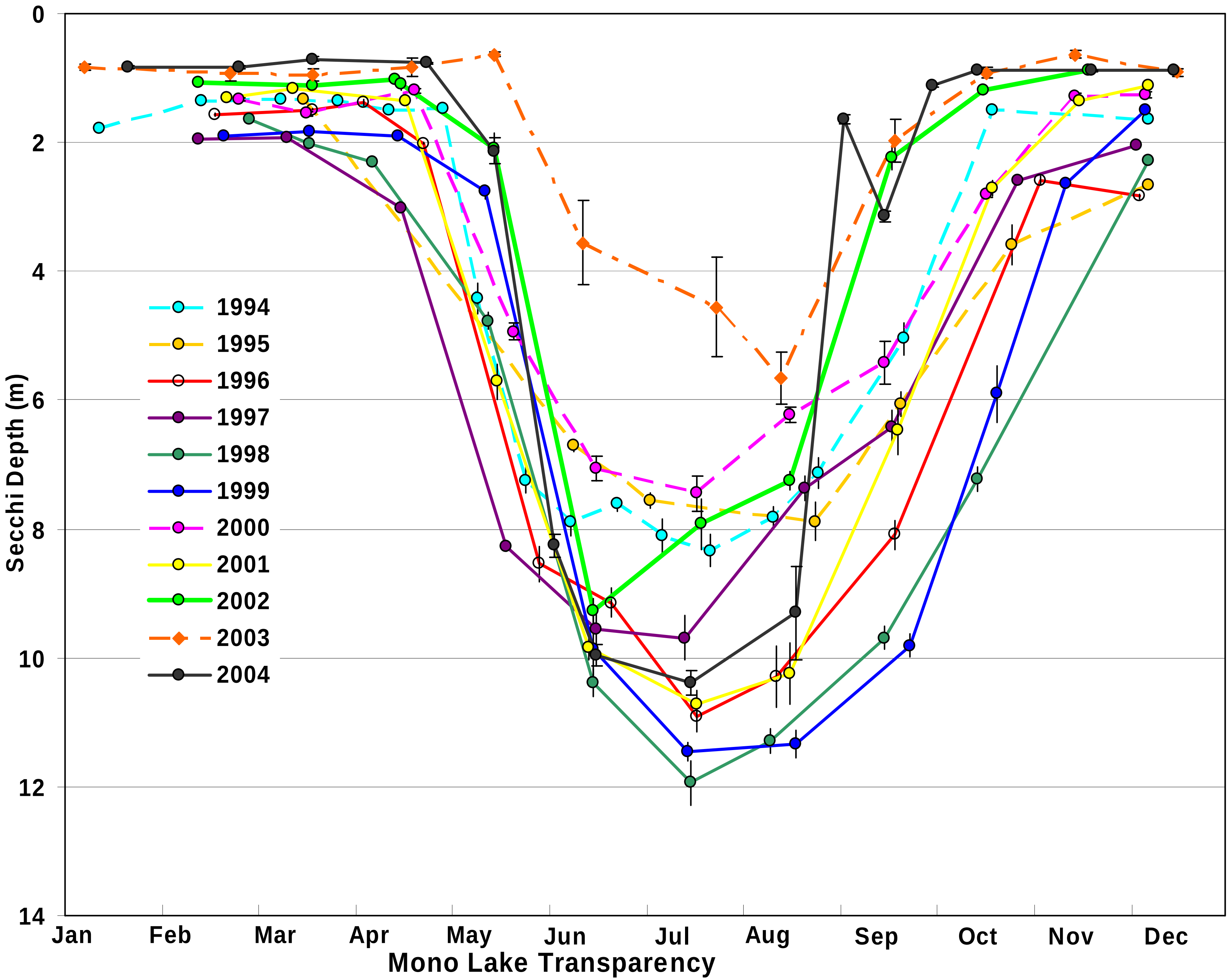
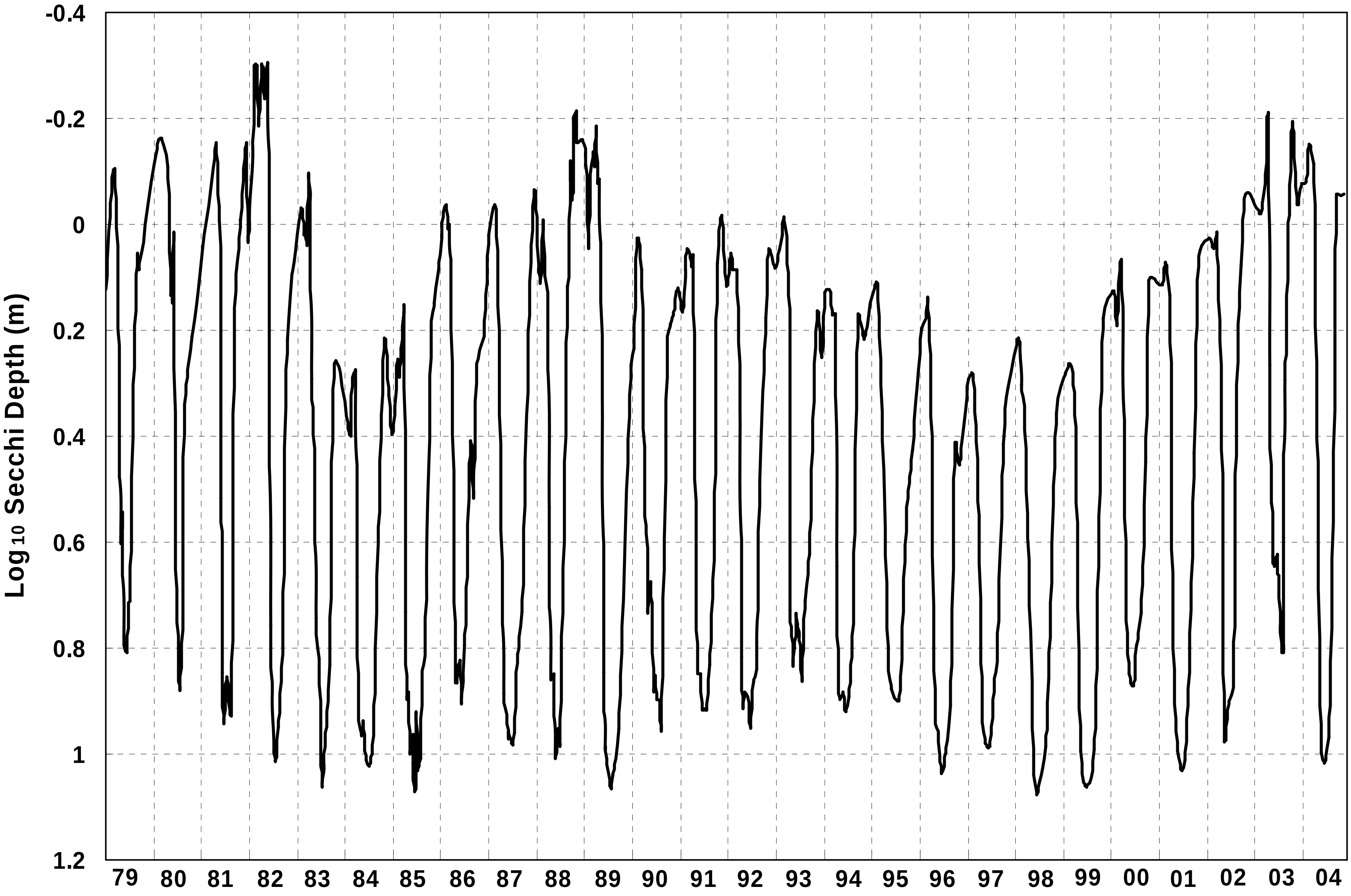
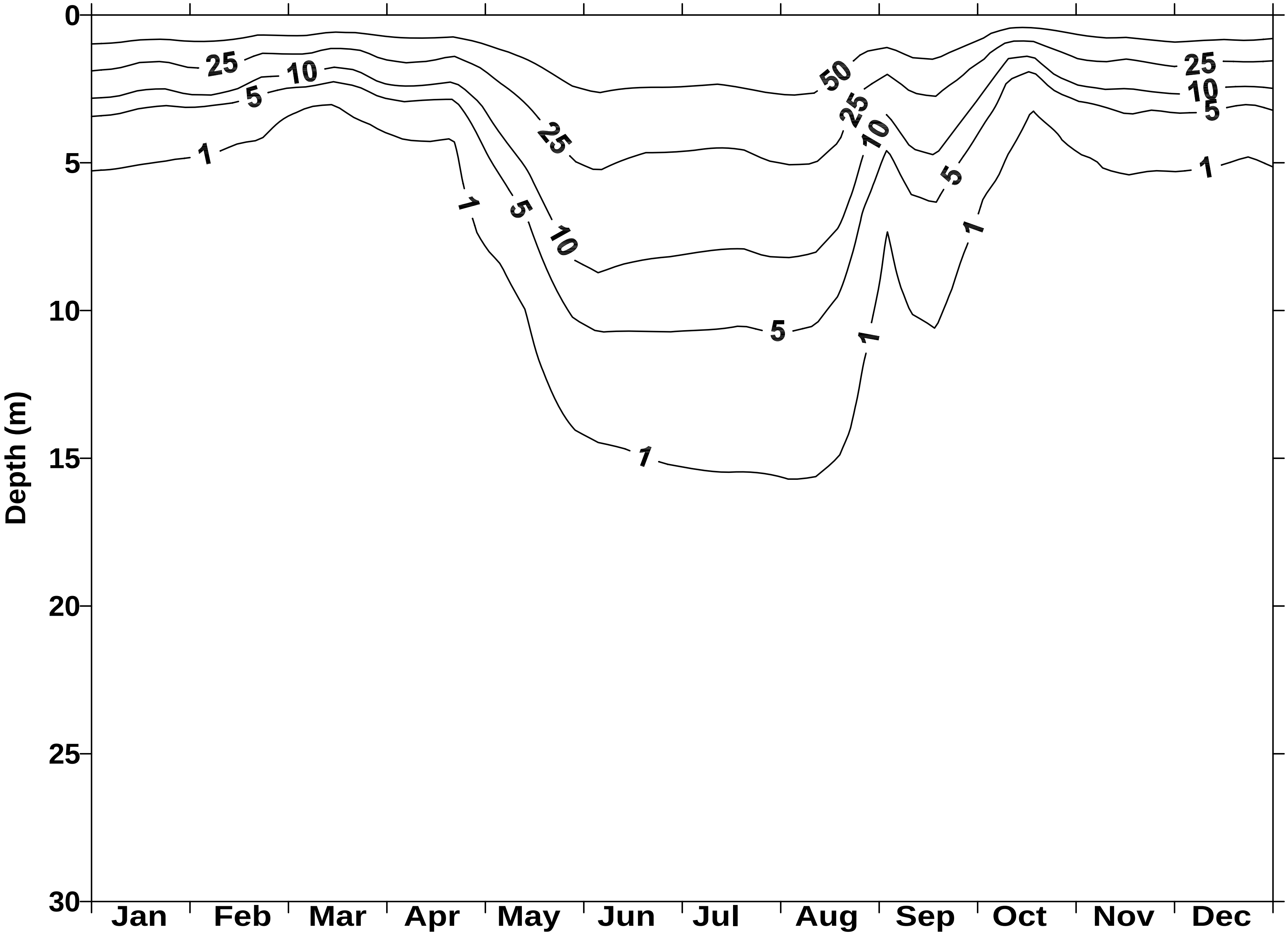

Secchi Depth (m)
0
2
4
6
8
10
12
14
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Mono Lake Transparency
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004

Figure 11



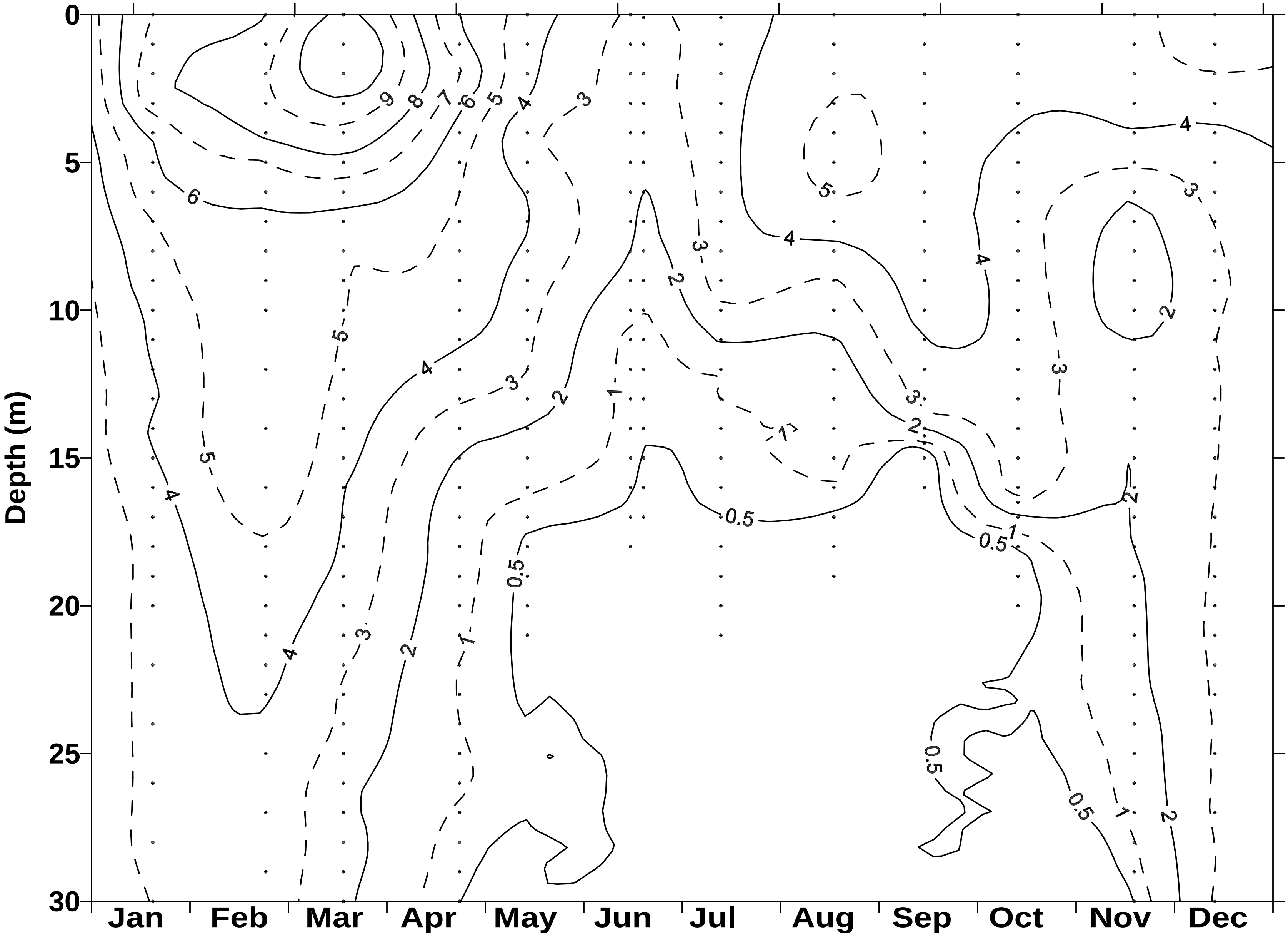
Transparency in Mono Lake

Figure 12



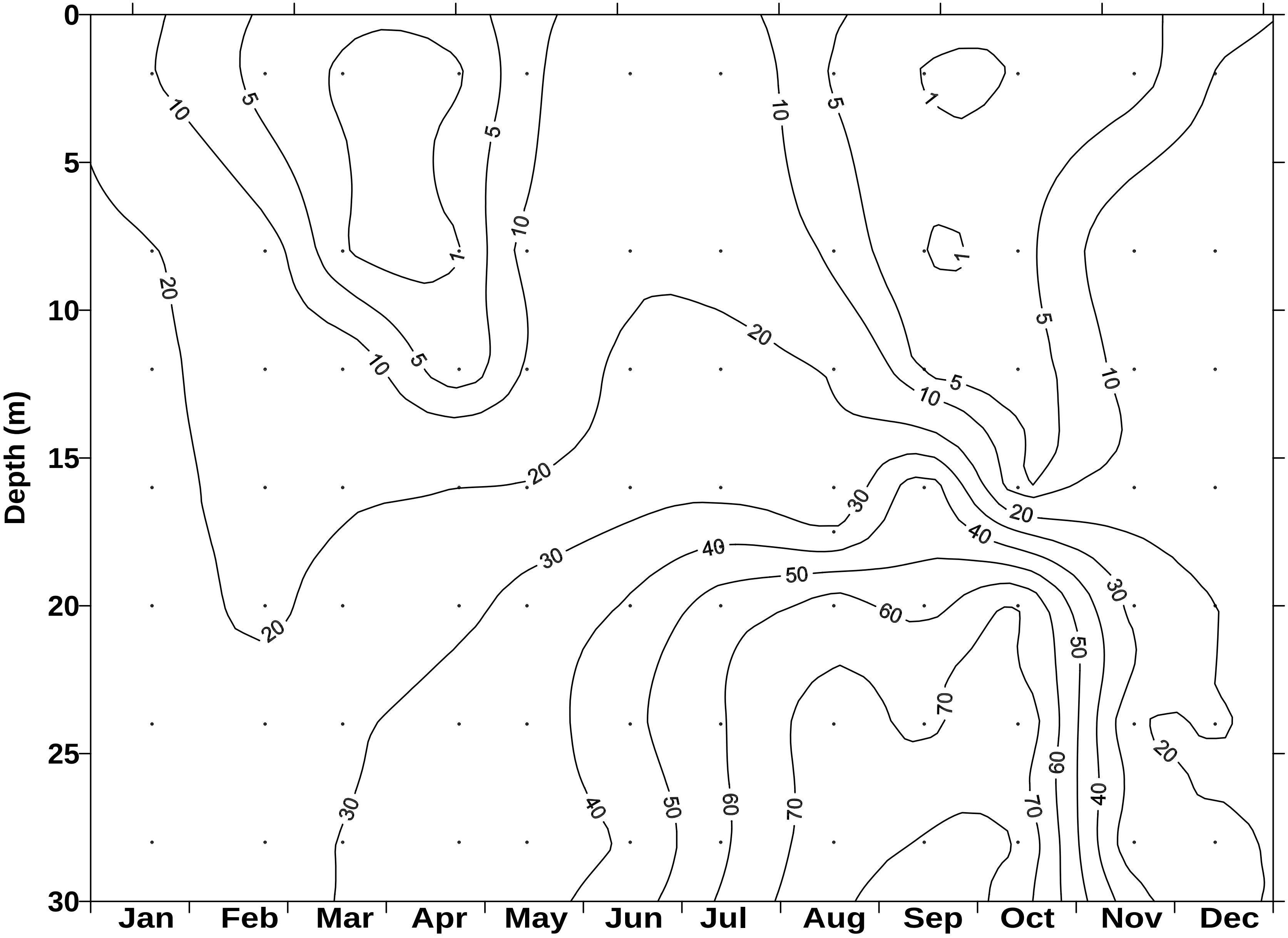
Light Attenuation (% of Surface) at Station 6, 2004

Figure 13



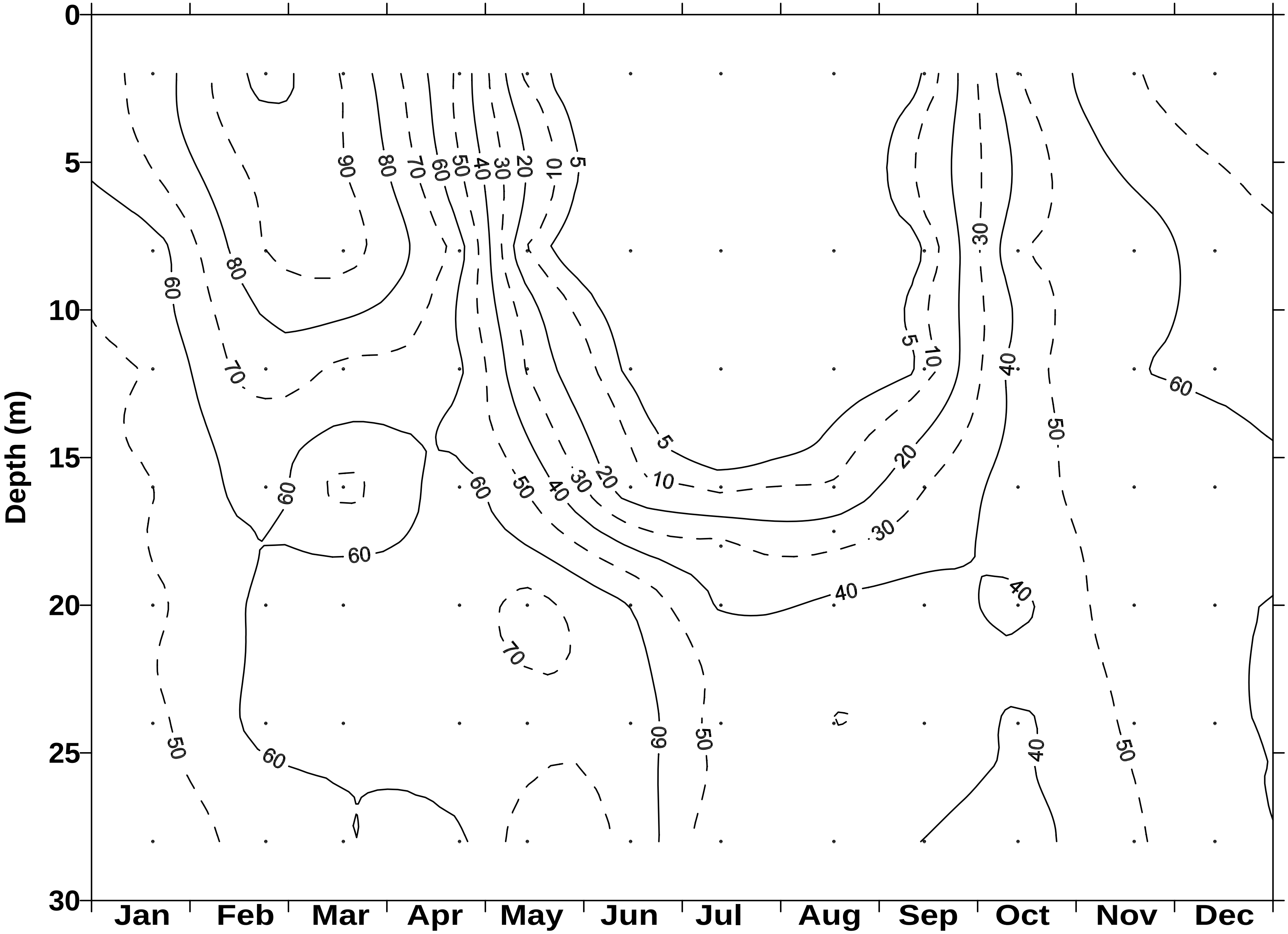
Dissolved Oxygen (mg/l) at Station 6, 2004

Figure 14



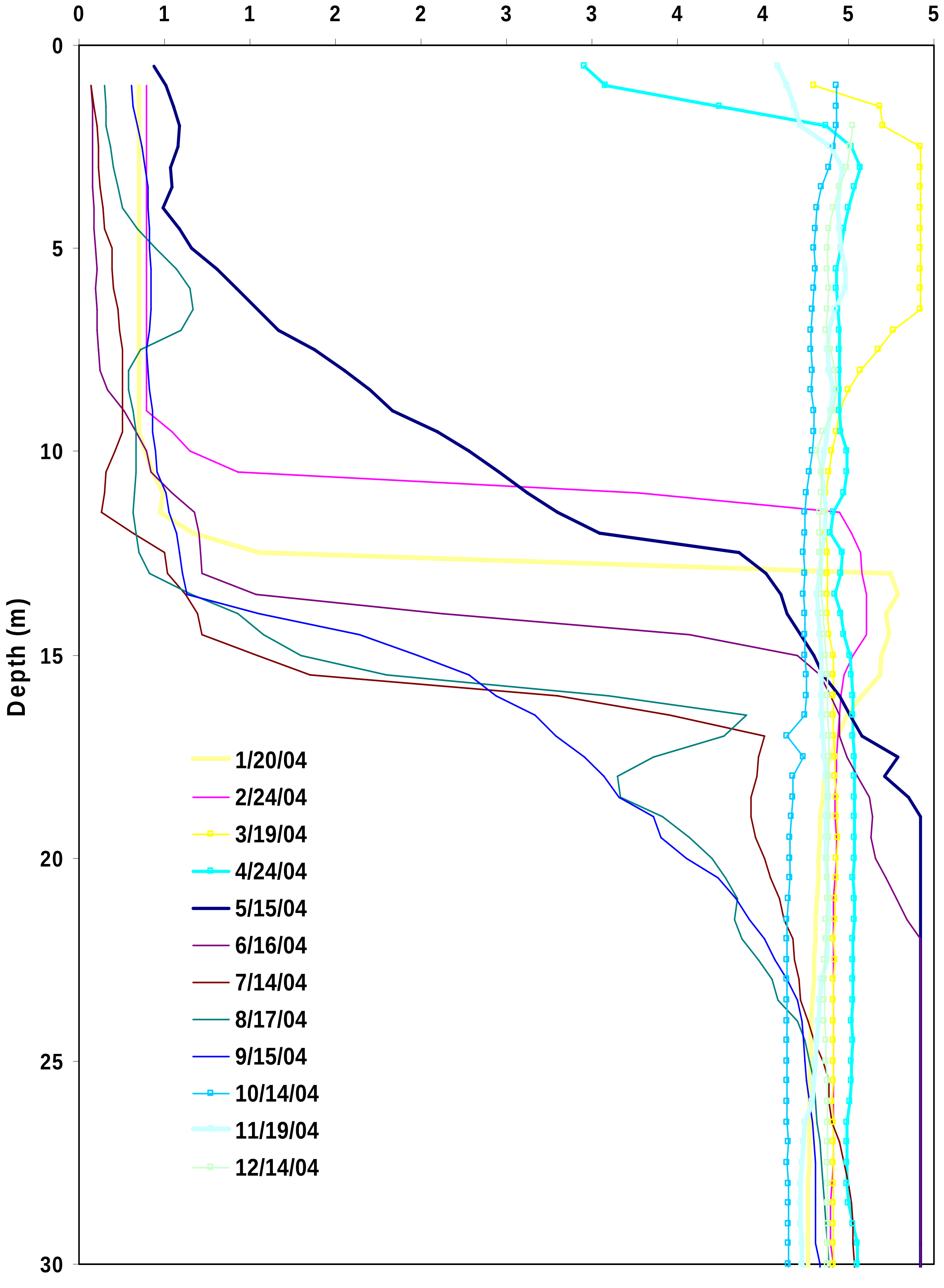
Ammonia (uM) at Station 6, 2004

Figure 15



Chlorophyll a (µg/l) at Station 6, 2004

Figure 16



2004 Seasonal fluorescence profiles at Station 6

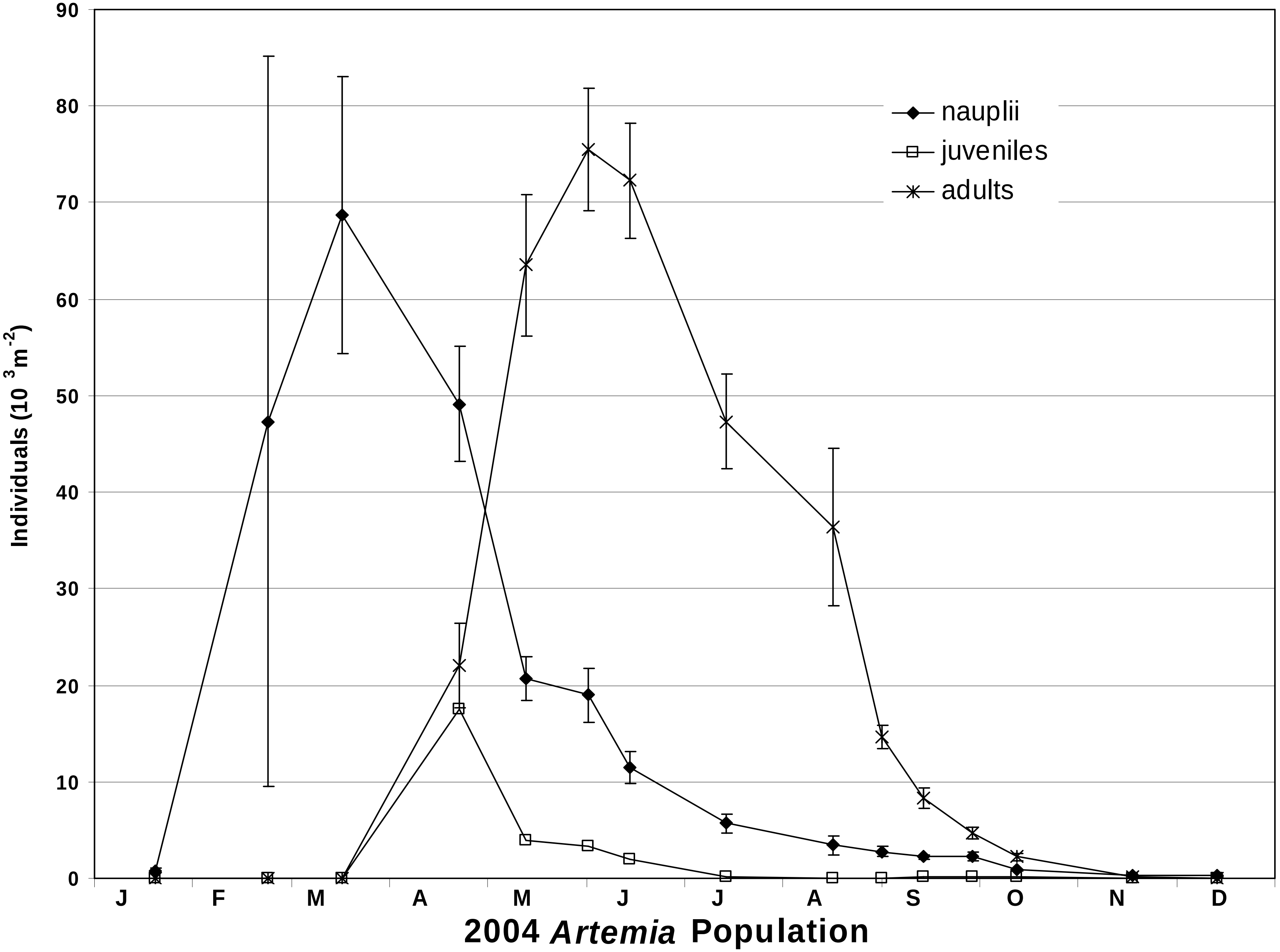
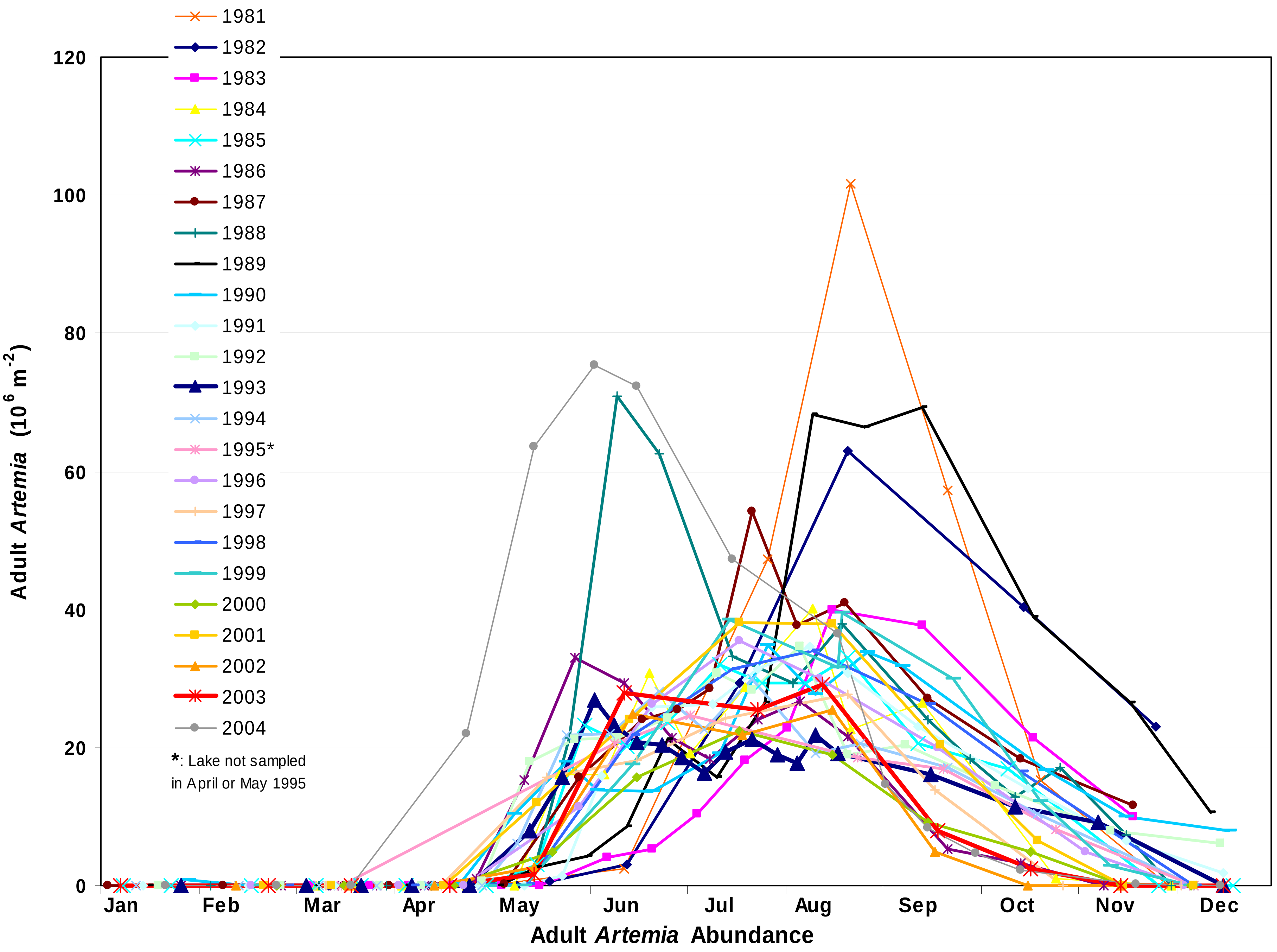

