May 9, 2006

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) 2006-2007
- Fisheries Monitoring Report for Rush, Lee Vining, Parker, and Walker Creeks, 2005
- Mono Basin Tributaries: Lee Vining, Rush, Walker, and Parker Creeks – Monitoring Results and Analysis for Runoff Season 2005-06
- Mono Basin Waterfowl Habitat and Population Monitoring 2005-2006

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 RY2005-06 and the restoration and monitoring activities proposed for RY 2006-07.

The filing of the reports and the restoration and monitoring performed by LADWP in the Mono Basin fulfills LADWP's requirements for RY 2005-06 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,

Thomas M. Erb

Thomas M. Erb
Director of Water Resources

MH:mm

Enclosure

c: Dr. Mark Hanna

Mono Basin Distribution List
May 2006

Ms. Victoria Whitney, Chief Division of Water Rights State Water Resources Control Board 1001 I Street Sacramento, California 95812	Mr. Jim Canaday Division of Water Rights State Water Resources Control Board PO Box 2000 Sacramento, California 95812-02000 (916) 341-5308
Mr. Matt Myers Environmental Scientist State Water Resources Control Board 1001 I Street, 14th Floor Sacramento, CA 95814	Ms. Lisa Cutting Mono Lake Committee PO Box 29 Lee Vining, California 93541 (760) 647-6595
Mr. Gary Smith, NAFWB Department of Fish and Game 1416 Ninth Street Sacramento, CA 95814	Mr. Rob Lusardi California Trout Inc. Box 3442 Mammoth Lakes, CA 93546 (760) 924-1008
Mr. Steve Parmenter Department of Fish and Game 407 West Line Street, #8 Bishop, CA 93514 (760) 872-1171	Dr. Rob Titus Department of Fish and Game 8175 Alpine Avenue, Suite F Sacramento, California 95826
Marshall S. Rudolph Mono County Counsel P.O. Box 2415 Mammoth Lakes, CA 93546 (760) 934-7616	Board of Supervisors Mono County PO Box 715 Bridgeport, California 93517 (760) 932-5534
Dr. William Trush McBain & Trush PO Box 663 Arcata, CA 95518 (707) 826-7794	Mr. Chris Hunter 616 Wintergreen Court Helena, Montana 59601 (406) 449-6561
Mr. James Barry Department of Parks and Recreation PO Box 942896 Sacramento, California 94296-0001 (916) 653-9408	Mr. Ken Anderson Department of Parks and Recreation PO Box 266 Tahoma, CA 96142
Ms. Molly Brown USDA Forest Service P.O. Box 148 Mammoth Lakes, CA 93546 (760) 924-5553	Mr. Burt Almond USDA Forest Service 351 Pacu Lane, Suite 200 Bishop, CA 93514 (760) 873-2439

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, 2006

Los Angeles Department of Water and Power

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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, 2006

Los Angeles Department of Water and Power

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Introduction

Pursuant to State Water Resources Control Board (SWRCB) Decision 1631 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 monitor streamflows, and to restore and monitor the fisheries, stream channels, and waterfowl habitat. This summary provides an overview of the activities LADWP and its consultants completed during Runoff Year (RY) 2005-06 for compliance. This summary also provides a list of planned work/activities for RY 2006-07. Additionally, included in this section is a summary list of the items that LADWP has completed since the Orders were issued.

RY 2005-06 was the ninth full field season and seventh 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.

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

Figure 1: Aerial Photograph of Mono Basin

Exports from the Mono Basin during RY 2005-06

During RY 2005-06, LADWP exported 15,930 acre-feet from the Mono Basin. According to the State Water Resources Control Board Decision 1631, LADWP was allowed to export 16,000 acre-feet during RY 2005-06. Under normal operating procedures, LADWP will export water from the Mono Basin with a steady, consistent flow rate. This year, to help raise the extremely low Grant Lake Reservoir elevations in order to assist with the Grant Lake Resort Marina operations, LADWP halted exports until later in the summer when the reservoir was at a higher level. In addition, LADWP increased exports in the late summer months to help cool the water and improve the fishery in the Upper Owens River

Restoration and Monitoring Activities Performed During 2005

Restoration Activities

In 2005, LADWP undertook several restoration measures. These included:

- Test of the Rush Creek peak flow augmentation from the Lee Vining Conduit
- Peak flow operations for Rush, Parker, Walker, and Lee Vining Creeks.
- Preliminary operation of the newly upgraded Lee Vining Creek diversion facility including bypass of sediment through the facility;
- Continued investigation of sediment bypass for Parker and Walker Creeks;
- 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.
- Continued Investigation of Side-Channel Openings on Rush Creek; and
- Continuation of the grazing moratorium.

Below is a detailed description of the above listed restoration activities.

Rush Creek Augmentation Test

LADWP tested the ability to augment peak flows on Rush Creek using the 5-Siphon Bypass facility on the Lee Vining Conduit. In early June LADWP installed bulkhead inside the Lee Vining Conduit just downstream of the 5-Siphon Bypass Facility. LADWP then began diverting water from Lee Vining Creek into the conduit, which was then forced out through the 5-Siphon Bypass Facility, down the raceway, and into Rush Creek. LADWP successfully tested the facility to 100 cfs.

Peak Flow Operations

– Rush Creek peak operations included an increased ramping rate, peak releases of 350 cfs from the MGORD (Mono Gate One Return Ditch) augmented by 50 cfs from the Lee Vining Conduit through the 5-Siphon Bypass Facility.
– Parker Creek peak flow operations consisted of allowing the peak flowrate to bypass LADWP's diversion facilities by not diverting water.
– Walker Creek peak flow operations consisted of allowing the peak flows to bypass LADWP's diversion facilities by not diverting water.

– Lee Vining Creek peak flow operations consisted of closing the Lee Vining Conduit prior to the arrival of peak flows and completely opening the diversion facility. This procedures ensures that the peak flowrate passes downstream unobstructed and also allows for the bypass of sediments when the transport rate is highest.

Preliminary Operation of the Lee Vining Diversion Facility Upgrade

LADWP completed the upgrade of the Lee Vining Creek diversion facility during the fall and winter of 2004 and 2005. The facility was upgraded to provide LADWP the ability to more accurately monitor and control releases to Lower Lee Vining Creek and provide the opportunity to bypass sediment during high flow events. Preliminary operations of the upgraded Lee Vining Diversion facility were conducted during RY 2005-06. During spring runoff, the new facility was operated according to requirements to "pass the peak" flowrate through the facility to lower Lee Vining Creek. This was done in such a manner that during the peak flows the conduit was completely closed while the new diversion gate was completely opened to ensure sediment passed through the facility.

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.

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.

Side-Channel Openings

LADWP is currently working with the Stream Scientists and the Mono Basin parties to finalize a plan to complete the necessary side-channel openings.

Grazing Moratorium

There was no grazing on LADWP's land in the Mono Basin during RY 2005-06. 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).

Monitoring Activities

In 2005, LADWP continued the restoration monitoring program. This included:

- Mr. Chris Hunter's fishery monitoring program;
- Dr. Bill Trush's stream monitoring program;
- LADWP's streamflow monitoring program;
- Dr. Brian White's waterfowl monitoring program;

Below is a detailed description of the above listed restoration activities.

Fishery Monitoring

Mr. Chris Hunter continued the fishery monitoring program on Rush, Lee Vining, Parker, and Walker creeks. Mr. Hunter's results are presented in Section 3 of this compliance report.

Stream Monitoring

Dr. William Trush continued the stream channel monitoring program on Rush, Lee Vining, Parker, and Walker creeks. Dr. Trush's results are presented in Section 4 of this compliance report.

Highlights include the Peak Flows, Flow Duration, and Ramping Study for Rush Creek. Because the Rush Creek peak flow variance was granted by the SWRCB, peak flows, duration, and ramping rates were studied more thoroughly during RY 2005-06. This study focused on further connecting the hydrology to the geomorphology and biology of the system.

Streamflow Monitoring

LADWP continued to monitor the streamflows, temperatures, and precipitation in the Mono Basin.

Waterfowl Monitoring

In RY 2005-06, LADWP continued the waterfowl habitat monitoring and restoration program. The following is a summary of activities:

- Monitored Mono Lake Hydrology;
- Monitored Mono Lake Limnology
- Monitored Mono Lake Ornithology
- Monitored Mono Lake Vegetation
- Aerial/Satellite Imagery Capture

Mono Lake Hydrology

The elevation of Mono Lake was monitored on 41 occasions during the runoff year over which time the lake elevation ranged from 6381.2 feet above mean sea level (amsl) on April 7, 2005 to 6382.6 feet amsl on March 30, 2006. The average surface area during RY 2005-06, based on the Pelagos Corp. 1986 bathymetric study, was approximately 70.3 square miles, or 44,990 acres.

Mono Lake Limnology
UC Santa Barbara conducted ten limnological surveys. Inclement weather prevented the annual February survey. Annual primary production was double the long-term mean. Average Artemia biomass was 25% higher than the long-term mean.

Mono Basin 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 22, 2005.

Mono Basin Vegetation
Dr. David Martin, Watershed Resources Specialist with LADWP, conducted vegetation transect studies in lake-fringing wetlands located at Samman Springs, Warm Springs and the Dechambeau embayment and at the Lee Vining Creek and Rush Creek deltas.

Mono Basin Aerial/Satellite Imagery
LADWP contracted with Space Imaging (presently known as GeoEye) to capture satellite imagery of the Mono Basin. The images were captured in August 2005.

Informational Meetings

LADWP sponsored two meetings during the RY 2005-06 for the experts and interested parties to present and discuss restoration and monitoring activities, hydrology, and other issues related to the Mono Basin. The meetings were held on April 20 and December 13, 2005.

Spring Mono Basin Restoration Tracking Meeting*:*
This meeting, held on Wednesday, April 20, 2005, provided an opportunity for LADWP to discuss its annual Mono Basin operations plan for the runoff year, and for the Stream Scientists to discuss their proposed RY 2005 scope of work.

The preliminary RY 2005-06 runoff forecast and operations were discussed by LADWP. The preliminary runoff forecast indicated a "Wet-Normal" year. Because of the large snowpack yet low Grant Lake Reservoir Elevations, LADWP discussed the ability to alter the peak flow operations on Rush Creek to study the effects of peak flow duration and increased ramping rates.

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.

Chris Hunter described the fish movement study to be employed in September 2005.

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

Table 1
Spring Mono Basin Restoration Tracking Meeting Attendees

Name	Agency/Affiliation
Jim Canaday	SWRCB
Christopher Hunter	Fisheries Crew
Ross Taylor	Fisheries Crew
Bill Trush	McBain and Trush
Mark Hanna	LADWP
Milad Taghavi	LADWP
Brian Tillemans	LADWP
David Martin	LADWP
Brian White	LADWP
Cathy Greenman	Consultant to LADWP (MWH)
Janet Goldsmith	Lawyer for LADWP (KMTG)
Greg Reis	Mono Lake Committee
Lisa Cutting	Mono Lake Committee
Peter Vorster	Mono Lake Committee consultant
Rob Lusardi	CalTrout
Deana Freeman	CA State Parks
Sacha Heath	PRBO
Doug Smith	Grant Lake Marina

Fall Mono Basin Restoration Tracking Meeting*:* This meeting, held on Tuesday, December 13, 2005, provided an opportunity for the Stream Scientists and waterfowl experts to present and discuss their RY 2005-06 monitoring data, as well as allow all the interested parties an opportunity to learn about the upcoming instream flow study.

The group continued discussions of termination criteria and SWRCB explained how the 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 fisheries 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 400 cfs was held in Rush Creek for a total of eight days and that peak flows on Lee Vining Creek reached nearly 400 cfs on two separate occasions.

Attendees included those shown in **Table 2**.

Table 2
Fall Mono Basin Restoration Tracking Meeting Attendees

Name	Agency/Affiliation
Jim Canaday	SWRCB
Matt Myers	SWRCB
Christopher Hunter	Chris Hunter's Fish Monitoring Team
Ken Knudsen	Chris Hunter's Fish Monitoring Team
Matt Sloat	Chris Hunter's Fish Monitoring Team
Bill Trush	McBain and Trush
Mark Hanna	LADWP
Milad Taghavi	LADWP
Brian Tillemans	LADWP
David Martin	LADWP
Akiko Kawaguchi	Consultant to LADWP (MWH)
Stephanie Theis	Consultant to LADWP (MWH)
Janet Goldsmith	Lawyer for LADWP (KMTG)
Steve Parmenter	CDFG
Rob Titus	CDFG
Greg Reis	MLC
Lisa Cutting	MLC
Peter Vorster	Consultant to MLC
Richard Ridenhour	Consultant to MLC
Rob Lusardi	CalTrout
Tamara Sasaki	CA State Parks
Sacha Heath	PRBO

Restoration and Monitoring Activities Planned for 2006

Restoration Activities

In 2006, LADWP plans to continue the restoration program with the following activities:

Sediment Bypass at Parker and Walker Creek Intakes

Design and development of a sediment bypass methodology will be presented to the parties for comments during RY 2006-07.

Sediment Bypass at Lee Vining Creek Intake

LADWP will operate the upgraded Lee Vining Creek diversion facility according to the orders, so no diversions will take place during peak flow. During this operation, the new diversion gate will be in the fully open position to ensure that sediment will bypass the facility into lower Lee Vining Creek.

Channel Rewatering

LADWP plans to rewater certain Rush Creek side channel(s) described in the stream plan pending final recommendations from the Stream Scientists and approval by the SWRCB. The remaining channel openings have been deferred based on previous recommendations from the Stream Scientists (see prior reports).

Instream Flow Study

An interagency instream flow study for Rush and Lee Vining Creeks with Mr. Hunter's fish monitoring team as the lead has been postponed pending agreement from the Mono Basin parties. The purpose of the flow study is to determine base flow needs suitable for the various life stages of the trout fishery now that the Mono Basin streams are under recovery and have changed considerably since the restoration program began.

Waterfowl Funds

Pending final plans from the USFS, LADWP plans to provide the funds requested for waterfowl habitat work at DeChambeau Ranch.

Monitoring Activities

In 2006, LADWP plans to continue the restoration monitoring program with the following activities:

- The fishery monitoring program;
- The stream and stream channel monitoring program;
- The streamflow monitoring program; and
- The waterfowl and limnology monitoring program.

Fishery Monitoring

Mr. Hunter's fish crew team will continue the fishery monitoring program for Rush, Lee Vining, Parker, and Walker creeks utilizing the same monitoring sites and methodologies that were used in past years.

The fish movement study begun during RY 2005-06 will continue in RY 2006-07. Results from the fish movement study should determine:

1. Whether young fish move into the MGORD from Rush Creek and remain there growing to larger sizes than they would attain in lower 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.

Stream and Stream Channel Monitoring
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:

Waterfowl and Limnology Monitoring
Dr. White will continue to oversee the waterfowl monitoring program including oversight of UCSB's Mono Lake limnology program.

Informational Meetings

LADWP will host two meetings with SWRCB staff, the Stream Scientists, and interested parties, to discuss the progress of the 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 27, 2006. The second meeting will be held in the fall of 2006.

Physical Projects Remaining

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, as well as the ability to bypass sediment downstream. 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 (5-Siphon Bypass) 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.

Channel Rewatering

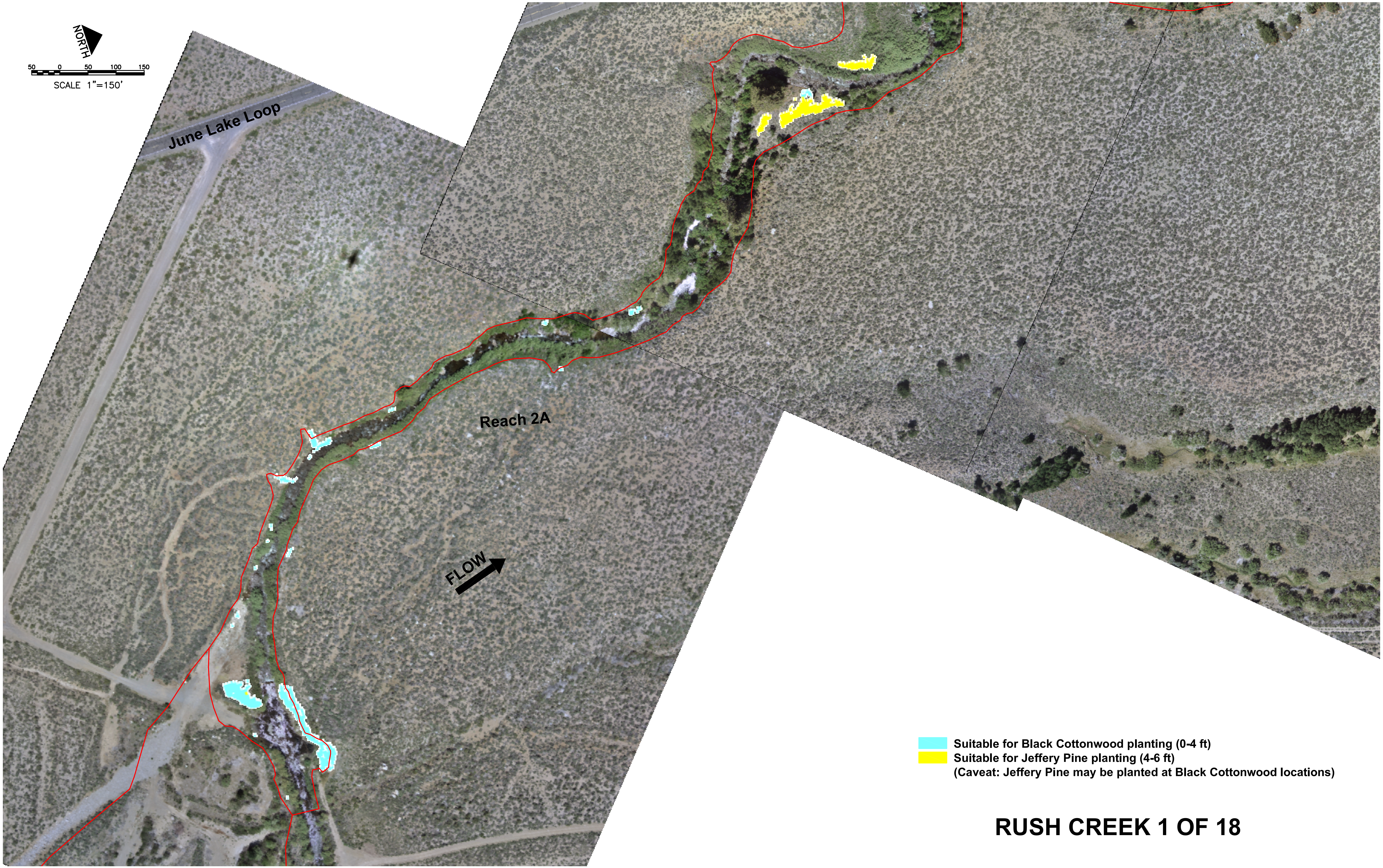
Plans to rewater the channels described in the waterfowl plan have been postponed until further notice based on recommendations from the Stream Scientists and final decision from the SWRCB (see discussion above).

Appendix - Jeffrey Pine / Black Cottonwood Planting Maps for Rush and Lee Vining Creeks provided by McBain & Trush

LADWP requested McBain & Trush to create planting suitability models for planting Jeffrey Pine and Black Cottonwood trees in Rush and Lee Vining Creeks. The following maps are the results of this modeling effort, and should be used as a guide for future revegetation efforts of those species within the areas covered by the maps.

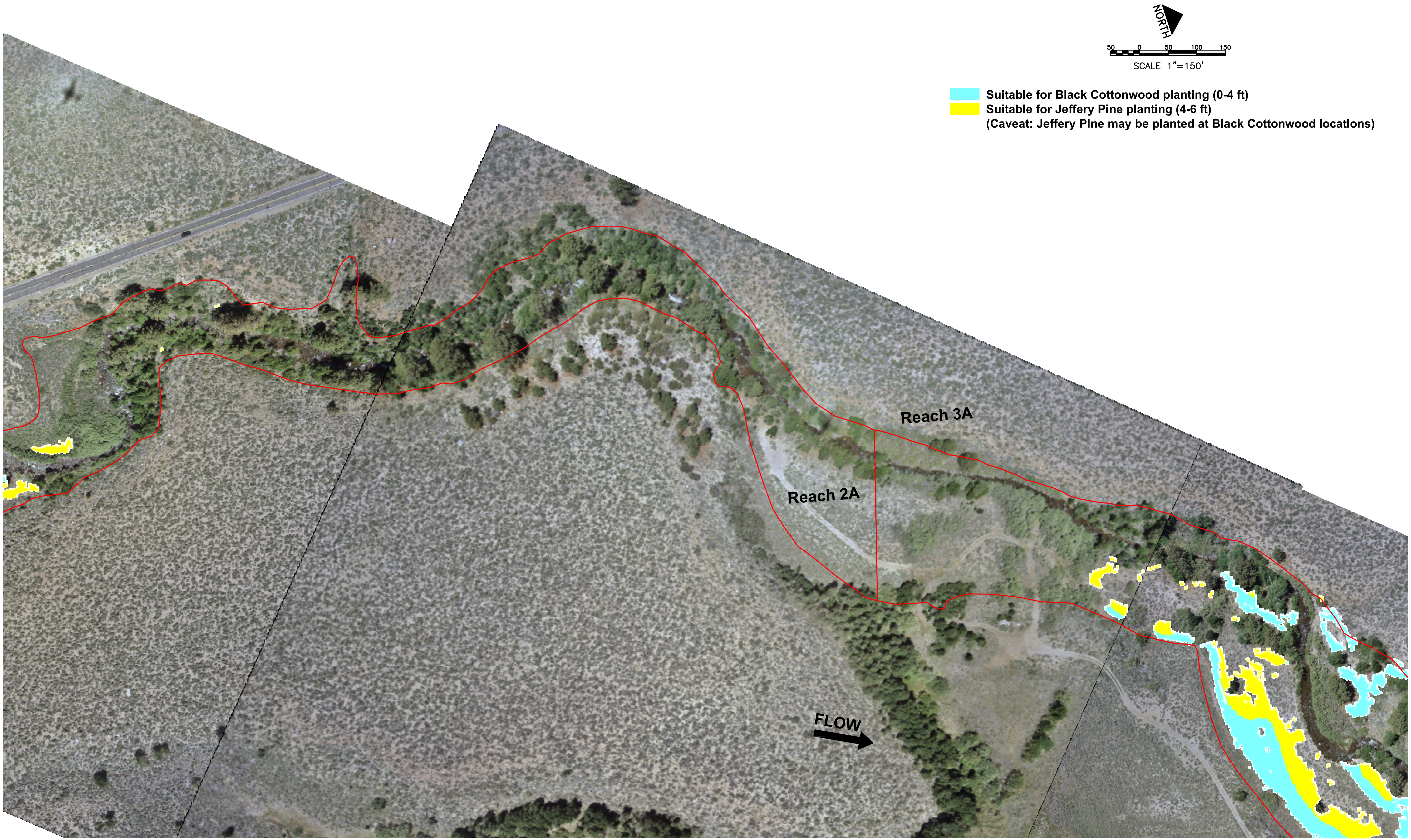
Rush Creek Planting Suitability Model Results

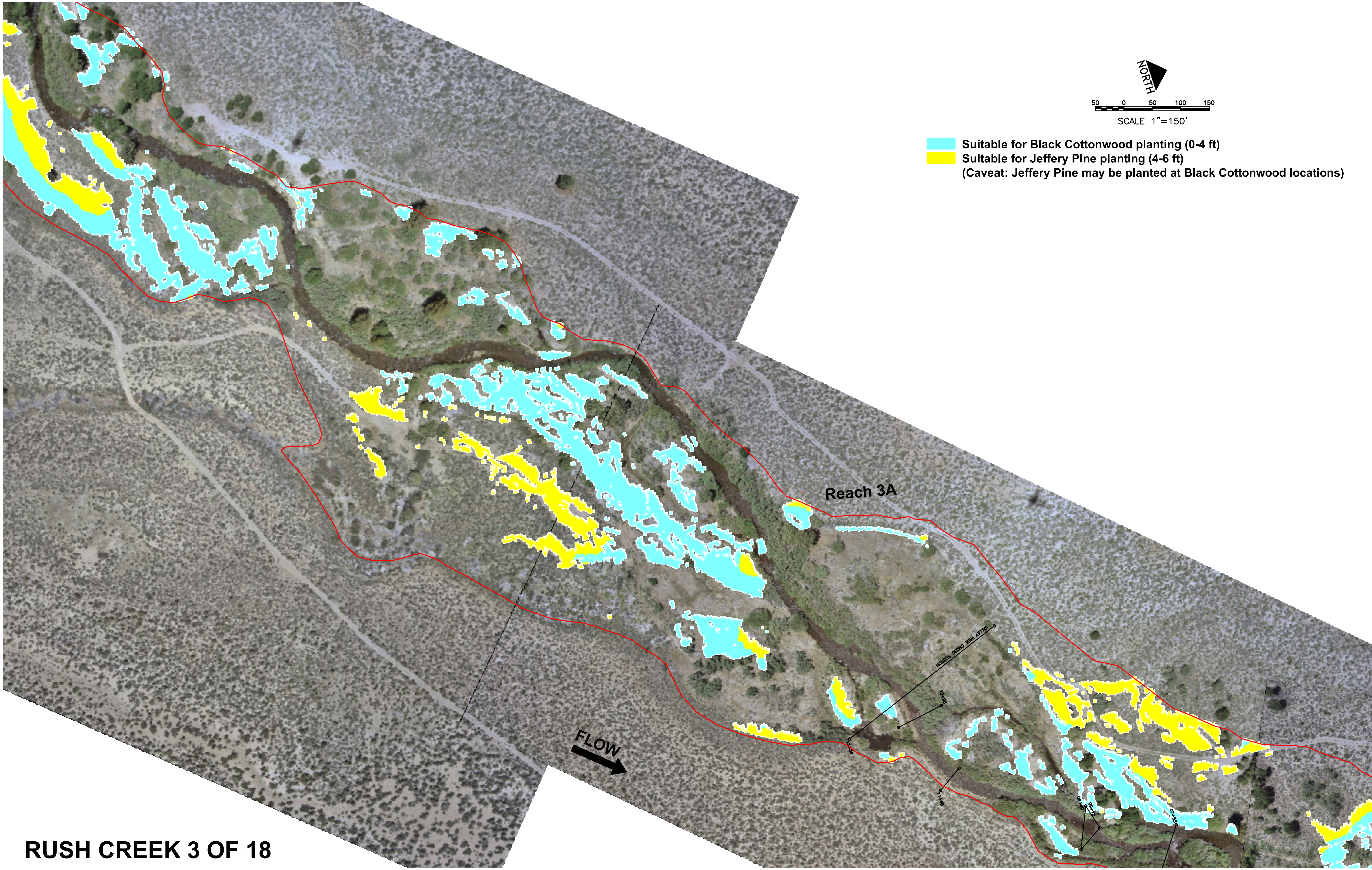
Jeffrey Pine and Black Cottonwood



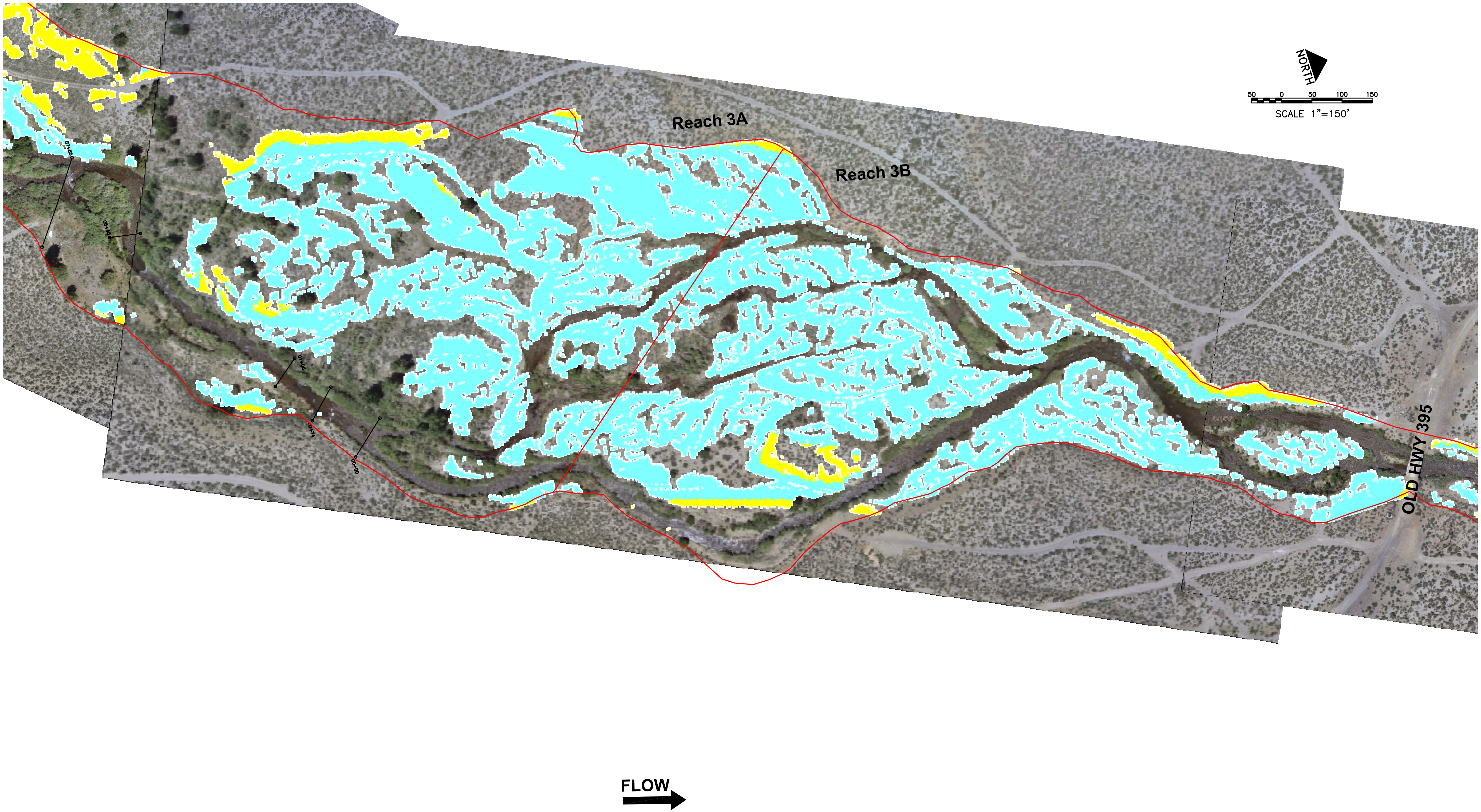
RUSH CREEK 1 OF 18

RUSH CREEK 2 OF 18



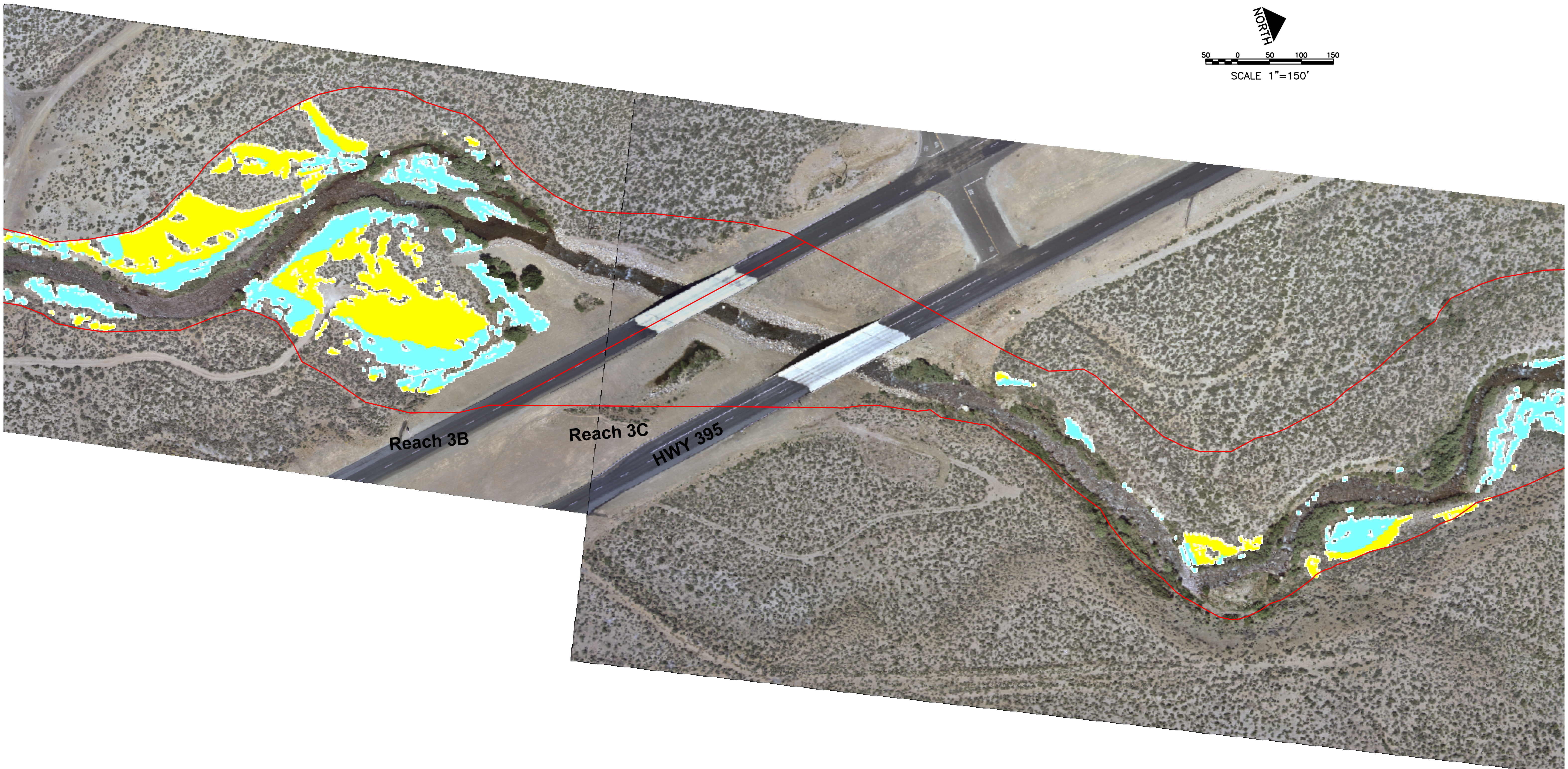


RUSH CREEK 3 OF 18



Suitable for Black Cottonwood planting (0-4 ft)
Suitable for Jeffery Pine planting (4-6 ft)
(Caveat: Jeffery Pine may be planted at Black Cottonwood locations)

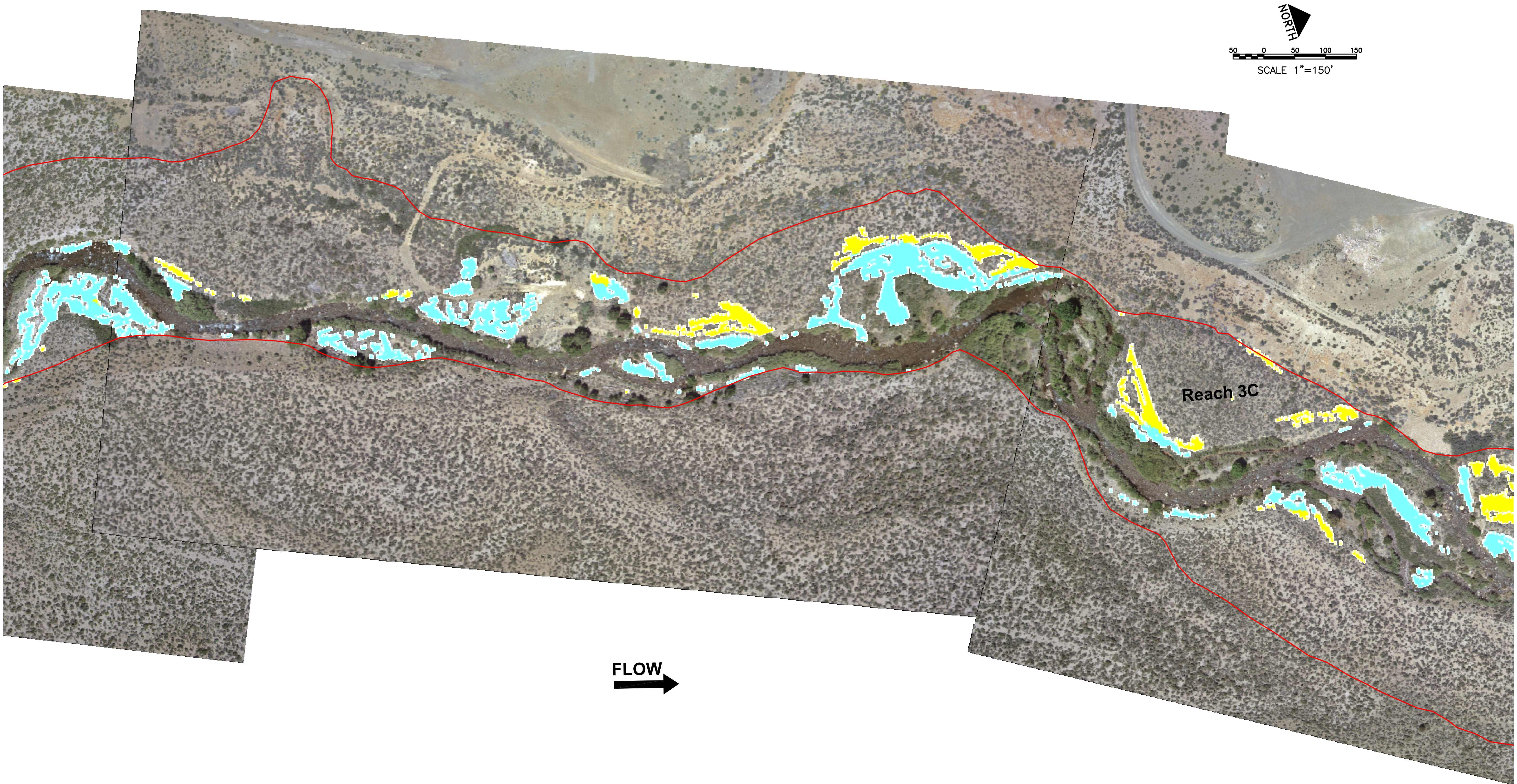
RUSH CREEK 4 OF 18



FLOW

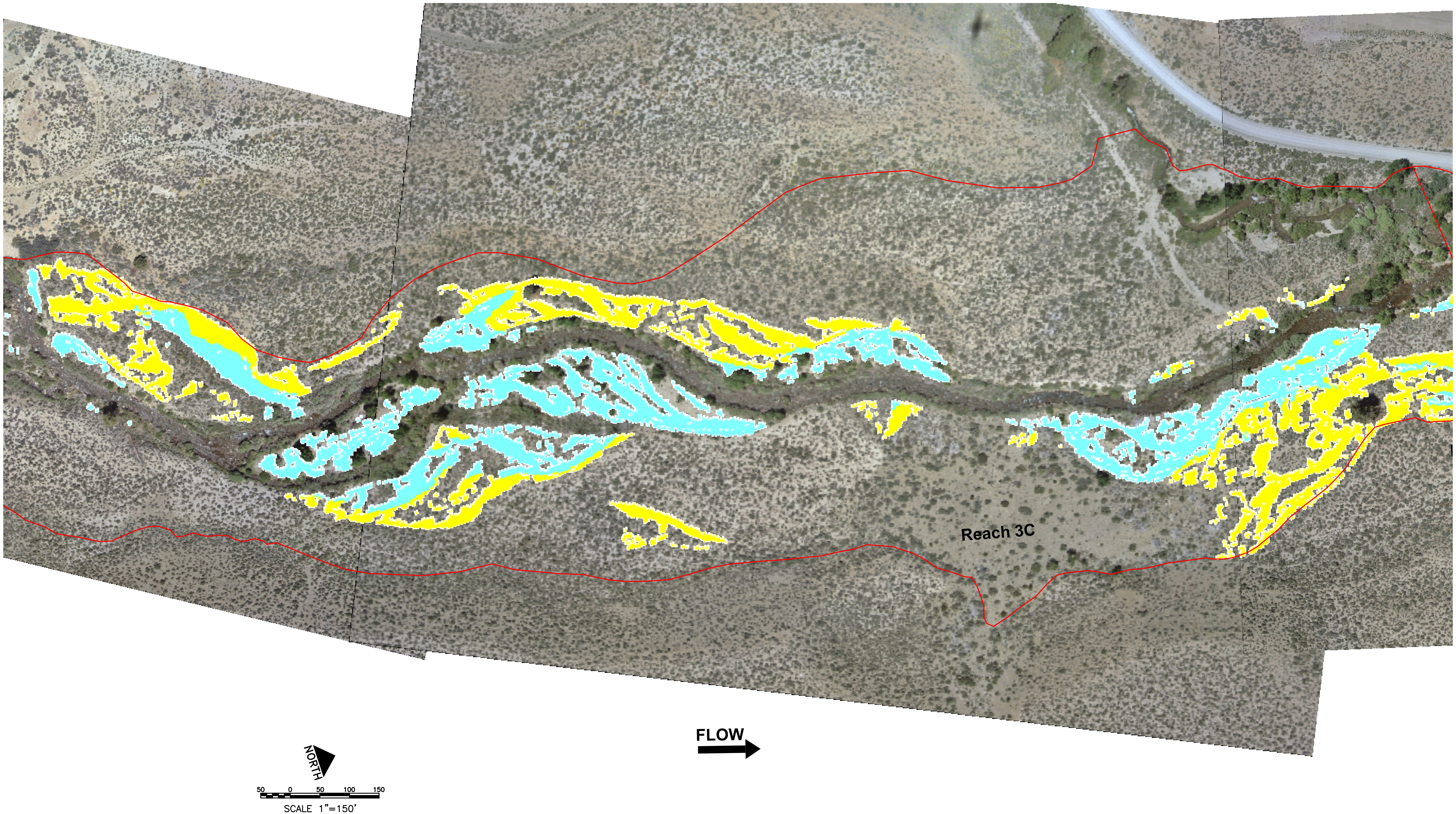
Suitable for Black Cottonwood planting (0-4 ft)
Suitable for Jeffery Pine planting (4-6 ft)
(Caveat: Jeffery Pine may be planted at Black Cottonwood locations)

RUSH CREEK 5 OF 18



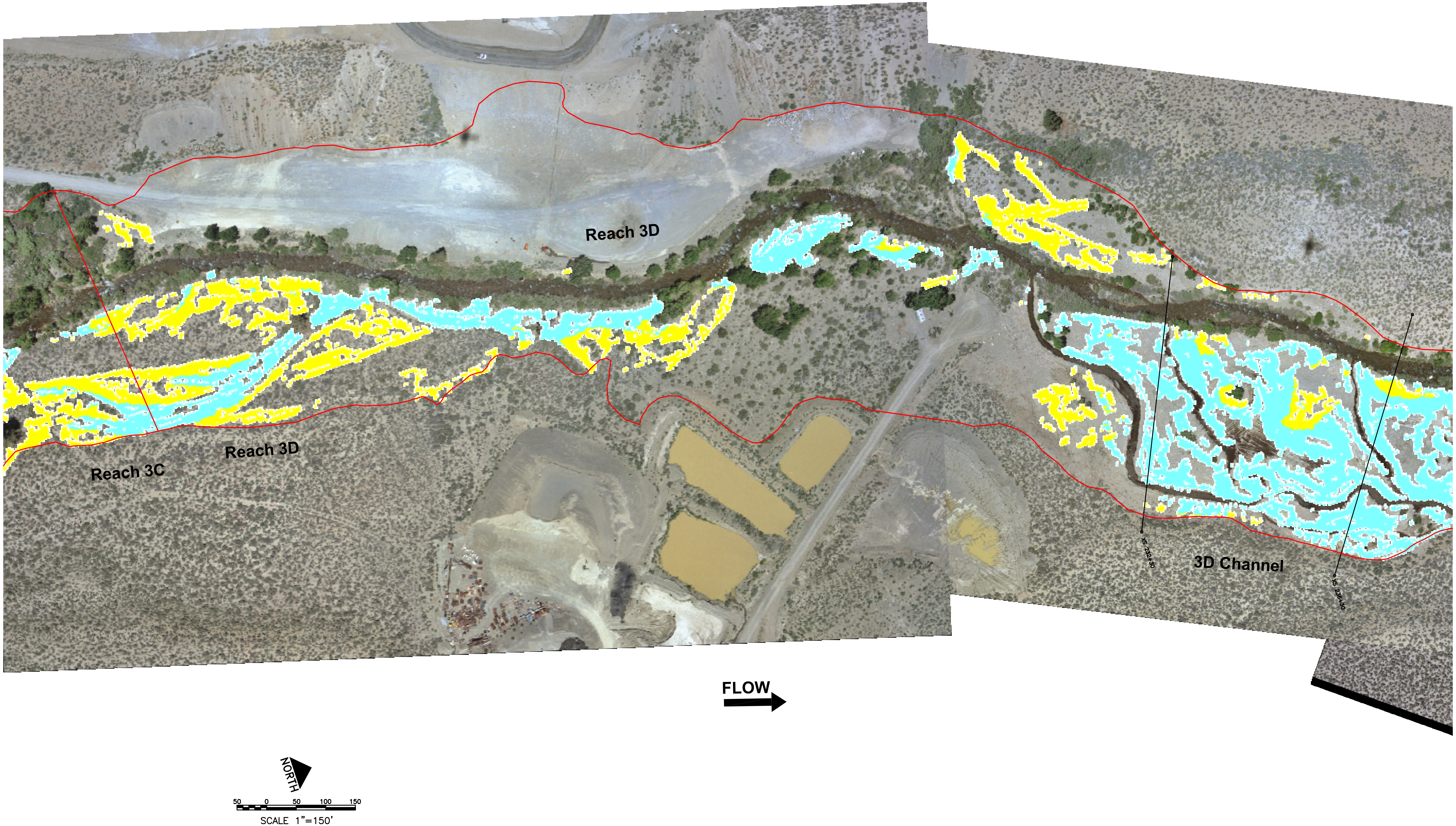
Suitable for Black Cottonwood planting (0-4 ft)
Suitable for Jeffery Pine planting (4-6 ft)
(Caveat: Jeffery Pine may be planted at Black Cottonwood locations)

RUSH CREEK 6 OF 18



RUSH CREEK 7 OF 18

Suitable for Black Cottonwood planting (0-4 ft)
Suitable for Jeffery Pine planting (4-6 ft)
(Caveat: Jeffery Pine may be planted at Black Cottonwood locations)



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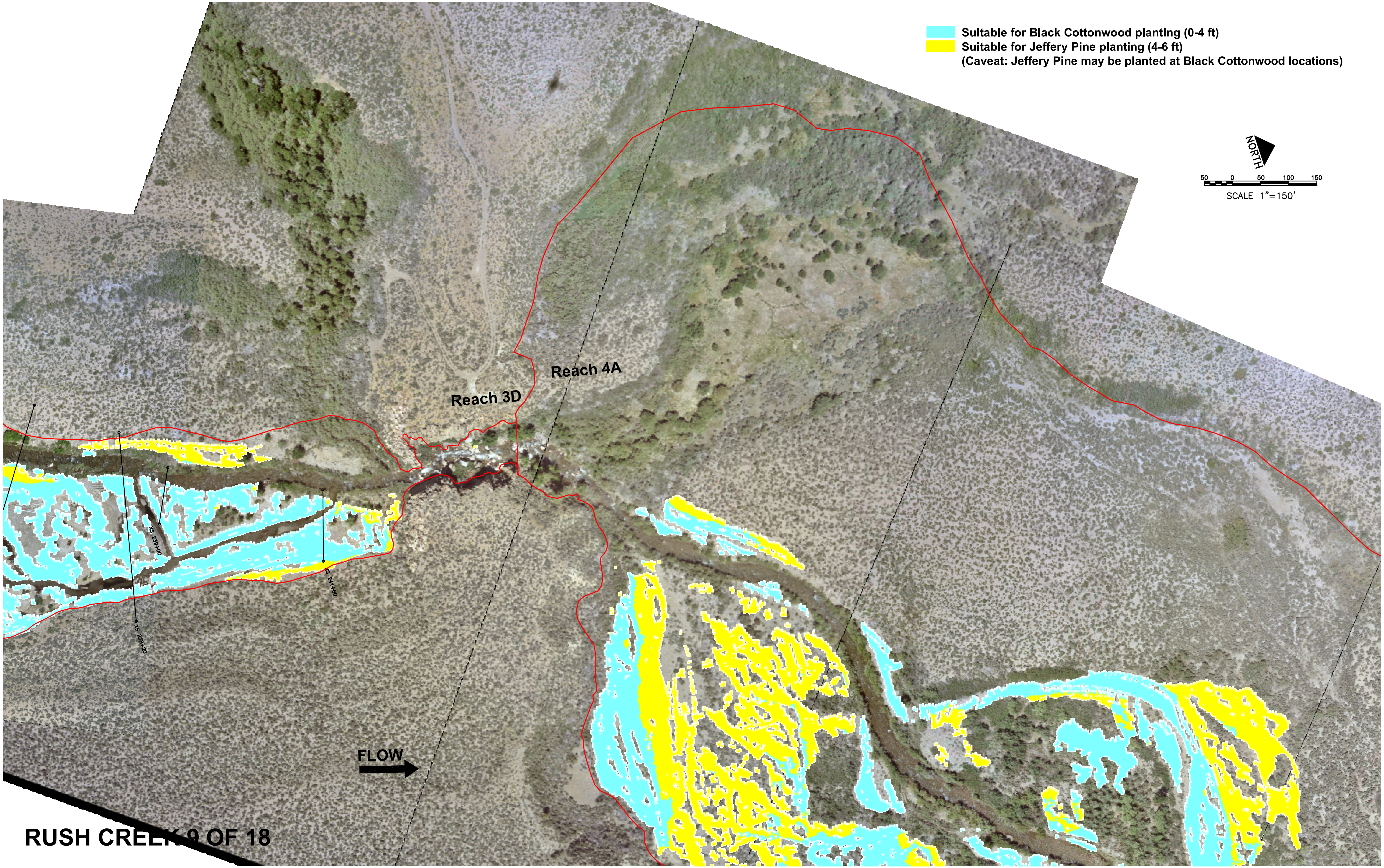
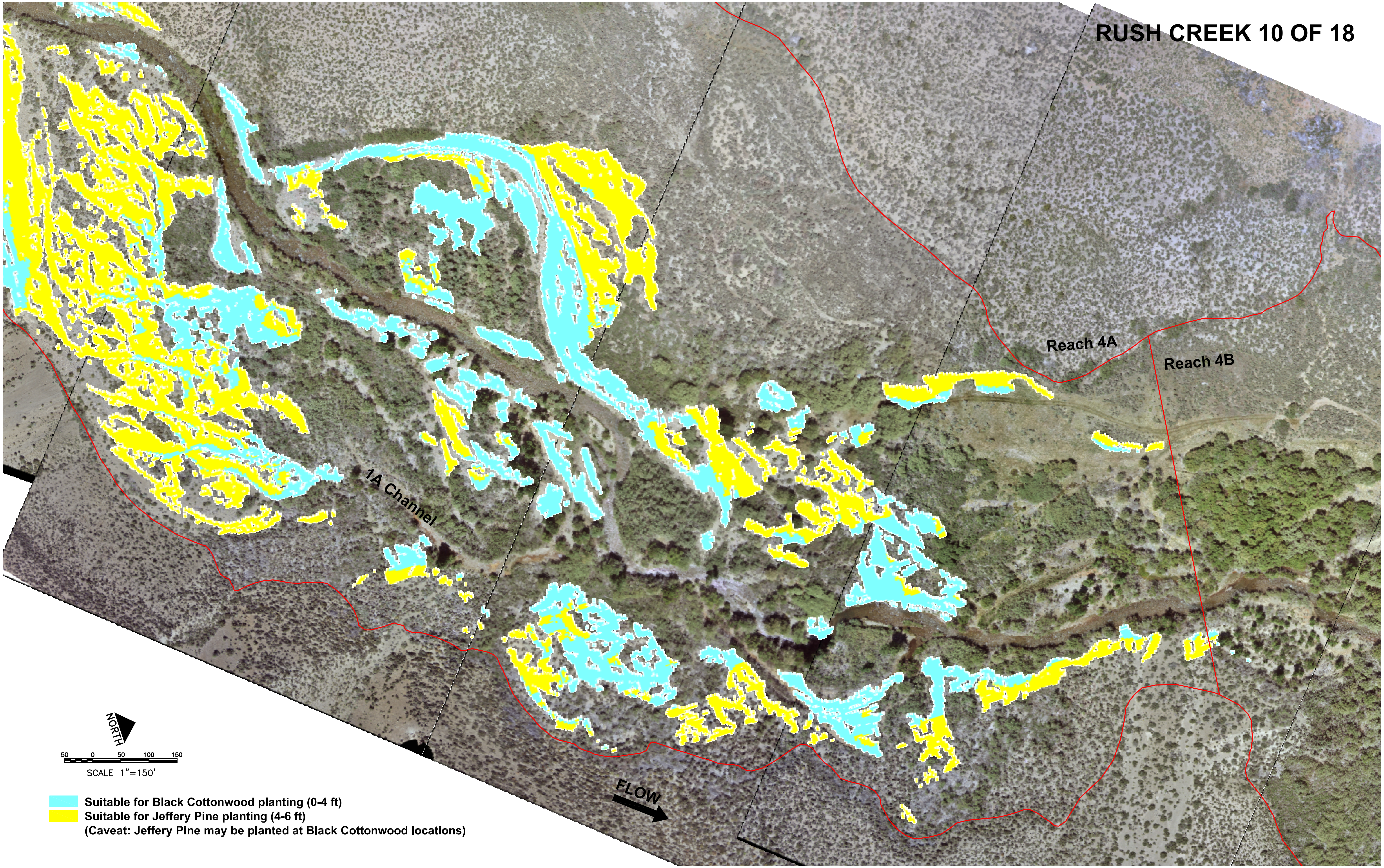
Suitable for Jeffery Pine planting (4-6 ft)
(Caveat: Jeffery Pine may be planted at Black Cottonwood locations)

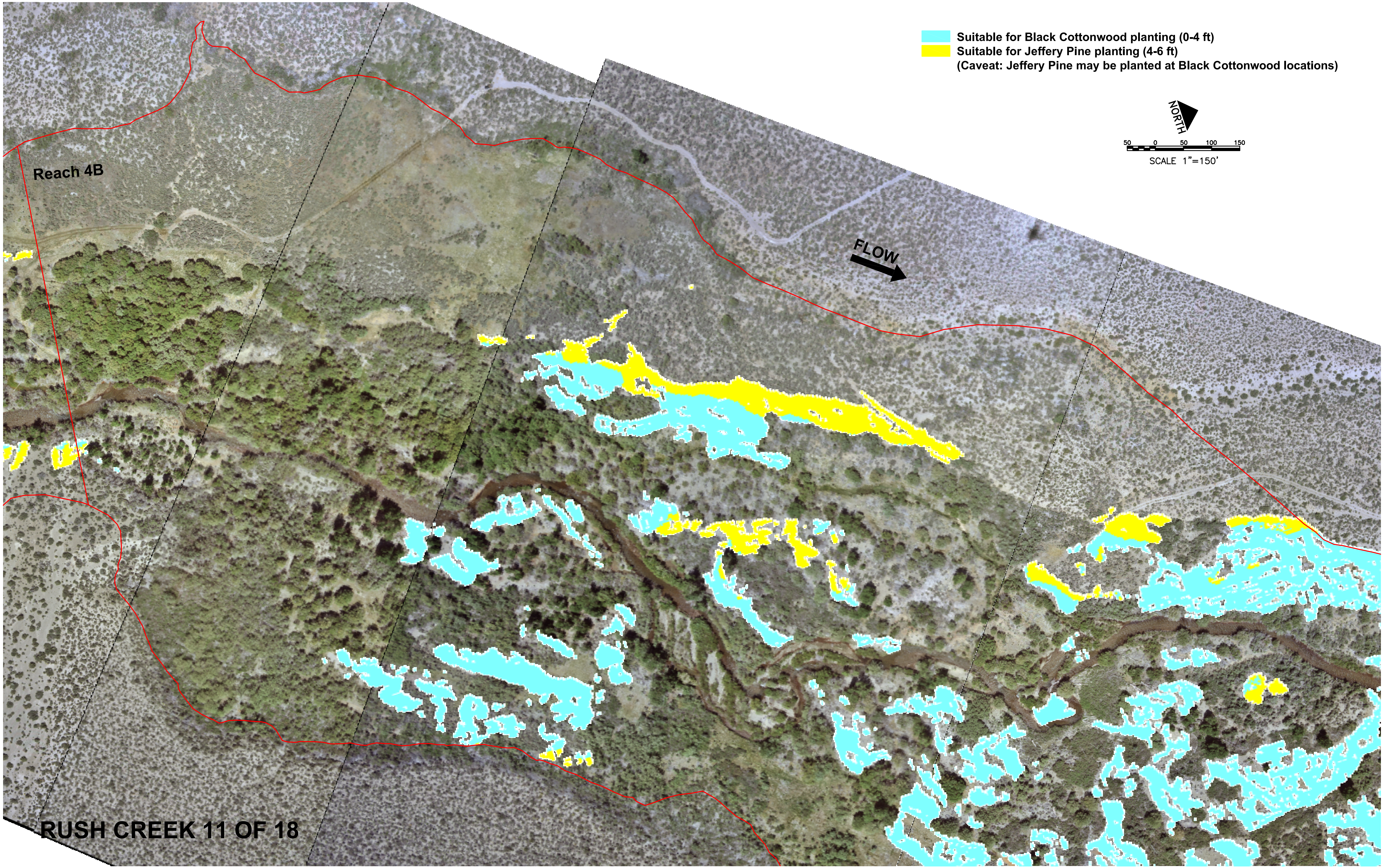
RUSH CREEK 8 OF 18

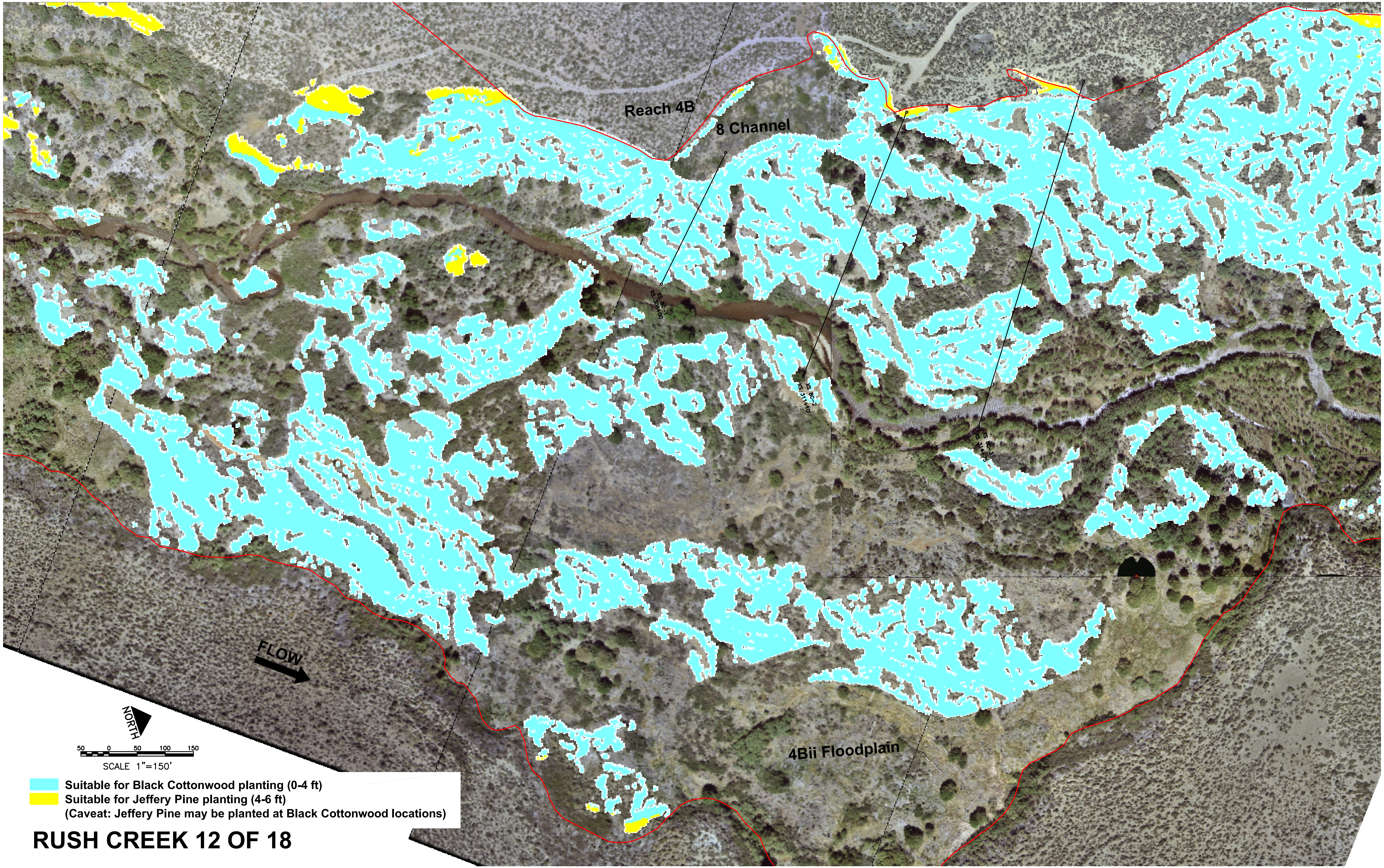


Suitable for Black Cottonwood planting (0-4 ft)
Suitable for Jeffery Pine planting (4-6 ft)
(Caveat: Jeffery Pine may be planted at Black Cottonwood locations)
NORTH
50 0 50 100 150
SCALE 1"=150'
Reach 4A
Reach 3D
XS 239+00
XS 241+80
XS 238+20
FLOW
RUSH CREEK 9 OF 18

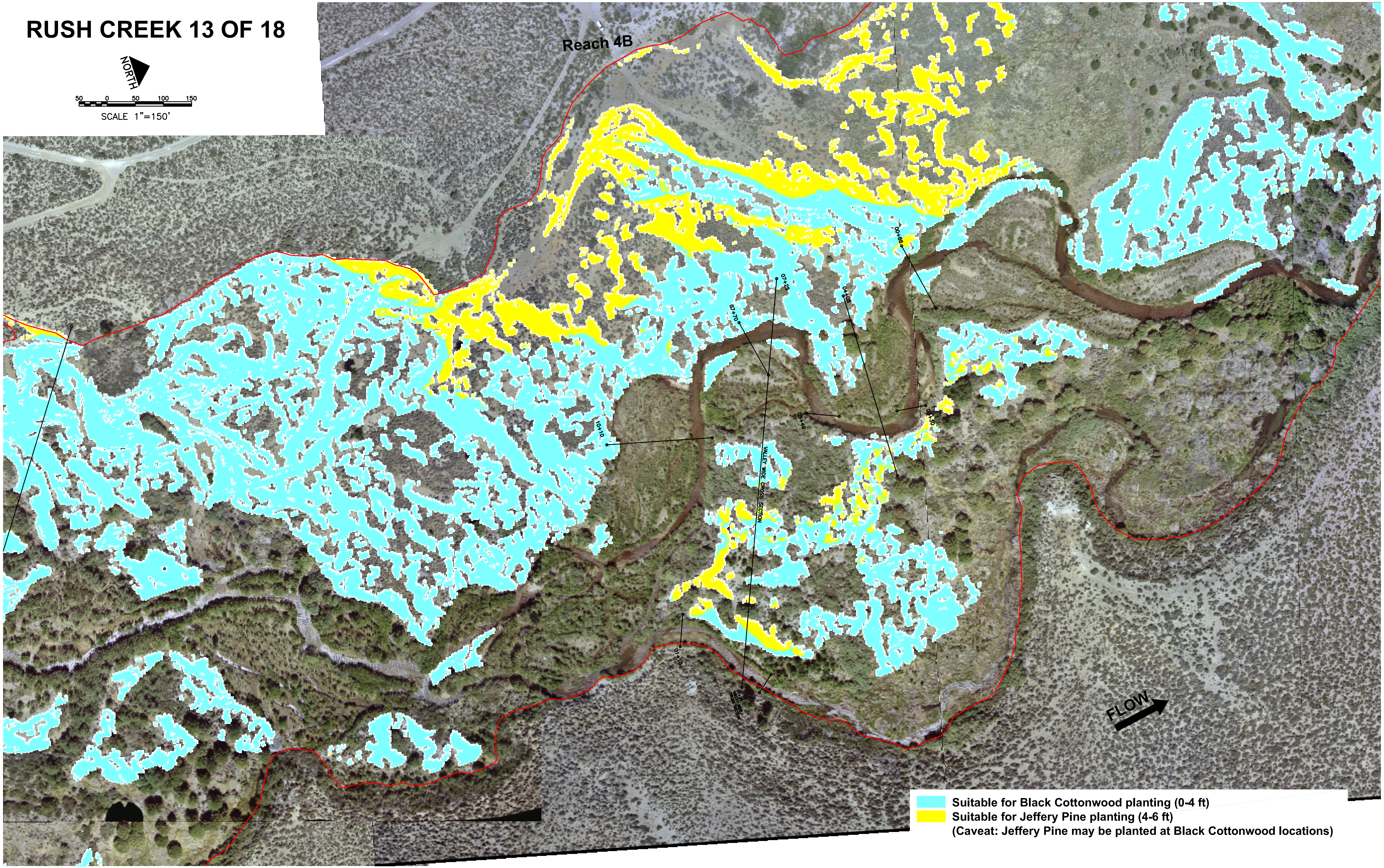


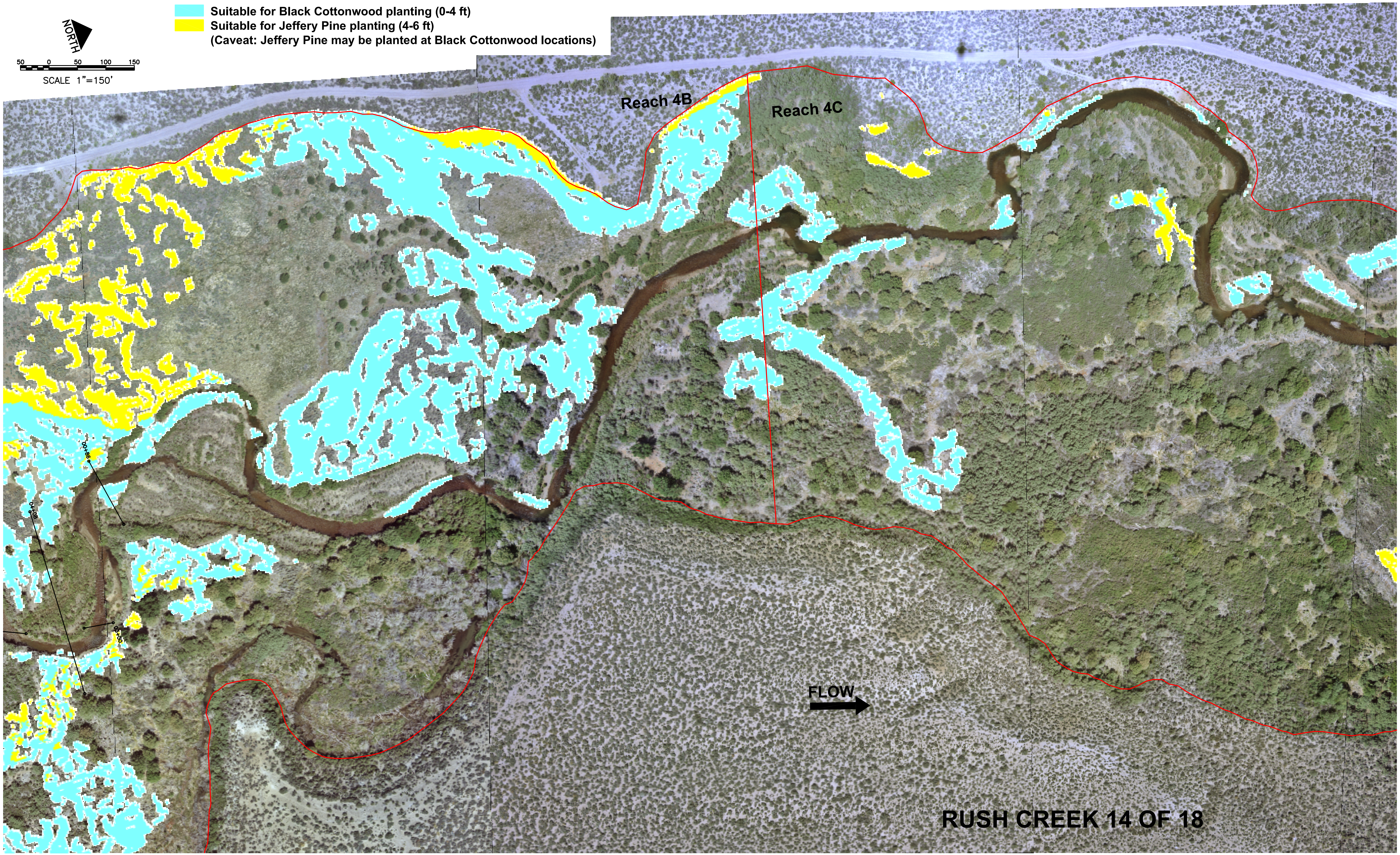
RUSH CREEK 10 OF 18
Reach 4A
Reach 4B
1A Channel
NORTH
50 0 50 100 150
SCALE 1"=150'
FLOW
Suitable for Black Cottonwood planting (0-4 ft)
Suitable for Jeffery Pine planting (4-6 ft)
(Caveat: Jeffery Pine may be planted at Black Cottonwood locations)

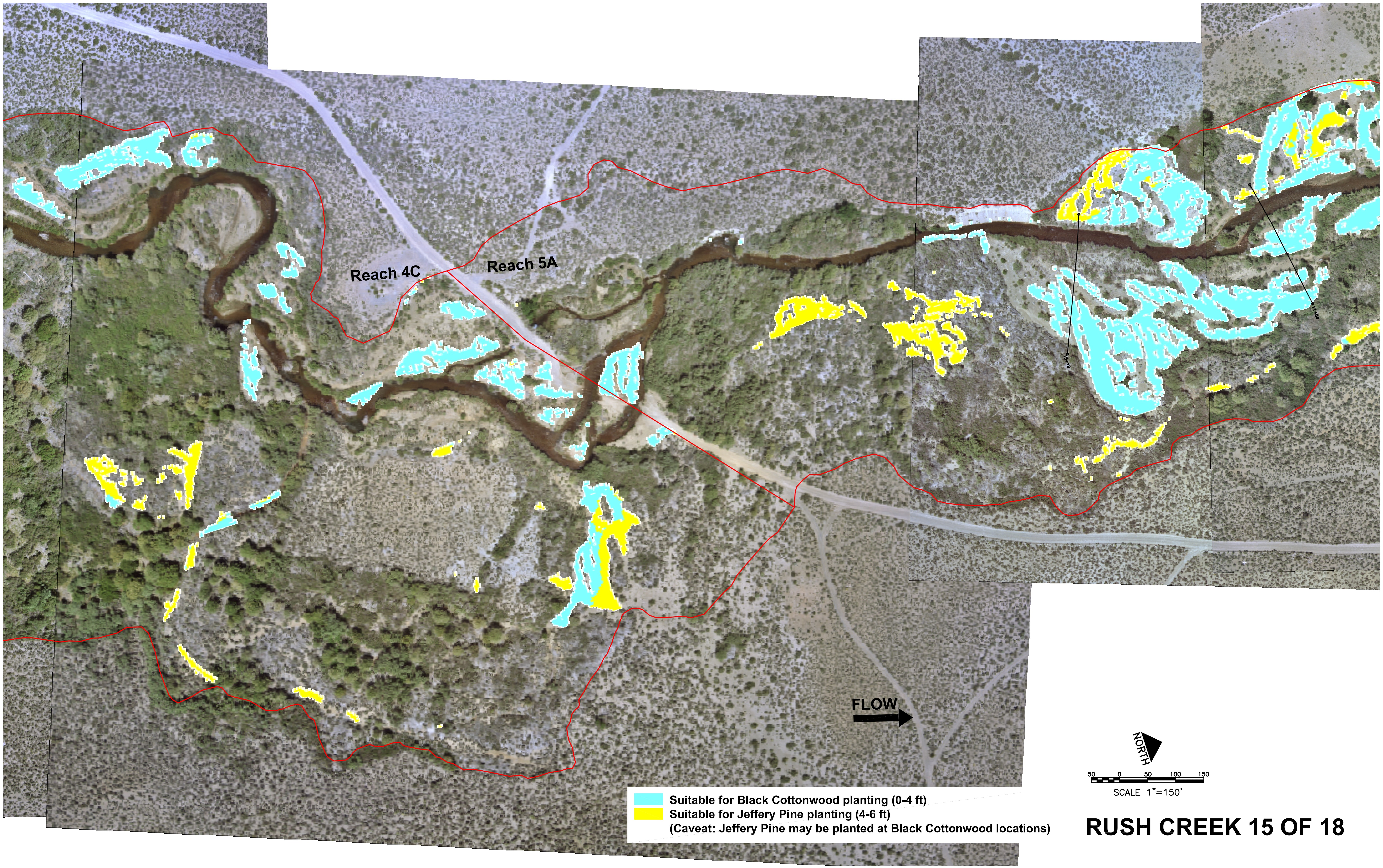

Suitable for Black Cottonwood planting (0-4 ft)
Suitable for Jeffery Pine planting (4-6 ft)
(Caveat: Jeffery Pine may be planted at Black Cottonwood locations)
NORTH
50 0 50 100 150
SCALE 1"=150'
Reach 4B
FLOW
RUSH CREEK 11 OF 18


Reach 4B
8 Channel
4Bii Floodplain
FLOW
NORTH
50 0 50 100 150
SCALE 1"=150'
Suitable for Black Cottonwood planting (0-4 ft)
Suitable for Jeffery Pine planting (4-6 ft)
(Caveat: Jeffery Pine may be planted at Black Cottonwood locations)
RUSH CREEK 12 OF 18

RUSH CREEK 13 OF 18




Suitable for Black Cottonwood planting (0-4 ft)
Suitable for Jeffery Pine planting (4-6 ft)
(Caveat: Jeffery Pine may be planted at Black Cottonwood locations)
NORTH
50 0 50 100 150
SCALE 1"=150'
Reach 4B
Reach 4C
FLOW
RUSH CREEK 14 OF 18


Reach 4C
Reach 5A
FLOW
NORTH
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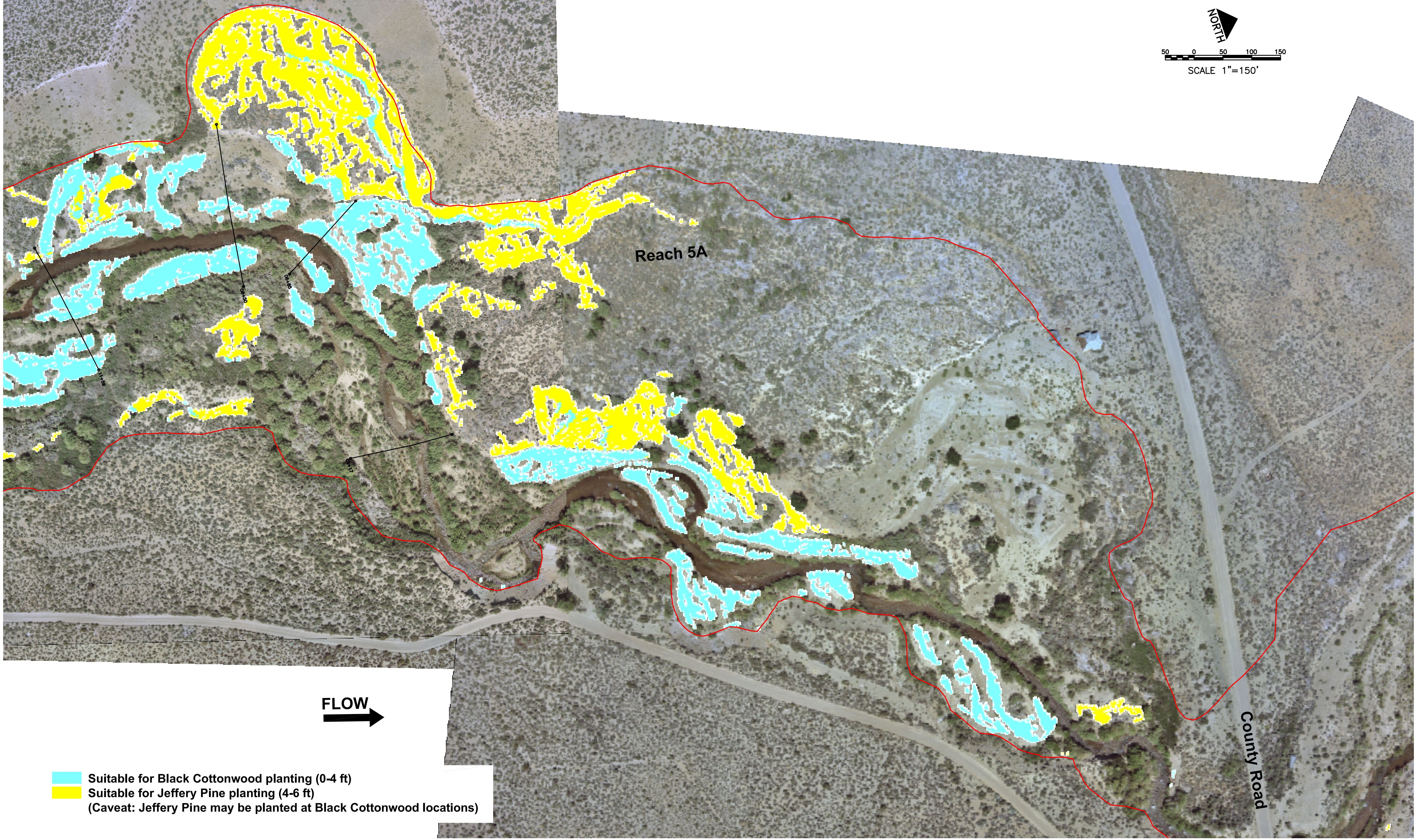
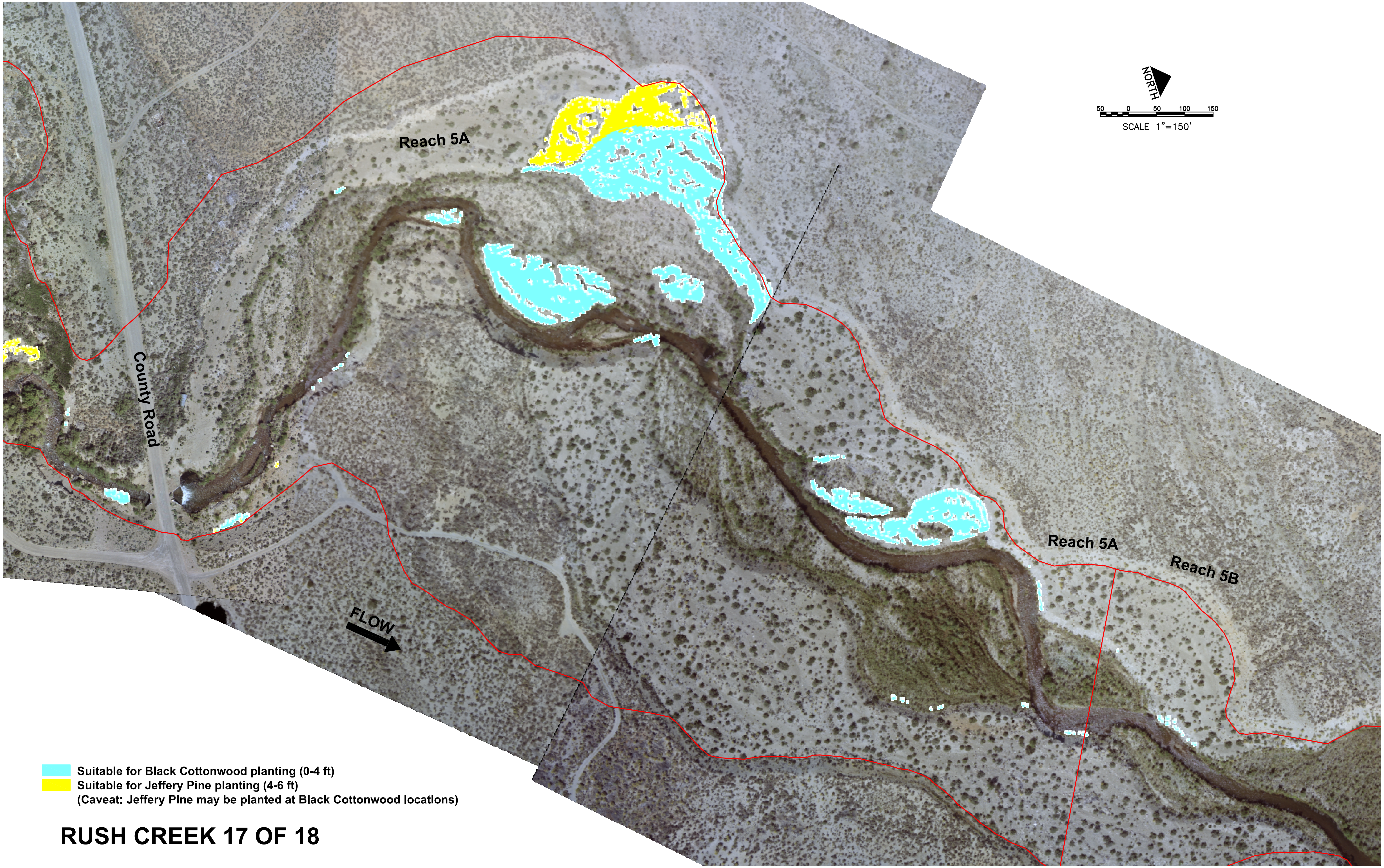
SCALE 1"=150'
Suitable for Black Cottonwood planting (0-4 ft)
Suitable for Jeffery Pine planting (4-6 ft)
(Caveat: Jeffery Pine may be planted at Black Cottonwood locations)
RUSH CREEK 15 OF 18