90
80
70
60
50
40
30
20
10
0
Individuals ($10^3 m^{-2}$)
nauplii
juveniles
adults
J
F
M
A
M
J
J
A
S
O
N
D
2004 *Artemia* Population

Figure 18

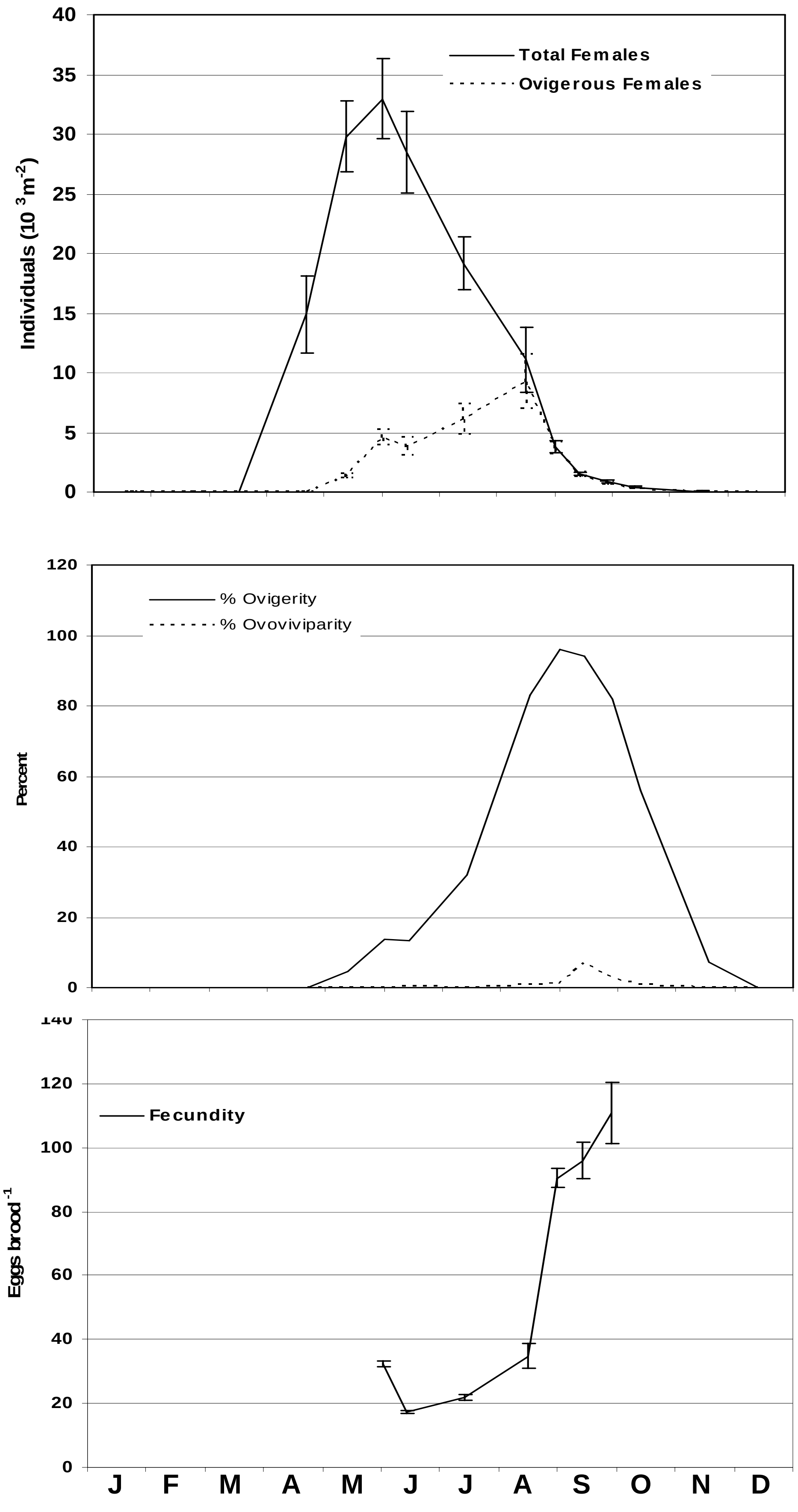


*****: Lake not sampled in April or May 1995

Figure 19

Figure 20

2004 *Artemia* Reproduction



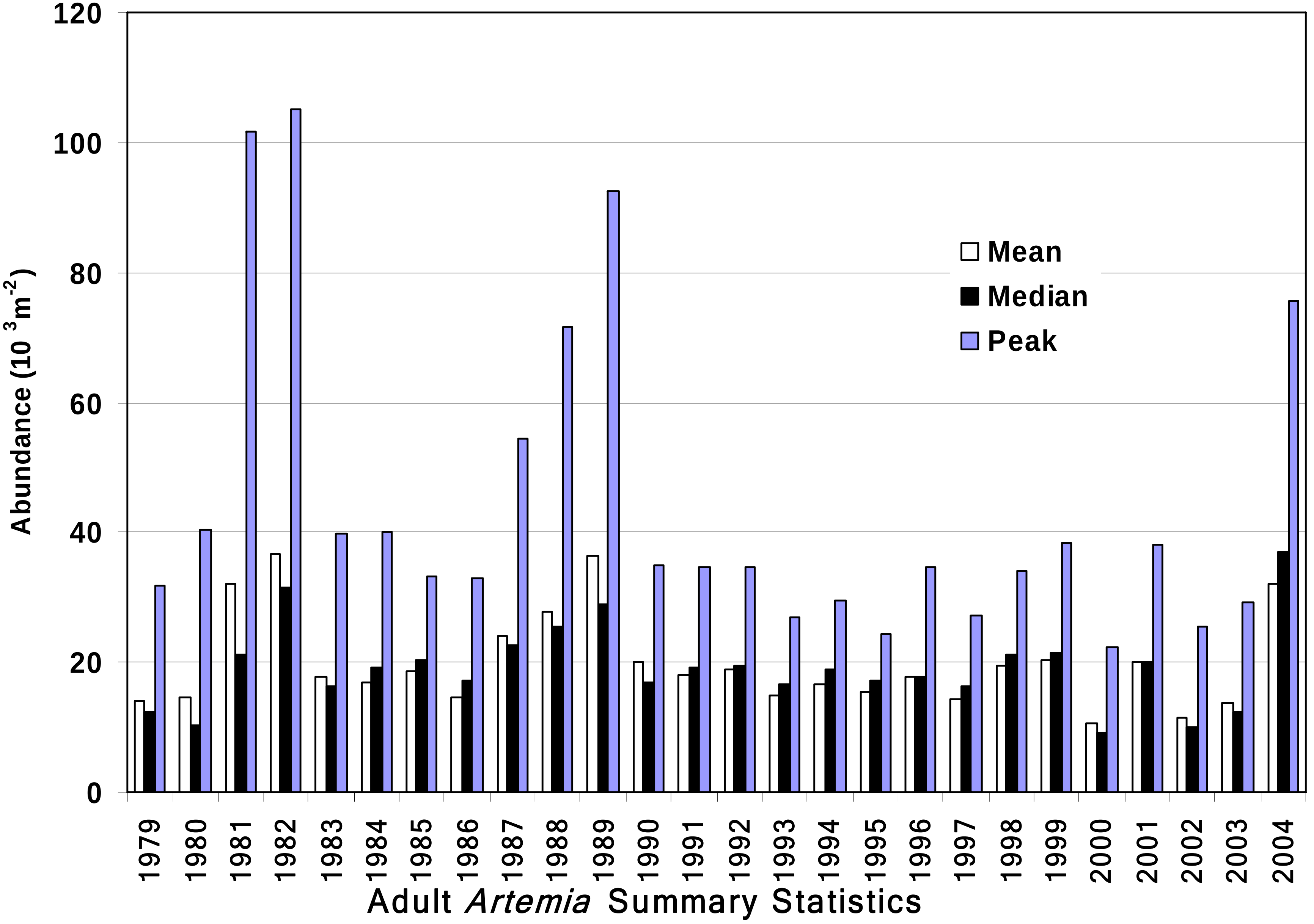
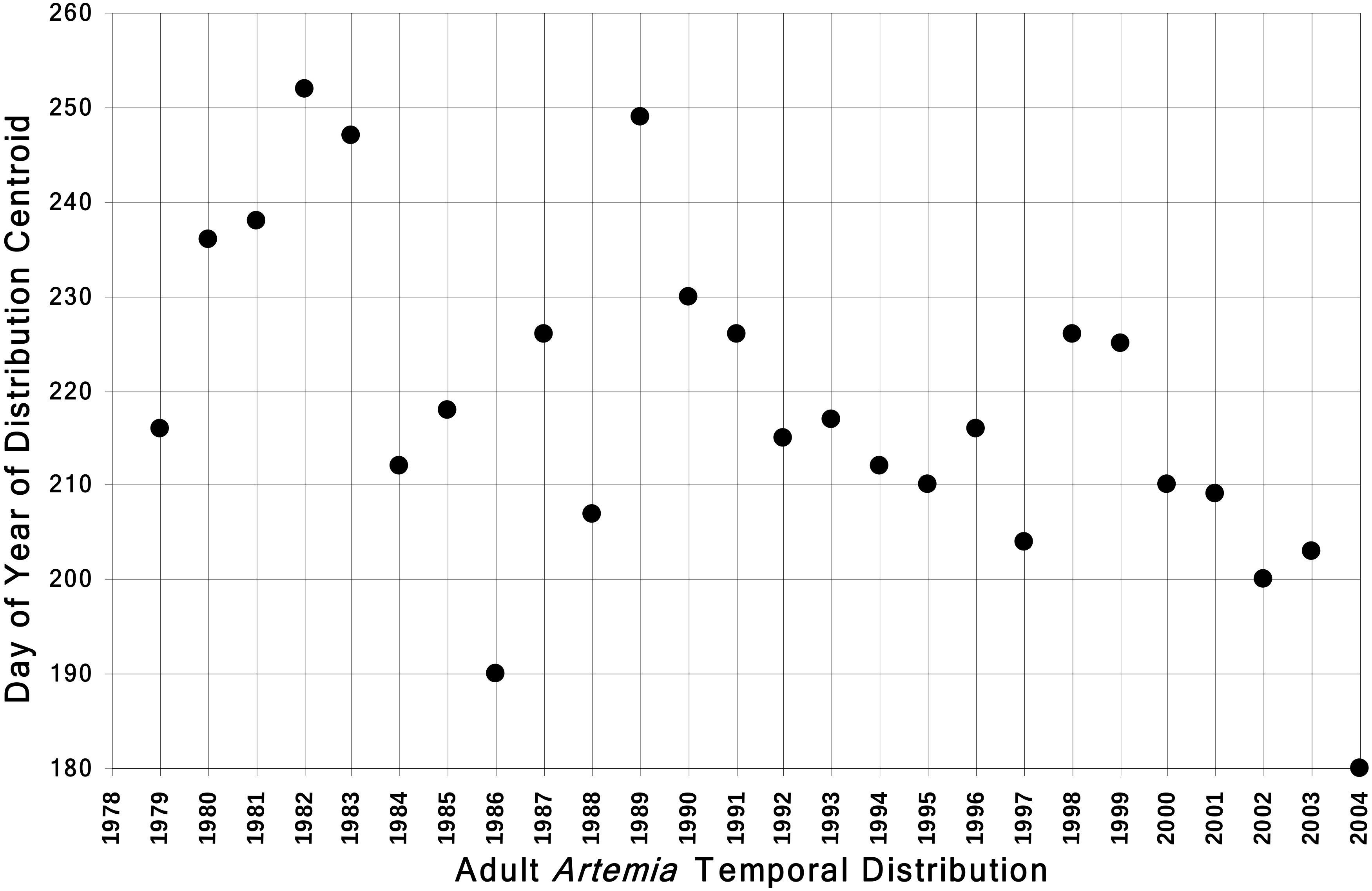

Abundance (10^3 m^{-2})
0
20
40
60
80
100
120
Mean
Median
Peak
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Adult *Artemia* Summary Statistics

Figure 21



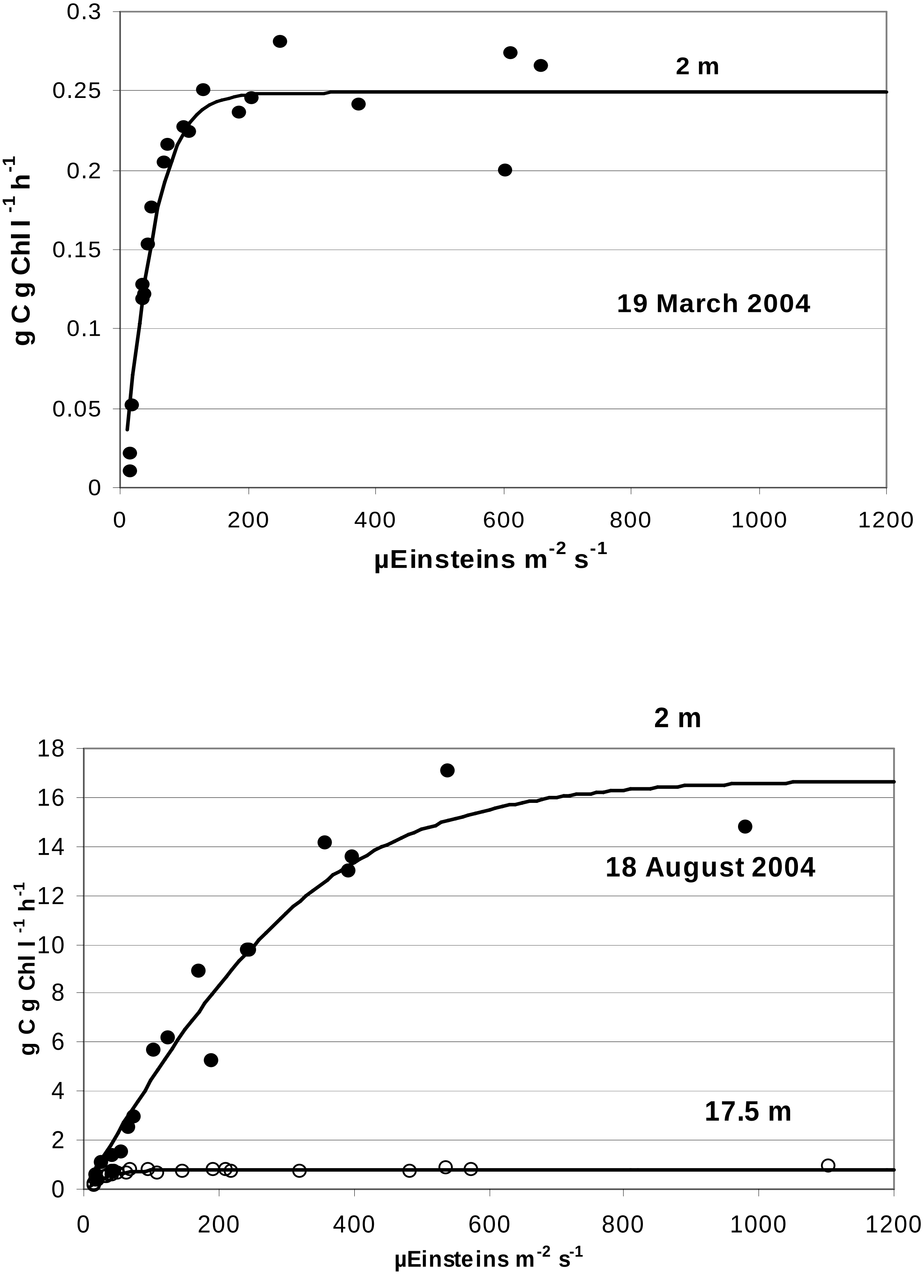
Day of Year of Distribution Centroid
260
250
240
230
220
210
200
190
180
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Adult *Artemia* Temporal Distribution

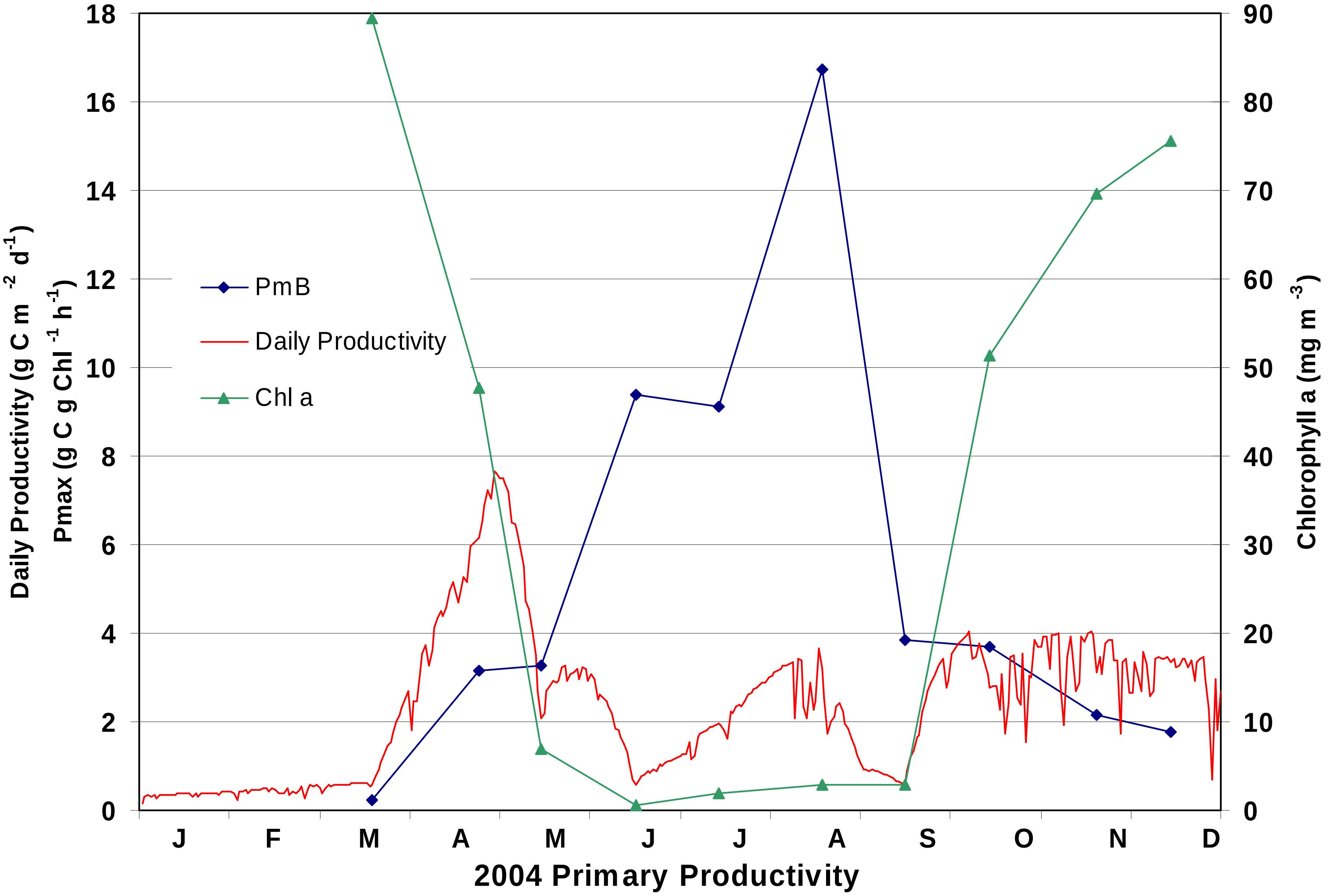
Figure 22

Figure 23

2004 Carbon uptake measurements

(examples from March and August)



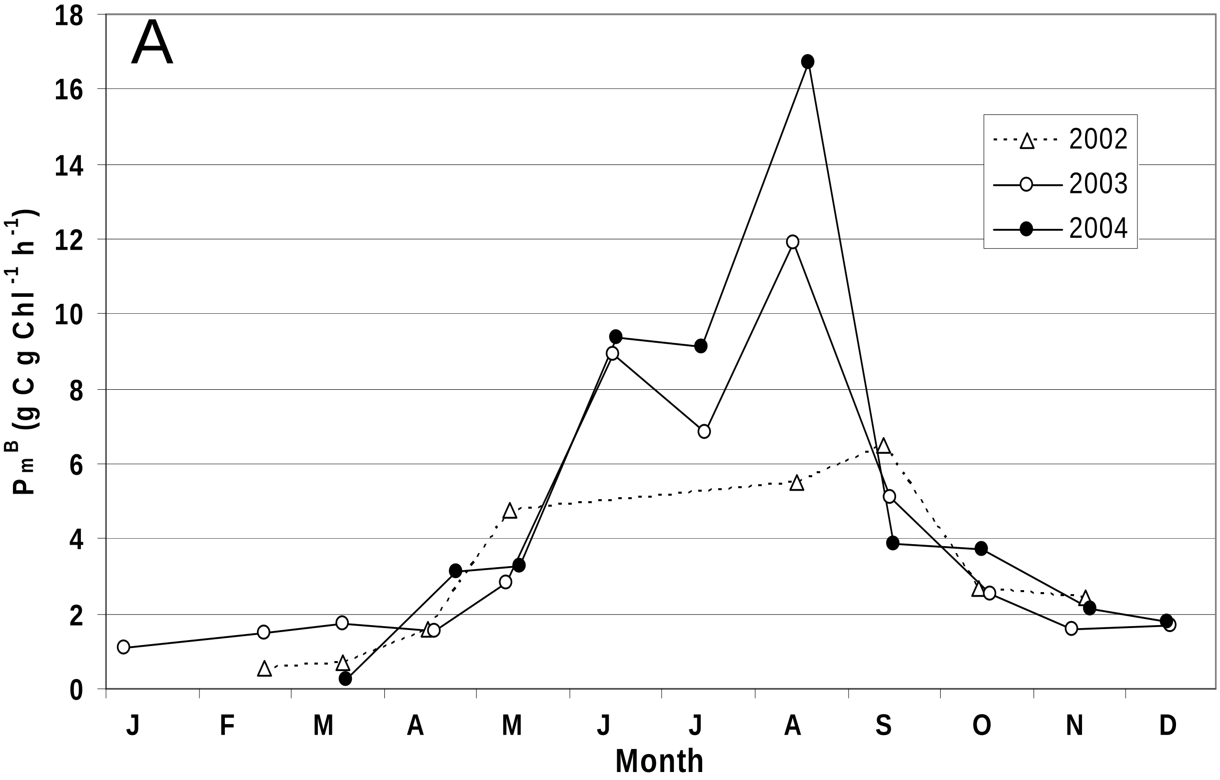


Daily Productivity (g C m $^{-2}$ d^{-1})
Pmax (g C g Chl $^{-1}$ h^{-1})
Chlorophyll a (mg m $^{-3}$)
0
2
4
6
8
10
12
14
16
18
0
10
20
30
40
50
60
70
80
90
PmB
Daily Productivity
Chl a
J
F
M
A
M
J
J
A
S
O
N
D
2004 Primary Productivity

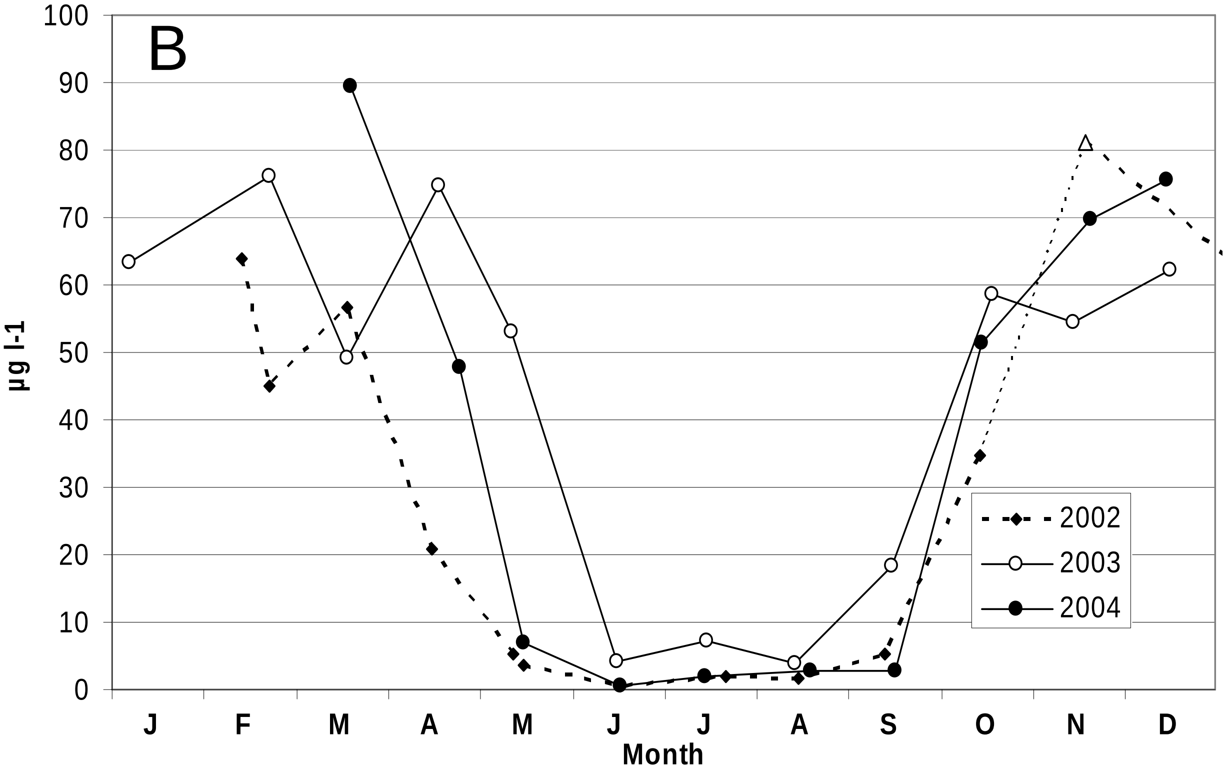
Figure 24

Figure 25

Mixed-layer P_m^B (2 m depth)



Mixed-layer Chlorophyll (2 m depth)



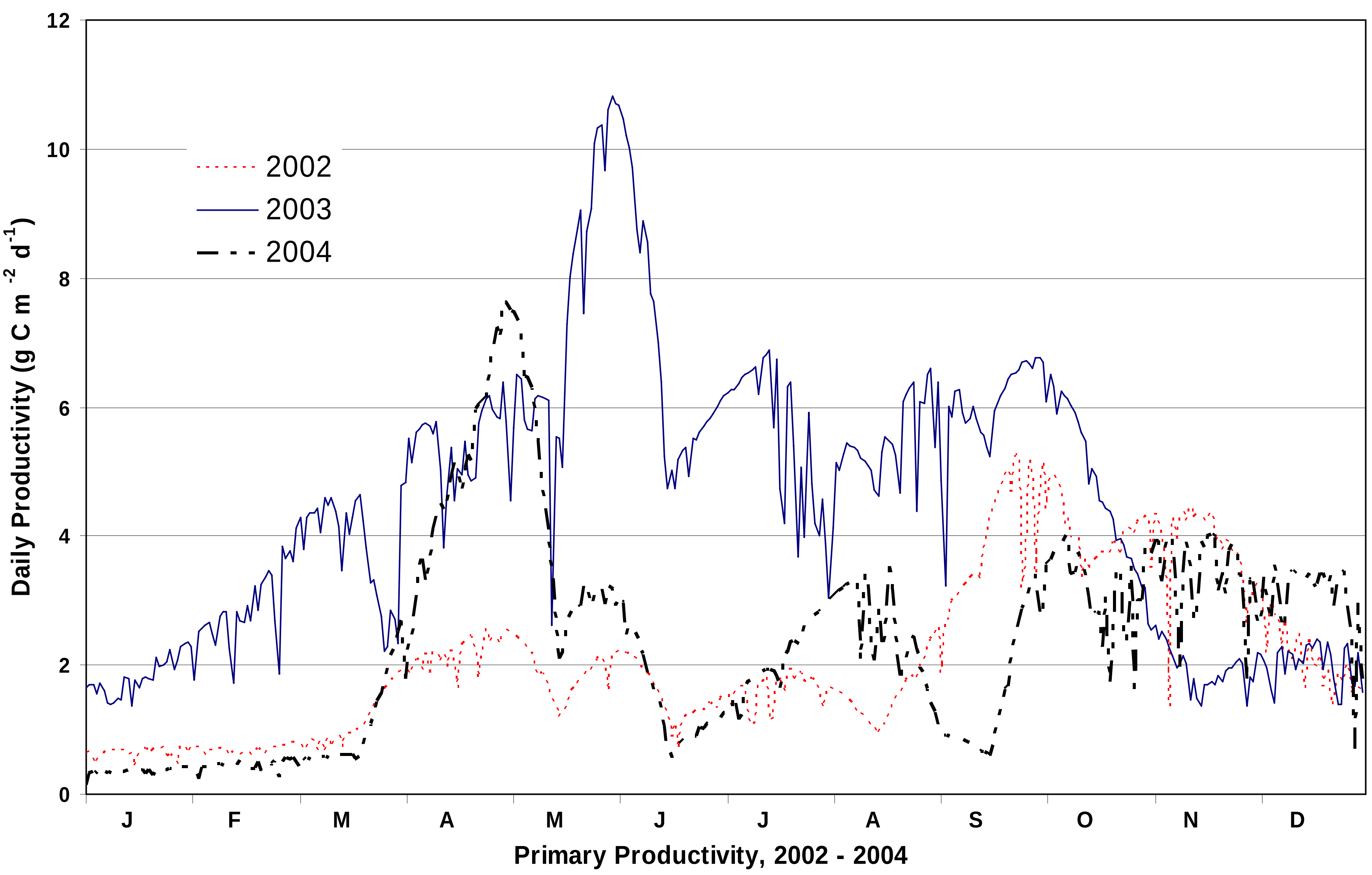

12
10
8
6
4
2
0
Daily Productivity (g C m $^{-2}$ d^{-1})
2002
2003
2004
J
F
M
A
M
J
J
A
S
O
N
D
Primary Productivity, 2002 - 2004

Figure 26

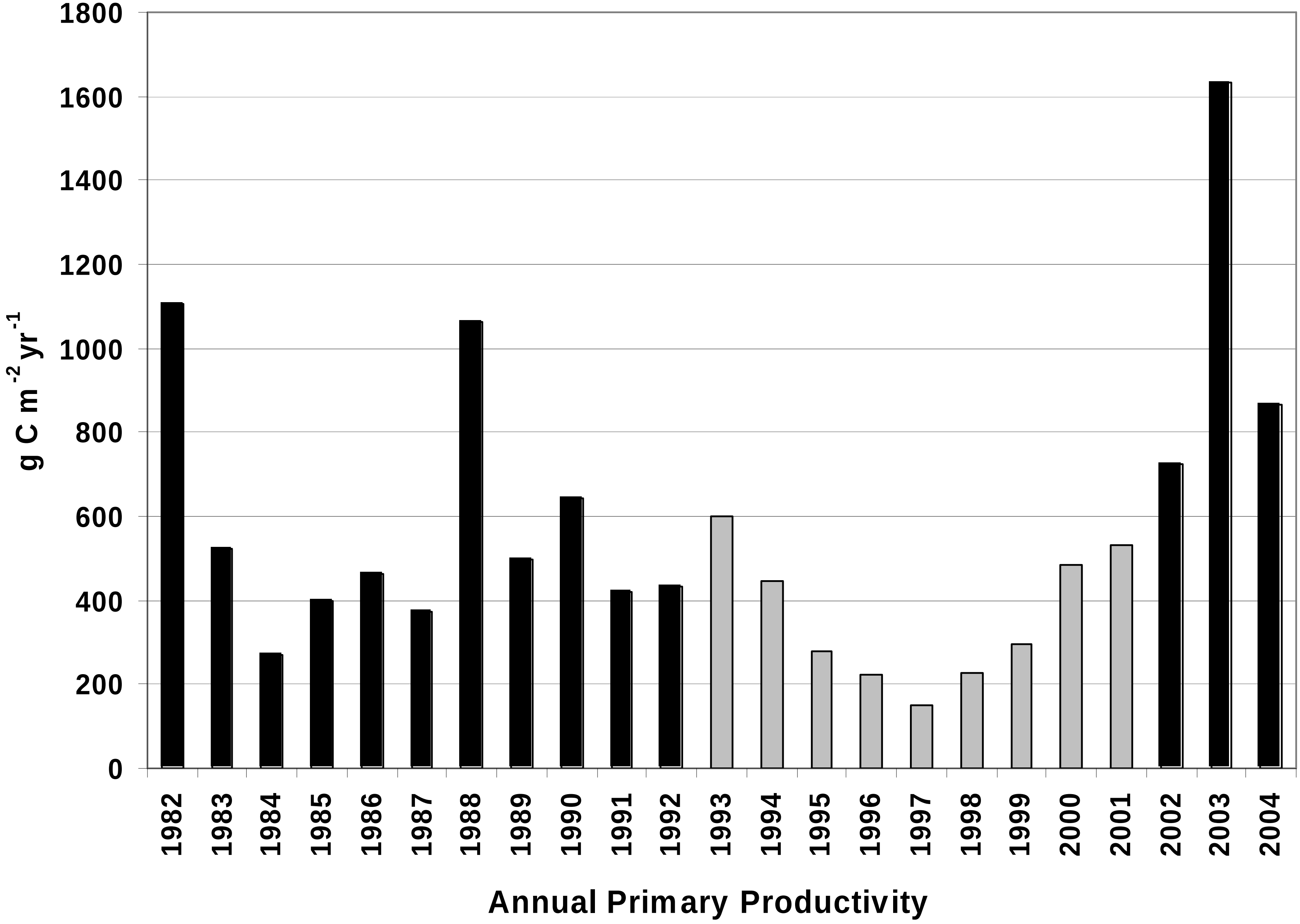

1800
1600
1400
1200
1000
800
600
400
200
0
g C m-2 yr-1
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Annual Primary Productivity

Figure 27

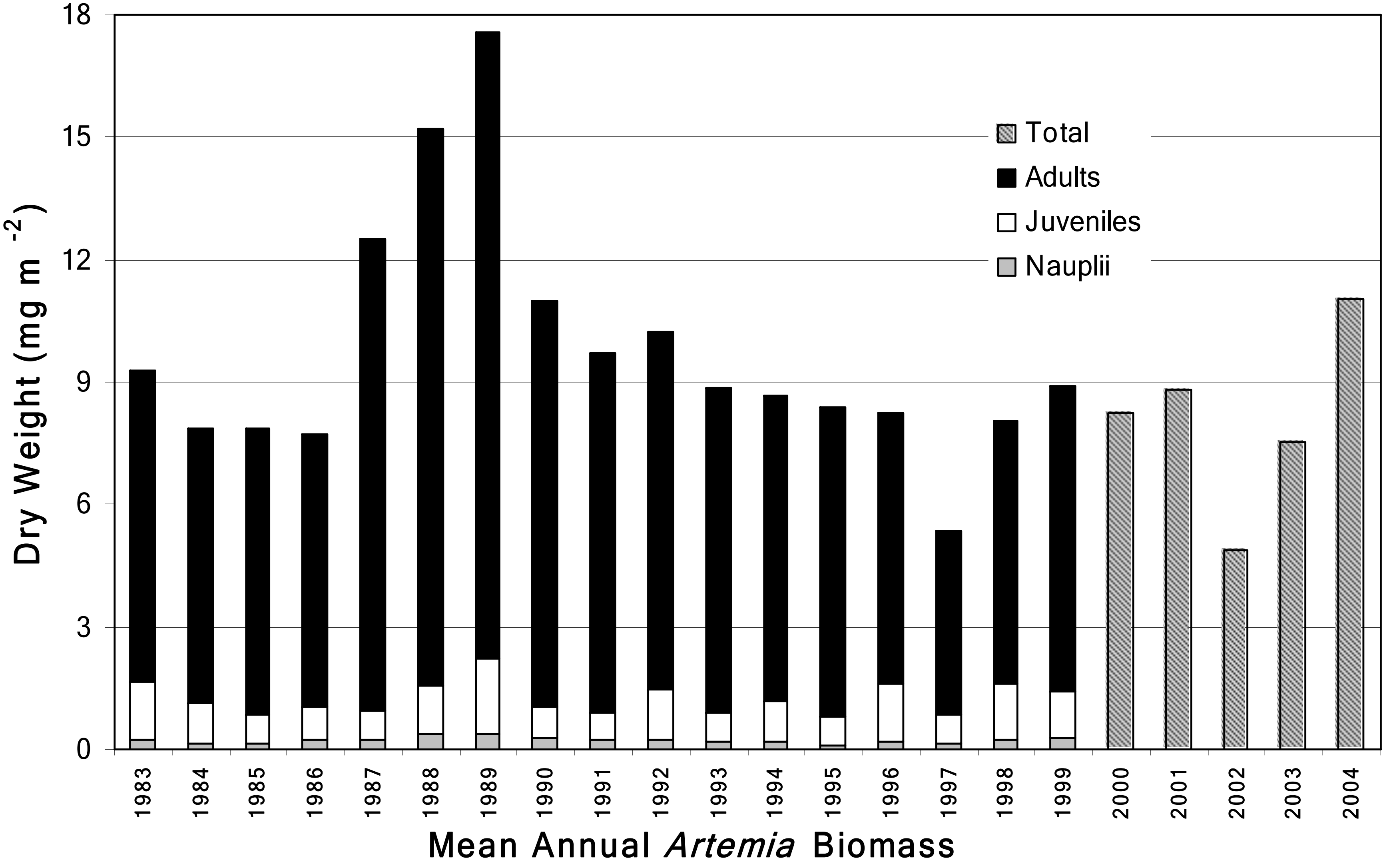
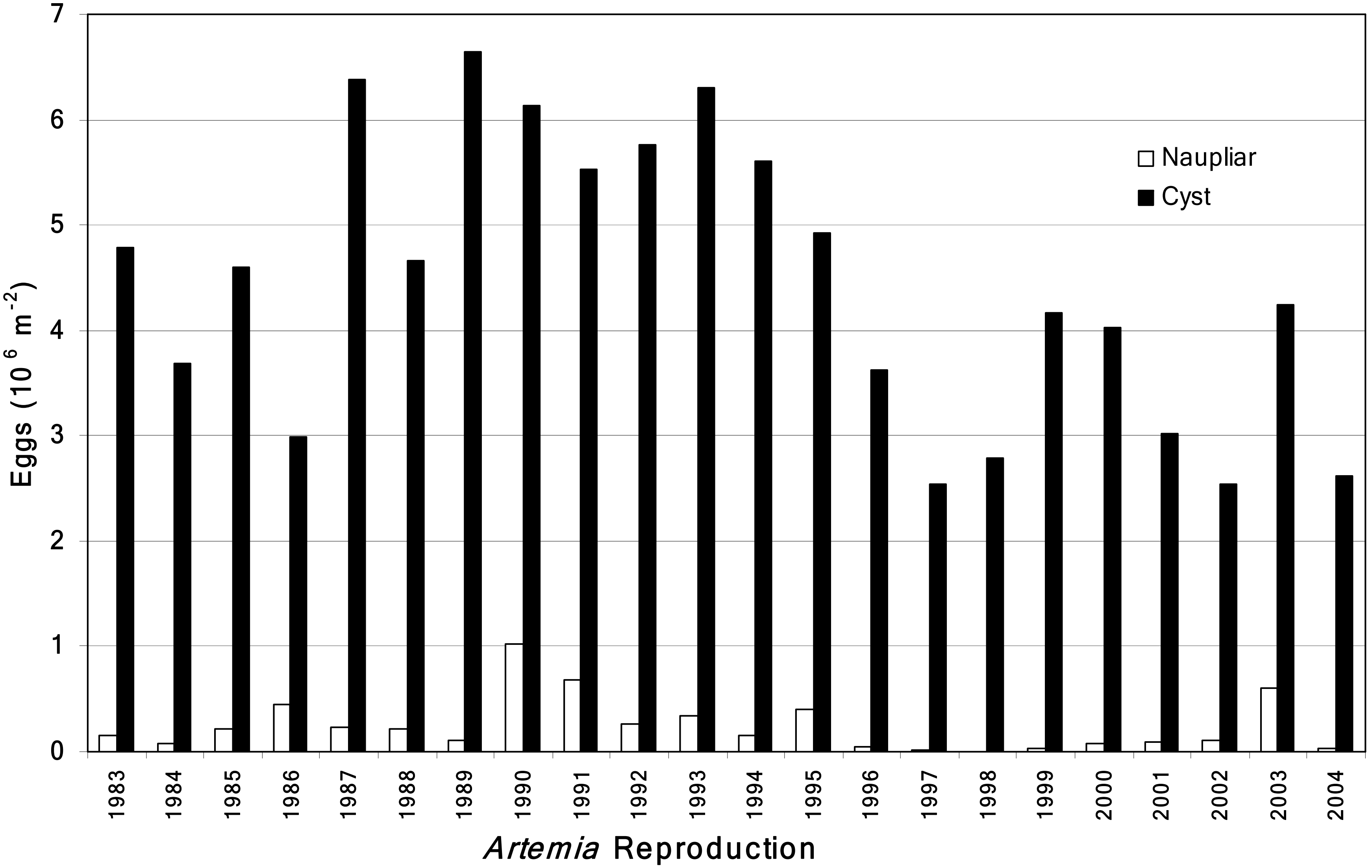

Dry Weight (mg m $^{-2}$)
18
15
12
9
6
3
0
Total
Adults
Juveniles
Nauplii
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Mean Annual *Artemia* Biomass

Figure 28



7
6
5
4
3
2
1
0
Eggs (10^6 m^{-2})
Naupliar
Cyst
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
Artemia Reproduction

Figure 29

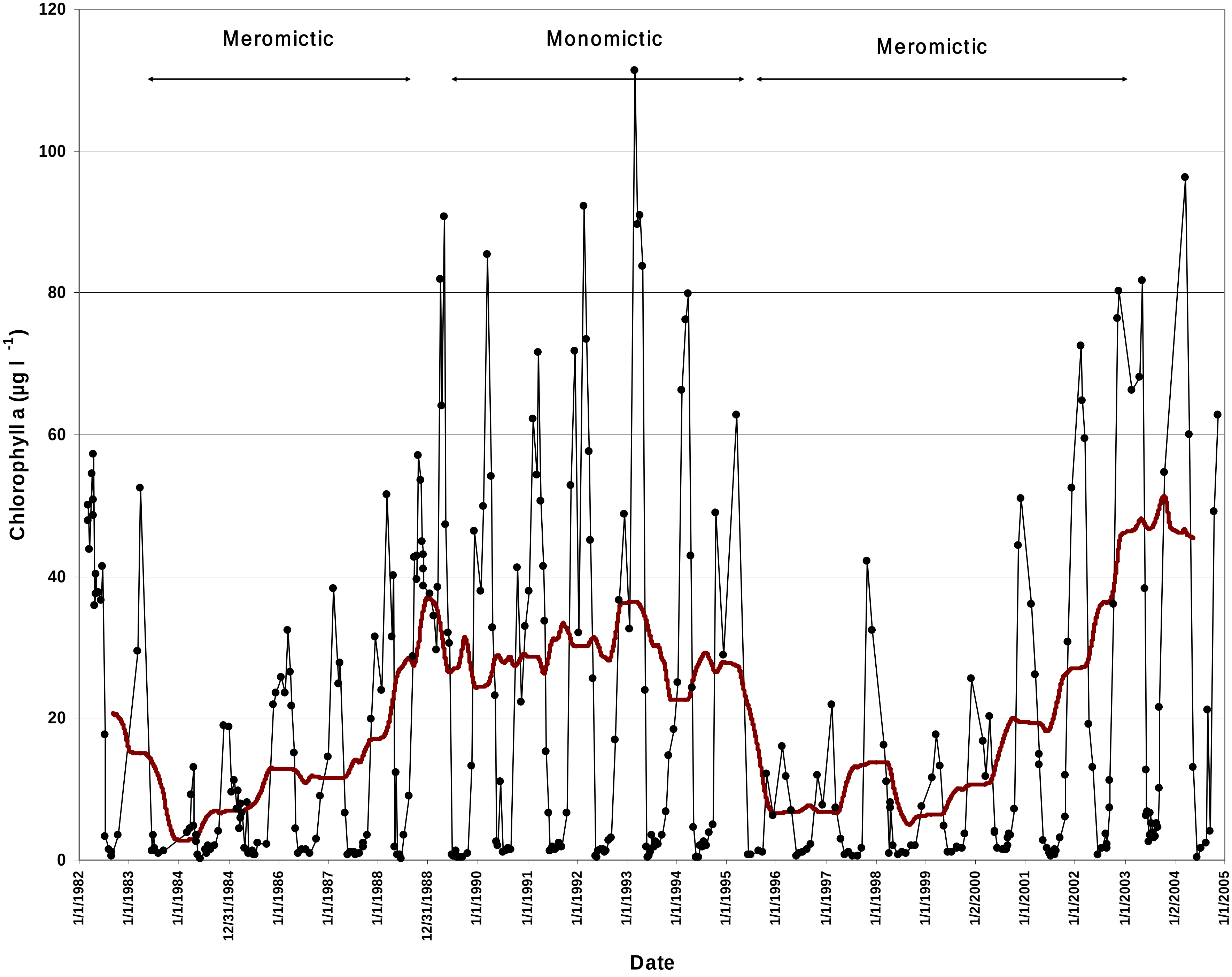

Meromictic
Monomictic
Meromictic
120
100
80
60
40
20
0
Chlorophyll a (µg l -1)
1/1/1982
1/1/1983
1/1/1984
12/31/1984
1/1/1986
1/1/1987
1/1/1988
12/31/1988
1/1/1990
1/1/1991
1/1/1992
1/1/1993
1/1/1994
1/1/1995
1/1/1996
1/1/1997
1/1/1998
1/1/1999
1/2/2000
1/1/2001
1/1/2002
1/1/2003
1/2/2004
1/1/2005
Date

Figure 30

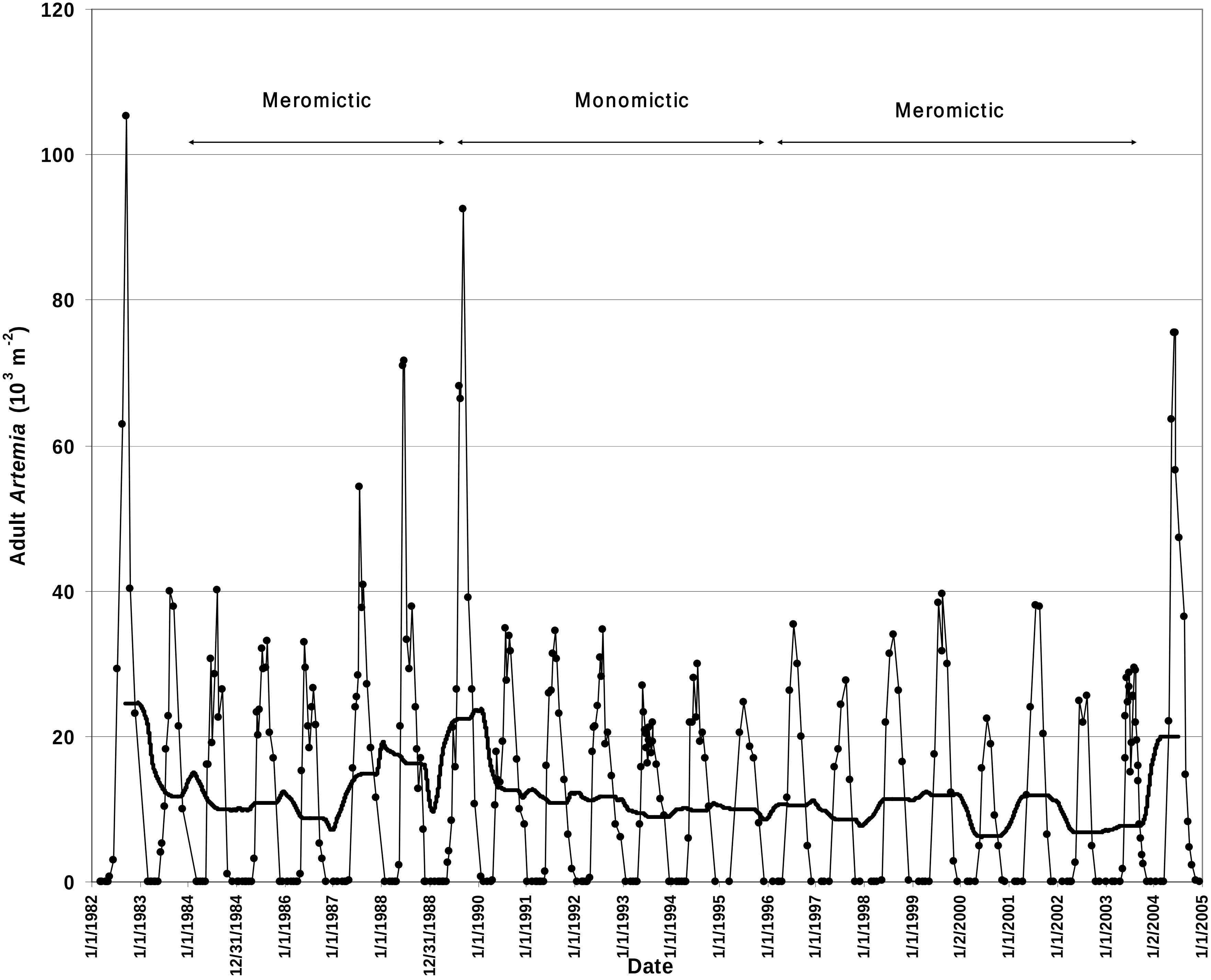

Meromictic
Monomictic
Meromictic
120
100
80
60
40
20
0
Adult *Artemia* (10³ m⁻²)
1/1/1982
1/1/1983
1/1/1984
12/31/1984
1/1/1986
1/1/1987
1/1/1988
12/31/1988
1/1/1990
1/1/1991
1/1/1992
1/1/1993
1/1/1994
1/1/1995
1/1/1996
1/1/1997
1/1/1998
1/1/1999
1/2/2000
1/1/2001
1/1/2002
1/1/2003
1/2/2004
1/1/2005
Date

Figure 31

APPENDIX 3

Ornithology

MONO LAKE WATERFOWL POPULATION MONITORING

2004 ANNUAL REPORT

9/23/2004

LOS ANGELES DEPARTMENT OF WATER AND POWER
PREPARED BY DEBBIE HOUSE
WATERSHED RESOURCES SPECIALIST
BISHOP, CA 93514
April 2005

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Data summary

Executive Summary

Waterfowl populations were monitored in 2004 at Mono Lake, Bridgeport Reservoir and Crowley Reservoir in compliance with State Water Resources Control Board Order 98-05. At Mono Lake, three summer ground surveys and six fall aerial surveys for waterfowl were conducted. To evaluate whether long-term trends observed at Mono Lake are mirrored at other Eastern Sierra water bodies, six fall aerial surveys were also conducted at Bridgeport and Crowley Reservoirs.

A total of eleven waterfowl species were encountered at Mono Lake during summer surveys. The five most common species were Gadwall, Mallard, Cinnamon Teal, Canada Goose, while six species used Mono Lake shoreline habitats and Restoration Ponds (DeChambeau and County Ponds) for brooding. Gadwall was the most abundant waterfowl species breeding at Mono Lake. This species also had the greatest spatial distribution.

A minimum of 46 unique broods were observed using Mono Lake shoreline habitats and Restoration Ponds in the summer. These 46 broods included 28 Gadwall, eight Canada Goose, five Mallard, two Northern Pintail, two Cinnamon Teal and one Green-winged Teal brood. Mill Creek supported the greatest number of waterfowl broods.

A total of 17 shorebird species were encountered during the summer surveys. Of the shorebird species that were detected throughout the summer, the most abundant species was American Avocet. Shorebird species for which evidence of breeding was detected include American Avocet, Wilson's Phalarope, Killdeer, Spotted Sandpiper, and Snowy Plover. The Sammann's Springs and Warm Springs areas attracted the greatest number of shorebird species throughout the summer season.

A total of thirteen waterfowl species were recorded at Mono Lake during fall aerial surveys. In terms of total detections, 51,371 waterfowl individuals were detected on the lake during these surveys, while 117 individuals were detected using the Restoration Ponds.

The peak number of waterfowl detected on any one survey at Mono Lake in 2004 was 17,844 and occurred on the September 30 survey.

The primary area of waterfowl use (excluding Ruddy Ducks) during fall 2004 was the Wilson Creek delta. Ruddy Ducks exhibited a shift in distribution throughout the fall, occurring in a fairly concentrated area primarily off-shore early in fall, but with increased proportions close to the shoreline later in the fall.

A total of 15 waterfowl species were recorded at Bridgeport Reservoir during fall aerial surveys. The peak number of waterfowl detected at Bridgeport Reservoir was 11,860 individuals, and occurred during the September 7 survey. A total of 30,547 waterfowl individuals were detected at Bridgeport Reservoir throughout the fall season. The most abundant species were Northern Shoveler, Mallard, and Green-winged Teal. The primary area of waterfowl concentration was the West Bay area.

A total of 16 waterfowl species were recorded at Crowley Reservoir during fall aerial surveys. The peak number detected at Crowley Reservoir was 15,002 individuals and occurred during the September 16 survey. A total of 65,583 waterfowl individuals were detected at Crowley Reservoir throughout the fall season. The most abundant species were Green-winged Teal, Northern Pintail and Mallard. The primary areas of waterfowl concentration were McGee Bay, Layton Springs and the Upper Owens River.

Comparison counts of Bridgeport and Crowley Reservoirs indicate a large disparity among the three bodies of water with regard to total detections of the dominant species. Data indicate that use was higher of Mono Lake than either Bridgeport or Crowley Reservoirs by Ruddy Ducks and Northern Shovelers. Conversely, use of Mono by Green-winged Teal, Mallard, Gadwall, and Northern Pintail was less when compared to Bridgeport and Crowley Reservoirs.

An analysis of the trend in peak waterfowl numbers indicates a significant, positive trend in the peak number of waterfowl, (exclusive of Ruddy Ducks) detected at Mono Lake since 1996.

Waterfowl Monitoring Compliance

This report fulfills the Mono Lake waterfowl population surveys and studies requirement set forth in compliance with the State Water Resources Control Board Order No. 98-05. The waterfowl monitoring program consists of summer ground counts at Mono Lake, fall migration counts at Mono Lake, fall comparative counts at Bridgeport and Crowley Reservoirs, and photos of waterfowl habitats taken from the air. Three summer grounds counts and six fall aerial surveys were conducted at Mono Lake in 2004. Six comparative fall aerial counts were completed at Bridgeport and Crowley Reservoirs. Photos of shoreline habitats and the restoration ponds were taken from a helicopter on September 23, 2004.

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2004 Mono Lake Waterfowl Population Monitoring

Los Angeles Department of Water and Power
Prepared by Debbie House
Watershed Resources Specialist
Bishop, CA

INTRODUCTION

In order to evaluate the response of waterfowl populations to restoration efforts in the Mono Basin watershed, waterfowl population monitoring is being conducted on an annual basis at Mono Lake [State Water Resources Control Board Order Numbers 98-05 and 98-07 (Orders)]. The monitoring of waterfowl populations in the Mono Basin is expected to continue until at least the year 2014, or until the targeted lake level (6392 foot elevation) is reached and the lake cycles through a complete wet/dry cycle (LADWP 2000a). Restoration activities in the Mono Basin that are expected to influence waterfowl use include the rewatering of Mono Lake tributaries, an increase in the lake level, leading to increased surface area of open-water habitats, a subsequent decrease in the salinity of the lake, and changes to lake-fringing wetlands, and the creation of freshwater pond habitat. With the exception of the creation and maintenance of freshwater pond habitat at the DeChambeau and County Pond complexes, the majority of the changes in waterfowl habitats will come through passive restoration – proper flow management in the tributaries to achieve healthy, functional riparian systems, and decreased water diversions from the watershed that will result in increases in level of the lake.

Summer ground surveys are conducted in order to document summer use by waterfowl and shorebird species of the Mono Lake shoreline, selected tributaries, and the freshwater restoration ponds. Fall aerial surveys are conducted to provide an index to the number of waterfowl using Mono Lake in the fall. Since waterfowl are migratory, their populations are influenced by factors on their wintering grounds, summering grounds, and along their migration route. In order to evaluate whether long-term trends observed at Mono Lake are mirrored at other Eastern Sierra water bodies, or are specific to changes occurring at Mono Lake, fall waterfowl surveys are also conducted at Bridgeport and Crowley Reservoirs.

All summer surveys were conducted by the author. Fall surveys were conducted by the author with assistance from Chris Allen, of Montgomery-Watson-Harza.

METHODS

Summer Ground Surveys

Three ground counts surveys were conducted at three-week intervals beginning in early June. These ground surveys were conducted as area searches. Area searches were conducted as either transect surveys, or by making observations from a stationary point. Three days were required to complete a survey of all areas. The date and time of day that surveys were done at each area in 2004 are provided as Appendix 1.

The locations surveyed were those identified in the Waterfowl Restoration Plan as current or historic waterfowl concentration areas, namely, South Tufa (SOTU), South Shore Lagoons (SSLA), Sammann's Spring (SASP), Warm Springs (WASP), Wilson Creek (WICR), Mill Creek (MICR), DeChambeau Creek delta (DECR), Rush Creek bottomlands and delta (RUCR), Lee Vining Creek bottomlands and delta (LVCR), DeChambeau Ponds (DEPO), and County Ponds (COPO). Areas surveyed during summer grounds counts are shown in Figure 1.

Transect surveys along the shoreline were conducted at South Tufa, South Shore Lagoons, Sammann's Spring, Warm Springs, DeChambeau Creek, Wilson Creek and Mill Creek sites. Transects surveys were conducted by walking at an average rate of approximately 2 km/hr. Due to the fact that waterfowl are easily flushed, and females with broods are especially wary, the shoreline was scanned well ahead of the observer in order to increase the probability of detecting broods.

Transect surveys were also conducted in lower Rush and Lee Vining Creeks, from the County Road down to the deltas. Surveys along lower Rush Creek were conducted by walking along the southern bluff above the creek. This route offered a good view of the creek while limiting wildlife disturbance or the flushing of waterfowl far ahead of the observer. In Lee Vining Creek, surveys of the creek channel were conducted by walking north of the main channel, which offered the best view of the channel. At the mouth of the creek, the main channel splits in two and forms two delta areas separated by a tall berm-like formation. In order to obtain good views of both delta areas, it was necessary to cross the main channel and walk on top of this berm. In both areas, birds within 100 meters either side of the deltas were also recorded.

At the DeChambeau Pond complex, observations were taken from a stationary point at each of the five ponds. Observation points were selected as to provide a full view of each pond. At the County Ponds, observations were taken from a single location that allowed full viewing of both ponds. At the stationary observation points at the ponds, a minimum of 5 minutes was spent at each point.

All summer ground surveys began within one hour of sunrise and were completed within approximately six hours. The order in which the various sites were visited was varied in order to minimize the effect of time of day on survey results. The total survey time was recorded for each area.

For every waterfowl and shorebird species encountered, the following were recorded based upon initial detection: the time of the observation, the habitat type the individual was using, and an activity code indicating how the bird, or birds, were using the habitat. The activity codes used were resting, foraging, flying over, nesting, brooding, sleeping, swimming, and other. The common name, scientific name and 4-letter code for all species mentioned in the document, can be found as Appendix 2.

If a waterfowl brood was detected, the size of the brood was recorded, a GPS reading was taken (UTM, NAD 27, Zone 11, CONUS), and the location of each brood was marked on an air photo while in the field. Each brood was also assigned to an age class based on plumage and body size (Gollop and Marshall 1954). Since the summer surveys were conducted at three-week intervals, any brood assigned to class I (which would include subclasses Ia, Ib, and Ic) using the Gollop and Marshall age classification scheme, would be a brood that hatched since a previous visit. Assigning broods to an age class allowed for the determination of the minimum number of “unique broods” using Mono Lake wetland and shoreline habitats.

The habitat categories used follows the classification system found in the report entitled “1999 Mono Basin Vegetation and Habitat Mapping” (LADWP 2000b). The habitat classification system defined in that report is being used for the mapping of lakeshore vegetation and the identification of changes in lake-fringing wetlands associated with changes in lake level. The specific habitat categories used in that mapping effort, and in this project, include: marsh, wet meadow, alkaline wet meadow, dry meadow/forb, riparian scrub, great basin scrub, riparian forest, freshwater stream, ria, freshwater pond, brackish lagoon, hypersaline lagoon, and unvegetated. For reference, the definition of each of these habitat types is provided as Appendix 3. Representative photos of these habitats can be found in the report entitled *Mono Lake Waterfowl Population Monitoring 2002 Annual Report* (LADWP 2003). Two additional habitat types, open water near-shore (within 50 meters off-shore) and open water offshore (>50 meters offshore), were used in order to more completely represent areas used by waterfowl and shorebirds. Although a “>50 meter” category was used, these observations will not be included in final calculations unless the presence of waterfowl off-shore is likely due to observer influence (e. g. the observer sees a that a female duck is leading her brood offshore and is continuing to swim away from shore).

Fall Aerial Surveys

Overview of methodology

Aerial surveys were conducted in the fall at Mono Lake, Bridgeport Reservoir and Crowley Reservoir. Six surveys were conducted at two-week intervals beginning the first week of September and ending the middle of November. Surveys at all three bodies of water were conducted on the same day. A summary of the fall survey schedule is provided as Appendix 4.

Surveys of Mono Lake were started at approximately 0900 hrs and completed in approximately one and one-half hours. Bridgeport Reservoir was surveyed second, followed by Crowley. All three surveys were completed by 1200 hrs. High winds forced the rescheduling of the first fall survey, and a resultant 5-day delay of the flight. The mid-October flight was conducted two days early due to scheduling conflicts.

Observations were recorded onto a handheld digital recorder, and later transcribed. A second observer was available for four of the six flights. At Mono Lake, the second observer sat on the same side of the plane as the author during the perimeter flights, and counted shorebirds and waterbirds. During the cross-lake transect counts, the second observer sat on the opposite side of the plane and censused Ruddy Ducks. At Bridgeport and Crowley, the second observer sat on the opposite side of the plane during the entire survey, and counted waterfowl. Since the second observer was only counting shorebirds at Mono Lake during perimeter flights, and the majority of ducks (with the exception of Ruddy Ducks) are detected along the shoreline, the 2004 counts are comparable to prior counts. Thus, the addition of a second observer will not affect trend analysis which excludes Ruddy Duck numbers (see *Trend Analysis* section below).

Mono Lake Aerial Surveys

Aerial surveys of Mono Lake consisted of a perimeter flight of the shoreline and fixed cross-lake transects. The shoreline was divided into 15 lakeshore segments (Figure 2) in order to document spatial use patterns of waterfowl. Coordinates forming the beginning of each segment were generated from the 2002 aerial photo of Mono Lake (2002 aerial image taken by A. K. Curtis, and processed by Air Photo, USA) and can be found as Appendix 5, along with the four-letter code for each lakeshore segment. The segment boundaries are the same as those used by Jehl (2002) except for minor adjustments made in order to provide the observer with obvious landmarks that are seen easily from the air.

Eight parallel cross-lake transects are conducted over the open water at Mono Lake. The eight transects used for surveys are spaced at one-minute intervals and correspond to those used by Boyd and Jehl (1998) for conducting monitoring of Eared Grebes during fall migration. The latitudinal alignment of each transect is provided as Appendix 6.

Each of the eight transects is further divided into two to four subsegments of approximate equal length (see Figure 2). The total length of each cross-lake transect was first determined from the 2001 aerial photo. These lengths were then divided into the appropriate number of subsections for a total of twenty-five subsegments of approximately 2-km each. This approach creates a grid-like sampling system that will allow for the evaluation of the spatial distribution of waterfowl on the open water. Since the airspeed and approximate length of each subsection was known, it was possible to use a stopwatch to determine the starting and stopping locations of each subsection when over open water.

Aerial surveys were conducted in a Cessna 172 XP at a speed of approximately 130 kilometers per hour, and at a height of approximately 60 meters above ground. Perimeter surveys were conducted at approximately 250 meters from the shoreline. When conducting aerial surveys, the perimeter of the lake was flown first in a counterclockwise direction, starting in the Ranch Cove area. Cross-lake transects were flown immediately afterward, starting from the southernmost transect and proceeding north. In order to reduce the possibility of double-counting, only birds seen from or originating from the observer's side of the aircraft were recorded.

Bridgeport Reservoir Aerial Surveys

The shoreline of Bridgeport was divided into three segments (Figure 3). Appendix 5 contains the four-letter code for each lakeshore segment and the coordinates of the beginning of each section. Flights started at the dam at the north end of the reservoir and proceeded counterclockwise. The distance from shore, flight speed, and height above ground were the same as at Mono Lake. When flying over fishermen on the water, the pilot temporarily increased the height above ground. The reservoir was circumnavigated twice during each survey due to the small size of the reservoir and the presence of large concentrations of waterfowl. The second flight allowed for the confirmation of both numbers of birds and species composition.