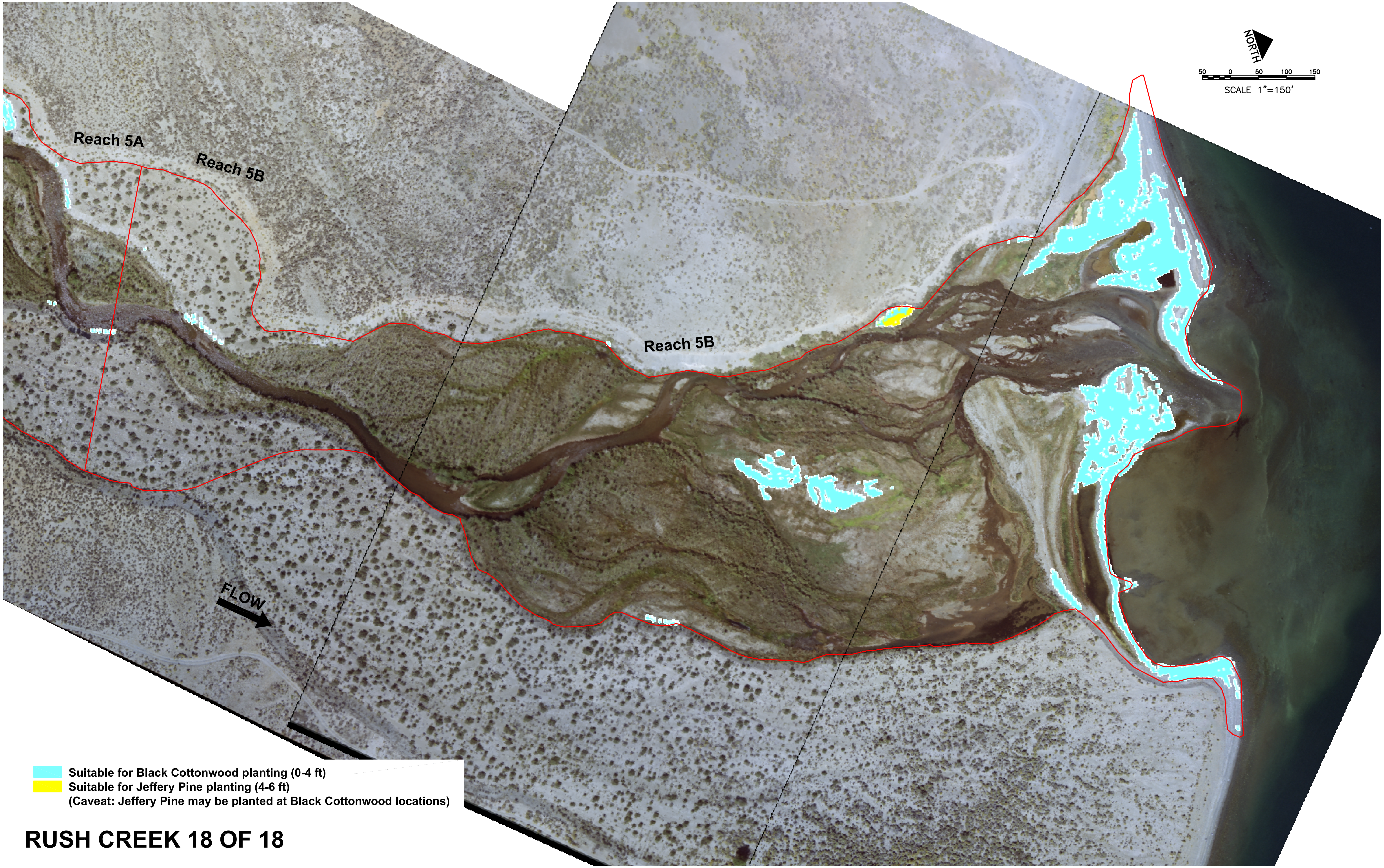
RUSH CREEK 16 OF 18





Suitable for Black Cottonwood planting (0-4 ft)
Suitable for Jeffery Pine planting (4-6 ft)
(Caveat: Jeffery Pine may be planted at Black Cottonwood locations)

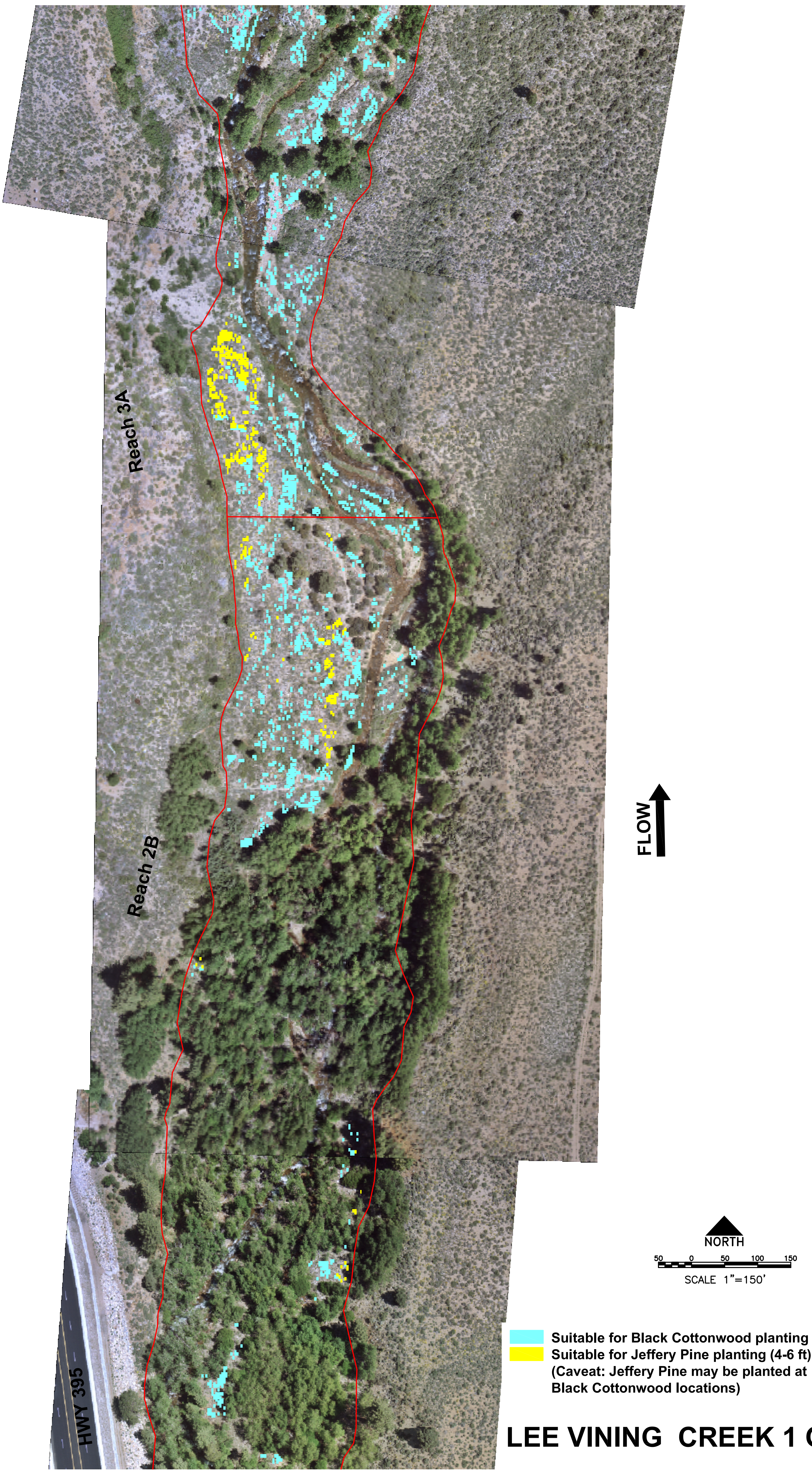
RUSH CREEK 17 OF 18



RUSH CREEK 18 OF 18

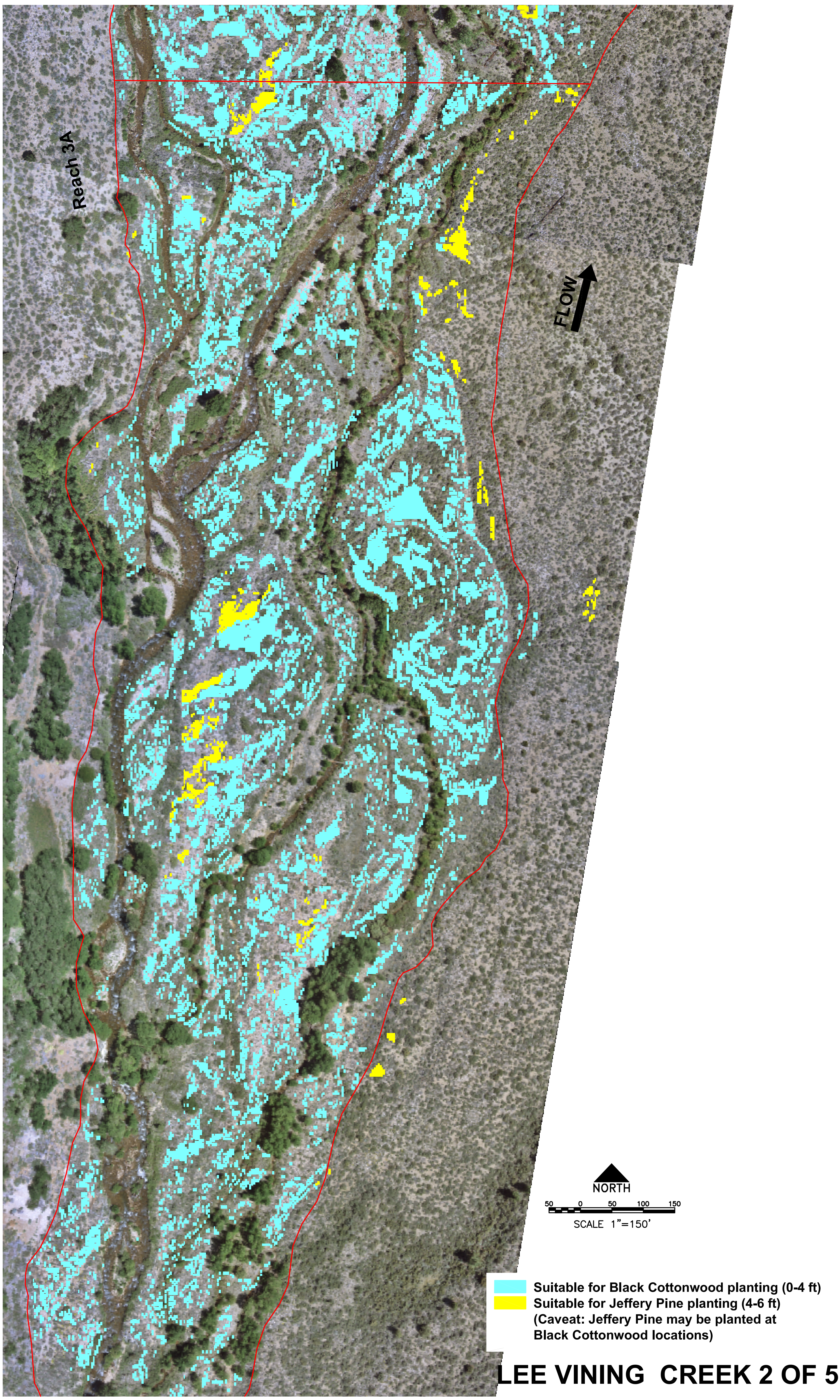
Lee Vining Creek Planting Suitability Model Results

Jeffrey Pine and Black Cottonwood



Suitable for Black Cottonwood planting (0-4 ft)
Suitable for Jeffery Pine planting (4-6 ft)
(Caveat: Jeffery Pine may be planted at Black Cottonwood locations)

LEE VINING CREEK 1 OF 5


Reach 3A
FLOW
NORTH
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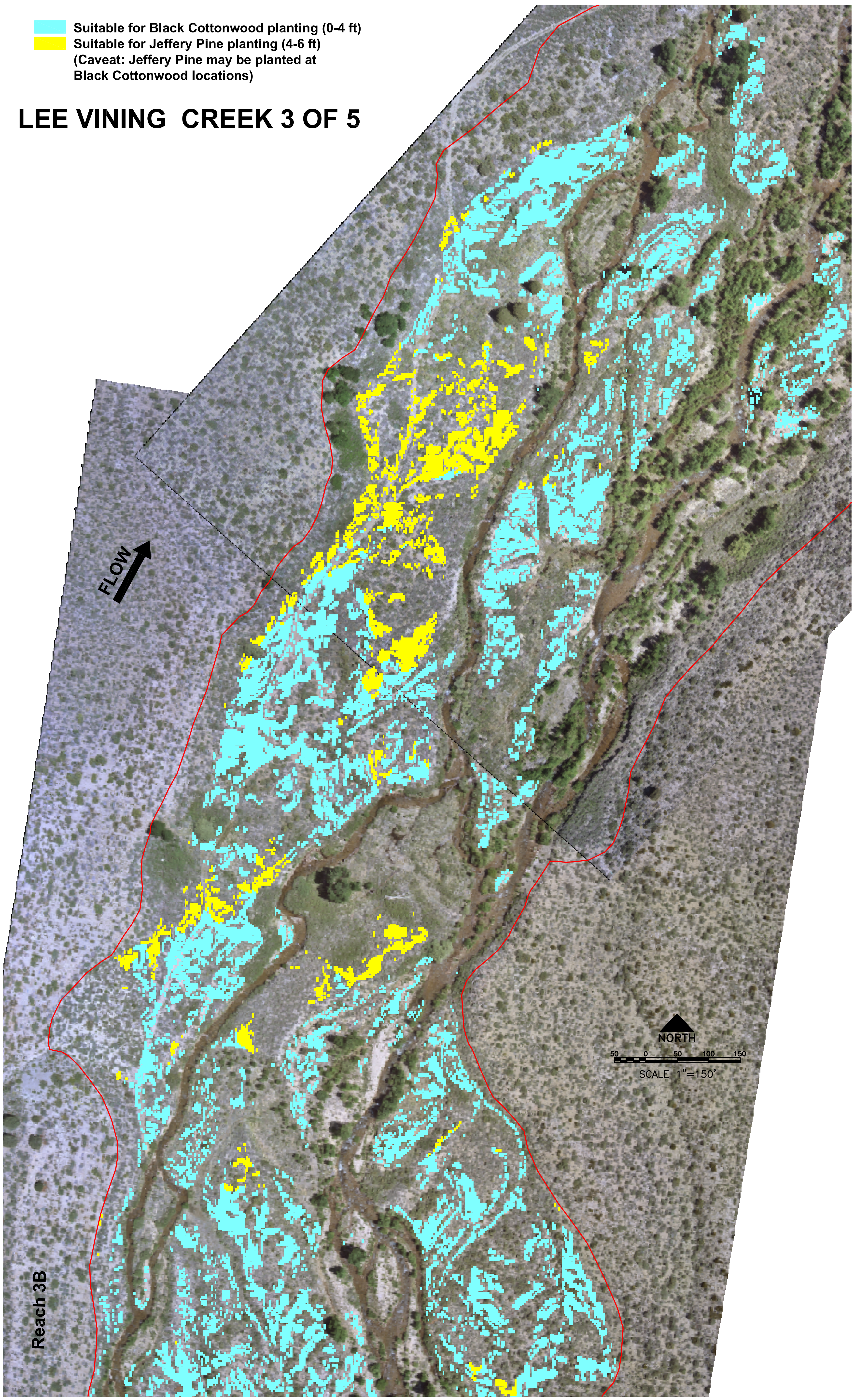
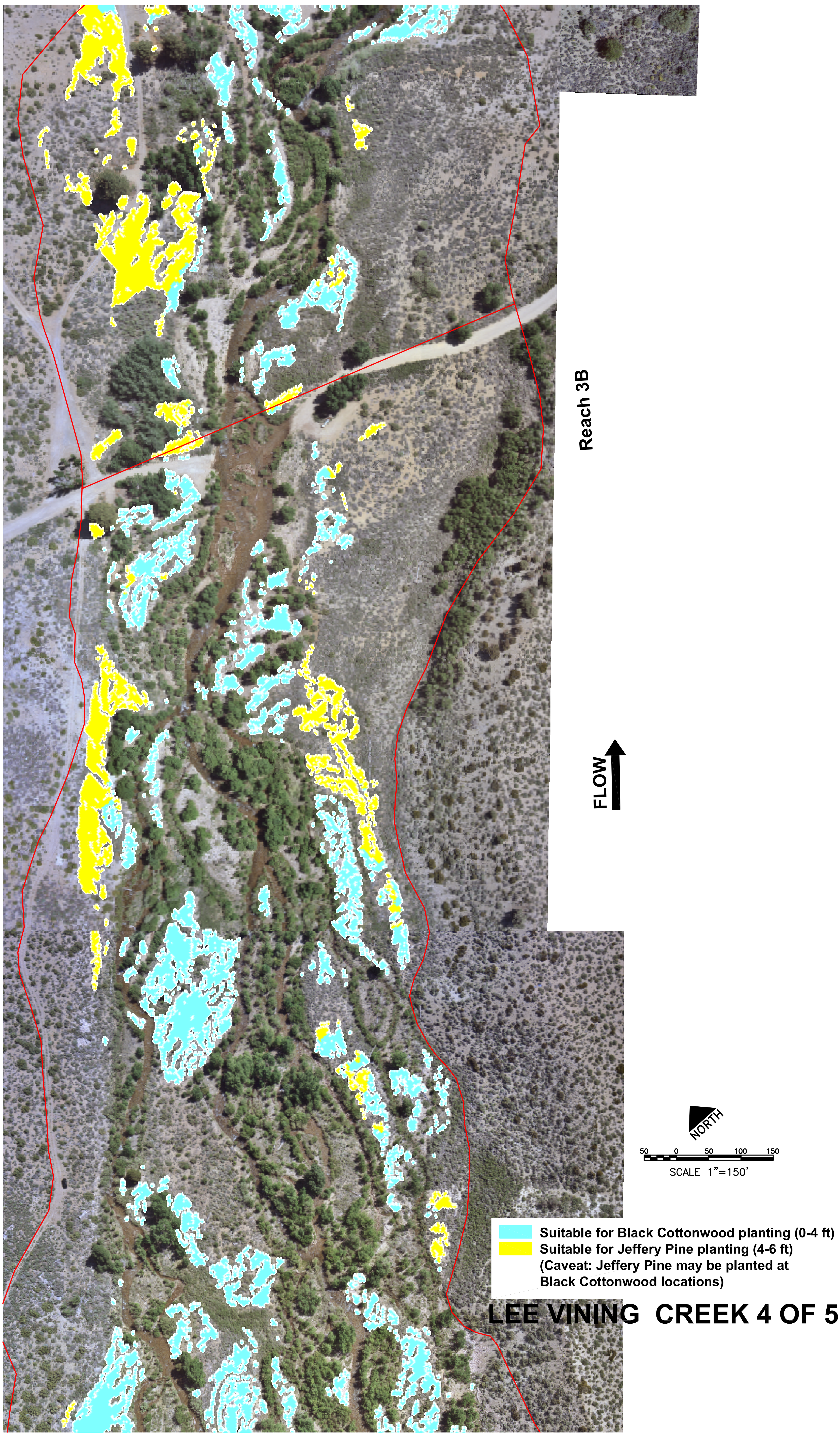
SCALE 1"=150'
Suitable for Black Cottonwood planting (0-4 ft)
Suitable for Jeffery Pine planting (4-6 ft)
(Caveat: Jeffery Pine may be planted at
Black Cottonwood locations)
LEE VINING CREEK 2 OF 5

LEE VINING CREEK 3 OF 5





Reach 3B
FLOW
NORTH
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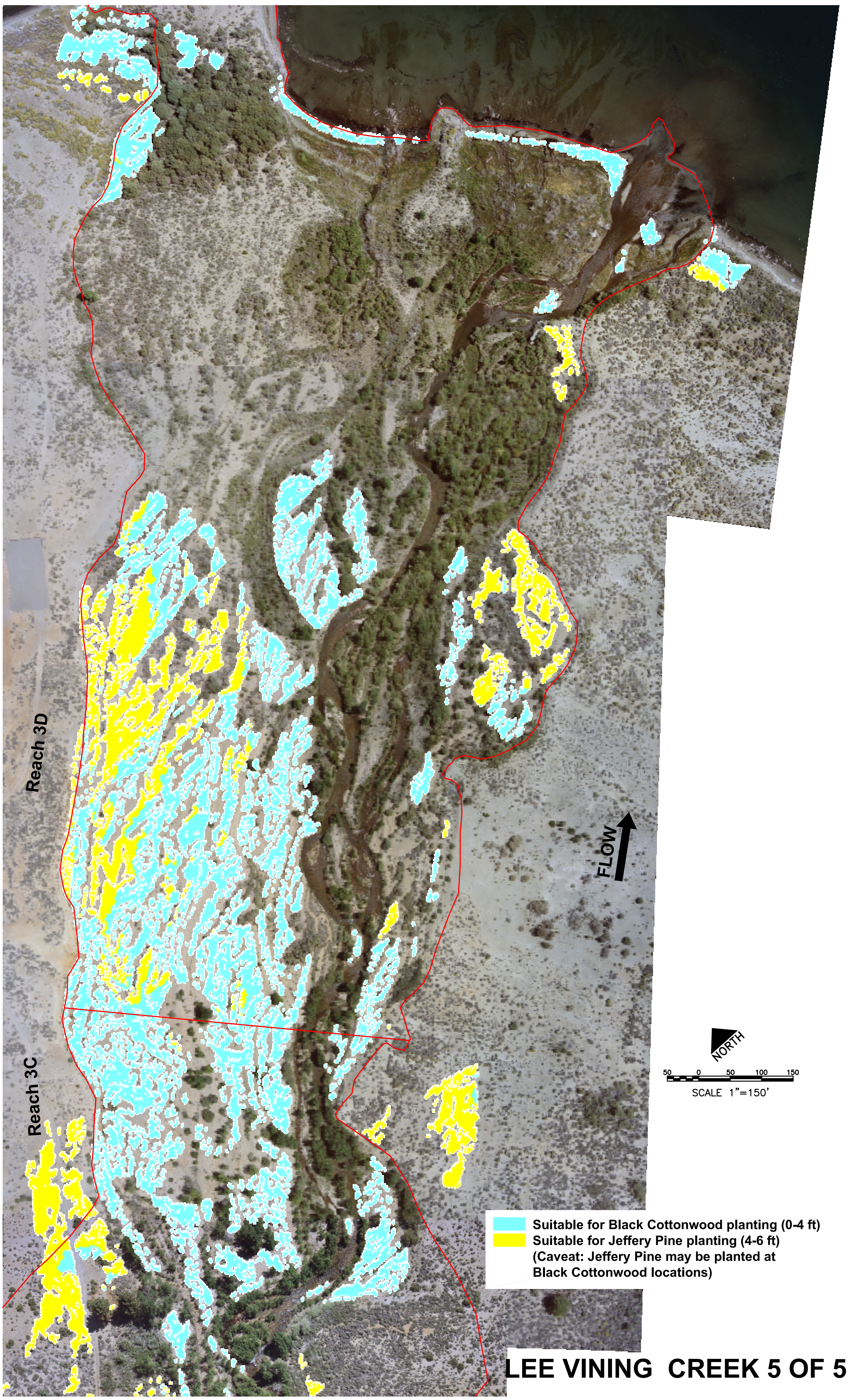
SCALE 1"=150'
Suitable for Black Cottonwood planting (0-4 ft)
Suitable for Jeffery Pine planting (4-6 ft)
(Caveat: Jeffery Pine may be planted at
Black Cottonwood locations)
LEE VINING CREEK 4 OF 5


Reach 3D
Reach 3C
FLOW
NORTH
50 0 50 100 150
SCALE 1"=150'
Suitable for Black Cottonwood planting (0-4 ft)
Suitable for Jeffery Pine planting (4-6 ft)
(Caveat: Jeffery Pine may be planted at
Black Cottonwood locations)
LEE VINING CREEK 5 OF 5

Section 2

Los Angeles Department of Water and Power's
Mono Basin Preliminary Operations Plan
Runoff Year
2006-07

May 10, 2006

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 2006-07

The Mono Basin forecast for the Runoff Year 2006-07 (RY 2006-07) beginning April 1, 2006, and ending March 31, 2007, is 180,000 acre-feet, or 147 % of normal (using the 1951-2000 average of 122,557 acre-feet). This year is thus classified as "Wet" according to the provisions of the State Water Resources Control Board (SWRCB) Decision 1631 (Decision 1631) and Order 98-05.

To meet SWRCB requirements, the Los Angeles Department of Water and Power (LADWP) intends to follow the guidelines shown in the enclosure titled "Guideline F", with the following modifications:

1. LADWP expects Grant Lake Reservoir to spill, and combined with Mono Gate One Return Ditch (MGORD) releases, it is expected that lower Rush Creek flows will meet or exceed the required release of 450 cubic feet per second (cfs) for five days, followed by 400 cfs for ten days.
2. As Grant Lake Reservoir nears the point of spilling, in order to maintain a smooth transition, LADWP may need to increase the ramping rate on lower Rush Creek on the ascending limb of the hydrograph.

<u>Forecast for RY 2006-07</u>
The April 1, 2006 (April 1) runoff forecast for the Mono Basin was 134% of normal. During the month of April however, some regional snow courses and snow pillows recorded more than 20% of the total snowfall for the year. Because of the large discrepancy between median and actual precipitation, and the fact that the April 1 forecast was close to the break point between the two year types of "Wet-Normal" and "Wet" (136.5% is the break point), LADWP revised the April 1 runoff forecast using all available data.

The revised April 1 runoff forecast, completed on April 24th, 2006, is 147% of normal. According to the provisions of SWRCB Decision 1631 (Decision 1631) and Order Number 98-05 (Order 98-05), 147% of normal sets the Mono Basin solidly within the "Wet" year type. A wet year is defined as a year when the runoff forecast falls between 136.5 and 160% of normal. As such, LADWP plans to operate all Mono Basin facilities in accordance with Guideline F (enclosed) from LADWP's 1996 Grant Lake Operation Management Plan (GLOMP). A copy of the revised runoff forecast results and Guideline F from the GLOMP are enclosed with this letter.

Mono Lake
The Mono Lake surface elevation on April 1, 2006, was recorded at 6,383.0 feet above mean sea level (AMSL) US Geological Survey datum. LADWP models predict Mono Lake to rise an additional 2.1 feet during the runoff year, with a peak elevation of 6,385.1 feet AMSL on March 31, 2007. Model results of the predicted Mono Lake elevation for RY 2006-07 are enclosed.

Mono Basin Exports
In accordance with Decision 1631, LADWP plans to export 16,000 acre-feet during RY 2006-07. Exports will begin shortly after Grant Reservoir stops spilling and will continue through March 31, 2007, when 16,000 acre-feet will have been exported. LADWP normally plans to export the allowed volume evenly throughout the course of the runoff year; however, this year 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.

Grant Lake Reservoir
The April 1, 2006, Grant Lake Reservoir storage was approximately 42,500 acre-feet, placing the surface elevation at approximately 7,125.8 feet AMSL. Maximum capacity of the reservoir is 47,575 acre-feet and the reservoir spillway elevation is 7,130 feet AMSL. Depending on the runoff season, the reservoir is expected to spill sometime between June 1 and July 15, 2006. The Grant Lake Reservoir storage target on March 31, 2007, is approximately 36,000 acre-feet with a surface elevation of 7,120 feet AMSL.

Rush Creek
Following Guideline F (enclosed), spring and summer base flows will be maintained between 70 and 150 cfs. Winter base flows will be between 52 and 70 cfs. Spring peak flow requirements are 450 cfs for five days and 400 cfs for ten days, both of which may be exceeded through a controlled spill event from Grant Lake Reservoir and possible augmentation. The spring peak will be maximized by maintaining a high Grant Lake Reservoir elevation and watching reservoir inflows. As Grant Lake Reservoir nears the

spill point, LADWP will ramp MGORD releases up to approximately 350 cfs to attempt a smooth transition to the spill event. After reservoir spill is initiated, MGORD releases will be reduced until the combined flow of the MGORD and spillway drops below 300 cfs, at which time MGORD flows will ramp up to halt the spill event and slowly ramp flows down (at 10 % or less) to baseflow conditions.

Note: If during the course of Rush Creek peak flow operations, MGORD releases combined with Grant Lake Reservoir spill volumes do not approach the minimum Rush Creek peak flow requirement of 450 cfs, and Lee Vining Creek is not experiencing peak flows, LADWP will divert water from Lee Vining Creek for augmentation through the 5-Siphon Bypass (or into Grant Lake Reservoir) to provide the extra water for lower Rush Creek.

Lee Vining Creek
Spring base flows of 54 cfs will be maintained until diversions are halted in early to mid-May. LADWP plans to halt diversions from Lee Vining Creek prior to May 15 and will not resume diversions until the peak flow has passed the diversion facility and Grant Lake Reservoir storage becomes available. During this period of no diversions, LADWP will lower the Lee Vining diversion gate to the completely open position in order to allow peak flows to pass the diversion. This operation will also facilitate sediment passage to lower Lee Vining Creek.

Parker and Walker Creeks
LADWP will continue operating the Parker and Walker diversions as flow-through.

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

Sincerely,

Thomas M. Erb

Thomas M. Erb
Director of Water Resources

MH:jmm

Enclosures

c: All w/ enclosures:
Enclosed mailing list
Dr. Mark Hanna

Mono Basin Distribution List
May 2006

Ms. Victoria Whitney, Chief Division of Water Rights State Water Resources Control Board 1001 I Street Sacramento, California 95812	Mr. Jim Canaday Division of Water Rights State Water Resources Control Board PO Box 2000 Sacramento, California 95812-02000 (916) 341-5308
Mr. Matt Myers Environmental Scientist State Water Resources Control Board 1001 I Street, 14th Floor Sacramento, CA 95814	Ms. Lisa Cutting Mono Lake Committee PO Box 29 Lee Vining, California 93541 (760) 647-6595
Mr. Gary Smith, NAFWB Department of Fish and Game 1416 Ninth Street Sacramento, CA 95814	Mr. Rob Lusardi California Trout Inc. Box 3442 Mammoth Lakes, CA 93546 (760) 924-1008
Mr. Steve Parmenter Department of Fish and Game 407 West Line Street, #8 Bishop, CA 93514 (760) 872-1171	Dr. Rob Titus Department of Fish and Game 8175 Alpine Avenue, Suite F Sacramento, California 95826
Marshall S. Rudolph Mono County Counsel P.O. Box 2415 Mammoth Lakes, CA 93546 (760) 934-7616	Board of Supervisors Mono County PO Box 715 Bridgeport, California 93517 (760) 932-5534
Dr. William Trush McBain & Trush PO Box 663 Arcata, CA 95518 (707) 826-7794	Mr. Chris Hunter 616 Wintergreen Court Helena, Montana 59601 (406) 449-6561
Mr. James Barry Department of Parks and Recreation PO Box 942896 Sacramento, California 94296-0001 (916) 653-9408	Mr. Ken Anderson Department of Parks and Recreation PO Box 266 Tahoma, CA 96142
Ms. Molly Brown USDA Forest Service P.O. Box 148 Mammoth Lakes, CA 93546 (760) 924-5553	Mr. Burt Almond USDA Forest Service 351 Pacu Lane, Suite 200 Bishop, CA 93514 (760) 873-2439

2006 RUNOFF FORECAST
April 1, 2006

APRIL THROUGH SEPTEMBER RUNOFF

	MOST PROBABLE VALUE (Acre-feet)	MOST PROBABLE VALUE (% of Avg.)	REASONABLE MAXIMUM (% of Avg.)	REASONABLE MINIMUM (% of Avg.)	LONG-TERM MEAN (1951 - 2000) (Acre-feet)
MONO BASIN:	**154,900**	**149%**	161%	136%	104,277
OWENS VALLEY:	**423,000**	**139%**	152%	126%	305,167

APRIL THROUGH MARCH RUNOFF

	MOST PROBABLE VALUE (Acre-feet)	MOST PROBABLE VALUE (% of Avg.)	REASONABLE MAXIMUM (% of Avg.)	REASONABLE MINIMUM (% of Avg.)	LONG-TERM MEAN (1951 - 2000) (Acre-feet)
MONO BASIN:	**180,200**	**147%**	160%	134%	122,557
OWENS VALLEY:	**556,100**	**135%**	147%	122%	413,210

MOST PROBABLE - That runoff which is expected if median precipitation occurs after the forecast date.

REASONABLE MAXIMUM - That runoff which is expected to occur if precipitation subsequent to the forecast is equal to the amount which is exceeded on the average once in 10 years.

REASONABLE MINIMUM - That runoff which is expected to occur if precipitation subsequent to the forecast is equal to the amount which is exceeded on the average 9 out of 10 years.

Mono Basin Operations, Guideline F

Year Type:... WET
Forecasted Runoff in acre-feet...166,700 – 195,400

Lower Rush Creek

Base Flows:

	April	May–Jul	Aug–Sep	Oct-Mar
Flow (cfs)	80	150	80	55

Minimum base flows are 68 cfs for Apr-Sep and 52 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: - 450 cfs for 5 days followed by 400 cfs for 10 days (see augmentation).

Ramping:
- Begin ramping on June 1st (rule of thumb). Note peak operations will take 36 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 100-cfs from Lee Vining for 5 days, followed by up to 50-cfs for 10 days. This should begin 14 days after peak flow in Lee Vining.

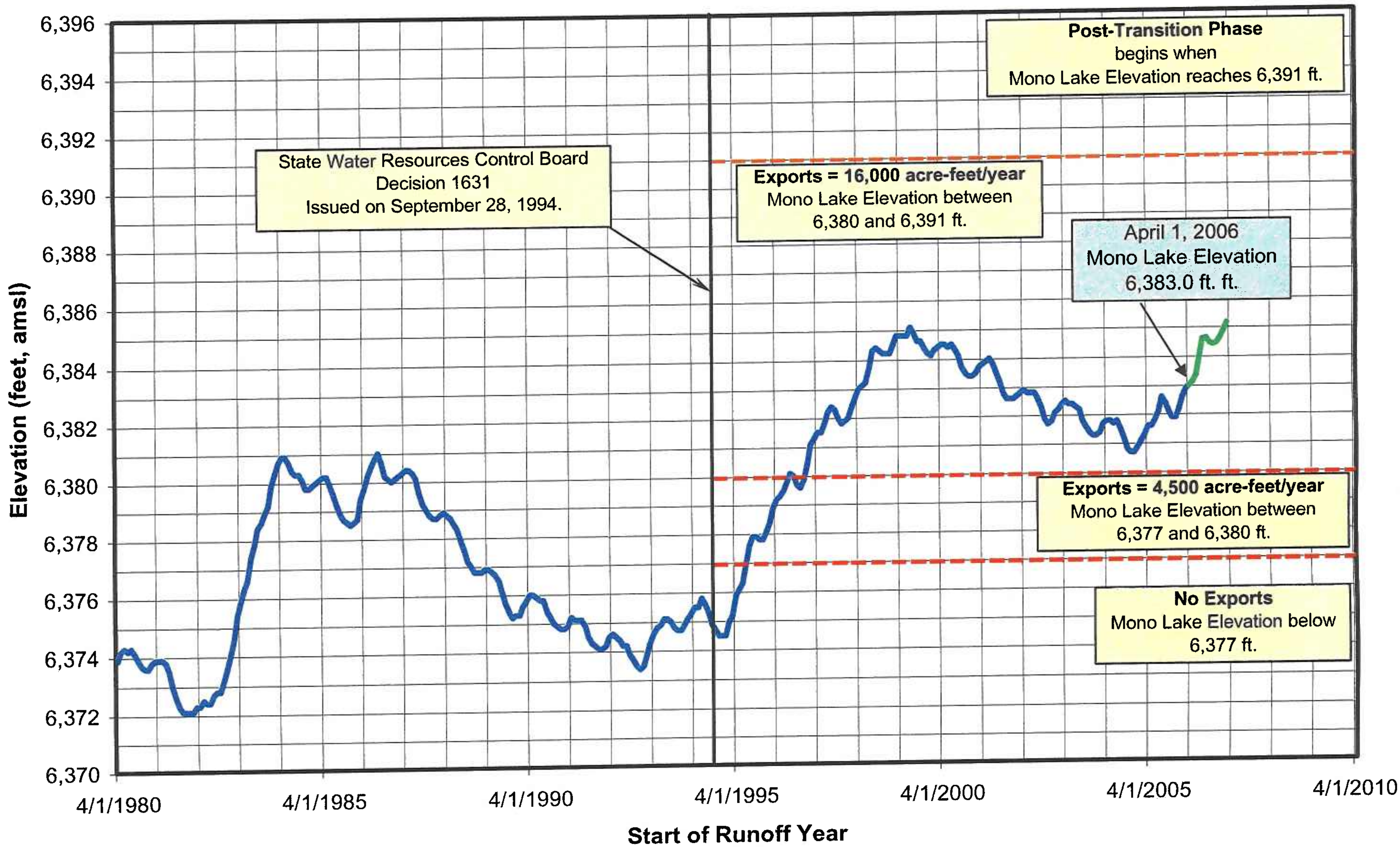
Parker and Walker Creeks

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 Lake Elevation and Transition Period Exports



Note: The time until the Mono Lake elevation reaches 6,391 ft is called the "Transition Period". Export rules change at the end of that interval.
USGS Datum

5/4/2006 by Paul Scantlin
Mono Lake Elev, data-chart

Section 3

Fisheries Monitoring Report for
Rush, Lee Vining, Parker, and Walker Creeks
2005

Fisheries Monitoring Report for Rush, Lee Vining, Parker and Walker creeks 2005

Prepared by: Chris Hunter
Ross Taylor
Ken Knudson
Brad Shepard
Matt Sloat

Prepared for: Los Angeles Department of Water and Power

Date: May 2006

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Executive Summary

This report presents the results of the ninth year of fish population monitoring for Rush, Lee Vining, Parker, and Walker creeks pursuant to State Water Resources Control Board (SWRCB) Decision #1631 and the seventh year following SWRCB Orders #98-05 and #98-07. Pilot studies were conducted in 1997 and 1998 to determine appropriate methods for generating statistically valid population estimates with 1999 being the first year estimates were generated for all study sections.

The 2005 field season occurred between September 1st and 19th. Mark-recapture electro-fishing techniques were utilized to estimate trout populations in three sections of Rush Creek and two main stem sections of Lee Vining Creek. Fish population estimates for two Lee Vining Creek side-channels and Parker and Walker creeks were made using electrofishing depletion methods. Scales (189 samples) and otoliths (one sample) were collected to estimate fish ages. A radio telemetry-movement study of brown trout in Rush Creek was also initiated.

In 2005, the Upper Lee Vining side-channel (A-4) was cut-off from the main-channel's flow during the year's large snowmelt run-off and was reduced to isolated pools when sampled on September 10th. Thus for this study section only a depletion estimate and a condition factor were computed since metrics dependant on surface area (density and standing crop) were invalid due to the inability of accurately measuring the sporadic and shrinking areas with surface flow. All trout captured in this study section were relocated to the main channel of Lee Vining Creek.

<u>Density Estimates for Age-1 and older Brown Trout</u>

Estimated densities (number per hectare) of age-1 and older brown trout increased in two sections and decreased in one section of Rush Creek in 2005. The estimated density of age-1 and older brown more than doubled in the Upper Rush section between 2004 and 2005. In the Lower Rush section, the estimated densities of age-1 and older brown trout nearly tripled between 2004 and 2005. The County Road section experienced a slight drop in estimated densities between 2004 and 2005.

Estimated densities (number per hectare) of age-1 and older brown trout decreased in 2005 in the Upper main-channel and Lower side-channel sections of Lee Vining Creek. In contrast, the Lower main-channel section experienced an increase of 31% between 2004 and 2005.

Densities of age-1 and older brown trout in Parker Creek increased by 45% between 2004 and 2005, with the 2005 density estimate approximately equal to the 2002 estimate. In Walker Creek the 2005 density estimate was 49% less than the 2004 estimate. Even with this drop, the 2005 density estimate of age-1 and older brown trout for Walker Creek was still greater than any estimate for any other study section across all seven years of sampling (excluding pilot seasons of 1997 and 1998).

Density Estimates for Age-0 Brown Trout

In 2005, age-0 brown trout populations experienced large decreases in eight of nine sample sections. Most of these decreases were the lowest values ever recorded in the various sections. Upper Rush Creek had a slight (6%) increase in the density of age-0 brown trout between 2004 and 2005. In contrast, the Lower and County Road sections of Rush Creek dropped again in 2005 to the lowest densities ever recorded for these two sections (the previous lows were recorded in 2004). The most drastic decreases occurred in Walker Creek and the Lower Lee Vining main channel where estimated densities dropped by 98% between 2004 and 2005.

Density Estimates for Age-1 and older Rainbow Trout

For a third straight year, the estimated densities of age-1 and older rainbow trout declined dramatically in all sections of Lee Vining Creek with none sampled in the Upper side-channel. These low numbers and continued decline were not surprising considering the extremely poor recruitment of age-0 rainbow trout in Lee Vining in 2003 and 2002. Recruitment of age-0 rainbow trout was also poor in 2004 in three of the four Lee Vining Creek study sections. In Rush Creek, all three annually-sampled sections experienced continued declines in estimated densities of age-1 and older rainbow trout.

Density Estimates for Age-0 Rainbow Trout

Estimated densities of age-0 rainbow trout were extremely low in 2005 in all sample sections, including no age-0 rainbows captured in the main-channel sections of Upper and Lower Lee Vining Creek. In Upper Rush Creek five age-0 rainbow trout were sampled and in Lower Rush Creek a single age-0 rainbow trout was captured. No age-0 rainbow trout were captured in the Rush Creek County Road study section.

Standing Crop Estimates of Brown Trout

Estimates of brown trout standing crops (kg/hectare) in the Lee Vining Upper main-channel and Lower side-channel sections decreased from 2004 to 2005, whereas the Lower main-channel section experienced an increase of 23%.

In Rush Creek brown trout standing crops estimates increased from 2004 to 2005 in the Upper and Lower study sections, by 39% and 41% respectively. For the Upper Rush section this was the first increase in standing crop after four years of steady declines between 2000 and 2004. The estimated standing crop of brown trout in the County Road section decreased by 12% between the 2004 and 2005 sampling periods.

Standing crop estimates in Walker Creek have now decreased for two seasons (2004-2005); with the largest decrease (50%) occurring between 2004 and 2005. In Parker Creek, the standing crop estimate increased by nearly 20% between 2004 and 2005.

Relative Weight and Condition Factor

Relative conditions of brown trout captured during 2005 were similar to those found in 2002-04 in Upper and Lower Rush Creek sections. However, condition factors for brown trout between 150 to 250 mm in total length showed that fish in the County Road section of Rush Creek were in better condition than those in the other two sections. Condition factor for the County Road section in 2005 was the highest ever computed for this section. Increases in condition factors may be related to declines in abundance – density dependence.

Condition factors for brown trout in three Lee Vining Creek sections (Lower main, Lower side-channel, Upper main) were slightly higher than the previous three to four years. The condition factor for the Upper side-channel in 2005 was the lowest documented in this section that was cut-off from the main-channel (reduced to isolated pools) when sampled. Lower condition may be related to higher densities and lower flows in this side channel.

In Parker Creek, the condition factor for brown trout (150 to 250 mm in total length) dropped slightly in 2005, when compared to 2004. In Walker Creek, the condition factor for brown trout (150 to 250 mm in total length) improved in 2005 to the highest value computed for this section for seven seasons of data collection.

Scale and Otolith Analyses

In 2005, 189 scale samples were obtained from 175 brown trout and 14 rainbow trout. In Rush Creek scales were taken from 88 brown trout and one rainbow trout. The majority of the Rush Creek brown trout scales came from the 54 fish implanted with radio tags for the movement study. The remaining Rush Creek brown trout scale samples were 24 larger trout (205-266 mm) that had their adipose fins removed at age-0 in 2003, nine age-1+ trout (168-202 mm) that had their left pelvic fin removed in 2004, and one mortality from the County Road section (164 mm brown trout from which an otolith was taken too). In Lee Vining Creek, scale samples were obtained from 87 brown trout and 13 rainbow trout >200 mm in length. Interpretation of ages and growth from these scales will be reported in the 2006 report.

Radio Telemetry-Movement Study

Radio tags were implanted in a total of 54 brown trout. Fourteen tags were implanted in larger brown trout captured in the MGORD on September 9th, 15 tags in the Upper Rush section on September 13th, 11 tags in the County Road Rush section on September 14th, and 13 tags in the Lower Rush section on September 15th. The final tag deployed was on September 16th in a large male brown trout captured between the County Road and Lower Rush sections. Immediate post-surgery mortality occurred on one fish which was found dead the day after surgery.

A fixed receiving station was installed at the lower end of the MGORD and became fully operational on September 21, 2005. Brown trout tagged in the MGORD were relocated with a mobile receiver (by driving the road parallel to the diversion canal) on September 19th. These relocations confirmed that no radio-tagged fish had left the MGORD prior to installation of the fixed station. More detailed movement study results will be developed for the 2006 annual report.

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 2005, the main channel sections of Lee Vining Creek supported 21.2 and 27.1 trout ≥200 mm (~8 inches) per 100 meters of channel length and the side-channel sections supported 4.5 (Upper section) and 7.2 (Lower section) brown trout ≥200 mm per 100 meters of channel. During 2005, no brown trout were captured in Lee Vining Creek that exceeded 330 mm (~13 inches) and only one brown trout over 300 mm (~12 inches) was captured. Seven rainbow trout greater than 300 mm were captured in Lee Vining in 2005, but their eroded fins clearly identified them as hatchery trout most likely planted upstream of Highway 395.

In the three Rush Creek sections sampled annually, only seven brown trout longer than 300 mm (~12") were captured in 2005 (all from Upper Rush Creek). Five of these fish were over 300 g (0.66 pounds; range of 0.72 to 2.5 pounds) in weight. In 2005 Rush Creek supported 17.1, 17.3, and 40.9 brown trout ≥200 mm (~8 inches) per 100 meters of channel length in the three sample sections (County Road, Lower and Upper; respectively).

The data collected over the past nine years suggests that Rush and Lee Vining creeks in their current condition are still 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.

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 compiled flow and water temperature data. We have begun to explore potential relationships between trout (standing crop and length structure) and these physical features. 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 ninth year of fish population monitoring for Rush, Lee Vining, Parker, and Walker creeks pursuant to State Water Resources Control Board (SWRCB) Decision #1631 and the seventh year following SWRCB Orders #98-05 and #98-07. 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. 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, B1 and A4 side-channels), and the Walker and Parker Creek sections sampled in previous years were again sampled between September 1st and 19th of 2005 (Figure 1). In 2005 the MGORD was sampled only to collect brown trout for the movement study, not for generating a population estimate. While we expressed previous concerns (Hunter et al. 2001) about the dynamic nature of the stream channels (particularly in Rush Creek) making sample sections subject to change, 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.

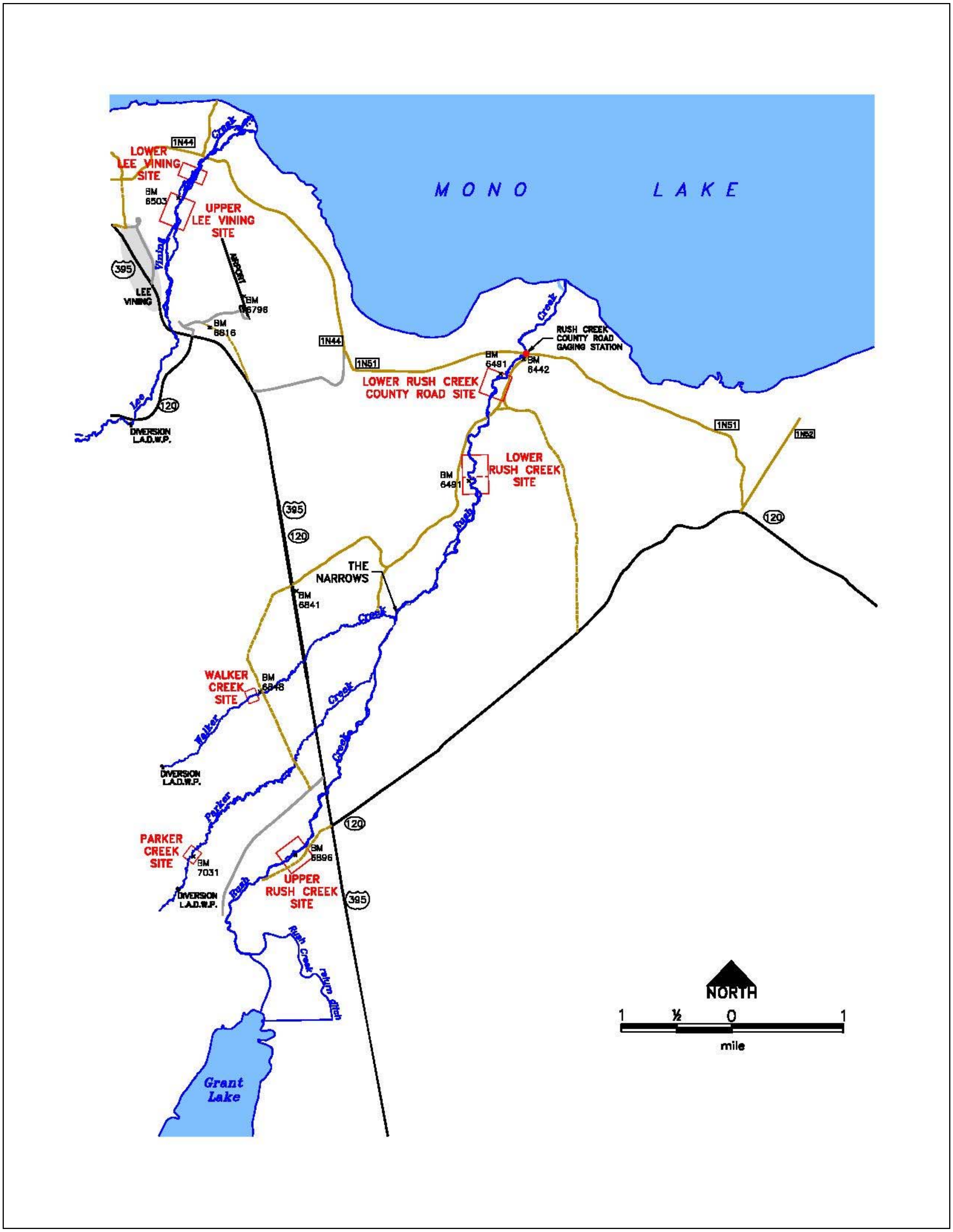


Figure 1. Map of Mono Basin study area with fish sampling sites displayed (modified from McBain and Trush 2000).

Most sample sections experienced negligible channel changes from 2004 to 2005 with the exception of the County Road and Upper sections of Rush Creek and the Upper side channel section of Lee Vining Creek. The County Road section of Rush Creek was approximately 1.1 meters narrower in 2005 than in 2004, whereas the Upper Rush section was about 0.6 meters wider (Table 1). Although the channel within the County Road section appeared noticeably narrower and deeper, the changes may also be the result of where the channel widths were randomly measured and how many widths were measured. The Upper Lee Vining Creek side-channel (A4) had no surface flow entering it during the 2005 sampling period and habitat consisted primarily of isolated pools with little surface water flowing between them, thus no estimate of surface area was calculated.

Table 1. Total length (m), average wetted width (m), and total surface area (m^2) of sample sections in Rush, Lee Vining, Parker, and Walker creeks sampled between September 1st and 19th, 2005. Values for 2004 provided for comparisons. **Bold font** designates noticeable changes in average channel widths between 2004 and 2005.

Section	Length (m) - 2004	Width (m) - 2004	Area (m^2) - 2004	Length (m) - 2005	Width (m) - 2005	Area (m^2) - 2005
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	**8.6**	3,698.0
Rush - MGORD	2,230	12.0	26,760.0	2,230	12.0	26,760.0
Lee Vining – Lower main	155	4.8	744.0	155	5.2	806.0
Lee Vining - Lower-B1	195	4.8	936.0	195	4.6	897.0
Lee Vining – Upper main	330	5.8	1,914.0	330	7.4	2,442.0
Lee Vining - Upper-A4	201	4.2	844.2	201	N/A	N/A
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, due to the high amount of snowfall during the winter of 2004-05 and the augmented peak flow release of 467 c.f.s. on June 29th (Figure 2). Due to the deep snow pack and late-spring accumulations, stream flow exceeded 200 c.f.s from June 6th through July 31st. Flows in Rush Creek below the Narrows remained above 100 c.f.s. through August 11th. Stream flows in Lee Vining Creek below the intake were also a function of the deep snow pack and extended run-off (Figure 3). Lee Vining Creek experienced four distinct peaks during the snowmelt and spring run-off as a function of a rain storm (5/16-19) and from snowmelt occurring at distinct breaks in elevation. Valleys between the later peak discharges were also periods when Lee Vining flow was diverted to Grant Reservoir to test the new gate facilities and to augment the peak Rush Creek flow (Hanna, pers. comm.).

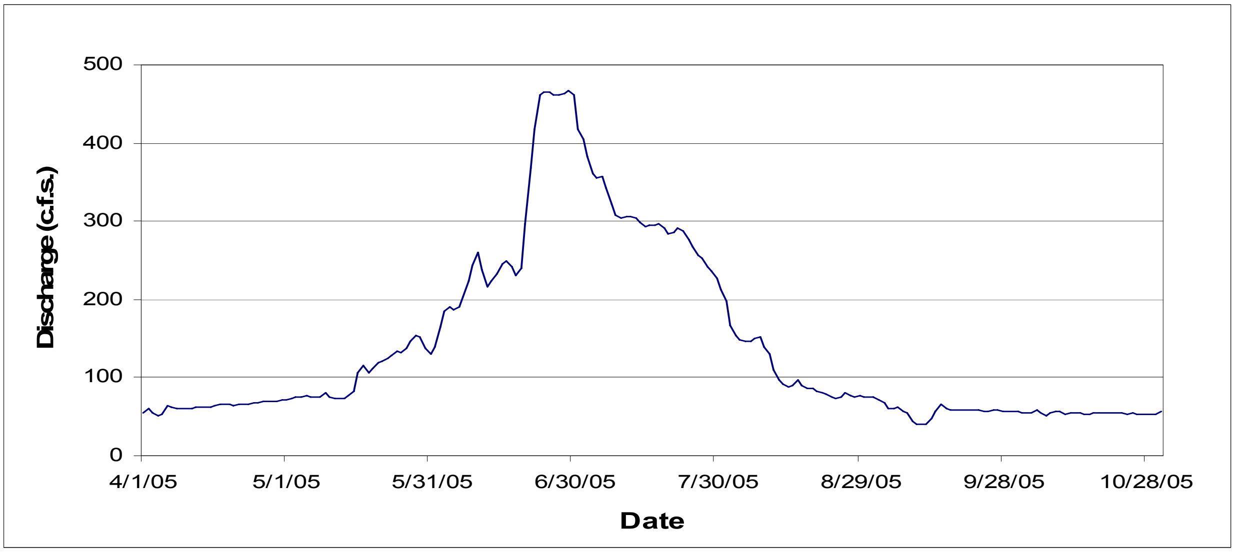


Figure 2. Daily stream flows (cubic feet per second; c.f.s) in Rush Creek below the Narrows between April and October 2005. Data were provided by Los Angeles Department of Water Power.

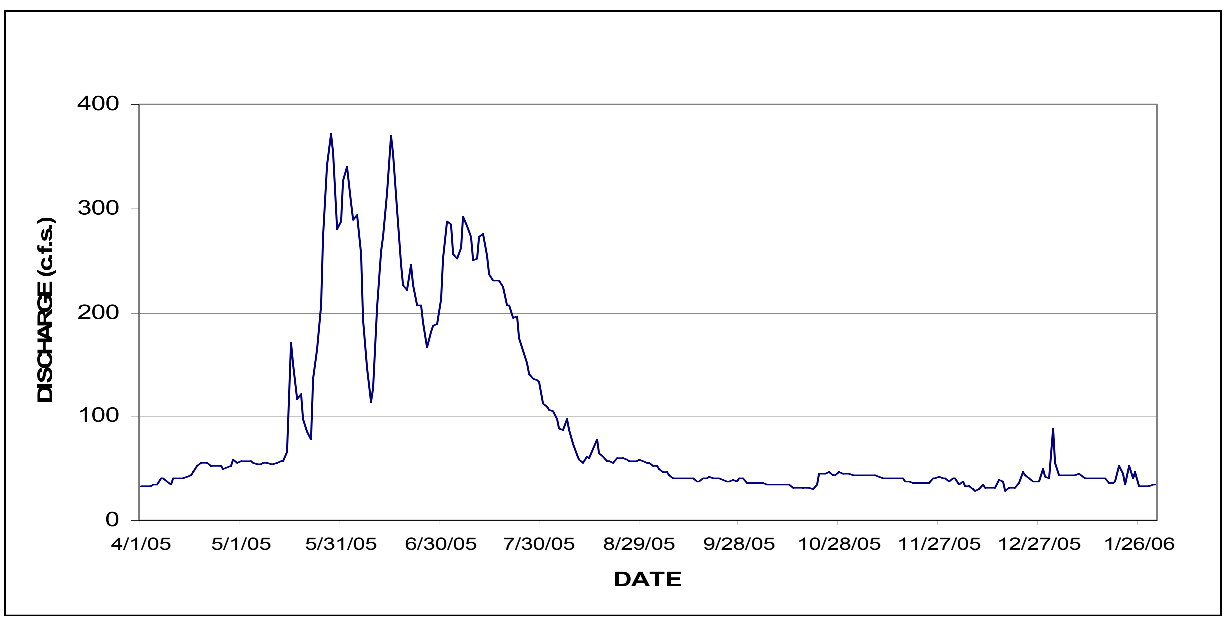


Figure 3. Daily stream flows (c.f.s) in Lee Vining Creek below the diversion between April and October 2005. Data were provided by Los Angeles Department of Water Power.

Methods

Fish Population Estimates

Sampling for generating fish population estimates occurred during the late summer between September 1st and 19th, 2005. Mark-recapture estimates were made in the County Road, Lower, and Upper sections of Rush Creek. In past years 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. However in 2005 the generator failed to operate properly, thus all fish were captured with Smith-Root® BP backpack electro-fishers (Models 12B and LR-24).

During mark-recapture electro-fishing an insulated cooler with two battery-powered aerators was carried in the barge to transport captured fish. A person operating a backpack electro-fisher and a dip netter fished each half of the stream in a downstream direction (total of two electro-fisher operators and two dip netters). The fifth crew member walked the barge downstream and monitored the condition of captured fish in the live-well. 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. 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 main channel 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 electro-fishers were used when sampling the Lee Vining main-stem and side-channel sections, whereas a single backpack electro-fisher 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 electro-fisher. An extra 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 section, were blocked at both ends prior to sampling. Block fences were not placed at the boundaries of the County Road section; however this section was long enough (813m) that effects of movements at the ends of the sample section 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. Rocks were hand-placed along the bottom edge of the hardware cloth to prevent fish from passing underneath the block fence. 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 specifically to maintain these fences. However, there was still some difficulty in maintaining the block fences at either end of the Upper Rush Creek Section and the fences at Lower Lee Vining Creek. The upper boundary fence at Upper Rush Creek went down four times and the lower boundary fence went down three times. On Lower Lee Vining Creek the upper boundary fence went down once and the lower boundary fence went down three times. Finally, on Lower Rush Creek the boundary fence at the side channel failed twice. Therefore, the assumption of population closure during the estimates was not fully met for Upper and Lower Rush Creek and for Lower Lee Vining Creek. However, these fences were effective most of the time between the marking and recapture runs. The set of block fences were successfully kept up for the entire seven-day period between mark and recapture electro-fishing on Upper 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 lower caudal fin was clipped to mark fish in the County Road section of Rush Creek and the Upper Lee Vining Creek main channel section. The upper caudal fin was clipped to mark fish in the Upper Rush Creek section. The anal 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 2005 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

In Rush Creek, scale samples were taken from all trout captured that received fin clips as age-0 fish (adipose fin clips in 2003 and left pelvic clips in 2004) and from all brown trout implanted with a radio tag for the movement study. In Lee Vining Creek scales were only sampled from trout (both species) >200 mm because previous analyses determined that few fish were older than two years. As a fish grows its 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 only from 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 right pelvic fins clipped off as a permanent mark to identify them as age-0 fish in 2005. 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 (identifying them as an age-0 fish in 2003 and age-2 fish in 2005) or if their left pelvic was clipped (identifying them as age-0 fish in 2004 and age-1 fish in 2005). All recaptured clipped (adipose or left pelvic) fish were noted on data sheets, a scale sample was taken for aging, and their lengths and weights were averaged by stream and sample section to derive empirical growth rates.

Radio Telemetry-Movement Study in Rush Creek

In 2005 a movement study of brown trout in Rush Creek was initiated. The purpose of this study was to document the seasonal movement patterns and corresponding habitat occupied by brown trout in the Rush Creek system between Grant Reservoir and Mono Lake. This movement and habitat data will be used to expand and refine the habitat suitability/stream discharge relationships being developed for Rush Creek. The data will also add to the information base necessary to establish realistic and sustainable termination criteria for Rush Creek. The goals of the study were:

GOAL (A): Document movement patterns of -

(1) Adult brown trout (age 3+ and >640 g in weight) implanted with radio transmitters in the MGORD during September 2005 to determine if these fish seasonally utilize other reaches of Rush Creek.

(2) Adult brown trout (age 2+ and between 180 - 225 g) and juveniles (Age 1+/2 between 85 - 105 g) implanted with radio transmitters in sections of Rush Creek during September 2005 to determine if these fish make seasonal migrations or move up into the MGORD.

GOAL (B): Document habitat occupied by radio-implanted adult and juvenile brown trout in Rush Creek -

(1) During all seasons and hydrologic periods, determine how (or if) habitat occupied by the tagged fish changes throughout the year. Particular emphasis was placed on documenting the habitat and survival of juvenile brown trout before, during and after winter (ice) conditions as well as before, during and after the spring runoff (high stream discharge) period.

(2) During brown trout spawning in October – December, determine the locations and habitat characteristics of the most heavily-used spawning areas.

A tentative relocation schedule and associated objectives for nine sampling episodes were developed for the fall of 2005 through summer of 2006 (Table 2). The first sampling episode involved learning to use the manual receiver, assessing post-surgery survival, and refining methods for measuring habitat variables. The remaining sampling episodes occurred during eight distinct time periods covering all major seasons and hydrological events (Table 2).

All tags and tracking equipment were purchased from Lotek Wireless Inc. located in Ontario, Canada. A total of 60 tags were purchased, in three different sizes (Table 3). Tags were divided among four radio frequencies (148.400, 148.440, 148.640, 148.660 MHz) and a unique code number identified each tag. To further extend the battery life of the smallest tags (NTC-4-2L) the pulse rate was set for 10 seconds (Table 3).

Radio tags were surgically inserted into the peritoneal cavity generally following techniques described by Schmetterling (2001). To reduce surgery time and risk of infection, surgical staples were utilized instead of sutures to close incisions (Swanberg et al. 1999). Surgeries typically required one to three minutes to complete (from initial incision to closure). After surgery, fish were placed in a nine gallon plastic tote (drilled with holes for circulation) within the creek and then released when they appeared fully recovered. Recovery times were relatively quick, generally less than ten minutes.

Table 2. Rush Creek brown trout movement study schedule and seasonal objectives.

Sampling Episode	Expected Date (s)	Season	Objectives
1	Sept. 17th - 24th	Late Summer	Learn proper use of radio-tracking equipment. Assess post-surgery survival. Fine-tune habitat measurement protocol. Document habitat occupied by brown trout during late summer.
2	Late Oct.	Mid Autumn	Document movement of brown trout just prior to, or during early part of spawning season to assist in identifying important spawning habitats.
3	Mid Nov.	Late Autumn	Same goal as late October, except this survey will occur later in the spawning season.
4	Mid Dec.	Early Winter	Document post-spawn movement of mature brown trout. Document habitat areas occupied by brown trout prior to the formation of shelf ice.
5	Late Jan	Mid Winter	Determine how or if occupied habitat changes after formation of shelf ice (and anchor ice and ice dams if those conditions exist).
6	Early Mar	Late Winter	Document the occupied habitat and survival rates of brown trout after ice-out.
7	Mid April	Early Spring	Document the habitat occupied by brown trout prior to spring runoff. Note the locations of any rainbow trout redds.
8	Late May	Late Spring	Determine how or if occupied habitat changes during peak runoff conditions.
9	Late June	Early Summer	Document the occupied habitat and survival rates of brown trout after spring runoff.

Table 3. Specifications of 60 Lotek Wireless Inc. tags utilized in Rush Creek brown trout movement study, 2005.

LOTEK Tag Model	Air Weight (grams)	Duty Cycle (hours)	Signal Burst Interval (seconds)	Operational Life (days)	Minimum Weight Range of Fish (g)
MCFT-3A	16.0	24	5	761	640-800
NTC-6-2	4.5	12	5	416	180-225
NTC-4-2L	2.1	12	10	299	85-105

Radio-tagged brown trout were relocated with two receivers, the first being an SRX 400A W7A fixed-station receiver/data logger located at the downstream end of the MGORD. This fixed station was comprised of two, AN-4YG-150 antennas routed into an ASP-8 switch box attached to the receiver. This receiver was powered by two deep-cycle 12-volt batteries (size = 27 group) wired to a solar panel (Figure 4). The receiver and batteries were locked in a waterproof steel cylinder to protect them from theft and weather (Figure 4). The antennas were installed with one facing upstream approximately 225 feet from the receiver (Figure 5) and one facing downstream approximately 25 feet from the receiver (Figure 6). Due to a greater length of coaxial cable the upstream antenna was set at a gain of 40, whereas the lower antenna was set at a gain of 0. The spread of the antennas enabled identification of which direction a tagged fish was moving, dependant on which antenna initially detected signals and changes in signal strength. The antenna array was initially tested by a crew member walking two enabled tags through the array while a second crew member observed the receiver and recorded signal strengths from the antennas when the tags were at specific locations.

The fixed station provided continuous, 24-hour tracking of individual fish movements into or out of the MGORD for all the large brown trout equipped with MCFT-3A transmitters. However, potential movements of smaller fish (implanted with NTC-6-2 and NTC-4-2L tags) into or out of the MGORD was not as thorough due to the twelve-hour off/on duty cycles of these transmitters.

All radio-tag recapture events recorded by the fixed-station receiver’s data logger recorded both the date and time, thus the duration of fish movements through the antenna array was captured. The data stored in the receiver were retrieved on a monthly basis using Lotek’s WinHost Version 4.324 program on a laptop computer. After WinHost captured these data, they were converted into Excel spreadsheets for analyses.

Figure 4. Solar panel and fixed station receiver location at lower end of the MGORD in September, 2005.

Figure 5. Upstream antenna location of fixed station receiver at lower end of the MGORD in September, 2005.

Figure 6. Downstream antenna location of fixed station receiver at lower end of the MGORD in September, 2005.

The second receiver was an SRX 400W5XG mobile receiver. This receiver utilized an F150-3-FB hand-held antenna to relocate tagged brown trout to specific habitat locations throughout Rush Creek. A two-person crew manually relocated tagged fish. One person operated the receiver and completed the field data form, while the second crew member carried a flow meter, GPS unit, and measuring rod and measured habitat variables and took latitude/longitude readings. Manual relocations generally comprised the following steps:

1. Started relocation at the downstream end of the reach to be surveyed. Next, conducted a four-channel scan at a high gain (≥40) in both directions (upstream and downstream) to determine which channel/frequency was closest.

2. Set receiver to the appropriate channel and kept gain at a high setting. Adjusted receiver to display signal strength and code number. Walked in the direction of the signal and confirmed increase in signal strength.

3. When signal strength increased to a range of 210-238, reduced gain and proceeded towards signal.

4. Attempted to relocate fish on a gain of 20 or less. Locations were fine-tuned by aiming antenna at specific locations and holding steady until a new power reading was displayed. Fish was relocated to point of the highest power reading.

5. Once a tagged fish was relocated to a specific spot the person operating the receiver would hold the antenna steady as the second crew member waded to the spot and attempted to make the relocated fish move by poking around with the measuring staff or with their feet. This procedure was done to assess if a tagged fish was alive or dead. If a tagged fish was spooked and moved, the power reading on the receiver dropped. The receiver operator would then attempt to determine if the fish moved upstream or downstream. Whether a fish moved, or not, was noted in the data sheet's "comments" column.

6. Data collected for each relocated fish included: date, time of relocation, tag code #, power and gain, habitat type (pool, riffle, run), depth (to 0.1'), velocity at 0.6 of total depth (to 0.1 ft/sec.), and velocity at 0.9 of total depth. Velocities were measured with a Marsh-McBirney Flo-mate using the integrated "real-time averaged" setting in which velocities were continuously measured and an average value was computed every ten seconds. The latitude and longitude were measured with a handheld GPS unit in decimal-degrees and WGS84 datum at the relocation spot. Accuracy was typically ±14-17 feet.

7. Distance to various cover types was measured to the nearest 0.1 feet and included: bubble curtain, over-hanging vegetation, undercut bank (depth of undercut also measured), woody accumulation, root wad, large rock, submerged vegetation, and depth >3.0 feet. Maximum distances measured were up to 10.0 feet, but cover type was noted up to 20 feet if present within the habitat unit.

Results

Fish Population Abundance

Rush Creek

County Road Section

Unlike previous years when age-0 fish comprised most of brown trout captured, in 2005 the majority of the brown trout captured in the County Road Section of Rush Creek were between 130 and 240 mm and the longest brown trout captured was 289 mm (Figure 7). This section supported an estimated 889 age-0 and 502 age-1 and older brown trout in 2005 (Table 4). Estimates of brown trout were relatively imprecise with standard errors ranging from 15.1 to 32.2% of the estimates. For rainbow trout, only two fish (175 and 257 mm in length) were sampled in 2005.

Lower Section

Unlike previous years when age-0 fish comprised most of brown trout captured, in 2005 nearly equal numbers of age-0 (148 fish) and age-1 and older (140 fish) trout were captured in the Lower Section (Figure 7). The longest brown trout captured was 290 mm. This section supported an estimated 411 age-0 and 290 age-1 and older brown trout in 2005 (Table 4). Estimates of all size classes of brown trout were relatively imprecise with standard errors ranging from 18.4 to 22.3% of the estimates. Only two rainbow trout (76 and 173 mm in length) were sampled in 2005 (Figure 8).

Upper Section

A majority of the brown trout captured in the Upper Section were less than 100 mm in length (Figure 7). The longest brown trout sampled was 513 mm in length and was captured on the marking run. The second largest brown trout was 415 mm in length and was also captured on the marking run. The Upper Section of Rush Creek supported an estimated 1,662 age-0 and 502 age-1 and older brown trout in 2005 (Table 4). Estimates of all size classes of brown trout were relatively imprecise with standard errors ranging from 15.1 to 24.3% of the estimates. More rainbow trout were captured in the Upper Section than in the lower two sections, however the numbers continue to drop compared to 2002-04 (Figure 8). Only 11 rainbow trout were captured in 2005 and no estimate was generated.

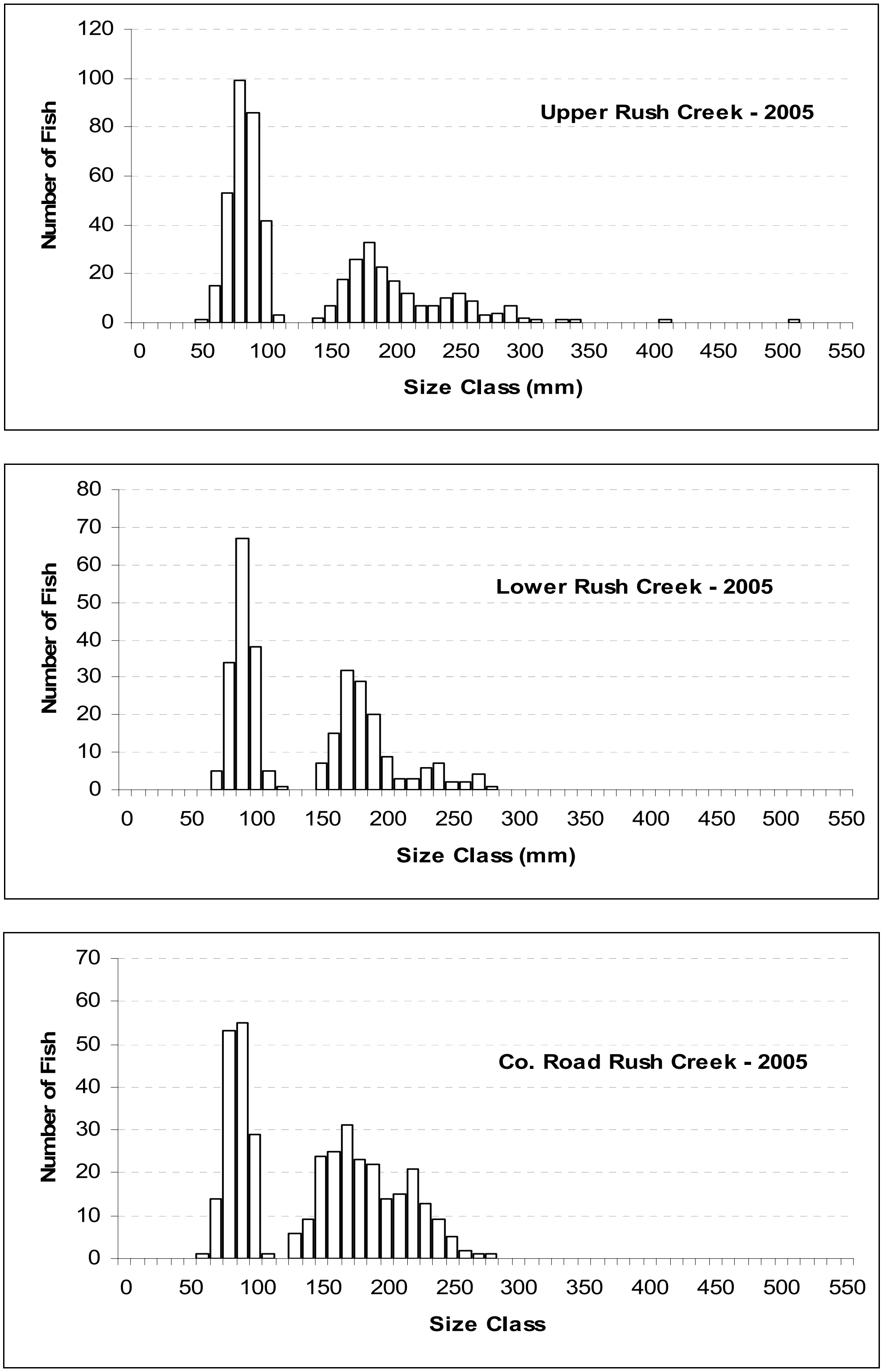
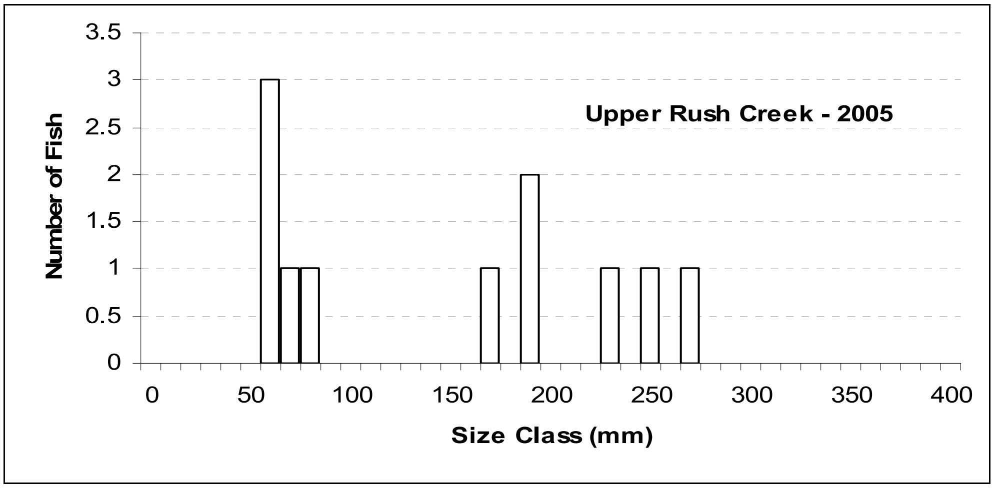


Figure 7. Length frequency histograms of brown trout captured in the Upper (top), Lower (middle) and County Road (bottom) sections of Rush Creek between September 1st and September 19th, 2005. Note different scales on the vertical axes between graphs.



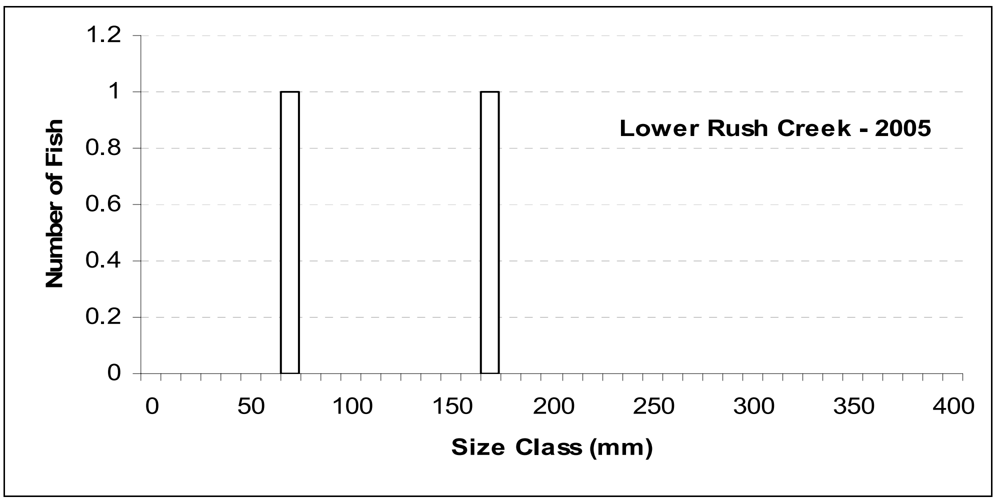


Figure 8. Length frequency histograms for rainbow trout captured in the Upper (top), Lower (middle) and County Road (bottom) sections of Rush Creek between September 1st and 19th, 2005. Note the different scales on the vertical axes between graphs.