Crowley Reservoir Aerial Surveys

The shoreline of Crowley Reservoir was divided into seven segments (Figure 4). Coordinates forming the beginning of each segment were generated from the 2000 aerial photo of Crowley Reservoir (2000 aerial image taken by A. K. Curtis, and processed by Air Photo, USA) and can be found as Appendix 5, as well as the four-letter code used for each segment. Each survey began at the mouth of the Owens River (UPOW) and proceeded counterclockwise. The distance from shore, flight speed, and height aboveground were the same as at Mono Lake during most of each flight. On occasion, there were large numbers of fishermen on the water. This required the pilot to temporarily increase the height above ground during the flight in some areas of the lake. The reservoir was circumnavigated twice during each survey due to presence of large concentrations of waterfowl. The second flight allowed for the confirmation of both numbers of birds and species composition.

Ground verification counts

Ground verification counts were conducted when flight conditions did not allow the identification of a large percentage of waterfowl encountered, or to confirm the species or numbers present. During a ground validation count, the total waterfowl present in an area was recorded first, followed by a count the number of individuals of each species present. Appendix 7 provides the notes from the ground counts conducted in 2004.

Statistical Analysis

Summer ground counts – waterfowl distribution; shorebird distribution and species richness

Single-factor Repeated Measures Analysis of Variance (RM ANOVA) was used to determine if total waterfowl detections differed among lakeshore segments. Detections at the Restoration Ponds were not included in this analysis. For shorebirds, single-factor RM ANOVA was used to determine if total detections or species richness differed among lakeshore segments. The Tukey test (Zar 1996) was used when the ANOVA test found significant differences among sites. The Tukey Test is a multiple comparison test that can be used to determine which lakeshore segments differ significantly from the others.

Habitat use

Chi-square goodness-of-fit analysis was used to determine if waterfowl and shorebirds used the various habitats out of proportion to one another. This analysis was done for the most abundant summering species, provided that there was a minimum of 30 observations. For waterfowl, all observations (foraging, resting, brooding, etc) except those of flyovers were included in analysis. Riparian forest was excluded because no waterfowl were seen to use this habitat in 2004. The waterfowl species for which habitat use data were analyzed were Gadwall, Mallard, Cinnamon Teal and Canada Goose. Initially, a heterogeneity chi-square analysis (Zar 1996) was used to determine if habitat use data from 2002-2004 could be pooled. Habitats which were not used by the species in any of the three years were excluded. Based on this analysis, the only species for which data could be pooled from years was Canada Goose. Only the 2004 data was used for the three other species. For all significant goodness-of-fit tests, Bonferonni confidence intervals were calculated for each category following Byers and Steinhorst (1984) to determine which specific habitats were used out of proportion.

Shorebird habitat use was analyzed the same except that analysis was confined to foraging observations only. Analysis was done for American Avocet, Killdeer, Wilson's Phalarope, Spotted Sandpiper, and Snowy Plover. The only species for which data was pooled was Snowy Plover.

Fall counts - Trend analysis

Simple linear regression analysis was used to evaluate the trend in peak waterfowl numbers detected at Mono Lake since 1996. This analysis was done only on waterfowl counts excluding Ruddy Duck numbers due to the difference in survey methods employed for this species from 1996-2001 versus 2002 to present. The regression equation was then tested using ANOVA to determine the significance of the regression, e.g. is the slope significantly different from zero (Zar 1996).

Photo documentation

As required by the Orders, photo documentation of lake-fringing waterfowl habitats was completed in 2004. Photos were taken from a helicopter at all bodies of water on September 23, 2004.

Photos at Mono Lake are provided as Figure 5. The photos of Mono Lake were georeferenced using the 2002 digital aerial photos of Mono Lake. The extent of the shoreline included in each digital photo taken from the helicopter was determined using the aerial photos. The coordinates for the shoreline area depicted in each photo were then generated from the 2002 aerial photos. The coordinates are shown on each photo. The general shoreline area depicted in each photo is also indicated on an outline of lake provided with each set of photos.

Photos of Crowley Reservoir were taken on September 23, 2004 and are provided as Figure 6. The general shoreline area depicted in each photo is indicated on an outline of the reservoir.

Photos of Bridgeport Reservoir were taken on September 23, 2004 and are provided as Figure 7. The general shoreline area depicted in each photo is indicated on an outline of the reservoir.

Data Summary

Summer ground counts

Shoreline counts - waterfowl

The number of waterfowl detected in each survey area during each visit are found in Tables 1-3. Table 4 provides a summary of the number of detections for each species during each survey.

A total of eleven waterfowl species were encountered during summer surveys, seven of which were present through the summer. Evidence of breeding was documented for six of these species. The only summering species for which evidence of breeding was not seen was Ruddy Duck. As in previous years, Gadwall was the most abundant and widespread species during the summer, followed by Mallard and Cinnamon Teal.

There was a significant difference in waterfowl detections among the lakeshore segment areas ($p = 0.002$, $F = 5.470$, $df = 26$). The number of waterfowl detected at Mill Creek and Wilson Creek was significantly greater than at both South Tufa and Warm Springs (Tukey test, $p < 0.05$). The results of the Tukey test indicated there were no significant differences among the other sites in terms of waterfowl detected through during summer surveys.

Restoration Ponds - Waterfowl

All five DeChambeau Ponds contained water all season. The DeChambeau Ponds did not experience the algal blooms to the same degree as the County Ponds. Surface algae were apparent at the DeChambeau Ponds only on the third survey. At that time, Pond 4 was about 50% covered with algae, while only small amounts of surface algae were seen on the other ponds. There was a lightening-caused fire in the DeChambeau pond area in mid-June. This fire burned some of the Coyote Willow (*Salix exigua*), meadow vegetation, and sagebrush scrub west of the ponds, and burned to the edge of Ponds 4 and 5.

Surface algae were more abundant at the County Ponds during the summer of 2004 than at the DeChambeau Ponds. During the first survey, approximately 1/3 of the surface of County Pond 1 (east pond = COPOE) was covered with algae, and by the third week of July, this pond was about ¾ covered with algae. At the beginning of the season, County Pond 2 (west pond = COPOW) contained a mix of open water and emergent vegetation, but by third week of July, this pond was drying and over ¾ of its surface was covered with algae.

A total of seven waterfowl species (Tables 1-3) and broods of two species (see *Brood summary* below) were seen at the restoration ponds. Seven waterfowl broods were detected at the DeChambeau Ponds. At least three American Coot broods were raised at the DeChambeau Pond complex. Only one waterfowl brood was seen at the County Ponds. No American Coot broods were seen at the County Ponds.

Brood summary

A total of 65 broods were detected during summer counts, with 46 of those categorized as "unique". The number of unique broods represents the minimum number of broods using the lake and restoration ponds. The number of unique broods was determined by eliminating Class II broods or broods believed to have been detected during a previous survey.

Table 5 shows the number of unique broods detected per species in each of the summer survey areas. Figure 8 shows the locations of all of the broods detected in 2004. The greatest number of unique broods (16) was detected in the Mill Creek area, followed by DeChambeau Ponds (7). Six broods were detected at Wilson Creek, the South Shore Lagoon area and in the DeChambeau Creek area. No broods were detected in the Warm Springs or South Tufa areas.

A minimum of 28 Gadwall broods were detected with the majority of these broods at Mill Creek and the DeChambeau Ponds. Gadwall broods were also detected at South Shore Lagoons, Wilson Creek, Lee Vining Creek and County Ponds. Mallard broods (five total) were seen at Mill and Wilson Creeks, and along the south shore in the South Shore Lagoon and Sammann's Springs areas. A Cinnamon Teal brood was seen at Wilson Creek as well as the DeChambeau Ponds. Eight Canada Goose broods were detected, with the majority of these (6) in the DeChambeau Creek area. Northern Pintail broods (2) were seen only at Mill Creek. The only brood seen at Rush Creek was that of a Green-winged Teal.

The majority of broods (40 total) were detected on the second and third surveys (Table 5). In addition, I believe that the majority of broods raised at Mono Lake were detected by the completion of the third survey. By the third survey, there were three females that may have still been nesting including one female Gadwall at Mill Creek, and a female Mallard and female Cinnamon Teal at Sammann's Spring. During the third survey, however, there were no remaining male/female pairs seen. In addition, the number of waterfowl detected had dropped from 354 at the end of June to 155, possibly due to the departure of drakes following breeding. A similar drop in numbers was seen in 2002 and 2003 between the second and third surveys.

Waterfowl Habitat Use

Table 6 provides the habitat use data and chi-squared goodness-of-fit and Bonferonni test results for Gadwall, Mallard, Cinnamon Teal and Canada Goose. Figure 9 is a bar graph depicting the proportional use of habitats by each of these species.

Gadwall used the various habitat types out of proportion to one another (χ^2 = 2007.8, n = 619, df = 12). Gadwall were seen using the open water habitat close to shore (<50 meters) and unvegetated areas significantly more than expected (Bonferonni test, $p < 0.05$). Their use of open water was generally away from the immediate area of turbulence (which would have been classified as ria), but in the vicinity of the creek mouths or spring outflow areas such as the Wilson Creek Delta where the freshwater outflows may still be influencing the water chemistry. The number of observations of birds using hypersaline lagoon was not different than expected. All other habitats were used less than expected.

Mallards used the various habitat types out of proportion to one another (χ^2 = 208.8, n = 145, df = 12). Unvegetated areas, freshwater ponds, open water (<50 meters from shore), and ria were used out of proportion to other habitat types (Bonferonni test, $p < 0.05$). Areas where Mallards were seen using freshwater ponds most frequently were the east end of South Shore Lagoons segment and the Sammann’s Spring area. Like Gadwall, Mallards were also seen close to shore in the Wilson and Mill Creek bays. Mallard were also seen using the immediate outflow areas (ria) at all of the creek mouths.

Cinnamon Teal were seen using freshwater ponds, unvegetated areas, brackish and hypersaline lagoons and these were used out of proportion to one another (χ^2 = 384.0, n = 80, df = 12). Proportionally more observations of Cinnamon Teal were of birds using freshwater ponds such as those at Sammann's Springs, Rush Creek, and the restoration ponds (Bonferonni test, $p < 0.05$). Brackish lagoons and unvegetated areas were not used more than expected, while hypersaline lagoons were used less than expected. All other habitats showed no use by Cinnamon Teal in 2004.

Canada Goose were seen using wet and alkaline meadow, unvegetated areas, ria, and open water (<50 meters from shore), and these habitats were used out of proportion to one another (χ^2 = 238.3, n = 113, df = 5). Canada Geese used unvegetated areas (typically mudflats) proportionally more than all other habitats (Bonferonni test, $p < 0.05$). Observations of birds using ria areas was proportional, while meadow habitats, hypersaline lagoons and open water areas were used less than expected. All other habitat categories showed no use from 2002-2004.

Summer transect surveys – shorebirds

A total of 17 shorebird species were encountered during the summer surveys. The number of shorebirds detected in each survey area during each visit can be found in Tables 1-3, while Table 4 provides a summary of the number of detections for each species during each survey. The total number of shorebird species detected throughout the summer was highest at Sammann's Springs (13 species) and Warm Springs (12 species). Mean shorebird species richness also differed among sites ($p < 0.001$, F = 8.465, df = 26), however the mean number of individuals detected among the lakeshore segment areas did not ($p = 0.113$, F = 2.003, df = 26). The number of shorebird species detected at Warm Springs was significantly greater than all sites except Sammann's Spring and Rush Creek

(Tukey test, $p < 0.05$), while the number of shorebird species detected at Sammann's Spring was significantly greater than all sites except Rush Creek and Mill Creek (Tukey test, $p < 0.05$).

The shorebird species for which evidence of breeding was detected include American Avocet, Killdeer, Wilson's Phalarope, Spotted Sandpiper, and Snowy Plover. American Avocet was most abundant of the summering shorebird species, with the main concentration of birds in the Sammann's Spring and Warm Spring areas. The most widespread shorebird species was Killdeer which was detected at all survey areas, followed by Wilson's Phalaropes and American Avocet.

Phalaropes (including both Wilson's and Red-necked Phalaropes), were the most abundant migrant shorebirds during the summer survey period. The number of phalaropes reported in Tables 1-3 represent only individuals seen within 50 meters of shore, although large rafts could be seen offshore in some areas. In 2004, large numbers of phalaropes could be seen staging well offshore (Wilson Creek delta area), but unlike 2003, large numbers of phalaropes were not detected staging on- or near-shore in any of the areas surveyed, and thus were not included in the analysis.

Shorebird Habitat Use

Table 7 provides the foraging habitat use data and chi-squared goodness-of-fit and Bonferonni test results for American Avocets, Wilson's Phalaropes, Killdeer, Spotted Sandpiper and Snowy Plover. Figure 10 depicts the proportional use of habitats by each of these species.

American Avocets used the shoreline habitats out of proportion (χ^2 = 16179.8.0, n = 2453, df = 9) and used open-water areas close to shore proportionally more than expected (Bonferonni test $p < 0.05$), generally foraging at the water's edge. The second most frequently used habitat was hypersaline lagoons, and use was as expected. The use of all other habitats by American Avocets was less than expected. American Avocets were not seen using any meadow habitat or vegetated riparian habitat.

Like American Avocets, Wilson's Phalaropes also used open-water areas close to shore proportionally more than expected (χ^2 = 29200.9, n = 4416, df = 8, Bonferonni test, $p < 0.05$). The next most frequently-used habitats were ria and brackish lagoon, although these were used less than expected. Marsh, meadow and vegetated riparian habitats were not used for foraging by Wilson's Phalaropes.

Killdeer (χ^2 = 488.9, n = 89, df = 8, Bonferonni test, $p < 0.05$) and Snowy Plovers (χ^2 = 277.4, n = 159, df = 2, Bonferonni test, $p < 0.05$) foraged primarily on unvegetated areas and used all other habitats less than expected. Spotted Sandpipers used unvegetated areas and ria more than expected (χ^2 = 63.4, n = 32, df = 6, Bonferonni test, $p < 0.05$). Spotted Sandpipers were not seen foraging in marsh, meadow or vegetated riparian habitats.

Fall Aerial Surveys

Mono Lake

A total of thirteen waterfowl species and 51,372 individuals were recorded at Mono Lake during fall aerial surveys (Table 8). The peak number of waterfowl detected at Mono Lake on any single count was 17,844 and occurred on the September 30 survey (Table 8, Figure 11). Compared to the 2003 counts, these numbers represent an 18% increase in total detections and an 80% increase in the one-day peak count at Mono Lake. Unlike previous years, the peak number of both Northern Shovelers and Ruddy Ducks occurred on the same day, thus partially explaining this increase in one-day peak count. The peak count, exclusive of Ruddy Ducks was 8,994, or approximately 28% higher than the peak count of 7,011 in 2003. In terms of total detections, Ruddy Ducks and Northern Shovelers were the dominant species during fall migration (Figure 12) with Ruddy Ducks accounting for 45.7% (23,465) of all detections, and Northern Shovelers accounting for 44.5% (22,874) of all detections (Table 8). There was a 110% increase in total detections of Northern Shovelers in 2004 as compared to 2003 (10,853), and this species made up a larger percentage of total detections in 2004 (44.5%) as compared to 2003 (25%). There was a 14% decrease in total detections of Ruddy Ducks in 2004 as compared to 2003 (27,357), and this species made up a smaller percentage of total detections in 2004 (45.7%) as compared to 2003 (63.3%). There were fewer detections of all other species at Mono as compared to 2003 except Canada Goose, Cinnamon Teal and Northern Pintail.

Tables 9 – 14 provide the results of each of the six fall surveys in terms of number of each species detected in each lakeshore segment. There was a significant difference in the proportional use of the lakeshore segments by waterfowl during the fall period ($p < 0.001$, $F = 11.66$, $df = 95$). The proportion of waterfowl using the Wilson Creek delta was significantly greater than all other areas of the lake except the open water (=offshore) ($p < 0.05$). Figure 13 shows the relative percent use of each lakeshore segment by waterfowl during each fall survey. Note that Wilson Creek attracted a large proportion of the waterfowl early in the fall (Figure 13), but that the relative proportion of waterfowl using this area decreased through the fall period. This is largely due to the fact that the majority of the Northern Shovelers, which are the dominant species early in the fall, congregated and remained mainly in the Wilson Creek area. Following their departure, the proportion of waterfowl in this area was noticeably less, while the proportional use of offshore areas increased. This change was driven by the lingering presence of Ruddy Ducks, of which a significant proportion are often offshore.

A total of eight waterfowl species and 117 individuals (less than 1% of all fall detections) and 183 American Coots were detected at the DeChambeau and County Pond complexes during fall surveys (Table 15). Sixty-five (over 60%) of the waterfowl detected at the Restoration Ponds were seen at the County Ponds. County Pond 2 (COPOW) continued to be largely algae-covered into the fall.

The most abundant shorebirds at Mono Lake during fall were phalaropes and American Avocets (Table 16). During fall, the main concentration of American Avocets was at Sammann's Springs, Warm Springs, and the north shoreline areas including Northeast Shore, Bridgeport Creek, and DeChambeau Embayment (see Tables 9-14).

Ruddy Duck Distribution – Mono Lake

The distribution of Ruddy Ducks varied throughout the fall migratory period (Figure 14). Table 17 provides the number and percent of total Ruddy Ducks detected along each cross-lake segments and in each lakeshore segment for each survey. The relative width of the lines on Figure 14 represents the percent of total detections on that survey. Initially, Ruddy Ducks staged in areas offshore of DeChambeau Embayment, Bridgeport Creek and the Northeast Shore areas and most of the individuals (96.3 - 99.2%) were detected on cross-lake transects. From October on, Ruddy Ducks were more dispersed, and 1/3 to ½ of the Ruddy Ducks were detected close to the shore along much of the shoreline, exclusive of the Warm Springs, Northeast Shore and Bridgeport Creek areas.

Bridgeport Reservoir

The water level at Bridgeport Reservoir was noticeably lower than in the previous two years. The water level was low at the beginning of the survey period and remained low throughout the remainder of the monitoring period. The water level appeared to be at its lowest on the October 28 survey.

A total of 15 waterfowl species and 30,547 individuals were recorded at Bridgeport Reservoir during fall aerial surveys (Table 18). The peak number of waterfowl detected on any single count at Bridgeport Reservoir was 11,860 individuals and occurred on September

7 (Table 18, Figure 11). Compared to the 2003 counts, these numbers represent a 48% decrease in total detections and a 43% decrease in the one-day peak count at Bridgeport.

The most abundant species, in terms of total detections were Northern Shoveler followed by Mallard, Green-winged Teal and Gadwall. These four species comprised approximately 68% of all waterfowl identified. Northern Shovelers, Mallards and Gadwall were the most abundant species through September (Figure 15). From October on, Green-winged Teal was the most abundant species detected at Bridgeport. The total detections of all species were less than last year with the exception of Cinnamon Teal. Northern Shovelers were proportionally more abundant at Bridgeport this year than in 2003 (~30% of identified birds as compared to ~21%), however the total number of Northern Shovelers detected was approximately 25% less in 2004.

Tables 19-24 provide the results of each of the six fall surveys in terms of number of each species detected by lakeshore segment. There was a significant difference in the mean number of waterfowl detected at each of the lakeshore segments ($p < 0.001$, $F = 26.4$, $df = 17$). The greatest proportion of waterfowl were detected in the West Bay area (Tukey test, $p < 0.05$). The West Bay area was the primary area of waterfowl concentration throughout the fall season except during the October 28 survey during which most of the waterfowl appeared to be in the North Arm (Figure 16). This anomalous shift in the distribution of waterfowl may have been related to the lake level, which was extremely low at the time. There was no significant difference in use between the North Arm and East Shore lakeshore segment areas.

Crowley Reservoir

A total of 16 waterfowl species and 65,583 individuals were detected at Crowley Reservoir during fall aerial surveys (Table 25). The peak number of waterfowl detected on any single count at Crowley Reservoir was 15,002 individuals and occurred on September

16 (Table 25, Figure 11). Compared to the 2003 counts, these numbers represent an 11% decrease in total detections and a 4% decrease in the one-day peak count at Crowley.

The most abundant species, in terms of total detections were Green-winged Teal followed by Northern Pintail and Mallard. Figure 17 shows the number of each species detected per survey at Crowley for all species that comprised at least 1% of the total detections for fall. Green-winged Teal, Mallards and Gadwall were the dominant species early in September (Figure 17). For the remainder of the fall, Green-winged Teal, Northern Pintail, and Mallard were the dominant species.

Tables 26-31 provide the results of each of the six fall surveys in terms of number of each species detected by lakeshore segment. The mean proportion of waterfowl detection differed among lakeshore segments ($p < 0.01$, $F = 35.2$, $df = 41$). McGee Bay, the Upper Owens, and Layton Springs area accounted for a total of 93% of all detections through the fall (Figure 18). The proportion of waterfowl detected at McGee Bay was greater than all other lakeshore segments (Tukey test, $p < 0.05$). There was no significant difference among the other lakeshore segments.

Comparison of Mono Lake with Bridgeport and Crowley Reservoirs

Figure 11 shows the total number of waterfowl detected at each of the three bodies of water during the fall counts. Both Mono Lake and Bridgeport Reservoir show a peak count, followed by declines in number of waterfowl throughout the remainder of the season, while the number of waterfowl at Crowley remained relatively stable throughout the late fall.

The absolute abundance of waterfowl species differed greatly between Mono Lake and the two reservoirs. Figure 19 depicts the total detections of the most abundant species for Mono, Bridgeport and Crowley over the entire fall season. These graphs illustrate a noticeable disparity between the two reservoirs and Mono Lake in terms of total detections for several species. The total detections of Ruddy Ducks and Northern Shovelers over the season were much higher at Mono Lake than at either Bridgeport or Crowley. In contrast, the total detections of species dominant at both reservoirs, namely Gadwall, Green-winged Teal, Mallard, were noticeably lower at Mono. There were many more Northern Pintails and Green-winged Teal detected at Crowley than at either Mono Lake or Bridgeport. This disparity between Mono and the two reservoirs (especially Bridgeport and Mono) was more apparent from last year's data and may be related to the fact that the total detections at Bridgeport in general, were much lower this year than last year.

Analysis of trend in waterfowl numbers

Figure 20 illustrates the relationship of the peak number of waterfowl detected at Mono Lake from 1996-2004. The regression coefficient (r = 0.827) indicates that there is a positive relationship between the peak number of waterfowl and year. Analysis of variance indicates that this relationship is statistically significant (p = 0.006, F = 15.3, df = 1,7).

DISCUSSION

As in previous years, summer waterfowl use was concentrated in the Mill and Wilson Creek areas. The total number of waterfowl broods detected in 2004 (46) represents a decrease from the number of broods detected in 2003 (65). While it is impossible to know the reason for the decrease, it was apparent that some areas along the shoreline were drier than the previous year. This was especially apparent in the South Shore Lagoon area, where brackish lagoons have continued to contract in size as compared to 2002. Mill Creek and the DeChambeau Ponds attracted a greater percentage of the broods than last year, while Wilson Creek and other areas such as the South Shore Lagoons appeared to attract a smaller percentage than in the previous two years.

Spatial distribution patterns for shorebirds appear different than waterfowl distribution patterns at Mono Lake during the summer. There were usually more shorebirds at Warm

Springs, Sammann's Spring and Wilson Creek, although ANOVA was unable to detect a statistical difference due to the variability in the data. Warm Springs received low use by waterfowl in the summer, but this area along with Sammann's Spring, was also quite diverse in terms of shorebirds species.

Shoreline habitats used by the most abundant waterfowl summering at Mono Lake included freshwater ponds, unvegetated areas, open water areas near shore, and brackish and hypersaline lagoons. Shoreline habitats most frequently used by shorebird species in the summer were unvegetated areas and open water areas near shore.

The primary area of waterfowl use during fall was the Wilson Creek area. While the Wilson Creek area appears attractive to Northern Shovelers, after the departure of the majority of Northern Shovelers, few waterfowl were detected in this area. Instead, the main area of use by waterfowl later in the season was the open water, where the majority of the waterfowl remaining at the lake, namely Ruddy Ducks, were found.

The total number and proportional abundance of Northern Shovelers detected at Mono Lake in 2004 was greater than in 2003 (see LADWP 2004). Without knowledge of how long individual birds stay at Mono, it is impossible to say whether more Northern Shovelers used Mono Lake this year. Despite that, the greater total number of detections in 2004 as compared to 2003 indicates a higher overall use by this species in 2004.

Ruddy Ducks exhibited a shift in distribution throughout the fall, occurring in a fairly concentrated area primarily off-shore early in fall, but with increased proportions close to the shoreline later in the fall. Johnson and Jehl (2002) report that Ruddy Ducks eat primarily brine fly larvae at Mono Lake and forage in shallow areas of the lake in the vicinity of hard substrates. The areas where Ruddy Ducks concentrate coincide well with shallow-water areas of the lake with the exception of the eastern shore, where generally few are detected. This exception is likely due to the fact that the eastern end of the lake, while shallow, has very limited submerged, hard substrates with which the brine fly are associated. With the information available, it is difficult to interpret completely the seasonal pattern of Ruddy Duck distribution. Some questions that remain unanswered include whether the time budgets of the birds in the off-shore areas early in fall are significantly different than those occurring in the near-shore areas later in the fall, how long individuals remain at the lake, and whether individuals exhibit seasonal movement while at the lake due to body condition, molt stage, or prey availability. Ruddy Ducks were more dispersed around the lake throughout the fall than in 2003, but the reasons for this are unclear.

Bridgeport Reservoir showed a substantial decrease in use by waterfowl in the fall of 2004 as compared to 2003. While the level of the water in the reservoir level was noticeably below what it was in 2003, it is unclear if this was the direct or indirect cause of the decrease in number of waterfowl detected at Bridgeport, or if decreases were due to factors outside the local area.

The comparison count data provided insight regarding the relative use of Mono Lake, Bridgeport Reservoir, and Crowley Reservoir by waterfowl during fall migration. On any single count throughout the fall, the number of Ruddy Ducks at Mono Lake was greater than at either Bridgeport or Crowley, and there were significantly more total detections of Ruddy Ducks at Mono Lake. While it is not known how long individual Ruddy Ducks stay at Mono Lake, the fact that there were always more Ruddy Ducks at Mono Lake indicates a higher proportional use of Mono Lake than Bridgeport or Crowley Reservoirs by this species. The large disparity in total detections of Green-winged Teal, Mallard, Gadwall, between Mono Lake and the two reservoirs indicates that either a comparable number of individuals of these species are not stopping at Mono Lake, or that the turnover rate of individuals at Mono Lake is high, or both.

The analysis of the trend in peak waterfowl numbers indicates a continued significant, positive trend in the peak number of waterfowl, (exclusive of Ruddy Ducks) detected at Mono Lake since 1996. The variable nature of population data necessitates caution in the interpretation of this relative short-term trend.

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Table 1. Summer ground data, Survey 1 – June 7-9, 2004

Waterfowl	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
Anas sp.	51											**51**
Blue-winged x Cinnamon Teal hybrid		1										**1**
Canada Goose			22							19		**41**
Cinnamon Teal		1		10	3			2			4	**20**
Gadwall	8	34	22	9	5	5	19	27	3	96	117	**345**
Green-winged Teal		6	2							4	1	**13**
Mallard		8	4		2	3	10	23	1	1	7	**59**
Northern Pintail	4			2			9	3	2	1	3	**24**
Northern Shoveler				1			2					**3**
Redhead										4		**4**
Ruddy Duck										6		**6**
Total waterfowl by area	**63**	**50**	**50**	**22**	**10**	**8**	**40**	**55**	**6**	**131**	**132**	**567**

Shorebirds	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
American Avocet		2	27			35	67	67	11		77	**286**
Black-necked Stilt						2	2					**4**
Killdeer	3	5	16		1	9	6	1	8	6	4	**59**
Long-billed Curlew						1	1		1			**3**
Snowy Plover						16	13	2				**31**
Spotted Sandpiper	10	7	3							5		**25**
Wilson's Snipe			4									**4**
Wilson's Phalarope	2	2	20			101	191	31		14	22	**383**
Total shorebirds by area	**15**	**16**	**70**	**0**	**1**	**164**	**280**	**101**	**20**	**25**	**103**	**795**

Table 2. Summer ground data, Survey 2 – June 28- 30, 2004

Waterfowl	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
Anas sp.					2			5				**7**
American Wigeon								1				**1**
Blue-winged Teal					1							**1**
Canada Goose			12				2					**14**
Cinnamon Teal		1		4		2	3		1		1	**12**
Gadwall		13	30	4	3		7	39	5	76	62	**239**
Green-winged Teal			6		2					1	2	**11**
Mallard	1	5	3	1	1	2	18	11	1	9	6	**58**
Northern Pintail							2			1		**3**
Northern Shoveler				1								**1**
Ruddy Duck										7		**7**
Total waterfowl by area	**1**	**19**	**51**	**10**	**9**	**4**	**32**	**56**	**7**	**94**	**71**	**354**

Shorebirds	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
American Avocet		2	61			4	85	66	4		177	**399**
Black-necked Stilt			2			2	2				2	**8**
Greater Yellowlegs						3						**3**
Killdeer	2	7	15	2	1	2	1	3	8	3	5	**49**
Least Sandpiper						23	1					**24**
Long-billed Curlew		1					4	3				**8**
Snowy Plover						5	17					**22**
Spotted Sandpiper	4	8								4	1	**17**
Western Sandpiper		7										**7**
Willet						2	1					**3**
Wilson's Phalarope	105	14	168		1	1141	52	8	1	105	3202	**4797**
Total shorebirds by area	**111**	**39**	**246**	**2**	**2**	**1182**	**163**	**80**	**13**	**112**	**3387**	**5337**

Table 3. Summer ground data, Survey 3 – July 19-21, 2004

Waterfowl	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
Canada Goose			8					8	2			**18**
Cinnamon Teal		2		13		13		12			10	**50**
Gadwall	1		4	6				4		22	6	**43**
Green-winged Teal		1						1			1	**3**
Mallard		4		4			5	3			17	**33**
Northern Pintail								2			2	**4**
Ruddy Duck										4		**4**
Total waterfowl by area	**1**	**7**	**12**	**23**	**0**	**13**	**5**	**30**	**2**	**26**	**36**	**155**

Shorebirds	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
American Avocet		2	217			278	1951	147	13	11	379	**2998**
Black-bellied Plover						3	2					**5**
Greater Yellowlegs						10	1				1	**12**
Killdeer	5	5	22	1		14	2		8		3	**60**
Least Sandpiper		12				11	50	4	18			**95**
Lesser Yellowlegs									1			**1**
Long-billed Curlew						3		1				**4**
Marbled Godwit								7				**7**
Red-necked Phalarope	70						1				80	**151**
Short-billed Dowitcher			1			8	56					**65**
Snowy Plover						2	27					**29**
Spotted Sandpiper	3	7									3	**13**
Western Sandpiper		2										**2**
White-faced Ibis						10	6					**16**
Willet						2	1					**3**
Wilson's Phalarope	30	3	75			5	80	19			965	**1177**
Phalaropus spp.											35	**35**
Total shorebirds by area	**108**	**31**	**315**	**1**	**0**	**346**	**2177**	**178**	**40**	**11**	**1466**	**4673**

Table 4. Summary of ground count data for Mono Lake, 2004

Waterfowl	Survey 1	Survey 2	Survey 3	Total Detections
American Wigeon		1		1
Blue-winged Teal		1		1
Blue-winged x Cinnamon Teal hybrid	1			1
Canada Goose	41	14	18	73
Cinnamon Teal	20	12	50	82
Gadwall	345	239	43	627
Green-winged Teal	13	11	3	27
Mallard	59	58	33	150
Northern Pintail	24	3	4	31
Northern Shoveler	3	1		4
Redhead	4			4
Ruddy Duck	6	7	4	17
Unidentified *Anas* spp.	51	7		58
Total Waterfowl	567	354	155	1076

Shorebirds	Survey 1	Survey 2	Survey 3	Total Detections
American Avocet	286	399	2998	3683
Black-bellied Plover			5	5
Black-necked Stilt	4	8		12
Greater Yellowlegs		3	12	15
Killdeer	59	49	60	168
Least Sandpiper		24	95	119
Lesser Yellowlegs			1	1
Long-billed Curlew	3	8	4	15
Short-billed Dowitcher			65	65
Marbled Godwit			7	7
Red-necked Phalarope			151	151
Snowy Plover	31	22	29	82
Spotted Sandpiper	25	17	13	55
Western Sandpiper		7	2	9
White-faced Ibis			16	16
Willet		3	3	6
Wilson's Phalarope	383	4797	1177	6357
Phalaropus spp.			35	35
Total Shorebirds	791	5337	4673	10801

Table 5. Number of unique broods of each species detected per visit in each summer survey area

	Shoreline segment	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	Total broods
Survey 1	CAGO			1							1		2
	CITE				1								1
	GADW										1		1
	GWTE												0
	MALL								1			1	2
	NOPI												0
	Total broods	0	0	1	1	0	0	0	1	0	2	1	6
Survey 2													
	CAGO			5				1					6
	CITE											1	1
	GADW				2	1			2		4	3	12
	GWTE												0
	MALL							1			1		2
	NOPI										1		1
	Total broods	0	0	5	2	1	0	2	2	0	6	4	22
Survey 3													
	CAGO												0
	CITE												0
	GADW	1			4				3		6	1	15
	GWTE		1										1
	MALL										1		1
	NOPI										1		1
	Total broods	1	1	0	4	0	0	0	3	0	8	1	18
Total broods per area		1	1	6	7	1	0	2	6	0	16	6	46

Table 6. Chi-square goodness-of-fit results for waterfowl habitat use data. Grayed categories were excluded from analysis. The results of the Bonferroni Test are indicated in the "Sign" (= significance) column. NS indicates that there was no significant difference between expected and observed use of a habitat type at the $p < 0.05$ level.