Table 4. Mark-recapture estimates for 2005 showing total number of fish marked (M), total number captured on the recapture run (C), 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 captured during the mark run, but died prior to the recapture run. Mortalities were not included in mark-recapture estimate and should be added to the estimate for an accurate total estimate. NP = estimate not possible

Stream / Section / Date / Species	Size Class	Mark - recapture parameter values M	C	R	Morts	Estimate	S.E.
Rush Creek							
County Road							
09/07/2005							
Brown Trout							
	0 - 124 mm	69	88	6	2	**889**	286.5
	125 - 199 mm	53	100	14	1	**363**	71.3
	$\geq$ 200 mm	60	38	16	0	**139**	21.0
Lower Rush							
09/08/2005							
Brown Trout							
	0 - 124 mm	96	67	15	2	**411**	79.9
	125 - 199 mm	68	47	14	0	**220**	40.5
	$\geq$ 200 mm	26	20	7	0	**70**	15.6
Upper Rush							
09/06/2005							
Brown Trout							
	0 - 124 mm	192	111	12	8	**1662**	403.5
	125 - 199 mm	59	59	10	0	**326**	77.2
	$\geq$ 200 mm	56	58	18	0	**176**	26.6
Lee Vining Creek							
Lower Lee Vining							
09/04/2005							
Brown Trout							
	0 - 124 mm	0	1	0	0	**NP**	-
	$\geq$ 125 mm	33	31	7	0	**135**	34.3
Rainbow Trout							
	0 - 124 mm	0	0	0	0	**0**	-
	$\geq$ 125 mm	3	3	0	0	**NP**	-

Table 4. (Continued).

Stream Section Date **Species**	Size Class	Mark - recapture parameter values M	C	R	Morts	**Estimate**	S.E.
Upper Main Lee Vining							
09/05/2005							
Brown Trout							
	0 - 124 mm	4	0	0	1	**NP**	-
	125 - 199 mm	17	15	7	0	**35**	6.3
	≥ 200 mm	36	24	12	0	**70**	10.6
Rainbow Trout							
	0 - 124 mm	0	0	0	0	**0**	0.0
	≥ 125 mm	9	9	5	0	**16**[1/]	2.5

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

Lee Vining Creek

Lower Section

Three age-0 brown trout were captured in the side-channel and only one age-0 brown trout was captured in the main-channel (Figure 9). No estimate was generated for age-0 brown trout in either channel due to the extremely low numbers sampled (Tables 4 and 5). The main-channel section supported an estimated 135, age-1 and older brown trout in 2005 (Table 4). The Lower Lee Vining side-channel supported an estimated 21, age-1 and older brown trout in 2005 (Table 5).

Six age-1 and older rainbow trout and no age-0 rainbow trout were captured in the main-channel sample section of Lee Vining Creek (Figure 10). Only nine rainbow trout were captured in the side-channel portion of the Lower Section with none in the age-0 size class (Figure 10). The side-channel supported an estimated six rainbow trout in the 125 – 199 mm size class (Table 5).

Upper Section

Only five age-0 brown trout were captured in the main-channel section of Upper Lee Vining Creek, thus no estimate was generated (Figure 9). The main-channel supported an estimated 105 age-1 and older brown trout in 2005 (Table 4). At the time of sampling, the Upper Lee Vining side-channel was cut-off from the main-channel and was mostly dry with minimal surface flow in riffles between pools. Most electro-fishing was conducted in isolated pools. Still, the side-channel section supported an estimated 16 age-0 brown trout in 2005. A total of 12 age-1 and older brown trout were sampled in 2005, and this section supported an estimated three brown trout 125 to 199 mm and nine brown trout ≥200 mm (Table 5).

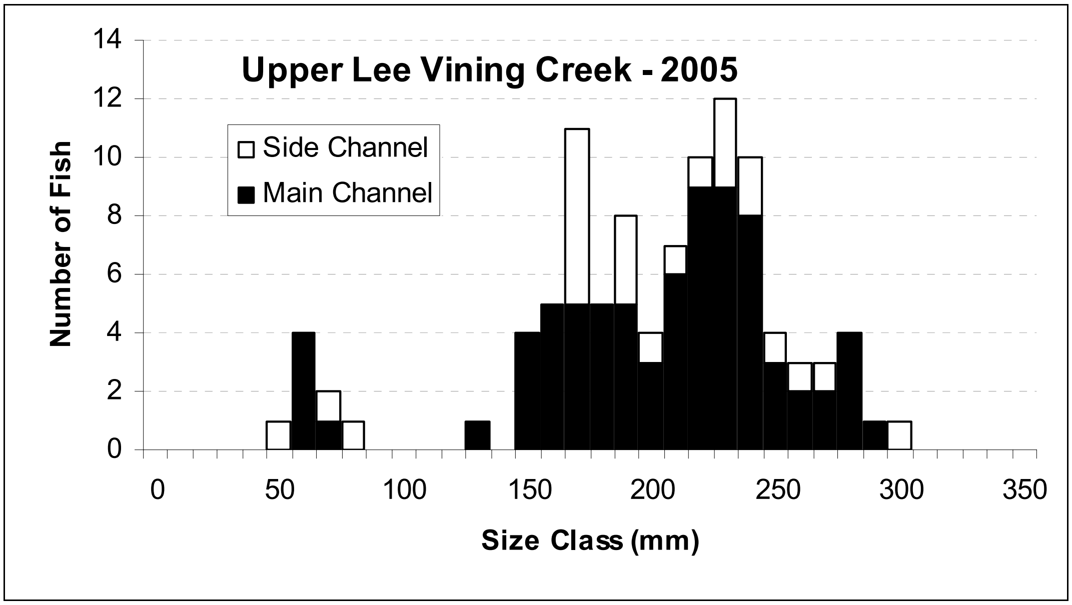
No age-0 rainbow trout were sampled in the Upper Lee Vining main-channel in 2005. The main-channel section of Upper Lee Vining Creek supported an estimated 16, age-1 and older rainbow trout in 2005 (Table 4). Only a single age-0 rainbow trout (41 mm in length) was sampled in the side-channel section (Table 5).

Parker Creek

As in past years, only brown trout were captured in Parker Creek (Figure 11). A total of 31 brown trout were captured in three electro-fishing passes in 2005 (down from a total of 53 fish in 2004). In 2005, Parker Creek supported an estimated 11 age-0 and 22 age-1 and older brown trout (Table 5).

Walker Creek

As in past years, in 2005 only brown trout were captured in Walker Creek; however very few of these (four fish) were age-0 fish (Figure 11). For comparison, in 2004 203 age-0 brown trout were captured that comprised 70% of the total catch. In 2005, a total of 47 brown trout were captured in two electro-fishing passes (down from 296 brown trout in 2004). In 2005, Walker Creek supported an estimated four age-0 and 45 age-1 and older brown trout (Table 5).



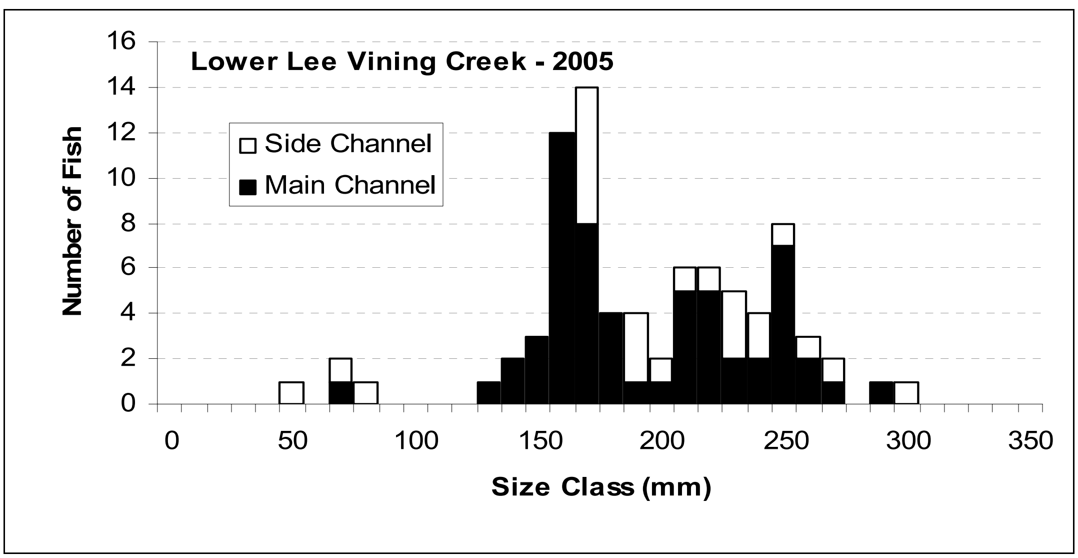
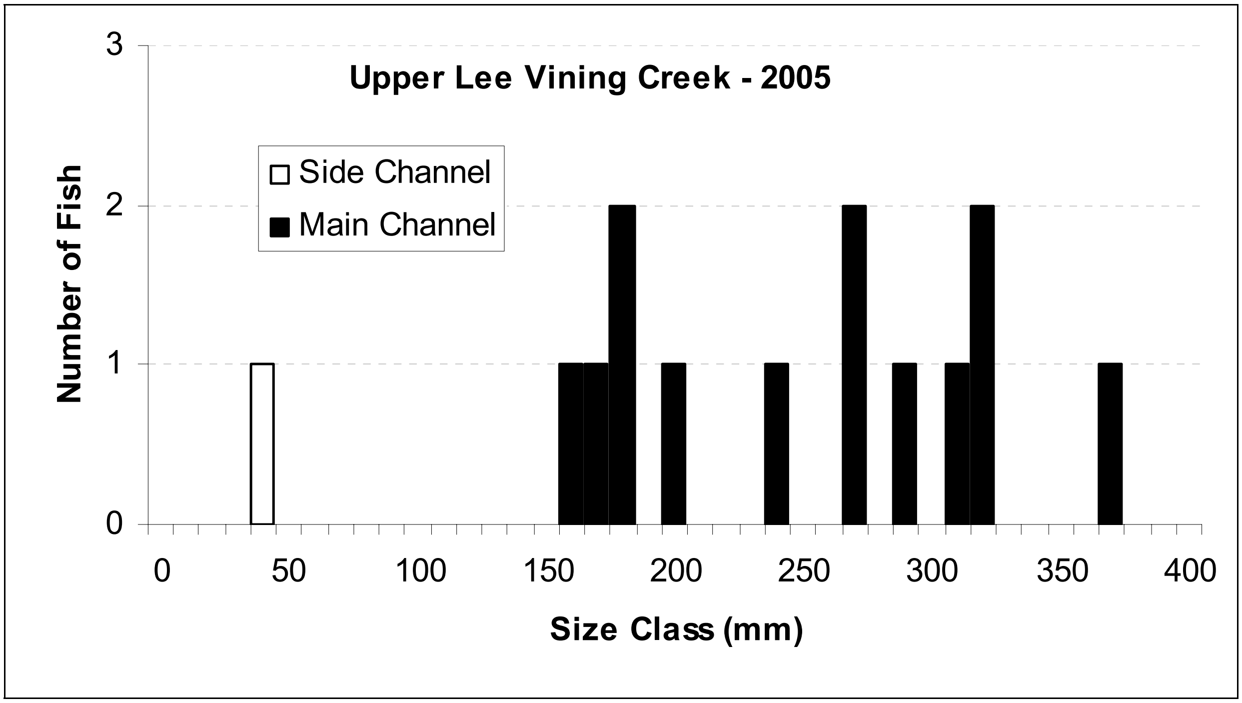


Figure 9. Length frequency histograms for brown trout captured in the Upper (top) and Lower (bottom) sections of Lee Vining Creek during September 2005 showing those fish captured in the main channel (dark bars) and side-channel (open bars) portions of each section. Note different scales on vertical axes.



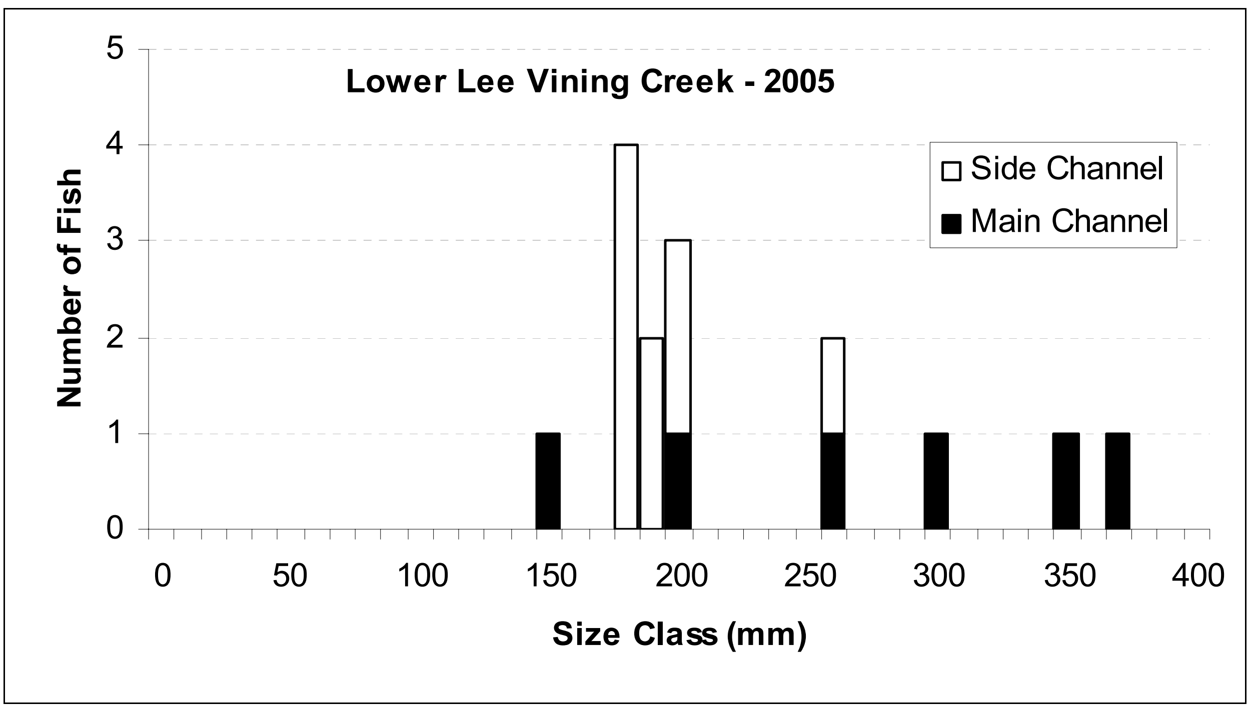


Figure 10. Length frequency histograms for rainbow trout captured in the Upper (top) and Lower (bottom) sections of Lee Vining Creek during September 2005 showing those fish captured in the main channel (dark bars) and side-channel (open bars) portions of each section. Note different scales on vertical axes.

Table 5. 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 2005 showing number of fish captured on each pass, estimated number, and standard deviation (S.D.) by species and length group.

Stream - Section / **Species**	Size Class	Removals	Removal Pattern	**Estimate**	S.D.
Lee Vining Creek – Lower Side Channel					
Brown Trout					
	0 - 124 mm	2	1 2	**NP**[1/]	
	125 - 199 mm	2	6 1	**7**	0.4
	200 + mm	2	14 0	**14**	0.0
Rainbow Trout					
	0 - 124 mm	2	0 0	**0**	0.0
	125 - 199 mm	2	6 0	**6**	0.0
	200 + mm	2	1 2	**NP**[1/]	
Lee Vining Creek – Upper Side Channel (most of this channel was dry in 2005)					
Rainbow Trout					
	Only one 41 mm rainbow captured on pass 1				
Brown Trout					
	0 - 124 mm	2	13 3	**16**	0.9
	125 - 199 mm	2	3 0	**3**	0.0
	200 + mm	2	8 1	**9**	0.4
Parker Creek					
Brown Trout					
	0 - 124 mm	3	9 2 0	**11**	0.2
	125 - 199 mm	3	5 8 1	**16**	3.6
	200 + mm	3	3 3 0	**6**	0.7
Walker Creek					
Brown Trout					
	0 - 124 mm	2	3 1	**4**	0.6
	125 - 199 mm	2	26 8	**36**	2.8
	200 + mm	2	8 1	**9**	0.4

[1/] NP indicates an estimate was not possible.

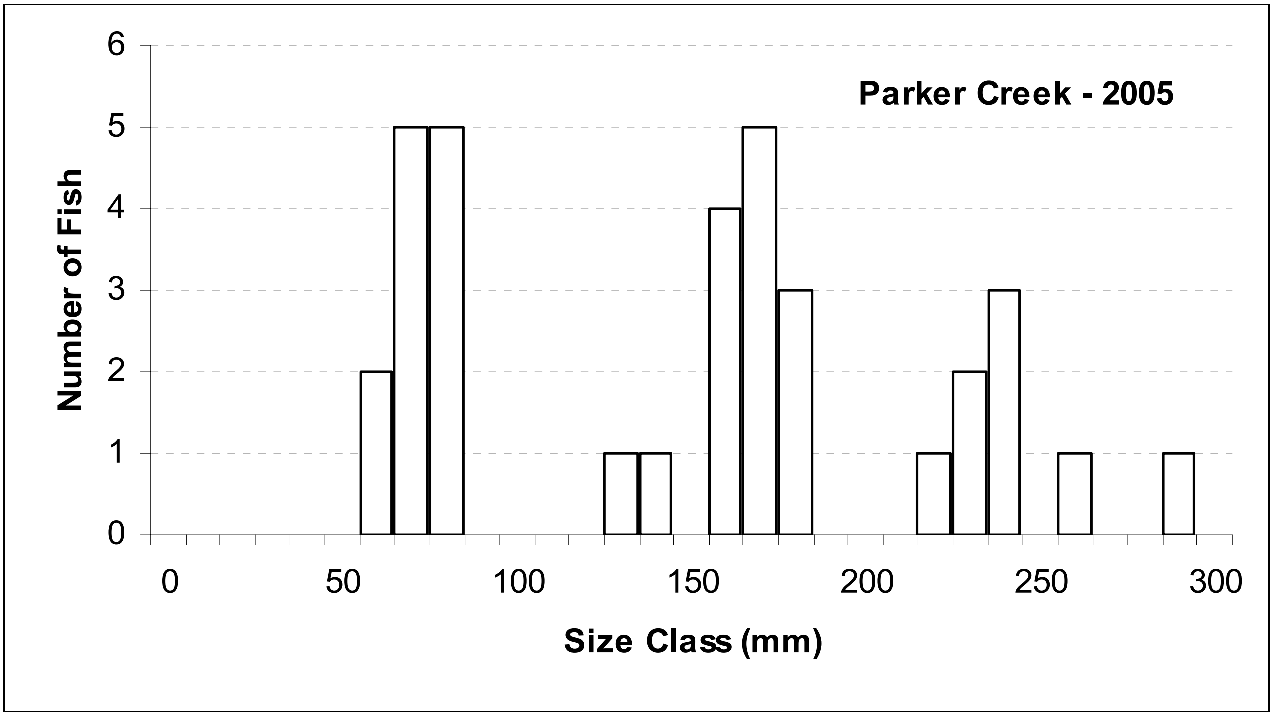


Figure 11. Length frequency histograms for brown trout captured in Parker (upper) and Walker (lower) creeks during September 2005. Note the different scales on the vertical axes.

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 6). A condition factor of 1.00 is considered average and most computed condition factors were close to 1.00 in 2005, indicating brown trout condition was about average when compared to other waters. Regression data for 2005 indicated that condition was similar among the three Rush Creek sample sections (Table 6).

Relative conditions of brown trout captured during 2005 were similar to those found in 2002-04 in Upper and Lower Rush Creek sections (Figure 12). However, computation of condition factors for brown trout between 150 to 250 mm in total length showed that County Road Rush Creek brown trout in this size range were in better condition than those in the other two sections (Figure 12). Brown trout condition in the County Road section in 2005 was the highest ever computed for this section (Figure 12).

Condition factors for brown trout in three Lee Vining Creek sections (Lower main, Lower side-channel, Upper main) were slightly higher than the previous three to four years (Figure 12). Because the Upper side-channel section in 2005 was cut-off from the main-channel and reduced to isolated pools when sampled, the condition factor was the lowest ever calculated. Over all seven years of sampling, the condition factors for brown trout in Lee Vining Creek were still highest back in 2000.

In Parker Creek, the condition factor for brown trout (150 to 250 mm in total length) dropped slightly in 2005, when compared to 2004 (Figure 12). In Walker Creek, the condition factor for brown trout (150 to 250 mm in total length) improved in 2005 to the highest value computed for this section for seven seasons of data collection (Figure 12).

Table 6. 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 2005 regression equations are in **bold** type.

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	$Log_{10}(WT) = 2.968*Log_{10}(L) – 4.937$	0.994	<0.01
	2005	**257**	**$Log_{10}(WT) = 2.969*Log_{10}(L) – 4.899$**	**0.984**	**<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	$Log_{10}(WT) = 2.935*Log_{10}(L) – 4.843$	0.995	<0.01
	2005	**189**	**$Log_{10}(WT) = 3.062*Log_{10}(L) – 5.143$**	**0.992**	**<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	$Log_{10}(WT) = 2.975*Log_{10}(L) – 4.944$	0.994	<0.01
	2005	**261**	**$Log_{10}(WT) = 3.016*Log_{10}(L) – 5.019$**	**0.995**	**<0.01**

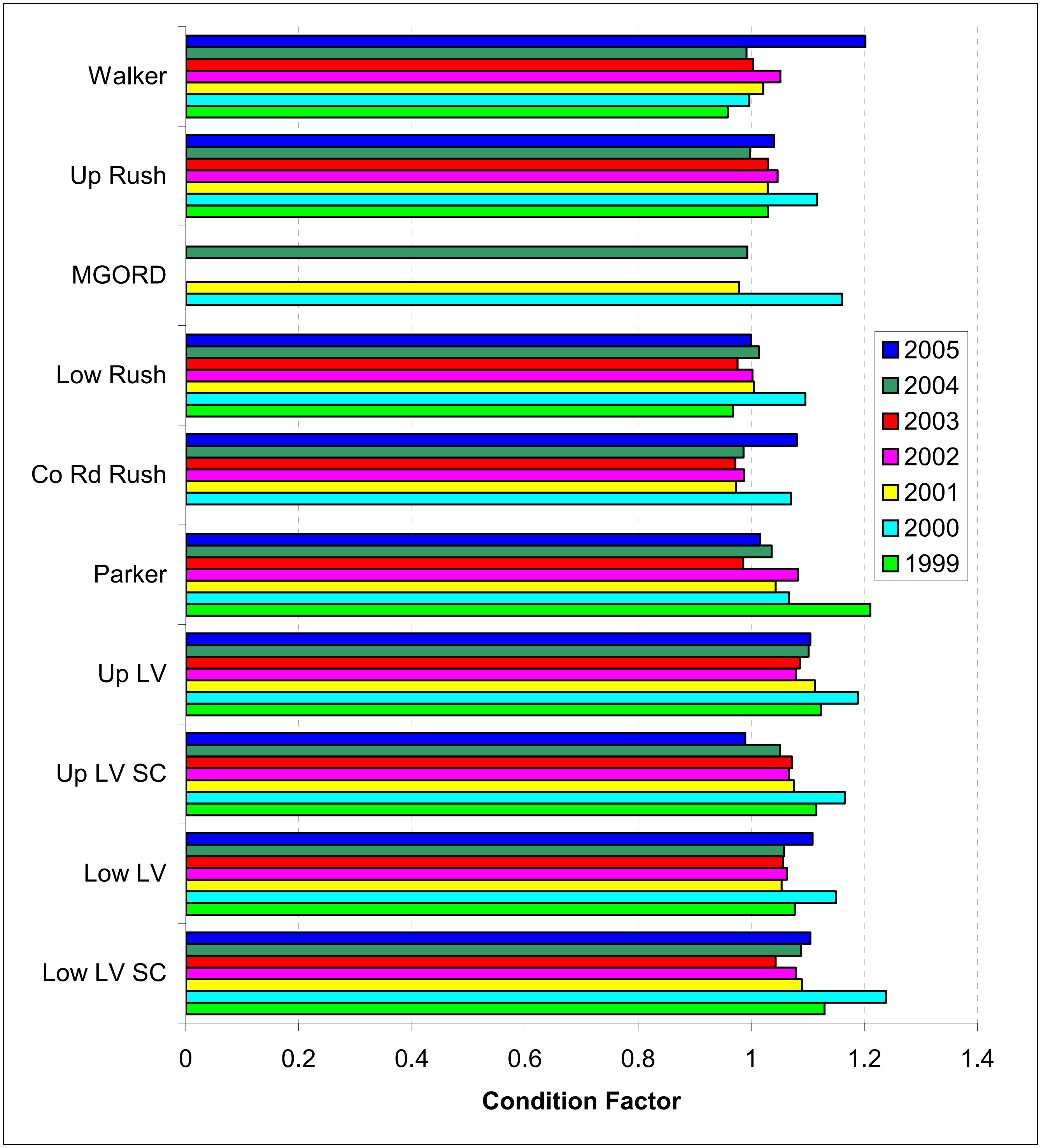


Figure 12. Condition factors for brown trout 150 to 250 mm long in Mono Lake tributaries from 1999 to 2005.

Age Estimates of Brown Trout

In 2005, 189 scale samples were obtained from 175 brown trout and 14 rainbow trout. In Rush Creek, scales were taken from 88 brown trout and one rainbow trout. The majority of the Rush Creek brown trout scales came from the 54 fish implanted with radio tags for the movement study. The remaining Rush Creek brown trout scale samples were 24 larger trout (205-266 mm) that had adipose fin clips administered in 2003, nine age-1+ trout (168-202 mm) that had left pelvic fin clips administered in 2004, and a 164 mm mortality from the County Road section (this was the only otolith taken too). In Lee Vining Creek, scale samples were obtained from 87 brown trout and 13 rainbow trout >200 mm in length. Results from these scale samples will be presented in the 2006 annual report.

During the 2003 sampling season 2,823 age-0 brown trout had their adipose fin removed so that survival and growth of this cohort of fish could be tracked in subsequent years (Table 7). In 2005, 45 of these adipose fin-clipped brown trout were re-captured (Table 8). Growth of adipose-clipped brown trout from age-0 to age-2 ranged from 130 to 154 mm and from 120 to 161 grams (Table 8). By section, the two-year (2003 to 2005) recapture rate of adipose fin-clipped fish was variable and ranged from a low of 0.3% in Lower Rush Creek to a high of 12.5% in the Upper Lee Vining main-channel (Table 8).

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 (Table 9). In 2005, 36 of the left pelvic fin-clipped brown trout were recaptured (Table10). Growth of left pelvic fin-clipped brown trout from age-0 to age-1 ranged from 62 to 89 mm and from 23 to 60 grams (Table 10).

During the 2005 sampling season 607 age-0 brown trout and six age-0 rainbow trout (<125 mm) had a segment of their right pelvic fins clipped off as a permanent mark so that survival and growth of this cohort of fish could be tracked in subsequent years (Table 11). Note that the number of young-of-year clipped in 2005 (613 fish) was nearly a 23% reduction compared to the average number of young-of-year clipped in 2003 and 2004.

Table 7. 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 Total 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 8. Age-2 brown trout captured in 2005 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	4	237	225	249	134	3.3%	140	125
Lee Vining – Lower Side	4	250	238	262	161	6.1%	152	151
Lee Vining – Upper Main	9	227	210	249	130	12.5%	130	120
Lee Vining – Lower Main	5	233	148	270	162	6.0%	136	153
Rush – Co Road	15	219	195	240	111	1.5%	132	104
Rush – Lower	2	246	239	252	145	0.3%	154	137
Rush – Upper	6	247	236	256	173	1.1%	143	161

Table 9. 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	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	94	64	124	8
Rush Ck– Lower	470(4)	93(73)	69(69)	126(80)	9(4)
Rush Ck – Upper	723(9)	93(83)	60(66)	129(96)	9(6)
Rush Ck – MGORD	21	114	101	124	15
Parker Creek	39	89	70	108	8
Walker Creek	203	85	58	104	7

Table 10. Age-1 brown trout captured in 2005 with **left pelvic** 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	1	148	148	148	30	0.5%	62	23
Lee Vining – Upper Main	1	178	178	178	67	3.7%	89	60
Lee Vining – Lower Main	1	180	180	180	68	2.4%	86	59
Rush – Co Road	23	161	132	195	52	3.1%	67	44
Rush – Lower	8	182	168	202	59	1.7%	89	50
Rush – Upper	1	175	175	175	56	0.1%	82	48
Walker Creek	1	166	166	166	56	0.5%	81	49

Table 11. Total number of age-0 trout that received **right pelvic** fin-clips during the 2005 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	0	-	-	-	-
Lee Vining – Lower Side	2	68	53	83	4
Lee Vining – Upper Main	4	68	62	75	3
Lee Vining – Lower Main	1	79	79	79	5
Rush – Co Road	152	92	69	135	8
Rush Ck– Lower	146(1)	96(76)	76(76)	122(76)	9(3)
Rush Ck – Upper	297(5)	89(71)	59(61)	119(85)	8(4)
Parker Creek	0	-	-	-	-
Walker Creek	5	81	71	93	6

Radio Telemetry-Movement Study in Rush Creek

Radio tags were implanted in a total of 54 brown trout. Fourteen tags (model MCFT-3A) were deployed in larger brown trout captured in the MGORD on September 9th. Fifteen tags (one MCFT-3A, seven NTC-6-2's and seven NTC-4-2L's) were deployed in the Upper Rush section on September 13th. Eleven tags (five NTC-6-2's and six NTC-4-2L's) were deployed in the County Road Rush section on September 14th. Thirteen tags (eight NTC-6-2's and five NTC-4-2L's) were deployed in the Lower Rush section on September 15th. The final tag deployed (model MCFT-3A) was on September 16th in a large male brown trout captured between the County Road and Lower Rush sections. Immediate post-surgery mortality occurred on one fish that was found dead the day after surgery (Code 17).

The MGORD fixed receiving station was installed and fully operational on September 21, 2005. Brown trout tagged in the MGORD were relocated with the manual receiver (by driving the road parallel to the diversion canal) on September 19th which confirmed that none had left the MGORD prior to the fixed station installation.

More detailed movement study results will be developed for the 2006 annual report.

Discussion

Reliability of Estimates

As explained in the methods, in 2005 there were problems in keeping block fences up in the Upper and Lower Rush Creek and the Lower Lee Vining Creek sections, 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 these three sections. Block fences did not fail in the Upper Lee Vining Creek main channel section. 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 over-estimates of the fish populations in Upper and Lower Rush Creek and Lower Lee Vining Creek sections; especially if marked fish moved out of, or unmarked fish moved into, the sample sections. However, we do not believe violations of population closure assumptions significantly affected population estimates in 2005. New hardware cloth will be purchased for block fences during the 2006 field season.

The 2005 Rush Creek mark-recapture estimates had higher standard errors associated with them compared to any of the previous six sampling seasons (1999-2004). These high error rates were likely due to the lower efficiency of the two back-pack electro-fishers versus the Smith-Root® 2.5 GPP electro-fishing system with a variable voltage pulsator (VVP) rated maximum output of 2,500 watts. Recapture rates of marked fish were lowest for age-0 fish, ranging from 7% to 22% in 2005 versus 30% to 40% in 2004. Lower recapture rates lead to higher standard errors and indicate that the true population could be much higher or much lower than the estimated number. For example, in the County Road section of Rush Creek there was an estimated 889 age-0 brown trout with a standard error of 286.5, so we are 95% certain that the actual population falls between 327 to 1,450 (estimate $\pm$ 1.96*SE), a relatively wide range of possible values for the true population number. In contrast, the 2004 estimate equaled 1,161 with a SE of 51.9, so we were 95% certain the actual population fell between 1,059 to 1,263, a much narrower range of possible values of the true population size.

Estimated Trout Density Comparisons

Trout populations were dominated by brown trout in all sample sections during 2005, similar to past years (Figure 13; Hunter et al. 2000; 2001; 2002; 2003; 2004; 2005). The high proportion of brown trout to rainbow trout in both Rush Creek and Lee Vining Creek is typical of most trout streams in the Mono Basin and the Owens River watershed. Studies by the California Department of Fish and Game documented brown trout as the dominant trout species in all 130 electro-fishing reaches sampled within 52 different Mono Basin streams and Owens River tributaries (Dienstadt et al. 1985, 1986, 1997).

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 might 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 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).

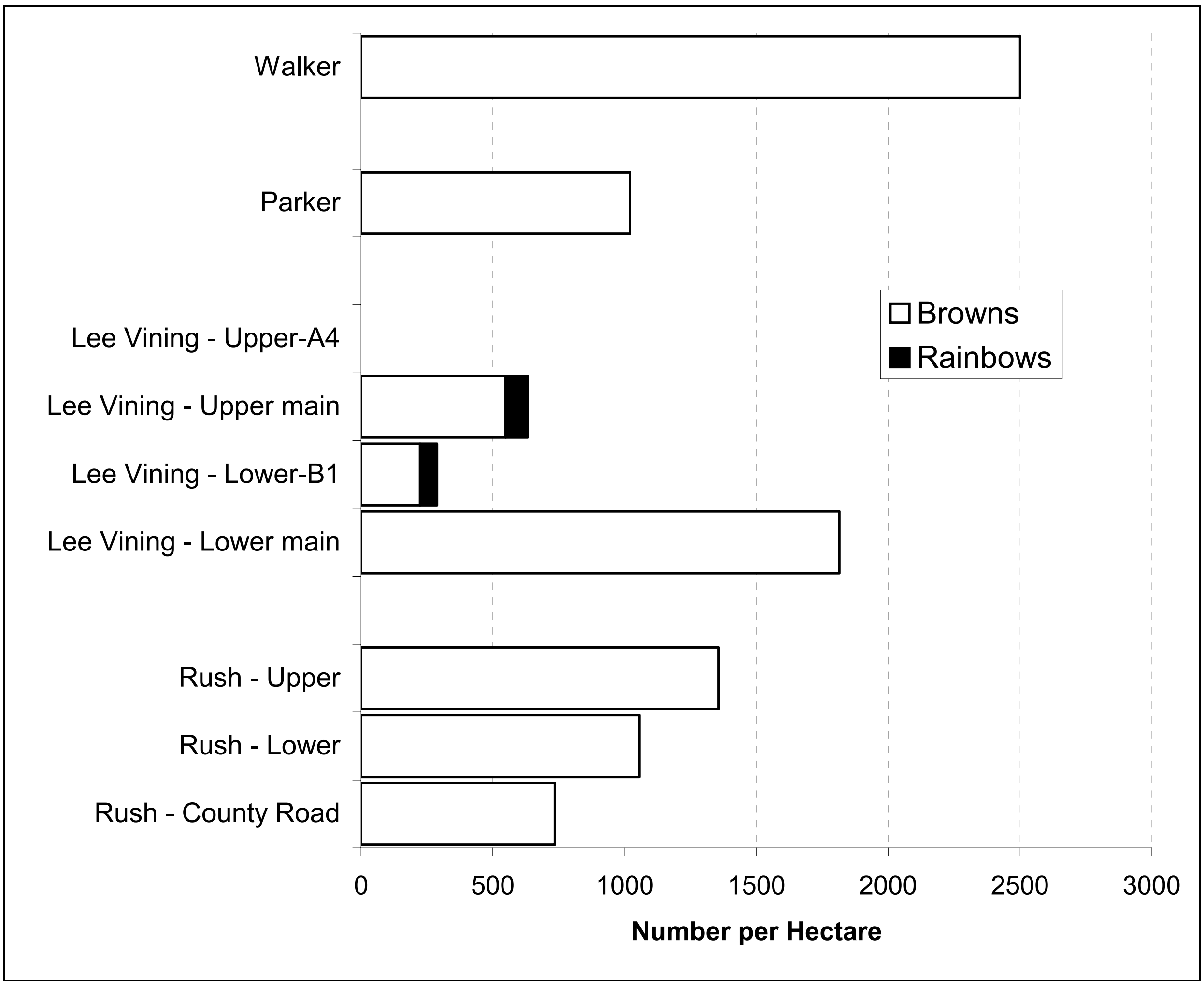


Figure 13. Densities (number/hectare) of age-1 and older brown and rainbow trout in selected Mono Lake tributaries in 2005. Due to isolated flows in the LV Upper side-channel no density estimated was generated for 2005.

Estimated densities (number per hectare) of age-1 and older brown trout in Rush for 2005 increased in two sections and decreased in one section (Figure 14). Between 2004 and 2005, in the Upper Rush section the estimated density of age-1 and older brown more than doubled from 619.9 fish/ha. to 1,357.5 fish/ha. In the Lower Rush section, the estimated densities age-1 and older brown trout nearly tripled between 2004 and 2005 (Figure 14). The County Road section experienced a slight drop in estimated densities between 2004 and 2005 (Figure 14).

Estimated densities (number per hectare) of age-1 and older brown trout decreased in 2005 in the Upper main-channel and Lower side-channel sections of Lee Vining Creek (Figure 14). In contrast, the Lower main-channel section experienced an increase of 31% between 2004 and 2005 (Figure 14).

Densities of age-1 and older brown trout in Parker Creek increased by 45% between 2004 and 2005, with the 2005 density estimate approximately equal to the 2002 estimate (Figure 14). In Walker Creek the 2005 density estimate was nearly 50% less than the 2004 estimate (Figure 14). Even with the 49% drop, the 2005 density estimate of age-1 and older brown trout for Walker Creek was still greater than any estimate for any other study section across all seven years of sampling.

For a third straight year, the estimated densities of age-1 and older rainbow trout declined dramatically in all sections of Lee Vining Creek, and none were sampled in the Upper side-channel (Figure 15). These low numbers and continued decline were not surprising considering the extremely poor recruitment of age-0 rainbow trout in Lee Vining in 2003 and 2002. Recruitment of age-0 rainbow trout was also poor in 2004 in three of the four study sections. In Rush Creek, all three annually-sampled sections experienced continued declines in estimated densities of age-1 and older rainbow trout (Figure 15).

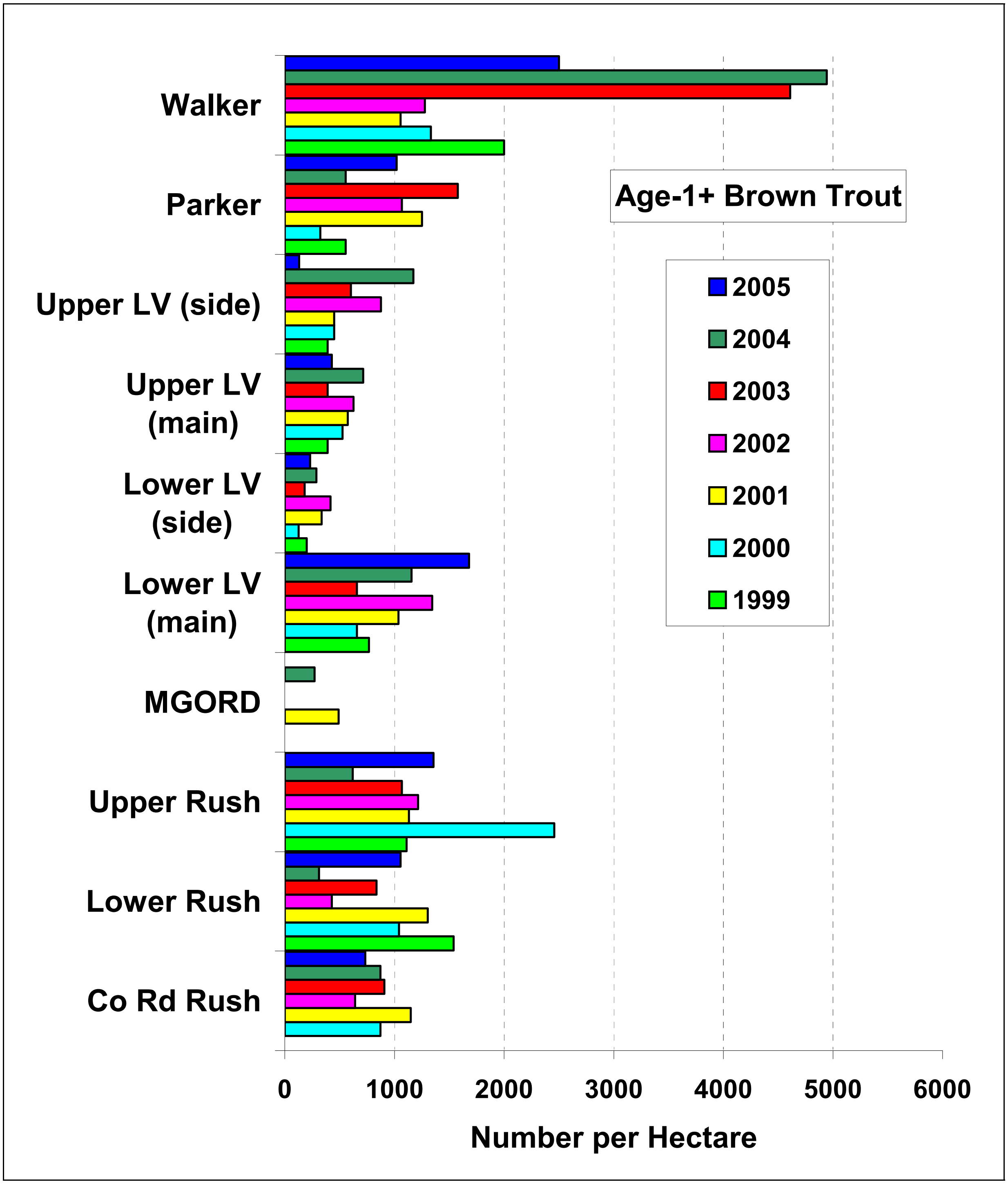


Figure 14. Estimated number of age-1 and older brown trout per hectare in sections of Walker, Parker, Rush, and Lee Vining creeks during September from 1999 to 2005. Due to isolated flows in the LV Upper side-channel no density estimate was generated for 2005.

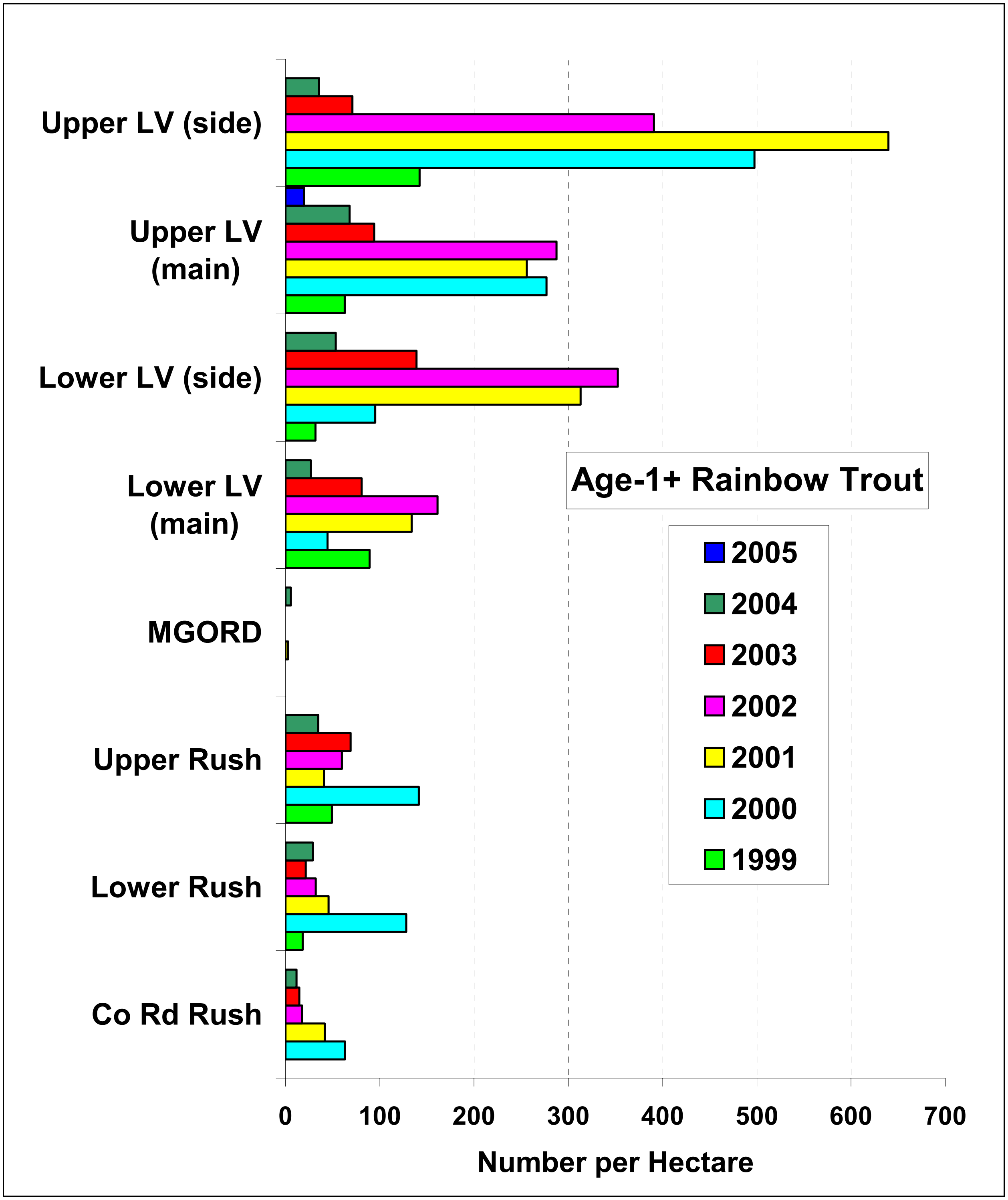


Figure 15. Estimated densities (number per hectare) of age-1 and older rainbow trout in sample sections of Lee Vining and Rush creeks, 1999 to 2005. Due to isolated flows in the Upper LV side-channel no density estimate was generated for 2005.

In 2005, age-0 brown trout populations experienced large decreases at eight of nine sample sections (Figure 16). Most of these decreases were to the lowest values ever recorded in the various sections. Upper Rush Creek had a slight (6%) increase in the density of age-0 brown trout between 2004 and 2005 (Figure 16). In contrast, between 2004 and 2005 age-0 brown trout decreased by 35% at the Rush Creek County Road section and by 48% at the Lower Rush section. The 2005 densities were the lowest ever recorded at these sections. Decreases in the densities of age-0 brown trout between 2004 and 2005 were even more dramatic at the sections on Walker Creek and Lower Lee Vining main channel (both 98%), Upper Lee Vining main channel (96%), Lower Lee Vining side channel (95%) and Parker Creek (73%).

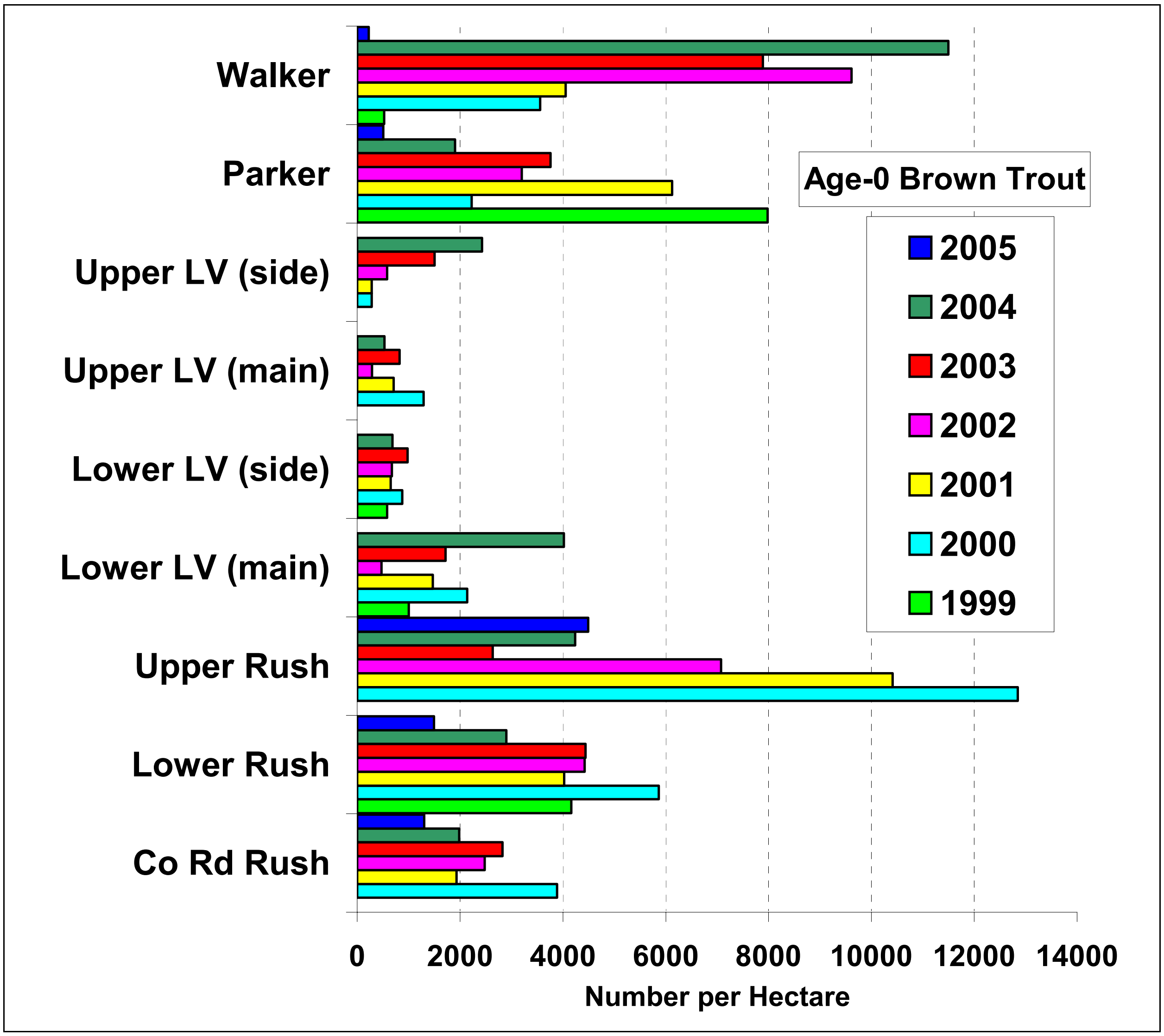


Figure 16. Estimated number of age-0 brown trout per hectare in sections of Walker, Parker, Lee Vining, and Rush creeks during September from 1999 to 2005. Due to isolated flows in the LV Upper side-channel no density estimate was generated for 2005.

The reason for the overall drop in densities of age-0 brown trout in the study sections was most likely due to the characteristics of Rush and Lee Vining creeks' hydrographs between May and July of 2005. As previously presented (Figures 2 and 3) both creeks experienced high peak discharges, sustained for many weeks. 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.

- 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.

Nuhfer et al. (1994) may best explain the severe drop in age-0 brown trout densities in 2005. In both Rush and Lee Vining creeks, the peak run-off from snow melt probably occurred soon after brown trout fry had emerged and were attempting to forage and establish territories along channel margin areas. During these extended peak flows the channel bed was most likely mobile and visibility was reduced by turbid conditions making it difficult to successfully forage and/or maintain positions along channel margins. Although age-0 brown trout numbers declined in 2005, this species still had a much more robust cohort of age-0's than rainbow trout.

Between 2004 and 2005, age-0 rainbow trout densities also declined to the lowest levels that have been found during the study period. At the four electro-fishing sections on Lee Vining Creek, only one age-0 rainbow trout was captured during 2005. On Rush

Creek, only five age-0 rainbows were captured in the Upper Section, along with a single age-0 at the Lower Section and none at County Road. Age-0 rainbow trout catch per hectare densities are shown on Figure 17. Catch (M + C – R) data are presented rather than Pederson population estimates, because less than seven marked fish (the minimum number needed for a non-biased estimate) were recaptured during 32 of the 34 sampling periods shown on this figure. Age-0 rainbow trout densities were generally higher at most of the sections from 1999-2002 (low runoff years) compared to 2003-2005 (increasingly higher runoff years) (Figure 17).

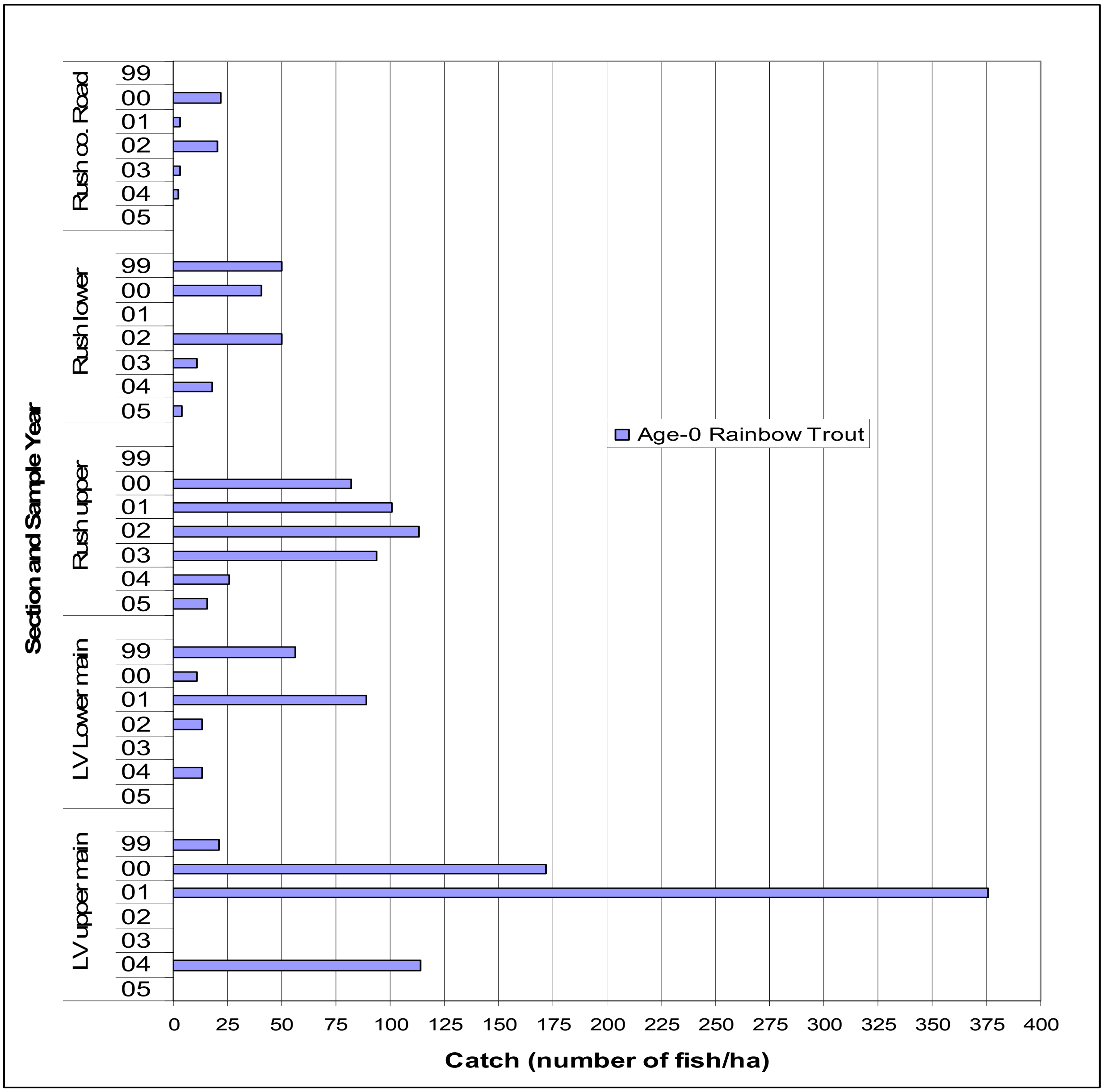


Figure 17. Densities (catch per hectare) of age-0 rainbow trout in sample sections of Lee Vining and Rush creeks, 1999 to 2005. Due to isolated flows in the LV Upper side-channel no density estimate was generated for 2005.

The six graphs in Figure 18 display relationships between the magnitude of peak discharge rates (Q) and age-0 brown and rainbow trout densities (# of fish/ha) at select electro-fishing sections from 2000-2005. The top two graphs are for age-0 brown trout at the Lower Rush and County Road sections. Stream flow data for these sections were measured at the "below Narrows" gauge site. From 2000-2003, when peak discharges ranged from 202-283 c.f.s. age-0 densities were noticeably higher than during 2004, which had a peak discharge of 354 c.f.s. During 2005, the highest peak discharge (467 c.f.s.) occurred, along with the lowest age-0 brown trout densities.

On Upper Rush Creek, age-0 brown trout densities did not directly correlate to changes in the magnitude of peak discharge rates (Figure 18). The highest density (12,847/ha) was present during 2000, when the peak discharge at the "Grant Lake Release" gauge site was 204 c.f.s. The lowest density (2,634/ha) was during 2003, when the peak discharge was almost exactly the same (203 c.f.s.). During 2004 the age-0 brown trout density increased to 4,233/ha when the peak discharge equaled 343 c.f.s. This density increased slightly again in 2005 to 4,494/ha when an even higher peak discharge of 403 c.f.s. occurred.

Age-0 rainbow trout densities at the Upper Rush Creek section between 2000 and 2005 were directly correlated to the magnitude of the peak annual discharge. From 2000 - 2003, when peak discharges ranged from 161-204 c.f.s. age-0 rainbow trout densities remained fairly constant (Figure 18). This density declined dramatically during 2004, when a peak discharge of 343 c.f.s. occurred. The lowest density of age-0 rainbow trout at the Upper Rush section was in 2005, when the highest peak discharge (403 c.f.s.) occurred. Although not shown on Figure 18, correlations between high peak discharges and low densities of age-0 rainbow trout at Lower Rush and County Road were similar to the correlations just described for Upper Rush (see data for these sections on Figure 17).

The final two graphs on Figure 18 depict relationships between age-0 brown trout densities and peak discharges at the Upper Lee Vining Creek main channel and Walker Creek electro-fishing sections. On Upper Lee Vining Creek, correlations between discharges and age-0 densities were weak until 2005, when the highest peak discharge (399 c.f.s.) occurred, along with by far the lowest densities of age-0 brown trout. On Walker Creek, age-0 brown trout densities quite closely correlated to magnitude of peak discharges. The highest density (11,500/ha) occurred during 2004 when the lowest peak discharge (19.5 c.f.s.) was recorded. Conversely, the lowest density occurred during 2005, when the highest annual peak discharge of 51.0 c.f.s. occurred.

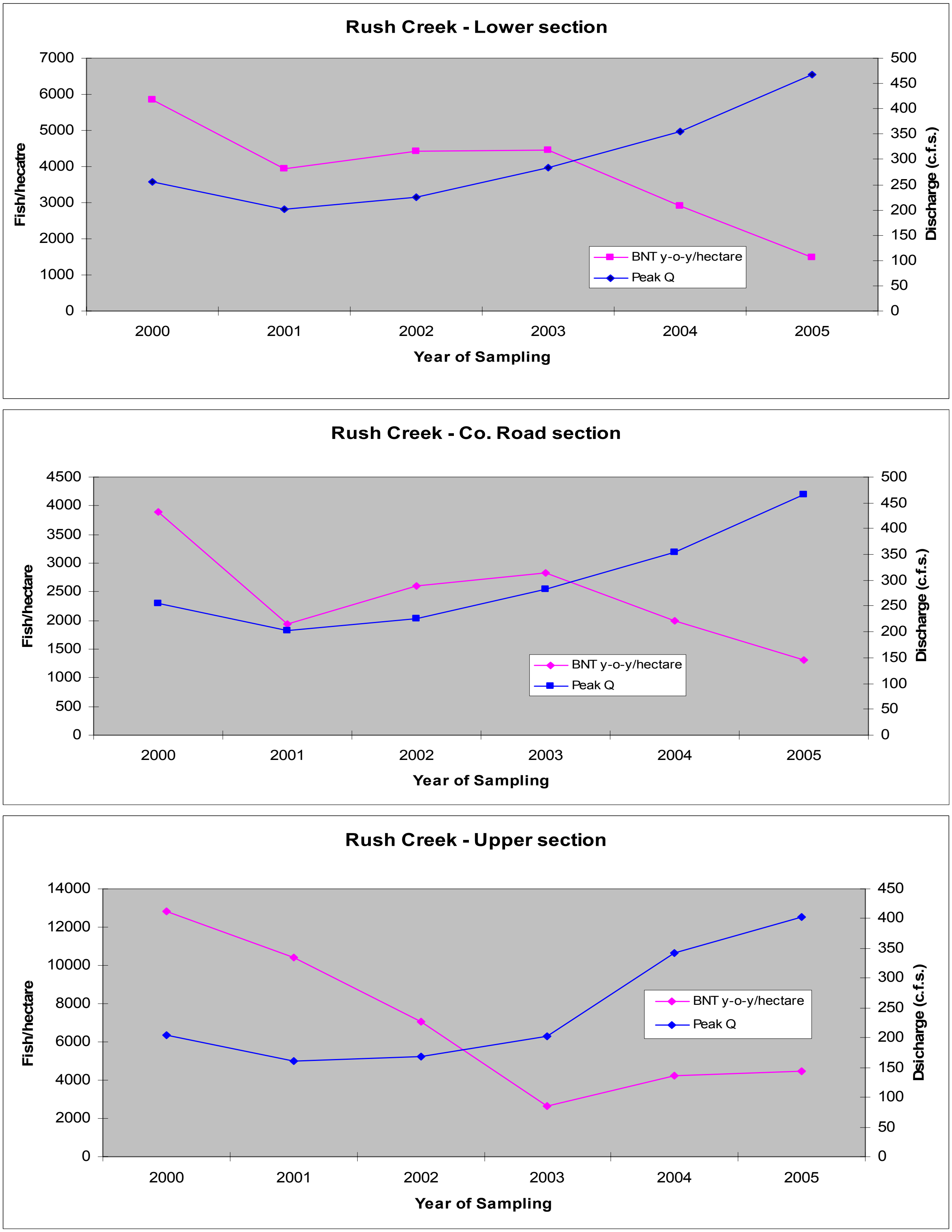


Figure 18. Relationships between age-0 trout densities (#/hectare) and peak discharge (c.f.s.) at selected Mono Basin study sections, 2000 – 2005.

Figure 18 (continued). Relationships between age-0 trout densities (#/hectare) and peak discharge (c.f.s.) at selected Mono Basin study sections, 2000 – 2005. NOTE: Upper Rush Creek is for age-0 rainbow trout.

Data on Figures 16, 17 and 18 indicate that, at nearly all of the electro-fishing sections in the study area, age-0 brown and rainbow trout densities were closely related to the magnitude of annual peak runoff. This was especially true during 2005, when highest peak discharges and lowest age-0 trout densities were present at nearly all of the sections (except for brown trout on Upper Rush). Other hydrologic variables such as duration of runoff and runoff ramping rates may also likely influence age-0 trout densities in the study area, but these variables were not as readily quantifiable as magnitude of peak discharge.

The almost complete absence of age-0 brown and rainbow trout on Lee Vining Creek during 2005 will likely reduce the densities and standing crops of adult wild trout on this stream in 2006. Preliminary scale sample analyses indicated that few trout on Lee Vining Creek live past age-2 (Hunter et al. 2004). If age-0 trout densities are again very low after the 2006 run-off, adult wild trout densities will likely continue to decline in 2007. The same holds true for the wild rainbow trout population on Rush Creek, where another year of poor age-0 production could severely impair the stream's already meager wild rainbow trout population.

Estimated Trout Standing Crop Comparisons

Estimates of brown trout standing crops (kg/ha) in the Upper main and side-channel and Lower side-channel Lee Vining sections decreased from 2004 to 2005 (Table 12). Conversely, in the Lee Vining Lower main-channel the estimated standing crop increased 23% in 2005 (Table 12).

In Rush Creek brown trout standing crops estimates increased from 2004 to 2005 in the Upper and Lower study sections, by 39% and 41% respectively (Table 12). For the Upper Rush section this was the first increase in standing crop after four years of steady declines between 2000 and 2004 (Figure 19). The estimated standing crop of brown trout in the County Road section decreased by 12.0% between 2004 and 2005 (Table 12).

Standing crop estimates in Walker Creek have now decreased for two consecutive seasons (2004 and 2005); with the largest decrease (49.7%) occurring between 2004 and 2005 (Table 12). In Parker Creek, the estimated standing crop increased by nearly 20% between 2004 and 2005 (Table 12). Most standing crop estimates were 50 kg/ha or higher, except in the Lower Lee Vining side-channel (Table 12).

Total trout standing crops (all age classes and species combined) have been estimated since 1999 to determine potential trends (Figure 19). 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 until the 2005 sampling season. 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 (except drop between 2002-03 seasons). 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 between 1999 and 2003, followed by drops between 2003 and 2005.

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 (2003-05) standing crops estimates are fairly similar to CDFG's estimates (Table 13). 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.

Table 12. Comparison of 2004 and 2005 brown trout standing crop (kg/ha) estimates in Mono Lake tributaries. NP stands for "not possible" and NA stands for "not available.

Collection Location	2004 Total Standing Crop	2004 Standing Crop Age-0	2004 Standing Crop Age-1 and older	2005 Total Standing Crop	Percent Change Between 2004 and 2005 – total standing crops
LV Upper Side	102.6	17.1	85.5	**NP**	**N/A**
Lee Vining Lower Side	33.1	6.2	26.9	30.3	-8.5%
Lee Vining Upper Main	73.5	4.1	69.4	55.0	-25.2%
Lee Vining Lower Main	133.6	34.4	99.3	173.7	+23.1%
Rush Co. Road	75.9	16.9	59.0	66.8	-12.0%
Rush Lower	55.8	25.2	30.6	94.1	+40.7%
Rush Upper	106.5	36.4	70.1	174.0	+38.8%
Parker Creek	75.2	15.0	60.2	91.6	+17.9%
Walker Creek	338.5	75.2	263.3	176.3	-47.9%

Table 13. Comparisons of LADWP and CDFG's brown trout standing crop (kg/ha) estimates in three sections of Rush Creek.

Collection Locations Similar to both Studies	2003 Total Standing Crop	2004 Total Standing Crop	2005 Total Standing Crop	CDFG 1984/85 Total Standing Crop	CDFG 1986 Total Standing Crop	CDFG 1991 Total Standing Crop
Rush Creek - Co. Road	79.7	75.9	66.8	88.6	54.2	131.5
Rush Creek - Lower	92.8	55.8	94.1	152.0	99.3	72.1
Rush Creek - Upper	124.9	106.5	174.0	95.8	131.3	91.1

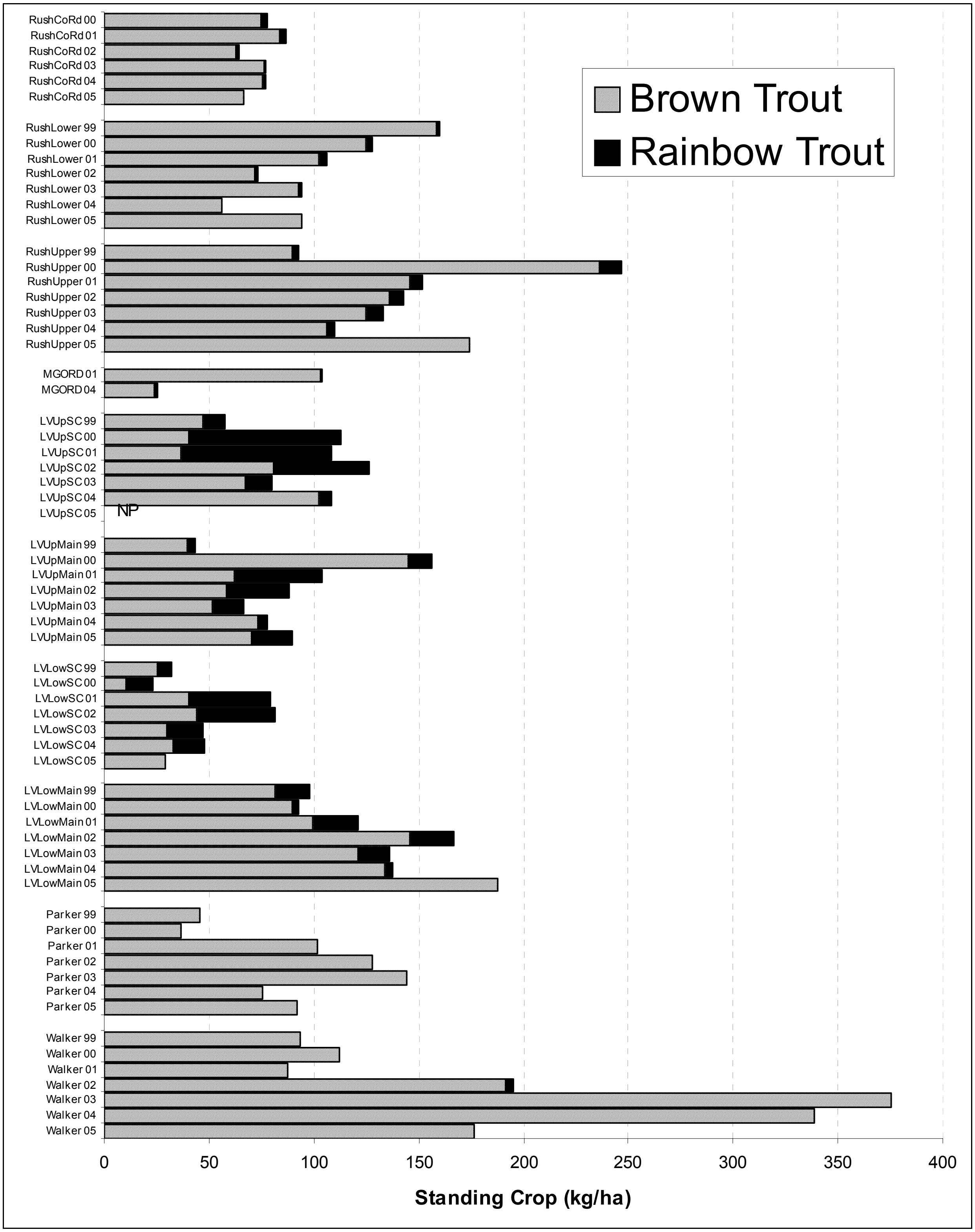


Figure 19. Estimated total standing crop (kilograms per hectare) of brown trout and rainbow trout in all sample sections, 1999 - 2005. **NP** indicates no estimate was possible.

Methods Evaluation

Mark-recapture electro-fishing has provided relatively reliable estimates; however, our difficulty in maintaining block fences (especially in Upper Rush Creek) may be biasing estimates for this section. Having a field technician dedicated to maintaining block fences reduced the frequency of block net failures in 2003-2005 compared to previous years, and is probably providing better estimates. New hardware cloth will be purchased in 2006 for block fences.

A significant channel change in the Upper Lee Vining section occurred during the 2005 snowmelt run-off which diverted flows from the A4 side channel that has been sampled since 1999. Consequently, when sampled in September of 2005 the A4 channel consisted of only a few isolated pools with little to no surface flow between them. We have also noticed continued channel changes in lower Rush Creek, particularly through the County Road section and at the upper end of the Lower Rush section. A side channel associated with the Upper Rush Creek section that we chose not to sample from 1999 to 2004 because it flowed overland through dense willow cover was almost totally abandoned during 2005. While these channel changes were expected because of the changes in the flow regime and Mono Lake levels, they make sampling challenging and we may need to consider replacing the Upper Lee Vining side channel with another side channel area in this portion of the creek. The continued channel changes make it imperative that channel lengths and wetted widths are re-measured at regular intervals to accurately compute density and standing crop estimates. All parties must recognize that documenting both the changing channel configuration and fish population response through time is an integral part of this monitoring effort.

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.

The clipping of age-0 trout for tracking empirical growth has provided data by recapturing marked fish to estimate annual growth. However, altering the methods for marking age-0 fish should be considered. In 2003 the adipose fin was removed on all age-0 fish and these complete clips have been easy to visually identify, even in 2005 two years after the clips were administered since there is little potential for regeneration of the adipose fin. In 2004 the left pelvic fins were clipped on all age-0 fish and depending on how much of this fin was removed some degree of regeneration occurred, making these clips much more difficult to identify on age-1 fish in 2005. We suspect that an unknown number of these clips were not noticed while handling age-1 fish in 2005. In 2006 we may again utilize an adipose fin clip, but should consider another means to mark fish such as a visible implant elastomer that injects a permanent dye underneath the skin that is externally visible.

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 2005, the main channel sections of Lee Vining Creek supported 21.2 and 27.1 trout ≥200 mm (~8 inches) per 100 meters of channel length and the side-channel sections supported 4.5 (Upper section) and 7.2 (Lower section) brown trout ≥200 mm per 100 meters of channel (Table 14). Note that main channel values increased and side-channel values decreased in 2005 compared to previous years (Table 14). During 2005, no brown trout were captured in Lee Vining Creek that exceeded 330 mm (~13 inches) and only one brown trout over 300 mm (~12 inches) was captured. Seven rainbow trout greater than 300 mm were captured in Lee Vining in 2005, but their eroded fins clearly identified them as hatchery trout most likely planted upstream of Highway 395.

The agreed upon termination criterion for Rush Creek states that Rush Creek fairly consistently produced brown trout weighing 0.75 to two 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 seven brown trout longer than 300 mm (~12”) were captured in 2005 (all from Upper Rush Creek). Five of these fish were over 300 g (0.66 pounds) in weight - 513 mm and 1,109 g (2.5 pounds), 415 mm and 729 g (1.6 pounds), 341 mm and 416 g (0.92 pounds), 340 mm and 401 g (0.88 pounds), and 316 mm and 323 g (0.72 pounds). In 2005 Rush Creek supported 17.1, 17.3, and 40.9 brown trout ≥200 mm (~8 inches) per 100 meters of channel length in the three sample sections (Table 14).

Although termination criteria-sized trout (300 - 365 mm) continue to be present in low numbers on Rush and Lee Vining Creeks, there appears to be a trend towards higher densities of trout ≥ 250 mm (10 inches) in length between 2000–2005 at many of the electro-fishing sections (Table 15). Less than seven marked fish, the minimum number needed for a valid Petersen population estimate, were recaptured during 60% (18/30) of the sampling efforts shown on Table 15. In an effort to make these estimates more valid, proportional estimates were calculated first utilizing the Petersen estimates for all trout ≥200 mm in length, and then multiplying by the decimal fraction of the catch that was ≥ 250 mm. These calculations are outlined in Appendix B. The highest density (264 fish/ha) was at the Upper Rush section in 2005 (Table 15). This density was nearly five times higher than was present at this section during 2000–2002 (53 fish/ha). Similarly, at Lower Rush, the 2005 density of trout ≥ 250 mm was nearly three times higher than during 2000. At County Road, densities of trout ≥ 250 mm were relatively low during 2005. However, the deepest pools in this section (where the largest fish were typically found) may not have been as effectively sampled with backpack shockers compared to the Upper and Lower Rush Creek sections. During most years, densities of trout ≥ 250 mm were generally higher on Lee Vining Creek compared to Rush Creek.

Table 14. Estimated numbers of brown trout greater than 200 mm and estimated numbers of brown trout greater than 200 mm per unit channel length in Mono Basin tributaries for sampling season 2005. Values in (#) are from 2004.

Stream Name and Section	Number of Trout ≥ 200 mm	Length of Section (m)	Number of Trout ≥200 mm per 100 m of Channel
Lee Vining – Upper Main Channel	70 (48)	330	21.2 (14.5)
Lee Vining – Lower Main Channel	42 (29)	155	27.1 (18.7)
Lee Vining – Upper Side Channel	9 (10)	201	4.5 (5.0)
Lee Vining – Lower Side Channel	14 (20)	195	7.2 (10.3)
Rush Creek – County Road	139 (147)	813	17.1 (18.1)
Rush Creek – Lower Section	70 (42)	405	17.3 (10.4)
Rush Creek - Upper Section	176 (122)	430	40.9 (28.4)

Table 15. Total numbers of brown and rainbow trout ≥ 250 mm marked (M), captured (C), and recaptured (R) at five Mono basin electro-fishing sections from 2000-2005. Catch = M+C-R. Population estimates were calculated for data sets with seven or more recaptures. When less than seven marked fish were recaptured, proportional estimates were calculated as outlined in Appendix B.

Section/Year	M	C	R	Catch	Pop. Est.	Proportional Est.	#/ha
Upper Rush							
2005	30	21	6	45	NP	84	264
2004	20	15	10	25	30	30	87
2003	19	15	9	25	31	29	91
2002	11	10	7	14	16	17	53
2001	11	9	6	14	NP	17	53
2000	3	8	1	10	NP	17	53
Lower Rush							
2005	8	7	4	11	NP	20	72
2004	7	3	3	7	NP	7	25
2003	8	10	8	10	10	10	36
2002	4	3	2	5	NP	6	22
2001	7	6	6	7	NP	7	32
2000	6	3	3	6	NP	6	27

Table 15 (Continued). Total numbers of brown and rainbow trout ≥ 250 mm marked (M), captured (C), and recaptured (R) at five Mono basin electro-fishing sections from 2000-2005. Catch = M+C-R. Population estimates calculated for data sets with seven or more recaptures. Proportional estimates generated for less than seven recaptures.

Section/Year	M	C	R	Catch	Pop. Est.	Proportional Est.	#/ha
Co. Road							
2005	9	3	1	11	NP	11	16
2004	14	15	9	20	23	23	39
2003	17	10	5	22	NP	27	40
2002	10	11	7	14	16	17	26
2001	10	7	7	10	10	13	20
2000	4	4	3	5	NP	7	11
Upper LV							
2005	14	12	6	20	NP	29	152
2004	14	13	11	16	17	17	89
2003	14	11	6	19	NP	21	110
2002	12	6	5	13	NP	14	73
2001	10	6	6	10	NP	13	68
2000	10	14	8	16	17	18	94
Lower LV							
2005	11	7	2	16	NP	16*	215
2004	6	5	5	6	NP	6	81
2003	15	13	12	16	16	16	215
2002	13	11	11	13	13	14	188
2001	11	10	10	11	11	12	133
2000	10	5	3	12	NP	13	145

*Total catch was used because pop. est. for all trout all trout ≥200 mm was also NP.

The #/ha values from Table 15 were illustrated on Figure 20. These figures also displayed the relative proportions of brown vs. rainbow trout at the sections (see Appendix B, Table 1 for these percentages). From 2000–2005 rainbow trout ≥ 250 mm were fairly uncommon at the Rush Creek sections compared to the Lee Vining Creek sections. However, as discussed earlier, many of the largest rainbows on Lee Vining Creek have been hatchery fish. On both streams, densities of trout ≥ 250 mm were generally higher from 2003–2005 compared to 2000–2002, with the highest densities being present during 2005 at four of five sections (Figure 20).

The riparian communities along both Rush and Lee Vining Creeks continued to rapidly mature from 2000 through 2005. The magnitude of peak discharges has been significantly higher during recent years; i.e. during 2004 and 2005 on Rush Creek and during 2003 and 2005 on Lee Vining Creek. It is probable that the combination of more mature riparian vegetation and higher runoff discharges have worked together to create deeper pools, providing additional habitat for additional larger trout.

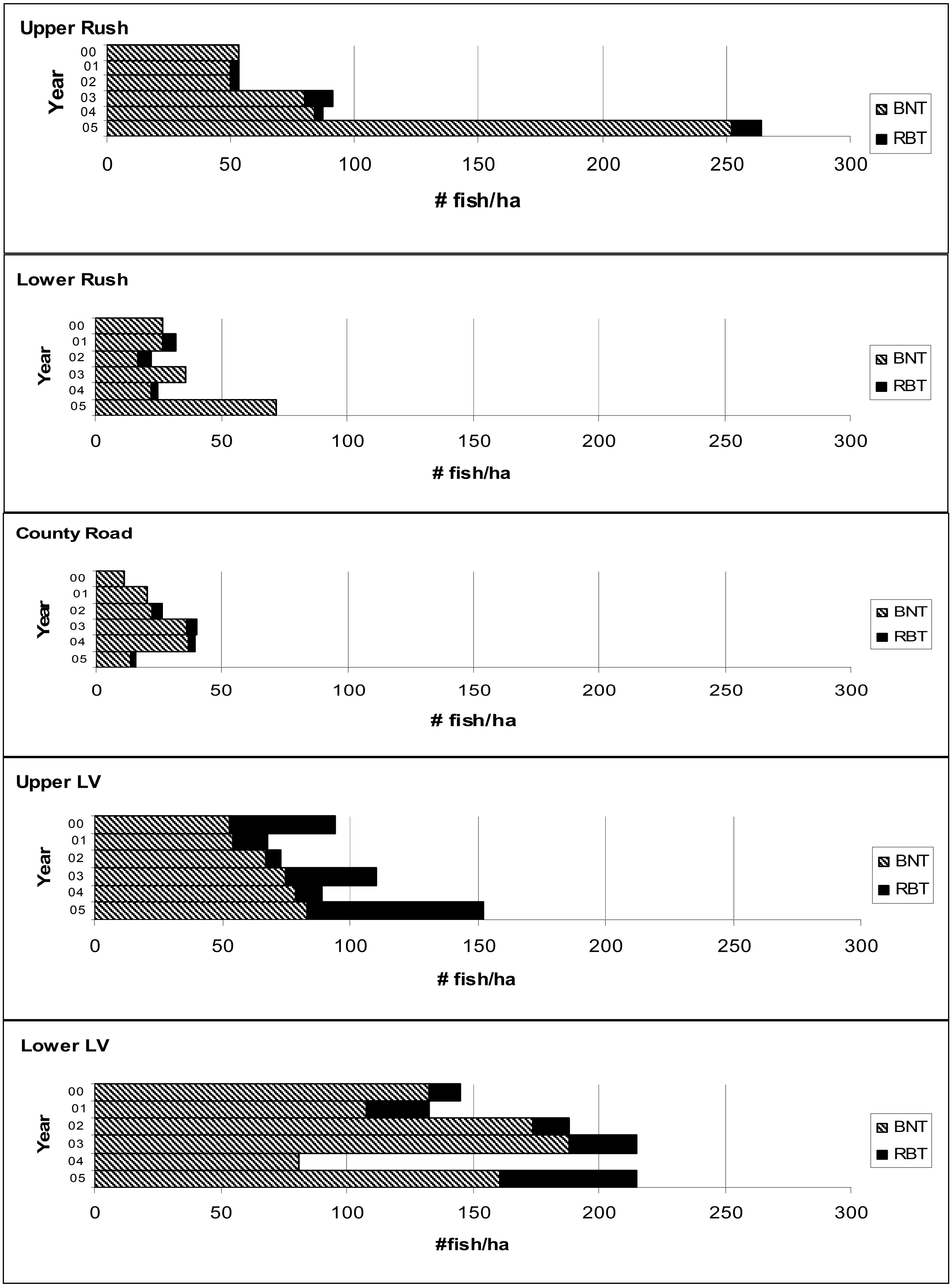


Figure 20. Total numbers per hectare of brown trout and rainbow trout ≥250 mm at five electro-fishing sections from 2000-2005.

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, 2005). 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. In 2007 a flow-study to examine changes in habitat quality and quantity as related to discharge in conjunction with the 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 seven years suggests that Rush and Lee Vining creeks in their current condition are still 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.

We are still evaluating potential termination criteria that would be based upon standing crop estimates, possibly examining values such as running multi-year averages and trends. Adequate annual data now exists to allow for these types of analyses (Table 16). 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.

Table 16. Total brown trout standing crops (kg/ha) for Mono Basin tributaries, sample seasons 1999 – 2005.

Collection Location	1999 Total Brown Trout Standing Crop (kg/ha)	2000 Total Brown Trout Standing Crop (kg/ha)	2001 Total Brown Trout Standing Crop (kg/ha)	2002 Total Brown Trout Standing Crop (kg/ha)	2003 Total Brown Trout Standing Crop (kg/ha)	2004 Total Brown Trout Standing Crop (kg/ha)	2005 Total Brown Trout Standing Crop (kg/ha)	All-years Combined Running Average of Standing Crops (kg/ha)
LV Upper - Main	39.9	145.0	62.3	58.4	51.7	73.5	55.0	69.4
LV Upper - Side	47.4	40.7	36.9	80.6	67.3	102.6	N/A	62.6
LV Lower - Main	81.4	89.5	99.5	145.7	121.1	133.6	173.7	120.6
LV Lower - Side	25.6	10.5	40.3	44.2	30.0	33.1	30.3	30.6
Rush Ck - Co. Rd	N/A	74.7	84.1	65.8	79.7	75.9	66.8	74.5
Rush Ck - Lower	158.6	124.7	100.8	71.7	92.8	55.8	94.1	99.8
Rush Ck - Upper	89.8	236.0	146.1	136.3	124.9	106.5	174.0	144.8
Rush Ck - MGORD	N/A	N/A	103.1	N/A	N/A	23.7	N/A	63.4
Parker Creek	45.9	36.8	101.9	127.6	144.1	75.2	91.6	89.0
Walker Creek	93.7	112.3	87.1	191.1	375.3	338.5	176.3	196.3

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 52 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 seven 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. Many streams included in the CDFG surveys were also augmented with plants of hatchery trout.

Regardless of the wide range of values, 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/ha** (Dienstadt et al. 1985). The second Owens River report summarized information collected in 50 sections within 23 streams that produced an average of **85.6 kg/ha** (Dienstadt et al. 1986). For comparison the brown trout total standing crops generated for the Mono basin tributaries between 1999–2005 produced an average of **119 kg/ha** (average of the seven-year averages). For the Lee Vining Creek Upper and Lower sections, the combined main channel and side channel values were 132.0 kg/ha and 151.2 kg/ha, respectively.

As we previously mentioned, most of the Owens River 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

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Personal Communications

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Appendix A. Sample Section Dimensions for 2000 – 2005

Stream Section	2000 Length (m)	2000 Width (m)	2000 Area(m^2)	2001 Length (m)	2001 Width (m)	2001 Area(m^2)	2002 Length (m)	2002 Width (m)	2002 Area (m^2)
Rush - County Road	813	8	6504	813	8	6504	813	8.4	6829.2
Rush - Lower	405	5.4	2187	405	6.9	2794.5	405	6.9	2794.5
Rush - Upper	430	7.4	3182	430	7.4	3182	430	7.4	3182
MGORD	Not measured	Not measured	N/A	2230	12	26760	Not measured	Not measured	N/A
Lee Vining - Lower	187	4.8	897.6	187	4.8	897.6	155	4.8	744
Lee Vining - Lower-B1	189	5	945	262	5	1310	195	4.8	936
Lee Vining - Upper-main	330	5.8	1914	330	5.8	1914	330	5.8	1914
Lee Vining - Upper-A4	201	4.2	844.2	201	4.2	844.2	201	4.2	844.2
Parker	98	2.2	215.6	98	2.2	215.6	98	2.2	215.6
Walker	100	1.8	180	100	1.8	180	100	1.8	180

Appendix A. Sample Section Dimensions for 2000 – 2005

Stream Section	2003 Length (m)	2003 Width (m)	2003 Area(m^2)	2004 Length (m)	2004 Width (m)	2004 Area(m^2)	2005 Length (m)	2005 Width (m)	2005 Area (m^2)
Rush - County Road	813	8.4	6829.2	813	7.3	5934.9	813	8.4	6829.2
Rush - Lower	405	6.7	2713.5	405	6.8	2754	405	6.8	2754
Rush - Upper	430	7.4	3182	430	7.99	3435.7	430	8.6	3698
MGORD	Not measured	Not measured	N/A	2230	12	26760	2230	12	26760
Lee Vining - Lower	155	4.8	744	155	4.8	744	155	5.2	806
Lee Vining - Lower-B1	195	4.8	936	195	4.8	936	195	4.6	897
Lee Vining - Upper-main	330	7	2310	330	5.8	1914	330	7.4	2442
Lee Vining - Upper-A4	201	4.4	884.4	201	4.2	844.2	Not measured	Not measured	N/A
Parker	98	2.2	215.6	98	2.2	215.6	98	2.2	215.6
Walker	100	1.8	180	100	1.8	180	100	1.8	180

Appendix B. Catch Data and Proportional Estimates of Trout ≥ 250 mm in Rush and Lee Vining creeks for 1999 – 2005

Table 1. Numbers of brown trout (BNT) and rainbow trout (RBT) ≥250 mm that were marked (M), captured (C) and recaptured (R) at five electrofishing sections in the study area from 2000-2005, along with population estimates and catch (M+C-R) data. Estimates for total trout ≥250 mm were only computed when seven or more fish were recaptured.

Section/ Year	Species	M	C	R	EST	Catch Number	Catch Percent
Upper Rush							
2005	BNT	29	20	6		43	0.955
	RBT	1	1	0		2	0.044
	Total	30	21	6	NP	45	
2004	BNT	19	14	9		24	0.960
	RBT	1	1	1		1	0.040
	Total	20	15	10	30	25	
2003	BNT	16	13	7		22	0.880
	RBT	3	2	2		3	0.120
	Total	19	15	9	31	25	
2002	BNT	10	9	6		13	0.929
	RBT	1	1	1		1	0.071
	Total	11	10	7	16	14	
2001	BNT	10	9	6		13	0.929
	RBT	1	0	0		1	0.071
	Total	00	9	6	NP	14	
2000	BNT	3	8	1		10	1.000
	RBT	0	0	0		0	0.000
	Total	3	8	1	NP	10	
Lower Rush							
2005	BNT	8	7	4		11	1.000
	RBT	0	0	0		0	0.000
	Total	8	7	4	NP	11	
2004	BNT	6	2	2		6	0.857
	RBT	1	1	1		1	0.143
	Total	7	3	3	NP	7	
2003	BNT	8	10	8		10	1.000
	RBT	0	0	0		0	0.000
	Total	8	10	8	10	10	
2002	BNT	3	3	2		4	0.800
	RBT	1	0	0		1	0.200
	Total	4	3	2	NP	5	
2001	BNT	6	5	5		6	0.857
	RBT	1	1	1		1	0.143

	Total	7	6	6	NP	7	
2000	BNT	5	3	3		5	1.000
	RBT	0	0	0		0	0.000
	Total	5	3	3	NP	5	

Table 1. Continued.

Section/ Year	Species	M	C	R	EST	Catch Number	Catch Percent
County Road							
2005	BNT	8	2	1		9	0900
	RBT	0	1	0		1	0.100
	Total	8	3	1	NP	10	
2004	BNT	13	14	8		19	0.950
	RBT	1	1	1		1	0.050
	Total	14	15	9	23	20	
2003	BNT	16	9	5		20	0.900
	RBT	1	1	0		2	0.100
	Total	17	10	5	NP	22	
2002	BNT	8	9	5		12	0.857
	RBT	2	2	2		2	0.143
	Total	10	11	7	16	14	
2001	BNT	10	7	7		10	1.000
	RBT	0	0	0		0	0.000
	Total	10	7	7	10	10	
2000	BNT	4	4	3		5	1.000
	RBT	0	0	0		0	0.000
	Total	4	4	3	NP	5	
Upper LV							
2005	BNT	9	5	3		11	0.550
	RBT	5	7	3		9	0.450
	Total	14	12	6	NP	20	
2004	BNT	13	11	10		14	0.875
	RBT	1	2	1		4	0.125
	Total	14	13	11	17	16	
2003	BNT	11	7	5		13	0.684
	RBT	3	4	1		6	0.316
	Total	14	11	6	NP	19	
2002	BNT	11	5	4		12	0.923
	RBT	1	1	1		1	0.077
	Total	12	6	5	NP	13	
2001	BNT	8	4	4		8	0.800
	RBT	2	2	2		2	0.200
	Total	10	6	6	NP	10	
2000	BNT	6	7	4		9	0.563

	RBT	4	7	4		7	0.437
	Total	10	14	8	17	16	

Table 1. Continued.

Lower LV							
2005	BNT	9	5	2		12	0.750
	RBT	2	2	0		4	0.250
	Total	11	7	2	NP	16	
2004	BNT	6	5	5		6	1.000
	RBT	0	0	0		0	0.000
	Total	6	5	5	NP	6	
2003	BNT	13	11	10		14	0.875
	RBT	2	2	2		2	0.125
	Total	15	13	12	16	16	
2002	BNT	12	10	10		12	0.923
	RBT	1	1	1		1	0.077
	Total	13	11	11	13	13	
2001	BNT	9	9	9		9	0.818
	RBT	2	1	1		2	0.182
	Total	11	10	10	11	11	
2000	BNT	9	5	3		11	0.917
	RBT	1	0	0		1	0.083
	Total	10	5	3	NP	12	

Table 2. Total numbers of trout ≥ 250 mm and ≥200 mm that were marked (M), captured (C) and recaptured (R) at five electrofishing sections in the study area from 2000-2005. The final two columns show the catch ratio (which is the catch for trout ≥250 mm ÷ the catch for those ≥200 mm), and the proportional estimate for trout ≥250 (which is the catch ratio X the estimate for trout ≥200 mm).

Section/ Year	Length Class	M	C	R	EST	Catch	Catch Ratio	Prop. Est.
Upper Rush								
2005	250+	30	21	6	NP	45	0.4545	84
	200+	58	59	18	185	99		
2004	250+	20	15	10	30	25	0.2404	30
	200+	74	71	41	128	104		
2003	250+	19	15	9	31	25	0.2475	29
	200+	74	72	45	118	101		
2002	250+	11	10	7	16	14	0.1944	17
	200+	52	47	27	90	72		

2001	250+	11	9	6	NP	14	0.1750	17
	200+	55	57	32	97	80		
2000	250+	3	8	1	NP	10	0.1695	17
	200+	29	42	12	98	59		
Lower Rush								
2005	250+	8	7	4	NP	11	0.2821	20
	200+	26	20	7	70	39		
2004	250+	7	3	3	NP	7	0.1591	7
	200+	39	39	34	45	44		
2003	250+	8	10	8	10	10	0.2083	10
	200+	42	39	33	50	48		
2002	250+	4	3	2	NP	5	0.0980	6
	200+	40	34	23	59	51		
2001	250+	7	6	6	NP	7	0.1489	7
	200+	35	43	31	49	47		
2000	250+	6	3	3	NP	6	0.1429	6
	200+	32	35	25	45	42		
County Road								
2005	250+	9	3	1	NP	11	0.1325	11
	200+	60	39	16	143	83		
2004	250+	14	15	9	23	20	0.1527	23
	200+	93	99	61	151	131		
2003	250+	17	10	5	NP	22	0.1803	27
	200+	87	85	50	147	122		
2002	250+	10	11	7	16	14	0.1217	17
	200+	83	81	49	137	115		
2001	250+	10	7	7	10	10	0.0769	13
	200+	93	82	45	169	130		
2000	250+	4	4	3	NP	5	0.0467	7
	200+	75	61	29	156	107		

Table 2. Continued.

Section/ Year	Length Class	M	C	R	EST	Catch	Catch Ratio	Prop. Est.
Upper LV								
2005	250+	14	12	6	NP	20	0.3509	29
	200+	42	30	15	82	57		
2004	250+	14	13	11	17	16	0.3137	17
	200+	42	38	29	55	51		
2003	250+	14	11	6	NP	19	0.3958	21
	200+	42	29	23	53	48		
2002	250+	12	6	5	NP	13	0.1884	14
	200+	59	47	37	75	69		
2001	250+	10	6	6	NP	10	0.1471	13
	200+	50	43	25	85	68		
2000	250+	10	14	8	17	16	0.3636	18
	200+	20	40	16	50	44		
Lower LV								
2005	250+	11	7	2	NP	16	0.5161	16*
	200+	22	14	5	NP	31		
2004	250+	6	5	5	NP	6	0.1200	6
	200+	44	35	29	53	50		
2003	250+	15	13	12	16	16	0.4706	16
	200+	31	26	23	35	34		
2002	250+	13	11	11	13	13	0.2321	14
	200+	48	44	36	59	56		
2001	250+	11	10	10	11	11	0.2558	12
	200+	39	26	22	46	43		
2000	250+	10	5	3	NP	12	0.4800	13
	200+	20	19	14	27	25		

*The total catch was used for this year, since the EST for all trout in 2004 was also NP

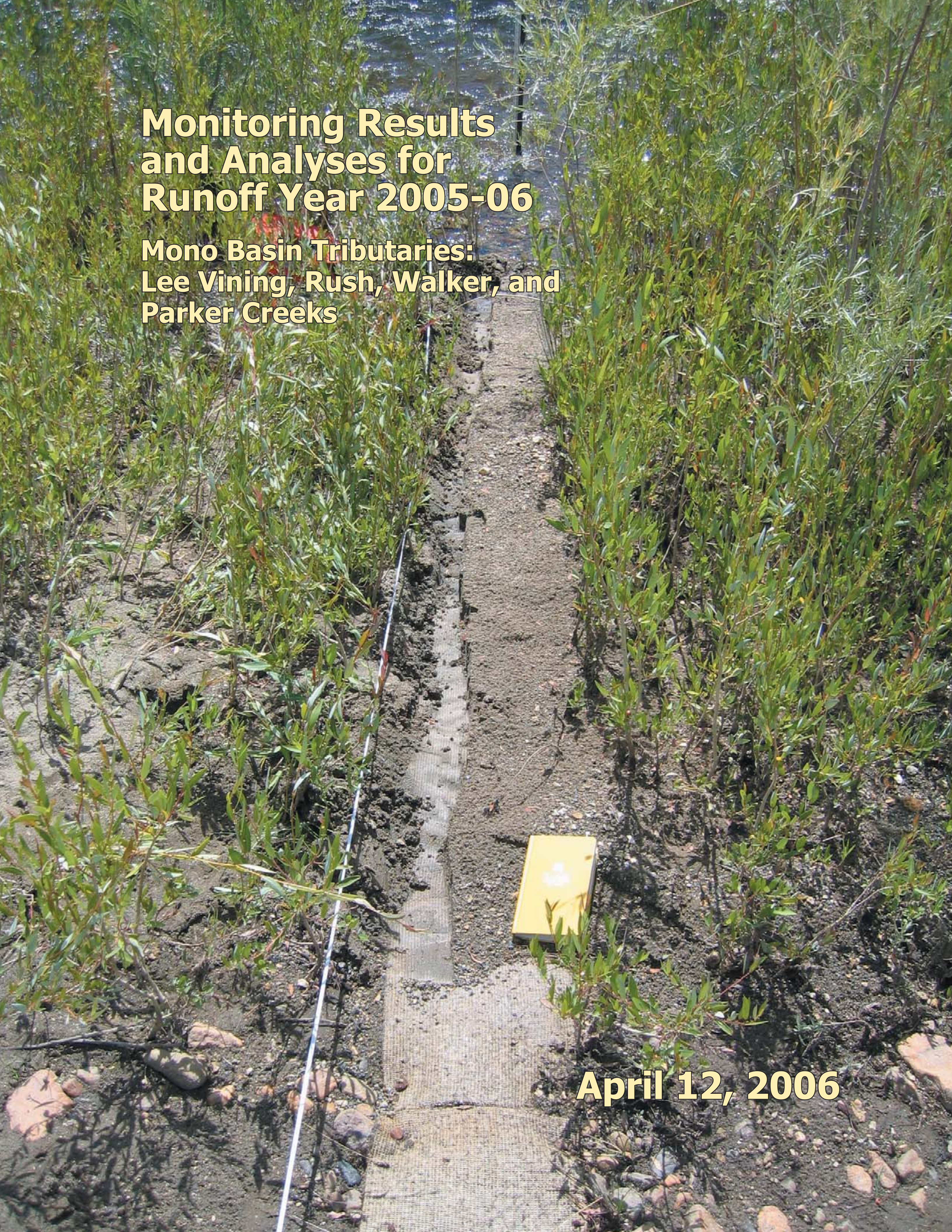
Section 4

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

Monitoring Results and Analysis
For Runoff Season 2005-2006

Monitoring Results and Analyses for Runoff Year 2005-06

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



April 12, 2006

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

Monitoring Results and Analyses for
Runoff Year 2005-06

Prepared for:
Los Angeles Department of Water and Power

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(707) 826-7794

April 12, 2005

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1 INTRODUCTION

The 2005 runoff season in the Mono Basin was highlighted by a large snowmelt runoff event and extensive field monitoring on Rush and Lee Vining creeks, marking the ninth consecutive year of monitoring in the Mono Basin (Figure 1), and the seventh official year following the State Water Resources Control Board (SWRCB) Decision 1631 and Order 98-05. The moderately large Stream Restoration Flow (SRF) releases on Rush Creek, augmented with Lee Vining Creek diversions, initiated the measurement of sediment transport rates at upper and lower Rush Creek sites, and the continuation of studies designed to quantify rates and pathways of fine sediment deposition onto Rush Creek floodplains. Similar floodplain studies were implemented on Lee Vining Creek. Studies evaluating the linkage between overbank flows (accessing side channels and inundating floodplains) and groundwater elevations continued on Rush Creek and Lee Vining Creek and included: (1) monitoring groundwater elevation with piezometers, (2) mapping selected floodplain areas to show the extent and duration of inundation, and (3) installing and monitoring dataloggers and stream gages to obtain continuous discharge and groundwater data in lower Rush and Lee Vining creeks. Other geomorphic studies were continued, including painted tracer rock and scour core experiments, before-and-after cross section and longitudinal profile surveys, and planmapping of Lee Vining Creek study sites. Water temperature and synoptic discharge measurements were collected.

The 2005 field season also had a large riparian vegetation monitoring component. Studies during the 1999-2000 field season to evaluate riparian vegetation species composition and stand structure on Rush and Lee Vining creeks were repeated in 2005. These studies included (1) reoccupying 76 nested-frequency transects on Rush Creek and 96 transects on Lee Vining Creek to document species composition, relative abundance, and frequency, and (2) monitoring five valley-wide band transects to document plant stand structure (height, age, and density of woody riparian vegetation) and location. Other vegetation monitoring components were added, including (3) monitoring life history stages such as time of flowering, fruiting, and seed dispersal for several riparian hardwood species, and (4) evaluation of riparian vegetation recruitment at two experimental channel/floodplain sites. The nested frequency and band transect data sets were compared to previous data to describe changes since 1999. Seed dispersal timing was related to the snowmelt flood and recession hydrograph to assess SRF release timing on successful riparian species regeneration. Success of riparian vegetation recruitment was evaluated for the 3D and 8 floodplains.

Field activities during RY 2005 are summarized in Table 1.

2 HYDROLOGY

2.1 Runoff Year 2005 Annual Hydrographs

The Eastern Sierra received a large snow pack during the winter 2004-05, significantly exceeding the annual mean. The April 1, 2005 forecast projected the runoff year as “Wet-Normal” according to the provisions of the SWRCB Order 98-05, with predicted runoff of 161,800 acre-feet (af), or 132% of the 1951-2000 average runoff of 122,557 af (LADWP 2005). Runoff Year (RY) 2005 ranked the 15th wettest year during the period 1941-2005, with an exceedence probability of 23%. The Wet-Normal runoff conditions allowed Grant Reservoir to rise from an April 1, 2005 low of 15,000 af of storage to full capacity during the 2005 runoff season.(LADWP 2005). Mono Lake elevation also rose during the 2005 runoff season, and climbed 2.0 ft from a November 2004 seasonal low of 6380.6 ft MSL to 6382.6 ft by August 2005. Lake elevation had receded to 6382.3 ft. by January 2006 due to lake evaporation and lower inflows.

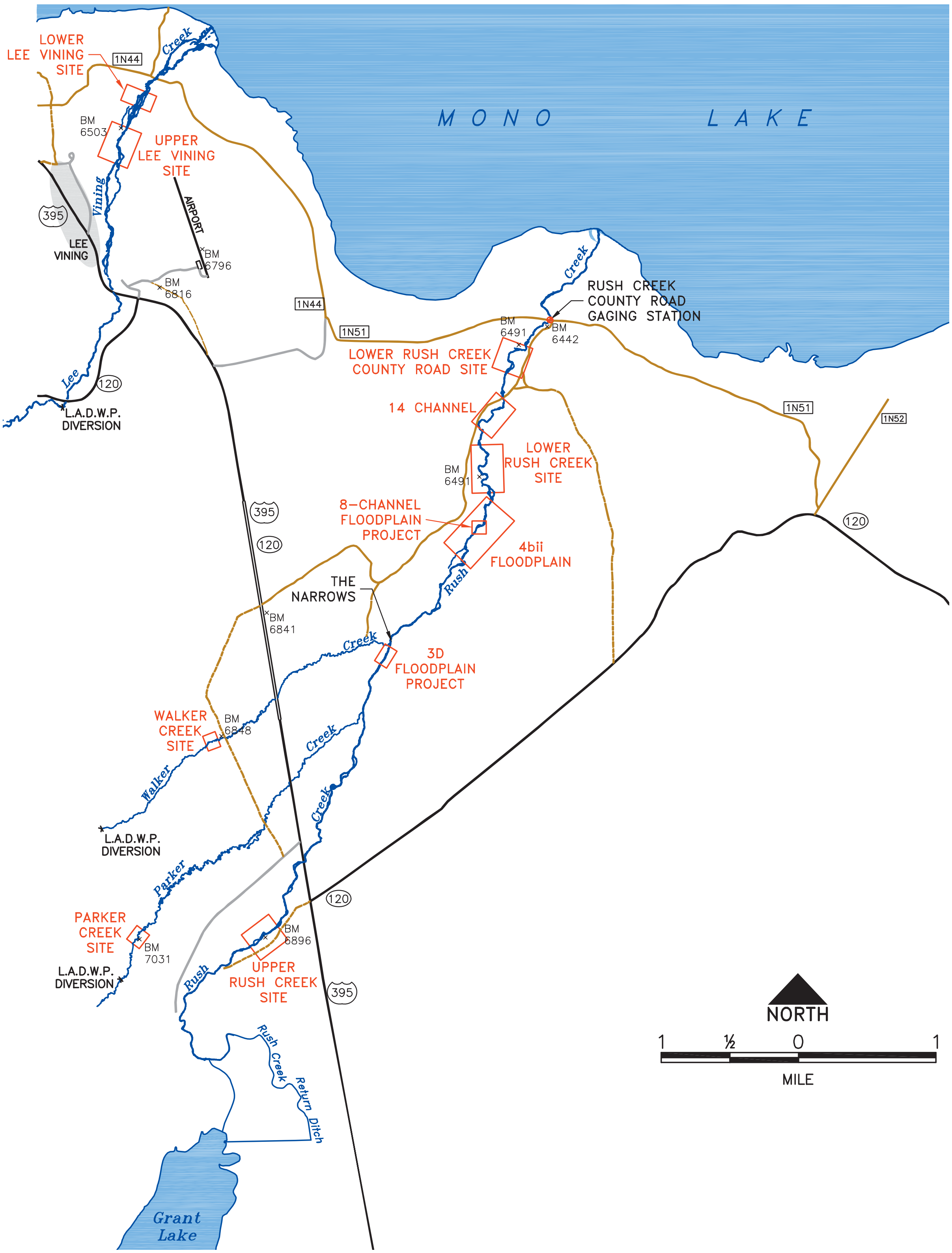


Figure 1. Location and study sites for the four Mono Basin tributaries: Rush, Parker, Walker, and Lee Vining creeks.

Table 1. Summary of hydrologic and geomorphic monitoring activities conducted on Rush Creek and Lee Vining Creek during the RY 2005 SRF and snowmelt runoff.

DATE	FLOW RELEASES		HYDROLOGIC SAMPLING				GEOMORPHIC SAMPLING		
	Rush Creek Return Ditch	Rush Creek Narrows	Synoptic Discharge (Rush Creek)	Synoptic Discharge (Lee Vining Creek)	Groundwater (piezometers)	Floodplain Mapping	Mobility Experiments	Bedload Transport	Floodplain Aggradation
1-May	49	72							
2-May	49	74							
3-May	49	75							
4-May	49	75							
5-May	49	77							
6-May	49	75							
7-May	49	74							
8-May	49	75							
9-May	50	80							
10-May	50	75					Tracer Rock and Scour Core Installation: Lee Vining Creek		Carpet Installation: Lee Vining Creek
11-May	50	74							
12-May	51	74					Tracer Rock and Scour Core Installation: Rush Creek		Carpet Installation: Rush Creek
13-May	51	74			3D and 8C				
14-May	51	76							
15-May	51	82							
16-May	52	107							
17-May	51	116							
18-May	48	107							
19-May	48	112							
20-May	49	119							
21-May	50	121							
22-May	51	124							
23-May	52	129							
24-May	51	133							
25-May	46	132							
26-May	46	137							
27-May	47	147			3D and 8C				
28-May	47	154		LVC BConn=17cfs LVC B1=100cfs					
29-May	47	152							
30-May	48	138							
31-May	48	130							
1-Jun	53	140			3D and 8C				
2-Jun	71	164							
3-Jun	99	185							
4-Jun	111	190							
5-Jun	111	187							
6-Jun	121	191			3D and 8C				
7-Jun	142	204		LVC BConn=24cfs LVC B1=52cfs					
8-Jun	168	223							
9-Jun	194	243							
10-Jun	212	260							
11-Jun	187	239							
12-Jun	161	217							
13-Jun	162	223							
14-Jun	163	232							
15-Jun	164	245							
16-Jun	164	250			3D and 8C				
17-Jun	164	242		LVC BConn=29cfs LVC B1=62cfs					
18-Jun	165	231							
19-Jun	182	240							
20-Jun	245	298	Rush 3D=35cfs Lower Rush=262cfs		3D and 8C			Lower Rush	

Table 1. Summary of hydrologic and geomorphic monitoring activities conducted on Rush Creek and Lee Vining Creek during the RY 2005 SRF and snowmelt runoff. Continued.

DATE	FLOW RELEASES		HYDROLOGIC SAMPLING				GEOMORPHIC SAMPLING		
	Rush Creek Return Ditch	Rush Creek Narrows	Synoptic Discharge (Rush Creek)	Synoptic Discharge (Lee Vining Creek)	Groundwater (piezometers)	Floodplain Mapping	Mobility Experiments	Bedload Transport	Floodplain Aggradation
21-Jun	314	367	Rush 8C(top)=1.9cfs Lower Rush=329cfs	LVC BConn=21cfs LVC B1=50cfs	8C			Upper Rush Lower Rush	
22-Jun	362	418	Upper Rush=345cfs Rush 3D=54 Rush 4Bii=13cfs Rush 8C(top)=3.2cfs Rush 8C(bot)=1.6cfs Lower Rush=381cfs		3D and 8C			Upper Rush Lower Rush	Sediment transport/ aggradation
23-Jun	402	461	Rush 3D=66cfs Rush 4Bii=26cfs Rush 8C(top)=3.3cfs Rush 8C(bot)=4.1cfs Rush 10C=162cfs		3D and 8C			Upper Rush Lower Rush	Sediment transport/ aggradation
24-Jun	402	465	Upper Rush=370cfs Rush 3D=63cfs Rush 8C(top)=4.1cfs Rush 8C(bot)=5.6cfs Lower Rush=460cfs		3D and 8C			Upper Rush Lower Rush	Sediment transport/ aggradation
25-Jun	401	465	Lower Rush=461cfs		3D and 8C			Upper Rush Lower Rush	Sediment transport/ aggradation
26-Jun	400	462							Sediment transport/ aggradation
27-Jun	402	462			8C			Upper Rush Lower Rush	
28-Jun	403	464							Sediment transport/ aggradation
29-Jun	403	467			3D and 8C	4, 8, 3D Floodplains			
30-Jun	389	461			8C			Upper Rush Lower Rush	Sediment transport/ aggradation
1-Jul	333	418			3D and 8C				Sediment transport/ aggradation
2-Jul	304	404							
3-Jul	276	382							
4-Jul	261	360							
5-Jul	261	356							
6-Jul	255	356							
7-Jul	232	343							
8-Jul	207	323							
9-Jul	195	308							
10-Jul	198	304							
11-Jul	198	306			3D and 8C				
12-Jul	195	306							
13-Jul	193	305							
14-Jul	192	298							
15-Jul	192	293							

Table 1. Summary of hydrologic and geomorphic monitoring activities conducted on Rush Creek and Lee Vining Creek during the RY 2005 SRF and snowmelt runoff. Continued.

DATE	FLOW RELEASES		HYDROLOGIC SAMPLING				GEOMORPHIC SAMPLING		
	Rush Creek Return Ditch	Rush Creek Narrows	Synoptic Discharge (Rush Creek)	Synoptic Discharge (Lee Vining Creek)	Groundwater (piezometers)	Floodplain Mapping	Mobility Experiments	Bedload Transport	Floodplain Aggradation
16-Jul	193	295							
17-Jul	192	295							
18-Jul	192	297							
19-Jul	191	292							
20-Jul	191	285							
21-Jul	190	286							
22-Jul	192	291							
23-Jul	191	288							
24-Jul	191	276				8 Floodplain			
25-Jul	190	268			8C				
26-Jul	190	257							
27-Jul	190	253							
28-Jul	180	241							
29-Jul	173	237							
30-Jul	165	227			3D and 8C				
31-Jul	154	212							
1-Aug	140	197							
2-Aug	115	167							
3-Aug	106	154							
4-Aug	102	148							
5-Aug	101	146							
6-Aug	101	147							
7-Aug	102	150							
8-Aug	99	151			3D and 8C				
9-Aug	91	139				4, 8, 3D Floodplains			
10-Aug	84	130							
11-Aug	65	109							
12-Aug	56	98							
13-Aug	51	91							
14-Aug	51	89							
15-Aug	51	89			3D and 8C				
16-Aug	50	97							
17-Aug	49	91							
18-Aug	48	86					Data Collection: Lee Vining Creek		
19-Aug	49	85	Lower Rush=78cfs				Data Collection: Rush Creek		

2.1.1 Rush Creek

The Wet-Normal runoff year class requires a baseflow release of 47 cfs and a Stream Restoration Flow (SRF) of 400 cfs for 5 days followed by 350 cfs for 10 days. Proposed modifications to the SRF releases were approved by the SWRCB and the Stream Scientists, and were designed to test the effects of an extended duration SRF on geomorphic processes (bed mobility and transport, floodplain deposition, bank erosion and channel migration) and groundwater processes (floodplain inundation, groundwater elevations, and soil moisture decay rate). The proposed hydrograph included a rapid ramp up to 350 cfs peak releases at the Mono Gate One Return Ditch (hereafter Return Ditch), eight days of 400 cfs release achieved with augmentation of 50 cfs from Lee Vining Creek, and a receding limb not to exceed 10% change per day.

The unimpaired Rush Creek Runoff estimate (modeled 'unregulated' flow) and Rush Creek at Damsite (actual inflow to Grant Lake) both peaked on June 16, with respective discharges of 541 cfs and 441 cfs (Figure 2, Table 2). The recurrence interval for the unimpaired estimate is approximately 2.4 years. The Rush Creek Runoff hydrograph had a long duration peak with 80 days exceeding 300 cfs, 40 days exceeding 400 cfs, and 5 days exceeding 500 cfs. The Rush Creek at Damsite hydrograph also had a long duration peak, with 46 days exceeding 400 cfs.

The SRF releases from the Return Ditch began June 1, 2005 and reached a 350 cfs release from the Ditch on June 23 (Figure 3). The Return Ditch release was combined with 50 cfs augmentation from Lee Vining Creek to achieve Rush Creek flows above the Narrows of 400 cfs (from June 23 to June 30). The ascending hydrograph limb had slightly higher daily releases than were planned, with a 10-day bench at or above 162 cfs. The final day of the 8-day peak period had a daily average value of 389 cfs, slightly less than the 400 cfs target, because flow changes were made by LADWP

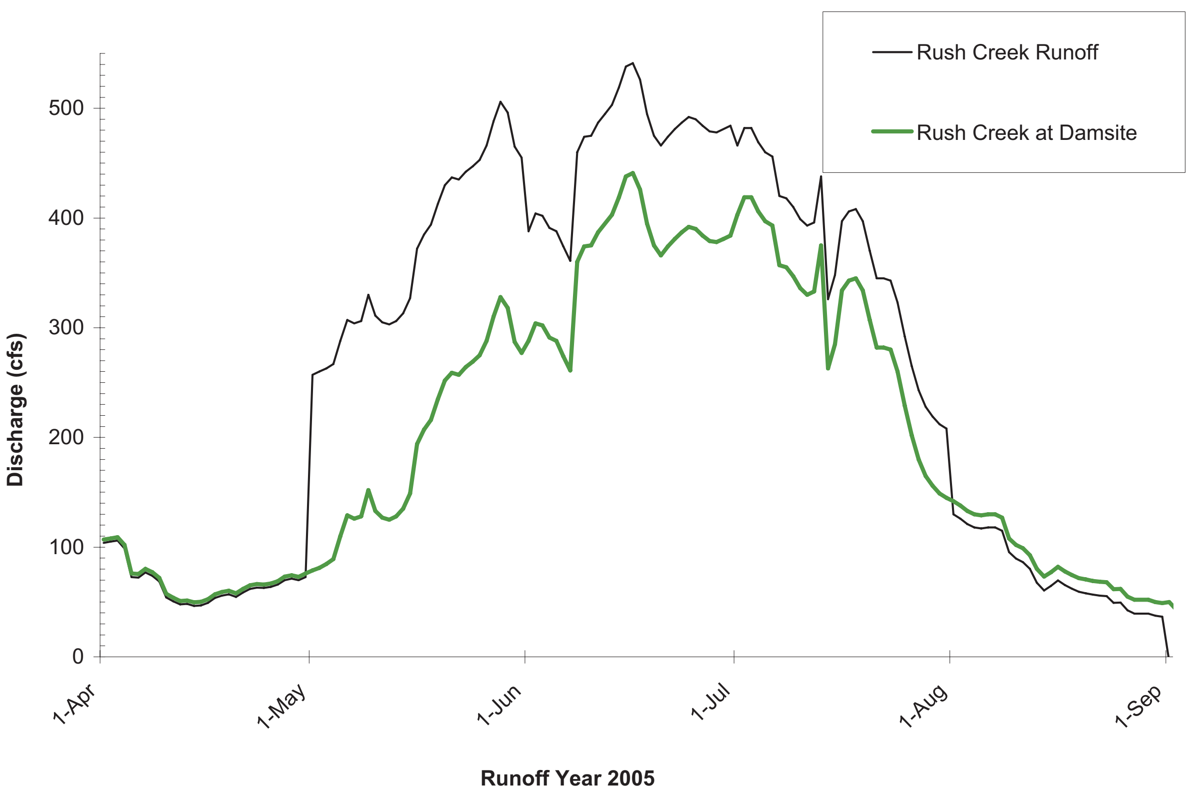


Figure 2. Annual hydrographs for Rush Creek Runoff and Rush Creek at Damsite for the first half of Runoff Year 2005-06.

Table 2. Summary of peak discharges and dates for the Mono Basin tributaries during the past 8 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	RY 2005	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	541	16-Jun-05
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	441	16-Jun-05
Rush Creek below 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	403	29-Jun-05
Rush Creek below 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	550	16-Jun-05
Rush Creek below 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	467	29-Jun-05
[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	286	29-Jun-05
[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	181	29-Jun-05
Rush Creek at County Road Culvert (5186)											151	8-Jun-02					402	29-Jun-05
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	374	28-May-05
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	372	28-May-05
[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	289	28-May-05
[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	83	28-May-05
[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	100	28-May-05
[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	272	28-May-05
[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	100	28-May-05
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	74	13-Jul-05
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	51	28-May-05

[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 gaged stations provide instantaneous peaks; stations that are calculated provide only the maximum daily average discharge;
[5] measured flow

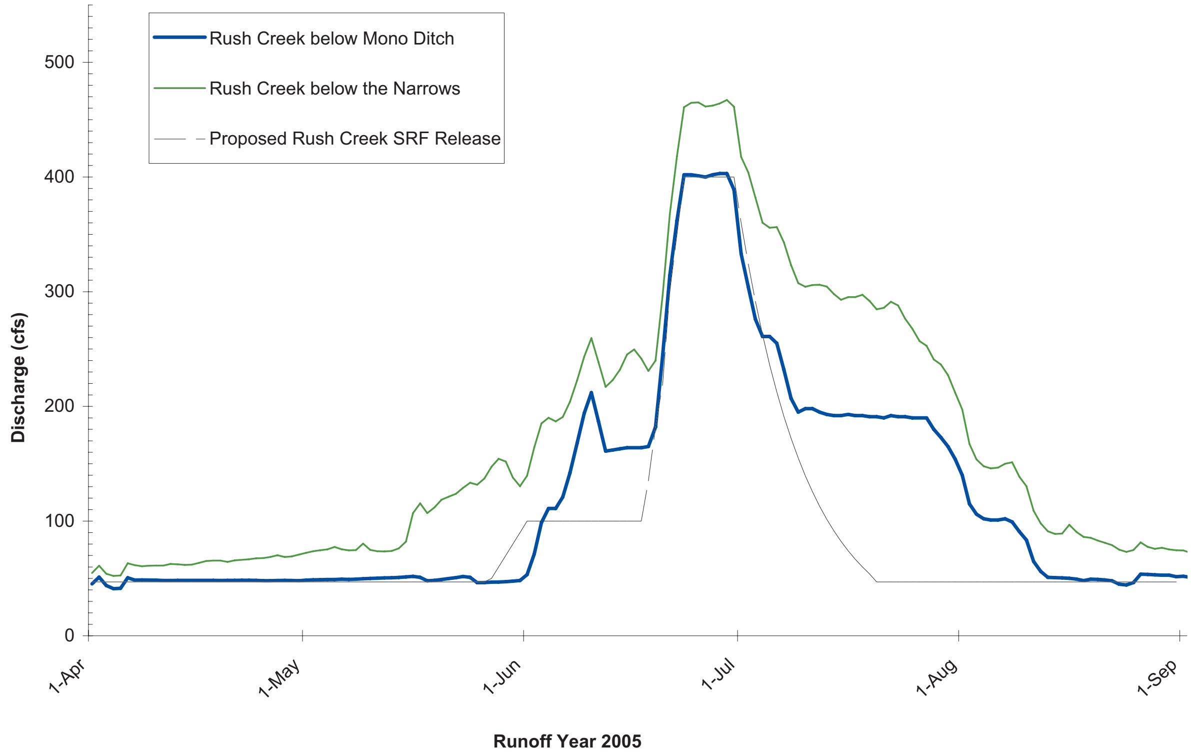


Figure 3. Annual hydrographs for Rush Creek below Grant Lake and below the Narrows for the first half of Runoff Year 2005-06.

in the afternoons to facilitate downstream fieldwork activities. The peak discharge was 403 cfs (daily average) on June 29, 2005. The descending limb of the hydrograph had an extended bench above 190 cfs for 18 days (July 9 to 27) that translated to flows below the Narrows above 280 cfs through July 23, 2005. This flow exceeded thresholds for entrances to side channels (e.g., 3D and 8 channels), thus generating distributary flows. A shorter bench of 5 days at 100 cfs occurred August 4 to 8.

Below the Narrows on Rush Creek, peak flows were higher due to contributions from Parker and Walker creeks. The estimated unimpaired (daily average) peak discharge (Rush Creek Runoff + Parker Creek + Walker Creek) was 627 cfs on June 16, 2005, with recurrence interval of 2.4 to 2.5 years on the unimpaired (below Narrows) record. The actual peak flow below the Narrows (calculated from Return Ditch releases + Lee Vining augmentation + Parker Creek + Walker Creek) was 467 cfs on June 29, 2005. This flow also had a recurrence interval of approximately 2.4 years (similar to the unimpaired estimate), but from the flood frequency analysis of regulated peak flows.

2.1.2 Lee Vining Creek

Lee Vining snowmelt runoff extended from approximately May 22 to August 7, 2005. Lee Vining Creek also had relatively large peak flows during the 2005 runoff season with the largest peak since 1998 (Figure 4) (Table 2). The SWRCB Order 98-05 requires baseflows of 54 cfs or the natural flow at the point of diversion (whichever is lowest), and for the peak flow to pass the diversion structure. The unimpaired ‘Lee Vining Creek Runoff’ estimate and the ‘Lee Vining Creek above Intake’ gage had daily average peak flows of 409 cfs (May 28) and 374 cfs (June 15), respectively. Recurrence intervals for these peaks were 2.7 years (using the unimpaired record) and 5.6 years (using the regulated record), respectively.

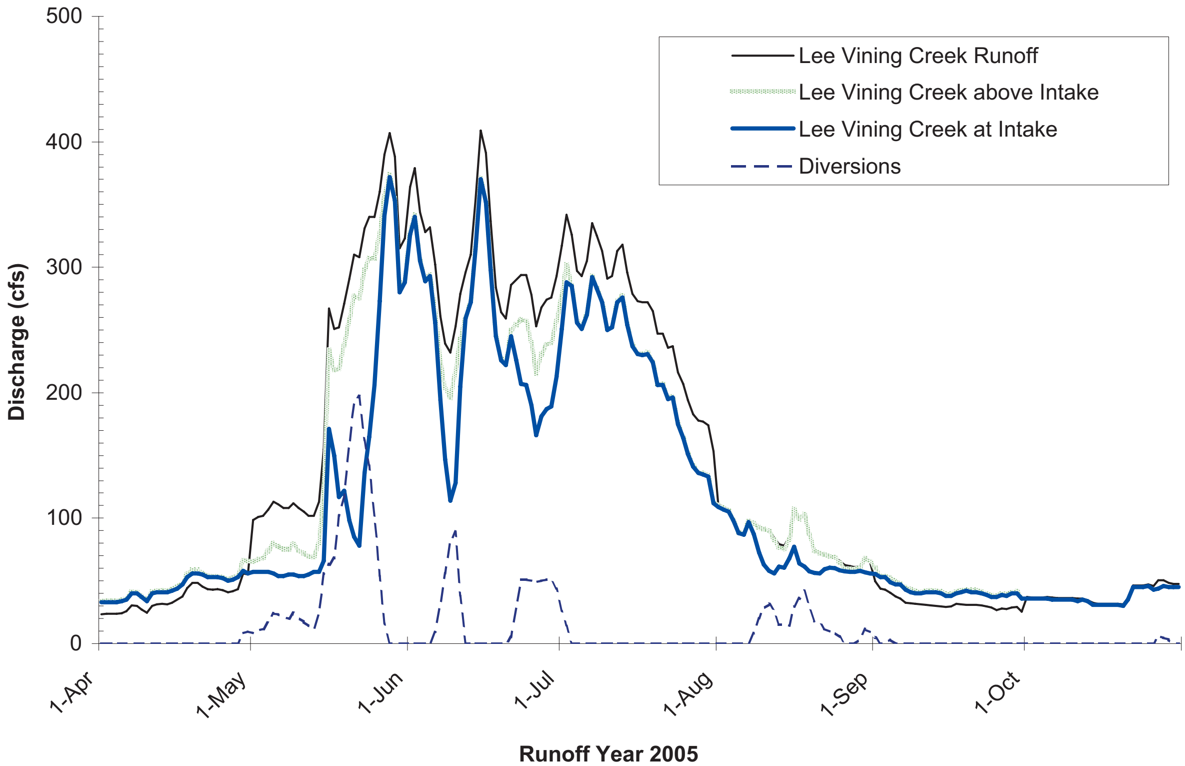


Figure 4. Annual hydrographs for Lee Vining Creek for the first half of Runoff Year 2005-06.

For Lee Vining Creek below the diversion structure there were at least three distinct peaks during the snowmelt: 372 cfs, 370 cfs, and 292 cfs daily average flows were recorded on May 28, June 15, and July 7, 2005, respectively. Several smaller, intermittent peaks also occurred. The 372 cfs peak on May 28 was the annual maximum daily average discharge in Lower Lee Vining Creek and had a recurrence interval of 5.6 years.

Flow diversion occurred on Lee Vining during four distinct periods: April 29 to May 27, June 6 to 11, June 21 to July 2, and August 8 to 25. Diversions totaled approximately 7,600 af. Diversions occurred during either ascending hydrograph limbs or during troughs between peaks and did not affect peak discharges in lower Lee Vining Creek. The descending limb of the hydrograph from July 13 to August 7 was preserved with no diversions. Lee Vining Creek had a gradual recession.

2.1.3 Parker and Walker creeks

Streamflows from Parker and Walker creeks were not diverted. The snowmelt runoff for these Rush Creek tributaries was similar to the Lee Vining Creek hydrograph: relatively long-duration snowmelt, numerous peaks, and gradual recession (Table 2). Peak daily average flow for Parker Creek was 74 cfs on July 13, 2005 (Figure 5). Peak daily average flow for Walker Creek was 51 cfs on May 28, 2005 (Figure 6). Both peaks were the largest since 1995. Flood frequency analyses have not been updated on these creeks; recurrence intervals are likely similar to those of Lee Vining Creek.

The timing of Parker Creek and Walker Creek peaks was different. Two distinct snowmelt periods were visible in the hydrographs, possibly explained by snowmelt in the lower, then upper watersheds, in succession. A shorter duration peak occurred near the end of May and a longer duration peak occurred just before the middle of July. On Parker Creek the May peak was smaller (56 cfs) than the July peak (74 cfs); the July peak flow period lasted nearly the entire month, and came just after the

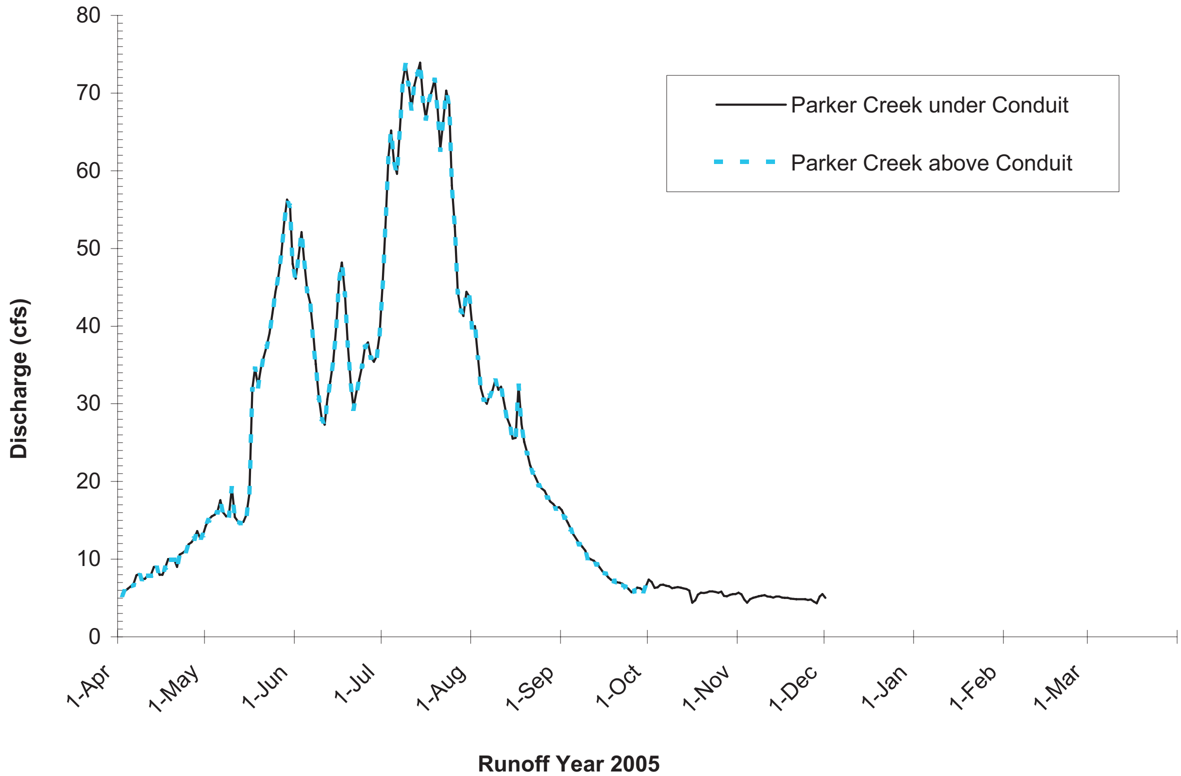


Figure 5. Annual hydrographs for Parker Creek for the first half of Runoff Year 2005-06.

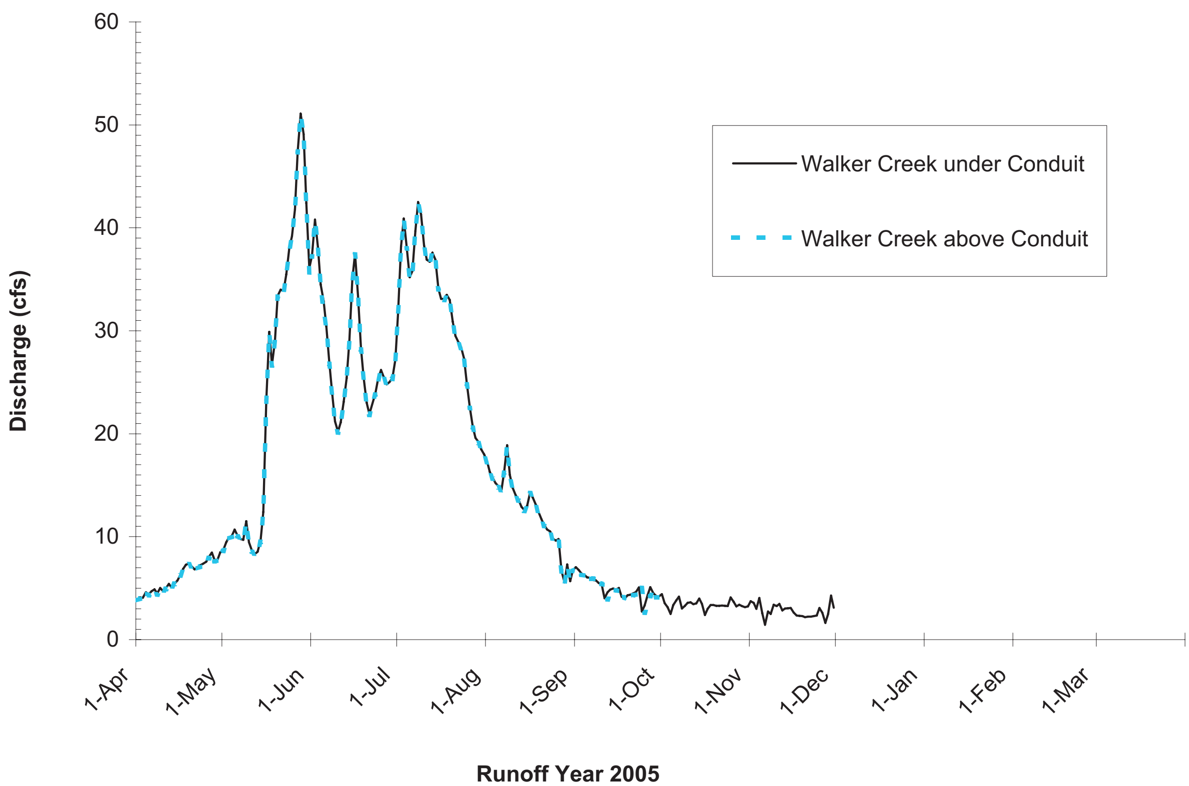


Figure 6. Annual hydrographs for Walker Creek for the first half of Runoff Year 2005-06.

Rush Creek SRF releases. On Walker Creek the May peak was dominant and of similar magnitude to Parker Creek, whereas the July peak period was much smaller in magnitude. In 2005, DWP's operational flexibility was limited because of the bedload sampling fieldwork scheduled during the SRF releases. Had Rush Creek SRF releases been delayed to complement Parker Creek's peak snowmelt, the Rush Creek peak below the Narrows could have attained 512 cfs. In future years, piggybacking SRF releases on top of tributary peaks may be attainable, and DWP operations could target Parker Creek because it has larger magnitude floods and the timing is more similar to Rush Creek than is Walker Creek. The average flow contributed to lower Rush Creek by Parker and Walker creeks combined was 94 cfs which significantly increased the extended duration bench from the 190 to 200 cfs range to the 290 to 304 cfs range during the snowmelt recession. These flows in lower Rush Creek accessed side channels and likely sustained higher groundwater elevations during July as a result.

2.2 Synoptic Streamflow Gaging

2.2.1 Lower Rush Creek Gage

LADWP provides streamflow data at several upstream sites on Rush and Lee Vining creeks. During the 2005 snowmelt we established two additional gaging sites to monitor streamflow on downstream reaches. The lower Rush Creek gage was installed on the main channel approximately 400 ft downstream of the 10 Channel confluence and 100 ft upstream of XS -9+82 (henceforth referred to as the lower Rush Creek gage). The objectives for collecting stream discharge data at the Lower Rush Creek site were:

(1) Compare discharge released into upper Rush Creek from the Return Ditch (and Lee Vining augmentation) to the discharge flowing out of Rush Creek into Mono Lake during the 2005 SRF releases;

(2) Identify thresholds and quantify streamflow losses to the Rush Creek floodplains and groundwater;

(3) Test the hypothesis that snowmelt runoff stored on floodplains and in the shallow groundwater aquifer during peak runoff would be yielded back to the stream during and shortly after the snowmelt recession.

The gage became operable June 12, 2005 and will be maintained into the foreseeable future. The gage is equipped with a Global WL14 water level logger that records water surface stage height. The datalogger is installed in a PVC housing, attached to a fencepost, and has a flexible conduit that runs underground into the channel. The pressure transducer sensor is secured inside the conduit and is attached to the base of the staff plate. Stream stage-height data were recorded every 15 minutes during the summer. During the 2005 SRF releases, discharge was measured at flows ranging from 78 cfs to 461 cfs, and a stage-discharge rating curve was developed (Figure 7). Discharge was measured by wading at flows up to 300 cfs, then from the cataraft (used in bedload transport measurements) at flows above 300 cfs. Stage data were converted to discharge using the rating curve. The hydrograph data are presented as daily average flow for comparison to data from LADWP. The hydrograph captured the ascending limb of the SRF releases, the peak discharge, and a portion of the snowmelt recession.

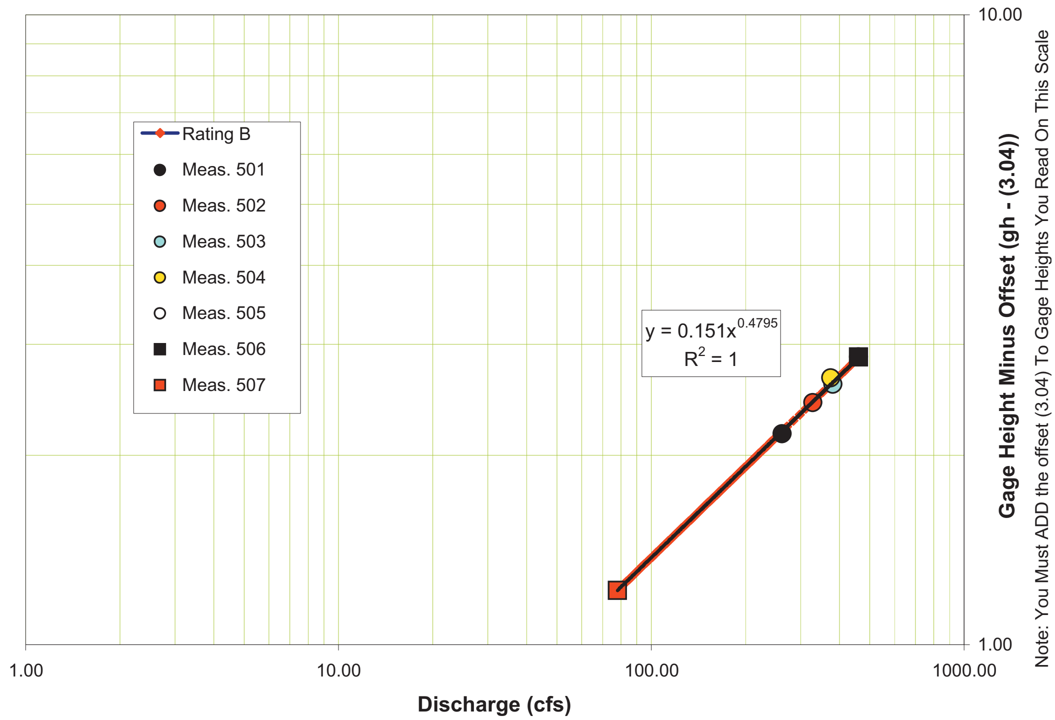


Figure 7. Stage discharge rating curve developed by McBain and Trush during 2005 for the Lower Rush Creek XS -9+82 gage.

The resulting hydrograph was different from the LADWP hydrograph (Rush Creek below the Narrows, Figure 8). The daily average peak flow of 446 cfs estimated from the lower Rush Creek gage was lower than the LADWP estimated peak discharge (467 cfs below the Narrows) and differed from on-site field measurements of 460 cfs and 461 cfs (Table 1). Conversely, at discharges below approximately 300 cfs the lower Rush Creek gage predicted higher flows than the LADWP flows below the Narrows. Because the rating curve contained only one discharge measurement at flows less than 260 cfs (Figure 7), the rating curve and resultant gage data and interpretations reported here are still preliminary.

The difference between the upper and lower Rush Creek hydrographs may be explained by a number of factors, such as: (1) attenuation of peak flow as flow releases traveled the length of Rush Creek from the Return Ditch to Mono Lake, (2) inundation and retention of floodwaters on floodplains, and consequent loss to groundwater and/or evaporation, (3) inflow from the groundwater aquifer in Lower Rush Creek, (4) bias in the rating curve from lack of low-flow data points, and/or drift in the data recorder (a condition that is not uncommon to Global dataloggers and will be evaluated and corrected once all data are downloaded from the datalogger), or (5) a combination of factors. The gage was last downloaded on August 8, 2005, so subsequent streamflow data were not yet available for the latter stages of the receding hydrograph limb. The rating curve will require additional discharge measurements, particularly at low and mid-range flows (from 50 cfs or lower baseflows up to 200 cfs). Our analyses will be completed when additional data are available from the datalogger, and with a better rating curve for low discharges.

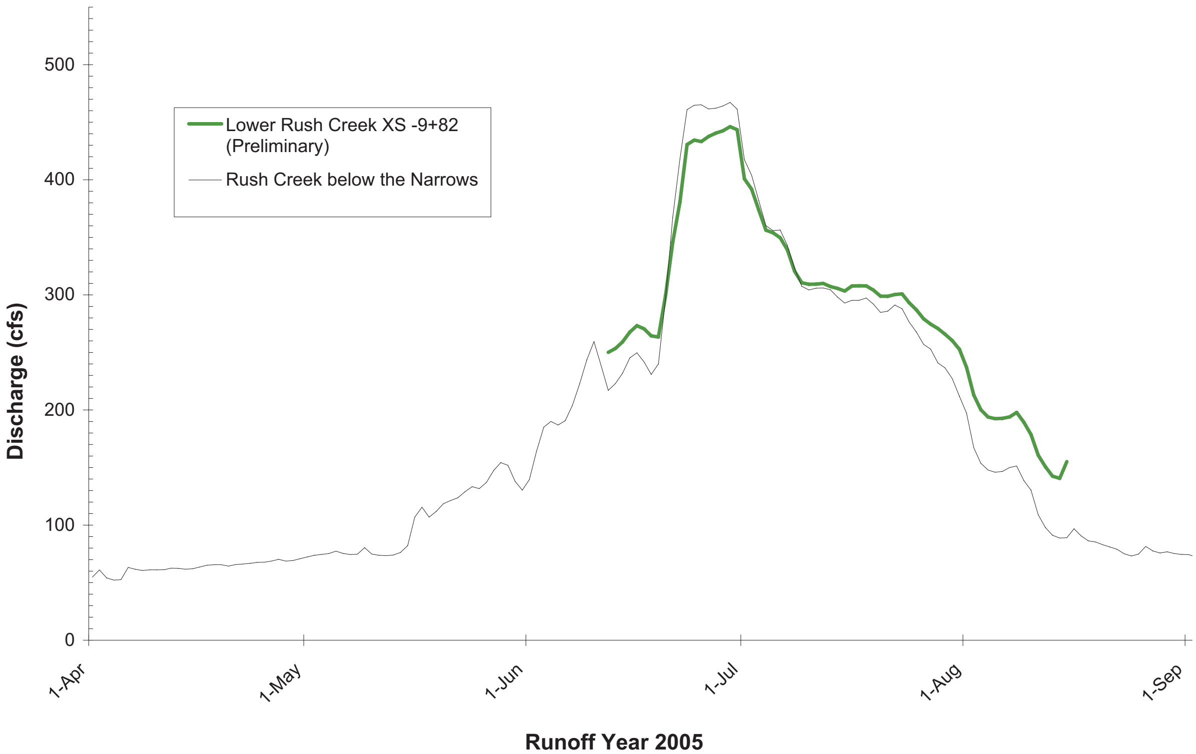


Figure 8. Daily average hydrograph for the Lower Rush Creek XS -9+82 gage, plotted with the LADWP hydrograph for Rush Creek below the Narrows.

2.2.2 Lower Lee Vining Creek Gage

During the 2005 runoff season we installed three dataloggers on different sections of Lee Vining Creek to collect stream stage data during the snowmelt. Dataloggers were installed May 26, 2005 just prior to the annual peak flow on May 28, 2005. Gaging locations were: (1) the upper main channel at XS 9+31, (2) upper main channel at XS 3+45 in association with the floodplain aggradation experiment, and (3) lower B-1 channel also in association with a floodplain aggradation experiment. The two dataloggers on the upper main channel were not vented properly and the data were not usable. The lower B-1 channel datalogger was downloaded and removed August 15, 2005. The objectives for collecting stream stage and discharge measurements in Lower Lee Vining were:

(1) Compare discharge from 'Lee Vining at Intake' to the discharge in the lower Lee Vining Creek distributary reaches during the 2005 snowmelt;
(2) As stated in Order 98-05 1.b.(2)(a), "Evaluate the effect on Lee Vining Creek of augmenting Rush Creek flows with… water from Lee Vining Creek in order to provide SRFs" by comparing water surface stage changes between diverted and un-diverted conditions.

During the snowmelt period, five sets of discharges were measured on Lee Vining Creek. The measurements were collected at the lower B-1 Channel and the B-Connector Channel because flows in the upper main channel were too high for wading. Flows in the upper main and A4 channels were then estimated based on the total discharge from 'Lee Vining at Intake'. The last set of measurements included the upper main channel on July 30, 2005. The discharge measurements produced a rating curve for the lower B-1 Channel, allowing stream stage data to be converted to a continuous discharge record (Figure 9).

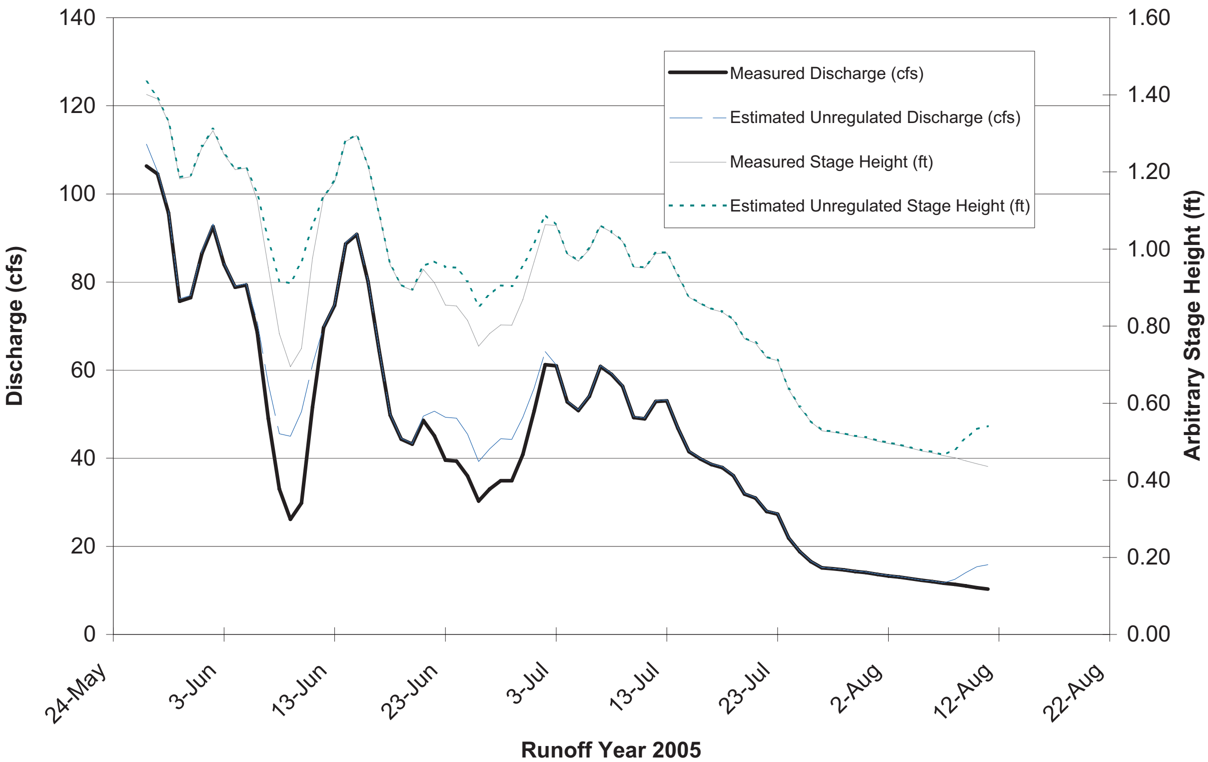


Figure 9. Daily average hydrograph for Lower Lee Vining Creek B-1 Channel plotted with the LADWP hydrograph for Lee Vining Creek at Intake.

The effect on Lee Vining Creek of flow diversions for augmentation was evaluated using the following procedure. We used the daily average flow from our stream gage on the B-1 Channel and the 'Lee Vining Creek at Intake' (LADWP data) (Figure 9) to determine the percentage of total flow in the B-1 channel. This percentage was then multiplied by the 'Lee Vining above Intake' LADWP data to estimate flow in the B-1 if no Lee Vining Creek diversions had occurred. The estimated and measured B-1 streamflows were then converted back to stage height to estimate the stream stage change from the diversions (Table 3). If substantial, this change in stage could affect groundwater elevations and riparian plant initiation or recruitment. For example, cottonwood seedlings can survive a maximum rate of change up to 0.08 ft/day (or 2.5cm/day). Our calculations determined that flow diversions from Lee Vining up to 89 cfs created approximately seven days in which the daily stage change exceeded 2.5 cm, and thus could have caused cottonwood seedling desiccation. Diversions in May were higher, peaking at 197 cfs, but these diversions were not recorded by our gage. The timing of the diversions and consequent stage changes was critical to determining impacts. Early season diversions (April-June) are less of a threat to riparian vegetation. Early diversions from Lee Vining in 2005 generally appeared well-timed, with larger diversions taken from the ascending hydrograph limb, but moderate diversions from troughs between peaks may have compromised cottonwood survival some days (Figure 9, Table 3). Small diversions from latter stages of the snowmelt recession did not affect stage change. Snowmelt peaks were allowed to pass.

2.2.3 Other Synoptic Discharge Measurements

In addition to discharge measurements collected at the lower Rush Creek and Lee Vining Creek B-1 gages, we measured discharge at several other locations during the SRF releases, including the 3D Side Channel, the 8 Channel, and the 4bii Channel.

Table 3. Lee Vining Creek discharge at Intake and from the gage installed at the B-1 Channel, used to estimate the stage changes resulting from Lee Vining Creek diversions for augmentation of Rush Creek SRF releases. There were no "unregulated" days with stage change > 2.5 cm/day.

	Lee Vining Creek Discharge		Lower B-1 Channel					
Date	above Intake (cfs)	below Intake (cfs)	Measured Discharge (cfs)	% of Total Flow in B-1	Estimated Unregulated Discharge (cfs)	Measured Stage Height (ft)	Estimated Unregulated Stage Height (ft)	Regulated Days with Stage Change > 2.5 cm/day
27-May	357	341	106.3	31%	111	1.40	1.4	
28-May	374	372	104.5	28%	105	1.39	1.4	
29-May	355	353	95.6	27%	96	1.3	1.3	
30-May	282	280	75.6	27%	76	1.2	1.2	30-May
31-May	290	288	76.4	27%	77	1.2	1.2	
1-Jun	328	326	86.5	27%	87	1.3	1.3	
2-Jun	342	340	92.6	27%	93	1.3	1.3	
3-Jun	306	305	84.0	28%	84	1.2	1.2	
4-Jun	290	289	78.8	27%	79	1.2	1.2	
5-Jun	294	293	79.3	27%	80	1.2	1.2	
6-Jun	265	256	68.6	27%	71	1.1	1.1	6-Jun
7-Jun	225	194	49.0	25%	57	1.0	1.0	7-Jun
8-Jun	203	147	33.0	22%	46	0.8	0.9	8-Jun
9-Jun	196	114	26.2	23%	45	0.7	0.9	9-Jun
10-Jun	217	128	29.8	23%	51	0.7	1.0	
11-Jun	243	205	51.7	25%	61	1.0	1.1	
12-Jun	260	259	69.6	27%	70	1.1	1.1	
13-Jun	273	272	74.7	27%	75	1.2	1.2	
14-Jun	315	314	88.7	28%	89	1.3	1.3	
15-Jun	371	370	90.8	25%	91	1.3	1.3	
16-Jun	353	352	80.1	23%	80	1.2	1.2	
17-Jun	299	298	64.5	22%	65	1.1	1.1	17-Jun
18-Jun	246	245	49.8	20%	50	1.0	1.0	18-Jun
19-Jun	227	226	44.3	20%	45	0.9	0.9	
20-Jun	223	222	43.2	19%	43	0.9	0.9	
21-Jun	250	245	48.6	20%	50	0.9	1.0	
22-Jun	254	226	45.1	20%	51	0.9	1.0	
23-Jun	258	207	39.5	19%	49	0.9	1.0	
24-Jun	257	206	39.3	19%	49	0.9	1.0	
25-Jun	240	190	36.0	19%	45	0.8	0.9	
26-Jun	215	166	30.3	18%	39	0.7	0.9	
27-Jun	231	181	33.0	18%	42	0.8	0.9	
28-Jun	238	187	34.9	19%	44	0.8	0.9	
29-Jun	240	189	34.9	18%	44	0.8	0.9	
30-Jun	257	213	40.8	19%	49	0.9	1.0	
1-Jul	277	251	50.7	20%	56	1.0	1.0	
2-Jul	302	288	61.2	21%	64	1.1	1.1	
3-Jul	286	285	61.0	21%	61	1.1	1.1	
4-Jul	257	256	52.8	21%	53	1.0	1.0	
5-Jul	252	251	50.8	20%	51	1.0	1.0	
6-Jul	263	262	54.0	21%	54	1.0	1.0	
7-Jul	293	292	60.8	21%	61	1.1	1.1	
8-Jul	284	283	59.0	21%	59	1.0	1.0	
9-Jul	273	272	56.3	21%	57	1.0	1.0	
10-Jul	251	250	49.3	20%	49	1.0	1.0	
11-Jul	253	252	49.0	19%	49	1.0	1.0	
12-Jul	273	272	52.9	19%	53	1.0	1.0	
13-Jul	277	276	53.0	19%	53	1.0	1.0	
14-Jul	255	254	46.8	18%	47	0.9	0.9	
15-Jul	238	237	41.5	18%	42	0.9	0.9	
16-Jul	232	231	39.9	17%	40	0.9	0.9	
17-Jul	231	230	38.6	17%	39	0.8	0.8	
18-Jul	232	231	37.9	16%	38	0.8	0.8	
19-Jul	225	224	36.0	16%	36	0.8	0.8	
20-Jul	207	206	31.9	15%	32	0.8	0.8	
21-Jul	207	206	30.9	15%	31	0.8	0.8	
22-Jul	196	195	27.9	14%	28	0.7	0.7	
23-Jul	197	196	27.3	14%	27	0.7	0.7	
24-Jul	176	175	21.9	13%	22	0.6	0.6	
25-Jul	165	164	18.8	11%	19	0.6	0.6	
26-Jul	152	151	16.5	11%	17	0.6	0.6	
27-Jul	142	141	15.1	11%	15	0.5	0.5	
28-Jul	137	136	14.9	11%	15	0.5	0.5	
29-Jul	136	135	14.7	11%	15	0.5	0.5	
30-Jul	134	133	14.3	11%	14	0.5	0.5	
31-Jul	113	112	14.1	13%	14	0.5	0.5	
1-Aug	110	109	13.6	13%	14	0.5	0.5	
2-Aug	108	107	13.3	12%	13	0.5	0.5	
3-Aug	106	105	13.0	12%	13	0.5	0.5	
4-Aug	99	98	12.7	13%	13	0.5	0.5	
5-Aug	89	88	12.3	14%	12	0.5	0.5	
6-Aug	88	87	12.0	14%	12	0.5	0.5	
7-Aug	98	97	11.6	12%	12	0.5	0.5	
8-Aug	96	87	11.4	13%	13	0.5	0.5	
9-Aug	93	73	11.0	15%	14	0.5	0.5	
10-Aug	91	63	10.6	17%	15	0.4	0.5	
11-Aug	90	58	10.3	18%	16	0.4	0.5	
12-Aug	83	56	10.0	18%	15	0.4	0.5	
13-Aug	77	62	9.7	16%	12	0.4	0.5	
14-Aug	75	60	9.4	16%	12	0.4	0.5	
15-Aug	83	68	9.2	13%	11	0.4	0.5	

<u>3D Side Channel.</u> Four measurements were taken in the 3D side channel between June 20 to 24; discharge peaked at 66 cfs on June 23, 2005 (Table 1). We were unable to observe when flow first accessed the 3D side channel, but estimated this to be during the first week of June when discharge from the Return Ditch ramped up from 99 cfs to 212 cfs (June 3 to 10). Discharge remained above 160 cfs through the duration of the SRF releases until approximately the first week of August when flows receded below 100 cfs, and the 3D side channel presumably went dry.

<u>8 Channel.</u> Streamflow was first observed entering the 8 Channel on June 6, 2005 (Rush Creek below Narrows = 191 cfs), with water initially seeping through the willow berm and flowing approximately 5 ft down the 8 Channel. By June 16 (Rush Creek below Narrows = 250 cfs), the 8 Channel was flowing for approximately 650 ft before flow went sub-surface. On June 20 (Rush Creek below Narrows = 298 cfs), surface flow had traveled nearly to Piezometer 8C-6. By June 22 (Rush Creek below Narrows = 418 cfs) the 8 Channel was reconnected to the main Rush Creek channel. During the SRF releases, measurements were taken on four days. The latter three days included measurements at the upper and lower ends of the side channel (Table 1). The highest measured flow in the 8 Channel was 5.6 cfs on June 24. Some surface flow from the 8 Channel meandered past the lone Jeffery Pine near Piezometer 8C-8.

<u>4bii Channel.</u> Gaging the total discharge conveyed onto the 4 Floodplain was difficult because flow escaped the main channel in several locations and did not coalesce into a single channel at any point along the 4 Floodplain. Despite this limitation, two measurements were taken during the SRF releases on June 22 and 23 at the upper end of the 4bii Channel where most flow was concentrated into a single channel. The highest measurement occurred on June 23, when 26 cfs was measured (Table 1). Field observations during the RY 2004 and 2005 SRF releases at the entrance of the 4bii Channel documented no flow entering the 4bii Channel when Rush Creek mainstem flows were 140 cfs, while flow approximately 0.5 ft deep was entering the 4bii Channel when Rush Creek mainstem flows were 270 cfs.

<u>Vestal Springs.</u> We relocated five springs known as the “Vestal Springs” situated on the east-facing meadow on Rush Creek left bank below the Narrows. These springs were monitored to determine if a wet runoff year would produce high spring discharge, comparable to previous years’ observations. Each spring (labeled A-E) has a V-notch weir installed to measure stage emanating from the springs, which can be converted to discharge. The weir locations were mapped on 2003 aerial photos to within approximately 5-10 ft, and locations were digitized. Several other springs in the vicinity appeared to yield as much or more unmeasured flow as the V-notch weirs, although there was no mechanism for measuring this flow. The V-notch weirs were read seven times during the 2005 snowmelt runoff period, beginning May 28 and ending October 12, 2005 (Table 4). Previous measurements date back to at least June 1995 (Reis 1996). We plotted our 2005 measurements at Weir B (which had the most flow) along with the 1995 data (Figure 10). The data indicated that while early season yield may have been lower in 2005 than in 1995, the peak flow at Weir B was comparable (0.035 cfs in 1995 compared to 0.032 cfs in 2005). The peak streamflow was higher and later in 1995 (647 cfs on July 31, 1995) than in 2005 (467 cfs on June 29, 2005). The weir recession also appeared to mirror the 1995 yield.

2.3 Temperature Monitoring

Water temperatures were monitored in Rush, Parker, Walker, and Lee Vining creeks for the sixth consecutive year, using Onset Optic Stowaway temperature thermographs (Appendix A). The twelve thermograph locations were described in the RY 2004 annual report (McBain & Trush 2005). Two thermographs were lost during the 2005 snowmelt: one on lower Parker Creek and one on lower Lee Vining Creek at the County Road crossing. Both were replaced in October 2005.

Table 4. Vestal Springs flow data (cfs) collected during the RY 2005 snowmelt period.