	GADW				MALL				CITE				CAGO			
Habitat	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign
Marsh	3	47.6	41.8	-	6	11.2	2.4	-	0	10	10.0	-				
Wet Meadow	12	47.6	26.6	-	2	11.2	7.5	-					4	18.8	11.6	-
Alkaline Wet Meadow	4	47.6	39.9	-	2	11.2	7.5	-					10	18.8	4.4	-
Dry Meadow/Forb	0	47.6	47.6	-	0	11.2	11.2	-								
Riparian Scrub	4	47.6	39.9	-	0	11.2	11.2	-								
Great Basin Scrub	0	47.6	47.6	-	0	11.2	11.2	-								
Riparian Forest																
Freshwater Stream	11	47.6	28.2	-	1	11.2	9.2	-	0	10	10.0	-				
Ria	29	47.6	7.3	-	13	11.2	0.3	+	0	10	10.0	-	12	18.8	2.5	NS
Freshwater Pond	34	47.6	3.9	-	29	11.2	28.6	+	49	10	152.1	+				
Brackish Lagoon	32	47.6	5.1	-	14	11.2	0.7	NS	16	10	3.6	NS				
Hypersaline Lagoon	47	47.6	0.01	NS	17	11.2	3.1	NS	1	10	8.1	-	2	18.8	15.1	-
Unvegetated	118	47.6	104.0	+	47	11.2	115.3	+	14	10	1.6	NS	76	18.8	174.0	+
Open Water <50m	325	47.6	1615.7	+	14	11.2	0.7	+	0	10	10.0	-	9	18.8	5.1	-
Total	619		2007.8		145		208.7		80		205.4		113		238.2	

Table 7. Chi-square goodness-of-fit results for shorebird foraging habitat use data. Grayed categories were excluded from analysis. The results of the Bonferroni Test are indicated in the "Sign" (=significance) column. NS indicates that there was no significant difference between expected and observed use of a habitat type at the $p < 0.05$ level.

	AMAV				KILL				WIPH				SNPL				SPSA			
Habitat	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign
Marsh																				
Wet Meadow	0	245.3	245.3	-	0	9.8	9.8	-												
Alkaline Wet Meadow	0	245.3	245.3	-					0	491	490.7	-	4	53	45.3	-				
Dry Meadow/Forb	45	245.3	163.5	-	0	9.8	9.8	-												
Riparian Scrub																				
Great Basin Scrub																				
Riparian Forest									2	491	486.7	-								
Freshwater Stream	0	245.3	245.3	-	3	9.8	4.7	-	25	491	441.9	-					1	4.6	2.8	-
Ria	8	245.3	229.5	-	4	9.8	3.4	-	140	491	250.6	-					8	4.6	2.6	+
Freshwater Pond	25	245.3	197.8	-	0	9.8	9.8	-	60	491	378.0	-					3	4.6	0.5	NS
Brackish Lagoon	20	245.3	206.9	-	4	9.8	3.4	-	111	491	293.8	-					0	4.6	4.6	-
Hypersaline Lagoon	218	245.3	3.0	NS	1	9.8	7.9	-	6	491	478.8	-	3	53	47.2	-	0	4.6	4.6	-
Unvegetated	11	245.3	223.8	-	75	9.8	433.8	+	15	491	461.2	-	152	53	184.9	+	19	4.6	45.6	+
Open Water <50m	2126	245.3	14419.2	+	2	9.8	6.2	-	4057	491	25919.1	+					1	4.6	2.8	-
Total	2453		16179.8		89		488.9		4416		29200.9		159		277.4		32		63.4	

Table 8. Summary of fall aerial survey counts for 2004 – Mono Lake

Species	7-Sep	16-Sep	30-Sep	12-Oct	28-Oct	10-Nov	**Total Detections**	**%Total Detections**
American Wigeon					6		6	0.01
Bufflehead					2		2	0.00
Canada Goose	12	42	25	73	97	94	343	0.67
Cinnamon Teal	180	53	4				237	0.46
Gadwall	10	110		8			128	0.25
Green-winged Teal	2	159	268	243	372	90	1134	2.21
Lesser Scaup				40			40	0.08
Mallard	16	28	71	70	35	90	310	0.60
Northern Pintail		37	3	42	700		782	1.52
Northern Shoveler	6072	3953	8263	4465	116	5	22874	44.53
Ross' Goose						1	1	0.00
Ruddy Duck	1435	1846	8850	4201	3953	3180	23465	45.68
Unidentified *Anas* spp.	66	869	360	97	636	22	2050	3.99
Total waterfowl	7793	7097	17844	9239	5917	3482	51372	

Table 9. Mono Lake - fall aerial survey, 7 September, 2004

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
Canada Goose				12												12	12
Cinnamon Teal				180												180	180
Gadwall												6	4			10	10
Green-winged Teal										2						2	2
Mallard	1			15												16	16
Northern Shoveler					700					4700	668				4	6072	6072
Ruddy Duck								2			8				1	11	1435
Unidentified *Anas*											10	56				66	66
Total Waterfowl	1	0	0	207	700	0	0	2	0	4702	686	62	4	0	5	**6369**	**7793**

Waterbird count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Avocet			50	3000	2300	2300	1330	430		3		60				9473	9579
Black-necked Stilt												15				15	15
Killdeer													4			4	4
Phalaropus spp.															120	120	13871
Calidris spp.		20	30					2					40	30		122	122
Marbled Godwit			6							4						10	10
White-faced Ibis	12							8								20	20
Total Waterbirds	12	20	86	3000	2300	2300	1330	440	0	7	0	75	44	30	120	**9764**	**23621**

Table 10. Mono Lake - fall aerial survey, 16 September, 2004

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
Canada Goose			42													42	42
Cinnamon Teal				50								3				53	53
Gadwall					5							105				110	110
Green-winged Teal	20			10	5	7				100		17				159	159
Mallard	4			5			5					13			1	28	28
Northern Shoveler	3				25		260			3600	60	2		3		3953	3953
Northern Pintail	37															37	37
Ruddy Duck								40			21		1	5		67	1846
Unidentified *Anas*	4				15		30			800		20				869	869
Total Waterfowl	68	0	42	65	50	7	295	40	0	4500	81	160	1	8	1	**5318**	**7097**

Waterbird count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Avocet			100	500	1500		1400									3500	3500
American Coot	4															4	5
Large shorebird	5															5	5
Western/Least Sandpiper								100								100	100
Phalaropus spp.								93								93	5072
Marbled Godwit			8													8	8
Killdeer													7			7	7
Total Waterbirds	9	0	108	500	1500	0	1400	193	0	0	0	0	7	0	0	**3717**	**8697**

Table 11. Mono Lake - fall aerial survey, 30 September, 2004

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
Canada Goose				25												25	25
Cinnamon Teal												4				4	4
Green-winged Teal				190				20				58				268	268
Mallard				20	30					1		20				71	71
Northern Pintail												3				3	3
Northern Shoveler				700	10			462	4	6500	270	300	8	5	4	8263	8263
Ruddy Duck				1200			900				70				8	2178	8850
Unidentified *Anas*										200		120		40		360	360
Total Waterfowl	0	0	0	2135	40	0	900	482	4	6701	340	505	8	45	12	**11172**	**17844**

Waterbird Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Avocet			6	4508	88	102	160	264	511	316		156				6111	6137
American Coot				48												48	48
Great Blue Heron													1	1		2	2
Killdeer		7														7	7
Marbled Godwit/Curlew			25													25	25
Phalaropus spp.								30								30	3952
Total Waterbirds	0	7	31	4556	88	102	160	294	511	316	0	156	1	1	0	**6223**	**10171**

Table 12. Mono Lake - fall aerial survey, 12 October, 2004

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
Canada Goose			18	4			11					40				73	73
Gadwall				8												8	8
Green-winged Teal			1	32							60	150				243	243
Lesser Scaup				40												40	40
Mallard				40	18									12		70	70
Northern Pintail											2	40				42	42
Northern Shoveler	12			12				802		3240	220	165	14			4465	4465
Ruddy Duck	35	494	88	85				35	250		300	180	400	18	469	2354	4201
Unidentified *Anas*				5									92			97	97
Total Waterfowl	47	494	107	226	18	0	11	837	250	3240	582	575	506	30	469	**7392**	**9239**

Waterbird Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Avocet				96	19	1	44	65	125	20						370	370
American Coot									12							12	26
American White Pelican		140														140	140
Marbled Godwit			15													15	15
Chalidris spp.									15							15	15
Total Waterbirds	0	140	15	96	19	1	44	65	152	20	0	0	0	0	0	552	566

Table 13. Mono Lake - fall aerial survey, 28 October, 2004

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Wigeon					6											6	6
Bufflehead															1	1	2
Canada Goose			63				9					25				97	97
Green-winged Teal				52						300		20				372	372
Mallard					25						10					35	35
Northern Pintail										500	200					700	700
Northern Shoveler	8			3				5			100					116	116
Ruddy Duck	85	19	3					1015	42		50		106	35	307	1662	3953
Unidentified *Anas*				33						400	200	3				636	636
Total Waterfowl	93	19	66	88	31	0	9	1020	42	1200	560	48	106	35	308	**3625**	**5917**

Waterbird Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Coot			22										5			27	27
American Avocet		6		8			1		35							50	50
American White Pelican			150													150	150
Killdeer			2													2	2
Marbled Godwit			3													3	3
Western Grebe				2												2	2
White-faced Ibis				3												3	3
Willet									6							6	6
Calidris spp.				21	27	6										54	54
Total Waterbirds	0	6	177	34	27	6	1	0	41	0	0	0	5	0	0	**297**	**297**

Table 14. Mono Lake - fall aerial survey, 10 November, 2004

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
Canada Goose				55				38					1			94	94
Green-winged Teal				45								40		5		90	90
Mallard				18	2			8					2	60		90	90
Northern Shoveler			5													5	5
Ross's Goose								1								1	1
Ruddy Duck	44	58	8	8				75	304	7	22	33	321	14	114	1008	3180
Unidentified *Anas*				22												22	22
Total Waterfowl	44	58	13	148	2	0	0	122	304	7	22	73	324	79	114	**1310**	**3482**

Waterbird Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Coot											50		23			73	76
American Avocet				16				5	27			3				51	51
Unidentified shorebirds					2											2	2
Great Blue Heron													1	1		2	2
Total Waterbirds	0	0	0	16	2	0	0	5	27	0	50	3	24	1	0	**128**	**131**

Table 15. Mono Lake Restoration ponds – Aerial waterfowl counts - 2004

Sept 7	CITE	GADW	MALL	*Anas*	AMCO
COPO_1 E					
COPO_2 W		1			
DEPO_1					10
DEPO_2					
DEPO_3					
DEPO_4	2				
DEPO_5			2	8	1
Total	2	1	2	8	11

Sept 16	*Anas*	GADW	AMCO
COPO_1 E		1	
COPO_2 W			
DEPO_1			10
DEPO_2	8		
DEPO_3	4		
DEPO_4	1		12
DEPO_5			
Total	13	1	22

Sept 30	NSHO	*Anas*	AMCO
COPO_1 E	1		10
COPO_2 W			1
DEPO_1			
DEPO_2			2
DEPO_3	1		4
DEPO_4		8	
DEPO_5			
Total	2	8	17

Oct 12	CAGO	NSHO	AMCO
COPO_1		30	
COPO_2		4	
DEPO_1	3	1	3
DEPO_2			1
DEPO_3			3
DEPO_4			10
DEPO_5			
Total	3	35	17

Oct 28	BUFF	MALL	NOPI	NSHO	*Anas*	AMCO
COPO_1 E			15			
COPO_2 W				12		5
DEPO_1						27
DEPO_2						12
DEPO_3						10
DEPO_4	2	5			5	20
DEPO_5						
Total	2	5	15	12	5	74

Nov 10	NSHO	TUSW	AMCO
COPO_1			
COPO_2	1		12
DEPO_1			8
DEPO_2			12
DEPO_3		2	
DEPO_4			10
DEPO_5			
Total	1	2	42

Total Detections	BUFF	CITE	CAGO	GADW	MALL	NOPI	NSHO	TUSW	*Anas*	Total Waterfowl	Total AMCO
	2	2	3	2	7	15	50	2	34	117	183

Table 16. Summary of shorebird/waterbird counts at Mono Lake during fall aerial counts

Survey Date	7-Sep	16-Sep	30-Sep	12-Oct	28-Oct	10-Nov	Total Detections
American Avocet	9579	3500	6137	370	50	51	19687
American Coot			48	26	27	76	177
American White Pelican				140	150		290
Black-necked Stilt	15	5					20
Great Blue Heron			2			2	4
Killdeer	4	5	7		2		18
Marbled Godwit/Curlew			25				25
Marbled Godwit				15	3		18
Phalaropus spp.	13871	100	3952				17923
Calidris spp.	122	5072		15	54	2	5265
Marbled Godwit	10	8					18
Western Grebe					2		2
White-faced Ibis	20	7			3		30
Willet					6		6
Total	23621	8697	10171	566	297	131	43483

Table 17. Seasonal distribution of Ruddy Ducks. Total Ruddy Ducks and % of total Ruddy Ducks detected along each cross-lake transect or lakeshore segment during fall surveys.

Segment	7-Sep	***%Det***	16-Sep	***%Det***	30-Sep	***%Det***	12-Oct	***%Det***	28-Oct	***%Det***	10-Nov	***%Det***
1a			2	***0.11***					26	***0.66***	14	***0.43***
1b	4	***0.28***					1	***0.02***	6	***0.15***	83	***2.53***
2a	1	***0.07***			4	***0.05***			91	***2.30***	78	***2.38***
2b	1	***0.07***	3	***0.16***	4	***0.05***			1	***0.03***	8	***0.24***
2c	13	***0.91***	28	***1.52***	8	***0.09***	96	***2.29***	634	***16.04***	328	***10.02***
3a					3	***0.03***	12	***0.29***	54	***1.37***	176	***5.37***
3b									22	***0.56***	28	***0.85***
3c	1	***0.07***	1	***0.05***	4	***0.05***			8	***0.20***	31	***0.95***
3d			3	***0.16***	932	***10.53***	32	***0.76***	113	***2.86***	51	***1.56***
4a			1	***0.05***			8	***0.19***	300	***7.59***	64	***1.95***
4b	6	***0.42***	34	***1.84***			21	***0.50***	60	***1.52***	153	***4.67***
4c	8	***0.56***	29	***1.57***			5	***0.12***	2	***0.05***	77	***2.35***
4d	4	***0.28***	8	***0.43***	39	***0.44***	29	***0.69***			21	***0.64***
5a			10	***0.54***	5	***0.06***	291	***6.93***	28	***0.71***	255	***7.79***
5b	5	***0.35***					2	***0.05***	48	***1.21***	9	***0.27***
5c	3	***0.21***	34	***1.84***					10	***0.25***	1	***0.03***
5d	5	***0.35***	14	***0.76***	19	***0.21***	196	***4.67***	272	***6.88***	38	***1.16***
6a	31	***2.16***	6	***0.33***			170	***4.05***	231	***5.84***	210	***6.41***
6b	7	***0.49***	139	***7.53***	8	***0.09***					12	***0.37***
6c			149	***8.07***	5	***0.06***	109	***2.59***	22	***0.56***	60	***1.83***
7a	20	***1.39***	33	***1.79***	126	***1.42***	364	***8.66***	276	***6.98***	373	***11.39***
7b	450	***31.36***	476	***25.79***			5	***0.12***			110	***3.36***
7c	38	***2.65***	17	***0.92***	2	***0.02***	48	***1.14***	57	***1.44***	8	***0.24***
8a	363	***25.30***	533	***28.87***	3383	***38.23***	177	***4.21***	28	***0.71***	33	***1.01***
8b	464	***32.33***	259	***14.03***	2130	***24.07***	281	***6.69***	2	***0.05***	46	***1.40***
RUCR							35	***0.83***	85	***2.15***	44	***1.34***
SOTU							494	***11.76***	19	***0.48***	58	***1.77***
SSLA							88	***2.09***	3	***0.08***	8	***0.24***
SASP					1200	***13.56***	85	***2.02***			8	***0.24***
WASP												
NESH												
BRCR					900	***10.17***						
DEEM	2	***0.14***	40	***2.17***			35	***0.83***	1015	***25.68***	75	***2.29***
BLPO							250	***5.95***	42	***1.06***	304	***9.28***
WICR											7	***0.21***
MICR	8	***0.56***	21	***1.14***	70	***0.79***	300	***7.14***	50	***1.26***	22	***0.67***
DECR							180	***4.28***			33	***1.01***
WESH			1	***0.05***			400	***9.52***	106	***2.68***	321	***9.80***
LVCR			5	***0.27***			18	***0.43***	35	***0.89***	14	***0.43***
RACO	1	***0.07***			8	***0.09***	469	***11.16***	307	***7.77***	114	***3.48***
Total	**1435**		**1846**		**8850**		**4201**		**3953**		**3275**	

Table 18. Summary of 2004 fall aerial survey counts – Bridgeport Reservoir

Species	7-Sep	16-Sep	30-Sep	12-Oct	28-Oct	10-Nov	Total Detections	%Total Detections
American Wigeon						60	60	0.20
Bufflehead			4		163	70	237	0.78
Canada Goose	334	120	253	147	350	250	1454	4.76
Canvasback	1				3		4	0.01
Cinnamon Teal	671	124					795	2.60
Common Merganser	4	3	7	3	2	6	25	0.08
Gadwall	1446	1267	173		10	60	2956	9.68
Green-winged Teal	460	463	680	403	890	348	3244	10.62
Lesser Scaup				5	5	13	23	0.08
Mallard	2014	2002	731	23	85	361	5216	17.08
Northern Pintail	100	252	100	1	640	216	1309	4.29
Northern Shoveler	5400	3203	542	145	37	9	9336	30.56
Redhead			6		10		16	0.05
Ruddy Duck	20	25	10		150		205	0.67
Tundra Swan						7	7	0.02
Unidentified	1410	3420	640	120	20	50	5660	18.53
Total Waterfowl	11860	10879	3146	847	2365	1450	30547	

Table 19. Bridgeport Reservoir - fall aerial survey, 7 September, 2004

Waterfowl Count	Lakeshore segment			Total
Species	NOAR	WEBA	EASH	
Canada Goose		284	50	334
Canvasback		1		1
Cinnamon Teal	11	600	60	671
Common Merganser	4			4
Gadwall		1440	6	1446
Green-winged Teal	30	400	30	460
Mallard	3	2008	3	2014
Northern Pintail		100		100
Northern Shoveler		5400		5400
Ruddy Duck		20		20
Unidentified		1200	210	1410
Total Waterfowl	48	11453	359	11860

Table 20. Bridgeport Reservoir - fall aerial survey, 16 September, 2004

Waterfowl Count	Lakeshore segment			Total
Species	NOAR	WEBA	EASH	
Canada Goose	0	120	0	120
Cinnamon Teal	24	100	0	124
Common Merganser	3	0	0	3
Gadwall	18	1200	49	1267
Green-winged Teal	5	450	8	463
Mallard	2	2000	0	2002
Northern Pintail	2	250	0	252
Northern Shoveler	3	3200	0	3203
Ruddy Duck	0	25	0	25
Unidentified	0	3000	420	3420
Total Waterfowl	57	10345	477	10879

Table 21. Bridgeport Reservoir - fall aerial survey, 30 September, 2004

Waterfowl Count	Lakeshore segment			Total
Species	NOAR	WEBA	EASH	
Bufflehead		2	2	4
Canada Goose		253		253
Common Merganser	7			7
Gadwall	2	170	1	173
Green-winged Teal		670	10	680
Mallard		720	11	731
Northern Pintail		100		100
Northern Shoveler	2	540		542
Redhead	4	2		6
Ruddy Duck		10		10
Unidentified		600	40	640
Total Waterfowl	15	3067	64	3146

Table 22. Bridgeport Reservoir - fall aerial survey, 12 October, 2004

Waterfowl Count	Lakeshore segment			Total
Species	NOAR	WEBA	EASH	
Canada Goose		147		147
Common Merganser	3			3
Green-winged Teal		400	3	403
Lesser Scaup		5		5
Mallard	3	20		23
Northern Pintail			1	1
Northern Shoveler	8	120	17	145
Unidentified		120		120
Total Waterfowl	14	812	21	847

Table 23. Bridgeport Reservoir - fall aerial survey, 28 October, 2004

Waterfowl Count	Lakeshore segment			Total
Species	NOAR	WEBA	EASH	
Bufflehead	53	100	10	163
Canada Goose		350		350
Canvasback		3		3
Common Merganser	2			2
Gadwall			10	10
Green-winged Teal	690	150	50	890
Lesser Scaup	5			5
Mallard	25	50	10	85
Northern Pintail	420	200	20	640
Northern Shoveler	23	8	6	37
Redhead	10			10
Ruddy Duck	50	100		150
Unidentified		10	10	20
Total waterfowl	1278	971	116	2365

Table 24. Bridgeport Reservoir - fall aerial survey, 10 November, 2004

Waterfowl Count	Lakeshore segment			Total
Species	NOAR	WEBA	EASH	
American Wigeon		60		60
Bufflehead	8	50	12	70
Canada Goose		233	17	250
Common Merganser	6			6
Gadwall		60		60
Green-winged Teal		328	20	348
Lesser Scaup	13			13
Mallard		355	6	361
Northern Pintail	6	210		216
Northern Shoveler			9	9
Tundra Swan		7		7
Unidentified		50		50
Total Waterfowl	33	1353	64	1450

Table 25. Summary of 2004 fall aerial survey counts – Crowley Reservoir

Species	7-Sep	16-Sep	30-Sep	12-Oct	28-Oct	10-Nov	Total Detections	%Total Detections
American Wigeon		102	152	20	505	450	1229	1.87
Bufflehead		8	4	6	301	789	1108	1.69
Canada Goose	346	149	300	400	193	238	1626	2.48
Cinnamon Teal	828	503	5				1336	2.04
Common Goldeneye						3	3	0.00
Gadwall	702	1750	1132	22	200	22	3828	5.84
Greater White-fronted Goose			23		9		32	0.05
Green-winged Teal	4339	3995	3750	1873	1375	1588	16920	25.80
Lesser Scaup	150		20	25	14	14	223	0.34
Mallard	2106	755	538	1617	2170	3284	10470	15.96
Northern Pintail	612	2900	1425	2082	2211	1800	11030	16.82
Northern Shoveler	820	1640	570	569	10	4	3613	5.51
Redhead		50		30	5		85	0.13
Ring-necked Duck	45		10	40	10	22	127	0.19
Ruddy Duck	500	300	400	714	1677	568	4159	6.34
Tundra Swan						60	60	0.09
Unidentified	2222	2850	2000	1093	980	589	9734	14.84
Total Waterfowl	12670	15002	10329	8491	9660	9431	65583	

Table 26. Crowley Reservoir - fall aerial survey, 7 September, 2004

Waterfowl Count	Lakeshore segment							Total detections
Species	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
Canada Goose	60			250	5	2	29	346
Cinnamon Teal	300	37	21	300	170			828
Gadwall	300		12	350	20		20	702
Green-winged Teal	200		9	4000	130			4339
Lesser Scaup				150				150
Mallard	100	6		2000				2106
Northern Pintail	10			600		2		612
Northern Shoveler	500			20	300			820
Ring-necked Duck				45				45
Ruddy Duck	100			400				500
Unidentified	400	2		1800	20			2222
Total Waterfowl	1970	45	42	9915	645	4	49	12670

Table 27. Crowley Reservoir - fall aerial survey, 16 September, 2004

Waterfowl Count	Lakeshore segment							Total Detections
Species	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	100			2				102
Bufflehead				8				8
Canada Goose	9			140				149
Cinnamon Teal	200		3	180	50		70	503
Gadwall	50			1200			500	1750
Green-winged Teal	600		30	3360	5			3995
Mallard	50			700	5			755
Northern Pintail	600			2200			100	2900
Northern Shoveler	400			1200	20		20	1640
Redhead				50				50
Ruddy Duck	150			150				300
Unidentified				2600			250	2850
Total Waterfowl	2159	0	33	11790	80	0	940	15002

Table 28. Crowley Reservoir - fall aerial survey, 30 September, 2004

Waterfowl Count	Lakeshore segment							Total Detections
Species	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	52						100	152
Bufflehead	1		3					4
Canada Goose				300				300
Cinnamon Teal					5			5
Gadwall	480	2		350			300	1132
Greater White-fronted Goose	23							23
Green-winged Teal	200		80	3000	20		450	3750
Lesser Scaup				20				20
Mallard	110			350		18	60	538
Northern Pintail	120			700	5		600	1425
Northern Shoveler	360		10				200	570
Ring-necked Duck							10	10
Ruddy Duck			150				250	400
Unidentified				1200			800	2000
Total Waterfowl	1346	2	243	5920	30	18	2770	10329

Table 29. Crowley Reservoir - fall aerial survey, 12 October, 2004

Waterfowl Count	Lakeshore segment							Total Detections
Species	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	20							20
Bufflehead			6					6
Canada Goose				400				400
Gadwall		2					20	22
Green-winged Teal	280		25	1260	8		300	1873
Lesser Scaup				25				25
Mallard	550		33	840	64	30	100	1617
Northern Pintail	160	1	1	1470			450	2082
Northern Shoveler	205	4		210			150	569
Redhead				20			10	30
Ring-necked Duck				30			10	40
Ruddy Duck	200	14	150	350				714
Unidentified	200	2	6	420		5	460	1093
Total Waterfowl	1615	23	221	5025	72	35	1500	8491

Table 30. Crowley Reservoir - fall aerial survey, 28 October, 2004

Waterfowl Count	Lakeshore segment							Total Detections
Species	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	300				5		200	505
Bufflehead		50	3	3	145	20	80	301
Canada Goose	180			13				193
Gadwall	150			10			40	200
Greater White-fronted Goose	7			2				9
Green-winged Teal	150		5	1200	20			1375
Lesser Scaup	4			10				14
Mallard	600		54	1000	180	40	296	2170
Northern Pintail	700		6	1200	5		300	2211
Northern Shoveler	10							10
Redhead	5							5
Ring-necked Duck				10				10
Ruddy Duck	50	140		647	210	30	600	1677
Unidentified		40		500	290		150	980
Total Waterfowl	2156	230	68	4595	855	90	1666	9660

Table 31. Crowley Reservoir - fall aerial survey, 10 November, 2004

Waterfowl Count	Lakeshore segment							Total Detections
Species	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon							450	450
Bufflehead	24	18	2	75	170	250	250	789
Canada Goose			8	190	40			238
Common Goldeneye					3			3
Gadwall			2				20	22
Green-winged Teal	20		88	1330			150	1588
Lesser Scaup				5	3	6		14
Mallard	2	6	166	1800	76	334	900	3284
Northern Pintail			100	380		120	1200	1800
Northern Shoveler							4	4
Ring-necked Duck				20		2		22
Ruddy Duck	75	28	3		48	54	360	568
Tundra Swan			6	54				60
Unidentified	143	16	30	200	20		180	589
Total Waterfowl	264	68	405	4054	360	766	3514	9431

Figure 1. Summer ground survey areas

Figure 2. Lakeshore segments, segment boundaries, and cross-lake transects used for fall aerial surveys of Mono Lake

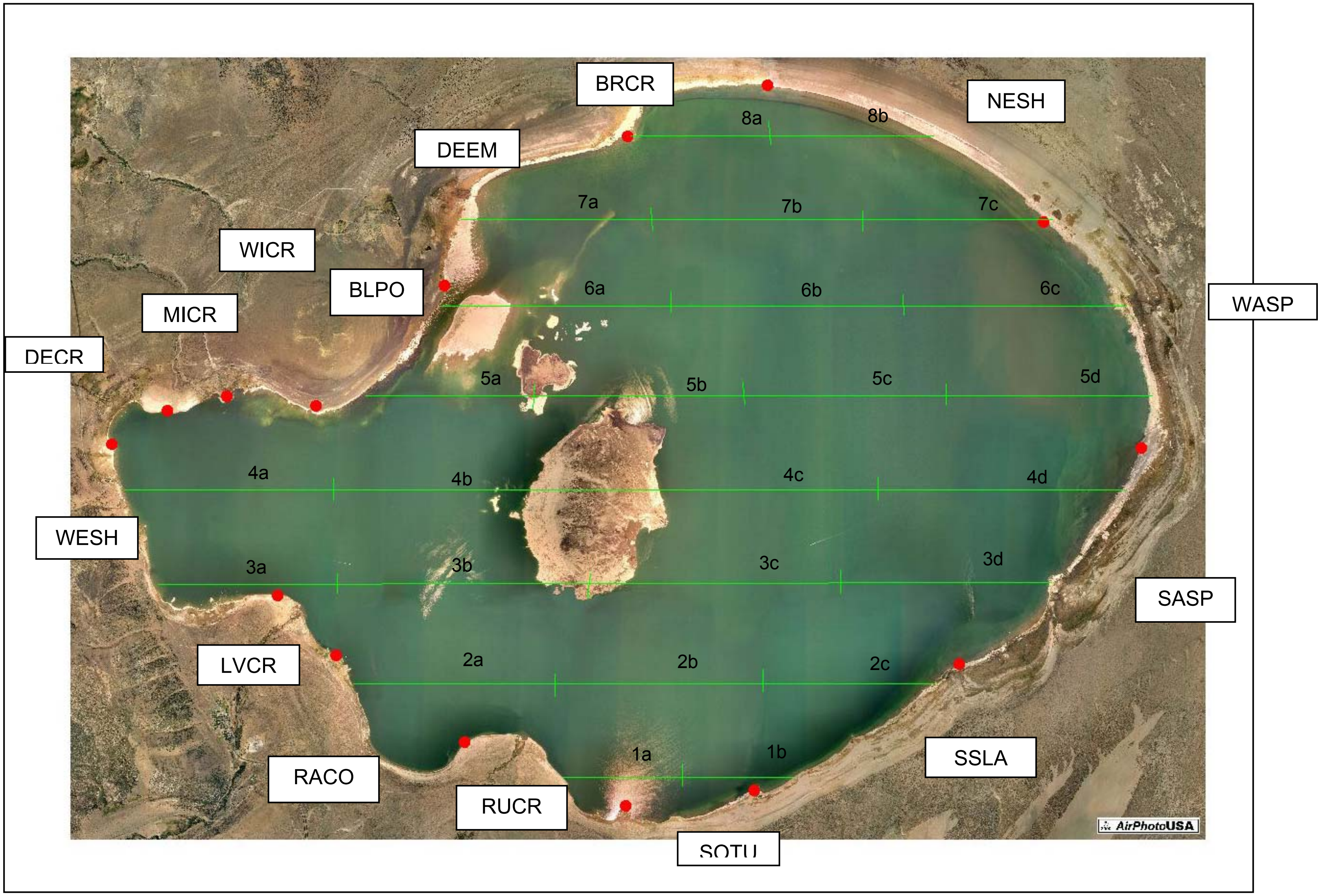


Figure 3. Lakeshore segments and segment boundaries used for fall aerial surveys of Bridgeport Reservoir

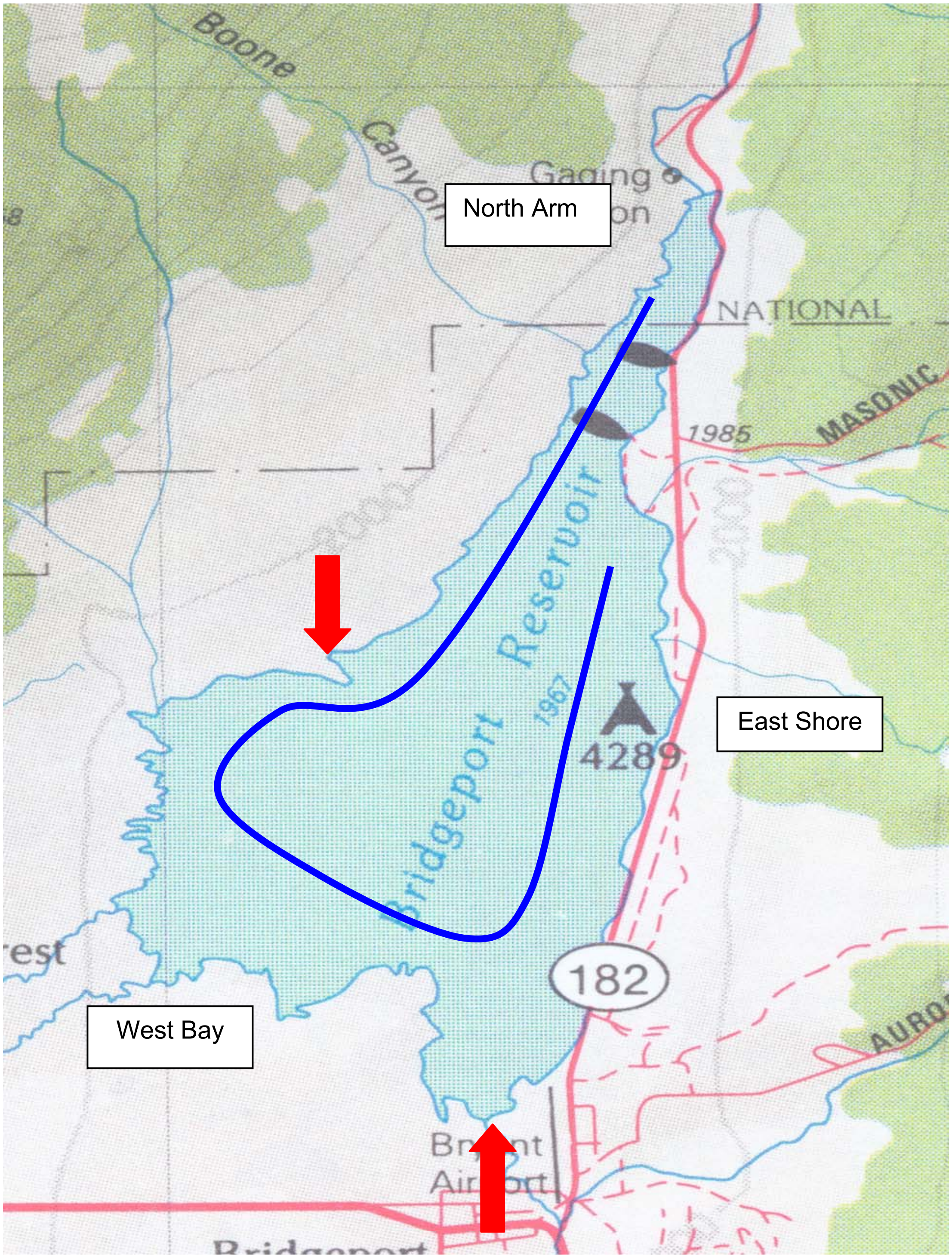


Figure 4. Lakeshore segments and segment boundaries used for fall aerial surveys of Crowley Reservoir

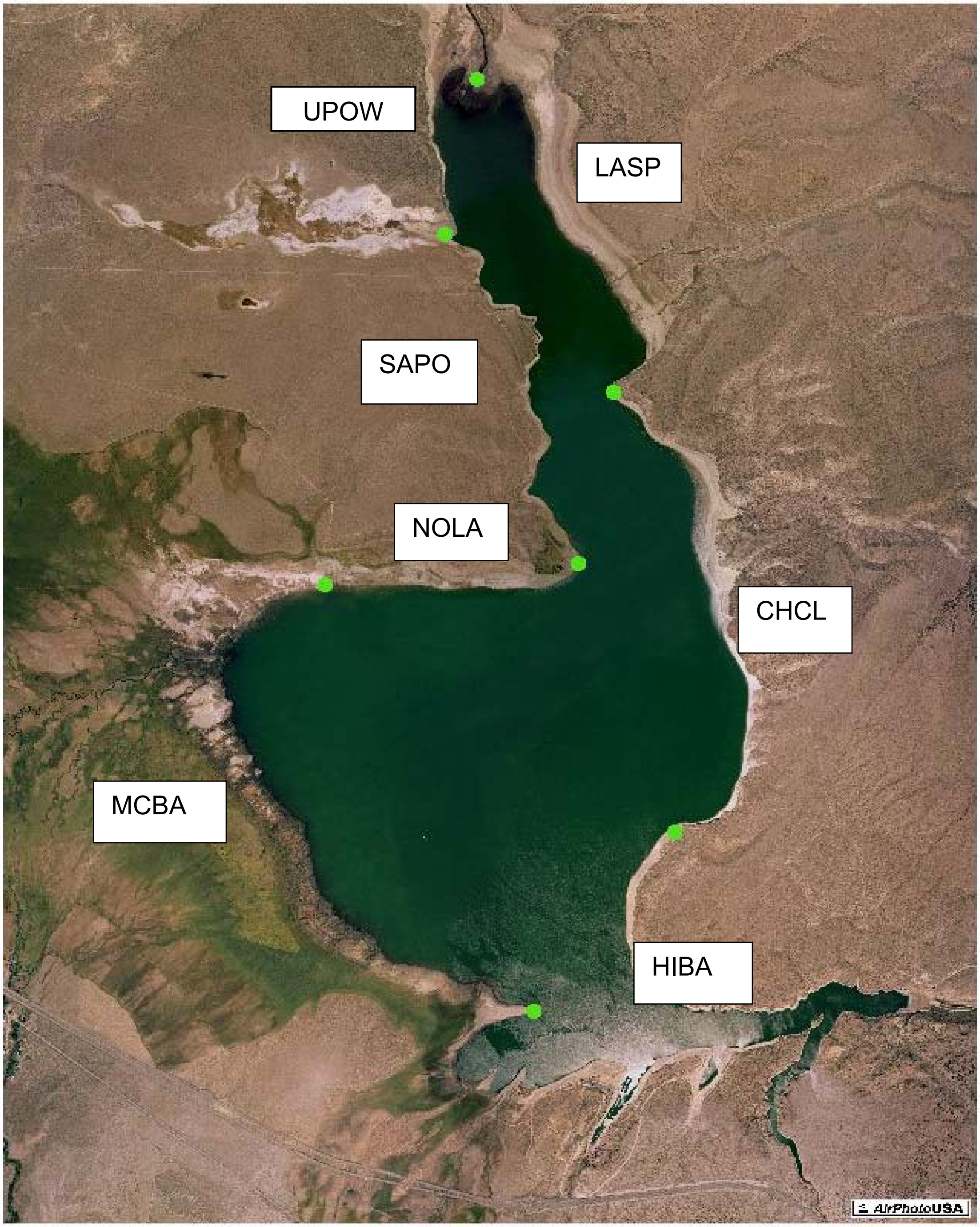
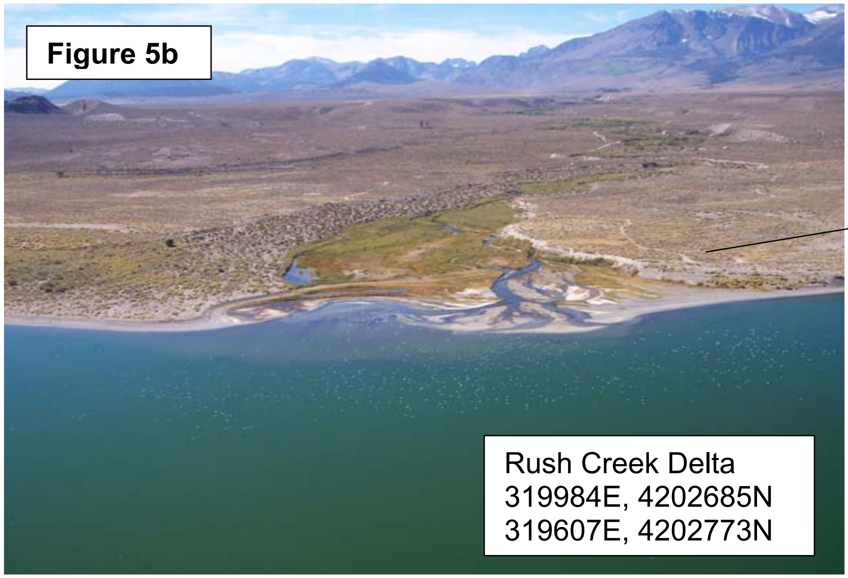


Figure 5. Photos of shoreline habitats at Mono Lake. Taken from a helicopter on September 23, 2004. The coordinates on each photo indicate the shoreline area depicted in the photo (NAD 27, Zone 11).

Figure 5a

Lee Vining Creek Delta
315427E, 4205036N
315283E, 4205406N

Figure 5b



Rush Creek Delta
319984E, 4202685N
319607E, 4202773N

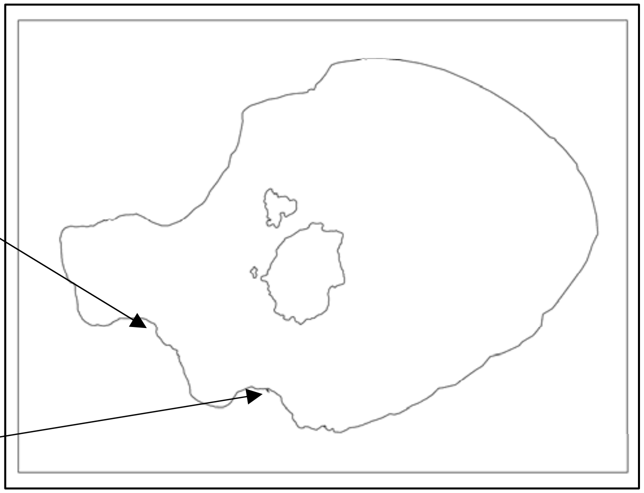
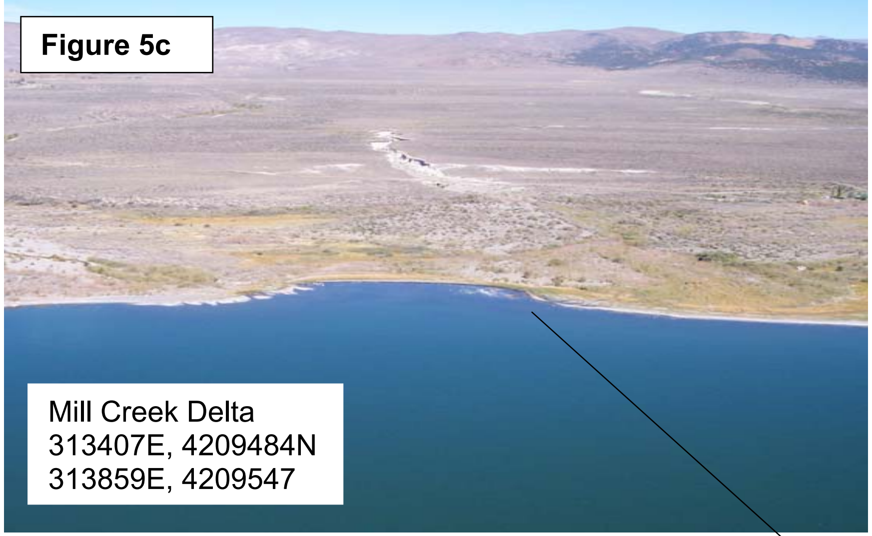
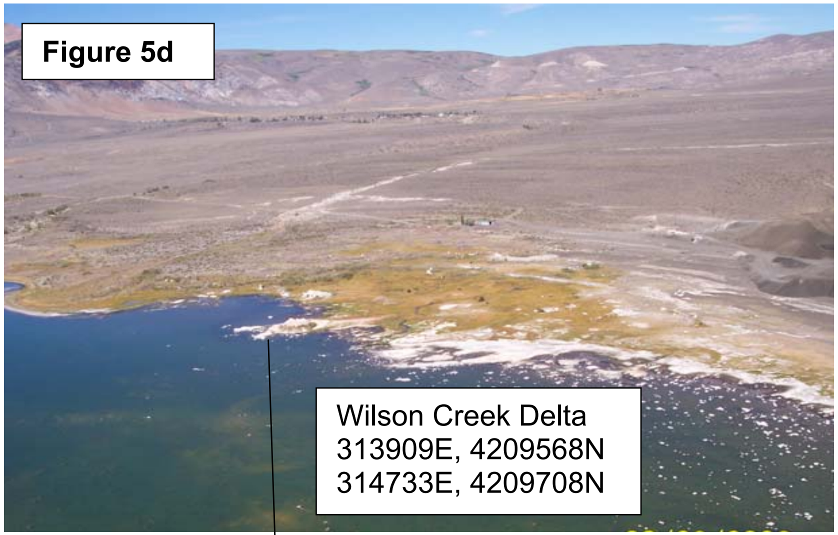


Figure 5c



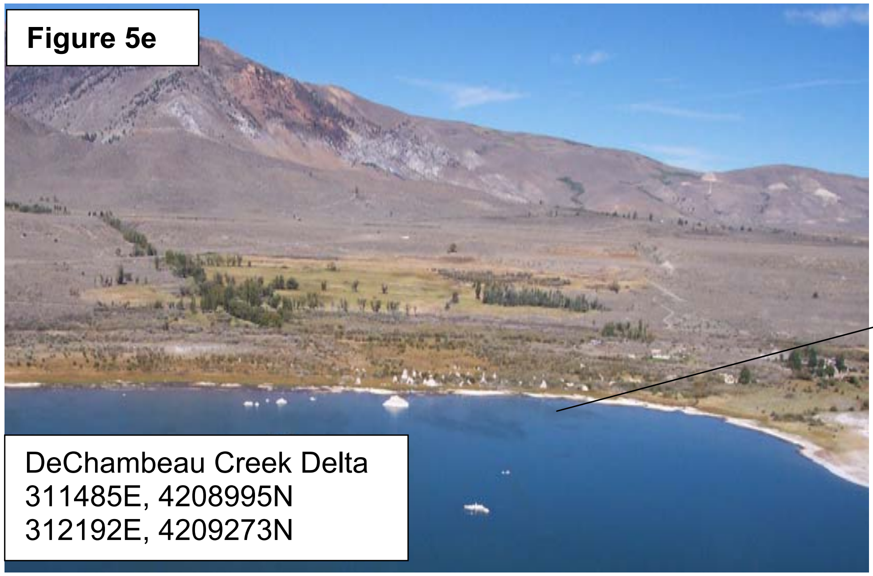
Mill Creek Delta
313407E, 4209484N
313859E, 4209547

Figure 5d



Wilson Creek Delta
313909E, 4209568N
314733E, 4209708N

Figure 5e



DeChambeau Creek Delta
311485E, 4208995N
312192E, 4209273N

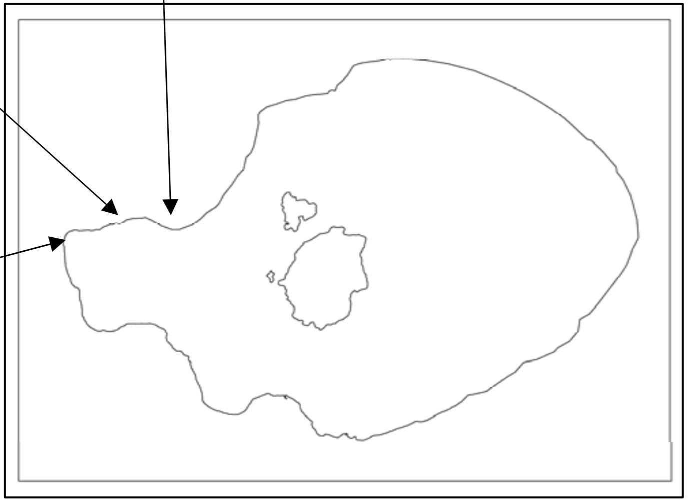


Figure 5f

Bridgeport Creek
321215E, 4214541N
321795E, 4214767N

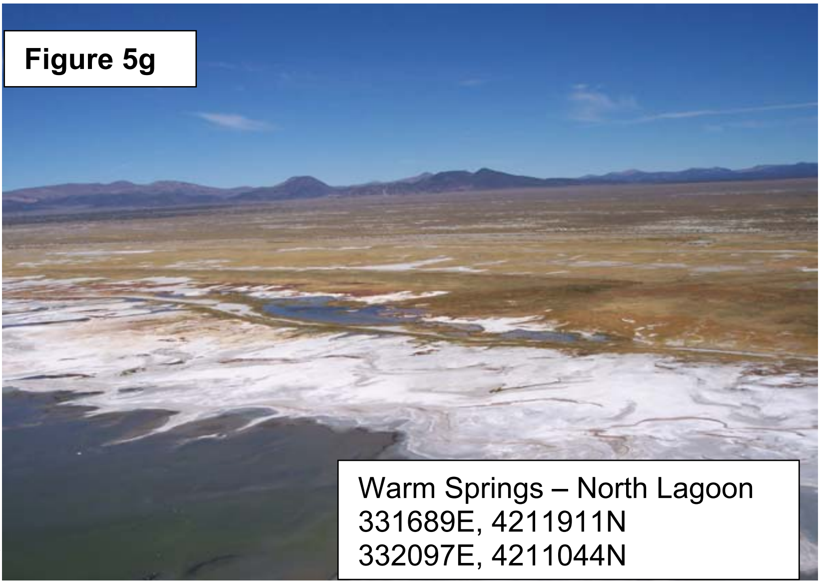
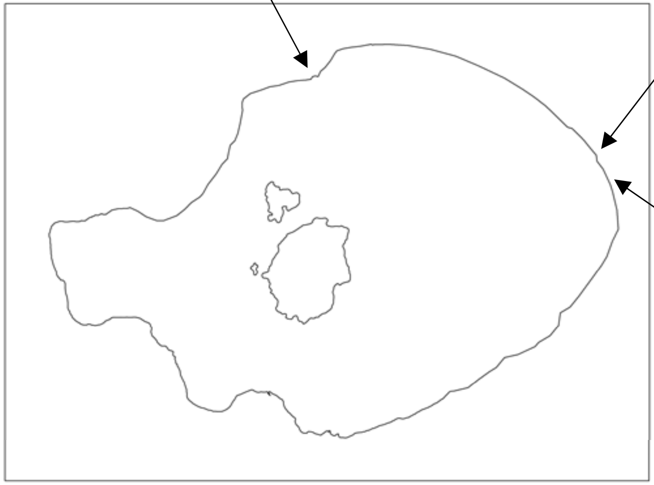


Figure 5g

Warm Springs – North Lagoon
331689E, 4211911N
332097E, 4211044N



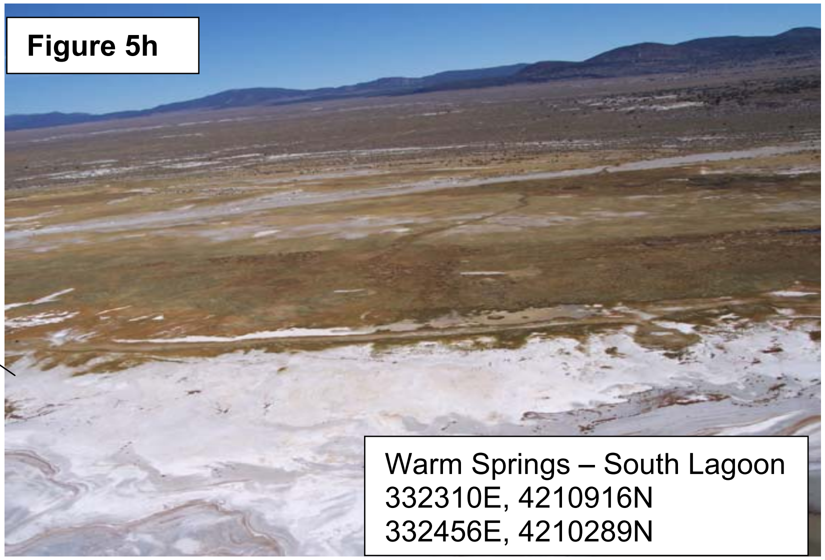


Figure 5h

Warm Springs – South Lagoon
332310E, 4210916N
332456E, 4210289N

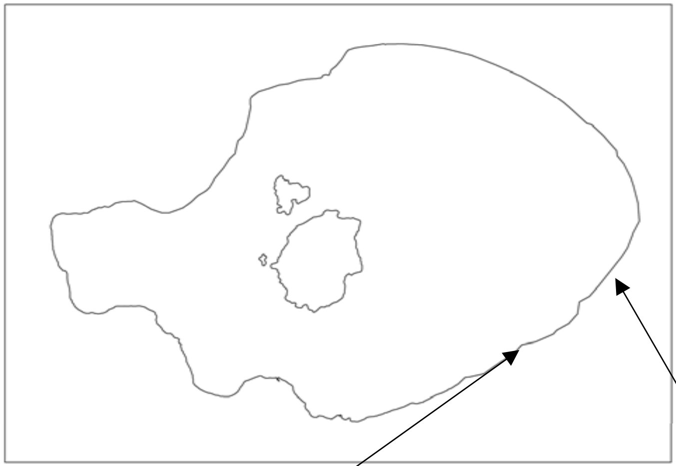


Figure 5i

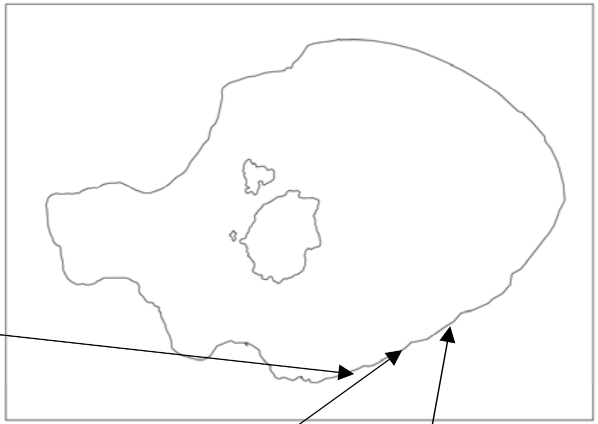
Sammann's Spring West
328627E, 4204133N
330454E, 4205727N

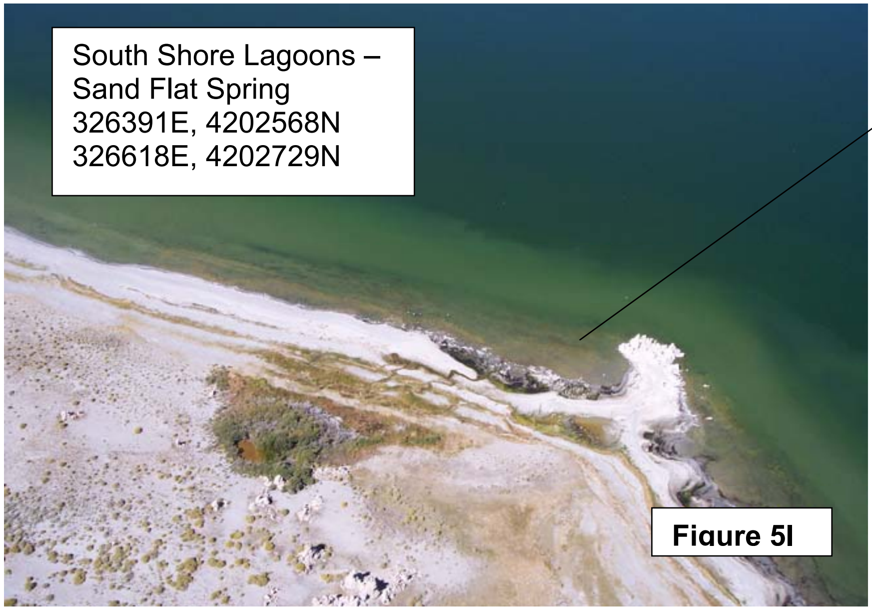
Figure 5j

Sammann's Spring East
330444E, 4205511N
332145E, 4208096N

South Shore Lagoons – First Lagoon
324573E, 4201695N
324715E. 4201593N

Figure 5k





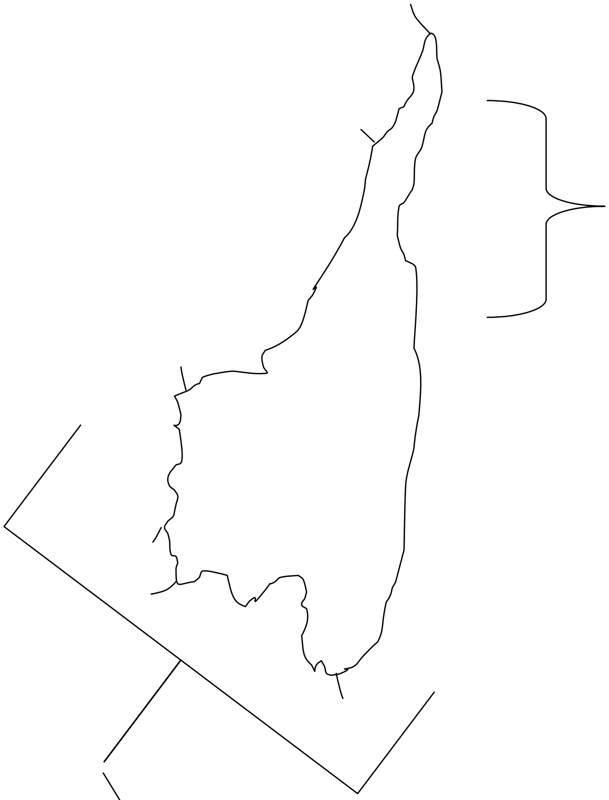
South Shore Lagoons –
Sand Flat Spring
326391E, 4202568N
326618E, 4202729N

Figure 5l

South Shore Lagoons – East End
328277E, 4203851N
328533E, 4204034N

Figure 5m

**Figure 6. Photos of shoreline habitats at Bridgeport Reservoir.
Taken from a helicopter on September 23, 2004**



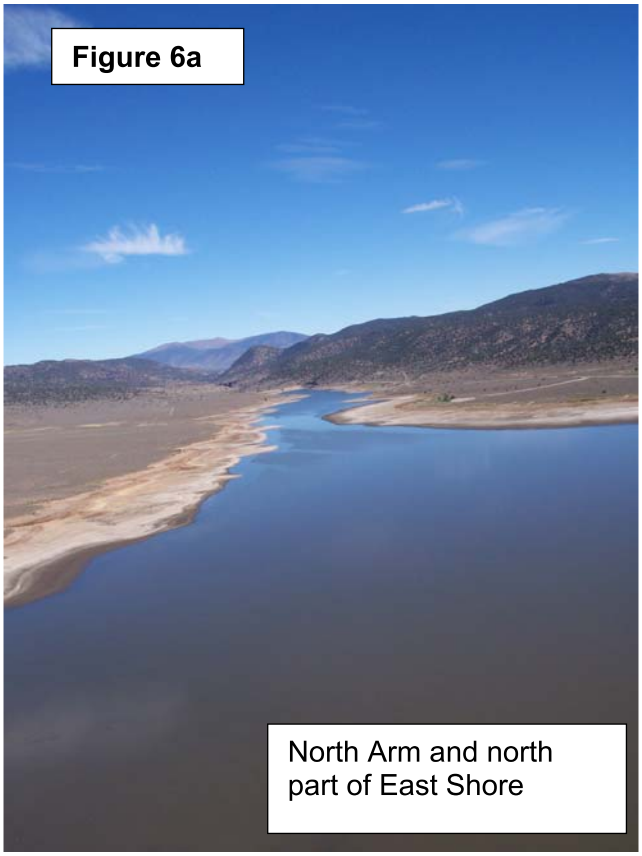


Figure 6a

North Arm and north part of East Shore

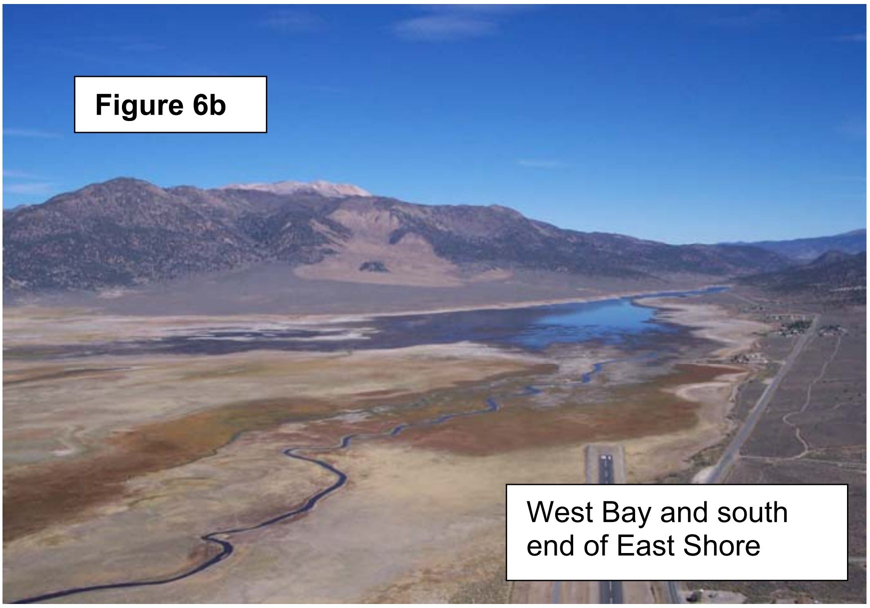


Figure 6b

West Bay and south end of East Shore

Figure 7. Photos of shoreline habitats at Crowley Reservoir. Taken from a helicopter on September 23, 2004

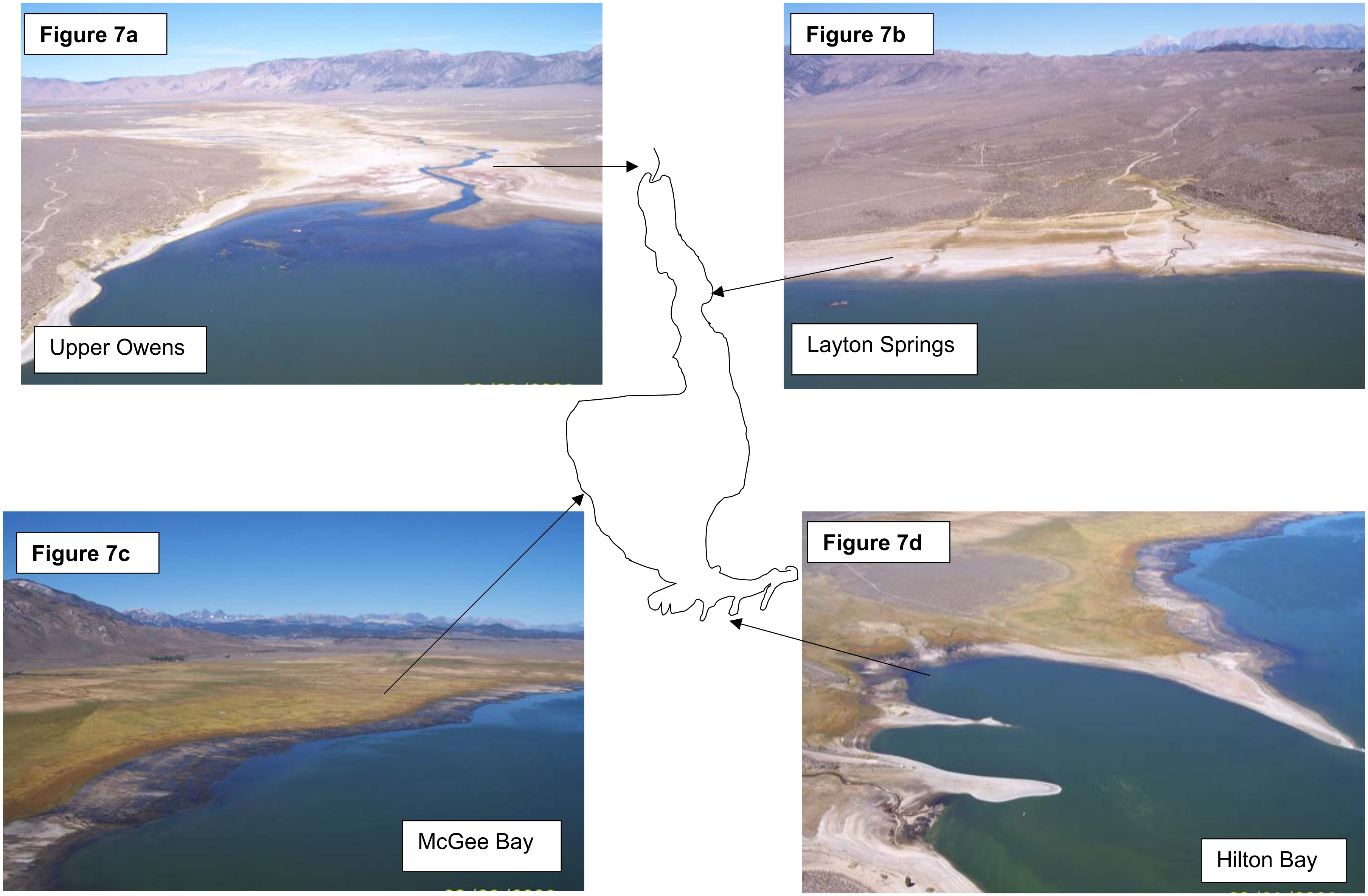


Figure 8. Brood locations 2004. The number in parentheses indicates the minimum number of broods of each species found in the indicated lakeshore segment or restoration pond complex.