Date	Weir-A	Weir-B	Weir-C	Weir-D	Weir-E
6/21/2005	0.000	0.009	0.000	0.000	0.000
6/23/2005	0.000	0.009	0.000	0.000	0.000
6/25/2005	0.000	0.012	0.000	0.000	0.000
6/30/2005	0.000	0.009	0.000	0.000	0.000
8/15/2005	0.002	0.032	0.002	0.000	0.000
10/12/2005	0.006	0.024	0.002	0.000	0.002

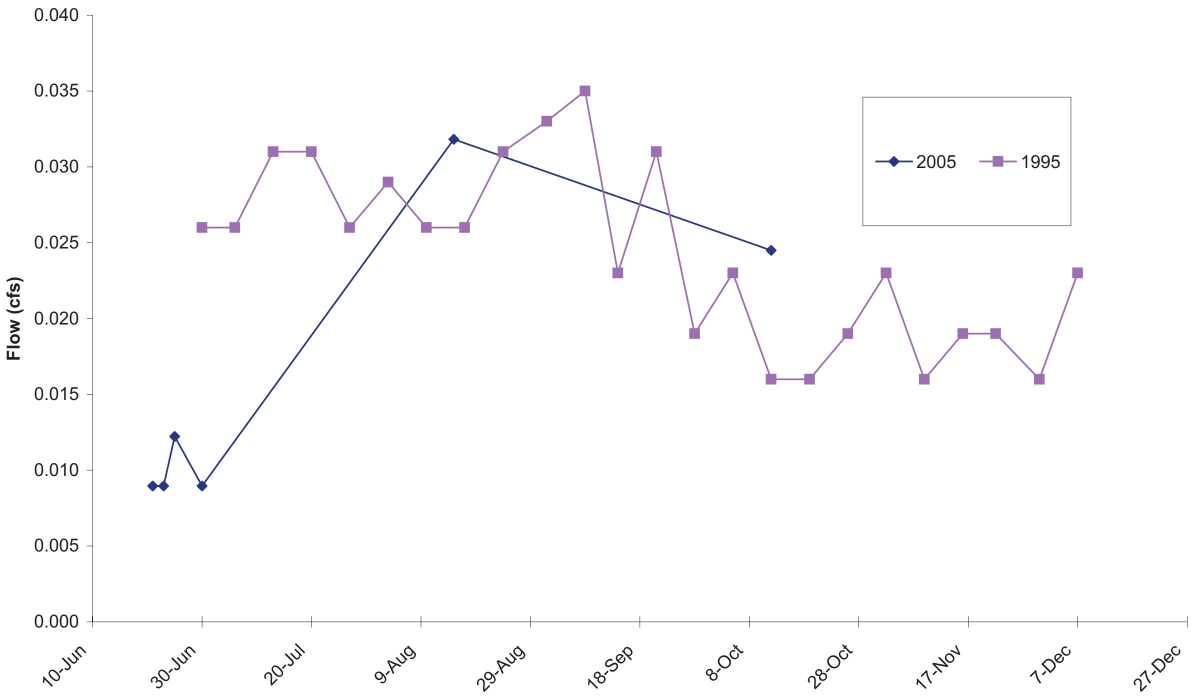


Figure 10. Vestal Springs Weir-B discharge for 1995 and 2005 snowmelt, estimated from the V-notch weir stage height.

In general, average and maximum water temperatures were colder in RY 2005 than in previous years' data (Appendix A). Colder water temperatures were the result of the Wet-Normal runoff year type that brought large snowmelt floods and longer duration high flows. As discussed in Section 2.1, snowmelt recession on Rush and Lee Vining creeks extended into August 2005 and did not return to summer baseflow levels until late-August, thus bridging the hottest summer months with higher-than-average streamflows.

2.3.1 Rush Creek Water Temperatures

On Rush Creek, the daily average temperature at County Road ranged from 45 to 49°F and was several degrees warmer than Lee Vining Creek. The average and maximum summer temperatures at the Return Ditch were several degrees colder than in several past years; the 2002 and 2003 average summer temperatures at the Return Ditch were 64°F compared with 57°F. Daily average summer water temperatures in the Return Ditch had been increasing between 2000 and 2003, possibly due to the lowering of Grant Lake elevation. The trend in increasing water temperatures as water flows downstream in Rush Creek, which in past years produced annual summer maximum water temperatures of 74 to 75°F at the County Road, was also much weaker in 2005. The annual maximum temperatures in 2005 at the Return Ditch, Old 395 Bridge, and the Meadows were 65, 66, and 68°F, respectively. The maximum annual temperatures at these sites occurred during a two-week span at the end of August, but not on the same day.

The Return Ditch water temperatures are influenced by Grant Lake temperatures, but lake temperature effects diminish by the time flow reaches the Old 395 Bridge area. A comparison of summer 2005 at the Return Ditch and Old 395 Bridge showed that while the summer minimum and average temperatures were identical, the Old 395 Bridge site had a slightly higher summer maximum (66°F at Hwy 395 compared to 65°F at the Return Ditch) and higher daily temperature fluctuations (9°F at Hwy 395 compared to 12°F at the Return Ditch). Maximum daily temperature fluctuations increased from the Old 395 Bridge downstream to the Narrows, ranging from 16 to 21°F at the Narrows. Temperature fluctuations remained in this range at the County Road, suggesting the influence of Grant Lake water temperatures was replaced by ambient temperatures by the time flow reached the Highway 395. Daily temperature fluctuations of this range (16 to 20°F) along the entire lower Rush Creek bottomlands are less favorable to resident trout populations than the more consistent temperatures in the Return Ditch and downstream to Hwy 395.

Winter water temperatures averaging 35 to 37°F have been consistent along the entire length of Rush Creek. Maximum winter temperatures were warmer in lower Rush Creek, reaching into the lower-to-mid 50's°F, whereas the Return Ditch maximum winter temperatures remained below 44°F.

2.3.2 Lee Vining Creek Water Temperatures

Lee Vining Creek water temperatures were slightly colder year-round than Rush Creek. Annual maximum temperatures remained below 69°F, while daily average temperatures ranged from 42 to 46°F. The Lee Vining A4 Channel appeared to have warmer water temperatures than the Lee Vining mainstem, although we have not collected enough data at both sites simultaneously to confirm this. The single record from 2004 showed annual maximum temperatures for Lee Vining Creek at the bottom of the A4 Channel of 69°F and at the County road of 66°F. Daily temperature fluctuations during summer months had a narrower range than Rush Creek, and maximum daily temperature did not fluctuate more than 18°F.

The timing of Lee Vining Creek annual maximum temperatures is a better indicator of the timing of natural peak water temperatures in the eastern Sierra than Rush Creek (because of the effects of Grant Reservoir). Six years of water temperature data from the B1 Channel in Lee Vining Creek show that the timing of the annual maximum temperature was consistent: July 30, 2000; August 7, 2001; August 16, 2002; August 20, 2003; August 10, 2004; August 9, 2005. The first three weeks of August provided the warmest water temperatures on Lee Vining; by the end of August, temperatures began to cool.

2.4 Groundwater Dynamics

The Lee Vining Creek snowmelt hydrograph and Rush Creek SRF releases help sustain existing vegetation within both stream corridors by raising the groundwater table and making water more available to plants. But does water availability remain longer than it would otherwise, if there had been no release, once high flows have receded? We call this potential lingering water availability the snowmelt hydrograph's 'signature' on the floodplain. A groundwater signature extending beyond August (or later) may allow vegetation to bridge the critical summer months, and encourage seedling germination that would expand the riparian corridor in wetter runoff years. Is the snowmelt signature real, is it significant ecologically, and can it be managed to revitalize and restore floodplain vegetation? The first step was detection. A straightforward strategy for detecting a snowmelt hydrograph signature is to install piezometers in a floodplain, then measure groundwater elevation in the piezometers before, during, and after releasing a high flow.

In RY 2004 groundwater elevation was measured on the 8 Floodplain of the Rush Creek bottomlands. The groundwater's elevational response to the 412 cfs instantaneous peak below the Narrows (RY 2004) was almost immediate if the piezometer monitored was close to the mainstem channel, but delayed if located farther away. The groundwater table in Piezometer 8C-4, only 55 ft from the mainstem left bank, responded immediately (Figure 13 in McBain and Trush 2005). But the groundwater elevation in Piezometer 8C-6, 445 ft from the mainstem bank, lagged considerably (Figure 14 in McBain and Trush 2005). Groundwater table elevations in both piezometers immediately after the high flow release, including the recession limb (ending late-June), were higher than before the release.

2.4.1 2005 Field Season Overview

Shallow groundwater was again monitored with piezometers in RY 2005. The critical difference between RY 2004 and RY 2005 was not the difference in flood peak magnitude, but the opening of the 8 Channel to allow flows with a much longer duration to enter the side channel. The observations of RY 2005 will be discussed below, as well as how groundwater conditions differed at the 8-channel as a result of the side channel being opened up.

Piezometers and staff plates installed at the Rush Creek 3D Floodplain and the 8 Floodplain were used to collect surface and groundwater data before, during, and after the SRF releases. At the 3D Floodplain eight piezometers and nine staff plates were monitored along the Rush Creek main and side channels, with one continuously recording datalogger deployed in piezometer 3D-8. At the 8 Floodplain, two additional piezometers were installed in May 2005 bringing the piezometer total to eight. Two piezometers had dataloggers installed for continuous data collection (8C-1 and 8C-8). Three staff plates were in place along the Rush Creek channel. In the Rush Creek bottomlands, the 8 and 4bii floodplains were mapped on June 28, 2005 and August 9, 2005 to show wetted and inundated areas. Field crews also monitored groundwater elevations at piezometers on Lee Vining Creek. One Lee Vining Creek piezometer (B-3) was equipped with a continuously recording datalogger.

<u>8 Channel and Floodplain.</u> Groundwater and stream stage data were collected in the current runoff year from May 13 to October 10, 2005 (Table 4). Groundwater data for RY 2004 and 2005 were then plotted and compared to adjacent stream stage data from staff plate readings (where available) and relative to ground surface elevation (Appendix B). Given the same side channel entrance conditions, these charts demonstrated groundwater response to different hydrographs; RY 2004 had a short duration SRF with peak daily average flow of 354 cfs below the Narrows; RY 2005 had a longer duration SRF with peak daily average flow of 467 cfs below the Narrows. Groundwater elevations responded accordingly, with higher overall peak stage, and elevated groundwater levels lasting much later into the summer season. Peak groundwater elevations close to the main channel (at Piezometers 8C- 2, 8C-4, and 8C-5) were more similar to the 2004 stage heights, whereas groundwater elevations farther from the channel but associated with the 8 Channel (Piezometers 8C-3 and 8C-6) had much higher peaks than in 2004. Piezometer 8C-6 showed the most dramatic response to longer duration SRF releases *and* flow in the 8 Channel; groundwater peaked 4.65 ft higher in 2005; groundwater elevation remained higher 74 days later in the year at our last measurement on October 12, 2005, than the peak on July 30, 2004 (Figure 11).

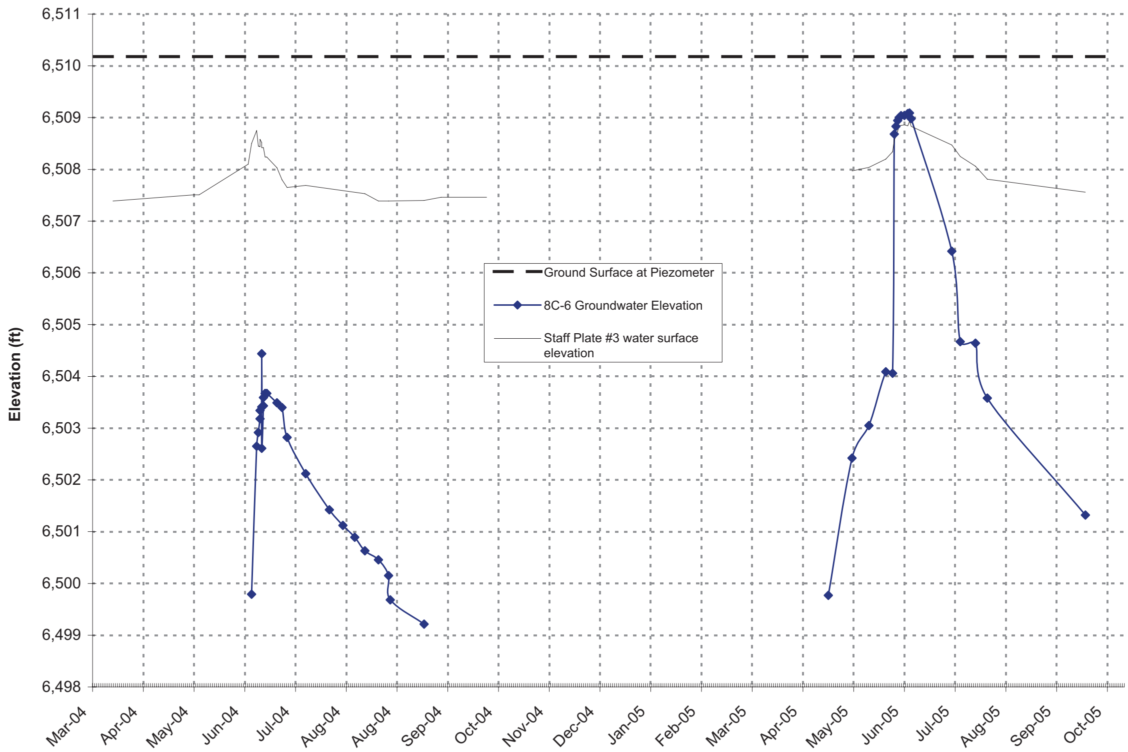


Figure 11. Groundwater elevations from Piezometer 8C-6 recorded synoptically by field staff for the RY 2004 and RY 2005 SRF releases.

Data from Piezometer 8C-6 also illustrates the rate of change of groundwater elevation relative to streamflow. On the ascending hydrograph limb (Figure 12), groundwater elevation increased at a similar rate to streamflow, and both peaked simultaneously on June 29, 2005. On the descending limb, groundwater and streamflow declined precipitously through mid-August; groundwater declined at an average rate of 4.1 cm/day from July 25 to August 15. This was the most rapid decline of all 8 Channel piezometers. Past July, however, the two curves diverged and the groundwater "signature" extended well beyond our last measurement into October. Groundwater decay rate decreased to 1.2 cm/day between August 15 and October 12, 2005.

We plotted XS 314+75 that bisects Piezometer 8C-6 (next to the 8 Channel), 8C-5 (next to the main channel), and staff plate #3 (in the main channel, Figure 13). Groundwater and streamflow elevations were added to the cross section for three sample dates on the ascending hydrograph limb (low, medium, peak flows) and three sample dates on the descending limb (peak, medium, low flows). Both piezometers stayed wetted the entire season, but groundwater elevation was low at 8C-6 until mid-June, and the groundwater surface sloped away from the main channel. The 8 Channel began flowing constantly after mid-June, and by the peak on June 29 groundwater surface had shifted to slope back toward the main channel. The groundwater profiles in Figure 13 indicate that the shallow alluvial aquifer adjacent to stream channels can be recharged from either (any) direction (from the main channel or side channel). Side channel flow accelerates recharging the shallow groundwater.

We plotted groundwater data from the two 8 Channel data loggers (8C-1 and 8C-8) and the Rush Creek hydrograph to illustrate how quickly groundwater responds to streamflow in the main channel and side channel (Figure 14). This topic was discussed in the RY 2004 Annual Report (McBain and Trush 2005). Groundwater at 8C-1 responded more rapidly to the gradual rise in flow during the

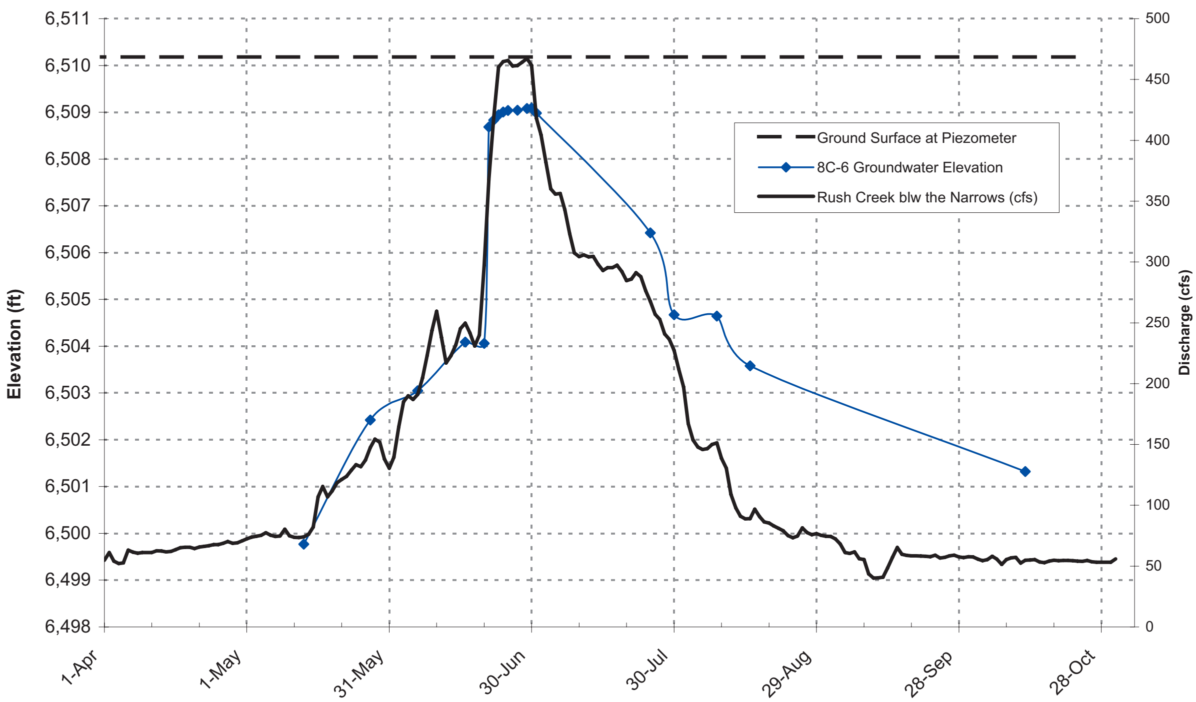
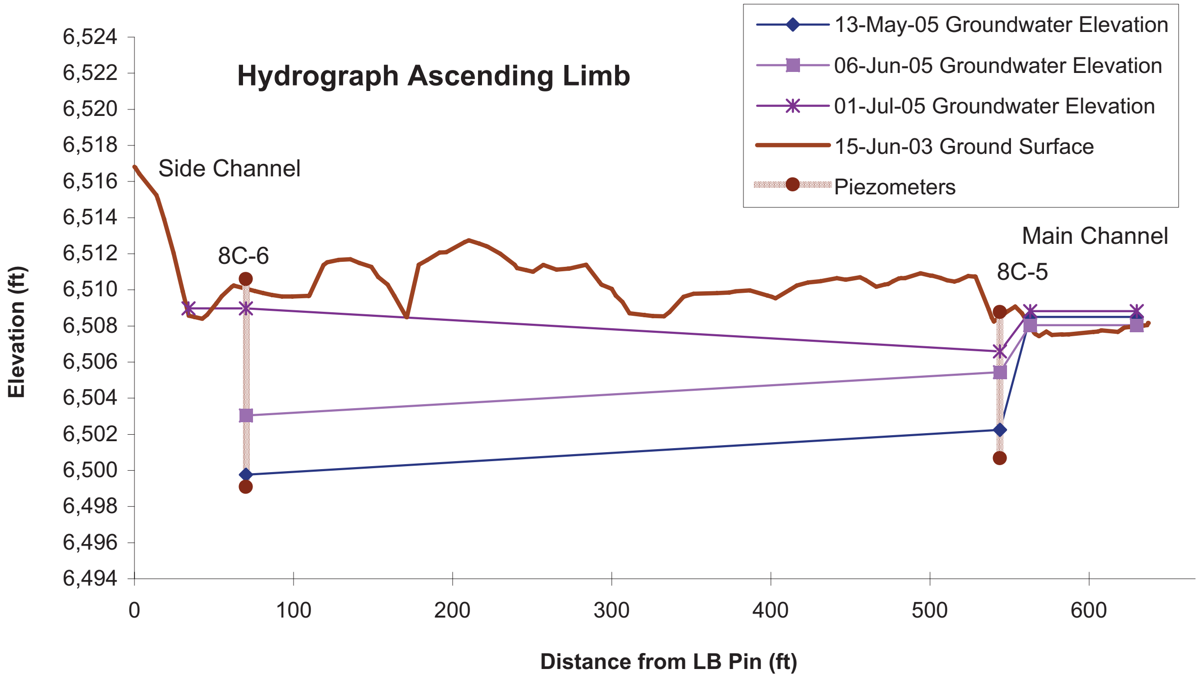


Figure 12. Groundwater elevations from Piezometer 8C-6 recorded synoptically by field staff for RY 2005 SRF releases, plotted with the LADWP hydrograph for Rush Creek below the Narrows.

ascending limb of the hydrograph, and rose more than three feet during the first two weeks of June when the 8 Channel began to flow. Piezometer 8C-8 recorded only one foot change in that interval. Groundwater response to increased ramping rates and higher peak flow releases beginning on June 20 was immediate at both piezometer locations, but remained higher longer into the summer at 8C-1 than at 8C-8 (Figure 14), likely due to the proximity of the 8 Channel.

<u>3D Floodplain.</u> Similar to the 8 Channel, groundwater and stream stage data were collected in the 2005 runoff year from May to October (Table 5), and groundwater data were plotted for RY 2004 and 2005 (Appendix C). Results were similar to those described above for the 8 Channel; 2005 groundwater elevations peaked later and remained elevated longer than 2004 peaks, in response to the timing and duration of the 2005 SRF hydrograph. However, groundwater elevations did not peak much higher across the 3D Floodplain in 2005 (as they did at the 8 Floodplain), even though the extent of saturated floodplain area was greater in 2005 (described in Section 2.4.2 below).

The 3D Side Channel was observed trickling on May 13 during our first field visit (65 cfs in the main channel), and had a peak measured flow of 66 cfs on June 23. We plotted cross section 236+30 that traverses the main channel, the floodplain (bisecting Piezometers 3D-4, 5, and 6, and staff plates 4 and 5), and the side channel, along with groundwater profiles for three sample dates during the ascending limb and three sample dates during the snowmelt recession (Figure 15). The earliest piezometer measurement on May 13, 2005 displayed a unique groundwater profile in which the groundwater adjacent the main channel (15 ft from right bank) was 6.15 ft lower than the stream stage, but groundwater next to the 3D Side Channel was near the thalweg elevation of the barely-flowing side channel. Later in the season when the main channel dropped back to baseflow and the 3D Side Channel stopped flowing, the groundwater table was different; all three piezometers were dry. Possible explanations for this pattern of groundwater flow include: (1) an external source of



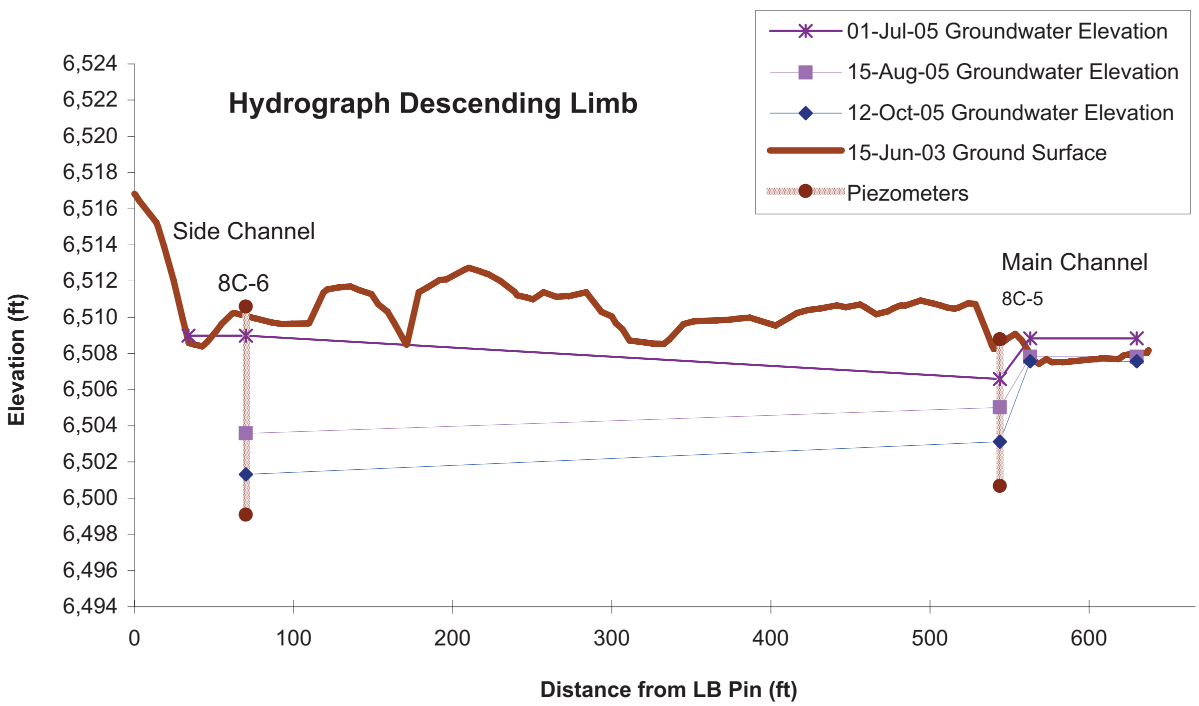


Figure 13. Lower Rush Creek 8 Channel XS 314+75 ground surface, with groundwater elevations before, during, and after the RY 2005 SRF release.

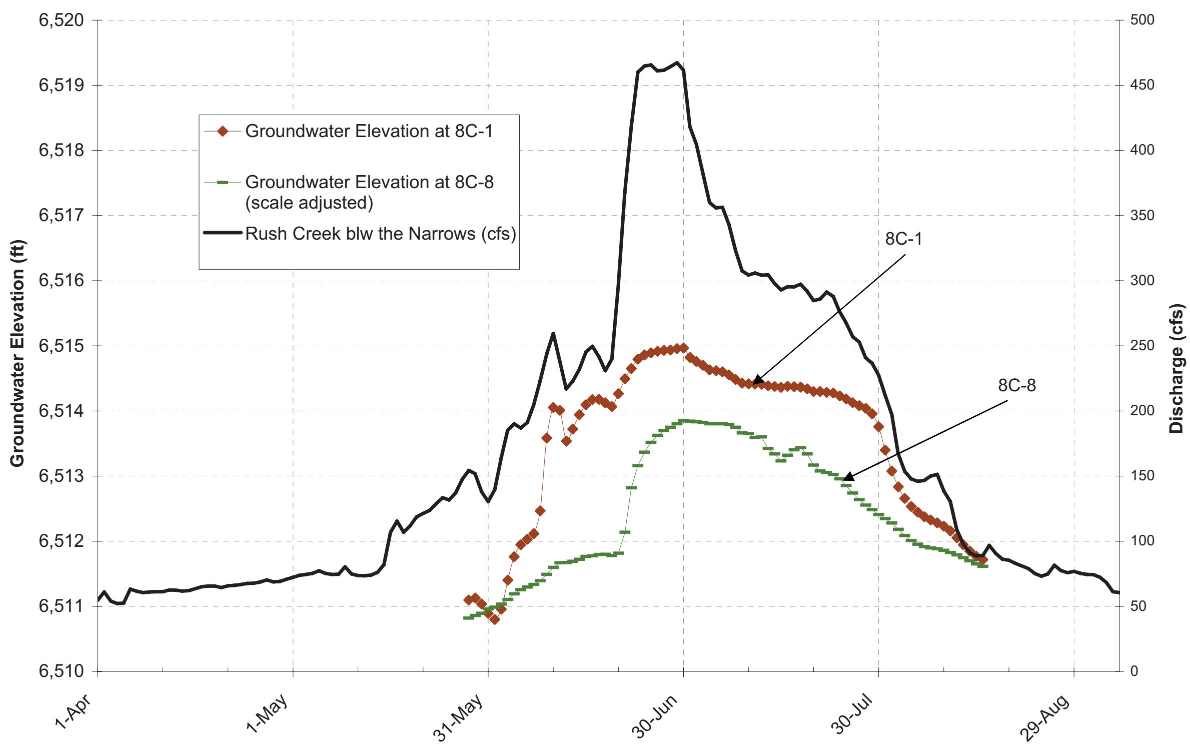


Figure 14. Lower Rush Creek 8 Channel Piezometers 8C-1 and 8C-8 equipped with continuously recording dataloggers during the RY 2005 SRF release.

groundwater entering the Rush Creek alluvial aquifer during the early stages of snowmelt runoff, (2) local clay or hardpan geology overlain by the shallow floodplain alluvium that exhibits control over groundwater elevation (i.e., groundwater is not homogenously distributed subsurface), and (3) the trickle of side channel flow was accumulatively a large enough volume to elevate groundwater on the backside of the floodplain.

2.4.2 Floodplain Inundation Mapping

During and after the 2005 Rush Creek SRF releases, floodplains surrounding the 8, 4, and 3D channels were mapped to show (1) areas *inundated* by overbank and side channel flow that displayed standing water, and (2) areas *wetted* by groundwater or the capillary fringe intersecting the ground surface that displayed moisture but not standing water on the ground surface. We used the term *saturated* in the RY 2004 Annual Report to describe *inundated* or *wetted* areas, because mapping in 2004 did not distinguish between wetted and inundated. The objective for floodplain mapping was to estimate the area of wetted and inundated floodplains and determine the duration that floodplain soils retained moisture. Laminated aerial photographs were used for field mapping, which were later digitized to produce floodplain inundation maps. The 8 and 4 floodplains were mapped on June 28 and August 9, 2005. The 3D Floodplain was mapped on June 29 and August 9, 2005.

At the 8 and 4bii side channels, floodplain inundation peaked during the latter days of the SRF releases. Both floodplains were mapped in late June 2005 (Figure 16) at the approximate peak of floodplain inundation. At the 8 Floodplain, 2.5 acres were wetted and 2.5 acres were inundated out of 18.58 total acres. At the 4bii Channel, 18.1 acres were wetted and 7.8 acres were inundated out of 38.8 total acres. In 2004, the 4 and 8 Floodplains were similarly mapped in June at the height of the SRF releases when floodplain conditions were wettest. The 2004 SRF release achieved 2.7 acres of

Table 5a. Groundwater and water surface elevation data from Rush Creek 8 Channel sites collected from piezometers and staff plates during RY 2004 and 2005.

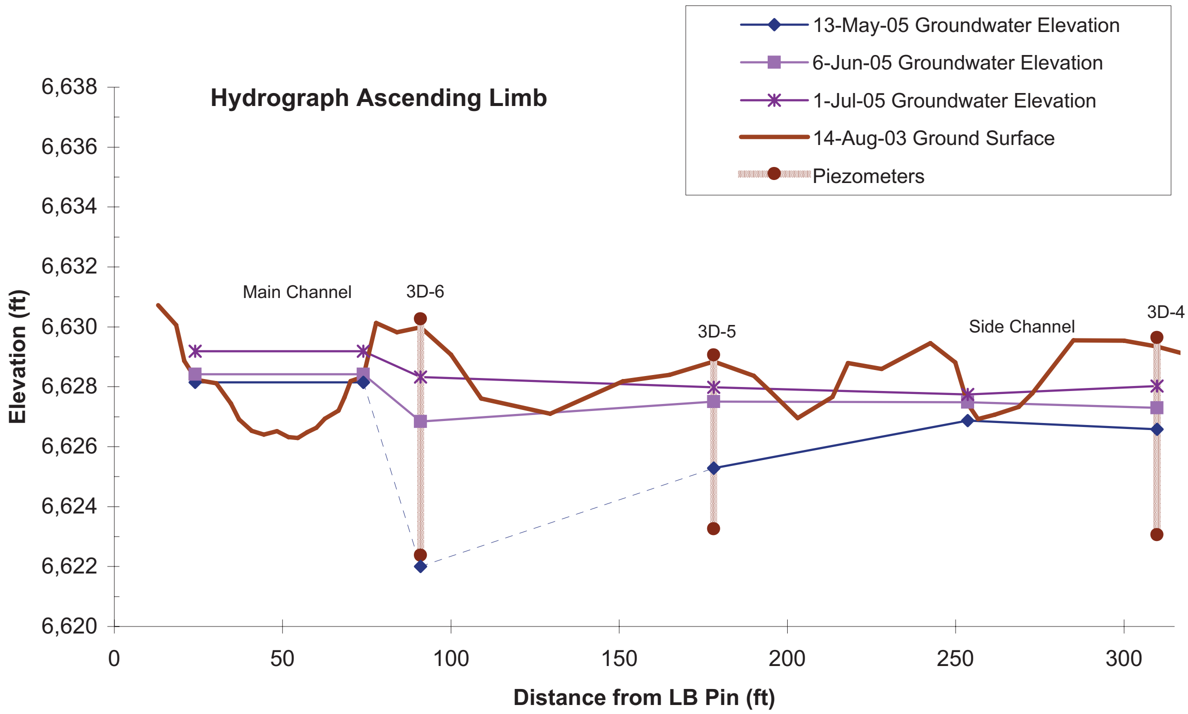
Date	Time	8C-1 Groundwater Elevation	8C-2 Groundwater Elevation	8C-3 Groundwater Elevation	8C-4 Groundwater Elevation	8C-5 Groundwater Elevation	8C-6 Groundwater Elevation	8C-7 Groundwater Elevation	8C-8 Groundwater Elevation	Staff Plate #1 water surface elevation	Staff Plate #2 water surface elevation	Staff Plate #3 water surface elevation
11-Sep-03	N/A	6511.51	6511.86	6509.64	6506.89	6500.99	6499.75					
7-Oct-03	N/A	6511.25	6511.37	6509.67	dry	dry	dry					
16-Mar-04	10:00 AM	6510.97	6511.21	6509.63	6506.27	dry	dry			6517.70	6513.06	6507.39
3-May-04	1:45 PM	6511.22	6511.63	6509.63	6506.90	dry	dry			6517.70	6513.08	6507.51
6-May-04	3:00 PM	6511.42	6512.23	6509.61	6507.42	6501.32	dry			6517.89	6513.15	6507.51
1-Jun-04	3:00 PM	6511.58	6512.39	6509.77	6507.58	6501.48	dry					
1-Jun-04	12:00PM	Datalogger	6512.14	6509.62	6507.49	6501.61	dry			6517.89		
4-Jun-04	4:00 PM	6512.98	6514.55	6509.57	6510.51	6505.27	dry			6518.51	6513.71	6508.10
5-Jun-04	4:00 PM	6513.56								6518.76		
6-Jun-04	10:00 AM	6513.95	6515.51	6509.57	6511.42	6505.74	6499.79			6518.86	6514.06	6508.50
7-Jun-04	10:00 AM	6514.33								6518.96		
9-Jun-04	2:30 PM	6514.82	6516.13	6509.59	6512.21	6506.17	6502.65			6519.11	6514.41	6508.75
10-Jun-04	10:30 AM	6514.71	6515.80	6509.57	6511.89	6505.90				6518.81	6514.41	6508.45
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	3:00 PM	6514.94	6516.12	6510.53	6512.21	6506.15	6503.34			6519.12	6514.46	6508.58
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	11:25 AM	6515.50	6516.25	6510.50	6512.30	6506.05	6504.44			6518.96	6514.24	6508.44
12-Jun-04	4:00 PM	6515.18	6516.10	6510.41	6512.18	6506.03	6502.61			6518.90	6514.18	6508.42
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	4:30 PM	6515.43	6515.43	6510.46	6511.43	6505.94	6503.59			6519	6514.18	6508.42
14-Jun-04	1:30 AM	6514.83	6515.80	6509.55	6511.93	6505.86	6503.67			6518.66	6513.96	6508.24
15-Jun-04	11:30 AM	6514.70	6515.71	6509.60	6511.75	6505.80	6503.67			6518.66	6513.96	6508.24
21-Jun-04	1:30 PM	6514.27	6515.20	6509.60	6511.06	6505.41	6503.49			6518.18	6513.61	6508.03
24-Jun-04	3:00 PM	6514.04	6514.91	6509.56	6510.80	6505.24	6503.40			6518.06	6513.42	6507.80
27-Jun-04	4:45 PM	6513.63	6514.51	6509.73	6510.23	6504.82	6502.82			6517.88	6513.24	6507.65
8-Jul-04	3:30 PM	6512.50	6513.13		6508.88	6504.08				6517.88	6513.18	6507.69
22-Jul-04	12:55 PM	6512.00	6512.67	6509.56	6508.33	6503.30	6501.42			6517.72	6513.15	
30-Jul-04	12:45 PM	6511.94	6512.67	6509.56	6508.26	6503.09	6501.12			6517.76	6513.18	
6-Aug-04	12:42 PM	6511.71	6512.34	6510.48	6507.94	6502.57	6500.89			6517.73	6513.16	
12-Aug-04	3:06 PM	6511.67	6512.35	6509.57	6507.86	6502.43	6500.63			6517.74	6513.07	6507.53
20-Aug-04	11:25 AM	6511.51	6512.01	6509.57	6507.38	6501.79	6500.45			6517.61	6512.91	6507.39
26-Aug-04	10:45 AM	Datalogger	6511.85	6509.57	6507.03	6501.28	6500.15			6517.61	6512.91	6507.39
27-Aug-04	13:40PM	Datalogger	6511.85	6509.63	6507.13	6501.05				6517.73		
16-Sep-04	4:55 PM	Datalogger	6511.56	6509.57	6506.51		6499.22			6517.62	6512.93	6507.40
26-Sep-04	5:58 PM	Datalogger	6511.50	6509.57	6506.49					6517.69	6513.02	6507.46
23-Oct-04	1:30 PM	Datalogger	6510.98							6517.71	6513.02	6507.46
13-May-05	4:00pm	Datalogger	6511.92 ft	6509.57	6507.54	6502.24	6499.77					
27-May-05	11:29 AM	Datalogger	6513.51	6509.51	6509.65	6504.93	6502.42	6501.48	6500.81	6518.3	6513.6	6508.0
6-Jun-05	3:00pm	Datalogger	6514.87	6509.47	6510.75	6505.44	6503.05	6501.92	Datalogger	6518.4	6513.7	6508.0
16-Jun-05	3:45pm	Datalogger	6516.33	6511.03	6512.25	6506.18	6504.09	6502.59	Datalogger	6518.6	6513.9	6508.2
20-Jun-05	N/A	Datalogger	6516.14	6511.34	6512.11	6505.91	6504.06	6502.41	Datalogger	6518.8	6514.0	6508.3
21-Jun-05	3:00pm	Datalogger	6516.42	6511.83	6512.58	6506.18	6508.68	6504.54	Datalogger	6518.9	6514.3	6508.6
22-Jun-05	1:21 PM	Datalogger	6516.63	6512.09	6512.94	6506.33	6508.83	6505.00	Datalogger	6519.2	6514.4	6508.6
23-Jun-05	11:30 AM	Datalogger	6516.77	6512.25	6513.16	6506.47	6508.94	6505.13	Datalogger	6519.2	6514.4	6508.7
24-Jun-05	N/A	Datalogger	6516.84	6512.40	6513.20	6506.56	6509.01	6505.27	Datalogger	6519.3	6514.5	6508.8
25-Jun-05	N/A	Datalogger	6516.89	6512.43	6513.29	6506.60	6509.04	6505.31	Datalogger	6519.3	6514.5	6508.9
27-Jun-05	1:17PM	Datalogger	6516.91	6512.50	6513.29	6506.61	6509.04	6505.08	Datalogger	6519.3	6514.5	6508.9
29-Jun-05	12:50 PM	Datalogger	6516.94	6512.36	6513.32	6506.64	6509.08	6505.02	Datalogger	6519.4		6508.8
30-Jun-05	10:35 AM	Datalogger	6516.99	6512.36	6513.35	6506.67	6509.09	6505.02	Datalogger	6519.4	6514.6	6508.9
1-Jul-05	10:27 AM	Datalogger	6516.85	6512.36	6513.18	6506.59	6508.98	6505.02	Datalogger	6519.3	6514.5	6508.8
25-Jul-05	8:15 AM	Datalogger	6516.20	6511.93	6512.20	6506.06	6506.42	6503.55	Datalogger	6518.9	6514.1	6508.5
30-Jul-05	2:30 PM	Datalogger	6515.79	6509.67	6511.60	6505.98	6504.67	6502.81	Datalogger	6518.6	6513.8	6508.3
8-Aug-05	2:50 PM	Datalogger	6514.99	6509.63	6510.89	6505.47	6504.64	6502.29	Datalogger	6518.3	6513.5	6508.1
15-Aug-05	11:20 AM	Datalogger	6514.31		6510.31	6505.02	6503.58	6501.92	Datalogger	6518.0	6513.2	6507.8
12-Oct-05	1:32 PM	Datalogger	6512.30		6507.05	6503.12	6501.32	6500.38	Datalogger	6517.7	6512.9	6507.6

Table 5b. Groundwater data from Rush Creek 3D Floodplain sites collected from piezometers and staff plates during RY 2004 and 2005.

Date	Time	3D-1 Groundwater elevation (ft)	3D-2 Groundwater elevation (ft)	3D-3 Groundwater elevation (ft)	3D-4 Groundwater elevation (ft)	3D-5 Groundwater elevation (ft)	3D-6 Groundwater elevation (ft)	3D-7 Groundwater elevation (ft)	3D-8 Groundwater elevation (ft)	3D-9 Groundwater elevation (ft)
12-Sep-03	8:00 AM	6633.5	6632.8	6633.0	6626.1	6625.1	6623.6	6621.7	6623.6	6614.6
7-Oct-03	9:00 AM	6632.7	6631.4	6632.4	6625.2	6623.9	dry	dry	6623.5	dry
16-Mar-04	5:00 PM	6632.6	dry	6632.1	6625.2	6624.1	dry	dry	6623.6	dry
3-May-04	8:00 AM	6632.83	6632.96 ft	6632.47	6625.50	6624.12	dry	dry	not read	dry
6-May-04	1:25 PM	6634.31	6632.96 ft	6632.80	6625.90	6624.44	dry	dry	6623.6	dry
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	6617.01
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	6618.15 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	6618.36 ft
11-Jun-04	12:30 PM	not surveyed	not surveyed	not surveyed	not surveyed	not surveyed	not surveyed	not surveyed	6624.8 ft	not surveyed
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	6618.21 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	6617.54 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	6616.85 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	6616.31 ft
27-Jun-04	3:00 PM		6633.77 ft	6632.87	6626.46	6626.15	6625.61	6623.54 ft	6622.5 ft	6614.98 ft
8-Jul-04	1:00 PM	6633.93	6633.62 ft	6632.82	6626.24	6625.73	6624.94	6622.97 ft	datalogger	6615.90 ft
15-Jul-04	2:20 AM	6634.17	6633.64 ft	6632.86	6627.94	6625.69	6624.90	6622.93 ft	datalogger	6615.58 ft
22-Jul-04	11:45 AM	6633.19	6631.80 ft	dry	6623.57	6623.57	6623.33	6621.78 ft	datalogger	6615.20 ft
30-Jul-04	11:45 AM	6634.14	6633.58 ft	6631.73	dry	dry	dry	6621.11 ft	datalogger	6615.15 ft
6-Aug-04	11:50 AM	6633.47	6632.26 ft	dry	dry	dry	dry	dry	datalogger	6614.57 ft
12-Aug-04	1:55 AM	6633.48	6632.30 ft	dry	dry	dry	dry	dry	datalogger	6614.51 ft
20-Aug-04	10:30 AM	6632.70	dry	dry	dry	dry	dry	dry	datalogger	dry
26-Aug-04	9:45 AM	6632.52	dry	dry	dry	dry	dry	dry	datalogger	dry
31-Aug-04	1:30 AM	6633.69	6632.99 ft	6632.92	6625.77	6624.63	dry	dry	datalogger	dry
16-Sep-04	4:15 AM	6632.38	dry	dry	dry	dry	dry	dry	datalogger	dry
26-Sep-04	5:00 PM	6632.69	dry	dry	dry	dry	dry	dry	datalogger	dry
23-Oct-04	12:00 AM	6632.28	dry	dry	dry	dry	dry	dry	datalogger	dry
13-May-05	5:30 PM	6633.96	6633.57 ft	6633.08	6626.58	6625.28	dry	dry	datalogger	dry
28-May-05	1:00 PM	6634.65	6634.01	6633.34	6626.89	6626.85	6624.96	6622.73	datalogger	6616.36
6-Jun-05	2PM	6635.21	6634.45	6633.49	6627.30	6627.51	6626.84	6623.94	datalogger	6617.19
16-Jun-05	2:40PM	6635.40	6634.66	6633.73	6627.64	6627.75	6627.55	6624.19	datalogger	6617.45
20-Jun-05	N/A	6635.56	6634.80	6633.85	6627.82	6627.86	6628.03	6624.29	datalogger	6617.75
22-Jun-05	11:00 AM	6635.90	6635.07	6634.11	6628.01	6627.95	6628.34	6624.40	datalogger	6618.24
23-Jun-05	8:00AM	6636.10	6635.12	6634.23	6628.09	6628.03	6628.49	6624.45	datalogger	6618.37
24-Jun-05	10:44 AM	6636.11	6635.15	6634.21	6628.22	6628.04	6628.49	6624.44	datalogger	6618.36
25-Jun-05	10:30 AM	6636.09	6635.14	6634.19	6628.69	6628.05	6628.48	6624.47	datalogger	6618.36
29-Jun-05	8:20AM	6636.03	6635.05	6634.09	6628.12	6628.02	6628.45	6624.45	datalogger	6618.36
1-Jul-05	9:09 AM	6635.90	6635.01	6634.01	6628.03	6627.98	6628.32	6624.46	datalogger	6618.22
11-Jul-05	12:05PM	6635.81	6635.01	6634.02	6627.93	6628.00	6628.04	6624.44	datalogger	6617.95
31-Jul-05	5:46 PM	6635.33	6634.26	6633.62	6627.48	6627.63	6627.46	6624.15	datalogger	6617.42
9-Aug-05	11:48	6635.09	6634.40	6633.34	6626.79	6627.46	6627.04	6623.99	datalogger	6616.76
16-Aug-05	13:28	6634.38	6633.75	6632.87	6626.26	6626.75	6626.18	6623.83	datalogger	6616.19
10-Oct-05	4.:55	6632.70	dry	dry	dry	dry	dry	dry	datalogger	dry

Table 5c. Water surface elevation data from Rush Creek 3D Floodplain sites collected from piezometers and staff plates during RY 2004 and 2005.

Date	Staff Plate #1 water surface elevation (ft)	Staff Plate #2 water surface elevation (ft)	Staff Plate #3 water surface elevation (ft)	Staff Plate #4 water surface elevation (ft)	Staff Plate #5 water surface elevation (ft)	Staff Plate #6 water surface elevation (ft)	Staff Plate #7 water surface elevation (ft)	Staff Plate #8 water surface elevation (ft)
12-Sep-03								
7-Oct-03								
16-Mar-04	6638.84	6635.14	6633.41	6627.96	6627.14	6624.06	6624.53	6617.48
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
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
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
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
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
11-Jun-04	not surveyed	not surveyed	6633.70 ft	6628.99 ft	not surveyed	not surveyed	6625.75 ft	6619.20 ft
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
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
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
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
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
8-Jul-04	6638.99 ft	6635.31 ft	dry	6628.11 ft	dry	6624.15 ft	plate washed out	6617.64 ft
15-Jul-04	6638.94 ft	6635.28 ft	dry	6628.08 ft	not surveyed	6624.15 ft	plate washed out	6617.59 ft
22-Jul-04	6638.79 ft	6635.19 ft	dry	6628.01 ft	not surveyed	6624.07 ft	plate washed out	6617.46 ft
30-Jul-04	6638.86 ft	6635.25 ft	dry	6628.04 ft	not surveyed	6624.12 ft	plate washed out	6617.52 ft
6-Aug-04	6638.82 ft	6635.22 ft	dry	6628.03 ft	not surveyed	6624.12 ft	plate washed out	6617.50 ft
12-Aug-04	6638.85 ft	6635.23 ft	dry	6628.05 ft	not surveyed	6624.12 ft	plate washed out	6617.52 ft
20-Aug-04	6638.63 ft	6635.10 ft	dry	6627.90 ft	not suveyed	6624.00 ft	plate washed out	6617.36 ft
26-Aug-04	6638.69 ft	6635.12 ft	dry	6627.95 ft	not surveyed	6624.03 ft	plate washed out	6617.39 ft
31-Aug-04	6638.59 ft	6635.20 ft	dry	6628.04 ft	6627.63 ft	6624.01 ft	plate washed out	6617.99 ft
16-Sep-04	6638.69 ft	6635.12 ft	dry	6627.95 ft	not surveyed	6624.03 ft	plate washed out	6617.39 ft
26-Sep-04	6638.79 ft	6635.19 ft	dry	6628.00 ft	6626.80 ft	6624.08 ft	plate washed out	6617.46 ft
23-Oct-04	6638.75 ft	6635.14 ft	dry	6627.94 ft	not surveyed	6624.05 ft	plate washed out	6617.43 ft
13-May-05	not surveyed	6635.39 ft	dry	6628.15 ft	6626.87 ft	6624.26 ft	plate washed out	6617.68 ft
28-May-05	6639.26	6635.53	6633.42	6628.27	6627.24	6624.39	6624.32	6617.92
6-Jun-05	6639.56	6635.65	6633.69	6628.42	6627.48	6624.53	6624.85	6617.92
16-Jun-05	6639.85	6635.75	6633.94	6628.58	6627.59	6624.65	6625.12	6618.70
20-Jun-05	6640.25	6635.93	6634.19	6628.80	6627.78	6625.04	6625.57	6619.06
22-Jun-05	6640.51	6636.12	6634.31	6629.12	6627.93	6625.09	6625.55	6619.18
23-Jun-05	6640.83	6636.27	6634.47	6629.29	6627.99	6625.14	6625.96	6618.31
24-Jun-05	6640.81	6636.27	6634.32	6629.29	6627.89	6625.39	6625.70	6619.18
25-Jun-05	6640.31	6636.24	6634.30	6629.34	6627.90	6625.29	6625.70	6619.18
29-Jun-05	6640.14	6636.22	6634.20	6629.31	6627.79	6625.14	6625.61	6619.20
1-Jul-05	6640.01	6636.09	6634.14	6629.19	6627.74	6625.19	6625.46	6619.06
11-Jul-05	6639.64	6635.90	6633.82	6628.32	6628.12	6624.94	6625.03	6618.80
31-Jul-05	6639.26	6635.75	6633.58	6628.54	6627.45	6624.59	6624.70	not surveyed
9-Aug-05	6638.87	6635.58	6633.11	6628.34	6627.19	6624.46	6624.25	6617.71
16-Aug-05	6638.57	6635.39	not surveyed	6628.20	not surveyed	6624.33	6623.83	6617.71
10-Oct-05	not surveyed	6635.15	not surveyed	6627.95	not surveyed	6624.11	not surveyed	6617.46



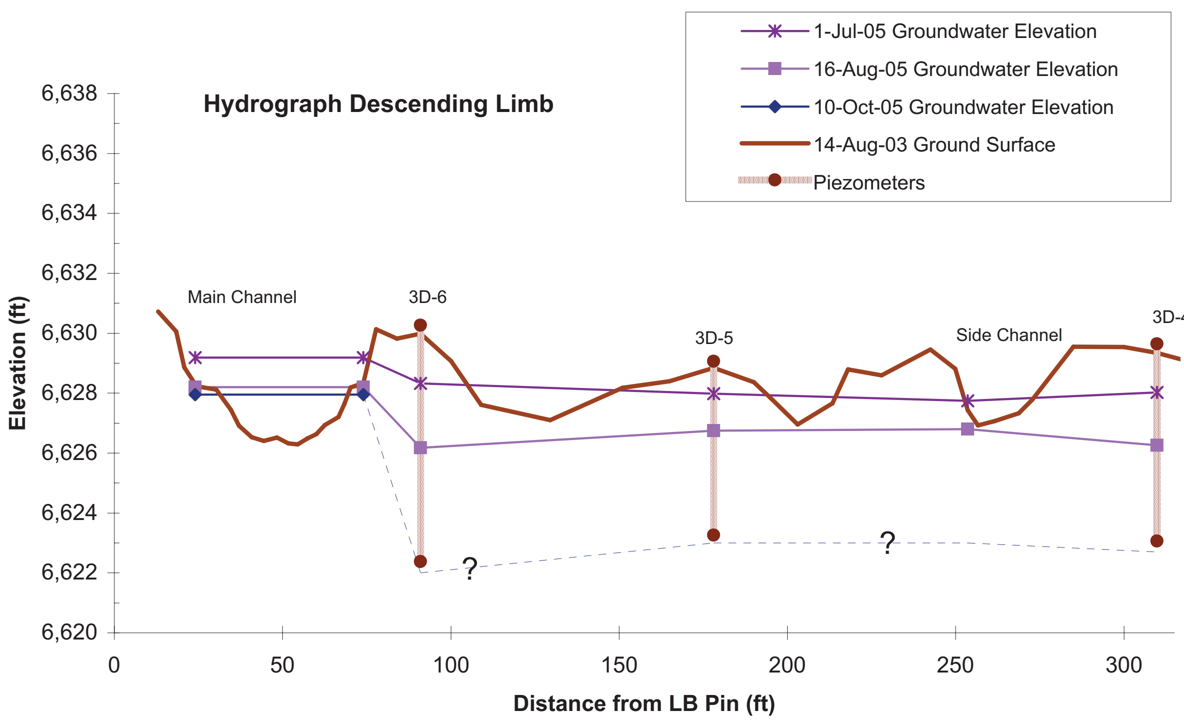


Figure 15. Rush Creek 3D Floodplain XS 236+30 ground surface, with groundwater elevations before, during, and after the RY 2005 SRF release.

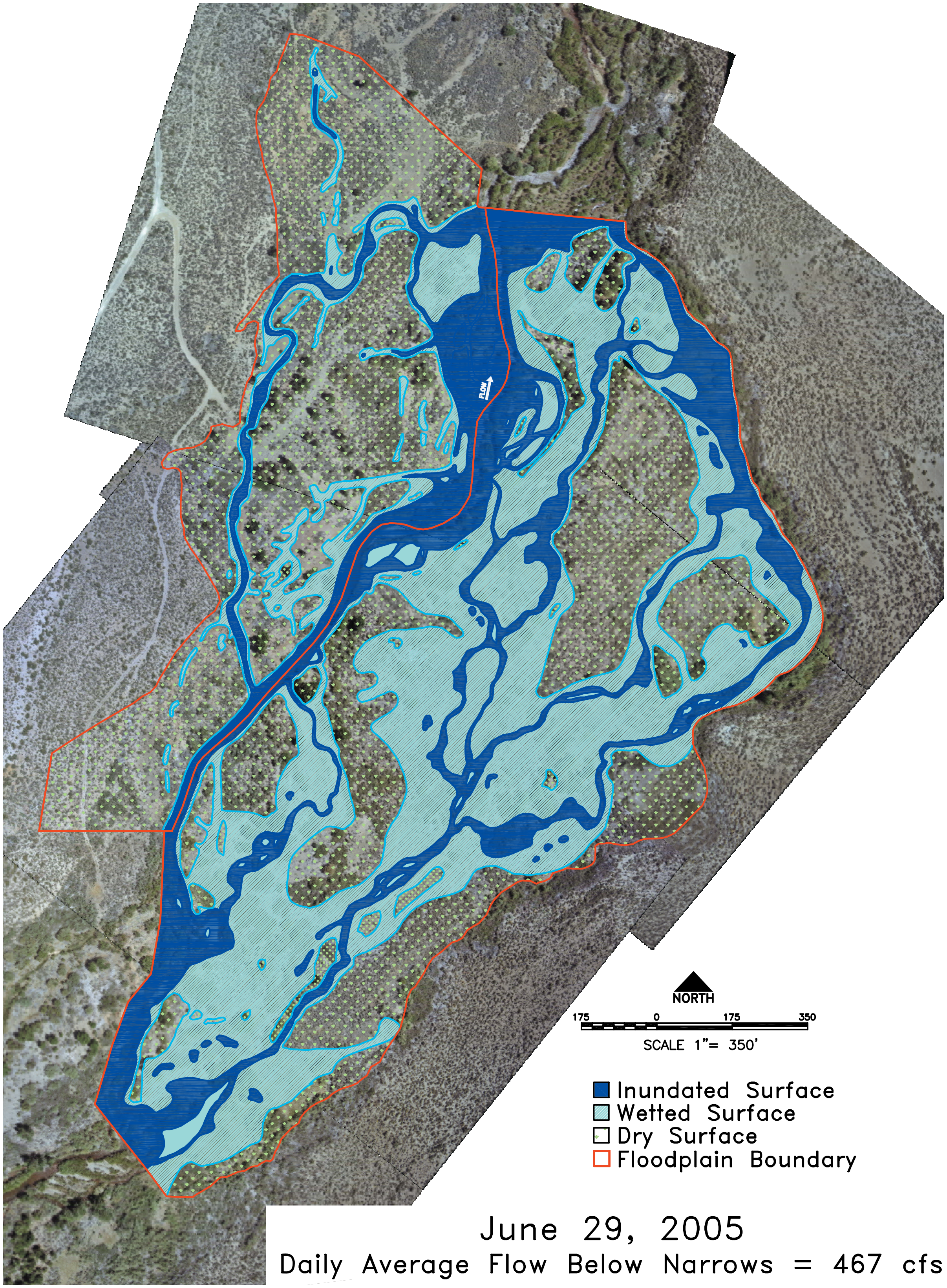


Figure 16a. The 8 and 4bii floodplains with the extent of wetted and inundated areas on June 28, 2005, resulting from flow entering the 8 Channel and 4bii Channel.

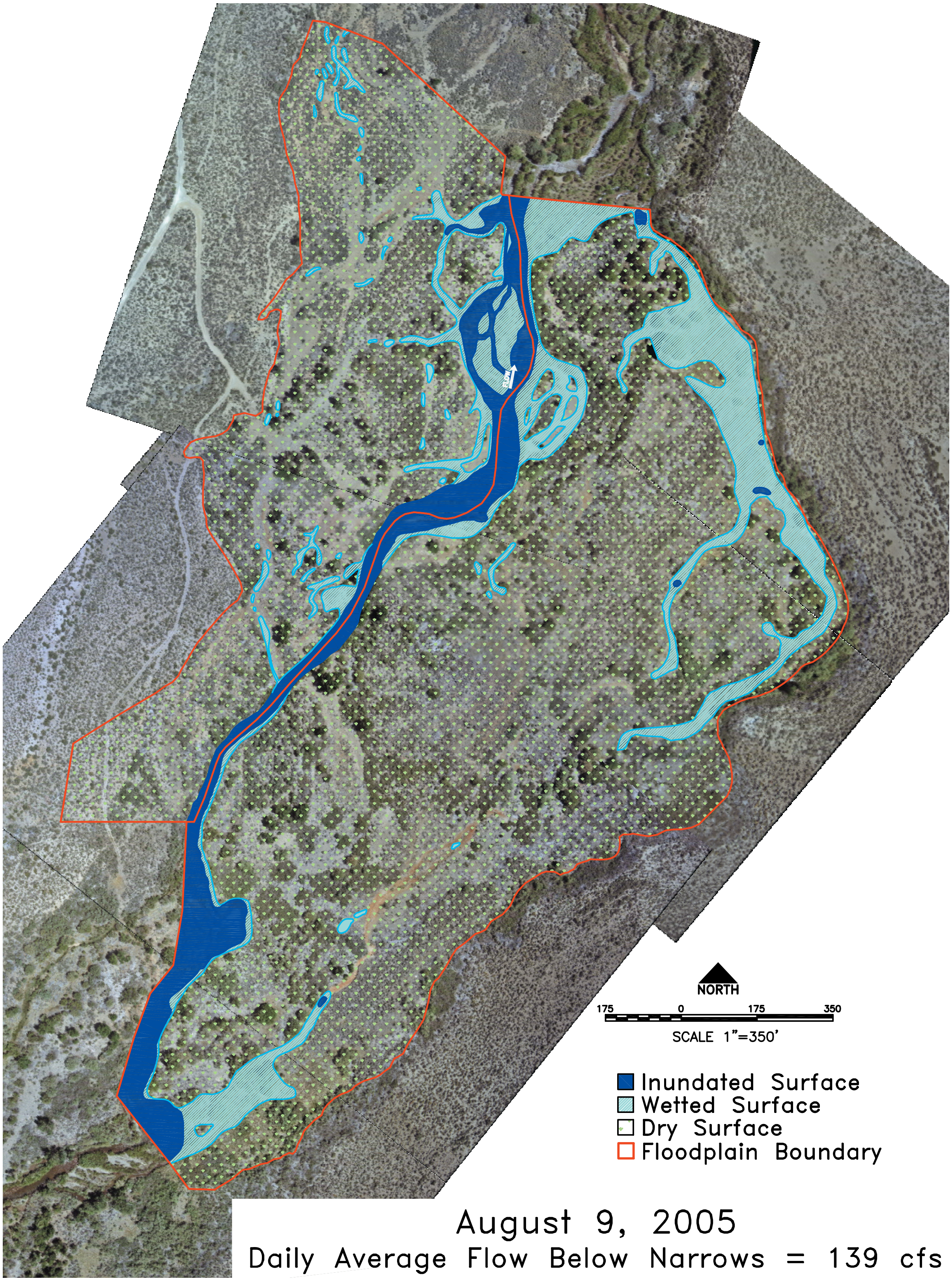
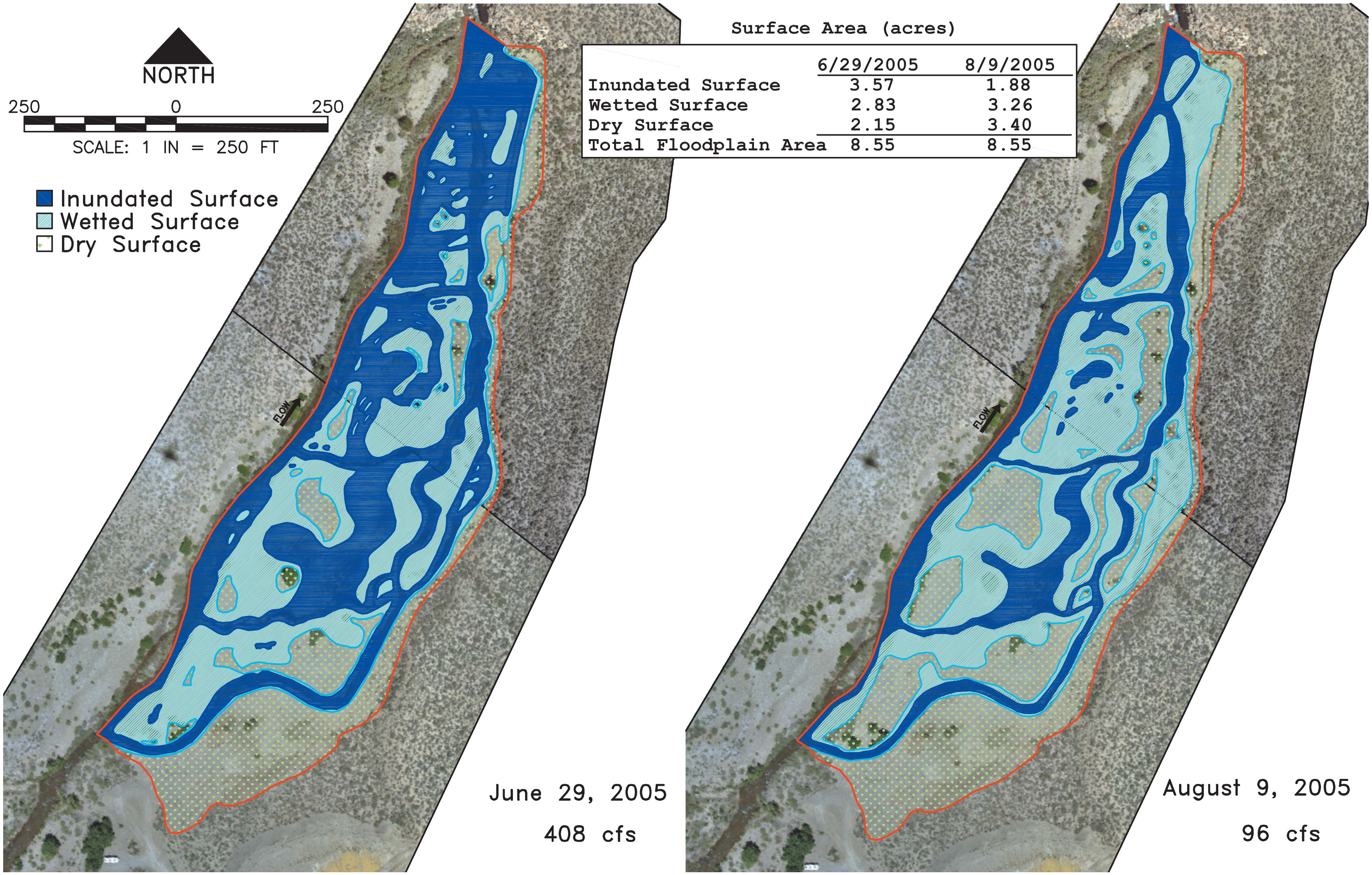


Figure 16b. The 8 and 4bii floodplains with the extent of wetted and inundated areas on August 9, 2005, resulting from flow entering the 8 Channel and 4bii Channel.



Surface Area (acres)

	6/29/2005	8/9/2005
Inundated Surface	3.57	1.88
Wetted Surface	2.83	3.26
Dry Surface	2.15	3.40
Total Floodplain Area	8.55	8.55

Figure 16c. Reconstructed 3D floodplain with the extent of inundation on. June 29, 2005, and August 9, 2005.

saturated floodplain at the 8 Floodplain, compared to 5.0 acres in 2005 (wetted and inundated areas lumped together). Thus there was an increase from 15 percent of total floodplain saturation in 2004 to 27 percent in 2005. Similarly, at the 4 Floodplain, 18.8 acres were saturated in 2004, compared to 25.9 acres in 2005, an increase from 49 to 67 percent. The larger magnitude, longer duration 2005 SRF releases, combined with flow in the 8 Channel, increased the saturated area of the 8 Floodplain by 12 %. The 4 Floodplain saturated area increased by 18 %. During a field tour on October 8, 2005, McBain and Trush staff observed no wetted or inundated areas across the 8 or 4 floodplains.

Note that our boundaries for floodplain inundation mapping were defined by the riparian corridor boundaries which extend to the base of the valley walls at the back of the 4 and 8 Floodplains (red lines in Figure 16). However, the 4 Floodplain includes approximately 9.9 acres of surface mapped as middle and high terrace; the 8 Floodplain includes approximately 5.9 acres of surface mapped as middle terrace and pre-1941 low terrace (now abandoned). These surfaces likely will never become inundated. The areas mapped as wetted and inundated included both floodplain *and* low terrace surfaces (the RY 2004 Annual Report [McBain and Trush 2005] contains geomorphic maps describing this area). Excluding the middle and high pre-41 terraces from the total floodplain area resulted in more than 90% of the “available” 4 Floodplain area and 39% of the “available” 8 Floodplain area saturated in RY 2005. An increase in flood magnitude may not increase saturated area in the 4 Floodplain; a higher magnitude or longer duration flood (or a lowered 8 Channel invert) might increase the wetted area at the 8 Floodplain by exposing those surfaces farther inland and downstream to more groundwater recharge.

At the 3D Floodplain, the peak 2005 SRF in late June wetted 2.8 acres and inundated 3.6 acres for a total of 6.4 saturated acres, or 75 percent of the total floodplain. The 2005 SRF releases saturated a broader area than in 2004 when approximately 41 percent of the floodplain was saturated. When mapping was repeated on August 9, 2005, the total area wetted or inundated had declined to 60 percent.

At the height of the SRF releases on Rush Creek (June 30, 2005), ponded water was observed in one location on the 14 Floodplain above the Rush Creek Ford (where the 13 Channel once joined the 14 Channel).

3 GEOMORPHOLOGY

3.1 Channel Dynamics

3.1.1 Cross Section and Longitudinal Profile Surveys

The RY 2004-05 annual report (McBain and Trush 2005) presented cross sections and longitudinal profiles on Rush and Lee Vining creeks, resurveyed in 2004. In RY 2005 surveys were not repeated uniformly at all sites. Selected cross sections and profiles were surveyed as part of various monitoring tasks, such as synoptic gaging, bedload transport measurements, floodplain aggradation studies, evaluation of side channel entrance dynamics, and valley-wide vegetation band transects. These surveys are presented in the appropriate report sections.

The Rush Creek 10 Channel threatens to capture all the lower Rush Creek flow. We have monitored where the 10 Channel diverges from the main channel, and where the 10 Return Channel splits to carry a large volume of flow back to the main channel (Figure 17). The main channel at the 10 Channel divergence has aggraded substantially the last several years. Some baseflow and most high flows are now routed across adjacent floodplains. A headcut passed through this reach, migrating up from the 10 channel. Downstream at the 10 and 10 Return Channel split, the channel also changed significantly in the 2005 SRF releases. A headcut migrated past the right bank bar, the shallow medial

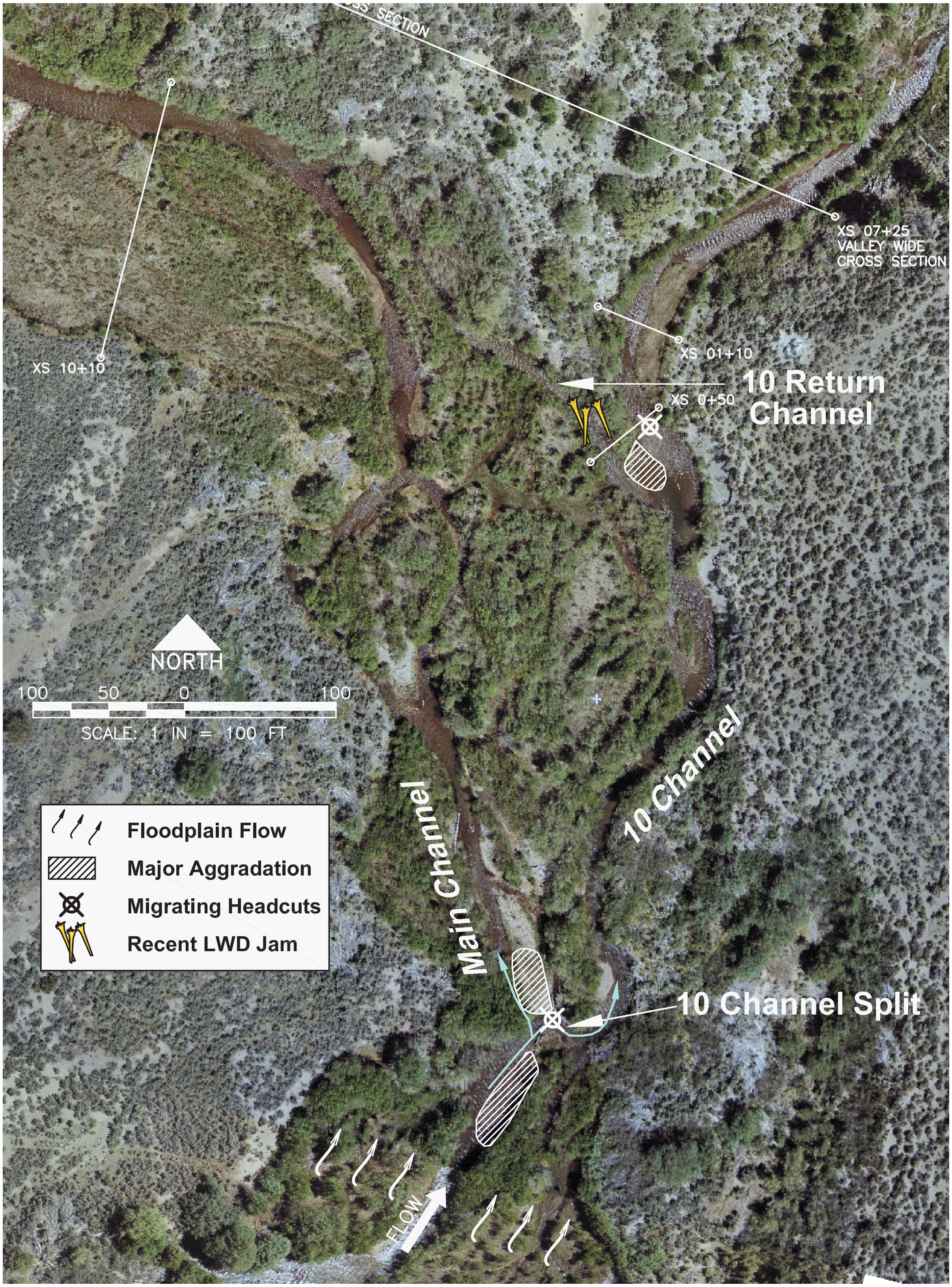


Figure 17. The 2003 aerial photograph of the 10 Channel, the Rush Creek main channel, and the 10 Return Channel.

bar between the two channels continued to aggrade, and a log jam formed at the entrance to the 10 Return Channel (Figure 18). All these conditions have slowly shifted more flow into the 10 Channel, and may eventually disrupt perennial flow down the 10 Return Channel.

3.1.2 Bed Mobility Experiments

Bed mobility experiments were conducted on Rush and Lee Vining creeks during the RY 2005 snowmelt floods, marking the eighth consecutive year for many of the tracer rock and scour core monitoring sites. With the moderate snowmelt floods on both creeks and the range of data now collected, 2005 was likely the last year tracer rock experiments will be deployed. Mobility data now span a wide range of snowmelt floods, and most tracer rock sets within the bankfull channel have achieved near total mobility. Mobility data from RY 2005 are presented for Rush Creek (Table 6) and Lee Vining Creek (Table 7), and for all monitoring years (Appendix D).

The 2005 SRF on Rush Creek emphasized hydrograph duration, with eight days of 400 cfs flow releases. The bed mobility experiments were designed to test the effect of flood magnitude, not duration (based on the percentage of rocks moved by a given discharge magnitude). However, when recovering tracer rock data, we searched downstream of the monitoring cross sections and noted all recovered rocks and the distances they had moved. In RY 2005 very few tracers were recovered, suggesting that high flows (both magnitude and duration) transported tracers farther downstream than our search area, and/or buried them.

On Rush Creek, tracer rocks placed on pool tails and within riffles had mobility exceeding 80% (which we define as "total" mobility of those geomorphic features; see McBain and Trush 2002 for description of mobility thresholds). In many cases 100% of the tracers moved. However, tracer rocks on point bar and floodplain features were not entirely mobilized. Lower Rush Creek XS -5+07 above the 10 Channel Falls is a good example of a lateral bar feature, that had only 30%, 70%, and 90% of D_{84}, D_{50}, and D_{31} particles mobilized, respectively.

Mobility rating curves were plotted for two tracer rock sets: one at Upper Rush Creek XS 12+95 and another at Lower Rush Creek XS 10+10 (Figure 19). Both sites are pool tails (relatively mobile geomorphic features). The data for each site showed a consistent trend in increasing mobility with discharge. The mobility threshold for each site was different, however. In Upper Rush Creek, bed mobility occurred between approximately 450 and 550 cfs. In Lower Rush Creek, mobility occurred between approximately 200 and 250 cfs.

On Lee Vining Creek, tracer rock sets have been monitored six years beginning 1999. Mobility data are more difficult to interpret than on Rush Creek. Data have been collected over a smaller range of flows capable of mobilizing the bed (the highest flows were 354 cfs in 1997; 391 cfs in 1998; 372 cfs in 2005). Also, peak flows are distributed among several distributary channels, and multiple channels require flow estimates that are less precise than direct discharge measurements. Most bed mobility monitoring sites have not had 100% mobility across the range of flows the last six years. Several sites have had only limited mobility, and higher surface sites such as point bars and floodplains have had no mobility.

Other notable highlights from RY 2005 include:

- None of the Upper Rush Creek tracer rock sets had complete (100%) mobility, whereas nearly all the Lower Rush Creek pool tail and riffle tracer sets had near or complete mobility (80 to 100%).
- In Rush Creek, 8 out of 11 sites achieved >80% mobility of all particle sizes in 2005; three other sites that were point bar or floodplain features were not mobilized.

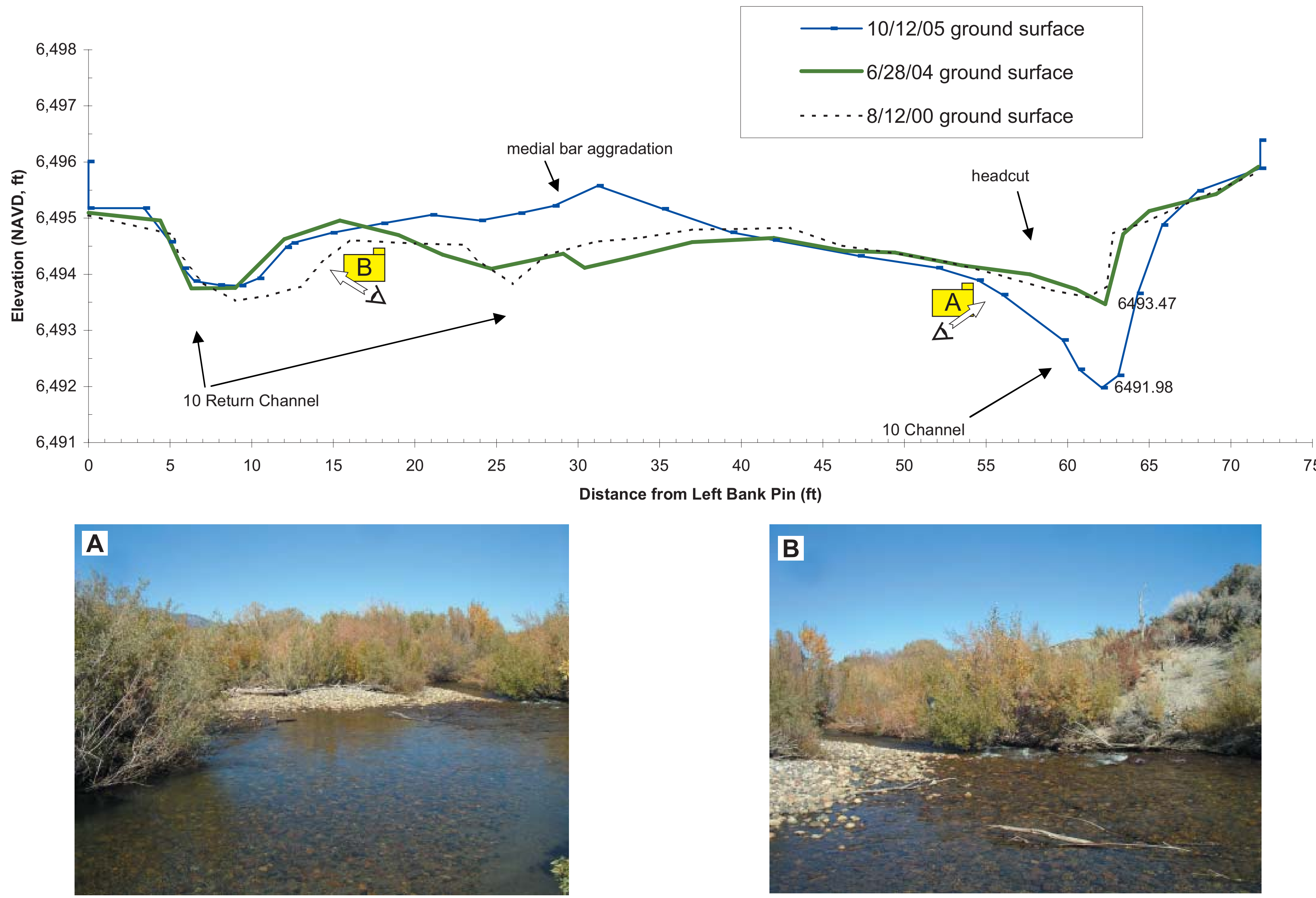


Figure 18. Cross section 0+50 that traverses the 10 Channel and 10 Return Channel split. A head cut (Photo A) migrated up the 10 Channel, stopping at the upstream end of the right bank floodplain; A medial bar (Photo B) formed between the two channels from RY 2005 deposition.

Table 6. Rush Creek tracer rock mobility data for RY 2005.