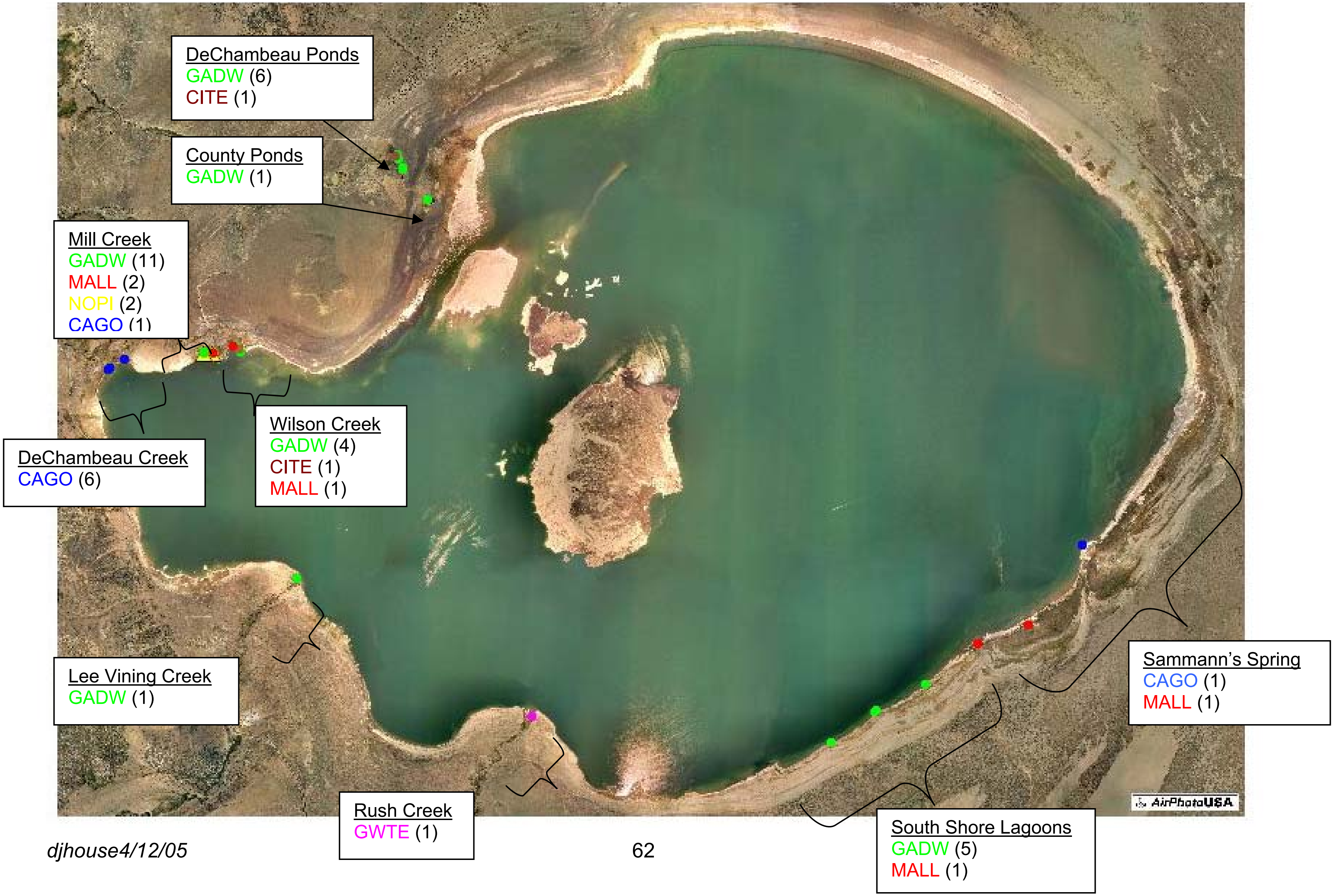


Figure 9. Habitat use by the dominant waterfowl species at Mono Lake. The numbers in parentheses indicate the sample size. The bars represent the percent of total observations.

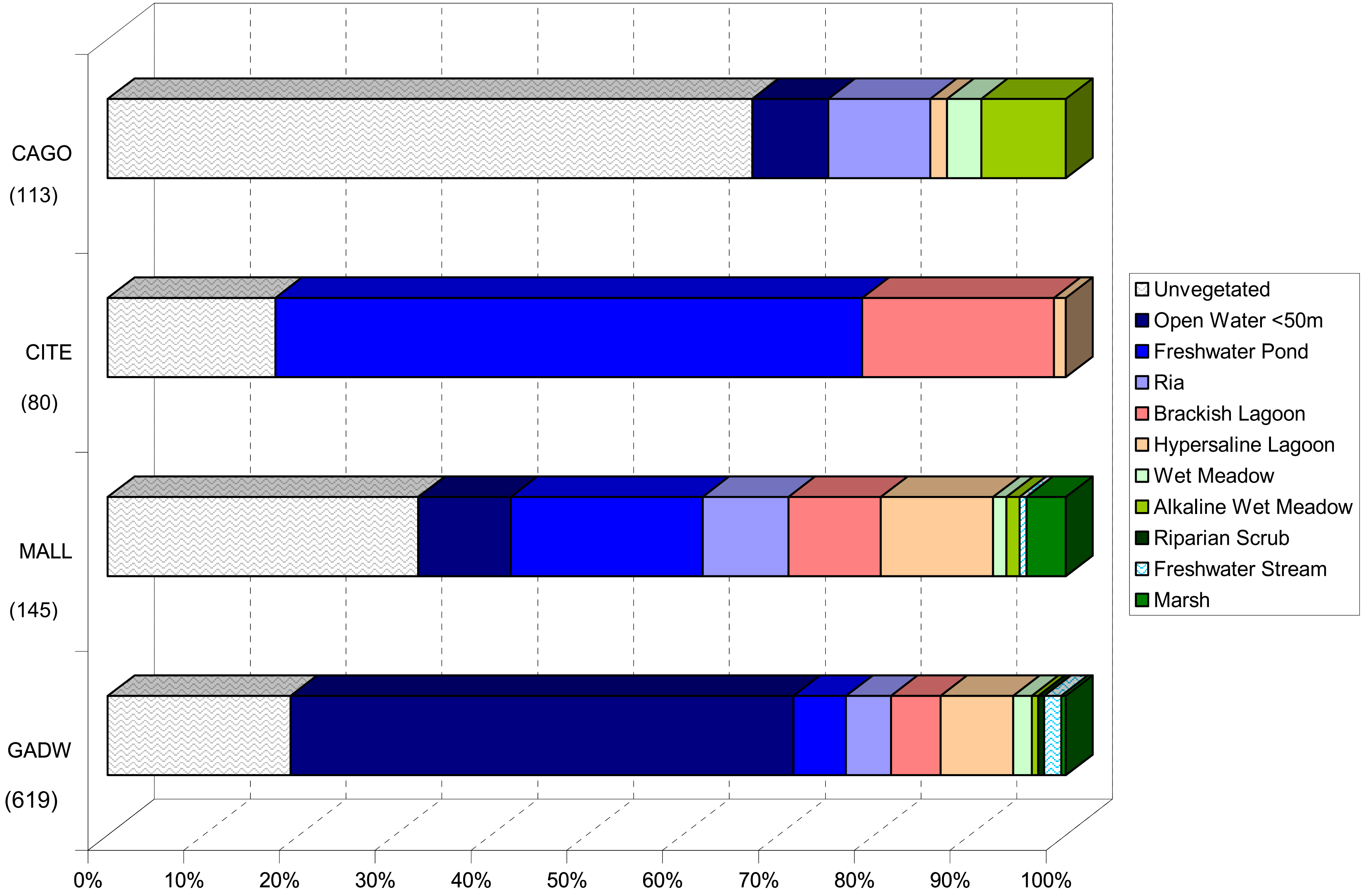


Figure 10. Foraging habitat use by the dominant shorebird species. The numbers in parentheses indicate the sample size. The bars represent the percent of total observations.

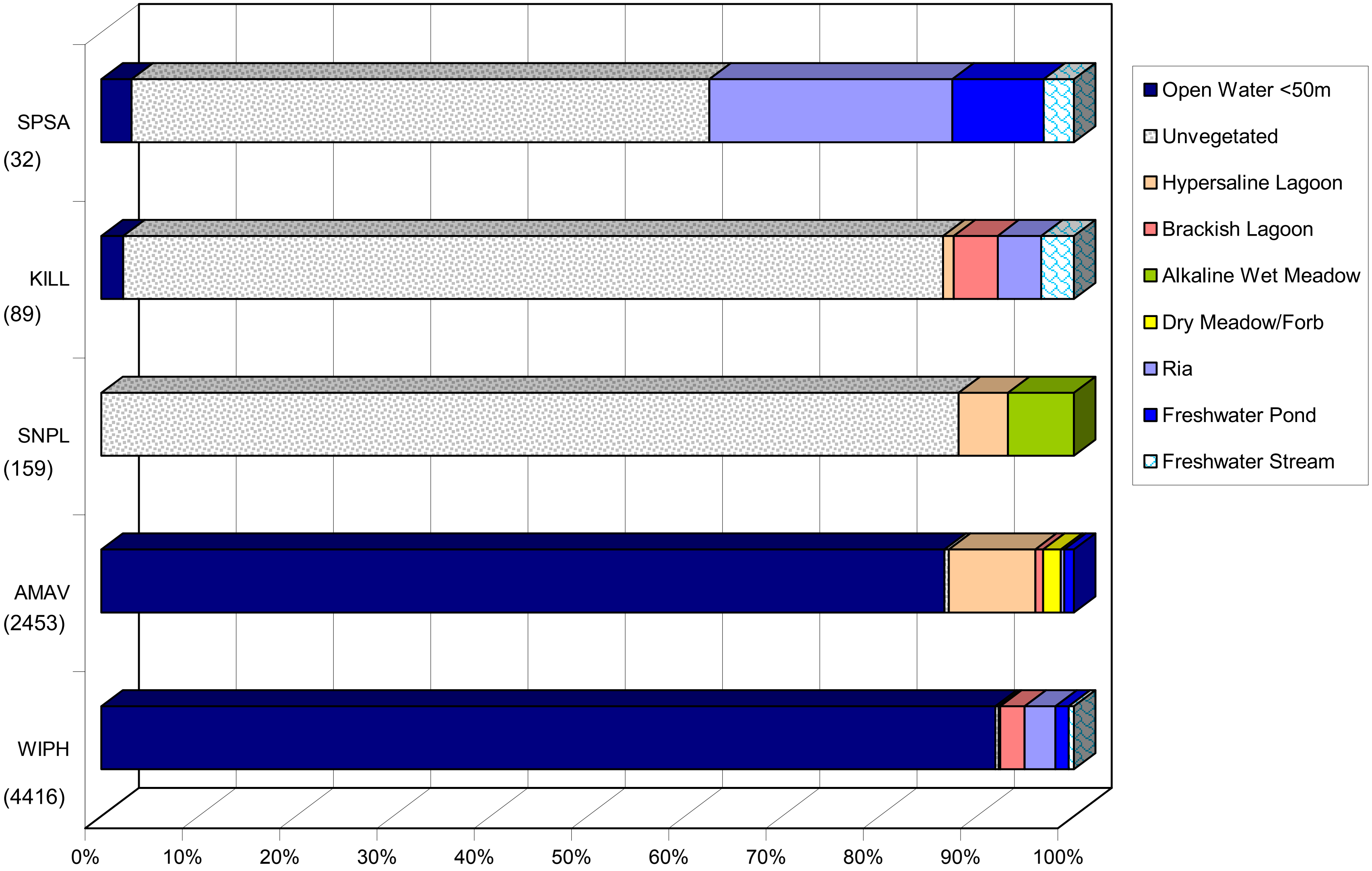


Figure 11. Total waterfowl detected at each waterbody during fall aerial surveys, 2004.

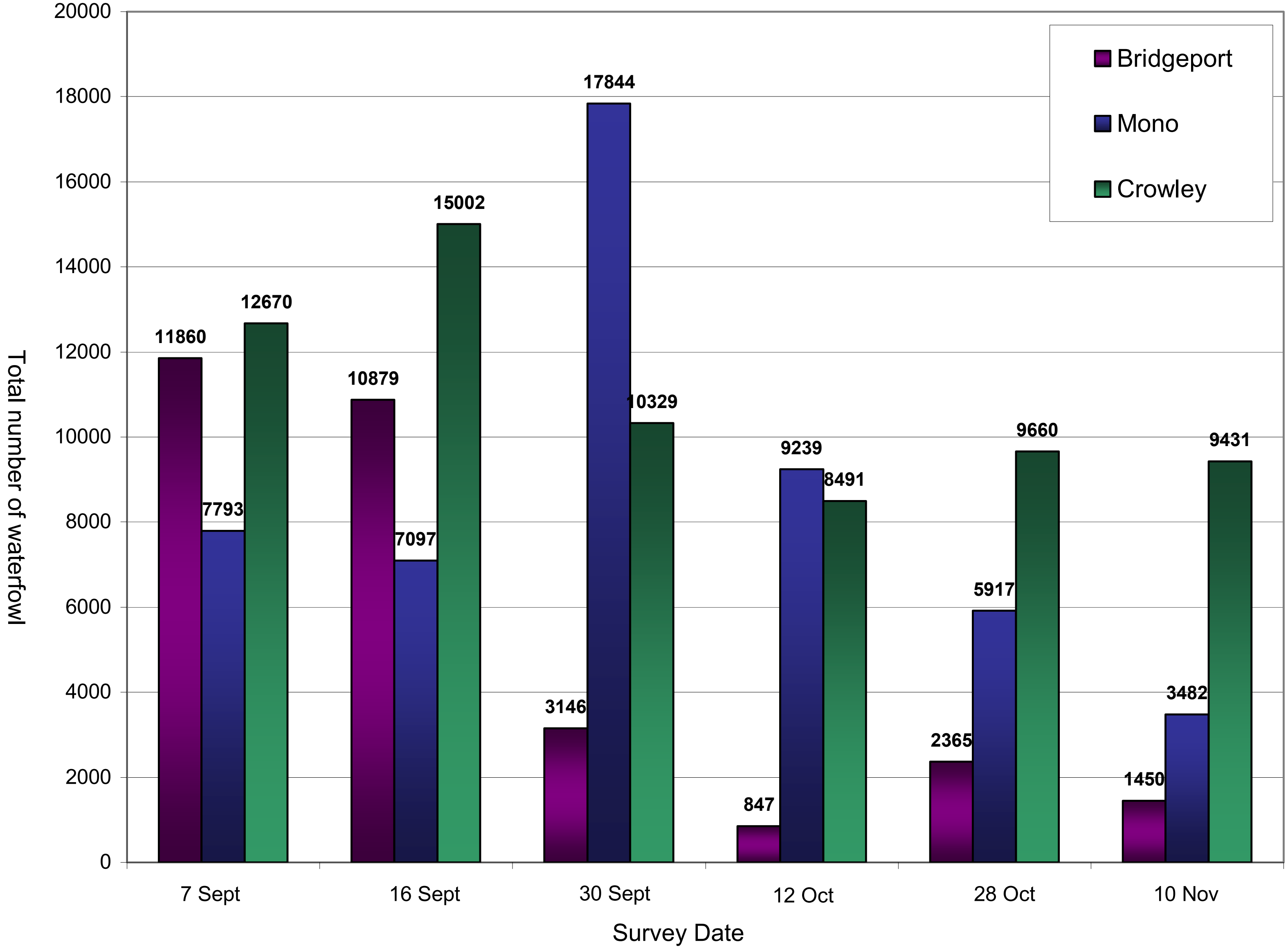


Figure 12. Total detections of dominant species at Mono Lake during fall aerial surveys

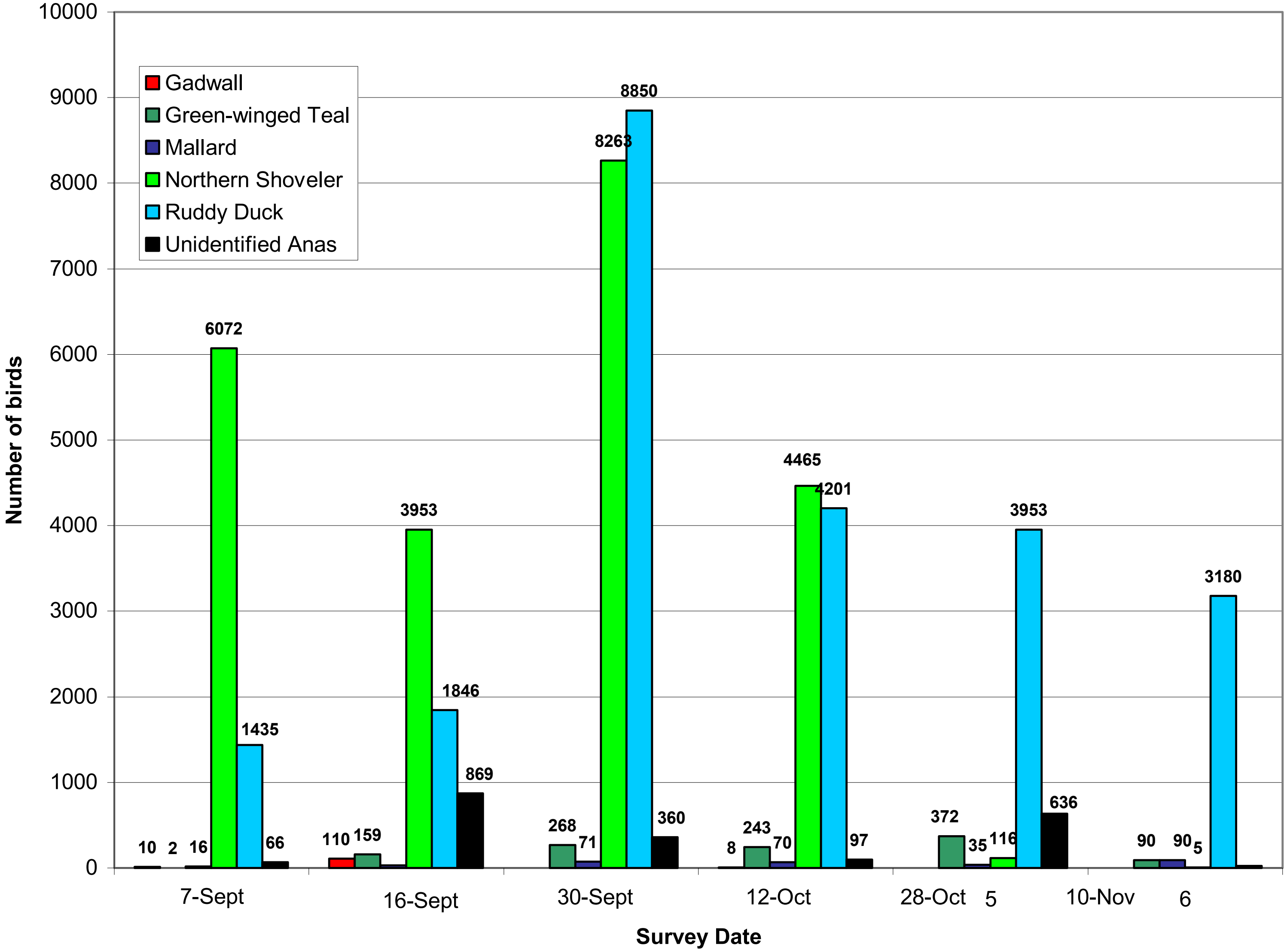


Figure 13. The proportion of waterfowl detected offshore (on crosslake transects) and in each of the lakeshore segments at Mono Lake during each fall aerial survey.

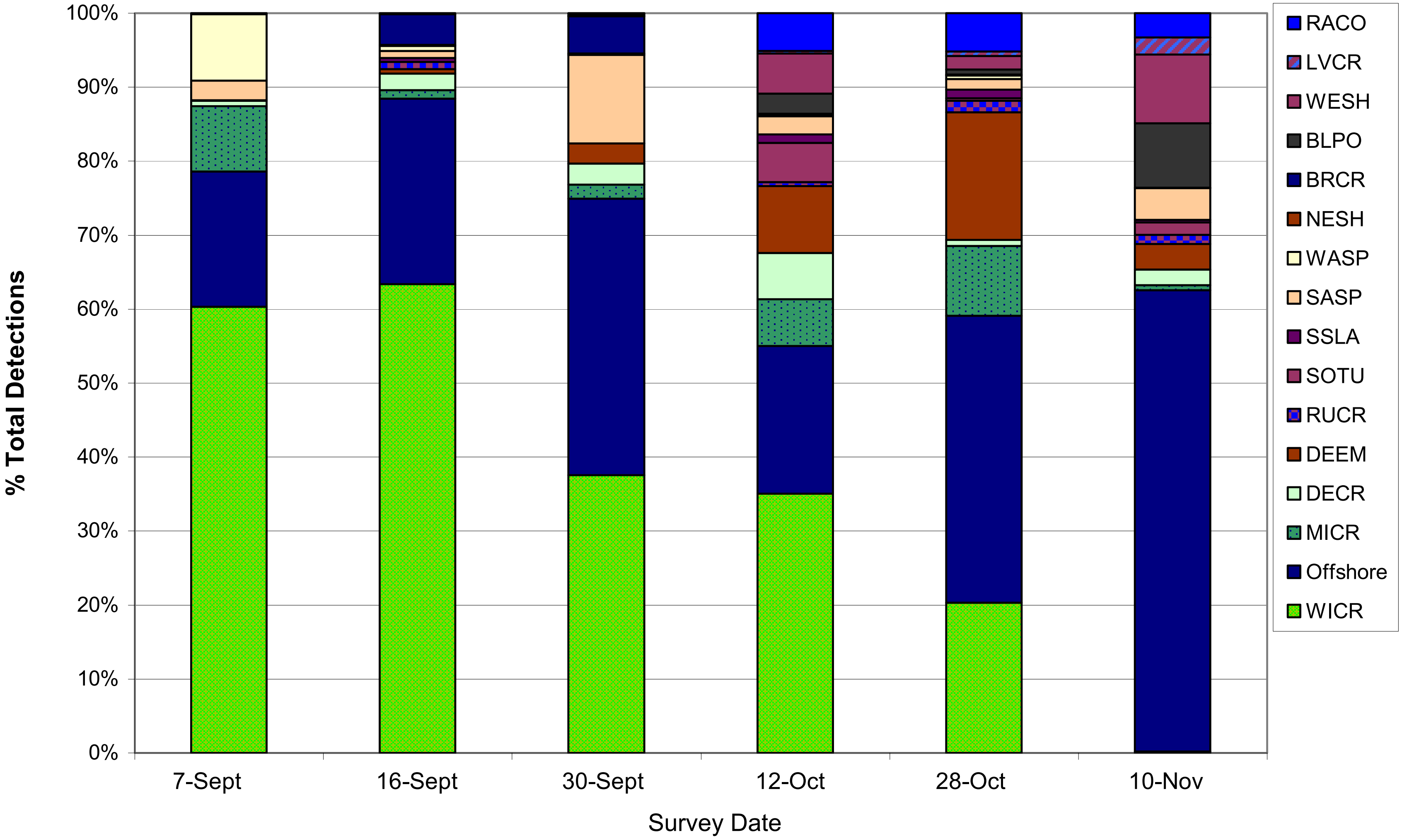
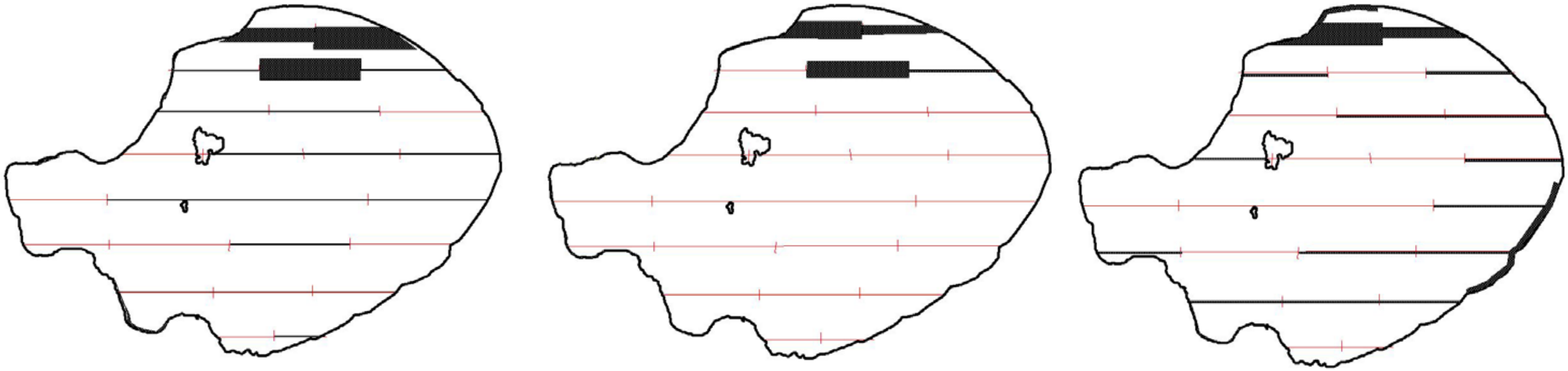


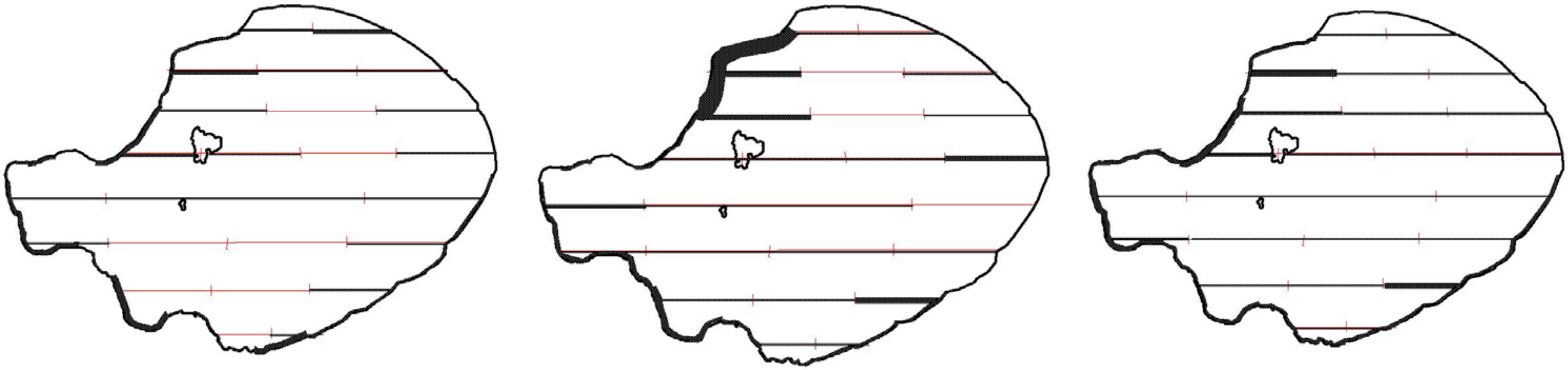
Figure 14. Relative distribution of Ruddy Ducks at Mono Lake during each fall survey, 2004.



4-September

18-September

2-October



14-October

4-November

14-November

Figure 15. Total detections of dominant species at Bridgeport Reservoir during fall aerial

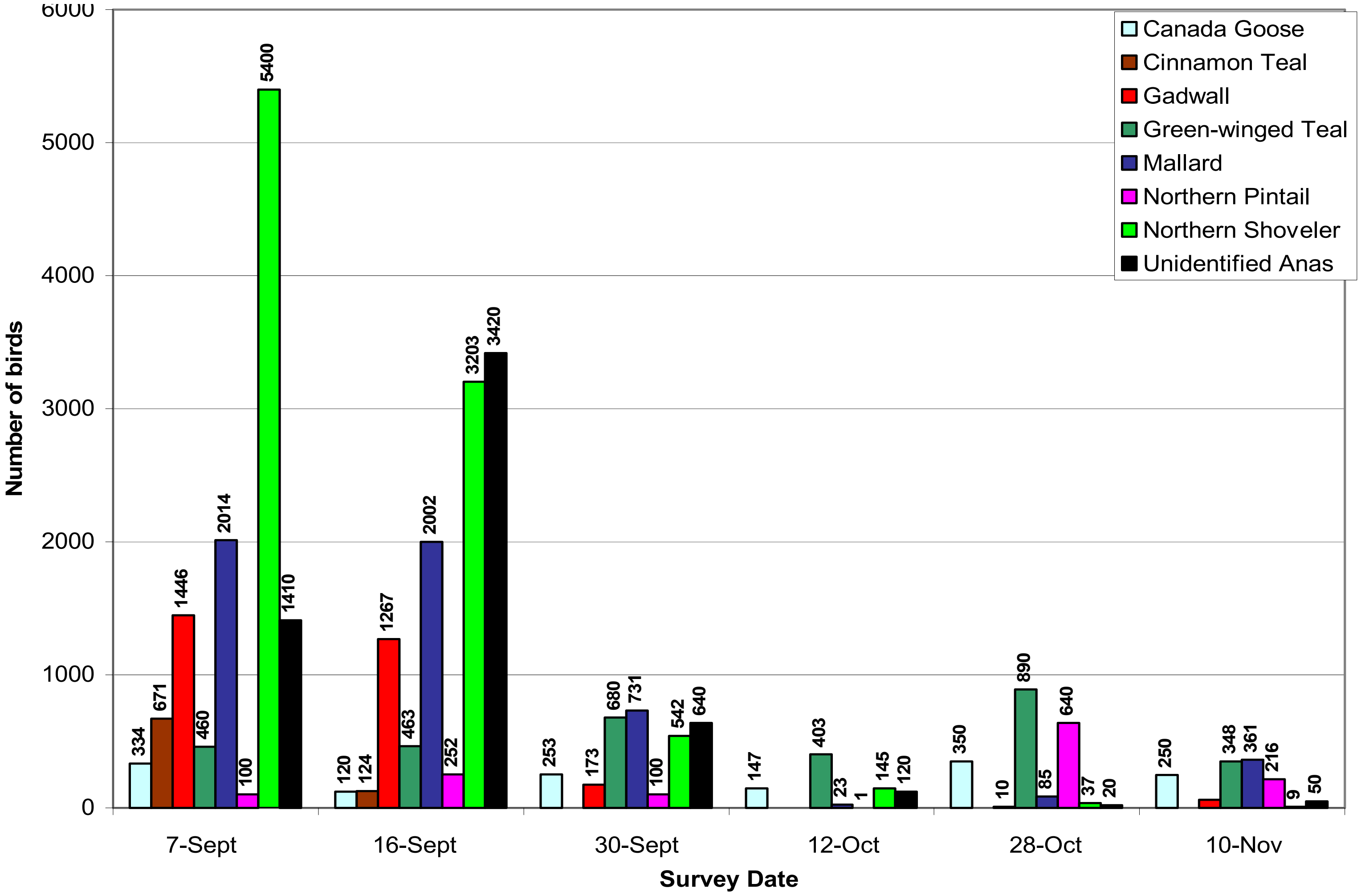


Figure 16. The proportion of waterfowl detected in each of the lakeshore segments at Bridgeport Reservoir during each fall aerial survey.