Site	Cross Section	Peak Date	Peak Discharge (cfs)	Discharge at XS (cfs)	Percent D_{84} Moved	Percent D_{50} Moved	Percent D_{31} Moved
Upper Rush Creek	0+74	29-Jun-05	403	403	47%	82%	76%
Upper Rush Creek	5+45	29-Jun-05	403	403	60%	80%	70%
Upper Rush Creek	12+95	29-Jun-05	403	403	70%	60%	70%
Lower Rush Creek	-9+82	29-Jun-05	467	467	100%	92%	100%
Lower Rush Creek	-5+07	29-Jun-05	467	286	30%	70%	90%
Lower Rush Creek	4+08	29-Jun-05	467	286	90%	90%	100%
Lower Rush Creek	7+25	29-Jun-05	467	286	90%	100%	100%
Lower Rush Creek	7+25	29-Jun-05	467	286	0%	0%	0%
Lower Rush Creek	7+70	29-Jun-05	467	286	80%	80%	90%
Lower Rush Creek	7+70	29-Jun-05	467	286	0%	0%	0%
Lower Rush Creek	10+10	29-Jun-05	467	286	90%	100%	100%
Rush Creek 10-Channel	1+10	29-Jun-05	467	181	100%	90%	100%
Rush Creek County Road	15+19	29-Jun-05	467	467	100%	83%	100%
Rush Creek County Road	6+85	29-Jun-05	467	467	100%	100%	100%

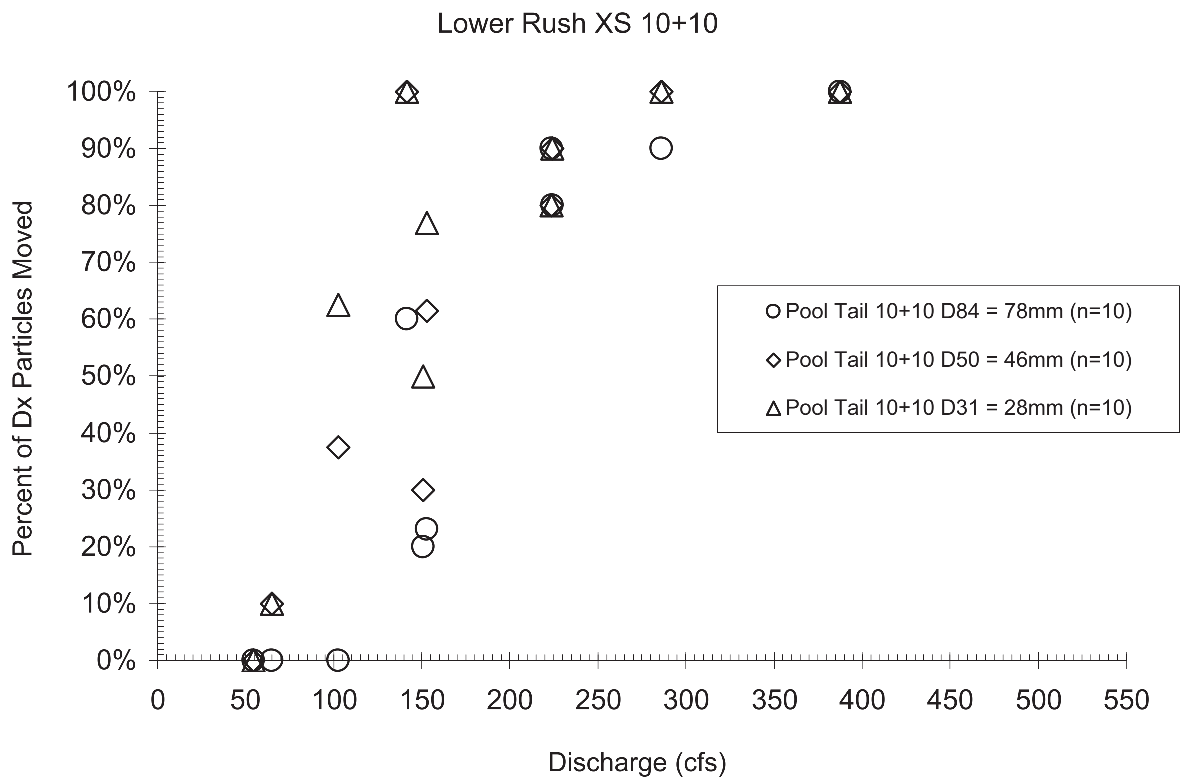
Table 7. Lee Vining Creek tracer rock mobility data for RY 2005.

Site	Cross Section	Peak Date	Peak Discharge (cfs)	Discharge at XS (cfs)	Percent D_{84} Moved	Percent D_{50} Moved	Percent D_{31} Moved
Upper Main Channel	3+45	28-May-05	372	289	80%	80%	87%
Upper Main Channel	6+61	28-May-05	372	289	0%	0%	0%
Upper Main Channel	9+31	28-May-05	372	289	no recovery data	no recovery data	no recovery data
Upper Main Channel	9+31	28-May-05	372	289	100%	100%	100%
Upper Main Channel	13+92	28-May-05	372	289	36%	36%	64%
A4 Channel	4+04	28-May-05	372	83	10%	20%	50%
A4 Channel	5+15	28-May-05	372	83	70%	70%	90%
A4 Channel	6+80	28-May-05	372	83	25%	75%	63%
Upper B1 Channel	06+08	28-May-05	372	100	38%	50%	88%
Lower Main Channel	01+15	28-May-05	372	272	80%	90%	100%
Lower B1 Channel	01+80	28-May-05	372	100	70%	70%	100%
Lower B1 Channel	00+87	28-May-05	372	100	20%	40%	50%

- As mentioned above, most tracer particles were mobilized too far from the placement site to be relocated; many were likely buried.
- In Lee Vining Creek, 3 out of 6 tracer rock sets in the main channel had >80% mobility of all particle sizes in 2005; in the upper A4 and B1, and lower B1 channels, none of the sites had complete mobility. The flood peak shifted away from the A4 and B1 channels where the bed was not completely mobilized, whereas in the mainstem channel, the coarse bed resisted mobilization.

3.1.3 Scour Core Experiments

On Rush and Lee Vining creeks, all scour cores were reset in May 2005 prior to the snowmelt runoff, and then recovered in August after the creeks had receded. Data were compiled with previous years' data and are presented in Tables 8 and 9 for Rush and Lee Vining creeks, respectively. On Rush Creek, most sites had scour ranging from 0.1 ft to 0.3 ft; one pool tail site on Lower Rush had 0.6 ft of scour, with similar depth of re-deposition. The scour core located at the County Road XS 6+85 was not relocated



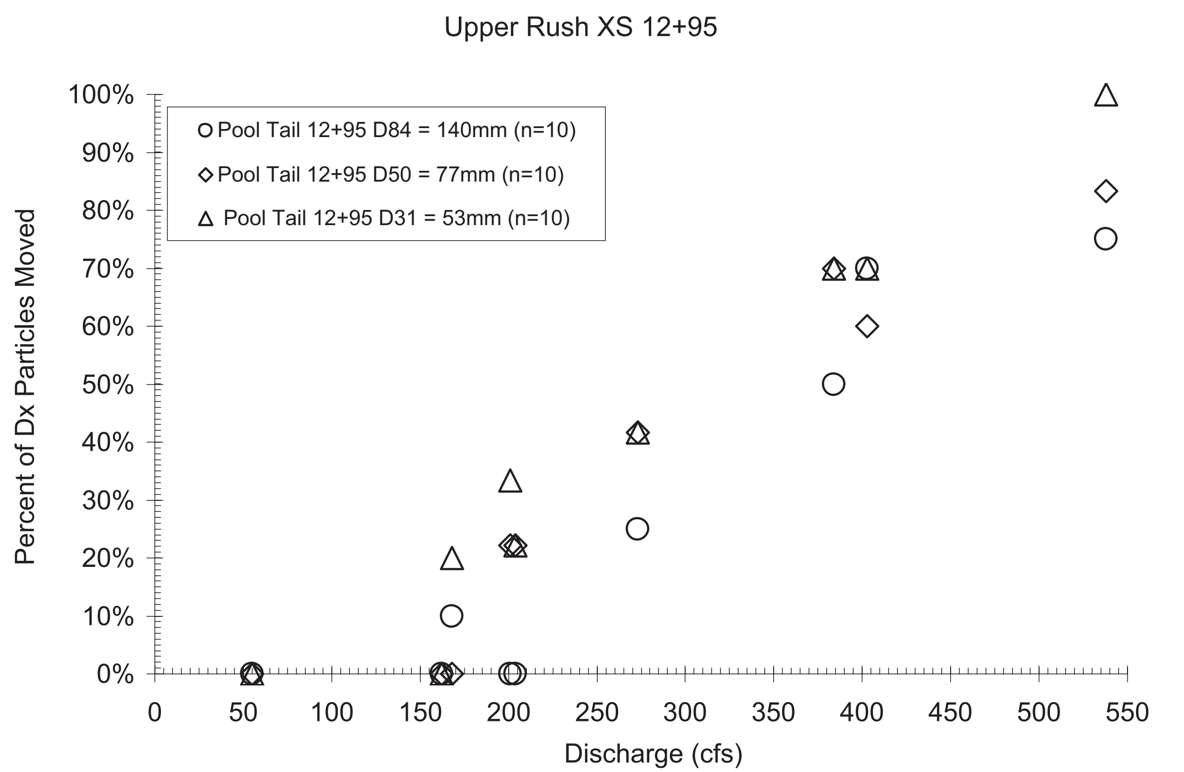


Figure 19. Tracer rock mobility vs. discharge rating curves from upper and lower Rush Creek cross sections, from RY 1998 to 2005, showing different mobility thresholds at each site. Each discharge represents a different runoff year.

Table 8. Rush Creek scour core data for RY 2005.

Reach	Cross Section	Year	Discharge at Cross Section (cfs)	Core #	Scour Depth (ft)	Redeposition Depth (ft)	Geomorphic Feature
Lower Rush Creek	00+86	2005	286	5	0.00	0.00	Upper point bar / floodplain
				4	0.05	0.11	Middle of point bar
				3	0.03	0.00	Point bar within low water channel
				2	0.02	0.07	Point bar within low water channel
				1	0.01	0.00	Pool Tail
Lower Rush Creek	03+30	2005	286	1	0.10	0.12	Pool tail at low flow, transverse bar at high flow
				2	0.05	0.06	Pool tail at low flow, transverse bar at high flow
Lower Rush Creek	04+08	2005	286	1	0.30	0.25	Low-gradient riffle
				2	0.09	0.16	Low-gradient riffle
Lower Rush Creek	05+49	2005	286	1	0.43	0.34	Riffle (transverse bar), within low water channel
				2	0.33	0.52	Riffle (transverse bar), within low water channel
				3	0.57	0.60	Riffle (transverse bar), within low water channel
				4	0.31	0.60	Riffle (transverse bar), within low water channel
Lower Rush Creek	07+25	2005	286		0.00	0.00	Upper point bar / floodplain
Lower Rush Creek	07+70	2005	286	1	0.00	0.00	Upper point bar / floodplain
Lower Rush Creek	10+10	2005	286	1	0.35	0.52	Pool Tail
				2	not recovered	0.55	Pool Tail
Upper Rush Creek	1+05	2005	403	1	0.33	0.28	Constructed pool tail
				2	0.13	0.46	Constructed pool tail
				3	0.20	0.08	Constructed pool tail
Upper Rush Creek	5+45	2005	403	1	0.33	0.28	Eddy deposit
				2	0.13	0.46	Lee deposit
				3	0.20	0.08	Eddy deposit
Upper Rush Creek	12+95	2005	403	1	0.08	0.52	Riffle
				2	0.01	0.12	Riffle
Rush Creek at County Road	6+85	2005			not recovered	0.40	point bar edge

but the cross section survey indicated an additional 0.4 ft of sediment deposition on the gravel bar (Figure 20) where approximately 1.3 ft of gravel had deposited in 2004. In Upper Rush, several scour cores had minor scour less than 0.3 ft, but with significantly more re-deposition up to 0.5 ft.

On Lee Vining Creek, some scour cores had scour up to 0.4 ft, with similar re-deposition depths. The main channel cross section 13+92 had scour cores installed in loose, unconsolidated eddy deposits along the left bank on a low bar surface. Those cores did not scour deeply (up to 0.14 ft). This area has become depositional and does not scour to the extent expected. The medial bar along the right bank at XS 10+44 was the most actively scoured, with scour depths of 0.37 ft and 0.42 ft, and with re-deposition up to 1.11 ft. This bar has been building (depositing fine gravel and sand) since at least 1999 when our monitoring began (Figure 21).

3.1.4 LWD Transport and Recovery Experiment

Large wood debris (LWD) is an important component of the channel; LWD increases channel complexity, provides cover for fish habitat, creates scour pools, and provides forage substrate for macro-invertebrates. The LWD transport experiment began in 2004 on Rush Creek, and expanded to include Lee Vining Creek in 2005. The goal was to assess how the Wet-Normal runoff year SRF mobilized and transported LWD in lower Rush and Lee Vining creeks.

In May of 2004 thirty-six pieces of LWD in place along Rush Creek channel were marked with metal identification tags and white nylon cord before the high flow release. The location and numeric identifier of each piece were recorded on aerial photos (refer to McBain and Trush 2005, Section 3.1.5 for initial methodology). After the June 2004 peak SRF releases of 354 cfs (daily average discharge)

Table 9. Lee Vining Creek scour core data for RY 2005.

Reach	Cross Section	Year	Discharge at Cross Section (cfs)	Core #	Scour Depth (ft)	Redeposition Depth (ft)	Geomorphic Feature
Lower Lee Vining	00+87	2005	100	1	0.10	0.00	Point bar, pea gravels
				2	not installed		
Upper Lee Vining Creek	13+92	2005	289	1	0.03	0.19	Eddy deposit, coarse sand
				2	0.14	0.14	Eddy deposit, medium gravels
Upper Lee Vining Creek	10+44	2005	289	1	0.42	0.64	Eddy deposit - exposed bar
				2	0.37	1.11	Eddy deposit - exposed bar
Upper Lee Vining Creek	03+73	2005	289	1	0.03	0.06	Point bar - pea gravels
				2	0.32	0.19	Point bar - pea gravels

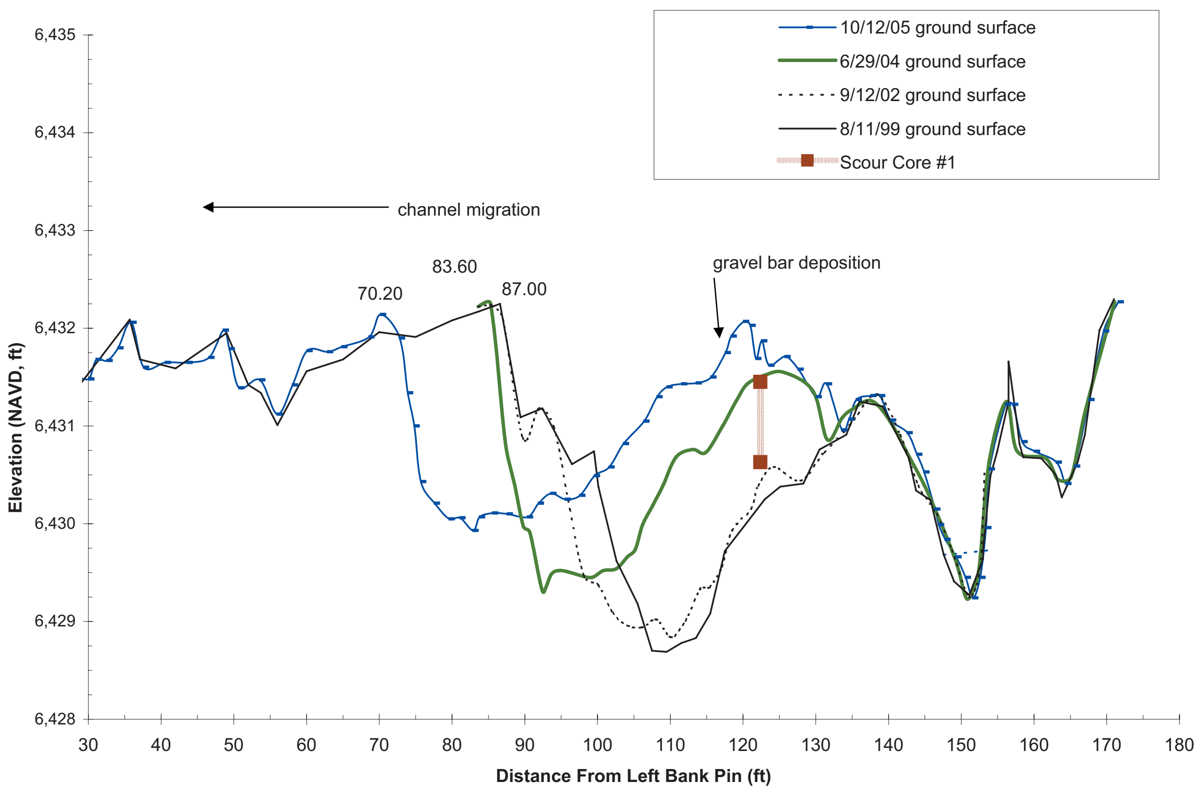


Figure 20. Lower Rush Creek County Road XS 6+85, re-surveyed in October 2005. The channel has migrated laterally approximately 17 ft in the last two years, and a gravel bar deposited on the right bank.

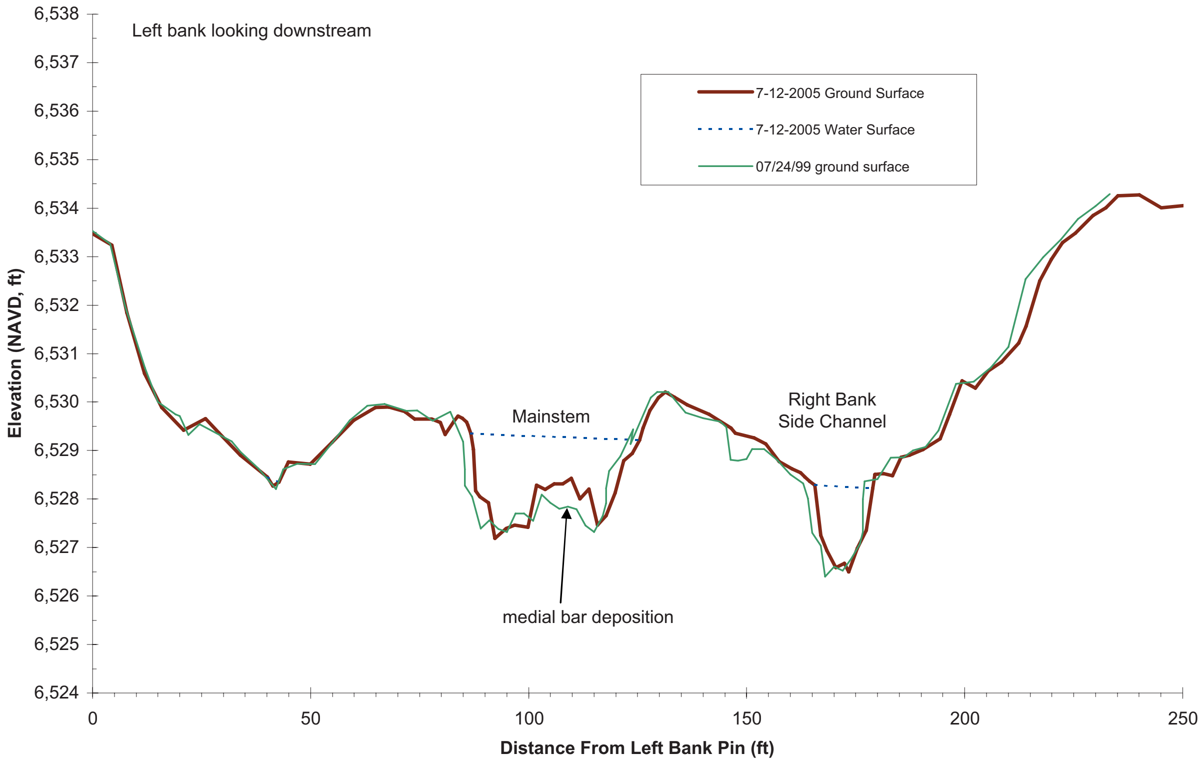


Figure 21. Upper Lee Vining Creek mainstem XS 10+44 re-surveyed in October 2005. The cross section has had considerable aggradation, bar building, and mainstem channel reconfinement since the 1999 survey.

below the Narrows, field crews searched and recovered marked LWD. In Rush Creek, no additional pieces were tagged previous to the 2005 SRF; in Lee Vining, 15 pieces were marked in May 2005. LWD recovery efforts were repeated October 11 and 16, 2005. Rush Creek recovery efforts were extended downstream to include the main channel and 10 Channel past the Lower Rush Creek study site. The new location of each recovered piece was recorded on field maps. Channel orientation and positioning were recorded in a fieldbook. Distance that each recovered piece traveled was calculated by digitizing the path of movement on the aerial photographs in AutoCAD (Appendix E).

A peak SRF of approximately 467 cfs moved LWD long distances in lower Rush Creek (Table 10). On Lee Vining, with peak discharge of 372 cfs (daily average discharge) only 3 of 15 moved, 2 of those pieces were on the A4 Channel, and none moved far (Table 11). Similar to the RY 2004 findings, channel orientation and size of the wood did not appear to be strong influences determining if a piece mobilized. Free-lying pieces lower in the wetted channel mobilized most often.

Rush Creek Highlights:

- Of the five pieces mobilized and recovered in 2004, four were mobilized again in 2005 (1, 4, 6, & 36);
- Four new pieces were mobilized in 2005 that did not mobilize in 2004 (7, 20, 22, & 25);
- Of the six pieces that mobilized and were not relocated in 2004, one piece was relocated in 2005 and had moved a total of 2020 feet downstream (17);
- LWD #36 broke in two pieces, one stayed in the main channel and the other went down the 10 Channel.

Table 10. Large wood debris movement on Rush Creek for RY 2005.

LWD#	Length (ft)	Diameter (ft)	Initial Orientation	Distance (ft)
1	7.8	0.4	Perpendicular	Unknown
4	20.7	1.4	Perpendicular	Unknown
6	31.3	0.7	Longitudinal	Unknown
7	20.8	0.7	Longitudinal	Unknown
17	9.4	0.9	Unknown	2,020
20	8.1	0.7	Perpendicular	1,637
22	9.8	0.8	Perpendicular	Unknown
25	17.5	0.6	Longitudinal	96
36a	15.6	0.9	Longitudinal	1,079
36b	15.6	0.9	Longitudinal	1,973

Table 11. Large wood debris movement on Lee Vining Creek for RY 2005.

LWD#	Length (ft)	Diameter (ft)	Channel	Initial Orientation	Distance (ft)
3	15	0.5	Main	Parallel	190
11	15	0.5	A-4	Perpendicular	159
15	15	0.5	A-4	Perpendicular	473

Lee Vining Creek Highlights:

- Out of the fifteen pieces marked, three were mobilized (3, 11, & 15), two of which were in the A4 Channel;
- All pieces were recovered.

3.2 Planmapping

The RY 2004 Annual Report (McBain and Trush 2005) updated the planmapping methods used on Rush and Lee Vining creeks based on high resolution aerial photographs. The new methods established consistent mapping units (e.g., floodplain, terrace, pool, riffle, woody debris, etc.) within three mapping categories, which were 'Geomorphology,' 'Aquatic Habitat,' and 'Other.' The updated mapping system was applied to the three study reaches of Rush Creek in the fall of 2004, and Rush Creek planmaps were presented in the RY 2004 report.

Planmapping was completed at the two study sites on Lee Vining Creek in May 2005 prior to the snowmelt runoff (Appendix F). Given the inaccuracies of the previous tape and compass methods with the 1999 planmaps, the 1999 and 2004 maps were not overlaid. The 2004 planmaps will be available as a baseline for future comparisons.

3.3 Sediment Transport Measurements

3.3.1 Background and Objectives

Between June 20 and 30, 2005, sediment transport was measured on the ascending limb and during the peak of the SRF releases on Rush Creek. Sediment transport measurements were focused on bedload (the portion of total sediment load moving on or near the streambed). However, some suspended load (the portion of the total load transported in the water column) was measured.

Previous sediment sampling on Rush Creek included bedload transport measurements by StreamWise (2004), as well as fine sediment bedload sampling for floodplain aggradation studies (McBain and Trush 2004 and Section 3.3 of this report). The StreamWise study was conducted during the 2004 SRF flow releases and measured bedload transport but not suspended sediment. Bedload sampling was performed at floodplain study sites as part of ongoing field experimentation to expand our understanding of floodplain aggradation rates and pathways.

Given that Grant Lake historically (glacial moraine lake) and contemporarily (man-made reservoir) has trapped most sediment supplied from the watershed, and flood magnitudes have been reduced, we hypothesized that:

H-1: Fine and coarse sediment supply to Rush Creek is near zero below Grant Lake;

H-2: Fine and coarse sediment transport increases downstream from Grant Lake due to increasing sediment supply, and;

H-3: Sediment transport rates decrease with duration of a high flow release (of constant magnitude) as sediment supply becomes limited.

The 2005 SRF had a planned release of 400 cfs for eight days. Previous bed mobility monitoring had shown that mobility thresholds of active alluvial features were exceeded by 300 to 400 cfs at both study sites. We estimated eight days would exceed the duration required to observe a decline in transport rates. These estimates assumed total bed mobility when 80 percent of the D_{84} size class was mobilized (McBain and Trush 2002). Based on our hypotheses and the scheduled 2005 SRF releases, our objectives for sediment sampling were:

(1) Measure sediment transport rates on the ascending limb and during the sustained peak of the 2005 SRF releases (assesses hypotheses #2 and #3);

(2) Compare sediment transport rates at upper and lower sampling sites (assess Hypothesis #1);

To address Hypothesis 1, sediment transport was measured in upper and lower Rush Creek mainstem reaches. Two of the three sites sampled by StreamWise in 2004 were reoccupied: Upper Rush Creek, approximately 60 ft upstream of cross section 01+05, and Lower Rush Creek at cross section -9+82 (Figure 22). Sampling sites experienced most of the SRF releases (i.e., no major side channels bypassed the sampling sites, and only minor floodplain inundation occurred). We measured flow in the two small side channels at the upper site, which had 4.7 cfs and 8.8 cfs on 6-24-05, which represented a small percentage of the total release of 402 cfs).

3.3.2 Sampling Methods

The Rush Creek SRF releases provided a ramp-up and steady flows of 400 cfs (Figure 23). McBain and Trush partnered with Graham Matthews and Associates (GMA) for field work and laboratory analyses. Sampling was performed from catarafts designed specifically for sediment sampling. Two catarafts were used, each dedicated to a site. A two-member crew traveled between sites to collect sediment samples; one crew member was certified by the U.S. Geological Survey (USGS) for sediment sampling. Sampling cross sections remained fixed during the entire sampling period (Figure 24).

Bedload samples were collected on eight sample days (June 20 to 25, 27, and 30) over the eleven day sampling period. Samples were collected using the ‘single equal-width-increment’ (SEWI) method (Edwards and Glysson 1999), and used a Toutle River-2 (TR-2) bedload sampler with a 6 inch by 12-inch nozzle and a 0.5 mm mesh collection bag. The TR-2 was sufficient at the Upper Rush Creek site to sample the entire width of the moving bed, but the Lower Rush Creek site required a 3-inch hand-held Helley-Smith sampler to sample the left edge of the moving bed. Using the SEWI method, bedload samples were collected at equal-width intervals (verticals) across the cross section, with the TR-2 sampler resting on the bed surface for three minutes at each vertical. The USGS generally recommends a one minute sampling duration, but we increased sample times to three minutes

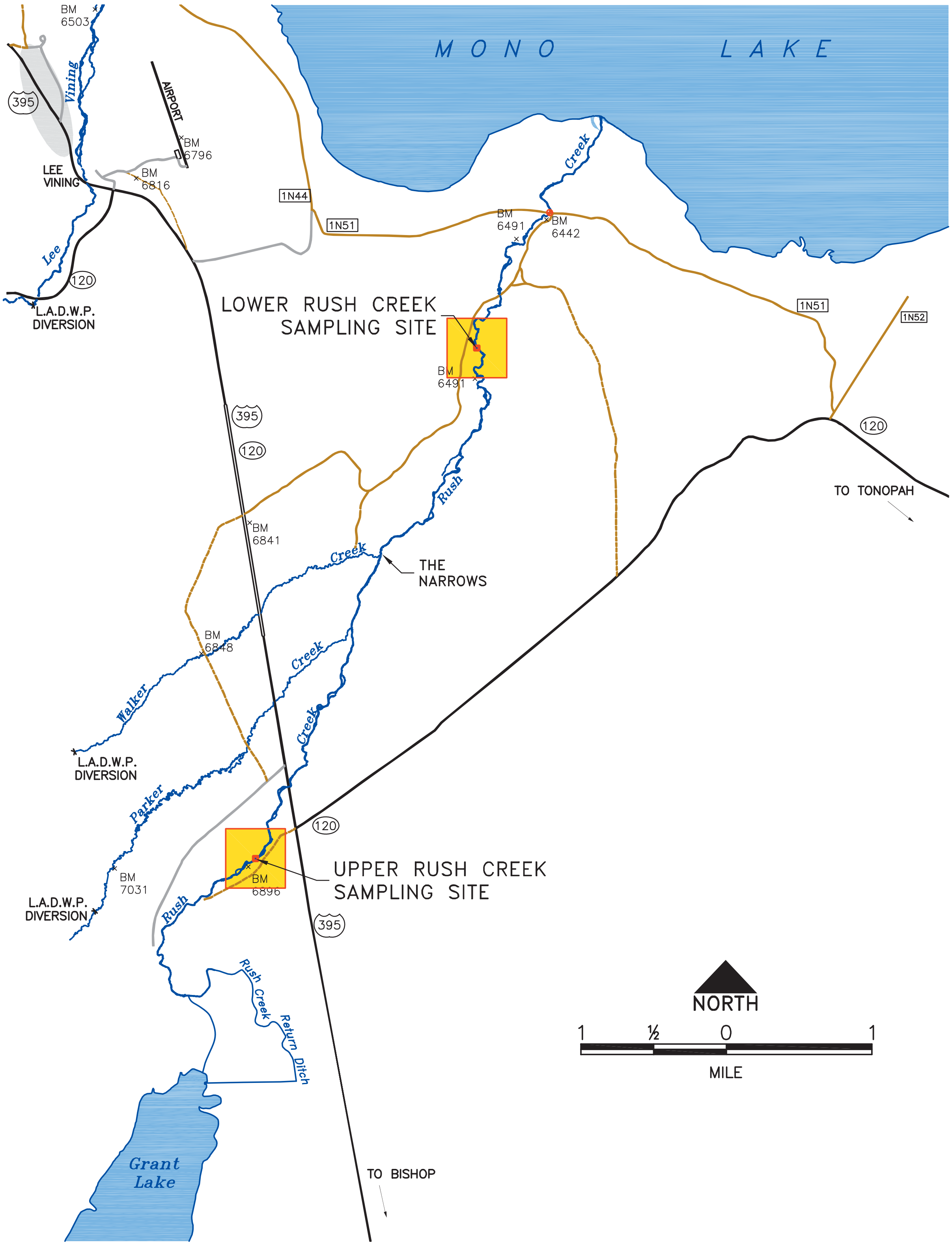


Figure 22. Upper and lower bedload sampling sites on Rush Creek.

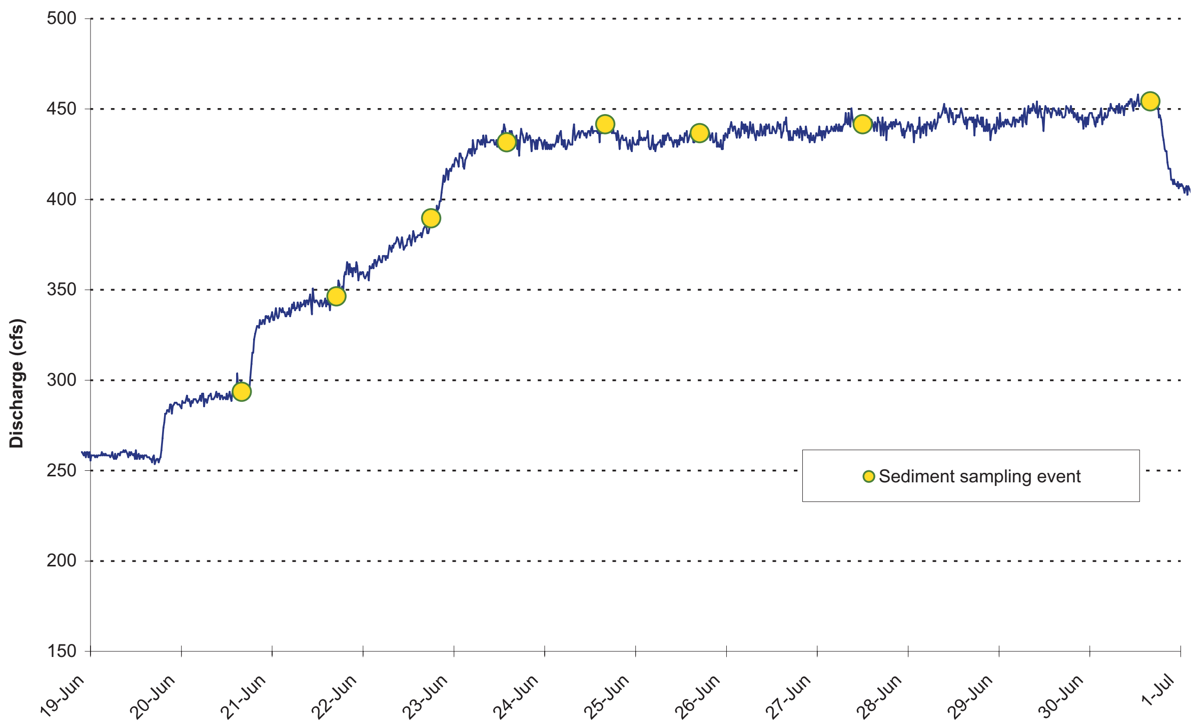


Figure 23. Preliminary 15-minute hydrograph at lower Rush Creek XS -9+82 with sediment sampling events plotted from June 20 – June 30, 2005.

duration to reduce variability in our bedload samples. Verticals were spaced every two feet (with a 1 ft wide nozzle), allowing 50 percent of the moving bed width to be sampled. This spacing provided high sampling precision. Three passes across the channel were made for each flow release. Starting at one bank and proceeding to the opposite bank (1 pass), individual samples were collected at each vertical, and then combined into a single sediment transport volume. The three passes were then averaged into one sample to compute the bedload transport rate for each discharge.

Suspended sediment samples were collected using a cable-deployed D-74 sampler; a hand-held DH-48 sampler was used at the Lower Rush Creek site to sample the channel margins. Sampling transit rates and sampler nozzle sizes were determined from measurements of maximum mean water velocity for each flow release. Depth-integrated (isokinetic) suspended sediment samples were collected for a single pass at each site, as there was less variability in suspended sediment transport.

To summarize, sediment sampling at each study site consisted of one bedload sample (three passes) and one suspended sediment sample (one pass). Each site was sampled once on each designated sampling day. Bedload transport rates were computed using the average of the three passes. Suspended sediment concentration was represented by a single pass.

Streamflows were obtained from either direct measurement by field crews or from LADWP gages (Figure 23). Water surface elevations in the reaches upstream of bedload sampling cross sections were measured for each sampled flow release using rebar stakes and staff plates. These reference marks were surveyed so water surface slopes could be computed for each sampling day.

After field sampling was completed, sediment samples were transported to a laboratory, then dried, weighed, and sieved for particle-size analyses. Samples were sieved in half-phi increments to -1

Figure 24a. Sediment sampling from the cataraft at the Upper Rush Creek site on June 25, 2005. The cataraft is attached to a cable that spans the channel, and is maneuvered between banks to collect sediment samples at discrete locations along the streambed and in the water column. One crew member operates a reel which raises and lowers the sampler, while the other crew member controls the sampler as it is lowered and raised through the water column. View is from the right bank, flow is from left to right and is approximately 400 cfs.

phi (2 mm) and then at whole-phi increments to 4 phi (0.063 mm). Suspended sediment samples were filtered, dried, and weighed to determine sediment concentration (mg/L). Concentrations were determined for 1 phi (0.5 mm), 4 phi (0.063 mm), and material passing 4 phi (finer than 0.063 mm).

3.3.3 Analysis and Results

Total sediment load is the mass of all sediment passing through a given cross section per unit time, including the coarsest material moving as bedload down to the finest particles traveling in suspension. An estimate of total sediment load was made from the data collected, because the estimate is not entirely additive (bedload + suspended sediment ≠ total sediment load) and requires several assumptions.

3.3.3.1 Bedload and suspended sediment transport computations

Bedload transport rates were calculated following Edwards and Glysson (1999) for each sampling date based on (1) the average mass collected during each sampling event, and (2) the total time the sampler was on the bed. Transport rates were calculated for total bedload transport, bedload transport finer than 8.0 mm, and bedload transport finer than 2.0 mm (Tables 12a and 12b;Figures 25a and 25b). Suspended sediment concentrations were determined for total suspended sediment, and for

Figure 24b. Cataraft set-up at the Lower Rush Creek site, June 25, 2005. Bank configuration on the left channel margin and vegetation along the right channel margin prevented the reel-operated samplers (TR-2 and D-74) to be used along the edges, so sampling along both channel edges was performed with hand-held samplers (3-inch Helley-Smith and DH-48). View is from the left bank, flow is from lower right and is approximately 465 cfs.

concentrations greater than 0.5 mm, greater than 0.063 mm, and finer than 0.063 mm. Suspended sediment concentrations measured for each flow release (Tables 13a and 13b;Figures 26a and 26b).

3.3.3.2 Measured sediment transport

The 400 cfs peak SRF releases began on June 23 and was held constant through June 30, 2005. Suspended sediment concentrations at both sites peaked on June 23 (Figures 26a and 26b), while bedload transport at both sites peaked on June 24 (Figures 25a and 25b). These data suggested suspended sediment responded more rapidly than bedload to changes in flow magnitude on the ascending hydrograph limb.

Following peak transport rates, both suspended sediment concentration and bedload transport showed similar trends in declining transport. Suspended sediment transport tapered off at both upper and lower sites, but the average rate of decline through June 25 (two day total) was much greater at Upper Rush Creek than at Lower Rush Creek: 3.57 mg/L/d at Upper Rush Creek compared to 0.6 mg/L/d at the Lower Rush Creek site. Suspended sediment supply became limited at Upper Rush Creek faster than at Lower Rush Creek, supporting our hypothesis that fine sediment supply increased with distance downstream.

Table 12a. Computed bedload transport rates (Qb, tons/day) for the Upper Rush Creek sampling site.

Date	Streamflow (cfs)[1]	Qb total (tons/day)	Qb < 8mm (tons/day)	Qb < 2mm (tons/day)	D84 (mm)	D50 (mm)
6/21/2005	314	4.26	3.6	2.16	7.5	2
6/22/2005	362	7.24	5	2.93	30.3	2.8
6/23/2005	402	12.05	8.1	4.23	25.4	3.6
6/24/2005	402	13.51	8	3.49	46.5	5.1
6/25/2005	401	5.95	4.5	2.57	17	2.5
6/27/2005	402	4.93	3.9	2.08	13.3	2.5
6/30/2005	389	7.87	3.8	1.71	67.3 [2]	8.8 [2]

[1] Daily average streamflow for Rush Creek below Mono Ditch.

[2] Results skewed due to anomalously large volume sampled during first sampling pass (Pass #1 of 3). Also see discussion in text.

Table 12b. Computed bedload transport rates (Qb, tons/day) for the Lower Rush Creek sampling site.

Date	Streamflow (cfs)[1]	Qb total (tons/day)	Qb < 8mm (tons/day)	Qb < 2mm (tons/day)	D84 (mm)	D50 (mm)
6/20/2005	298	2.1	2.0	1.64	2.7	0.9
6/21/2005	367	3.8	2.9	2.15	20.0	1.6
6/22/2005	418	7.6	5.1	3.18	65.5	3.3
6/23/2005	461	13.0	6.1	4.28	73.7	9.5
6/24/2005	465	18.2	9.1	5.57	103.5	8.4
6/25/2005	465	12.0	8.2	5.74	41.6	2.3
6/27/2005	462	8.0	5.7	3.73	23.2	2.5
6/30/2005	461	6.9	5.0	3.48	34.1	2.0

[1] Daily average streamflow for Rush Creek below Narrows.

The interpretation of limiting sediment supply in the upper river was also supported by the bedload data. Although the measured bedload transport peaked on June 24, a pronounced change in transport rate occurred on the ascending limb at Upper Rush Creek on June 23; Lower Rush Creek transport rates continued to rise at the same rate of approximately 5 tons/day, but daily Upper Rush Creek transport rates slowed from a rate of approximately 4 tons/day to 1.4 tons/day. This rate decrease implied that bedload supply became limited at Upper Rush Creek faster than Lower Rush Creek.

3.3.3.3 Transport trend deviations

Although both sites showed an overall decline in sediment transport rate following their peaks, two deviations were observed on June 30: bedload transport increased at the Upper Rush Creek site and suspended sediment concentration increased slightly at the Lower Rush Creek site. We noted that the first pass collected on June 30 was four times heavier and captured more large rocks than the subsequent two passes, skewing the three-pass average. Although previous sampling at both sites collected consistent sample masses, we attributed the large sample to an episodic pulse in bedload transport.

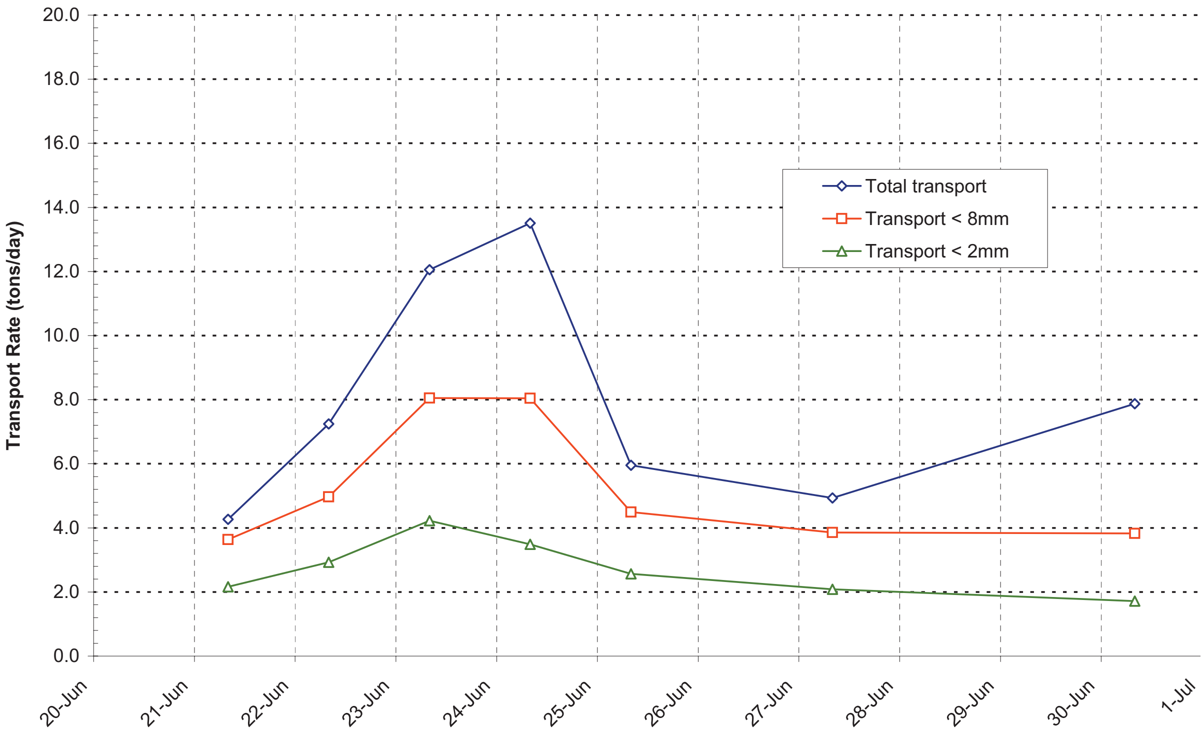


Figure 25a. Upper Rush Creek bedload transport (tons/day), June 20 to July 1, 2005.

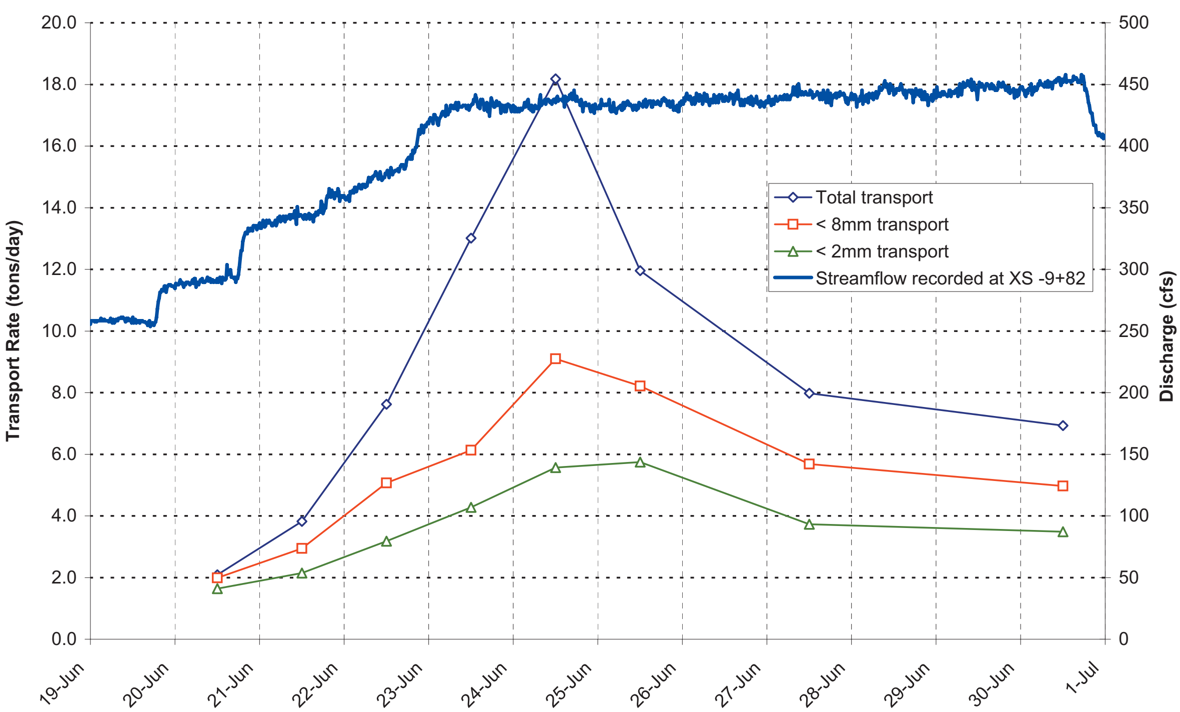


Figure 25b. Lower Rush Creek bedload transport (tons/day) and preliminary 15-minute hydrograph, June 19 to July 1, 2005.

Table 13a. Suspended sediment concentrations (SSC, mg/L) measured at the Upper Rush Creek sampling site.

Date	Streamflow (cfs)[1]	Total SSC (mg/L)	SSC > 0.5 mm (mg/L)	SSC > 0.063 mm (mg/L)	SSC < 0.063 mm (mg/L)
6/21/2005	314	10.7	0.98	4.88	4.83
6/22/2005	362	10.6	1.82	4.51	4.31
6/23/2005	402	15.7	5.24	5.66	4.74
6/24/2005	402	11.4	4.18	3.74	3.49
6/25/2005	401	8.56	2.4	3.07	3.09
6/27/2005	402	5.37	1.05	1.75	2.57
6/30/2005	389	3.96	<0.5	1.61	1.93

[1] Daily average streamflow for Rush Creek below Mono Ditch

Table 13b. Suspended sediment concentrations (SSC mg/L) measured at the Lower Rush Creek sampling site.

Date	Streamflow (cfs)[1]	Total SSC (mg/L)	SSC > 0.5 mm (mg/L)	SSC > 0.063 mm (mg/L)	SSC < 0.063 mm (mg/L)
6/21/2005	367	26	1.2	14.7	10.2
6/22/2005	418	29.1	3.64	16.8	8.7
6/23/2005	461	32.7	4.37	16.9	11.4
6/24/2005	465	31.6	5.58	16.4	9.64
6/25/2005	465	31.5	4.91	19.2	7.34
6/27/2005	462	18.7	2.18	10.4	6.16
6/30/2005	461	21.7	3.74	10.5	7.5

[1] Daily average streamflow for Rush Creek below Narrows.

A similar condition existed for the Lower Rush Creek suspended sediment sample collected on June 30, where suspended sediment concentration increased slightly from 18.7 mg/L on June 27 to 21.7 mg/L. Nothing in the data analysis or in the field notes suggested an anomalous condition, and we interpreted this increase as a perturbation in an overall decreasing trend. This perturbation was not observed at the Upper Rush Creek site.

3.3.4 Discussion

Trends in sediment transport occurred as expected (i.e., sediment transport rates increased on the ascending limb of the SRF release hydrograph and then tapered off after the flow was sustained at 400 cfs). However, sample volumes at the Upper Rush Creek site were much larger than expected. The following sections focus on results as they related to our hypotheses.

3.3.4.1 Sediment transport gradient (Hypotheses #1 and #2)

We hypothesized that sediment supply immediately below Grant Lake should be near zero (Hypothesis #1), but as drainage area increased below the dam, sediment supply would increase (Hypothesis #2). We expected to measure relatively little sediment at the Upper Rush Creek site compared to the lower site. Although lower transport rates were measured at the upper site, transport rates were much higher than expected, indicating a large volume of sediment was being transported

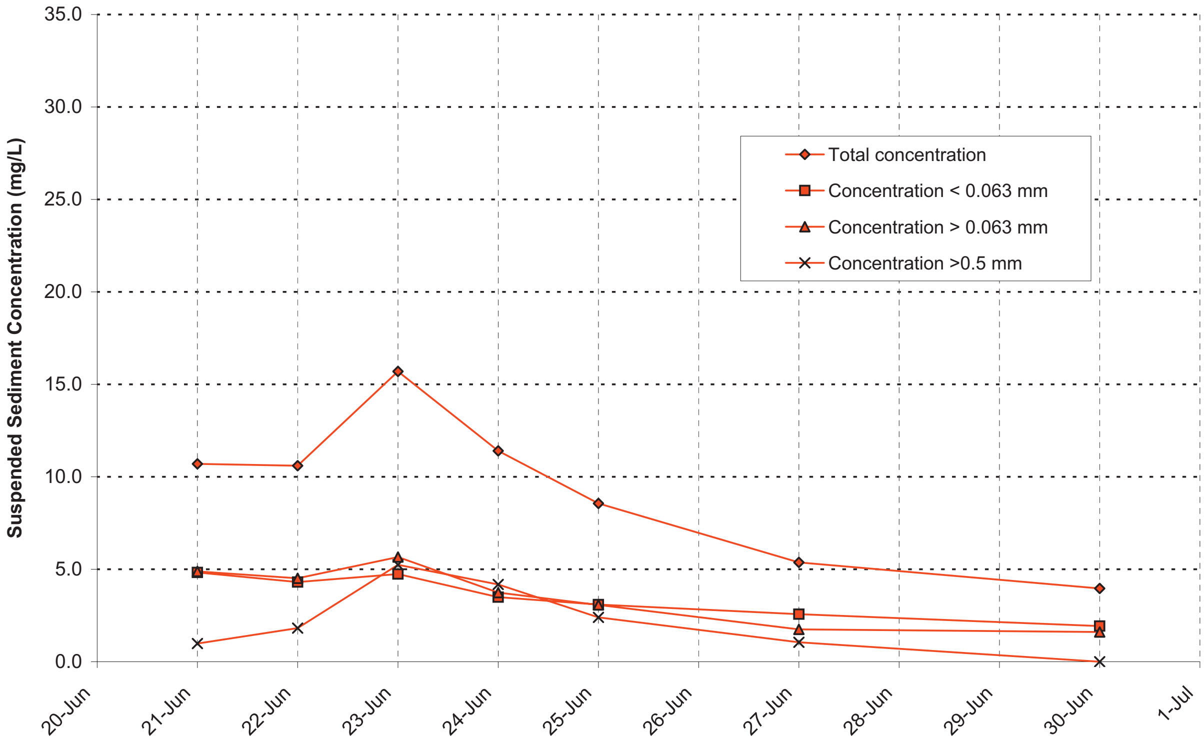


Figure 26a. Upper Rush Creek suspended sediment concentrations (mg/L), June 20 to July 1, 2005.

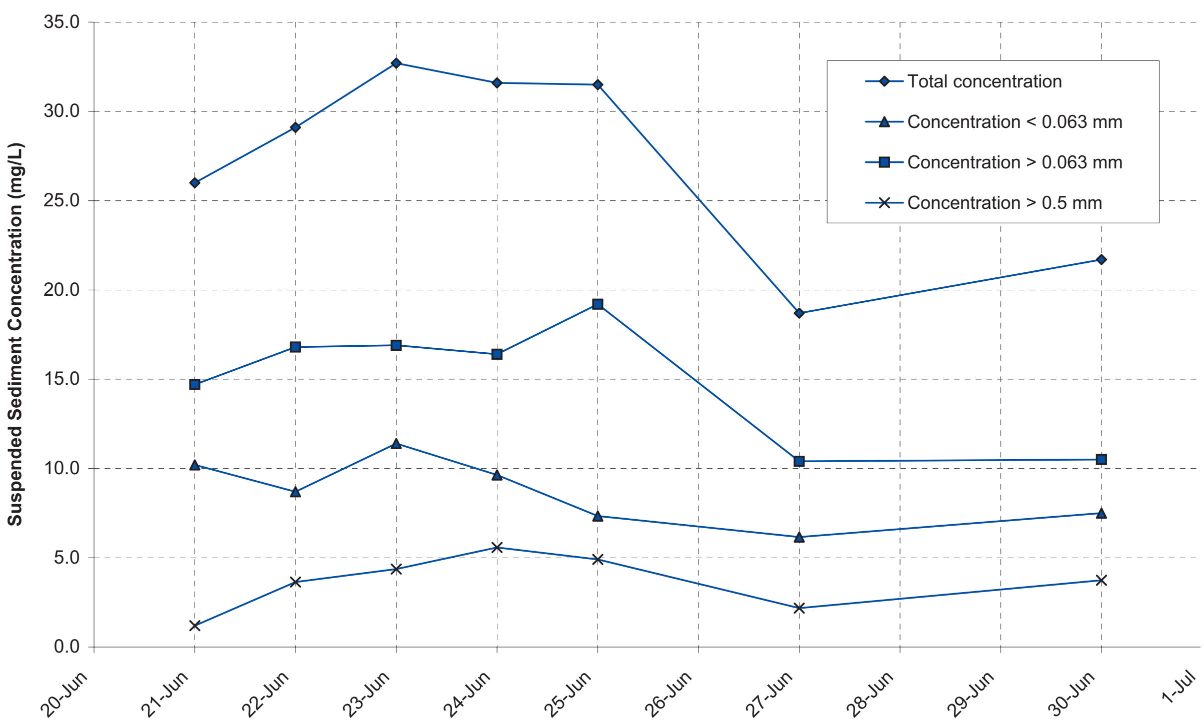


Figure 26b. Lower Rush Creek suspended sediment concentrations (mg/L), June 20 to July 1, 2005.

from the reach above the upper site, which includes approximately 8,130 ft of historic channel and approximately 7,850 ft of the Return Ditch. We were not able to determine the source of sediment delivered to the upper sampling site (i.e., is sediment being supplied by the Return Ditch, by the channel below the Return Ditch, or both?). One possibility is that recent Return Ditch construction may have increased sediment supply, which would likely be temporary.

3.3.4.2 Effectiveness of Flow Magnitude and Duration on Sediment Transport Rates (Hypothesis #3)

Do sediment transport rates decrease with flow duration? To evaluate the effect of flow duration at the Lower Rush Creek site, we plotted cumulative bedload transport during the 400 cfs release period (Figure 27a). We expected transport rates to approach an asymptote as an equilibrium was reached between sediment supply and sediment transport. This trend was observed at Lower Rush Creek, where over 75 percent of the total bedload transported over the 8-day bench was transported the first three days (Figure 27a). The remaining 25 percent was transported the last five days. For a 400 cfs release, two to three days may therefore be a sufficient duration to transport the majority of available bedload. A similar trend was observed in the Upper Rush Creek bedload data (Figure 28a), with 71 percent of the total bedload transported within the first three days.

Suspended sediment concentration curves at the Upper and Lower Rush Creek sites also had inflections at the third sampling day, corroborating the cumulative bedload transport curves (Figures 27b and 28b). At both upper and lower sites, 70 and 79 percent of the total suspended sediment transported over the 8-day bench were transported within the first three days. Therefore a 400 cfs

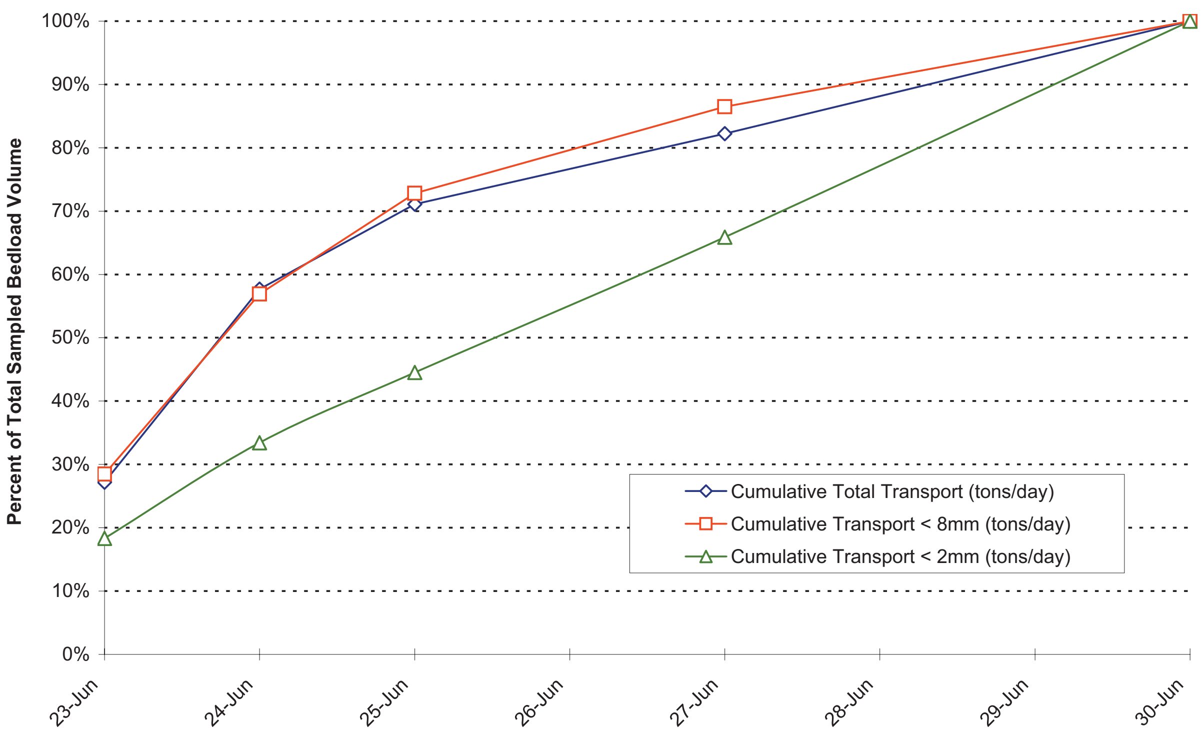


Figure 27a. Lower Rush Creek cumulative bedload transport volume for the scheduled 400 cfs SRF release period. An inflection in the percent of total bedload sampled occurred on June 25, 2005, with approximately 75 percent of the total bedload transported within the first three days.

release of two to three days may be sufficient to transport most available suspended sediment.

One notable difference was in the cumulative bedload transport between the upper and lower sites for the < 2.0 mm particle size range. Only 45 percent of the < 2.0 mm bedload fraction for Upper Rush Creek was transported within the first three days, and cumulative transport continued to increase in a linear trend through the final day of sampling. This cumulative transport rate did not asymptote similar to the < 8.0 mm curve or the total cumulative transport curves, suggesting that an equilibrium was not reached between sediment supply and sediment transport (i.e., the coarse sand supply did not approach a limiting condition). In addition, the Upper Rush Creek suspended sediment cumulative concentration curve showed a limiting trend, bracketing the non-limited particle size range between 0.5 mm and 2.0 mm (coarse sand). A large volume of coarse sand supply must have existed upstream of the upper sampling site.

3.3.4.3 Sediment Rating Curves

Sediment rating curves are used to estimate transport rates as a function of streamflow. Transport rates predicted from 2005 sampling would be specific to the 2005 SRF releases; for example, a similar-shaped hydrograph may not yield the same transport rates. Sediment transport estimates based on a rating curve from the 2005 SRF releases must therefore consider effects of flow duration, because our data demonstrated that bedload transport rates increased with flow magnitude, then decreased with duration. (Figure 29). Different portions of the hydrograph (e.g., rising limb or falling limb) had demonstrably different sediment transport rates, confounding the development of rating curves.

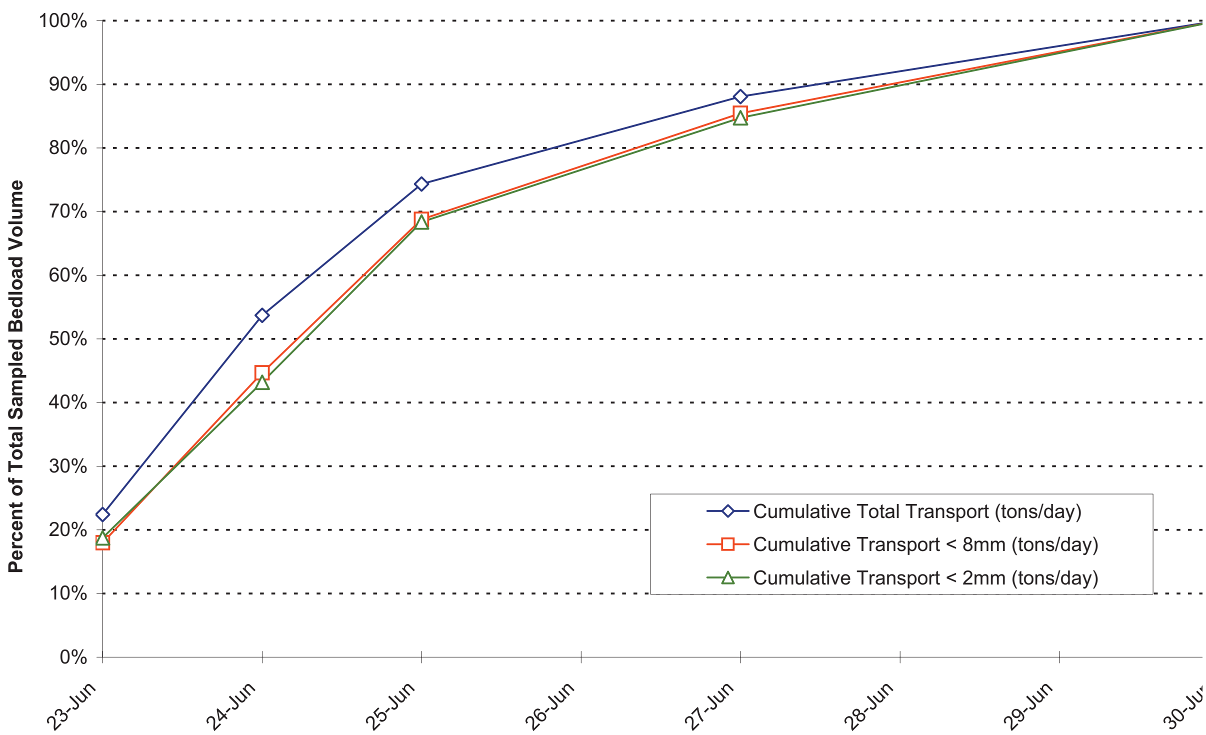


Figure 27b. Upper Rush Creek cumulative bedload transport volume for the scheduled 400 cfs SRF release period. An inflection in the percent of total bedload sampled occurred on June 25, 2005, with approximately 71 percent of the total bedload transported within the first three days.

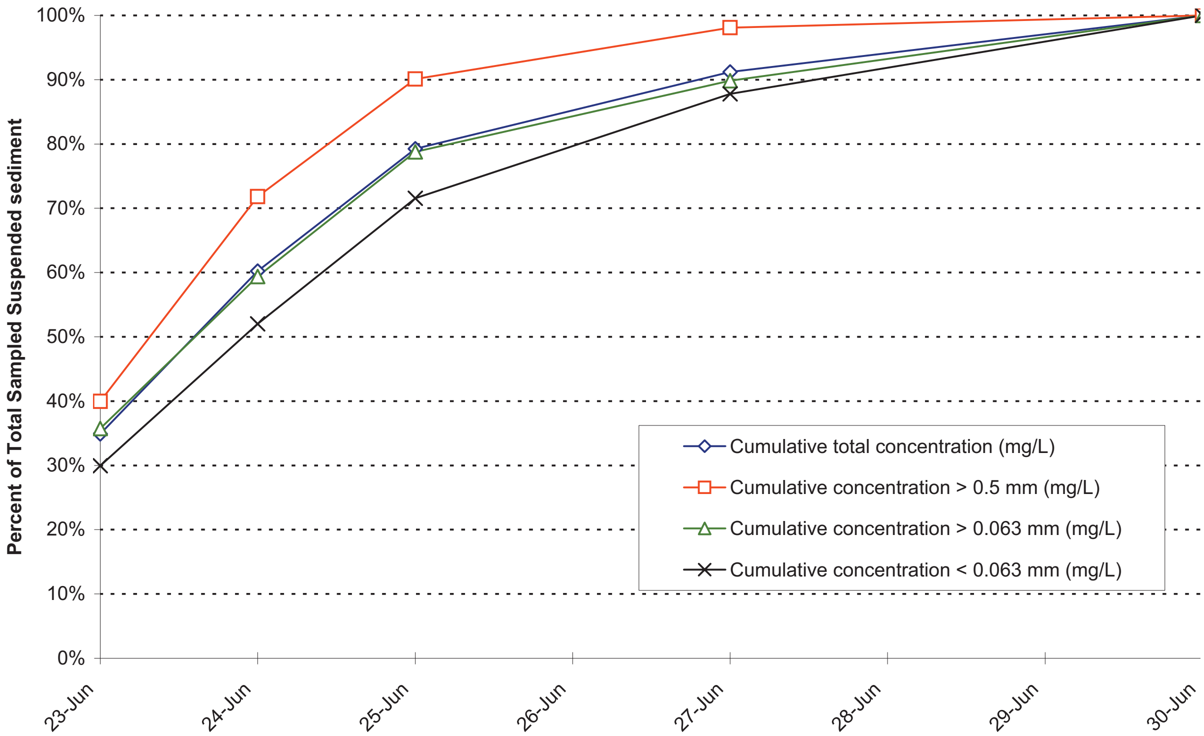


Figure 28a. Upper Rush Creek cumulative suspended sediment concentration for the scheduled 400 cfs SRF release period. An inflection in the percent of suspended sediment sampled occurred on June 25, 2003, with approximately 79 percent of the total suspended sediment (and up to approximately 90 percent of suspended sediment > 0.5mm) was transported within the first three days.

Hysteresis loops, a common effect in sediment transport versus discharge plots (e.g., Dunne and Leopold 1978; GMA 2005), graphically portray the variation of bedload transport with streamflow during a single storm or flood hydrograph. The hysteresis loop (Figure 29) demonstrated bedload transport was greatest on the rising limb of the hydrograph and then tapered off during the 400 cfs bench. The decrease in transport rates following the first day of the 400 cfs peak may be attributed to depletion of sediment supply following the rising limb of the SRF releases hydrograph (i.e., supply available for transport becomes limited). For the Rush Creek bedload transport data (Figure 29), a hysteresis loop would be better defined if additional sampling followed the 400 cfs bench. We added a hypothetical data point to demonstrate the expected hysteresis loop.

3.3.4.4 Summary

Our field equipment and methods yielded high quality bedload transport data and good quality suspended sediment data. Sediment transport was higher in Lower Rush Creek, but the difference was less than expected and does not necessarily support all our hypotheses. These results provided evidence to support Hypotheses #1 and #2, but more information would be needed to determine the cause for the greater-than-expected sediment transport at the upper sampling site. The sediment supply from the Return Ditch may be temporarily high due to reconstruction in 2003.

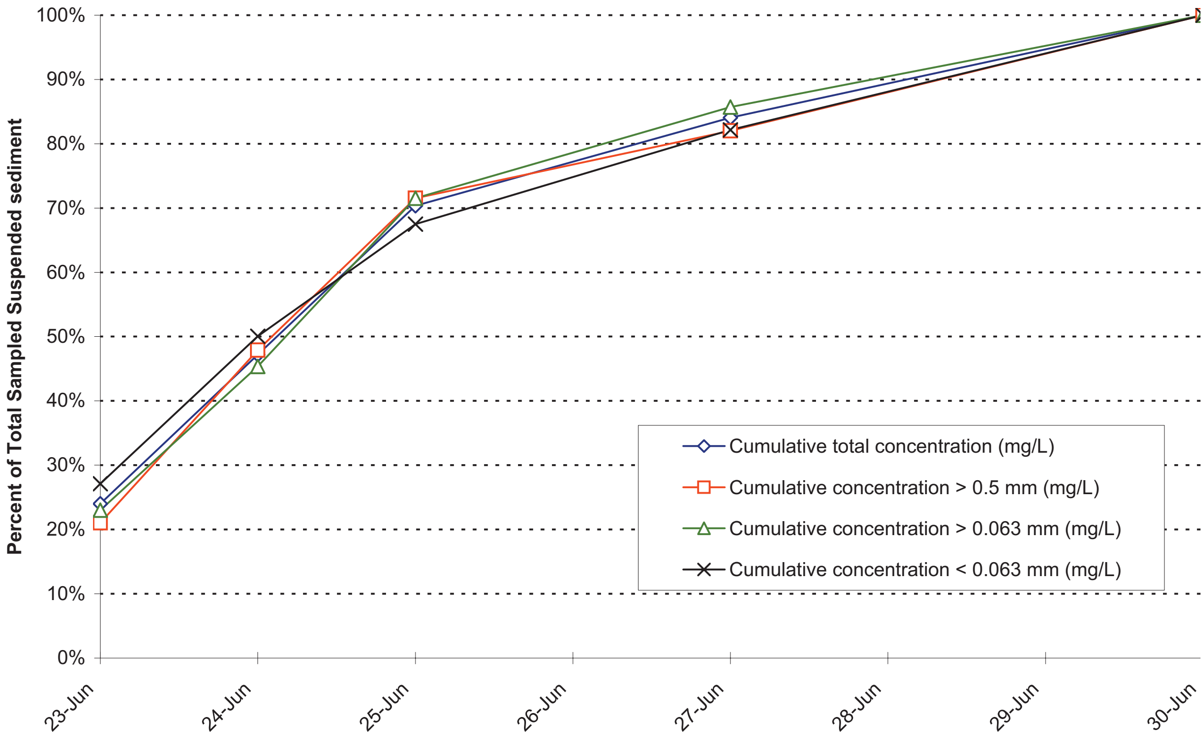


Figure 28b. Lower Rush Creek cumulative suspended sediment concentration for the scheduled 400 cfs SRF release period. An inflection in the percent of suspended sediment sampled occurred on June 25, 2003, indicating approximately 70 percent of the total suspended sediment was transported within the first three days.

Sediment transport decreased with increasing duration of constant flow magnitude, supporting Hypothesis #3. The first two to three days of the 400 cfs release transported a substantial portion of the total bedload and suspended sediment transported by the 2005 release. Shorter duration, higher magnitude high flow releases may be more water-efficient in accomplishing geomorphic work (using sediment transport flux as an index of "geomorphic work") than longer duration moderate flow releases. Other measures of geomorphic work, such as bed mobility, bed scour, channel migration, and sediment recruitment need to be considered in the magnitude and duration of future high flow releases. There are several possible high flow management implications from these findings, which will be explored in subsequent reports.

3.4 Floodplain Deposition Experiments

In RY 2004, we began field experiments to evaluate the role of streamflow magnitude and duration on reconfinement of the lower Rush Creek channel via natural floodplain construction processes (coarse and fine sediment deposition during high flows). In RY 2004, the SRF releases fluctuated between 240 cfs and 384 cfs over a three-day period. The duration of the 384 cfs peak was less than one day (the daily average peak was 354 cfs) (McBain & Trush, 2005). This peak flow release deposited small volumes of fine sediment at our floodplain study sites. The short peak duration combined with flow fluctuations ruled out any evaluation of duration in deposition rates and volumes.

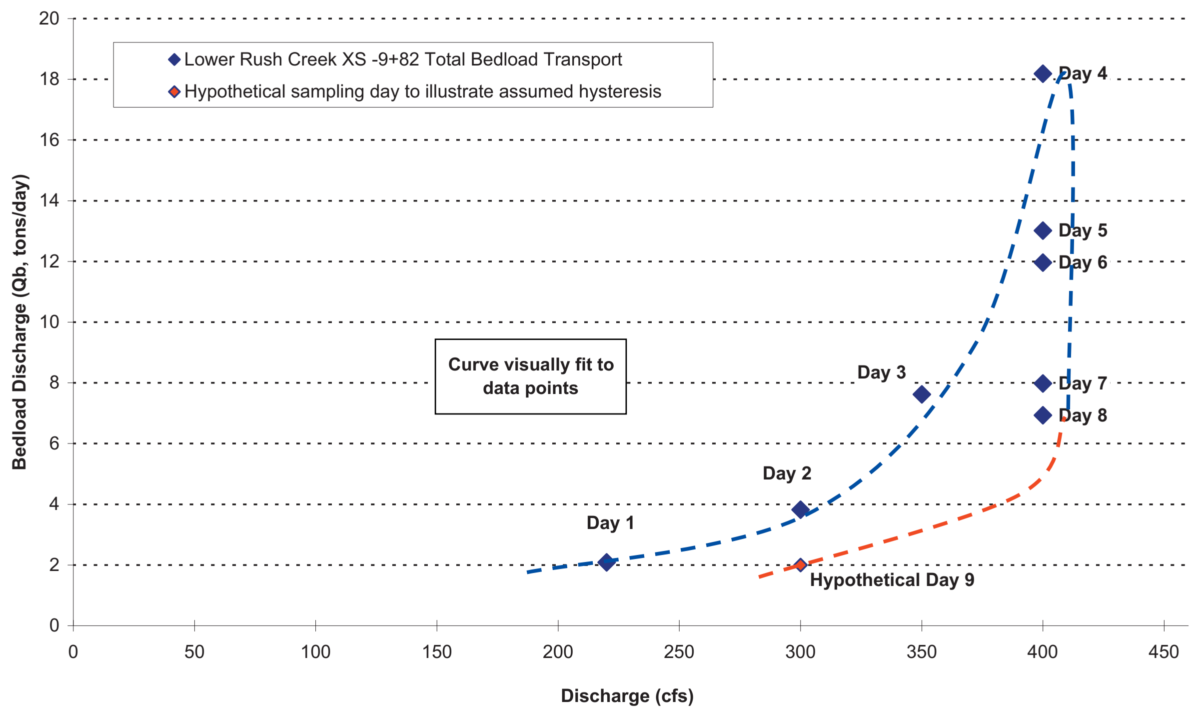


Figure 29. Lower Rush Creek total bedload discharge as a function of streamflow, with increasing transport rate on ascending limb of hydrograph, and then decreasing transport rate following the first day of the 400 cfs bench.

Wet-Normal runoff conditions in RY 2005, (see Section 2.1) provided an opportunity to evaluate the role of peak flow magnitude and duration on floodplain deposition and channel reconfinement processes. The Rush Creek SRF releases were modified, in part, to accommodate floodplain deposition experimental objectives. The higher magnitude snowmelt runoff anticipated on Lee Vining Creek also allowed us to plan and implement floodplain sediment deposition studies on Lee Vining Creek. Experimental sites were installed on the B-1 channel and main channel of Lee Vining Creek.

Previous annual reports describe historical floodplain conditions and the importance of channel confinement to stream recovery, as well as provide conceptual models describing floodplain processes that lead to confinement (McBain and Trush 2000, 2005). Objectives for RY 2005 monitoring were to address two primary questions:

(1) Do floodplain deposition rates decrease with increasing peak flow duration? Or rephrased, what additional deposition "work" is accomplished with each additional day of peak flow duration? Does fine sediment supply to the floodplains decrease with duration?

(2) How much floodplain deposition results from successive days of a 400 cfs peak flow release?

These questions address the sufficiency of the magnitude and duration of SRF peak flows to re-confine the bankfull channel, rebuild geomorphically active floodplain elevations, and re-create healthy aquatic habitat.

3.4.1 Sampling methods

Five cross sections were selected on lower Rush Creek for RY 2005 experiments (Figure 30): XS -25+00, XS 319+62, XS 321+02, XS 239+00, and XS 1+10. Several cross sections used in RY 2004 were abandoned in RY 2005 in favor of sites we anticipated to be more dynamic and responsive to the

2005 peak flow magnitude. Cross section 1+10 was located at the upstream end of the 10 Channel, while the remaining four cross sections were located on the main channel. Cross sections 319+62 and 321+02 were new locations not sampled in RY 2004, and were selected in part because they were located on a large developing floodplain where all the flow was in a single channel (compared to several RY 2004 cross sections adjacent to channels that only conveyed a portion of the total flow in the stream). Cross section 239+00 was selected because it traverses a recently constructed floodplain at the 3D site that is at a very low elevation relative to the channel (and therefore susceptible to deposition).

Four cross sections were selected on lower Lee Vining Creek for RY 2005 experiments (Figure 31): XS 0+87, XS 1+28, XS 4+31, and XS 3+45. Cross section 3+45 i on the main channel, and the remaining three are on the lower B-1 channel. All experiments were located on existing cross sections and were not sampled in RY2004.

In 2004, one-foot wide strips of indoor-outdoor carpet were installed on several cross sections to clearly detect deposition directly attributable to the 2004 SRF releases. This method proved successful, and carpet strips were installed at the four cross sections on Lee Vining Creek and the five cross sections on Rush Creek (Table 14). The carpets were installed upside down with a rough fabric surface facing upwards, and nailed onto the floodplain with 12” long spikes flush to the existing floodplain surface. Following the peak flow release, local deposition depths were measured at frequent intervals on the carpets with a metal ruler, and samples of deposited sediment were collected and transported to a laboratory to be dried, sieved, and weighed.

Bedload transport rates were measured at consistent stations on Rush Creek cross sections 319+62 and -25+00 during Day 1, 2, 3, 4, 6, and 8 of the 400 cfs peak SRF release (June 23, 24, 25, 26, 28, and 30). A 3-inch square Helley-Smith bedload sampler was used. Most samples were collected with the sampler held on the bed surface for 10 minutes. Bedload samples were also transported home for particle size analysis. Bedload sampling was initiated at cross section 1+10 and 321+02, but because transport rates were small, we stopped sampling after the first day of the peak flow release. Bedload sampling was not conducted on Lee Vining Creek due to uncertainty whether there would be adequate inundation and transport.

To address Question #1 (does deposition rate decrease with peak flow duration?), we attempted to use colored sand as a tracer. Colored sand was sprinkled immediately upstream of the carpet in places where there was noticeable deposition, with the expectation that it would settle in discrete horizontal layers on the carpet. With multiple layers of colored sand interspersed with naturally deposited sand, the distance between colored sand lenses could be measured, and that depth divided by the duration of flow (in days) that caused that deposition depth would yield a deposition rate. Colored sand was distributed as follows:

- Day 0-add yellow sand to signify initial conditions when Q=400 cfs;
- Day 1-add red sand to signify sand deposition after 1 day of 400 cfs;
- Day 2-add blue sand to signify sand deposition after 2 days of 400 cfs;
- Day 8-measure top of natural sand deposition to signify sand deposition after 8 days of 400 cfs.

The bedload and suspended sediment sampling on the mainstem of Rush Creek was closely coordinated with the floodplain deposition studies to correlate floodplain deposition rates and volumes with the mainstem sediment transport rates in Rush Creek as a function of longitudinal location (upstream versus downstream) and duration. This integrated monitoring addressed whether fine sediment supply was near zero at the outlet of Grant Lake, and significantly increased downstream of the Highway 395 Bridge where glacial outwash terraces may provide a higher sediment supply to Rush Creek.

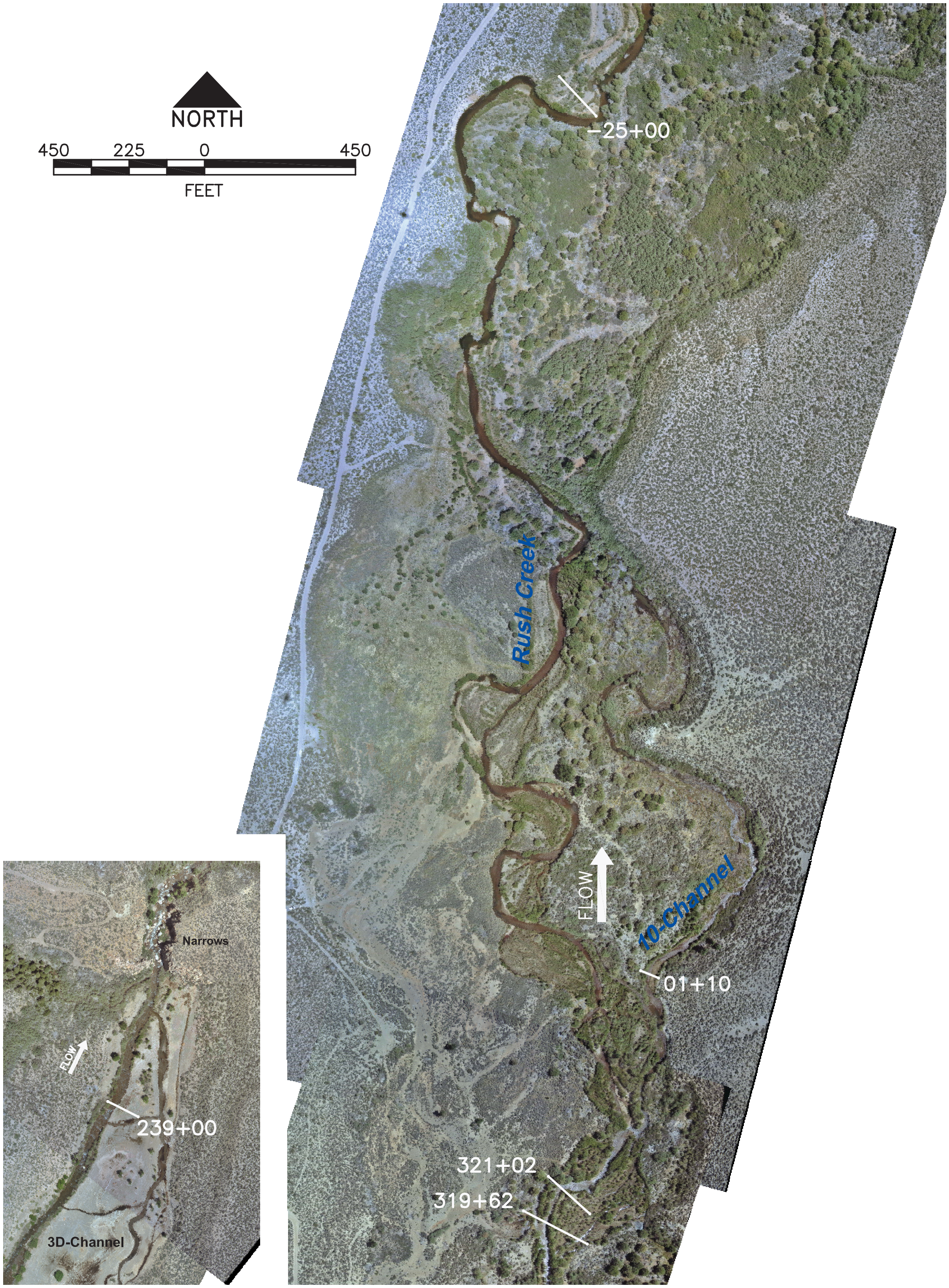


Figure 30. Location of Rush Creek floodplain deposition monitoring cross sections.

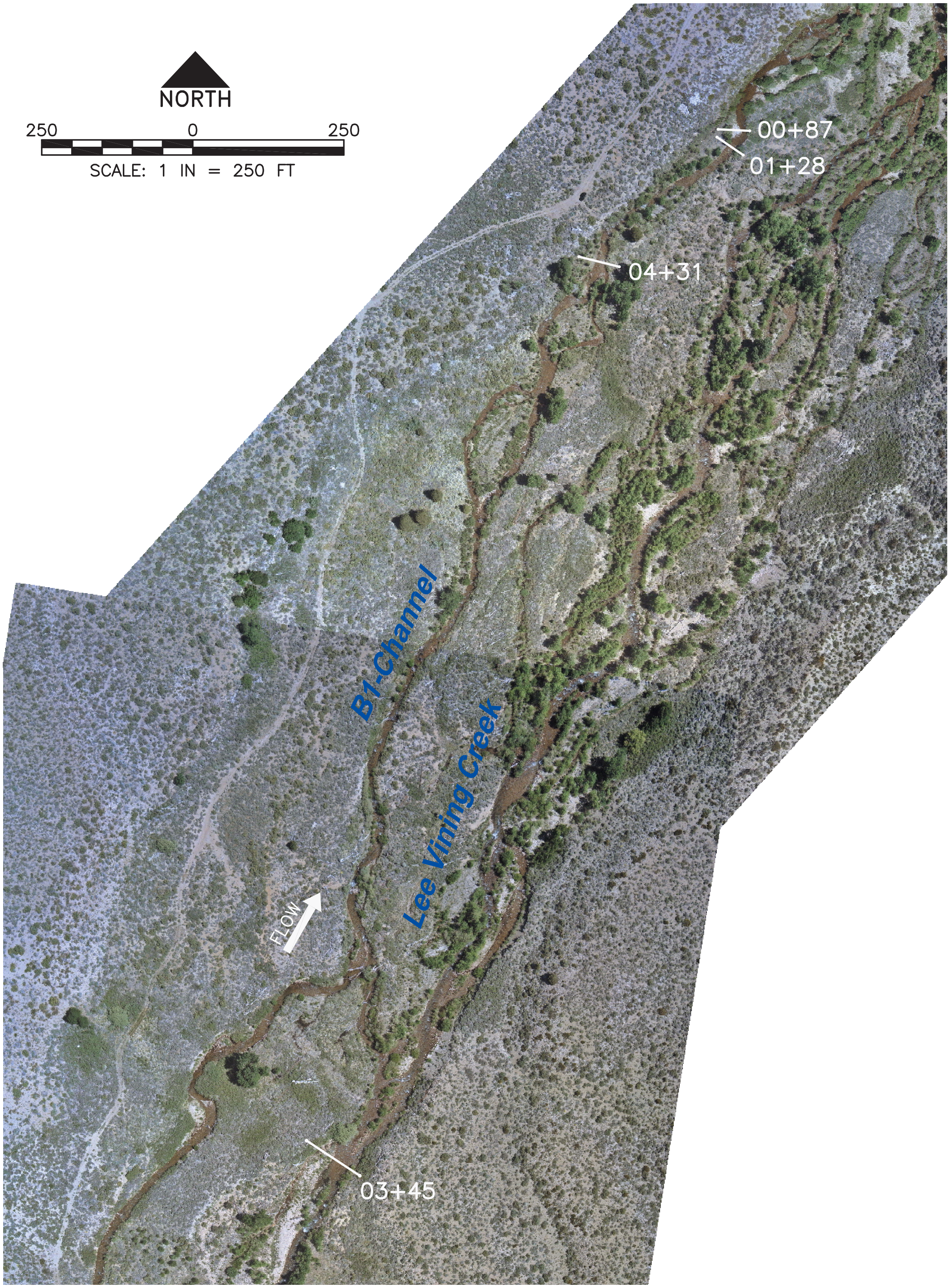


Figure 31. Location of Lee Vining Creek floodplain deposition monitoring cross sections.

Table 14. Summary of experiments at Lee Vining and Rush Creek cross sections conducted during the peak flow release for RY 2005.

Creek	Cross Section	Before/After Deposition Measured?	Colored Sand Experiment?	Bedload Sampling?	Figure # (Appendix G)
Rush Creek	239+00 (main channel)	N[1]	Y	N	G-1
	319+62 (main channel)	Y	Y	Y	G-2
	321+02 (main channel)	Y	Y	N[2]	G-3
	1+10 (10 Channel)	Y	Y	N[2]	G-4
	-25+00 (main channel)	Y	Y	Y	G-5
Lee Vining Creek	3+45 (main channel)	Y	N	N	G-6
	4+31 (B-1 Channel)	Y	N	N	G-7
	1+28 (B-1 Channel)	Y	N	N	G-8
	0+87 (B-1 Channel)	Y	N	N	G-9

[1] Gravel bar formed during high flow, no fine sediment deposition
[2] Bedload sampling initiated, but transport rates too low and not continued

3.4.2 Analysis and Results

As with RY 2004 results, sediment transport and floodplain deposition data collected during the 2005 SRF releases should be considered site-specific, and extrapolated only with caution for the following reasons: (1) there are site 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 of inundation during the June 2004 SRF releases and not selected to represent the range of floodplain surfaces found along Rush and Lee Vining creeks, and (3) the data are from only one peak flood event and may differ from other high flow releases of similar magnitude and duration, which have access to different sources and supplies of stored sediment.

Despite the site-specificity of our results, the 2005 SRF releases and corresponding floodplain deposition monitoring improved our understanding of floodplain recovery processes, particularly with regard to the magnitude and duration of SRF releases. Floodplain deposition depths and final elevations are illustrated in cross section plots in Appendix G-1 to G-12. Bedload transport rates measured at floodplain deposition sites are provided in Appendix G-13 to G-17, and floodplain depositional rates are illustrated in Figure 32. The D_{84} and D_{50} grain size of floodplain deposits are summarized in Table 15. In contrast to the floodplain deposition samples, the grain size of the bedload samples was too small to compute the D_{84} based on the sieve set used, so results are presented as:

(1) the range of sieves where the largest particle was trapped, and (2) the percent of total sample captured on that largest sieve opening (Table 16).

3.4.3 Discussion

The 2005 peak SRF release magnitude of 400 cfs (resulting in a 467 cfs peak in Lower Rush Creek) was larger than the RY 2004 releases (384 cfs), but more significantly, had a longer duration (1 day in 2004 versus 8 days in 2005). Consequently, floodplain deposition was more pronounced than in RY 2004. Deposition depths were still modest, however, with most deposition at our study sites less than 40 mm (1.5 inches) (Appendix G-4, G-5, G-7, G-9, G-10). Deposition depths were slightly larger along channel margins, with depths up to 100 mm (4 inches) (Appendix G-3, G-6, G-7, G-8).

Fine sediment deposition was greatest on the floodplain edge immediately adjacent to the channel margin. In addition, bedload transport rates and floodplain depositional rates were also greatest along the channel margins (Figure 32). Visual observations and particle size sampling on cross section -25+00 indicated the grain size and depth of the depositional material was greatest along the channel margins on the inside of point bars where coarser bedload was deposited (Table 15, Appendix G-14 and G-17). On the large floodplain traversed by cross section 319+62 (Figure 33), significant deposition occurred behind clumps of vegetation adjacent to lanes of substantial bedload transport across the floodplain (Appendix G-3 and G-12), but this deposition was still smaller than along the channel margins where bedload from the main channel was deposited among the first vegetation. This pattern of deposition explains the asymmetrical floodplain morphology frequently observed in Rush Creek, in which the floodplain elevation is highest along the channel margins and slopes downward away from the channel.

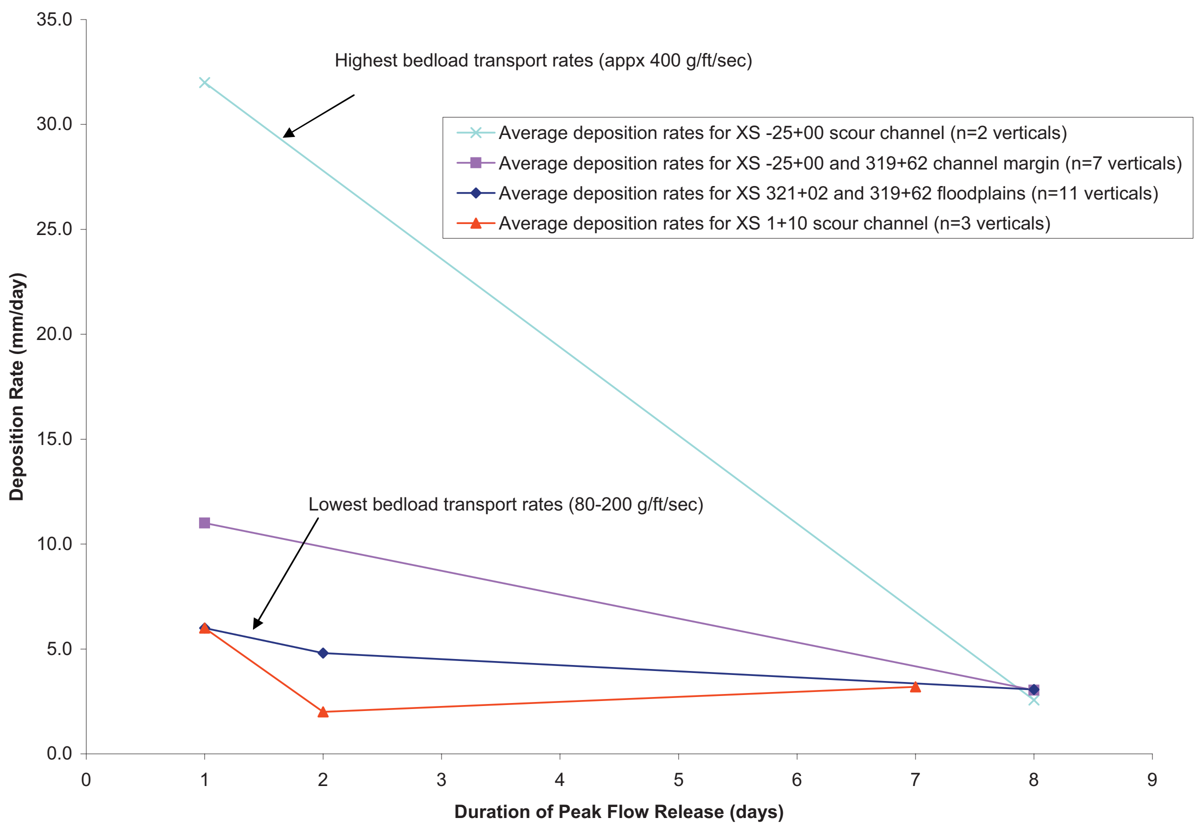


Figure 32. Average deposition rates as a function of peak flow release duration for geomorphic features on selected verticals on Rush Creek cross sections 321+02, 319+62, 1+10, and -25+00.

Floodplain bedload transport rates, while more variable than the mainstem bedload transport results presented in Section 3-3, followed the same trend of decreasing transport rates with duration (Appendix G-15 through G-17, Figure 32). With the exception of cross section -25+00 Station 126.0, the bedload transport rates decreased dramatically (by 50% or more) after a 3-day duration. A similar decrease in bedload transport rates was observed on the mainstem, but occurred after a 2-day duration, suggesting that there may have been a 1-day lag time between mainstem and floodplain transport rates. There was no detectable change in maximum grain size in bedload samples with increasing duration (Table 16), although the range of sieves did not allow a precise analysis of changing grain sizes with duration.

The colored sand experiments were not as useful as hoped due to several factors. The experiment would work well for sites where the primary depositional process was settling of suspended sediment (e.g., cross section 319+62 near station 172, Figure 34); however, most depositional features were formed by bedload deposition and many had a high exchange with bedload transport, preventing the desired "lenses" of colored sand from being retained. For those stations where the bedload exchange was minimal and the experiment performed well, the rates of deposition as a function of duration were computed and averaged for scour channel locations, channel margins, and floodplains (Figure

Table 15. Summary of D_{84} and D_{50} grain sizes of floodplain depositional features on Rush Creek and Lee Vining Creek cross sections.

Stream	Cross Section	Station (ft)	D_{84} (mm)	D_{50} (mm)
Rush Creek	319+62	101.2	0.31	0.17
		103.4	0.34	0.18
		107.3	0.34	0.17
		113.3	0.44	0.23
		119.6	0.65	0.37
		133.0	0.39	0.18
		150.3	0.40	0.18
		154.6	0.29	0.15
		155.6	0.48	0.34
		174.5	0.31	0.17
Rush Creek	321+02	143.6	0.83	0.44
		152.0	0.46	0.22
		157.7	0.46	0.25
		159.1	0.46	0.20
Rush Creek	1+10	45.0	0.38	0.20
		46.5	0.59	0.32
		50.4	0.38	0.20
Rush Creek	-25+00	123.6	0.42	0.20
		124.8	0.45	0.21
		159.5	1.25	0.44
		161.0	0.80	0.40
		162.5	0.88	0.42
		164.0	0.80	0.36
		165.5	1.63	0.64
		167.0	0.94	0.41
		168.7	0.61	0.34
Lee Vining Creek	3+45	38.0	0.43	0.27
Lee Vining Creek	4+31	20.2 - 21.2	1.03	0.56
Lee Vining Creek	1+28	26.3 - 27.3	0.41	0.20

Table 16. Summary of maximum grain sizes of floodplain bedload samples on Rush Creek as a function of duration.

Cross Section	Station	Date	Flow Release Duration (days)	Largest particle size class in bedload sample (mm)	Percent of total sample weight contained in the largest particle size class sieve
319+62	183.2	23-Jun-05	1	2 mm - 4 mm	2.2%
		24-Jun-05	2	4 mm - 8 mm	0.2%
		25-Jun-05	3	4 mm - 8 mm	0.4%
		26-Jun-05	4	4 mm - 8 mm	0.2%
		28-Jun-05	6	4 mm - 8 mm	0.2%
		30-Jun-05	8	4 mm - 8 mm	2.1%
319+62	152.6	23-Jun-05	1	8 mm - 16 mm	0.5%
		24-Jun-05	2	4 mm - 8 mm	0.9%
		25-Jun-05	3	8 mm - 16 mm	0.3%
		26-Jun-05	4	4 mm - 8 mm	1.0%
		28-Jun-05	6	4 mm - 8 mm	0.2%
		30-Jun-05	8	4 mm - 8 mm	0.5%
319+62	106.7	23-Jun-05	1	2 mm - 4 mm	0.8%
		24-Jun-05	2	4 mm - 8 mm	0.4%
		25-Jun-05	3	4 mm - 8 mm	0.1%
		26-Jun-05	4	4 mm - 8 mm	1.1%
		28-Jun-05	6	4 mm - 8 mm	0.2%
		30-Jun-05	8	2 mm - 4 mm	8.7%
-25+00	153.3	23-Jun-05	1	8 mm - 16 mm	0.4%
		24-Jun-05	2	8 mm - 16 mm	0.6%
		25-Jun-05	3	8 mm - 16 mm	0.5%
		26-Jun-05	4	4 mm - 8 mm	2.1%
		28-Jun-05	6	4 mm - 8 mm	4.0%
		30-Jun-05	8	4 mm - 8 mm	6.5%
-25+00	126.0	23-Jun-05	1	8 mm - 16 mm	3.4%
		24-Jun-05	2	8 mm - 16 mm	1.0%
		25-Jun-05	3	8 mm - 16 mm	2.3%
		26-Jun-05	4	8 mm - 16 mm	1.0%
		28-Jun-05	6	8 mm - 16 mm	0.7%
		30-Jun-05	8	8 mm - 16 mm	0.6%

32). While there was some variability at individual verticals, the average values indicated a decreasing rate of deposition with duration, and were most pronounced in zones where bedload transport was highest. This helped corroborate our qualitative field observations that most net deposition for a given high flow occurred rapidly, reaching equilibrium conditions in a day or two. The higher the sediment supply (inferred from bedload transport rates), the faster the initial deposition to near equilibrium conditions occurred. On floodplains with lower bedload transport rates and/or dominated by suspended sediment deposition, the rate of deposition did not appear to change significantly, although the small sample size tempered our confidence in this observation as a verified "conclusion". If the experiment were conducted again, a better approach would be to insert a thin metal ruler into the fresh deposit each day at consistent stations to track deposition depth. Hydraulic disturbance to the deposit would be minimal with this method, and disturbance to the micro-topography of the deposit would be reversed within a minute or two from fresh bedload exchange.

As observed in RY 2004, the primary depositional process during incipient floodplain development in 2005 was bedload deposition rather than suspended sediment deposition. Suspended sediment

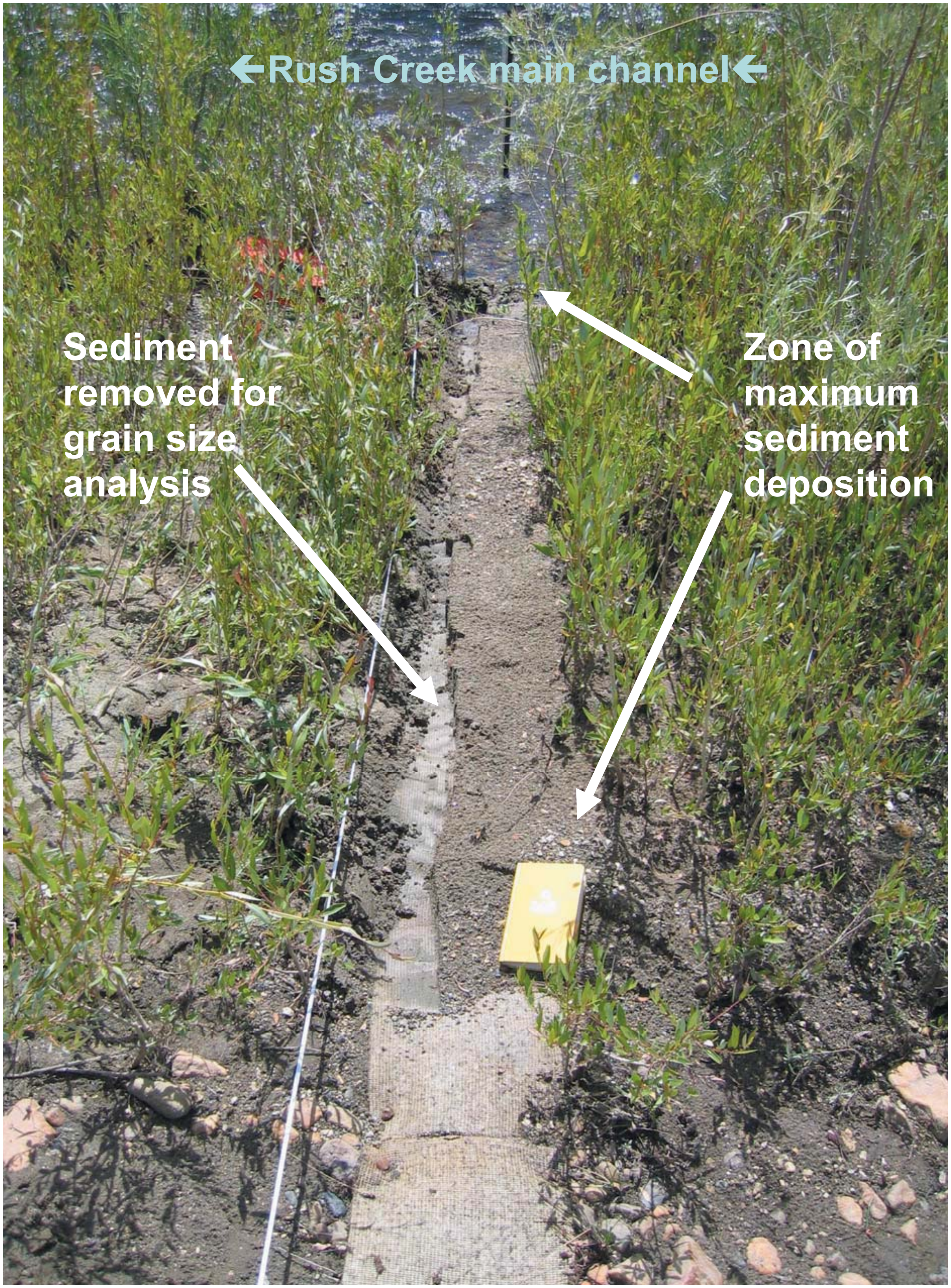


Figure 33. Floodplain deposition carpets installed across XS 319+62 on Lower Rush Creek, showing sediment deposited along the mainstem channel margin after the RY 2005 SRF recession.

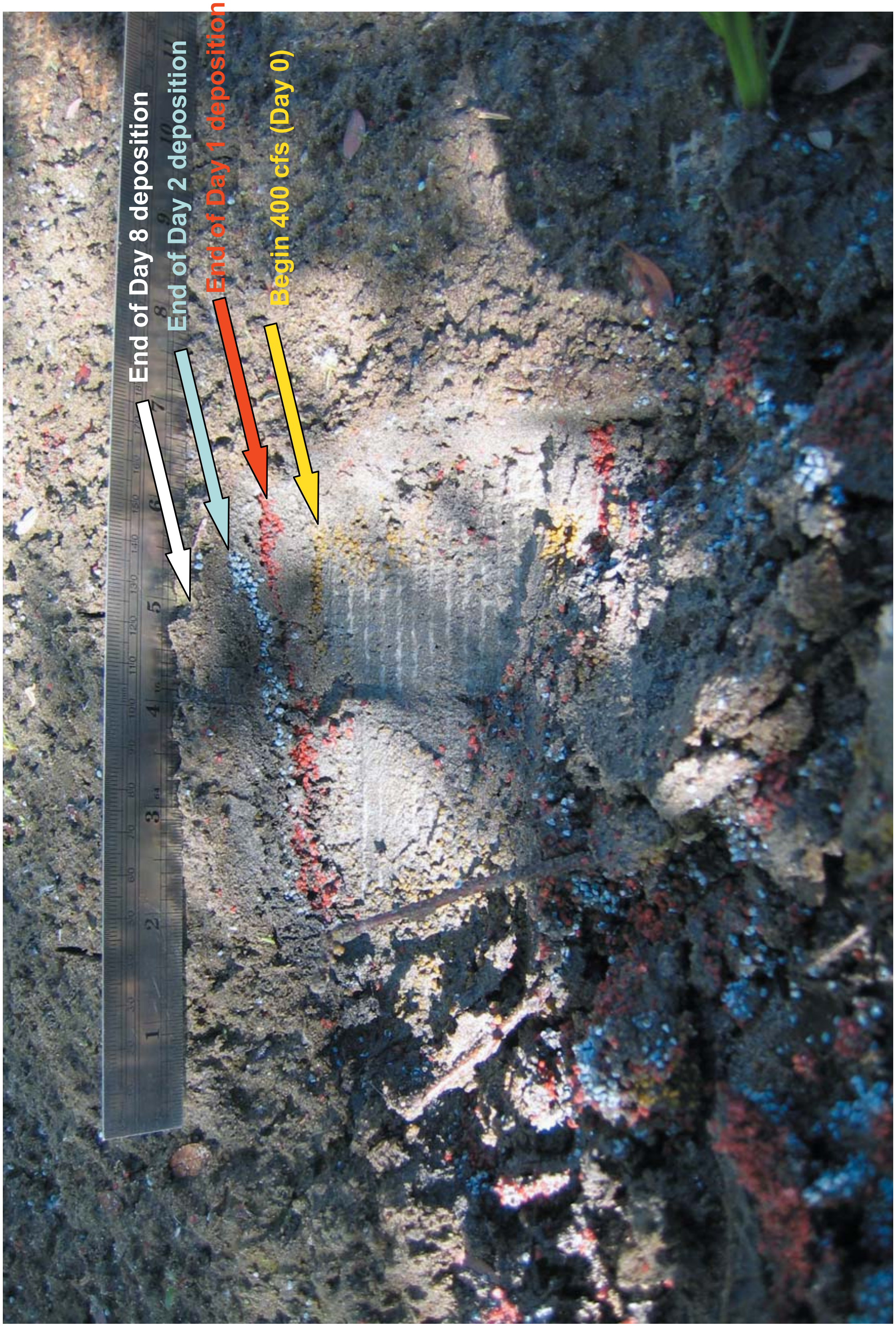


Figure 34. Close-up of floodplain deposition on Lower Rush Creek, showing successive depositional layers indicated by colored sand sprinkled across the surface during the SRF release.

concentrations were again low during this release (see Section 3-3), minimizing the contribution of suspended sediment deposition in floodplain development. Suspended sediment deposition was observed independent of bedload deposition on certain portions of cross sections (e.g., XS 319+62 at station 172), but the deposition depths were less than 20 mm (3/4 inch) (Appendix G-7). Accretion from fine sediment deposition likely plays only a minor role in floodplain building at the sites monitored.

Fine sediment deposition on what were considered floodplains on the Lee Vining Creek B-1 channel was minimal during the 2005 peak flow (372 cfs, approximately a 5.6-yr flood) because flow did not substantially inundate those surfaces. Channel incision within the multiple channels in Lee Vining Creek may have largely abandoned these former floodplains, preventing their inundation by frequent flood events (i.e., 1.5 to 2-year floods). The maximum deposition depth at the Lower Lee Vining B-1 cross sections was less than 20 mm at cross section 1+28 (Appendix G-8). More substantial fine sediment deposition occurred on the main channel cross section 3+45 (up to 100 mm) in the backwater channel (Appendix G-6). This backwater may eventually fill with fine sediment over the long term, unless the entrance opens up and the channel avulses.

As observed in RY 2004 and RY 2005, SRF release magnitudes of approximately 400 cfs met several important ecological objectives expected for a Normal and Wet-Normal runoff year type (see Figure 18 of RY 2003 Annual Report [McBain and Trush 2004]). As expected, this release magnitude appeared to be a minimum threshold for measurable fine sediment deposition on incipient floodplains. Flow magnitudes larger than 400 cfs scheduled for Wet and Extremely-Wet runoff year types will be required to re-build (aggrade) floodplains and re-confine channels close to pre-1941 levels. As a rough approximation of the discharge needed to initiate deposition, the stage height of a given high flow can be assumed commensurate with fine sediment deposition elevation. The RY 1999 Report (McBain and Trush 2000) recommended a minimum inundation depth of 0.5 ft for initiating floodplain deposition. In lieu of attempting complex fine sediment deposition models as a way to determine how to maximize floodplain deposition rates, we recommend targeting a minimum inundation depth. This approach would address the variability of floodplain elevations, and would require increasingly larger floods to achieve the same inundation depth as floodplains build over time. However, this need for larger floods is counterbalanced by increases in stage height for a given flow magnitude that results from increased channel and floodplain roughness. The RY 1999 Report (McBain and Trush 2000) provides additional description of this process.

3.5 Termination Criteria

Geomorphic termination criteria (main channel length, channel gradient, channel sinuosity) were updated in the RY 2004 Annual Report (McBain and Trush 2005) using the 2003 high resolution aerial photographs. In the RY 2004 Report, we stated that main channel length is an independent Termination Criteria and is used in the derivation of gradient and sinuosity, so that…

> "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. 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."

Updates to geomorphic termination criteria therefore require quantifying only the main channel length to assess what the three criteria are attempting to measure, (i.e., more complex, lower gradient, sinuous channels).

LADWP obtained aerial photographs of the Mono Basin (including Rush and Lee Vining creeks) on July 21, 2005, soon after the peak SRF releases. These photographs do not have the quality of resolution as the 2003 aerials, but did provide adequate resolution to identify a main channel centerline, and thus evaluate changes in the main channel length criterion. We therefore overlaid the main channel centerline from the 2003 aerial photos onto the new Ikonos 2005 aerial photos for Rush Creek and Lee Vining Creek, noted where significant changes had occurred since 2003, then recomputed the channel length.

No changes in channel length were observed in the Lee Vining Creek mainstem.

In Rush Creek, there were no changes in channel location in Reaches 2 and 3 above the Narrows, nor in Reach 4A which extends from the Narrows down to the entrance to "Indian Ditch" at elevation 6,553 ft. However, there were notable changes in channel planform location in Reach 4B (from Indian Ditch to 670 ft downstream from the 10 Channel "falls") (Figure 35), and Reach 5A (from the Ford downstream to the County Road) (Figure 36). Reach 4B added 70 ft and Reach 5A added 78 ft. No reaches lost main channel length, so the total increase in main channel length on Rush Creek was 148 ft. Reach 4B had met all three termination criteria by 2004. Channel changes observed in the 2005 aerial photos most likely occurred as a result of the 2004 and 2005 SRF releases. Bank erosion and channel migration at Rush Creek County Road XS 6+85 were discussed in the 2004 report, noting that:

> "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."

We projected the maximum extent of future lateral migration possible at XS 6+85 when the channel reaches the left valley wall (Figure 36). This potential future location would yield the longest channel, adding 120 ft to the 2005 channel length, bringing the length criterion in Reach 5A to within 127 ft of the termination criterion. Several other locations along the Reach 5A channel offer the prospect of gaining channel length to eventually attain the length criterion in this reach. However, more main channel length is needed to satisfy *all* the termination criteria in Reach 5A (i.e., length, gradient, and sinuosity) than can be predicted based on our observations of channel migration rates (see Table 14 of the RY 2004 Report).

Updated geomorphic termination criteria are presented in Tables 17 and 18.

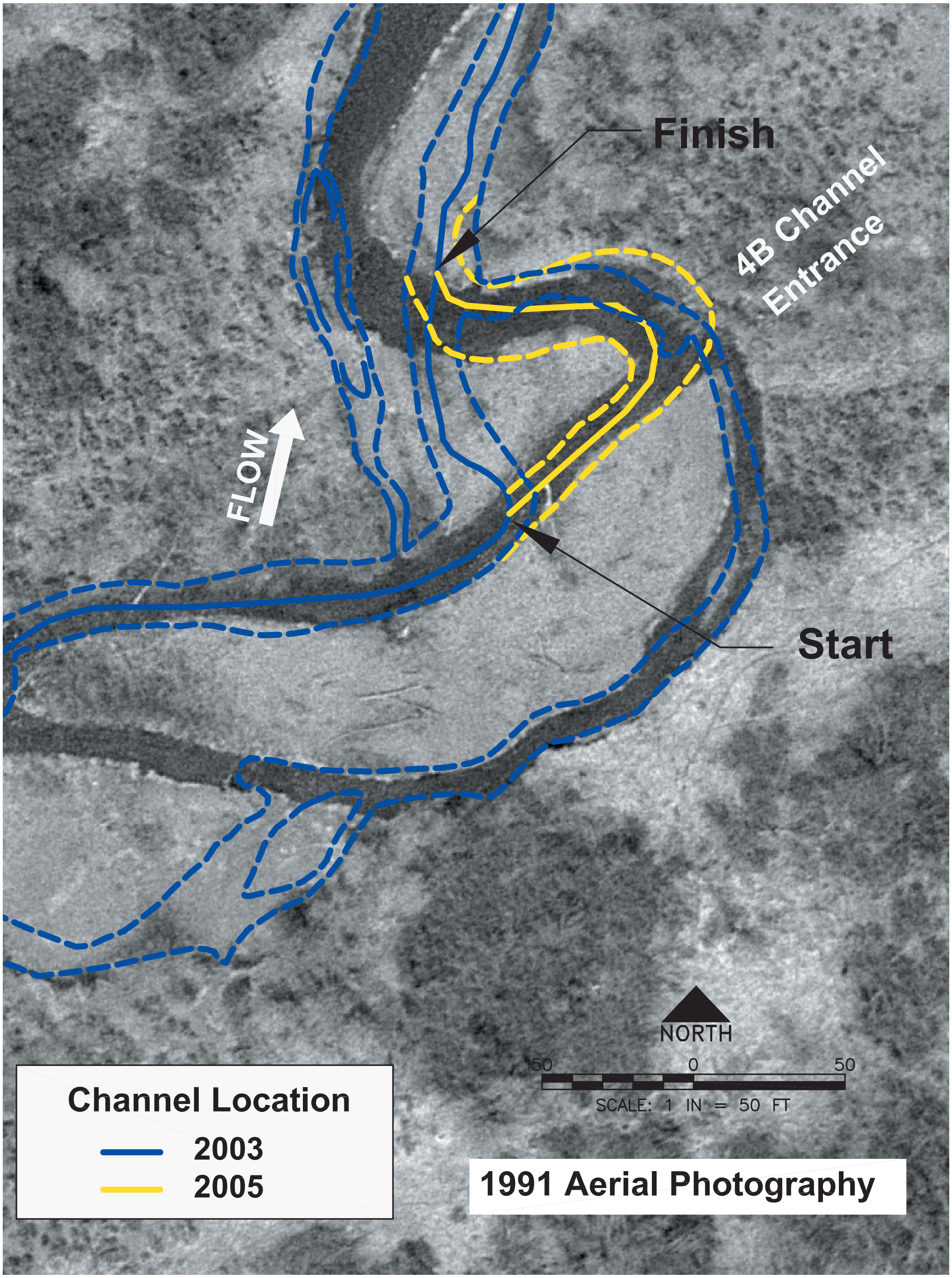


Figure 35. The 4bii Channel entrance on Lower Rush Creek from the 1991 aerial photographs, with the 2003 and 2005 channel boundaries and centerlines overlain, indicating the extent of channel changes resulting from the RY 2004 and 2005 SRF releases.

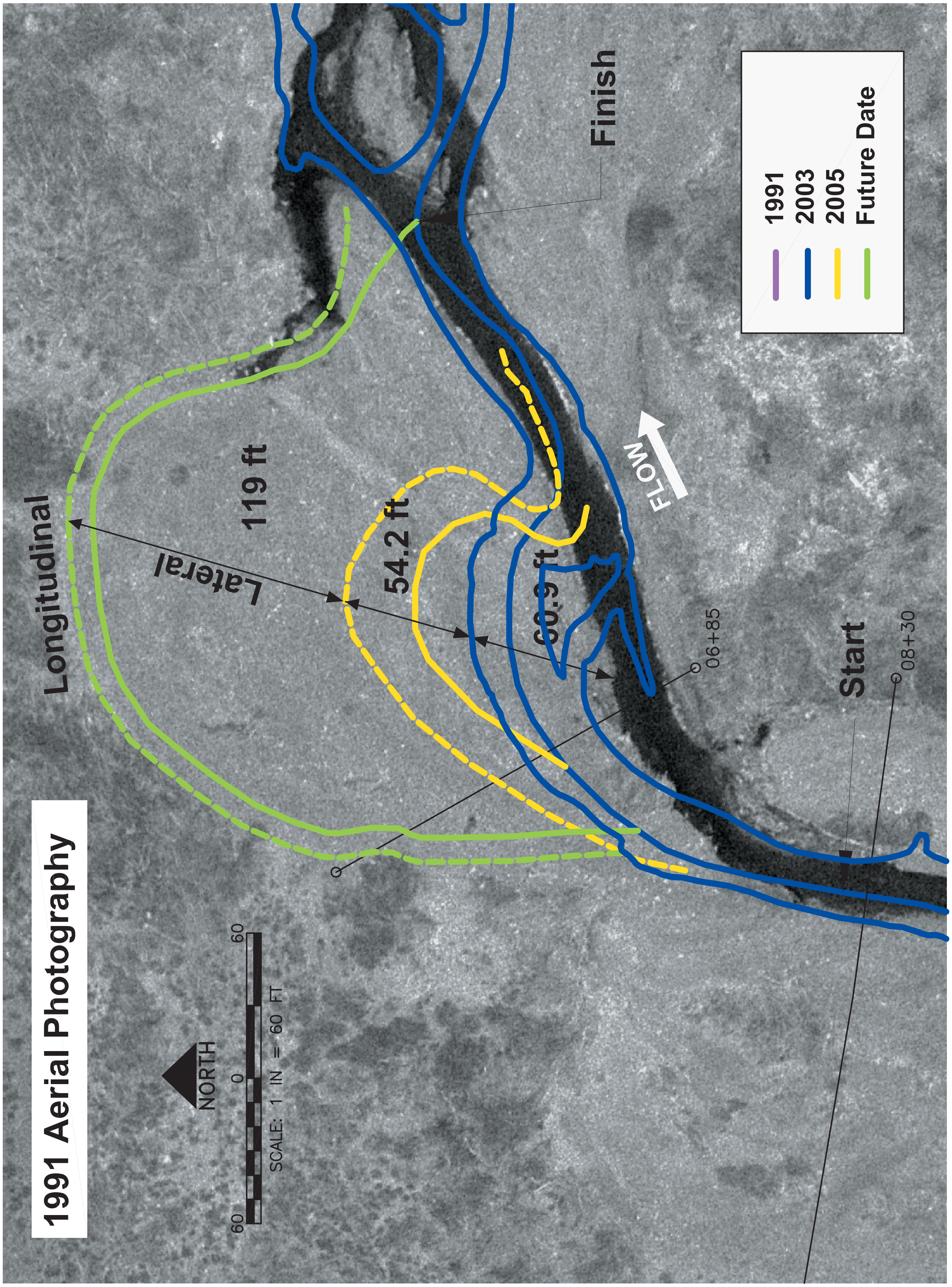


Figure 36. The Lower Rush Creek County Road reach surrounding XS 6+85, shown in the 1991 aerial photographs, and with the 2003 and 2005 channel boundaries and centerlines overlain, indicating the extent of channel changes resulting from the RY 2004 and 2005 SRF releases.

Table 17. Summary of the Geomorphic Termination Criteria values for each reach of Rush Creek, and updated values obtained from the 2005 aerial photographs.

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	N/A	4,820	3,800	3,100	6,940	3,370	3,070	7,810	4,360	7,320	N/A
	1995 RTC Report	N/A	4,820	3,800	2,700	7,040	3,300	2,910	7,930	2,610	5,950	N/A
	2003	N/A	4,820	3,800	2,956	6,964	3,235	3,078	8,071	3,393	7,073	N/A
Main Channel Gradient (ft/ft)	Termination Criteria	N/A	0.024	0.016	0.014	0.023	0.022	0.014	0.01	0.005	<0.007	N/A
	1995 RTC Report	N/A	0.024	0.016	0.012	0.023	0.023	0.015	0.01	0.008	0.009	N/A
	2003	N/A	0.026	0.017	0.016	0.023	0.021	0.017	0.010	0.007	0.008	N/A
Main Channel Sinuosity (ft/ft)	Termination Criteria	N/A	1.04	1.06	1.19	1.07	1.04	1.19	1.23	2.11	1.39	N/A
	1995 RTC Report	N/A	1.04	1.06	1.03	1.09	1.02	1.08	1.24	1.27	1.11	N/A
	2003	N/A	1.08	1.07	1.27	1.09	1.03	1.17	1.29	1.57	1.29	N/A
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: Extends from the confluence with Parker Creek to and including 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 670' downstream of the 10 Channel/Main Channel confluence.
Reach 4C: Reach 4C extends from 670' downstream of the 10 Channel/Main Channel confluence to the Ford.
Reach 5A: Extends from the Ford ~1800' downstream to the County Road.
Reach 5B: Extends from The County Road to the confluence with Mono Lake.

= updated numbers

Table 18. Summary of the Geomorphic Termination Criteria values for each reach of Lee Vining Creek, updated from the 2003 aerial photographs.

LEE VINING CREEK TERMINATION CRITERIA		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.

4 RIPARIAN VEGETATION MONITORING

4.1 Vegetation Structure and Composition Sampling

4.1.1 Introduction

In 2001, permanent nested frequency transects were established and sampled along Lee Vining Creek (n = 96) and Rush Creek (n = 76). Nested frequency transects were installed to quantify plant species composition and structure within the most common vegetation types in the riparian corridors of Rush Creek and Lee Vining Creek. The nested frequency data helped create a vegetation classification of 12 unique vegetation patch types akin to plant communities. By monitoring shifts in species composition and structure at these permanent transects at specified intervals, changes in vegetation resulting from SRF releases or other management actions were documented. Changes in vegetation could have important implications for termination criteria, riparian vegetation recovery, and the success or failure of the stream restoration flows. Results of the 2001 sampling period, including patch type descriptions, were presented in the Monitoring Results and Analyses for Runoff Season 2002-03 Report (hereafter 2002 Report, McBain and Trush 2003).

We re-sampled nested frequency transects during the summer of 2005. In this report, results from the 2005 sampling period were presented and compared to 2001 results. The specific questions addressed during data analysis included:

(1) Did species composition and vegetation structure change between 2001 and 2005.
(2) If so, how did composition and/or structure change?
(3) What are the underlying causes for the vegetation patterns and any changes that were observed?
(4) Were the results the same as the 2001 analysis when the 2001 data were updated with species information and re-analyzed?

4.1.2 Methods

A detailed nested frequency transect methodology was presented in the 2002 Report (McBain and Trush 2002). We revisited the nested frequency transects to determine if any changes in vegetation structure and/or species composition occurred since 2001. Three transects on Lee Vining Creek and four transects on Rush Creek could not be relocated and were subsequently reinstalled. For each transect, we recorded the presence and identity of each species within a 1m^2 sampling frame at 1 m intervals along a 15 m transect.

Unknown plants were assigned a unique code and a specimen was collected elsewhere (not from the transect). In many cases, plants were identified later in the season when diagnostic features such as flowers or fruits were present. The remaining unknowns were prioritized by the frequency in which they were sampled, and the most frequent unknowns were identified. During this process, the unknowns from the 2001 sampling season were also re-evaluated and prioritized. We identified many of the unknown plants from 2001. The 2001 data set was updated with species codes for formerly unknown specimens and then re-analyzed for comparison with the original cluster analysis and the 2005 cluster analysis.

Nested frequency data were analyzed in a similar way to the 2001 analysis. Data for each creek were analyzed separately. We converted presence/absence data into relative abundance data using a formula that calculated species abundance based on frequency relative to other species within the transect. Species that occurred in fewer than 5% of the transects were then omitted from the analysis. Infrequent species generally did not occur often enough to convey information regarding habitat affinity. Deleting them from analyses allowed any patterns in the data to emerge more clearly. Differences in species composition and abundance were evaluated using multiple response permutation procedure (MRPP) in the PC-ORD statistical package (McCune and Mefford 1999).

Similar to 2001, transect data were clustered into related groups based on species composition and relative abundance using *hierarchical cluster analysis*, and the resulting clusters were used to determine vegetation patch types. Cluster analysis was conducted separately on the 2005 data and on the updated 2001 data. We improved the objectivity of the cluster analysis results by using indicator species analysis as described by Dufrêne and Legendre (1997).

To compare the classification derived from the 2001 data to the classification of the 2005 data, mean similarity dendrograms were constructed using MEANSIM 6.0 (van Sickle 1998). Mean similarity dendrograms graphically display the overall strength of a classification and the similarity within each of the classes (in this case, patch types). EstimateS Version 7.5 (Colwell 2005) computed the similarity coefficients that were necessary to construct the mean similarity dendrograms.

In 2005 we added a second analysis, *indirect gradient analysis*, which used ordination to search for correlations between patterns of species abundance and composition and environmental variables that were measured. Indirect ordination is similar to cluster analysis in that the species composition and relative abundance of each transect is used to determine the final placement of transects. However, ordination places the transects in a complex, multi-dimensional space such that more similar transects are closer together and less similar transects are farther apart. The ordination process simplifies the multidimensional configuration of transects by extracting one, two, or three ordination axes. The axes are often interpreted as underlying gradients that "explain" the configuration of plots. The position or order of the transects along each axis can be correlated with a variety of measured environmental variables such as aspect, elevation, etc. The variables with the strongest correlations were used to interpret the axes. We used an indirect ordination technique called non-metric multidimensional scaling available in PC-ORD (McCune and Mefford 1999).

4.1.3 Results and Discussion

During 2005, we sampled and/or identified 227 plant species along Rush and Lee Vining creeks and cataloged an additional 24 unknown plants (Table 19). Some interesting observations of plant species along the 172 transects were:

- Wood's rose replaced sagebrush as the most frequently sampled plant species, found in 113 transects.
- Sagebrush was the second most frequently sampled plant species, found in 104 transects.
- Creeping wildrye was still the most frequently sampled herbaceous plant species, found in 96 transects.
- Kentucky bluegrass was still the most frequently sampled non-native riparian obligate plant species, found in 77 transects.
- *Juncus mexicanus* was still the most frequently sampled native riparian obligate plant species, found in 68 transects.
- Yellow willow replaced black cottonwood as the most frequently sampled riparian hardwood species, found in 53 transects.
- Black cottonwood occurred in 47 transects, only 5 of which were in the Rush Creek drainage.

Overall, we observed modest changes in vegetation since our previous sampling, and this observation was substantiated by the cluster analysis and the indirect gradient analysis. These changes are described in the following sections.

Table 19. Plant species sampled during 2005 nested frequency and band transect sampling.

Genus, Species, Variety and/or Subspecies	Common Name	Family	Hydric Code	Sampling Code
Trees				
Abies magnifica	red fir	Pinaceae	FACU	ABMA
Pinus contorta ssp. *murrayana*	lodgepole pine	Pinaceae	FAC	PICO
Pinus jeffreyi	Jeffrey pine	Pinaceae		PIJE
Pinus monophylla	singleleaf pinyon	Pinaceae		PIMO
Pinus sp.		Pinaceae		PINsp
Populus balsamifera ssp. *trichocarpa*	black cottonwood	Salicaceae	FACW	POBAT
Populus tremuloides	quaking aspen	Salicaceae	FAC+	POTR
Prunus andersonii	desert peach	Rosaceae		PRAN
Salix geyeriana	Geyer's willow	Salicaceae	OBL	SAGE
Salix laevigata	red willow	Salicaceae	FACW+	SALAE
Salix lucida ssp. *lasiandra*	shiny willow	Salicaceae	OBL	SALUC
Salix lutea	yellow willow	Salicaceae	OBL	SALU
Salix scouleriana	Scouler's willow	Salicaceae		SASC
Ulmus pumila	**Siberian elm**	**Ulmaceae**		ULPA
Shrubs				
Amelanchier alnifolia	serviceberry	Rosaceae	FACU	AMAL
Artmesia tridentata	sagebrush	Asteraceae		ARTR
Cercocarpus ledifolius var. *intermontanus*	curl-leaf mountain mahogany	Rosaceae		CELE
Chrysothamnus nauseosus	rubber rabbitbrush	Asteraceae		CHNA
Chrysothamnus visidiflorus	yellow rabbitbrush	Asteraceae		CHVI
Cornus sericea	red twig dogwood	Cornaceae	FACW	COSE
Ephedra viridis	green ephedra	Ephedraceae		EPVI
Eriogonum umbellatum	sulpher-flowered buckwheat	Polygonaceae	UPL	ERUM
Geum macrophyllum	bigleaf avens	Rosaceae	FACW	GEMA
Juniperus occidentalis var. *australis*	Sierra juniper	Cupressaceae		JUOC
Mimulus guttatus	monkey flower	Scrophulariaceae	FACW+	MIGU
Prunus emarginata	bitter cherry	Rosaceae	FACU	PREM
Purshia tridentata	bitterbush	Rosaceae		PUTR
Pyracantha angustifolia		**Rosaceae**		PYAN
Ribes aureum var. *aureum*	golden currant	Grossulariaceae		RIAU
Ribes velutinum	desert gooseberry	Grossulariaceae		RIVE
Rosa woodsii	Wood's rose	Rosaceae	FAC	ROWO
Salix boothii	Booth's willow	Salicaceae		SABO
Salix exigua	narrowleaf willow	Salicaceae	FACW	SAEX
Salix jepsonii	Jepson's willow	Salicaceae		SAJE
Salix lasiolepis	arroyo willow	Salicaceae	FACW	SALAS
Salix ligulifolia	strap-leaf willow	Salicaceae	FAC*	SALI
Shepherdia argentea	buffalo berry	Elaeagnaceae	UPL	SHAR
Tamarix ramosissima	**Tamarisk**	**Tamaricaceae**	**FAC**	TARA
Tetradymia canescens	horsebrush	Asteraceae		TECA
Herbs				
Abronia turbinata	tansmontane sand verbena	Nyctaginaceae		ABTU
Achillea millefolium	yarrow	Asteraceae		ACMI
Allium lacunosum var. *davisae*		Liliaceae		ALLA
Allium nevadense		Liliaceae		ALNE
Ambrosia acanthicarpa	flatspine bur ragweed	Asteraceae		AMAC
Apocynum cannabinum	Indian hemp	Apocynaceae		APCA
Aquilegia formosa	red columbine	Ranunculaceae	FAC	AQFO
Arabis cobrensis	Masonic rock cress	Brassicaceae		ARCO
Arabis inyoensis	Inyo rockcress	Brassicaceae		ARIN
Arabis puberula	rock cress	Brassicaceae		ARPU
Arabis sparsiflora var. *sparsiflora*	sickle-pod rock cress	Brassicaceae		ARSP
Arnica sororia		Asteraceae		ARSO
Artmesia douglasiana	mugwort	Asteraceae	FAC+	ARDO
Aster lanceolatus ssp. *hesperius*	western lanceleaf aster	Asteraceae		ASLA
Calochortus bruneaunis	desert mariposa lily	Liliaceae		CABR
Calochortus leichtlinii		Liliaceae		CALEI
Calyptridium roseum	rosy pussypaws	Portulaceae	FACU	CARO
Cardamine breweri var. *breweri*	Brewer's bittercress	Brassicaceae		CABRBR
Castilleja angustifolia	desert indian paintbrush	Scrophulariaceae		CAAN
Castilleja linariifolia	linear-leaf paintbrush	Scrophulariaceae		CALI
Castilleja miniata ssp. *miniata*	riparian indian paintbrush	Scrophulariaceae	OBL*	CAMI

Table 19. Plant species sampled during 2005 nested frequency and band transect sampling. Continued.

Genus, species, variety and/or subspecies	Common Name	Family	Hydric Code	Sampling Code
Caulanthus pilosus	chocolate drops	Brassicaceae		CAPI
Cerastium beeringianum var. *capillare*	mouse ear chickweed	Caryophyllaceae	NI*	CEBE
Cerastium fontanum var. *vulgare*	mouse ear chickweed	Caryophyllaceae		CEFO
Chaenactis douglasii var. *douglasii*	dusty maidens	Asteraceae		CHDO
Chenopodium leptophyllum	narrowleaf goosefoot	Chenopodiaceae		CHLE
Chenopodium nevadense	Nevada goosefoot	Chenopodiaceae		CHNE
Chenopodium sp.		Chenopodiaceae		CHsp
Cirisium vulgare	**bull thistle**	**Asteraceae**	**FAC**	CIVU
Collinsia parviflora	blue-eyed Mary	Scrophulariaceae		COPA
Conyza canadensis	horseweed	Asteraceae	FAC	COCA
Crepis acuminata	tapertip hawksbeard	Asteraceae		CRAC
Cryptantha circumscissa	cushion cryptantha	Boraginaceae		CRCI
Cryptantha confertiflora	yellow cryptantha	Boraginaceae		CRCO
Cryptantha watsonii	Watson's cryptantha	Boraginaceae		CRWA
Descurainia californica	Sierra tansy mustard	Brassicaceae		DECA
Descurainia pinnata ssp. *halictorum*	western tansy mustard	Brassicaceae		DEPI
Descurainia sophia	flixweed	Brassicaceae		DESO
Eatonella nivea	white false tickhead	Asteraceae		EANI
Epilobium angustifolium	fireweed	Onagraceae	FAC	EPAN
Epilobium ciliatum		Onagraceae	FACW	EPCI
Epilobium oregonense	Oregon willowherb	Onagraceae		EPOR
Eriastrum sparsiflorum		Polemoniaceae		ERSP
Erigeron aphanactis var. *aphanactis*	brass buttons	Asteraceae		ERAP
Erigeron divergens	fleabane daisy	Asteraceae		ERDI
Erigeron inornatus var. *inornatus*	rayless fleabane	Asteraceae		ERIN
Eriogonum ampullaceum	Mono buckwheat	Polygonaceae		ERAM
Eriogonum elatum var. *elatum*	tall woolly buckwheat	Polygonaceae		EREL
Eriophyllum lanatum var. *integrifolium*	Oregon sunshine	Asteraceae		ERLA
Erysimum capitatum ssp. *perenne*	western wallflower	Brassicaceae		ERCA
Galium trifidum var. *pacificum*	bedstraw	Rubiaceae	OBL	GATR
Gayophytum diffusum var. *parviflorum*	spreading groundsmoke	Onagraceae		GADI
Gayophytum ramosissimum	many flowered smoke weed	Onagraceae		GARA
Gilia cana ssp. *speciosa*		Polemoniaceae		GICA
Gilia inyoensis	Inyo gilia	Polemoniaceae		GIIN
Gilia leptomeria	Great Basin gilia	Polemoniaceae		GILE
Grayia spinosa	hop-sage	Chenopodiaceae		GRSP
Horkeliella congdonis		Rosaceae		HOCO
Hutchinsia procumbens		Brassicaceae		HUPR
Ipomopsis polycladon	scarlet gilia	Polemoniaceae		IPPO
Iris missouriensis	blue flag iris	Iridaceae	FACW	IRMI
Juncus patens	spreading rush	Juncaceae	FAC	JUPA
Lappula redowskii var. *redowskii*	Redowski's stickseed	Boraginaceae		LARE
Lepidium densiflorum var. *macrocarpum*	bigseed pepperweed	Brassicaceae		LEDE
***Lepidium* sp.**		**Brassicaceae**		LEPsp
Lepidium sparsiflorum	few-flowered pepperweed	Brassicaceae		LESP
Leptodactylon pungens	prickley phlox	Polemoniaceae		LEPU
Lupinus lepidus	Pacific lupine	Fabaceae		LULE
Luzula comosa		Juncaceae		LUCO
Machaeranthera canescens var. *canescens*	hoary aster	Asteraceae	FAC	MACA
Malacothrix torreyii	desert dandelion	Asteraceae		MATO
Melilotus alba	**white sweet clover**	**Fabaceae**	**FACU**	MEAL
Mentha arvensis	horse mint	Lamiaceae	FACW	MEAR
Mentzelia congesta		Loasaceae		MECO
Mentzelia nitens		Loasaceae		MENI
Mertensia oblongifolia var. *nevadensis*	sagebrush bluebells	Boraginaceae		MEOB
Mimulus cardinalis		Scrophulariaceae	OBL	MICA
Mimulus lewisii	Lewis's monkey flower	Scrophulariaceae	OBL	MILE
Mimulus pilosus		Scrophulariaceae		MIPI
Mimulus tilingii	mountain monkey flower	Scrophulariaceae		MITI
Mimulus sp.	monkey flower	Scrophulariaceae		MIsp
Montia fontana	water chickweed	Portulaceae	FACW	MOFO
Myosotis laxa	forget-me-not	Boraginaceae		MYLA
Oenothera elata ssp. *hirstuissima*	evening primrose	Onagraceae	FACW	OEEL
Orobanche fasciculata	clustered broom rape	Orobanchaceae		ORFA

Table 19. Plant species sampled during 2005 nested frequency and band transect sampling. Continued.

Genus, species, variety and/or subspecies	Common Name	Family	Hydric Code	Sampling Code
Oxytheca dendroidea ssp. *dendroidea*		Polygonaceae		OXDE
Penstemon rydbergii var. *oreorachis*		Scrophulariaceae	FAC	PERY
Penstemon speciosus		Scrophulariaceae		PESP
Phacelia bicolor var. *bicolor*		Hydrophyllaceae		PHBI
Phacelia ramosissima var. *eremophila*	branching phacelia	Hydrophyllaceae		PHRA
Phlox gracilis	slender phlox	Polemoniaceae		PHGR
Phlox stansburyi		Polemoniaceae		PHST
Phoenicaulis cheiranthoides		Brassicaceae		PHCH
Plagiobothyrus kingii var. *harknessii*	Great Basin popcorn flower	Boraginaceae		PLKI
Plantanthera hyperborea	green-flowered bog-orchid	Orchidaceae	FACW+	PLHY
Plantanthera leucostachys	white-flowered bog-orchid	Orchidaceae		PLLE
Polygonum arenastrum	**common knotweed**	**Polygonaceae**		POAR
Potentilla glandulosa	sticky cinquefoil	Rosaceae		POGL
Potentilla gracilis var. *elmeri*		Rosaceae	FAC	POGR
Potentilla norvegica		Rosaceae	FAC*	PONO
Potentilla sp.		Rosaceae	FAC	POTsp
Prenanthella exigua	thorny skeleton plant	Asteraceae		PREX
Ranunculus glaberrimus var. *glaberrimus*	sagebrush buttercup	Ranunculaceae		RAGL
Rorripia curvipes var. *curvipes*	yellow cress	Brassicaceae	OBL	ROCU
Rumex acetosella	**sheep sorrel**	**Polygonaceae**	**FACW-**	RUAC
Rumex crispus	**curly dock**	**Polygonaceae**	**FACW-**	RUCR
Rumex paucifolius		Polygonaceae	OBL	RUPA
Rumex salicifolia		Polygonaceae	OBL	RUSA
Rumex sp.		Polygonaceae	OBL	RUsp
Sagina subulata	scotch moss	Caryophyllaceae		SASU
Salsola tragus	**russian thistle**	**Chenopodiaceae**		SATR
Saponaria officinalis	**soapwort**	**Caryophyllaceae**	**FACU**	SAOF
Senecio hydrophilus	alkali-marsh ragwort	Asteraceae		SEHY
Sisymbrium altissimum	**tumble mustard**	**Brassicaceae**		SIAL
Sisyrinchium bellum	blue-eyed grass	Iridaceae		SIBE
Sisyrinchium idahoense	blue-eyed grass	Iridaceae	OBL	SIID
Smilacina stellata	star-flowered solomons seal	Liliaceae		SMST
Solidago spectabilis	showy goldenrod	Asteraceae		SOSP
Stellaria longipes var. *longipes*	long-stalk starwort	Caryophyllaceae	FACW*	STLO
Stephanomeria spinosa	wire lettuce	Asteraceae		STSP
Taraxacum officinale	**common dandelion**	**Asteraceae**	**FACW**	TAOF
Thelictrum fendleri var. *fendleri*	meadow-rue	Ranunculaceae		THFE
Tiquilia nuttallii	Nuttall's crinklemat	Boraginaceae	UPL	TINU
Tragopogon dubius	**goat's beard**	**Asteraceae**		TRDUB
Trifolium longipes	long-stalk clover	Fabaceae	FACW	TRLO
Trifolium monanthum	mountain carpet clover	Fabaceae	FACW	TRMO
Trifolium repens	**white clover**	**Fabaceae**	**FAC**	TRRE
Trifolium sp.		Fabaceae	FACW	TRsp
Trifolium wormskjoldii	cow's clover	Fabaceae		TRWO
Urtica dioica ssp. *holosericea*	stinging nettle	Urticaceae	FACW	URDI
Verbascum thapsus	**wooley mullien**	**Scrophulariaceae**	**NI**	VETH
Veronica americana	American brook-lime	Scrophulariaceae		VEAM
Veronica peregrina ssp. *xalapensis*	purslane speedwell	Scrophulariaceae		VEPE
Veronica serpyllifolia ssp. *humifusa*		Scrophulariaceae	NI*	VESE
Wyethia mollis	wooly mules ears	Asteraceae	FACU-	WYMO
Zigadenus paniculatus		Liliaceae		ZIPA
Aquatic/Emergent Herbs				
Carex lanuginosa	wooly sedge	Cyperaceae	OBL	CALA
Carex lenticularis var. *impressa*	lens sedge	Cyperaceae	OBL	CALEN
Carex microptera	small-wing sedge	Cyperaceae	FAC*	CAMIC
Carex nebrascensis		Cyperaceae	OBL	CANE
Carex praegracilis	clustered field sedge	Cyperaceae	FACW-	CAPR
Carex sp.		Cyperaceae		CAREX
Cyperus squarrosus	bearded nutsedge	Cyperaceae	OBL	CYSQ
Eleocharis pauciflora	few-flowered spike rush	Cyperaceae		ELPA
Eleocharis quinqueflora	spike rush	Cyperaceae	OBL	ELQU
Juncus covilleii var. *obtustatus*		Juncaceae	FACW	JUCO
Juncus mexicanus		Juncaceae	FACW	JUME
Juncus phaeocephalus		Juncaceae	FACW	JUPH

Table 19. Plant species sampled during 2005 nested frequency and band transect sampling. Continued.

Genus, species, variety and/or subspecies	Common Name	Family	Hydric Code	Sampling Code
Luzula subcongesta	hairy wood rush	Juncaceae	FACW	LUSU
Ranunculus aquatilis var. *capillaceus*	white water-buttercup	Ranunculaceae		RAAQ
Rorripia nasturtium-aquaticum	water cress	Brassicaceae	OBL	RONA
Scirpus microcarpus	small fruited bulrush	Cyperaceae	OBL	SCMI
Equisetum arvense	common horsetail	Equisetaceae	FAC	EQAR
Equisetum hyemale	common scouring rush	Equisetaceae	FACW	EQHY
Grasses				
Achnatherum hymenoides	Indian rice grass	Poaceae	UPL	ACHY
Achnatherum occidentalis spp. *californicum*		Poaceae		ACOC
Agrostis gigantea	redtop	Poaceae		AGGI
Agrostis idahoensis	Idaho bentgrass	Poaceae		AGID
Agrostis stolonifera	creeping bent	Poaceae		AGST
Aira caryophyllea	European hairgrass	Poaceae		AICA
Bromus carinatus var. *carinatus*	California brome	Poaceae		BRCAR
Bromus tectorum	**cheat grass**	**Poaceae**		BRTE
Carex athrostachya	slenderbeak sedge	Cyperaceae		CAAT
Carex disperma		Cyperaceae	OBL	CADI
Carex douglasii	Douglas' sedge	Cyperaceae	FACU	CADO
Carex hassei	golden sedge	Cyperaceae	FACW	CAHA
Carex multicostata	many-rib sedge	Cyperaceae		CAMU
Carex scopulorum	mountain sedge	Cyperaceae		CASC
Distichlis spicata	salt grass	Poaceae	FACW	DISP
Elymus elymoides ssp. *elymoides*	squirrel tail	Poaceae	FACU-	ELEL
Elymus glaucus ssp. *glaucus*	blue wild rye	Poaceae	FACU	ELGL
Hesperostipa comata ssp. *comata*	needle and thread	Poaceae		HECO
Leymus cinereus	basin wildrye	Poaceae		LECI
Leymus triticoides	creeping wildrye	Poaceae	FAC+	LETR
Muhlenbergia asperifolia	scratch-grass	Poaceae		MUAS
Muhlenbergia filiformes	pull-up muhly	Poaceae	FACW	MUFI
Muhlenbergia rigens	deergrass, purple muhly	Poaceae		MURI
Phleum alpinum	Mountain timothy	Poaceae	FACW	PHAL
Poa compressa	**Canada bluegrass**	**Poaceae**		POCO
Poa cusikii ssp. *cusikii*		Poaceae		POCU
Poa palustris	**fowl bluegrass**	**Poaceae**	**FACW**	POPA
Poa pratensis* ssp. *pratensis	**kentucky bluegrass**	**Poaceae**	**FAC**	POPR
Poa secunda spp. *juncifolia*	one-sided bluegrass	Poaceae	FACU	POSE
Poa sp.		Poaceae		POA1
Torreyochloa pallida var. *pauciflora*	weak mannagrass	Poaceae		TOPA

4.1.3.1 Structural Changes

The percentage of transects on Rush Creek dominated by trees increased from 1% in 2001 to 4% in 2005 (Appendix H-1). The relative abundance of trees in Rush Creek was noticeably smaller than in Lee Vining Creek. Eighteen percent of the transects on Lee Vining Creek were dominated by trees, compared to 16% in 2001. The conversion of shrub-dominated plots to tree-dominated plots has been a slow process, except in stands with young tree species near the tree layer.

Five transects on Rush Creek were dominated by the tree layer (>15 ft). Only two were dominated by black cottonwood; the other three transects were dominated by tall willows. The potential for willows to develop into tree-dominated riparian forests is limited; they are trees by height definition only. Many of the willows form dense thickets and shrubs that can never attain the stand structure and quality of forests dominated by riparian tree species. These limitations should be considered when evaluating the structural quality of the Rush Creek riparian corridor compared to Lee Vining.

The species composition and relative abundance on Lee Vining and Rush creeks did not show a significant change between 2001 and 2005 based on multiple response permutation procedure

(MRPP) results. The implication of the MRPP result is that stand recovery may have reached an asymptote. Desert stands were not observed evolving into riparian stands, and vice versa. Only gradual change may be expected over the next five years unless disturbance increases, a series of wet or extreme wet years facilitates recruitment on higher surfaces, or side channels are re-watered.

4.1.3.2 Cluster Analysis

Results of the 2005 cluster analysis were similar to the original 2001 analysis (Table 20). On Lee Vining Creek, nine patch types were described for both years. However, the resultant patch types were slightly different. Quaking aspen and sagebrush-creeping wildrye were defined for the 2005 analysis but absent from the original 2001 analysis. Black cottonwood-Wood's rose patches from 2001 were classified as either black cottonwood or Wood's rose patches in 2005. Similarly, sagebrush patches from 2001 were classified as sagebrush-bitterbrush patches in 2005.

On Rush Creek, the patch types were different, though not statistically (Table 20). Of the seven patch types described in the original 2001 analysis, six were the same in 2005. However, the 2005 analysis included four additional patches. The seventh patch type described in 2001, mugwort-soapwort, was not included in the 2005 analysis because no soapwort was sampled on Rush Creek. Rather, those transects were classified in 2005 as sagebrush-bitterbrush patches. In addition, black cottonwood, mixed willow, Wood's rose, and sagebrush-rabbitbrush patches were described in the 2005 analysis.

The 2001 data set was updated with newly identified plant species. When we re-analyzed the updated 2001 data, the cluster analysis results were more similar to the 2005 results. Sixty-nine percent of the transects on Lee Vining Creek were classified in the same patch type for both years (Appendix H-2). Sixty-eight percent of the transects on Rush Creek were classified in the same patch type for both years (Appendix H-3).

Table 20. Vegetation patch types sampled and evaluated in 2005.

Vegetation Patch Type	Creek Where Found†	Classification(s) in which Patch Type Occurred
Black Cottonwood	LVC, RC	2005, 2001 (new)
Black Cottonwood-Wood's Rose	LVC	2001 (original)
Juncus-Creeping Wildrye	RC	2005, 2001 (new), 2001 (original)
Mixed Willow	LVC, RC	2005, 2001 (new), 2001 (original, LVC only)
Mugwort-Soapwort	LVC	2005, 2001 (new), 2001 (original, RC also)
Narrowleaf Willow	LVC, RC	2005, 2001 (new), 2001 (original)
Narrowleaf Willow-Wood's Rose	RC	2005, 2001 (new), 2001 (original)
Quaking Aspen	LVC	2005, 2001 (new)
Wood's Rose	LVC, RC	2005, 2001 (new), 2001 (original, LVC only)
Sagebrush	LVC, RC	2005, 2001 (new, RC only), 2001 (original)
Sagebrush-Bitterbrush	LVC, RC	2005, 2001 (new), 2001 (original)
Sagebrush-Creeping Wildrye	LVC, RC	2005, 2001 (new), 2001 (original, RC only)
Sagebrush-Rabbitbrush	RC	2005
Sagebrush-Wood's Rose	LVC	2005, 2001 (new), 2001 (original)

† LVC= Lee Vining Creek
RC= Rush Creek

With all these classification schemes, how do we know which to believe? The answer can be found by looking at the mean similarity dendrograms (Appendix H-4 and H-5). Mean similarity dendrograms are branching graphs that compare the strength of the classifications by comparing the Jaccard similarity within each of the patch types. The Jaccard similarity is a proportion of the total number of species at two sites that are shared by both sites. Transects that share more species will have a higher Jaccard similarity value; patch types that share more species among the transects will also have a higher Jaccard similarity. The length of each branch indicates how similar transects are within a patch type; longer branches indicate stronger, more believable groups.

Overall, the 2005 classifications for Lee Vining Creek (Appendix H-4) and Rush Creek (Appendix H-5) were stronger than the new 2001 and the original 2001 classifications. Branch lengths of most patch types were longer in the 2005 classifications. The new analysis created a quaking aspen patch type which lends strength to the classification because this patch type is visually obvious and easily recognizable on the landscape. In addition, the ability to classify black cottonwood patches on Rush Creek and quaking aspen patches on Lee Vining Creek improved with time. This was evidenced by the change from a negative direction of the dendrogram branches in the new 2001 classification to a positive direction in 2005. In 2001, transects in cottonwood patches and quaking aspen patches were more similar to transects in other patch types than to transects in the same patch type. In 2005, these transects became slightly more similar to themselves than to other transects in other patches.

The original 2001 cluster analysis for Lee Vining Creek was better at classifying black cottonwood patches than the new 2001 analysis or the 2005 analysis (Appendix H-4). There were several factors that contributed to this result. Developing black cottonwood forests along Lee Vining Creek are in their beginning stages and thus the transects identified as black cottonwood patches may be more heterogeneous. More black cottonwood plants are growing into trees and forming black cottonwood patches so that transects that were formerly classified as mixed willow or native grasslands are being classified as black cottonwood patches. Additionally, as black cottonwood disperses seeds and recruits new individuals, its increased frequency in the shrub and herb layers of mixed willow stands may inhibit our ability to classify the vegetation as one patch type trends into another.

4.1.3.3 Indirect Gradient Analysis

Indirect gradient analysis on the Lee Vining transects extracted three axes (variables) that explained 85% of the variation in the species composition and abundance between transects (Table 21). These axes were interpreted as environmental gradients that account for the variation. Appendix H-6 shows the configuration of transects along two of the three axes. The transects are coded by the geomorphic unit upon which they occurred. The vectors emerging from the center of the graph represent those environmental variables that were strongly correlated with the axes.

The horizontal axis (= axis 1) was interpreted as substrate stability. Patches occurring on geomorphic units 1, 2, and 3 tended to occur near the negative end of the axis while geomorphic units 6, 7, and 8 tended to occur near the positive end. Lower geomorphic units are subject to greater scouring and sediment deposition frequency due to their proximity to the active channel. This process of scour and deposition creates disturbance within the riparian corridor. Riparian species are adapted to this frequent disturbance, but sagebrush species are not. Thus, sagebrush species are more diverse on stable substrates while riparian species are more diverse on less stable substrates.

The second axis was interpreted as a water availability gradient. Depth to the edge of water, or elevation above the groundwater surface, was positively correlated to this axis (Appendix H-6 and H-7). When transects were coded by the patch type in which they were classified by the 2005 cluster analysis, a strong pattern emerged. Riparian patch types (indicated by solid symbols) occurred near

Table 21. Environmental gradients affecting species composition and abundance on Lee Vining Creek and Rush Creek.

Creek	Axis	Gradient	r^2
Rush Creek			
	1	Distance to Groundwater	0.458
	2	Substrate Coarseness	0.216
	3	???	0.169
		cumulative r^2	0.843
Lee Vining Creek			
	1	Substrate Stability	0.455
	2	Distance to Groundwater	0.17
	3	Substrate Coarseness	0.225
		cumulative r^2	0.85

the negative end of axis 2 and therefore on surfaces closer to the groundwater. Desert sagebrush patch types (indicated by open symbols) occurred on surfaces farther from groundwater. Availability of water in any ecosystem is a logical, predictable variable, especially for riparian corridors in desert ecosystems.

The third axis was interpreted as a substrate coarseness gradient. Transects with organic matter and silt in the soil occurred near the negative end of axis while transects with larger gravels and cobbles occurred near the positive end. Riparian patch types tended to occur in transects with finer particle size and more organic matter and tended to be associated with the negative end of the axis. Silt and organic matter provide nutrients and hold moisture in the soil. Fresh deposits of fine particles provide suitable conditions for germination and growth through the first year. As a riparian hardwood stand develops, fine textured substrates become covered with leaves and branches and other organic debris. Overbank floods return organic build-up in riparian stands to the stream providing an important nutrient source for macro invertebrates and other animals reliant on organic debris for food. The third axis supports the idea that riparian stands are associated with fine textured sediment with some degree of organic material accumulation, while desert and transitional stands tend to be associated with coarser materials and no organic material accumulation.

Results of gradient analysis were similar for Rush Creek, although the correlation of axes and environmental variables did not follow the same order (Table 21). However, this was of little consequence because the axis number was arbitrary and did not imply importance. One notable difference was that distance to groundwater explained much more of the variation on Rush Creek than on Lee Vining Creek. Possibly the distance to groundwater and substrate stability was inversely correlated to the same axis on Rush Creek. On Lee Vining Creek, these variables acted as separate gradients. Another difference in the Rush Creek gradient analysis was that three axes were extracted from the ordination, but only two could be interpreted. The third axis was not correlated to any measured environmental variable but was strongly correlated to abundance of Wood’s rose.

Results of the gradient analysis suggested that riparian patch types are influenced by several factors: proximity to groundwater, and frequent disturbance (substrate instability) resulting in deposition of organic matter and silt (substrate coarseness). Although these gradients appeared independent in the form of separate axes, they are inter-related. For instance, sites that experience frequent scour and/or deposition are generally closer to groundwater. Increasing the groundwater level and creating new active floodplains will likely increase riparian vegetation.

4.2 Valley-Wide Band Transect Sampling and Riparian Vegetation Dynamics

4.2.1 Introduction

In RY 2001-02, two valley-wide band transects spanning the riparian corridor were established on Lee Vining Creek and three valley-wide band transects were established on Rush Creek. The purpose of the band transects was to document future trends in riparian woody plant initiation, establishment, and mortality, particularly in relation to water surface elevation and stream channel/floodplain elevation.

4.2.2 Methods

The detailed band transect sampling methodology is described in the 2001 Annual Report (McBain and Trush 2002). Band transects were re-sampled in July and August of 2005. Plant stand structure, woody plant recruitment, and species distributions were quantified within all five band transects. Two types of data were collected: percent cover of each species in each patch type and riparian hardwood plant location along the band transect. Results of the location data were used to develop maps of riparian hardwood locations in relation to ground surface elevation and water surface elevations (Appendix I-1 to 5).

4.2.3 Results & Discussion

The structure of the riparian vegetation along our five valley-wide cross sections did not change notably from 2001 to 2005. In most cases, similar numbers of riparian hardwood plants were sampled both years, indicating that recruitment of hardwood species was slow. Plants less than or equal to four years of age (hereafter "new") represented the number of plants recruited into the riparian vegetation since 2001. Four-year old plants would have been sampled as seedlings in 2001, and plants younger than four years old would not have been alive during 2001 sampling.

- Cross section 13+36 (Appendix I-1) on upper Rush Creek showed little change in structure of the existing riparian vegetation and no recruitment of new riparian vegetation. No riparian hardwood seedlings were sampled in either year. Most of the cross section was in the Juncus-creeping wildrye patch type, and narrowleaf willow and yellow willow were the dominant riparian hardwoods. Only four new plants were sampled in 2005. These plants (two narrowleaf willows and two yellow willows) were measured as individual stems in thickets that were 6 to 9 years old. As a result, they probably represent clonal resprouts of older plants as opposed to newly recruited individuals. Black cottonwood was not found along this cross section in 2001 or 2005.
- Cross section 08+30 (Appendix I-2) near the County Road on Rush Creek showed modest change in structure of the existing riparian vegetation. Sagebrush patches occurred on the pre-1941 floodplains while mixed willow patches occurred on the low terrace and active floodplain. The active floodplain on the right bank of the main channel was an area of seedling establishment. Comparable numbers of narrowleaf willow seedlings were measured in both years. Many seedlings measured in 2001 successfully recruited into small shrubs by 2005; sixty-three new plants were measured in 2005. An open patch in 2001 was trending toward a mixed willow patch in 2005. Black cottonwood was not found along this cross section in 2001 or 2005.
- Cross section 07+25 (Appendix I-3) on lower Rush Creek showed a similar pattern of seedling establishment and recruitment on the active floodplain. Comparable numbers of seedlings were measured in 2001 and 2005. A total of 69 new willow plants was measured on the active floodplain in 2005. Thirteen black cottonwood plants were measured along both banks of the 10 Channel during each round of sampling. In 2001, the cottonwoods were small plants less than 4 ft tall. In 2005, nine of the plants were trees, and seven were almost 20 ft tall or taller. However, no black cottonwood seedlings or new plants were measured in 2005, indicating that structure may have improved but total area has remained the same.

- Cross section 10+44 (Appendix I-4) on upper Lee Vining Creek showed a small increase in the number of black cottonwood plants. Plants measured in 2001 grew by as much as 16 ft. The active floodplain and middle terrace island in the main channel both served as areas of seedling establishment for willows as well as black cottonwoods. The A4 Channel near the left valley wall was another place where seedlings and new recruits were measured.
- Cross section 05+68 (Appendix I-5) on lower Lee Vining Creek had more black cottonwoods than any other cross section monitored (n=324). Fifty-five cottonwoods were trees. Most cottonwoods occurred on the lower left bank and the right bank of the main channel. Only four cottonwood seedlings were found along the entire cross section in 2005.

The vegetation along the valley wide cross sections was mostly static. Some areas (e.g., Rush Creek XS13+36 and XS08+30) experienced little recruitment of new riparian plants or improvement in existing riparian structure. Other areas experienced rapid improvement of riparian structure but relatively little recruitment of new riparian plants (e.g., Lee Vining Creek XS 10+44 and 05+68). The low number of newly recruited plants suggests riparian stands may have reached a recovery asymptote. Total acreages of desert, herbaceous riparian, and woody riparian patches that were mapped for each creek in 2004 may only continue modest changes in the next five to ten years.