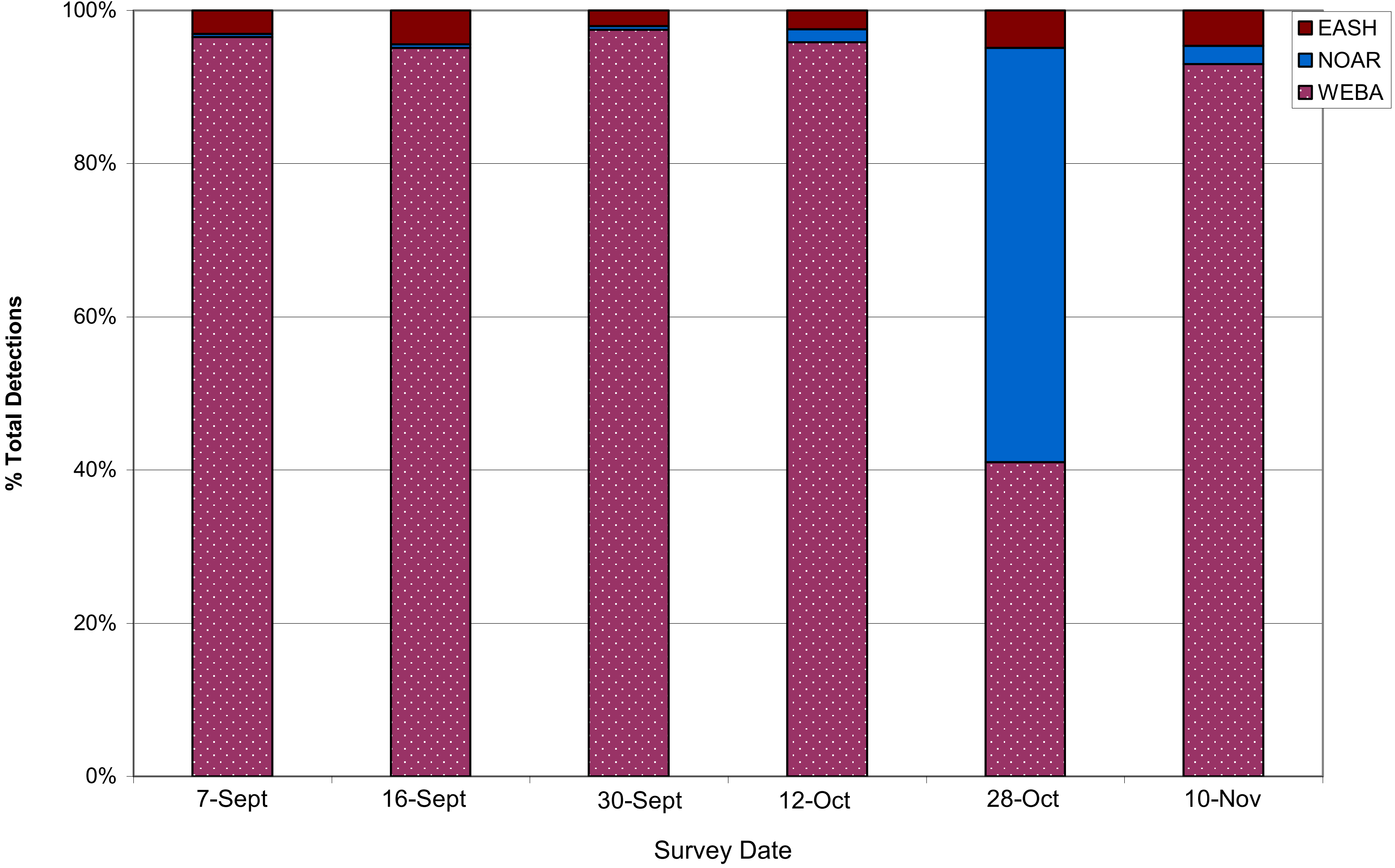


Figure 17. Total detections of dominant species at Crowley Reservoir during fall aerial

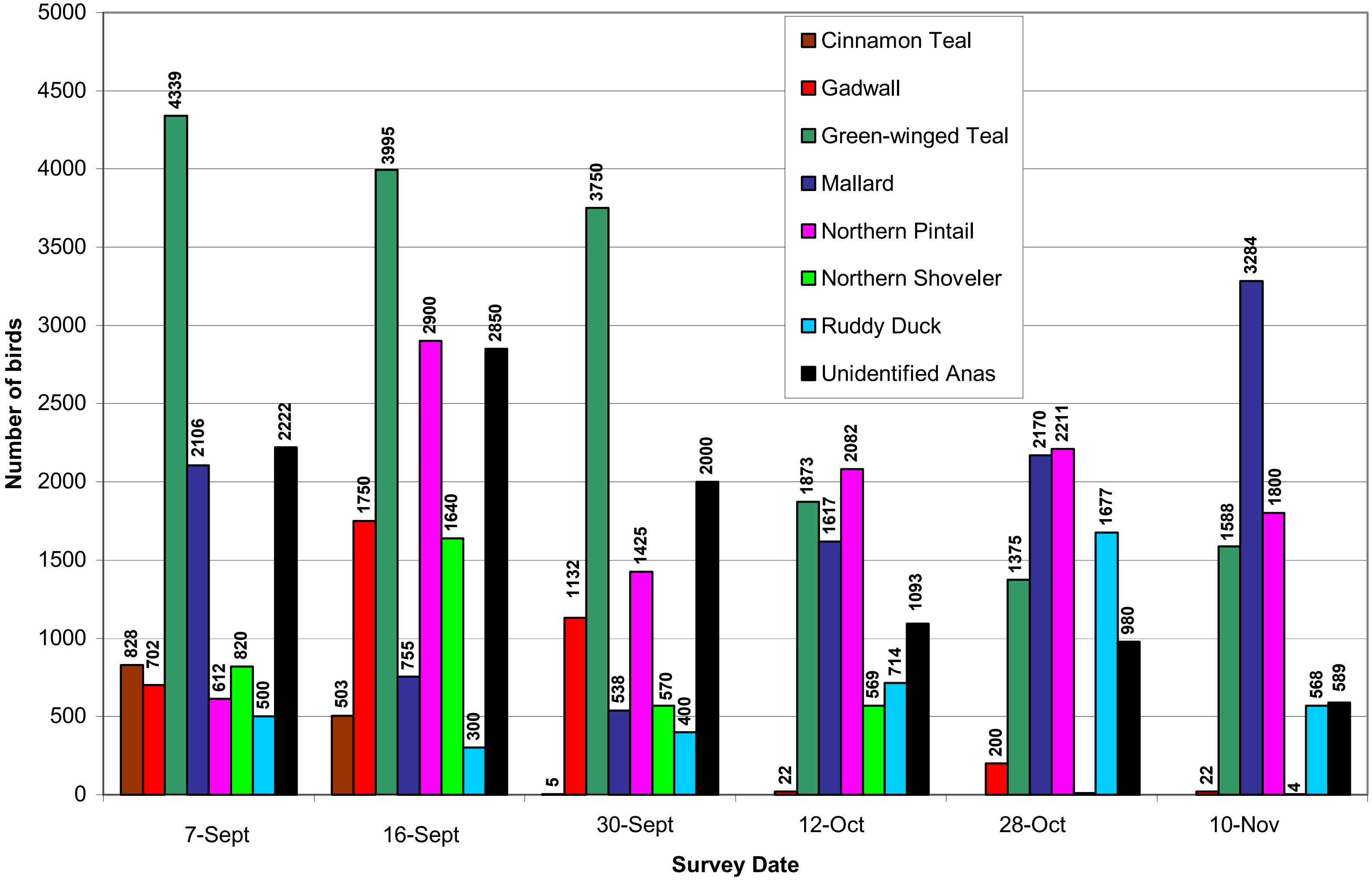


Figure 18. The proportion of waterfowl detected in each of the lakeshore segments at Crowley Reservoir during each fall aerial survey.

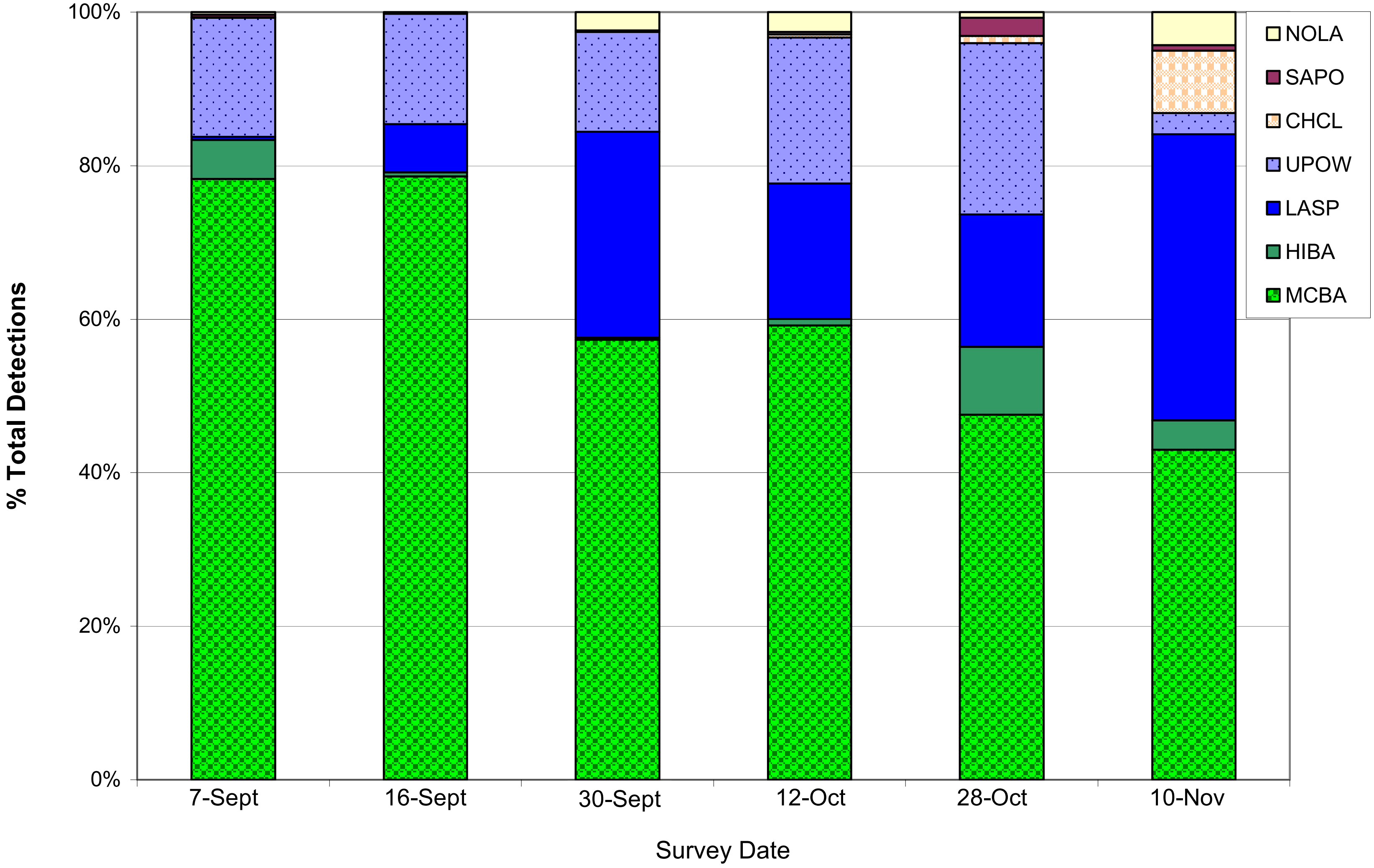


Figure 19. Total fall detections of the dominant species at all three bodies of water.

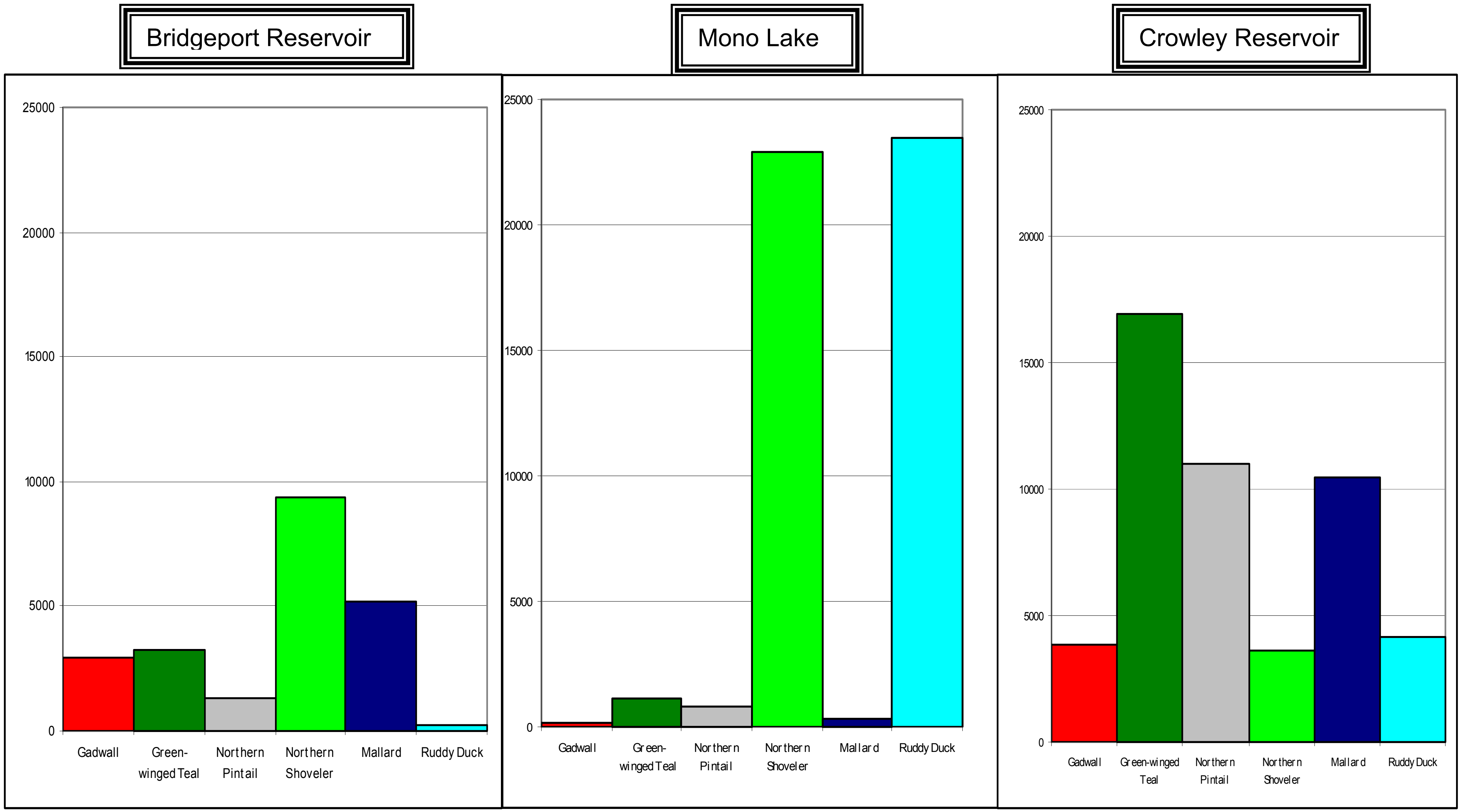
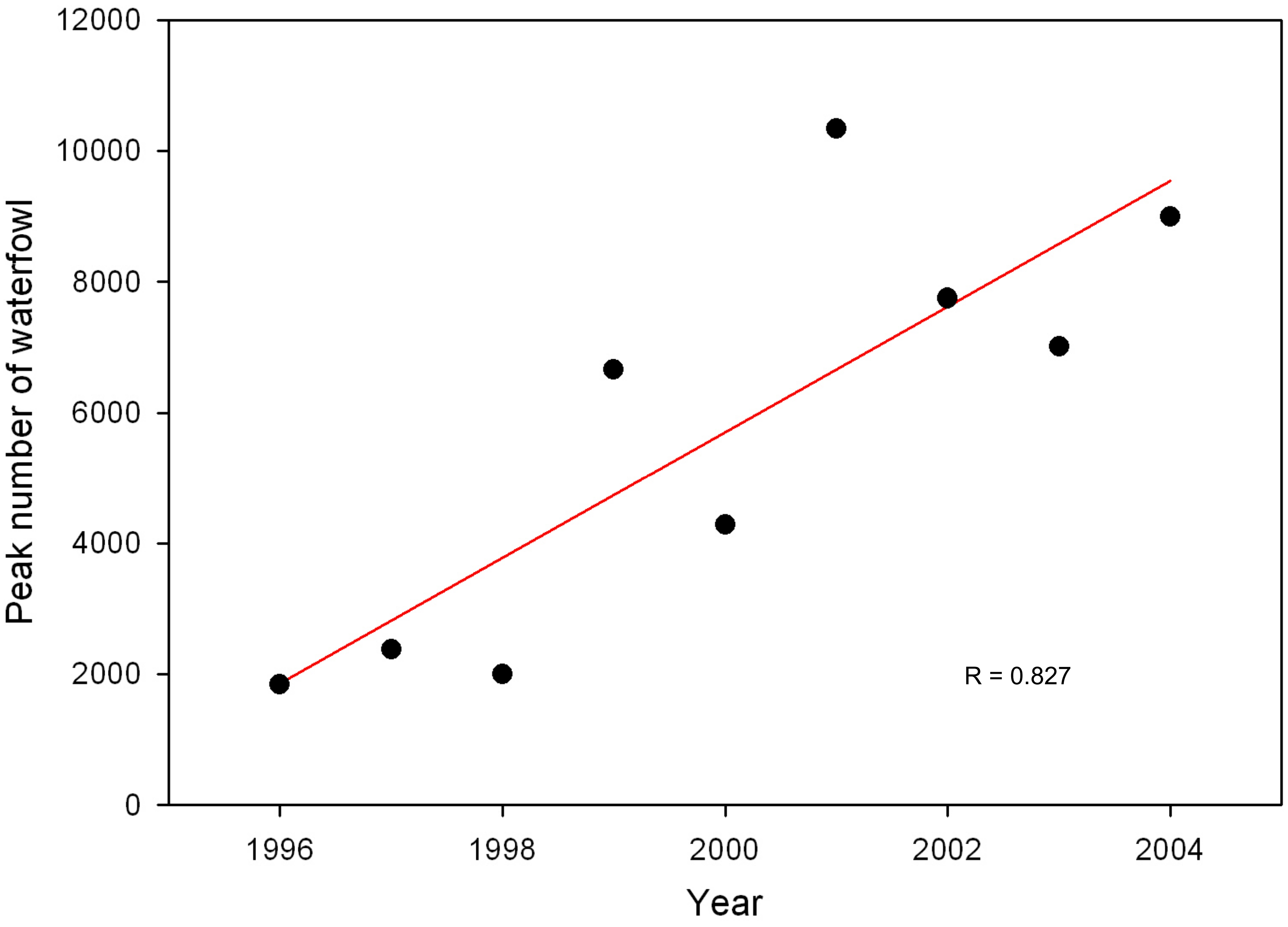


Figure 20. Trend in peak waterfowl numbers (not including Ruddy Ducks) at Mono Lake, 1996-2004



Appendix 1. 2004 Ground count surveys - Dates and times that surveys were conducted at each summer survey area.

Survey 1

Survey area	Survey Date and Time		
	June 7	June 8	June 9
RUCR	0523-0630 hrs		
SOTU	0709-0802 hrs		
SSLA	0803-1012 hrs		
SASP			0822-1100 hrs
WASP			0633-0820 hrs
WICR		0737-0831 hrs	
MICR		0627-0734 hrs	
DECR		0532-0627 hrs	
LVCR		1020-1050 hrs	
DEPO		1145-1225 hrs	
COPO		1130-1140 hrs	

Survey 2

Survey area	Survey Date and Time		
	June 28	June 29	June 30
RUCR	1124-1205 hrs		
SOTU	0543-0639 hrs		
SSLA	0643-0912 hrs		
SASP			0619-1004 hrs
WASP			1005-1130 hrs
WICR		0751-0905 hrs	
MICR		0644-0751 hrs	
DECR		0540-0644 hrs	
LVCR		1223-1300 hrs	
DEPO		1120-1150 hrs	
COPO		1045-1100 hrs	

Appendix 1. Continued

Survey 3

Survey area	Survey Date and Time		
	July 19	July 20	July 21
RUCR	0544-0637 hrs		
SOTU	0715-0811 hrs		
SSLA	0811-1015 hrs		
SASP			0820-1130 hrs
WASP			0624-0820 hrs
WICR		0752-0913 hrs	
MICR		0640-0750 hrs	
DECR		0545-0640 hrs	
LVCR		1207-1248 hrs	
DEPO		1049-1125 hrs	
COPO		1136-1150 hrs	

Appendix 2. Common, scientific names and codes for species names occurring in the document.

Common Name	Scientific Name	Code
American Avocet	*Recurvirostra americana*	AMAV
American Coot	*Fulica americana*	AMCO
American White Pelican	*Pelecanus erythrorhynchos*	AWPE
American Wigeon	*Anas americanus*	AMWI
Black-bellied Plover	*Pluvialis squatarola*	BBPL
Black-necked Stilt	*Himantopus mexicanus*	BNST
Blue-winged Teal	*Anas discors*	BWTE
Bufflehead	*Bucephala albeola*	BUFF
Canada Goose	*Branta canadensis*	CAGO
Canvasback	*Aythya valisineria*	CANV
Cinnamon Teal	*Anas cyanoptera*	CITE
Common Goldeneye	*Bucephala clangula*	COGO
Common Merganser	*Mergus merganser*	COME
Great Blue Heron	*Ardea herodias*	GBHE
Greater Yellowlegs	*Tringa melanoleuca*	GRYE
Greater White-fronted Goose	*Anser brachyrhynchus*	GWFG
Killdeer	*Charadrius vociferous*	KILL
Lesser Scaup	*Aythya affinis*	LESC
Lesser Yellowlegs	*Tringa flavipes*	LEYE
Least Sandpiper	*Calidris minutilla*	LESA
Long-billed Curlew	*Numenius americanus*	LBCU
Gadwall	*Anas strepera*	GADW
Green-winged Teal	*Anas crecca*	GWTE
Mallard	*Anas platyrhynchos*	MALL
Marbled Godwit	*Limosa fedoa*	MAGO
Northern Pintail	*Anas acuta*	NOPI
Northern Shoveler	*Anas clypeata*	NSHO
Redhead	*Aythya americana*	REDH
Red-necked Phalarope	*Phalaropus lobatus*	RNPH
Ring-necked Duck	*Aythya collaris*	RNDU
Ross's Goose	*Chen rossii*	ROGO
Ruddy Duck	*Oxyura jamaicensis*	RUDU
Short-billed Dowitcher	*Limnodromus griseus*	SBDO
Snowy Plover	*Charadrius alexandrinus*	SNPL
Spotted Sandpiper	*Actitis macularia*	SPSA
Tundra Swan	*Cygnus columbianus*	TUSW
Western Grebe	*Aechmorphorus occidentalis*	WEGR
Western Sandpiper	*Calidris mauri*	WESA
White-faced Ibis	*Plegadis chihi*	WFIB
Willet	*Catoptrophorus semipalmatus*	WILL
Wilson's Phalarope	*Phalaropus tricolor*	WIPH
Wilson's Snipe	*Gallinago delicata*	WISN

Appendix 3. Habitat categories used for documenting use by waterfowl and shorebird species (from *1999 Mono Basin Habitat and Vegetation Mapping, Los Angeles Department of Water and Power 2000*).

Marsh

Areas with surface water usually present all year and dominated by tall emergent species such as hard-stem bulrush (*Scirpus acutus*), cattail (*Typhus latifolia*), three-square (*Scirpus pungens*), alkali bulrush (*Scirpus maritimus*) and beaked sedge (*Carex utriculata*).

Wet Meadow

Vegetation with seasonally or permanently wet ground dominated by lower stature herbaceous plant species, such as sedges (*Carex* spp.), rushes (*Juncus* spp.), spikerushes (*Eleocharis* spp.), and some forbs (e.g. monkey flower [*Mimulus* spp.], paintbrush [*Castilleja exilis*]). Wet meadow vegetation was in areas where alkaline or saline soils did not appear to be present. This class included the “mixed marsh” series from Jones and Stokes 1993 mapping.

Alkaline Wet Meadow

This type was similar in stature to the wet meadow class but occurred in areas clearly affected by saline or alkaline soils. Vegetation was typically dominated by dense stands of Nevada bulrush (*Scirpus nevadensis*), Baltic rush (*Juncus balticus*), and/or saltgrass (*Distichlis spicata*). The high density and lushness of the vegetation indicated that it had a relatively high water table with at least seasonal inundation and distinguished it from the dry meadow vegetation class.

Dry meadow/forb

This vegetation class included moderately dense to sparse (at least 15 percent) cover of herbaceous species, including a variety of grasses and forbs and some sedges (e.g. *Carex douglasii*). As with the alkaline wet meadow type above, comparison to vegetation series in Jones and Stokes (1993) was sometimes problematic due to difficulty in distinguishing dry meadow from wet meadow types.

Riparian and wetland scrub

Areas dominated by willows (*Salix* spp.) comprised most of the vegetation classified as riparian.wetlands scrub. Small amounts of buffalo berry (*Shepardia argentea*) and Wood’s rose (*Rosa woodsii*) usually mixed with willow also were included in this class.

Great Basin scrub

Scattered to dense stands of sagebrush (*Artemisia tridentata*), rabbitbrush (*Chrysothamnus nauseosus*), and/or bitterbrush (*Purshia tridentata*) were classified as Great Basin scrub. This vegetation type included a range of soil moisture conditions, as rabbitbrush was often found in moist areas close to the lakeshore and sagebrush was typically in arid upland areas.

Riparian forest and woodland

Aspen (*Populus tremuloides*) and black cottonwood (*Populus trichocarpa*) were the two tree species most common in the riparian forest/woodland vegetation type.

Freshwater-stream

Freshwater-stream habitats are watered, freshwater channels such as exist in Rush Creek and Lee Vining Creeks.

Freshwater-ria

Freshwater-ria areas were surface water areas at the mouths of streams that likely have some salt/freshwater stratification.

Freshwater-pond

This type included ponds fed by springs within marsh areas or artificially by diversions from streams (e.g. DeChambeau/County ponds).

Ephemeral brackish lagoon

Lagoons along the shoreline created by the formation of littoral bars with an extensive area of marsh or wet meadow indicating the presence of springs was present landward, were identified as ephemeral brackish lagoons. In some cases, lagoons were not completely cut off from lake water, but were judged to still have brackish water due to freshwater input and reduced mixing.

Ephemeral hypersaline lagoon

Lagoons along the shoreline created by the formation of littoral bars, but without an extensive area of marsh or wet meadow present landward, were identified as ephemeral hypersaline lagoons. These were presumed to contain concentrated brine due to evaporation.

Unvegetated

Unvegetated areas were defined as those that were barren to sparsely vegetated (<15 percent cover). This class included sandy areas, alkaline flats, tufa, and delta outwash deposits.

Appendix 4. Fall aerial survey dates

Survey Number	1	2	3	4	5	6
Mono Lake	7 Sept	16 Sept	30 Sept	12 Oct	28 Oct	10 Nov
Bridgeport Reservoir	7 Sept	16 Sept	30 Sept	12 Oct	28 Oct	10 Nov
Crowley Reservoir	7 Sept	16 Sept	30 Sept	12 Oct	28 Oct	10 Nov

Appendix 5. Lakeshore segment boundaries (UTM, Zone 11, NAD 27, CONUS)

Mono Lake	Lakeshore Segment	Code	Easting	Northing
	South Tufa	SOTU	321920	4201319
	South Shore Lagoons	SSLA	324499	4201644
	Sammann's Spring	SASP	328636	4204167
	Warm Springs	WASP	332313	4208498
	Northeast Shore	NESH	330338	4213051
	Bridgeport Creek	BRCR	324773	4215794
	DeChambeau Embayment	DEEM	321956	4214761
	Black Point	BLPT	318252	4211772
	Wilson Creek	WICR	315680	4209358
	Mill Creek	MICR	313873	4209544
	DeChambeau Creek	DECR	312681	4209246
	West Shore	WESH	315547	4208581
	Lee Vining Creek	LVCR	314901	4205535
	Ranch Cove	RACO	316077	4204337
	Rush Creek	RUCR	318664	4202603
Crowley Reservoir				
	Upper Owens	UPOW	346150	4168245
	Sandy Point	SAPO	345916	4167064
	North Landing	NOLA	346911	4164577
	McGee Bay	MCBA	345016	4164414
	Hilton Bay	HIBA	346580	4161189
	Chalk Cliff	CHCL	347632	4162545
	Layton Springs	LASP	347177	4165868
Bridgeport Reservoir				
	North Arm	NOAR	306400	4244150
	West Bay	WEBA	304100	4240600
	East Shore	EASH	305600	4237600

Appendix 6. Cross-lake transect positions for Mono Lake

Cross-lake transect number	Latitude
1	37º 57’00”
2	37º 58’00”
3	37º 59’00”
4	38º 00’00”
5	38º 01’00”
6	38º 02’00”
7	38º 03’00”
8	38º 04’00”

Appendix 7. Notes on ground counts conducted during fall of 2004.

September 7, 2004

West Bay/East Shore - Bridgeport Reservoir

From the air, I estimated 10,000 – 12,000 total waterfowl at Bridgeport Reservoir, with the most abundant species being Northern Shoveler. A ground count was done approximately 45 minutes after the flight. From highway 395, a minimum of 10,000 waterfowl were counted in the West Bay area alone, with Northern Shoveler being the most abundant species. The estimates of total waterfowl and species composition from the flight were reported since the visibility of the area is better from the air than from the highway. The ground and air counts of total number of waterfowl were within +/-10 %.

September 16, 2004

DeChambeau Creek, Mono Lake

From the air, I estimated that there were 180 *Anas* spp. in this area. Due to poor lighting, I was unable to identify the birds to species. A ground count was done approximately three hours after the aerial survey of this area in order to determine the species composition. A total of 173 waterfowl were present in this area at the time of the ground count. Therefore, the estimate from the air was approximately 4% high. The species composition for the DeChambeau Creek area for this flight was determined during this ground count.

Rush Creek, Mono Lake

From the air, I estimated that there were 56 waterfowl in the mouth of Rush Creek. During a ground visit approximately 3.5 hours later, there were 65 ducks present, or approximately 16% more than were estimated from the air.

September 30, 2004

Upper Owens/Layton Springs – Crowley Reservoir

I conducted a ground count approximately one hour after the flight, at 1330 hrs. From the air, I estimated that there were approximately 3000 waterfowl in the Layton Springs area and 1700 waterfowl in the Upper Owens area. From the lookout on the west side of the Upper Owens River, the number of waterfowl in the Layton Springs and Upper Owens areas was estimated. From the ground it was determined that there were a minimum of 2500 ducks in the Layton Springs area, with the knowledge that the birds farthest away from the viewing point would probably be seen from this vantage point. There were also a minimum of 1200 ducks in the Upper Owens area. Because of the close proximity of these two lakeshore segments, and some movement between the two areas, the total number of ducks detected in the air and ground were compared. The air estimate was, at most, approximately 27% high, but likely lower than this due to an inability to see all of the ducks in the Layton Springs area from this vantage point.

October 28, 2004

Upper Owens/Layton Springs – Crowley Reservoir

I conducted a ground count approximately 45 minutes after the flight, at 1315 hrs. From the air, I estimated that there were approximately 3460 waterfowl in the Layton Springs/Upper Owens area. From the ground, Chris Allen and I counted approximately 3600 ducks, or approximately 4% more than were estimated from the air.

APPENDIX 4

Peer Review
Mono Lake Waterfowl Population Monitoring 2003 Annual Report
Robert McKernan

COMMENTS ON MONO LAKE WATERFOWL POPULATION MONITORING ANNUAL REPORT
PREPARED BY DEBBIE HOUSE, WATERSHED RESOURCES SPECIALIST, DEPARTMENT OF WATER AND POWER

Review By:

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Background

Between 1980 and 1999 R.L. McKernan conducted aerial surveys and ground counts at Salton Sea, Riverside and Imperial Counties, California. These annual surveys have provided McKernan with an ardent understanding of the power of aerial surveys and their limitations. In addition, McKernan has conducted multi-year near-shore and boat sampling of waterbird populations and has developed specific methodologies to assess loafing waterbirds on lakes. Prior to the initiation of the Waterfowl populations monitoring program by D. House, I communicated and provided a field review of D. House's monitoring program for DWP.

The 2003 Mono Lake Waterfowl Population Monitoring Report by Debbie House, *Los Angeles Department of Water and Power, April 2004, 74 pages*.

Waterfowl population trends in the Eastern Sierra area are surprisingly poorly known. Although many regional and local bird distribution guides and unpublished reports have been produced which authoritatively depict bird distribution and observational data for the region, no long-term systematic waterfowl monitoring of this area has been long-lasting. With the rich aquatic resources available for waterfowl, especially Mono Lake, Bridgeport and Crowley Reservoirs, these aquatic landscapes should be important to establish waterfowl populations' trends to determine significance, and assist in resources management.

Prior to some pioneering census work by Joseph R. Jehl, Jr. in the middle 1990s, data from Mono Lake had been limited to scattered notes, on out-of-range bird species, and a number of breeding gull biology papers. Needless to say, long-term waterfowl population trends for Bridgeport and Crowley Reservoirs to date have been largely anecdotal or uneven.

The 2003 Mono Lake Waterfowl Population Monitoring Report by Debbie House, *Los Angeles Department of Water and Power, April 2004*, is the first approach that is systematic that will determine trends in waterfowl use of these three Eastern Sierra lakes and provide an index for migratory and breeding use of these intriguing landscapes in California. These data will be a valuable source for agencies and conservationists to better understand waterfowl population trends in the Eastern Sierra region.

Overview

The 2003 Mono Lake Water Population Monitoring report is comprehensive regarding the collection of sufficient baseline data to illustrate summer utilization by waterfowl and shorebirds at Mono Lake. The fall migration counts by aerial surveys at Mono Lake, and the related counts at Bridgeport and Crowley Reservoirs provide excellent coverage of each body of water, and develop an excellent index for locality, seasonal, and spatial comparisons between all three lakes. Sampling methodologies have been developed and implemented well. The data included in this baseline report provide an excellent index for establishing waterfowl population trends at Mono Lake, Bridgeport and Crowley Reservoirs.

Specific Comments by Section

Page 3, 4th paragraph: for a point of transparency I would suggest developing a table which reflects time of day for each survey and location.

Page 6,

Mono Lake Aerial Surveys

- The methodology is clearly stated and I believe is excellent in determining waterfowl relative abundance.
- I would suggest for future aerial surveys to see if the pilot can reduce the air speed of the aircraft below 130 kilometers per hour. Air speeds between 100 – 115 kilometers per hour would help in species recognition and estimations.

Page 7,

2nd Paragraph, I would indicate when the ground verification counts took place—how long after the flight, 1 hr., 3 hrs, same day, etc.

Page 8,

For future analysis (next year), I would utilize pair wise single-degree-of-freedom test to determine which habitats/location had the highest bird numbers and use the sequential Bonferroni method to control the overall a error rate (Zar 1996). Also, I would suggest chi-square tests to determine spatial distributions per segments.

Pages 20 through 44, Tables.

All tables are well done and present numerical data in a clear concise fashion.

Page 45 through 58, Figures

Photographs are very instructive and provide a good perspective of survey routes and areas surveyed.

Page 59 through 70, Figures

The histograms are understandable; however, based on my copy, histogram bar shading should be different in some cases (e.g., stippling, etc.). The figure on page 69 should be separated, so each location resides on a separate page. These data are very important to communicate and I believe they lose their importance with all histograms on one page.

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