4.3 Phenology of Woody Riparian Plant Species

4.3.1 Methods

Phenology is the annual pattern of breaking dormancy, leafing out, flowering, fruiting, dispersing seeds, and going into dormancy. Flowering, fruit maturation, and seed dispersal are the most important components of phenology. The timing of seed dispersal relative to streamflows may control recruitment of many riparian hardwood species. To quantify phenologic patterns, we selected eight individuals of three riparian hardwood species within two sites on Rush Creek and two sites on Lee Vining Creek (Appendix J 1-4). Wherever feasible, phenology sites overlapped with sites used for other monitoring activities (i.e., piezometers, cross sections, staff plates, etc). The study began May 10, 2005 and ended July 31, 2005.

Seed traps were installed in black cottonwood, yellow willow, and narrowleaf willow canopies. Seed traps consisted of an 8.5x11 inch piece of plywood with hardware cloth tacked to the front and a seed sheet (i.e., the trap) inserted between the hardware cloth and the plywood (Appendix J-5). Seed sheets had a 1 cm grid printed on them as a record-keeping device when counting seeds and to facilitate sub-sampling when more than 200 seeds were trapped on a given sheet. The sheets were liberally coated with petroleum jelly before being placed in the trap. Between June 4 and July 27, seed sheets were exchanged weekly in each trap, and the seeds caught in the petroleum jelly counted. In addition, observations of flowering, catkin development, and fruit maturation were made weekly when seed traps were exchanged. We took notes about each plant and classified the percent of canopy in flower, with developing fruit, and with fruits dispersing seeds. Black cottonwood and narrowleaf willow seeds were still being dispersed on Lee Vining Creek when the last seed traps were removed at the end of July. Therefore, completion of seed dispersal for these two species was estimated from continued observations and on 2005 developmental history.

Black cottonwood seeds and willow seeds were easily separated visually. Willow seeds of various species could not be discerned. Black cottonwood seeds look like small sesame seeds while willow seeds look like flecks of pepper. Seeds were counted using a dissecting microscope and tallied into three categories: willow seeds, cottonwood seeds and other seed types. The beginning, peak, and end of seed dispersal were quantified using changes in seed number week-to-week.

Seed trap data were used to estimate the relative quantity of seeds being dispersed by each tree, and to identify the beginning of seed dispersal more accurately than through visual observation. The relative quantity of seeds was also used to assess the pattern of seed dispersal and to determine whether there were peaks in the quantity of seeds released. Willow seeds could not be identified to species and thus could not be segregated into discrete seed dispersal periods.

Air temperature was monitored at each phenology site using HOBO temperature recorders. The onset and duration of seed dispersal were compared to changes in air temperatures. The number of hours per year below 32ºF and the number of hours above 60ºF were quantified and related to patterns in yellow willow, narrowleaf willow, and black cottonwood seed dispersal. Patterns observed in 2005 phenology for the three species were then related to the total cumulative hours above 60ºF. Temperature thresholds were based on general plant physiology. When the air temperature reaches 60ºF, plants are physiologically active and the soil is warm enough for root growth and water uptake; this temperature is often used as a benchmark in physiologic modeling. When temperatures fall below 32ºF, water in plant cells becomes vulnerable to freezing, which in turn may cause cells to rupture and die. Plants may survive a few hours of freezing temperatures, but fruit abortion, or delayed or stunted growth, may result from several freezing hours per day for several consecutive days during active growth.

Stage-discharge graphs were constructed for one cross section on Lee Vining (XS10+44) and one cross section on Rush Creek (XS7+25). Using the relationships between measured water surfaces at each cross section, the RY 2005 streamflows were converted into water surface elevations at the two cross sections. Runoff Year stage-o-graphs were computed for specific cross sections. Seed dispersal periods and survivable water recession rates (i.e., 2.5 cm/day for cottonwoods) during and after seed dispersal for each species were compared with the actual recession rates experienced at each cross section. Effects of RY 2005 streamflows on the initiation of black cottonwood, yellow willow, and narrowleaf willow were assessed.

4.3.2 Results and Discussion

4.3.2.1 Seed Trap and Phenologic Data Interpretation

Seed dispersal results are summarized in Table 22 and Appendix J-6. On both Rush Creek and Lee Vining Creek, yellow willow dispersed seeds first, followed by black cottonwood, and finally narrowleaf willow (Table 22). Narrowleaf willow had the longest seed dispersal period, and black cottonwood had the shortest (Appendix J-6). The difference in the onset and duration of seed dispersal for all species studied was statistically significant ($p>0.05$). Seed dispersal started earlier and increased faster on Lee Vining Creek than on Rush Creek. However, yellow and narrowleaf willow seed dispersal on Rush Creek did catch up with, and eventually surpass, Lee Vining in late July.

Willow seeds began to disperse in early June and continued until August. The seed trap data alone could not segregate yellow willow from narrowleaf willow seeds (Appendix J-7). However when these data were combined with the visual observations, yellow willow seed dispersal were segregated from narrowleaf willow (Appendix J-8 and 9).

Yellow willow began seed dispersal in early June and ended early August (Appendix J-8). Female yellow willow plants develop and disperse seeds from one set of catkins annually. Catkins mature as daytime temperatures begin to rise above 60ºF, and seed dispersal onset, peak and completion rise and fall in a standard Poisson distribution. Yellow willows on Lee Vining began to set seed more slowly than those on Rush Creek, but within a few weeks had more catkins dispersing seeds than plants on Rush Creek. The peak of seed dispersal for yellow willow was July 5 on Lee Vining and July 10 on Rush Creek.

Narrowleaf willow began seed dispersal in mid June, and continued to disperse seeds through the middle of August (Appendix J-9). Narrowleaf willow is unusual among willows because it produces many sets of catkins in a growing season. Narrowleaf catkins take longer to mature and begin dispersing seeds, and seed dispersal does not follow a Poisson distribution. Catkins initially grow on a portion of the canopy; when these are fertilized another round of catkins begins to grow. The first round of catkins disperses seeds while the second round matures, and a third round begins to develop. Narrowleaf willow can usually produce five or six catkin iterations within a growing season. There was no detectable peak in narrowleaf seed dispersal. Instead, there was a constant seed rain from June 15 until the middle of August. Narrowleaf willow on Rush Creek began dispersing seeds on a similar date as those on Lee Vining; however the narrowleaf willows on Rush Creek had fewer catkins dispersing seeds when seed dispersal began. At the end of July, narrowleaf willows on Rush Creek surpassed those on Lee Vining in the number of catkins dispersing seeds.

Black cottonwoods began dispersing seeds in the middle of June (Appendix J-10). Rush Creek completed seed dispersal in the first week of July, while seed dispersal did not finish until August on Lee Vining. Rush Creek cottonwood seed dispersal lagged behind Lee Vining seed dispersal. The Rush Creek results were not expected. After the first week of July on Rush Creek, there was sharp decline in the number of catkins dispersing seeds, and many aborted catkins fell from the trees without dispersing seeds Appendix J-11). In sharp contrast, Lee Vining had dispersed less than half its seeds by the time Rush Creek cottonwoods were done. The Lee Vining results were expected, and presumably would have followed a Poisson distribution if the study had been extended through August.

The black cottonwood seed dispersal period for Lee Vining Creek provided a reasonable estimate of seed dispersal peak and duration for WY 2005 and can be used to guide SRF releases in future years. Black cottonwood seed dispersal on Rush Creek was shorter and occurred later than on Lee Vining Creek. The differences in timing and duration of black cottonwood seed dispersal between the two creeks were likely due to cooler temperatures on Rush Creek. Therefore, the seed dispersal period dates for Rush Creek should be lagged at least a week behind Lee Vining to accurately capture the difference in the timing of seed dispersal caused by cooler temperatures on Rush Creek.

4.3.2.2 Air temperature relationships to seed dispersal and annual phenology

Seed dispersal on Rush Creek lagged behind seed dispersal on Lee Vining Creek for all three species, suggesting a single causal mechanism. Daily air temperature is likely one of the primary controlling mechanisms in catkin development (Stanton and Villar 1996). We plotted the hourly air temperature data to evaluate differences between Rush Creek and Lee Vining Creek (Appendix J-12). Rush Creek had similar high temperatures as Lee Vining Creek; however, Rush Creek was below freezing more often during May and June when Lee Vining was not. Cooler temperatures on Rush Creek help explain why Rush Creek seed dispersal lagged behind Lee Vining.

To evaluate Rush Creek high and low temperature patterns, we determined the number of hours above 60ºF and below 32ºF from January through October for both creeks (Table 23). The number of hours Rush Creek was above 60ºF was similar to Lee Vining (Appendix J-13), but Rush Creek had many more hours below 32ºF in May and June than Lee Vining. Night temperatures dipped well below freezing for several nights on Rush Creek but not at all on Lee Vining Creek (Appendix J-14). The colder temperatures in May and June likely caused the aborted black cottonwood catkins and the truncated seed dispersal observed on Rush Creek; freezing temperatures came when catkins were growing fast due to higher daytime temperature, but the developing catkins froze at night.

We estimated the number of "degree-hours" required to initiate a plant's annual phenology pattern (Table 24). Combining visual observations, seed traps, and hourly air temperatures, we estimated the cumulative number of hours above 60ºF required to break bud, flower, develop fruit, and set seeds. We estimated the number of hours below 32ºF needed to cause leaves to yellow and induce the onset of dormancy. The number of cumulative hours above 60ºF and below 32ºF played a key

Table 22. Documented seed dispersal periods for three riparian woody plant species on Rush and Lee Vining creeks.

Creek	Common Name	Species	Begin Seed Dispersal	50% Dispersal	End Seed Dispersal
Rush Creek					
	black cottonwood	*Populus balsamifera* ssp. *trichocarpa*	15-Jun	25-Jun	6-Jul
	yellow willow	*Salix lutea*	1-Jun	10-Jul	10-Aug
	narrowleaf willow	*Salix exigua*	15-Jun	20-Jul	15-Aug
Lee Vining Creek					
	black cottonwood	*Populus balsamifera* ssp. *trichocarpa*	15-Jun	10-Jul	4-Aug
	yellow willow	*Salix lutea*	1-Jun	5-Jul	5-Aug
	narrowleaf willow	*Salix exigua*	20-Jun	25-Jul	20-Aug

Table 23. Monthly summary of hours where air temperatures were above 60ºF and below 32ºF near Rush Creek and Lee Vining Creek phenology study sites.

	Black Cottonwood	Yellow Willow	Narrowleaf Willow
Bud Swell	>0 hours but <100 hours	>0 hours but <50 hours	>0 hours but <100 hours
Bud Break	>100 hours but <250 hours	>50 hours but <100 hours	>100 hours but <250 hours
Flowering	>250 hours but <500 hours	>100 hours but <250 hours	>250 hours but <1,500 hours
Fruit Maturation	>500 hours but <750 hours	>250 hours but <500 hours	>500 hours but <1,750 hours
Begin Seed Dispersal	>750 hours but <1,000 hours	>500 hours but <750 hours	>750 hours but <2,000 hours
Seed Dispersal	>1,000 hours but <1,750 hours	>750 hours but <1,500 hours	>1,000 hours but < 2,000 hours
End Seed Dispersal	>1,750 hours but <2,000 hours	>1,500 hours but <1,750 hours	>1,750 hours but <2,000 hours
Onset of Dormancy(leaves color)	>150hrs	>150hrs	>150hrs

\# of hours above 60ºF
\# of hours below 32ºF

role in phenologic development when related to visual observations (Appendix J-13 and 14). While the results were not intended to be evaluated for statistical significance, nor to establish precise degree-hour relationships, they can bracket the number of hours above 60ºF necessary for plants to transition from one phenologic condition to another. If the need for synchronizing annual snowmelt hydrographs peaks and recessions to seed dispersal for optimizing recruitment is desired, these results suggested that developing a more precise degree-hour model is feasible.

4.3.2.3 Seed dispersal and stage-discharge evaluation for RY 2005

Lee Vining Creek streamflows peaked three times in RY 2005. The first was the largest (Appendix J-15) and caused a 1ft change in water surface elevation from the onset of snowmelt until summer baseflows. Black cottonwood, and yellow and narrowleaf willow began seed dispersal during or shortly after the second peak (mid-June). Streamflow recession never exceeded the cottonwood root growth rates of 0.08 ft/day. The streamflow fluctuated over 0.5 ft until the middle of July after the third and smallest peak. Streamflows gradually receded to summer baseflows near the beginning of August and were not a significant source of riparian woody plant mortality in 2005. However, seeds dispersed before the third peak were inundated and the germinating seedlings were subsequently drowned, which reduced the number of yellow willow seedlings observed during band transect sampling. Seedlings of all species were observed during band transect sampling.

Table 24. Preliminary degree hour model bracketing the cumulative hours needed above 60ºF, or below 32ºF, to induce a transition to another phenologic state.

	Number of hours air temperatures were below freezing (32ºF)		Number of hours air temperatures were above 60ºF	
	Upper Lee Vining Creek (HOBO#7)	Lower Rush Creek (HOBO#8)	Upper Lee Vining Creek (HOBO#7)	Lower Rush Creek (HOBO#8)
Jan-05	611 hours	585 hours	0 hours	0 hours
Feb-05	416 hours	429 hours	7 hours	0 hours
Mar-05	344 hours	359 hours	80 hours	39 hours
Apr-05	218 hours	261 hours	145 hours	133 hours
May-05	44 hours	98 hours	279 hours	270 hours
Jun-05	15 hours	83 hours	331 hours	343 hours
Jul-05	0 hours	0 hours	442 hours	443 hours
Aug-05	0 hours	10 hours	397 hours	375 hours
Sep-05	40 hours	140 hours	276 hours	278 hours
Oct-05	N/A	N/A	N/A	N/A
Nov-05	N/A	N/A	N/A	N/A
Dec-05	N/A	N/A	N/A	N/A

Rush Creek streamflows peaked once and had several distinctive benches associated with the SRF releases. Water surface elevations varied over 2 ft from the onset of snowmelt to summer baseflows (Appendix J-16). Yellow willow began to disperse seeds on the ascending limb while black cottonwood and narrowleaf willow began to disperse seeds shortly before the peak. Streamflows dropped more than 1.5 ft during the seed dispersal of all species, but the recession was slow enough to compensate for root growth (i.e., 0.08 ft/day [or 2.5cm/day] for cottonwoods). Therefore, streamflow recession rates along Rush Creek were not a significant mortality agent to seedlings. The timing, magnitude, and rate of recession were ideal for the germination of all three species, depending on the availability of suitable nursery sites. The stage-discharge results were supported by presence of black cottonwood, yellow willow, and narrowleaf willow seedlings during band transect sampling.

4.3.2.4 Summary

The annual variation in air temperatures is likely related to the type of runoff year. Typically, wetter years are colder and drier years are warmer. Warmer temperatures earlier in the season cause earlier snowmelt, which in turn causes earlier streamflow peaks and recessions. Annual variation and pattern of seed dispersal for dominant woody plant species on Rush and Lee Vining creeks suggested that air temperatures were a strong selective factor in the successful perpetuation of a species.

Yellow willow began to disperse seeds as streamflows rose in response to snowmelt and completed seed dispersal before summer baseflows arrived. Early dispersal of yellow willow seeds would give this species a competitive edge over other species, as it would have first access to nursery sites. This factor may explain its dominance in the riparian corridor. Yellow willow seeds dispersed early in the season may be scoured by increasing flows, but seeds dispersed later could access a wider range of micro-sites with suitable nursery conditions. Additionally, seeds dispersed later would be deposited higher on the bank by receding flows resulting in seedlings less prone to scour-related mortality. This strategy of early seed dispersal coupled with dispersal during the descending limb is effective in snowmelt dominated systems.

Narrowleaf willow had a slower and more steady pattern of seed dispersal, and began shortly before streamflows peaked and ended after summer baseflows arrived. Narrowleaf willow dispersed seeds longer than any other species monitored, due to multiple catkin crops. No peak in seed dispersal was observed. Narrowleaf willow seeds were less prone to scour by snowmelt floods than yellow willow seeds because of its later seed dispersal period. But recruits germinated along the low water edge may be prone to scour the following season. Narrowleaf willow may also infrequently recruit in areas where soil moisture is provided by sources other than snowmelt runoff. For this reason, this seed dispersal strategy is well suited to seasonal rainfall-dominated systems.

Black cottonwood began seed dispersal shortly before streamflows peaked and ended shortly after summer baseflows. Black cottonwood seeds are larger and heavier than willow seeds and may have a narrower range of dispersion than willows. However, black cottonwood seeds germinated in similar sites as yellow and narrowleaf willow. Black cottonwood seeds may have washed away early in the season but probably were re-deposited during the receding limb as fine washload on floodplains (where available). Seeds dispersed later had access to a wider range of micro-sites across floodplains and point bars, and many had suitable nursery conditions. While slightly different than the strategy used by yellow willow, this seed dispersal strategy is also ideal for species in snowmelt dominated systems because it relies on access to groundwater fed by snowmelt runoff.

The riparian hardwood species on Rush and Lee Vining creeks require the same conditions for successful seedling establishment. The species may experience direct competition between individual seedlings on suitable nursery sites, but differences in seed dispersal timing likely result in partitioning of the available nursery sites. Yellow willow disperses seeds earlier than the other species and often grows higher on streambanks. Narrowleaf willow disperses seeds longer than the other species and can exploit the low water edge. Black cottonwood disperses seeds concurrently with the other two species but its seeds are more likely to be deposited on floodplains during the receding limb. Additionally, an individual female black cottonwood tree may produce more than 13 million seeds. Our observations suggest that most of the seeds were deposited within 5m of the tree. The number of seeds falling in a suitable nursery site near a female cottonwood tree would overwhelm the number of other species' seeds. In such a case, black cottonwood would be more likely to establish.

4.4 Jeffery Pine Plantings Recommendations

We developed methods for selecting sites for planting Jeffrey Pine and Cottonwood on Lee Vining Creek and Rush Creek. These methods, and maps showing potential planting locations, are in Appendix K.

5 SIDE CHANNEL AND RESTORATION SITE MONITORING

5.1 Rush Creek 3D Side Channel

We replicated the 3D side channel longitudinal profile, surveyed after the 2004 SRF releases, to determine if the 2005 SRF releases had again caused major channel readjustments (bank erosion, channel incision, sediment deposition) such as occurred in 2004. Recall in 2004 the side channel had significant channel incision and the entrance to the side channel had become plugged by a thin sediment deposit across the channel. The 2005 SRF accessed the side channel beginning late May, 2005 and peaked at approximately 66 cfs on June 23. Following the SRF release's recession, the side channel again plugged with sediment and went dry. The thalweg profile was resurveyed October 10, 2005 (Figure 37). The plug had again reformed at approximately 0.18 ft higher elevation than in 2004, preventing flow from entering the side channel. Additional minor adjustments occurred in the side channel at the same location where major head-cutting happened in 2004, but elsewhere the channel maintained similar morphology as post-2004 SRF's.

5.2 Rush Creek 1A, 4Bii, 11, and 13 Channel Profiles

Several side channels on Rush Creek have been re-watered, while others remain under consideration. In 2000 we surveyed longitudinal profiles of the ground surface at the entrance to side channels, each beginning at the Rush Creek mainstem and traversing down the side channel to a point where excavation would not be necessary (where the re-watered channel would daylight into the existing ground contours). In 2005 additional side channel profiles were surveyed. Profiles were surveyed for:

- Channel 1A on the right bank below the Narrows;
- Channel 4bii on the right bank at elevation 6,534 in the bottomlands;
- Channel 11 just upstream of the 10 Channel/Main Channel confluence on the left bank;
- Channel 13 diverging from the right bank just below the 10 Channel confluence (and which would potentially re-water the Channel 14).

Longitudinal profiles are presented in Appendix L.

5.3 Rush Creek 3D and 8 Channel Riparian Vegetation Response Monitoring

5.3.1 Introduction

In summer 2002, the 8 Channel entrance was re-opened and a floodplain/side channel complex was constructed at the 3D Channel. A monitoring program was established to quantify the response of riparian and desert plant species to the channel re-opening and the floodplain construction. In 2004, a series of nested frequency plots was established and then monitored in the spring and fall. The plots were re-sampled in the fall of 2005 and the results were compared with the 2004 results.

5.3.2 Methods

In October 2005, sixteen plots at the 8 Channel and 16 plots at the 3D Channel were sampled. Quadrats were similar to the nested frequency plots in the vegetation description analysis. Detailed vegetation response monitoring methods are presented in the RY2004 annual report (McBain and Trush 2005). At each quadrat, we recorded species presence, relative abundance, and density of riparian hardwood species. Presence data were used to calculate frequencies for desert species, herbaceous riparian species, and riparian hardwood species.

5.3.3 Results & Discussion

Thirty-five species were sampled during 2005 vegetation response monitoring. Eighteen were riparian species and 17 were desert species. Twenty-four species were sampled in 2004 and again in 2005. Twelve species from 2004 were absent from quadrats sampled in 2005. Of those 12 species, two were riparian hardwoods (*Salix lucida* ssp. *lasiandra* and *S. geyeriana*). Eleven species sampled in 2005

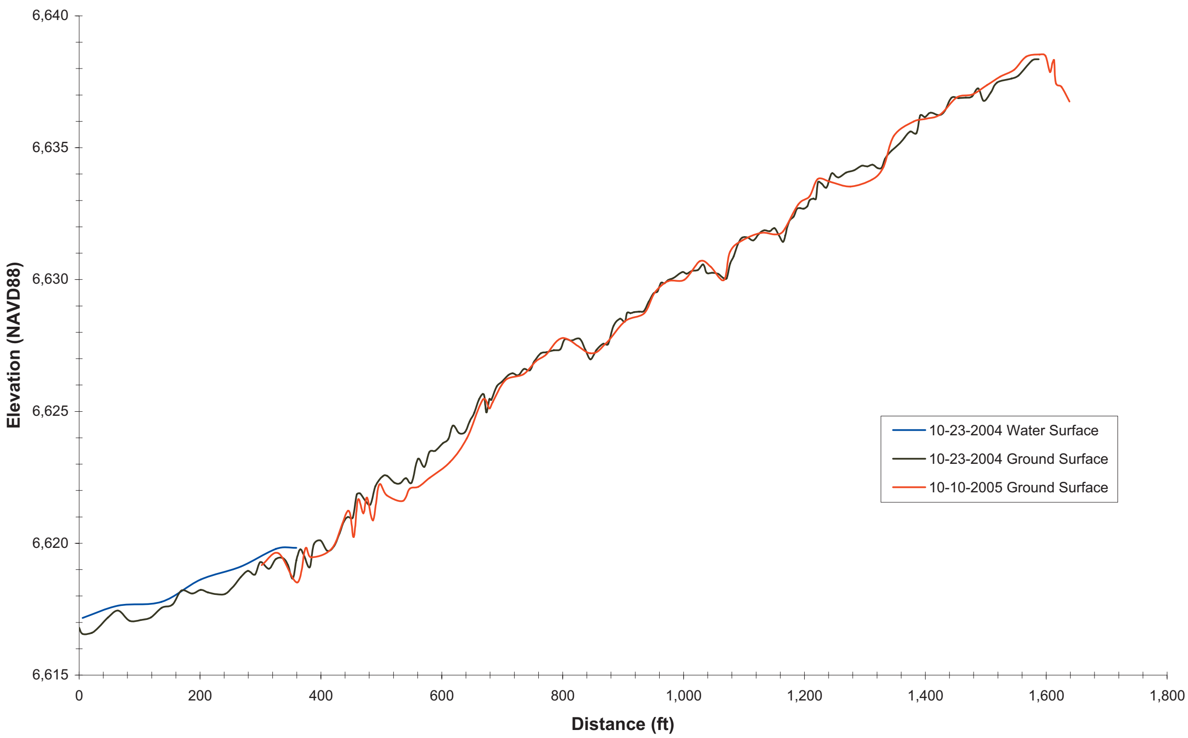


Figure 37. The Rush Creek 3D Side Channel longitudinal profiles from October of 2004 and 2005, with bed elevation adjustments the past two years.

were not found in 2004. There was a high turnover of species, which is characteristic of early site colonization and stand development. Over 50 species have been documented at both sites since the spring of 2004. The availability of new substrate combined with the timing and duration of inundation at the constructed sites facilitated the germination of many plant species. However, the suitability of the substrate and local soil moisture conditions required by each species dictated whether young plants survived.

Species richness in 2005 was still higher at the 3D Channel than at the 8 Channel. Overbank flows across the 3D site have delivered seeds to geomorphic settings appropriate to their life history strategies. In addition, riparian hardwood recovery appeared quicker at the 3D Channel than the 8 Channel (Tables 25 and 26). In 2005, three hundred fifty-eight riparian hardwood plants of three species (black cottonwood, yellow willow, and narrowleaf willow) were sampled in 16 quadrats at the 3D Channel. This contrasted sharply with only 21 plants of one species (narrowleaf willow) sampled in 16 quadrats at the 8 Channel.

The highest density of seedlings at the 3D Channel was measured during the first growing season following construction (Figure 38). In almost all cases, riparian hardwoods showed a steady and sometimes dramatic decrease in density (e.g., E-4) since spring 2004.

Gravel bars, edges of the main side channel, and depressions in the constructed 3D surface had high frequencies of riparian hardwood species (Figure 38). The areas surrounding gravel bars and channel edges showed the best regeneration of riparian hardwoods. No riparian hardwoods were documented on high spots in the constructed 3D surface in any monitoring event.

There was minor riparian hardwood regeneration documented in 8 Channel quadrats. Quadrats adjacent to the 8 Channel were the only locations where hardwoods were observed. At upstream and downstream sites, deposition of fine sediments created suitable habitat for riparian hardwood seeds to germinate and grow. The absence of hardwoods from these sites was likely a result of groundwater and soil moisture declines that occurred when main channel streamflows no longer accessed the 8 Channel.

In general the 8 Channel is drier than the 3D Channel. Surfaces adjacent to the 8 Channel receive water only part of the year and are considerably higher in elevation and farther from the main channel water surface. Regeneration of riparian hardwoods along the 8 Channel will thus be a longer process, with different composition and functions than hardwoods at the 3D Channel.

6 2006-07 MONITORING SEASON

The past several years emphasized field studies evaluating SRF flow releases and snowmelt runoff in Rush and Lee Vining creeks. These studies included: (1) bed mobility and scour experiments, (2) sediment transport and sediment deposition studies, (3) groundwater and soil moisture monitoring, and inundation mapping, (4) streamflow gaging and synoptic discharge measurements of main and distributary channels, (5) planmapping and aerial photo analysis, and (6) channel profile and cross section surveying. Most of the field data collection needed for an objective evaluation of the Rush Creek SRF's and Lee Vining Creek snowmelt is complete. We recommend several monitoring components and infrastructure elements be maintained the next several years, while others be removed, including:

- maintain the McBain and Trush stream gage at Lower Rush Creek XS -9+82 using the LADWP Stevens datalogger with stage-height readings at 15-minute intervals; download data bi-annually; when feasible, collect additional discharge measurements at low to moderate discharges;
- maintain the piezometer datalogger at the Rush Creek 8 Channel Piezometer 8C-6 with the LADWP Stevens datalogger with stage-height readings at 15-minute intervals; download data bi-annually;
- remove the top above-ground portion of piezometers, cap and bury them, and monument them with a rebar stake to facilitate relocation with magnetic locator if needed;
- maintain Onset Optic Stowaway stream temperature recorders at twelve locations on Rush, Lee Vining, Parker, and Walker creeks (locations described in McBain & Trush, 2005); record data hourly and download data bi-annually;
- maintain all McBain & Trush rebar monuments for survey control, cross section, and longitudinal profile monitoring at all Rush, Lee Vining, Parker, and Walker creek study sites and vegetation plots;
- remove all painted tracer rocks and visible scour core rocks from Rush and Lee Vining creeks;
- remove staff plates at the 3D and 8 Channel monitoring sites, with exception of those at the side channel entrances;

Table 25. Desert and riparian plant species' responses to the re-opening of the 8 Channel entrance in RY 2004 and 2005.

		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%
FALL 2005	Total Number of Desert Species	0	9	2	8
	Total Number of Riparian Species	0	8	0	6
	Frequency of Desert Species in Plots	0%	100%	25%	75%
	Frequency of Riparian Herb Species in Plots	0%	58%	0%	75%
	Frequency of Riparian Hardwood Species in Plots	0%	33%	0%	0%

Table 26. Desert and riparian plant species' responses to floodplain and side channel construction at the 3D Channel in RY 2004 and 2005.

		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%
FALL 2005	Total Number of Desert Species	3	3	2	9
	Total Number of Riparian Species	8	14	8	8
	Frequency of Desert Species in Plots	25%	58%	17%	100%
	Frequency of Riparian Herb Species in Plots	25%	75%	50%	58%
	Frequency of Riparian Hardwood Species in Plots	50%	100%	75%	0%

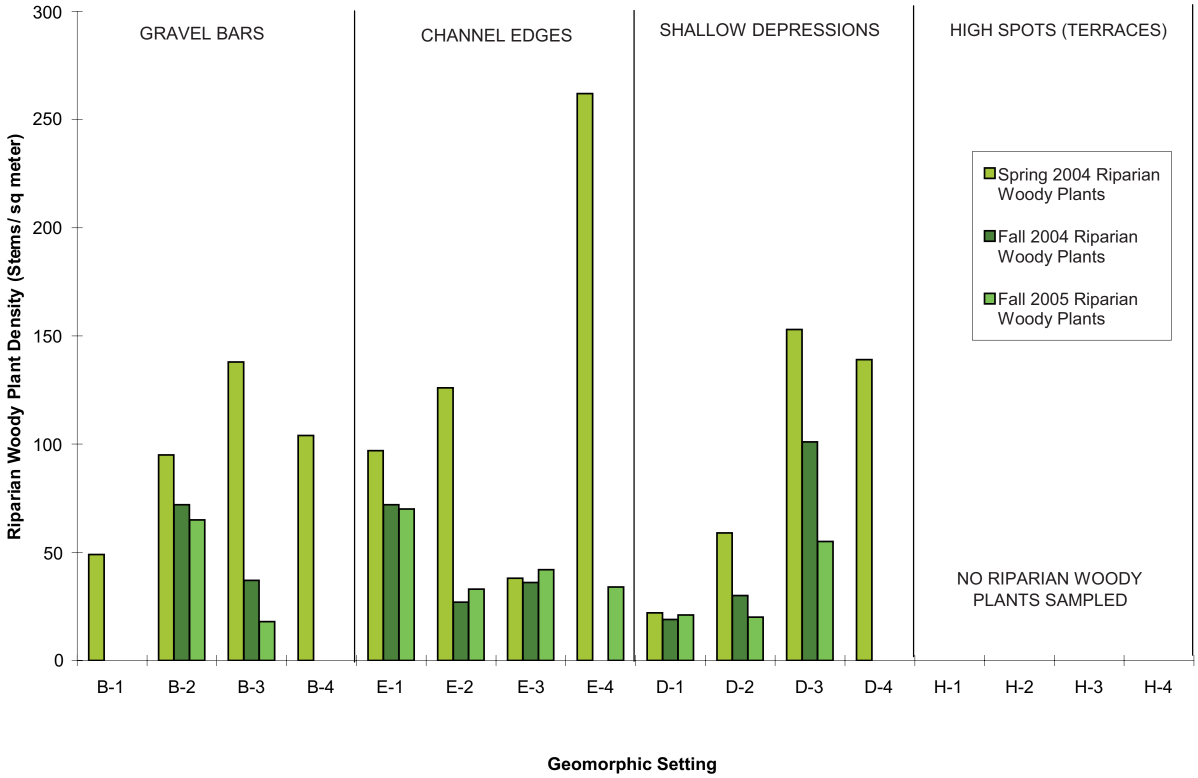


Figure 38. Hardwood seedling density in vegetation monitoring plots at the 3D Floodplain site.

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APPENDIX A

Water Temperatures

Table A1. Summary of water temperatures on Lee Vining Creek measured at the Parshall Flume, B1 Channel, and County Road sites for WY 2000-2005.

Lee Vining blw Parshall Flume						
WATER YEAR	2000	2001	2002	2003	2004	2005
DAILY AVERAGE (°F)						44
ANNUAL MAX (°F)						53
ANNUAL MIN (°F)						33
MAX DAILY FLUX (°F)						12
WINTER MAX (°F)						not available
WINTER MIN (°F)						not available
WINTER AVERAGE (°F)						not available
MAX WINTER FLUX (°F)						not available
SUMMER MAX (°F)						51
SUMMER MIN (°F)						43
SUMMER AVERAGE (°F)						47
MAX SUMMER FLUX (°F)						4
DATE OF ANNUAL MAX						not available
Start Date						17-Apr-05
End Date						15-Aug-05
Number of Days Sampled						120

Lower Lee Vining at B1 Channel						
WATER YEAR	2000	2001	2002	2003	2004	2005
DAILY AVERAGE (°F)	43	44	44	42	46	45
ANNUAL MAX (°F)	65	65	65	69	69	64
ANNUAL MIN (°F)	32	32	30	31	32	32
MAX DAILY FLUX (°F)	14	15	15	11	18	14
WINTER MAX (°F)	47	48	46	47	47	not available
WINTER MIN (°F)	32	32	30	31	32	not available
WINTER AVERAGE (°F)	35	34	34	35	37	not available
MAX WINTER FLUX (°F)	12	11	12	11	12	not available
SUMMER MAX (°F)	65	65	65	not available	69	59
SUMMER MIN (°F)	43	46	41	not available	43	51
SUMMER AVERAGE (°F)	54	56	55	not available	54	55
MAX SUMMER FLUX (°F)	15	15	13	not available	18	8
DATE OF ANNUAL MAX	7/30/00 3:00 PM	8/7/01 2:00 PM	8/16/02 3:00 PM	8/20/03 2:30 PM	8/10/04 2:00 PM	8/9/05 6:00 PM
Start Date	10-Oct-99	1-Oct-00	1-Oct-01	1/2002 to 3/21/20	1-Oct-03	1/2004 to 11/27/20
End Date	30-Sep-00	30-Sep-01	30-Sep-02	2/2003 to 9/30/20	29-Sep-04	8/2005 to 8/16/20
Number of Days Sampled	357	365	365	220	366	223

Lower Lee Vining at County Road						
WATER YEAR	2000	2001	2002	2003	2004	2005
DAILY AVERAGE (°F)					not available	not available
ANNUAL MAX (°F)					66	not available
ANNUAL MIN (°F)					not available	0
MAX DAILY FLUX (°F)					not available	not available
WINTER MAX (°F)					not available	47
WINTER MIN (°F)					not available	32
WINTER AVERAGE (°F)					not available	35
MAX WINTER FLUX (°F)					not available	12
SUMMER MAX (°F)					66	not available
SUMMER MIN (°F)					37	not available
SUMMER AVERAGE (°F)					53	not available
MAX SUMMER FLUX (°F)					14	not available
DATE OF ANNUAL MAX					8/10/04 3:15 PM	not available
Start Date					6-May-04	1-Oct-04
End Date					30-Sep-04	17-Apr-05
Number of Days Sampled					147	198

Table A2. Summary of water temperatures on Parker Creek for WY 2000-2005.

Upper Parker Creek						
WATER YEAR	2000	2001	2002	2003	2004	2005
DAILY AVERAGE (°F)	43	43	NA	43	NA	41
ANNUAL MAX (°F)	62	64	NA	69	NA	57
ANNUAL MIN (°F)	26	32	32	32	29	32
MAX DAILY FLUX (°F)	18	18	14	13	14	12
WINTER MAX (°F)	48	39	43	43	46	40
WINTER MIN (°F)	39	32	32	32	31	36
WINTER AVERAGE (°F)	41	33	33	33	33	38
MAX WINTER FLUX (°F)	18	3	9	8	9	5
SUMMER MAX (°F)	59	63	NA	69	NA	57
SUMMER MIN (°F)	52	47	NA	45	NA	37
SUMMER AVERAGE (°F)	54	55	NA	55	NA	49
MAX SUMMER FLUX (°F)	18	10	NA	11	NA	12
DATE OF ANNUAL MAX	7/30/00 6:00 PM	6/5/01 6:00 PM	NA	8/14/03 12:01 PM	NA	8/12/05 6:00 PM
Start Date	7-Nov-99	1-Oct-00	1-Oct-01	1-Oct-02	1-Oct-03	1-Oct-04
End Date	30-Sep-00	30-Sep-01	2-May-02	30-Sep-03	6-May-04	16-Aug-05
Number of Days Sampled	329	365	214	365	218	320
Lower Parker Creek						
WATER YEAR	2000	2001	2002	2003	2004	2005
DAILY AVERAGE (°F)					NA	NA
ANNUAL MAX (°F)					72	NA
ANNUAL MIN (°F)					NA	NA
MAX DAILY FLUX (°F)					16	NA
WINTER MAX (°F)					NA	NA
WINTER MIN (°F)					NA	NA
WINTER AVERAGE (°F)					NA	NA
MAX WINTER FLUX (°F)					NA	NA
SUMMER MAX (°F)					72	NA
SUMMER MIN (°F)					50	NA
SUMMER AVERAGE (°F)					60	NA
MAX SUMMER FLUX (°F)					14	NA
DATE OF ANNUAL MAX					8/11/04 4:15 PM	NA
Start Date					6-May-04	NA
End Date					30-Sep-04	NA
Number of Days Sampled					148	NA

Table A3. Summary of water temperatures on Walker Creek for WY 2000-2005.

Upper Walker Creek						
WATER YEAR	2000	2001	2002	2003	2004	2005
DAILY AVERAGE (°F)	46	45	NA	45	45	42
ANNUAL MAX (°F)	69	70	NA	77	76	69
ANNUAL MIN (°F)	30	32	32	32	29	31
MAX DAILY FLUX (°F)	NA	23	16	32	34	16
WINTER MAX (°F)	55	38	45	42	47	37
WINTER MIN (°F)	41	32	32	32	32	34
WINTER AVERAGE (°F)	43	33	33	33	33	35
MAX WINTER FLUX (°F)	34	6	12	9	12	4
SUMMER MAX (°F)	68	70	NA	71	76	69
SUMMER MIN (°F)	58	46	NA	43	35	35
SUMMER AVERAGE (°F)	61	59	NA	59	58	56
MAX SUMMER FLUX (°F)	32	19	NA	16	34	11
DATE OF ANNUAL MAX	7/30/00 3:00 PM	8/16/01 4:00 PM	NA	5/22/03 3:00 PM	9/14/04 3:15 PM	7/19/05 5:00 PM
Start Date	7-Nov-99	1-Oct-00	1-Oct-01	1-Oct-02	1-Oct-03	1-Oct-04
End Date	30-Sep-00	30-Sep-01	4-Apr-02	30-Sep-03	30-Sep-04	16-Aug-05
Number of Days Sampled	329	365	186	365	366	320
Lower Walker Creek						
WATER YEAR	2000	2001	2002	2003	2004	2005
DAILY AVERAGE (°F)					NA	43
ANNUAL MAX (°F)					76	71
ANNUAL MIN (°F)					NA	27
MAX DAILY FLUX (°F)					NA	17
WINTER MAX (°F)					NA	46
WINTER MIN (°F)					NA	34
WINTER AVERAGE (°F)					NA	36
MAX WINTER FLUX (°F)					NA	13
SUMMER MAX (°F)					76	71
SUMMER MIN (°F)					35	34
SUMMER AVERAGE (°F)					58	57
MAX SUMMER FLUX (°F)					34	17
DATE OF ANNUAL MAX					9/14/04 3:15 PM	7/17/05 6:00 PM
Start Date					6-May-04	1-Oct-04
End Date					30-Sep-04	15-Aug-05
Number of Days Sampled					147	318

Table A4. Summary of water temperatures on Rush Creek measured at the Return Ditch, Old Highway 395, above the Narrows, at the Meadows, and at the County Road Culvert for WY 2000-2005.

Rush Creek at Return Ditch						
WATER YEAR	2000	2001	2002	2003	2004	2005
DAILY AVERAGE (°F)	49	49	51	47	43	45
ANNUAL MAX (°F)	67	69	71	69	64	65
ANNUAL MIN (°F)	34	34	32	32	32	32
MAX DAILY FLUX (°F)	9	10	9	6	9	9
WINTER MAX (°F)	43	42	43	43	44	40
WINTER MIN (°F)	34	34	32	32	32	32
WINTER AVERAGE (°F)	37	37	37	37	37	34
MAX WINTER FLUX (°F)	5	5	5	5	5	5
SUMMER MAX (°F)	67	69	71	69	NA	65
SUMMER MIN (°F)	55	53	57	60	NA	53
SUMMER AVERAGE (°F)	60	62	64	64	NA	57
MAX SUMMER FLUX (°F)	9	10	8	6	NA	9
DATE OF ANNUAL MAX	8/27/00 5:00 PM	8/19/01 7:00 PM	7/30/02 3:00 PM	8/20/03 2:30 PM	10/1/03 2:30 PM	9/10/05 3:52 PM
Start Date	10-Oct-99	1-Oct-00	1-Oct-01	1-Oct-02	1-Oct-03	1-Dec-04
End Date	30-Sep-00	30-Sep-01	30-Sep-02	30-Sep-03	6-May-04	30-Sep-05
Number of Days Sampled	357	365	365	365	218	303
Rush Creek at Old Highway 395						
WATER YEAR	2000	2001	2002	2003	2004	2005
DAILY AVERAGE (°F)						NA
ANNUAL MAX (°F)						66
ANNUAL MIN (°F)						NA
MAX DAILY FLUX (°F)						NA
WINTER MAX (°F)						NA
WINTER MIN (°F)						NA
WINTER AVERAGE (°F)						NA
MAX WINTER FLUX (°F)						NA
SUMMER MAX (°F)						66
SUMMER MIN (°F)						53
SUMMER AVERAGE (°F)						57
MAX SUMMER FLUX (°F)						12
DATE OF ANNUAL MAX						8/27/05 3:22 PM
Start Date						1-Jun-05
End Date						30-Sep-05
Number of Days Sampled						122
Rush Creek at the Narrows						
WATER YEAR	2000	2001	2002	2003	2004	2005
DAILY AVERAGE (°F)	48	48	42	45	48	
ANNUAL MAX (°F)	71	73	67	67	72	
ANNUAL MIN (°F)	32	32	32	32	31	
MAX DAILY FLUX (°F)	20	20	18	21	16	
WINTER MAX (°F)	52	50	50	51	49	
WINTER MIN (°F)	32	32	32	32	31	
WINTER AVERAGE (°F)	37	36	36	37	35	
MAX WINTER FLUX (°F)	16	15	15	14	16	
SUMMER MAX (°F)	71	73	67	67	61	
SUMMER MIN (°F)	50	52	53	52	43	
SUMMER AVERAGE (°F)	59	61	58	58	58	
MAX SUMMER FLUX (°F)	17	16	14	14	14	
DATE OF ANNUAL MAX	8/27/00 5:00 PM	8/19/01 6:00 PM	9/21/02 4:00 PM	5/27/03 4:01 PM	7/23/04 5:01 AM	
Start Date	10-Oct-99	1-Oct-00	1-Oct-01	1-Oct-02	1-Oct-03	
End Date	30-Sep-00	30-Sep-01	30-Sep-02	30-Sep-03	30-Sep-04	
Number of Days Sampled	357	365	365	365	366	

Table A4. Summary of water temperatures on Rush Creek measured at the Return Ditch, Old Highway 395, above the Narrows, at the Meadows, and at the County Road Culvert for WY 2000-2005. Cont.

Lower Rush Creek at the Meadows						
WATER YEAR	2000	2001	2002	2003	2004	2005
DAILY AVERAGE (°F)					NA	52
ANNUAL MAX (°F)					74	68
ANNUAL MIN (°F)					NA	32
MAX DAILY FLUX (°F)					NA	18
WINTER MAX (°F)					NA	NA
WINTER MIN (°F)					NA	NA
WINTER AVERAGE (°F)					NA	NA
MAX WINTER FLUX (°F)					NA	NA
SUMMER MAX (°F)					74	67
SUMMER MIN (°F)					47	52
SUMMER AVERAGE (°F)					61	58
MAX SUMMER FLUX (°F)					18	13
DATE OF ANNUAL MAX					NA	8/28/05 3:27 PM
Start Date					7-Jun-04	10/1/2004 to 11/30/2004
End Date					30-Sep-04	4/17/2005 to 9/30/2005
Number of Days Sampled					116	226
Rush Creek at County Road Culvert						
WATER YEAR	2000	2001	2002	2003	2004	2005
DAILY AVERAGE (°F)	48	48	49	45	49	NA
ANNUAL MAX (°F)	72	71	75	74	75	NA
ANNUAL MIN (°F)	32	32	32	32	32	33
MAX DAILY FLUX (°F)	22	18	21	18	24	NA
WINTER MAX (°F)	53	47	48	45	56	52
WINTER MIN (°F)	32	32	32	32	32	34
WINTER AVERAGE (°F)	37	36	36	37	36	36
MAX WINTER FLUX (°F)	19	9	12	8	20	17
SUMMER MAX (°F)	72	71	75	NA	75	NA
SUMMER MIN (°F)	48	52	51	NA	47	NA
SUMMER AVERAGE (°F)	60	61	62	NA	61	NA
MAX SUMMER FLUX (°F)	18	17	16	NA	18	NA
DATE OF ANNUAL MAX	8/27/00 8:00 PM	7/1/01 8:00 PM	7/25/02 5:00 PM	8/16/03 3:00 PM	7/22/04 3:01 PM	NA
Start Date	10-Oct-99	1-Oct-00	1-Oct-01	10/1/2003 to 3/21/2003	10/1/2003 to 3/21/2003	1-Oct-04
End Date	30-Sep-00	30-Sep-01	30-Sep-02	8/11/2003 to 9/30/2004	8/11/2003 to 9/30/2004	30-Jun-05
Number of Days Sampled	357	365	365	221	366	273

APPENDIX B

Rush Creek 8 Floodplain Groundwater Data

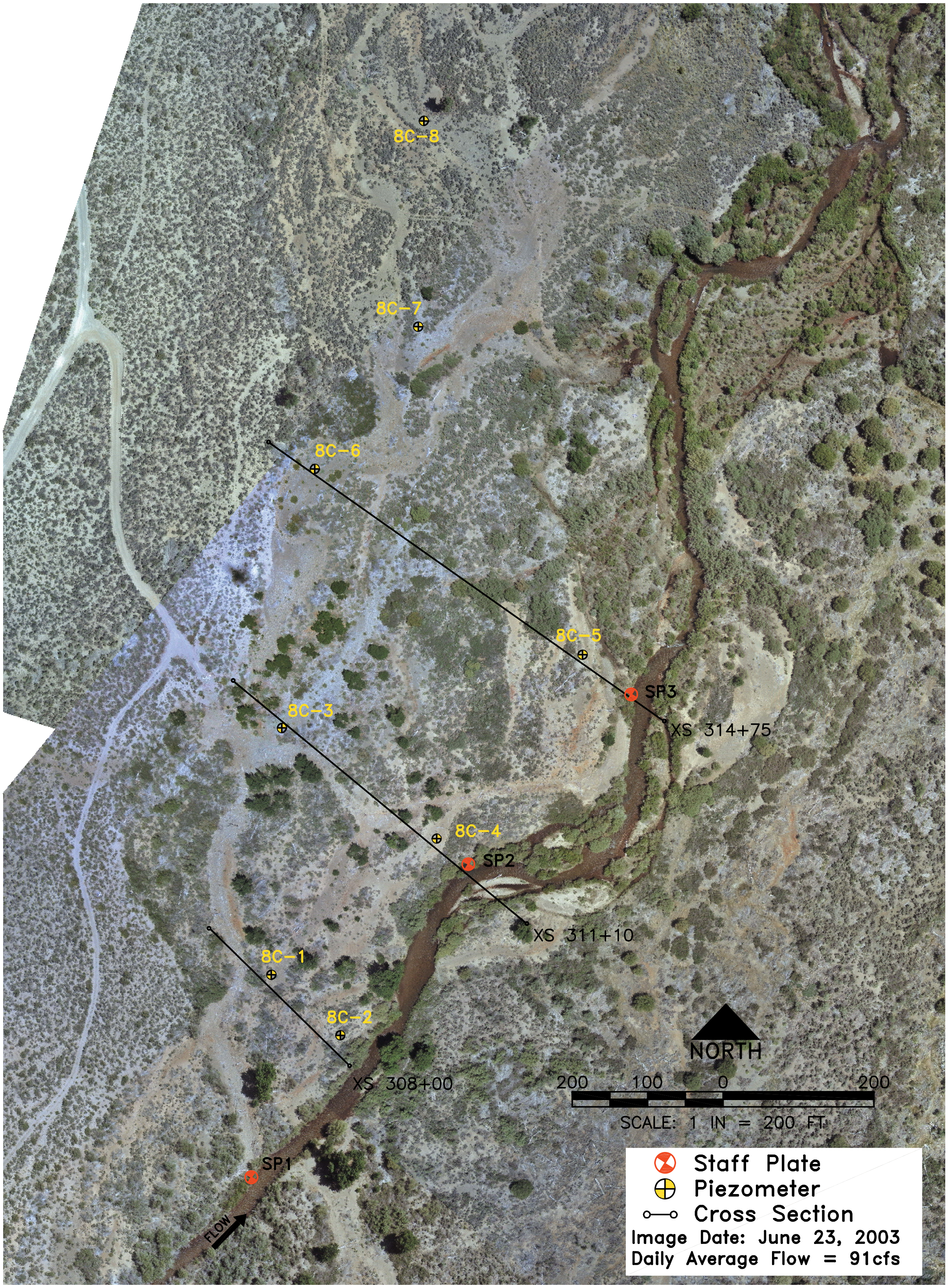
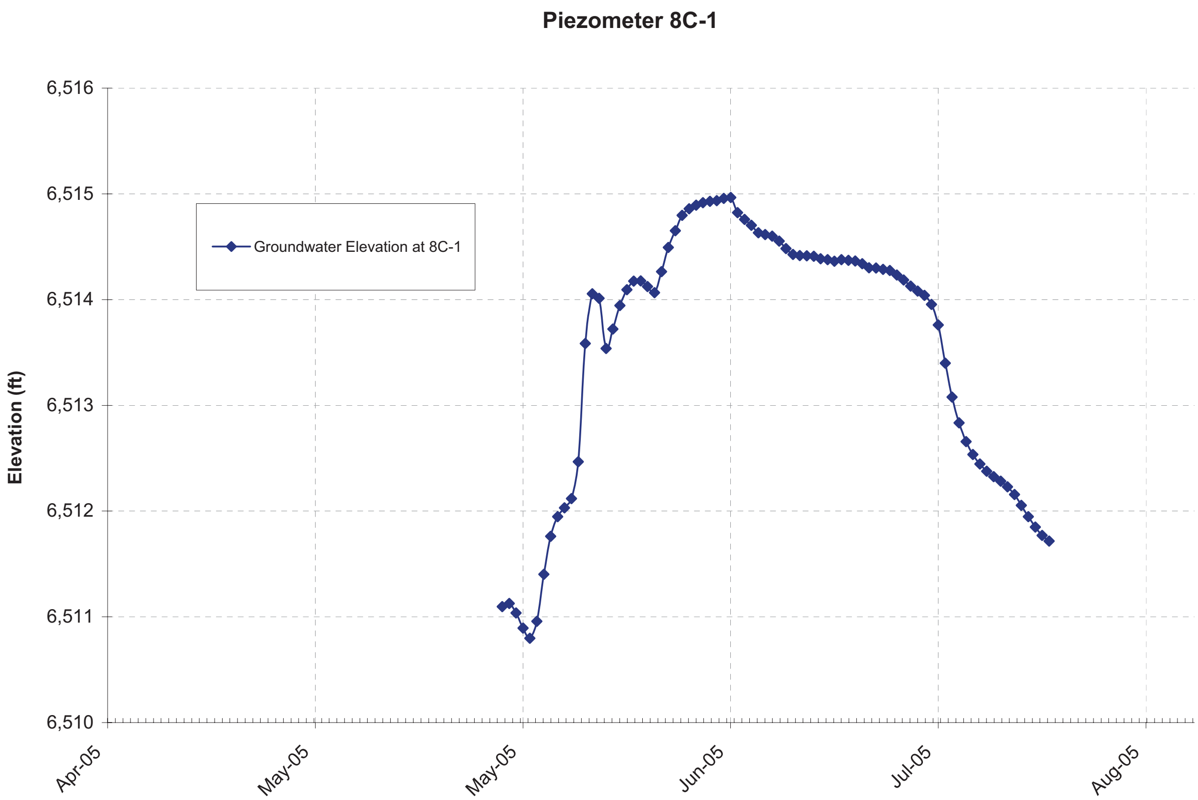
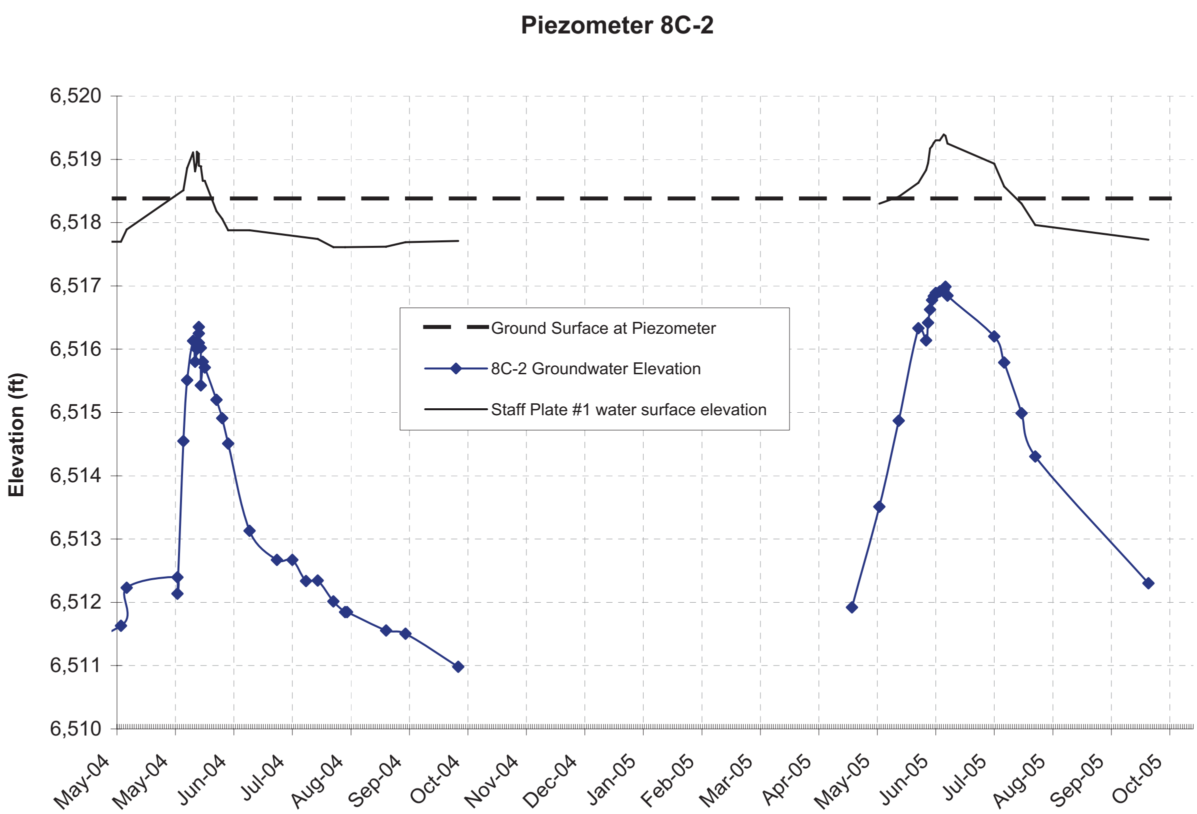
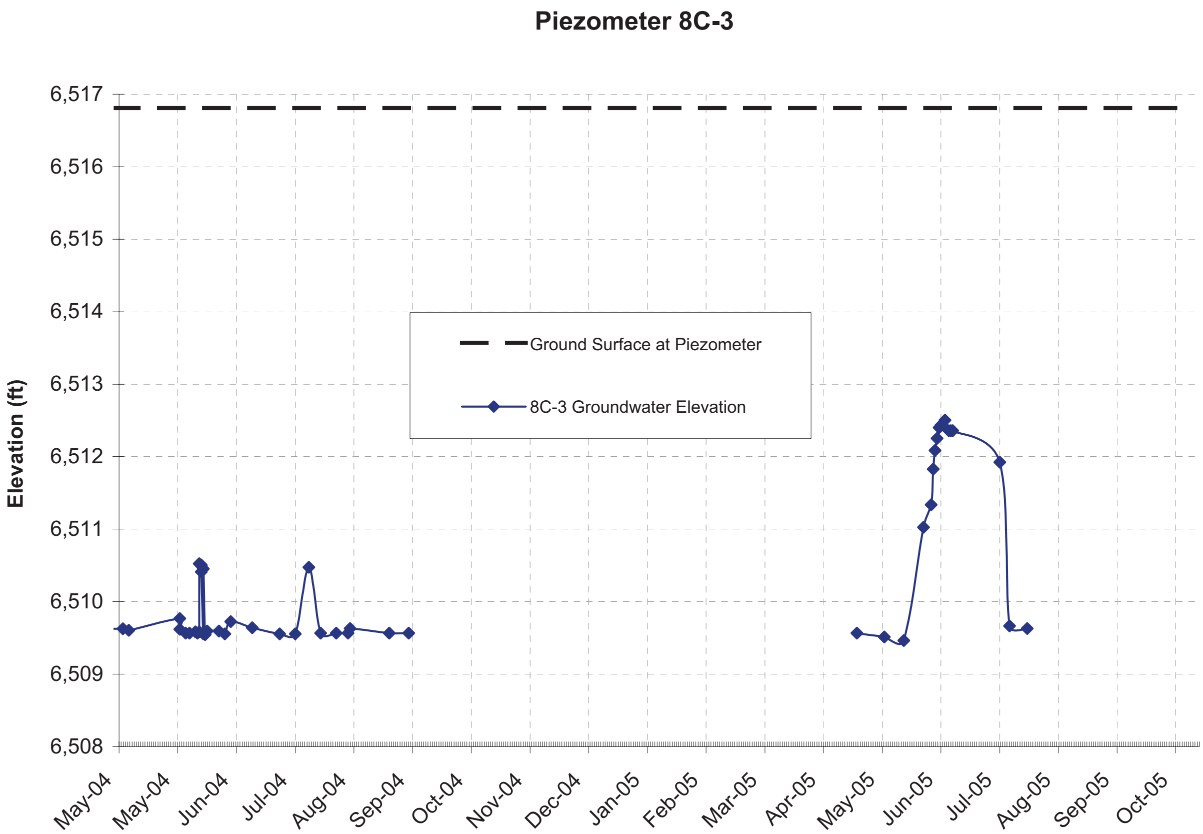
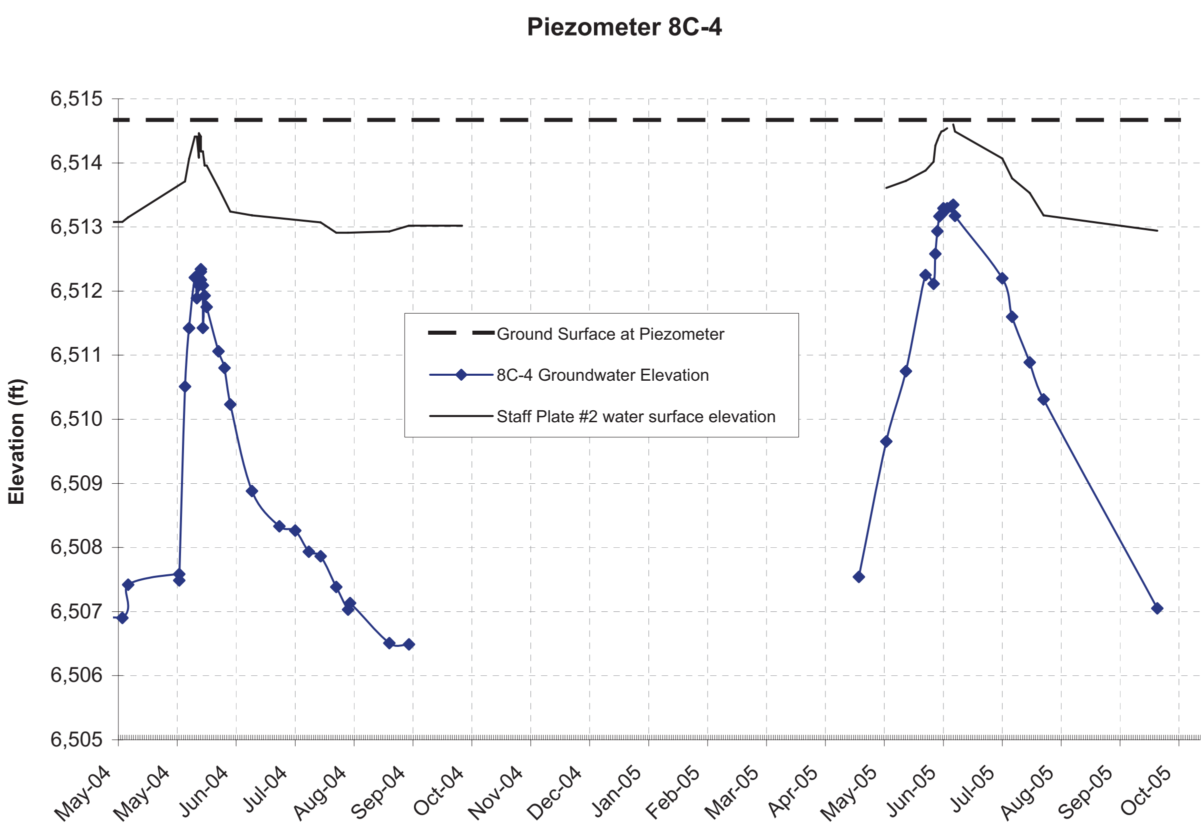


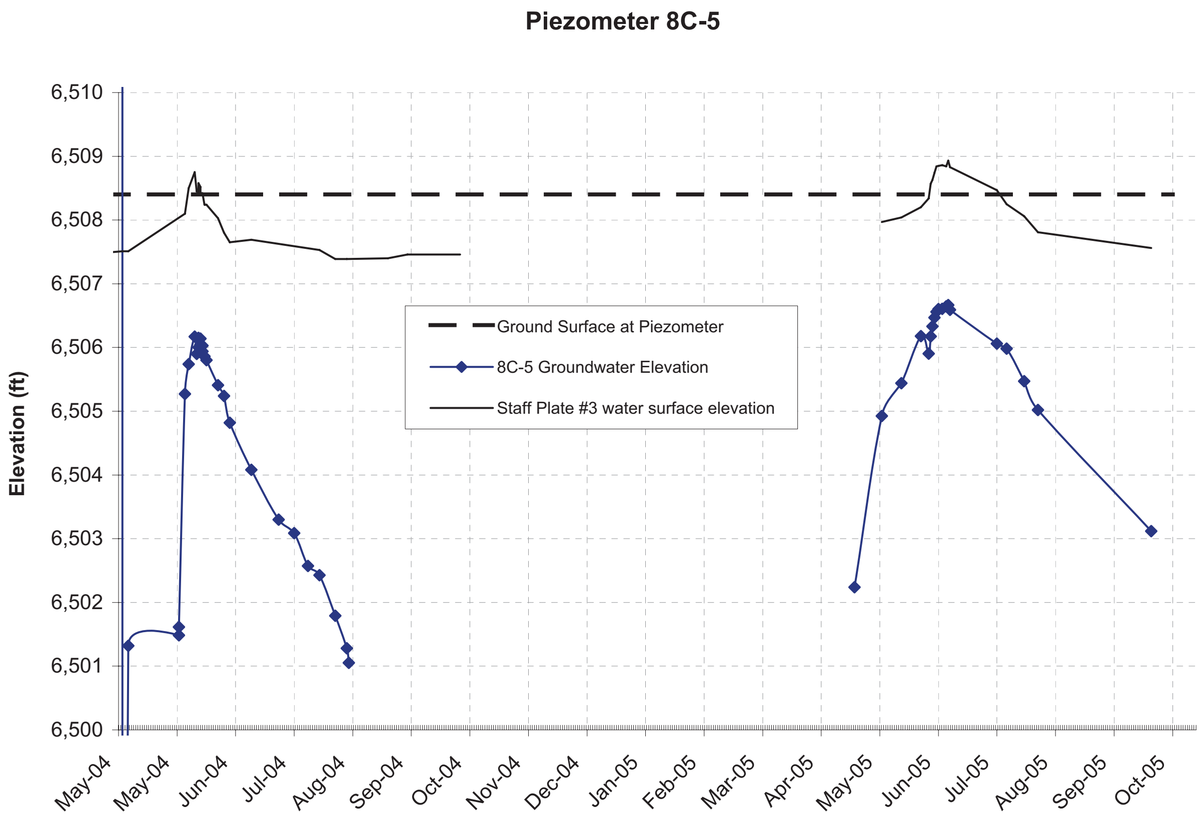
Figure B1. Locations of 8 Channel piezometers and staff plates used for groundwater monitoring during RY 2004 and 2005.

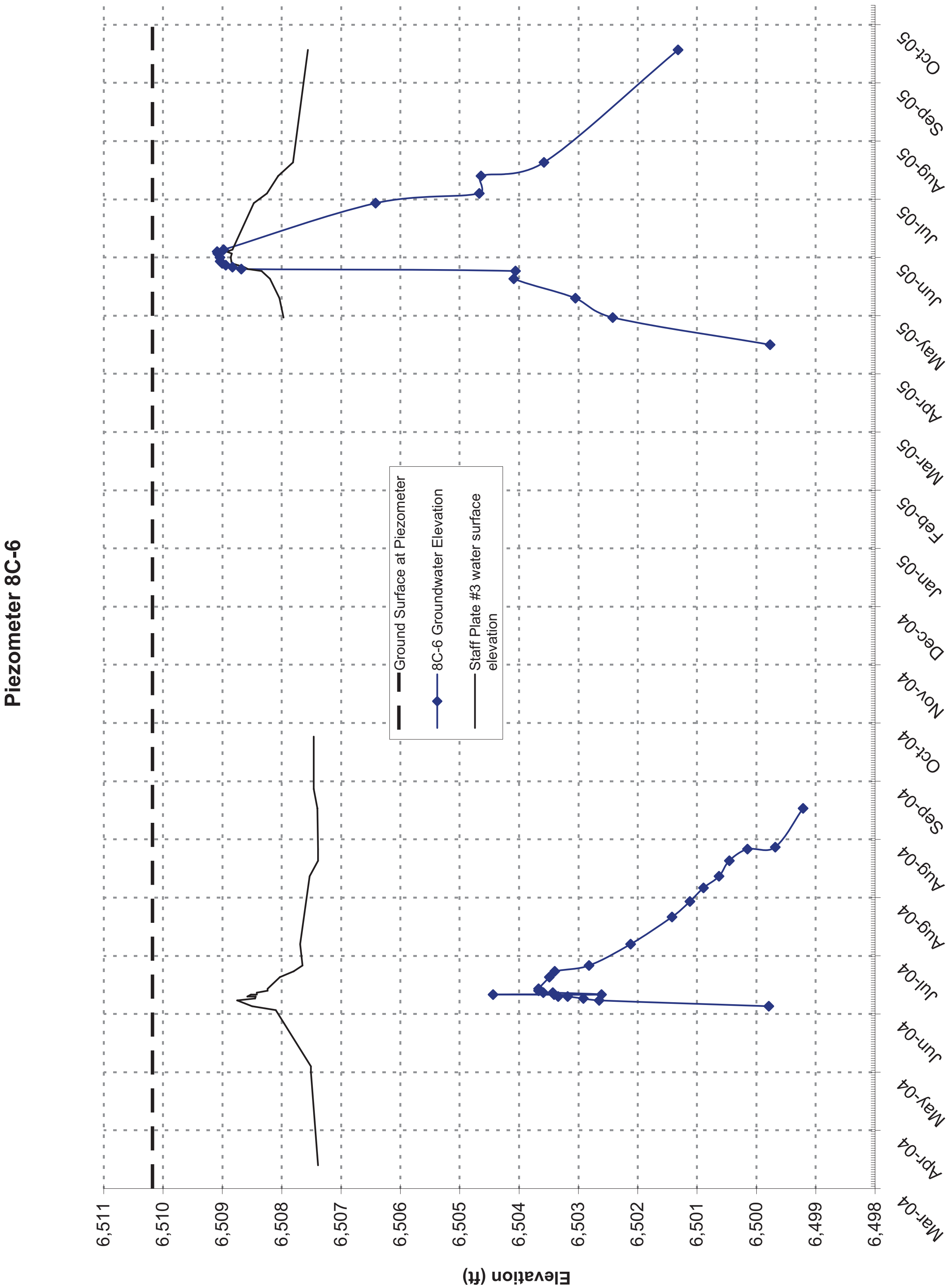

Piezometer 8C-1
Groundwater Elevation at 8C-1
Elevation (ft)
6,516
6,515
6,514
6,513
6,512
6,511
6,510
Apr-05
May-05
May-05
Jun-05
Jul-05
Aug-05

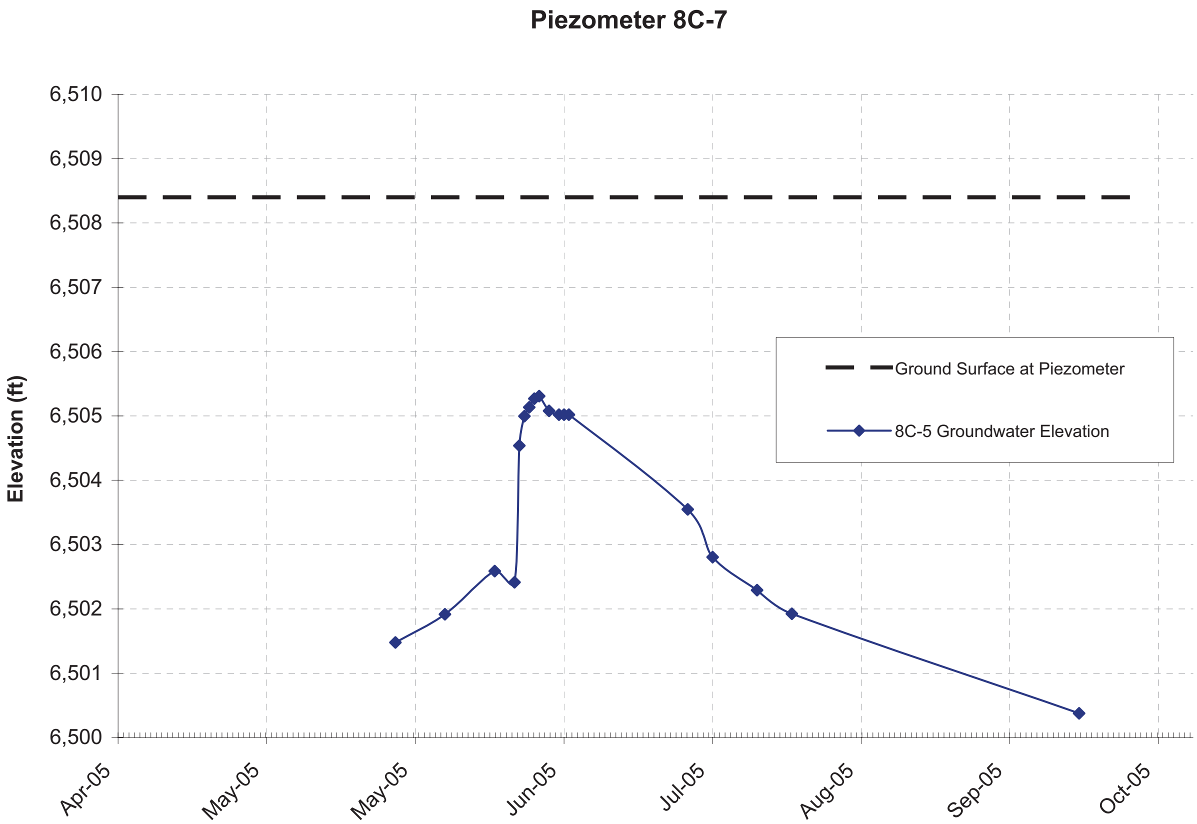

Piezometer 8C-2
Ground Surface at Piezometer
8C-2 Groundwater Elevation
Staff Plate #1 water surface elevation
Elevation (ft)
6,520
6,519
6,518
6,517
6,516
6,515
6,514
6,513
6,512
6,511
6,510
May-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05

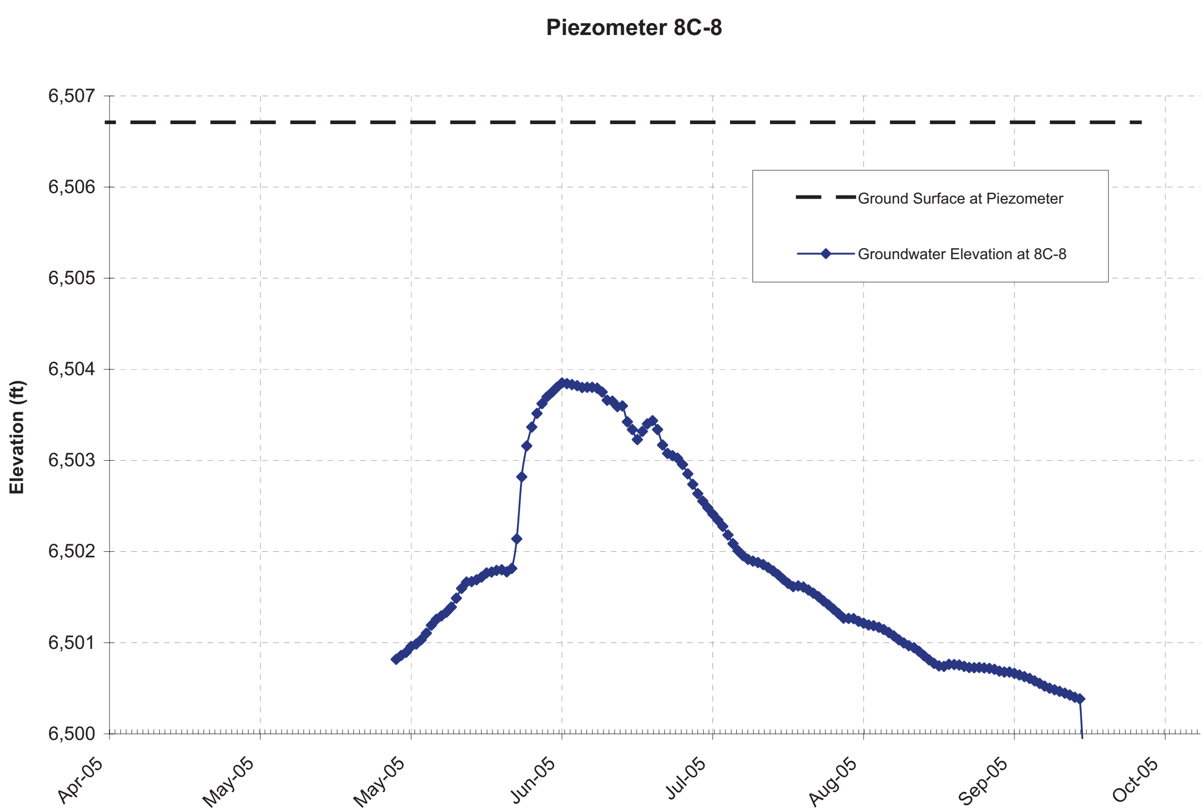

Piezometer 8C-3
Elevation (ft)
6,517
6,516
6,515
6,514
6,513
6,512
6,511
6,510
6,509
6,508
Ground Surface at Piezometer
8C-3 Groundwater Elevation
May-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05


Piezometer 8C-4
Elevation (ft)
6,515
6,514
6,513
6,512
6,511
6,510
6,509
6,508
6,507
6,506
6,505
Ground Surface at Piezometer
8C-4 Groundwater Elevation
Staff Plate #2 water surface elevation
May-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05


Piezometer 8C-5
Elevation (ft)
6,510
6,509
6,508
6,507
6,506
6,505
6,504
6,503
6,502
6,501
6,500
May-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Ground Surface at Piezometer
8C-5 Groundwater Elevation
Staff Plate #3 water surface elevation


Piezometer 8C-6
Elevation (ft)
6,511
6,510
6,509
6,508
6,507
6,506
6,505
6,504
6,503
6,502
6,501
6,500
6,499
6,498
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Ground Surface at Piezometer
8C-6 Groundwater Elevation
Staff Plate #3 water surface elevation


Piezometer 8C-7
6,510
6,509
6,508
6,507
6,506
6,505
6,504
6,503
6,502
6,501
6,500
Elevation (ft)
Ground Surface at Piezometer
8C-5 Groundwater Elevation
Apr-05
May-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05


Piezometer 8C-8
6,507
6,506
6,505
6,504
6,503
6,502
6,501
6,500
Elevation (ft)
Ground Surface at Piezometer
Groundwater Elevation at 8C-8
Apr-05
May-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05

APPENDIX C

Rush Creek 3D Floodplain Groundwater Data

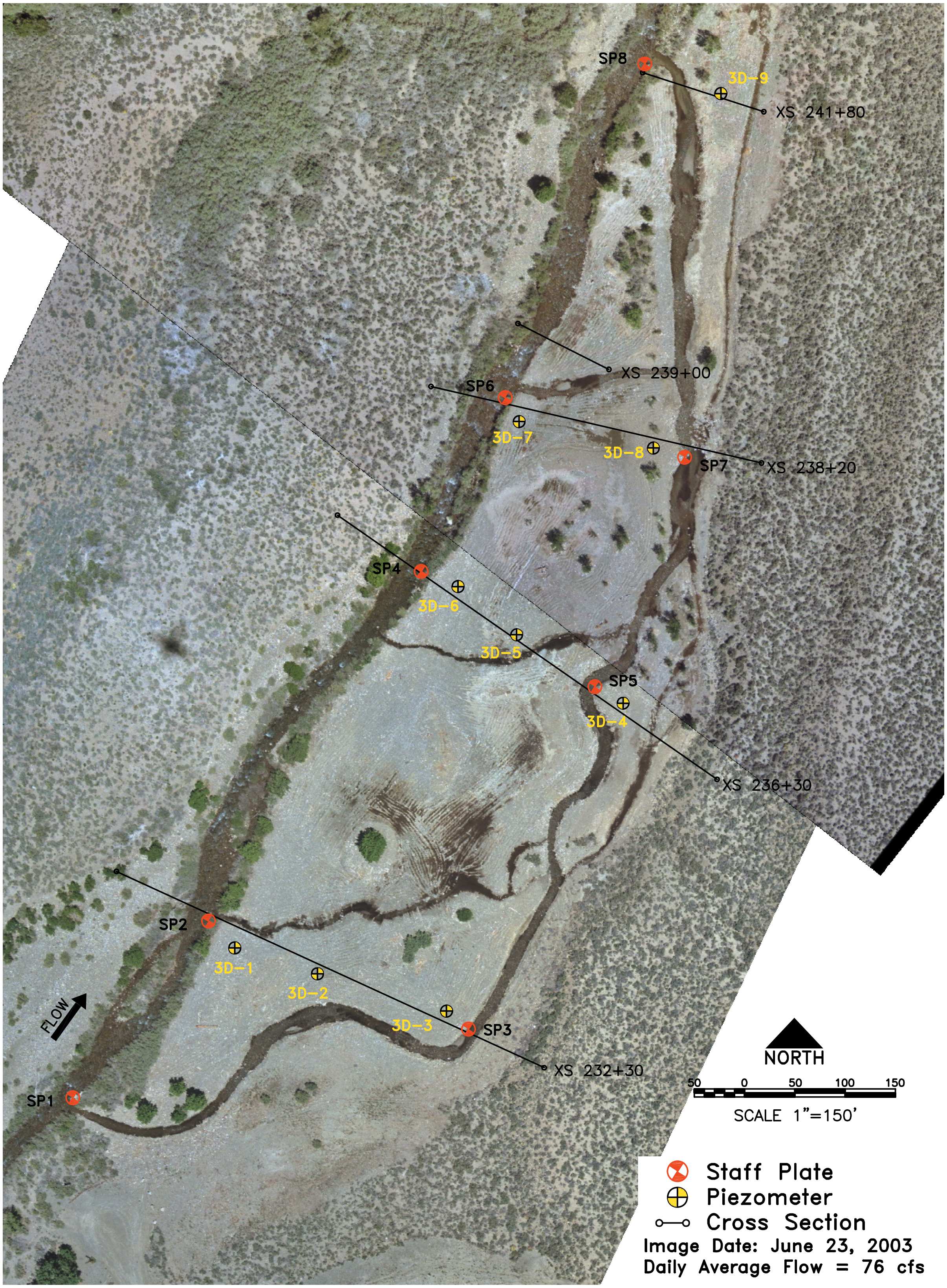
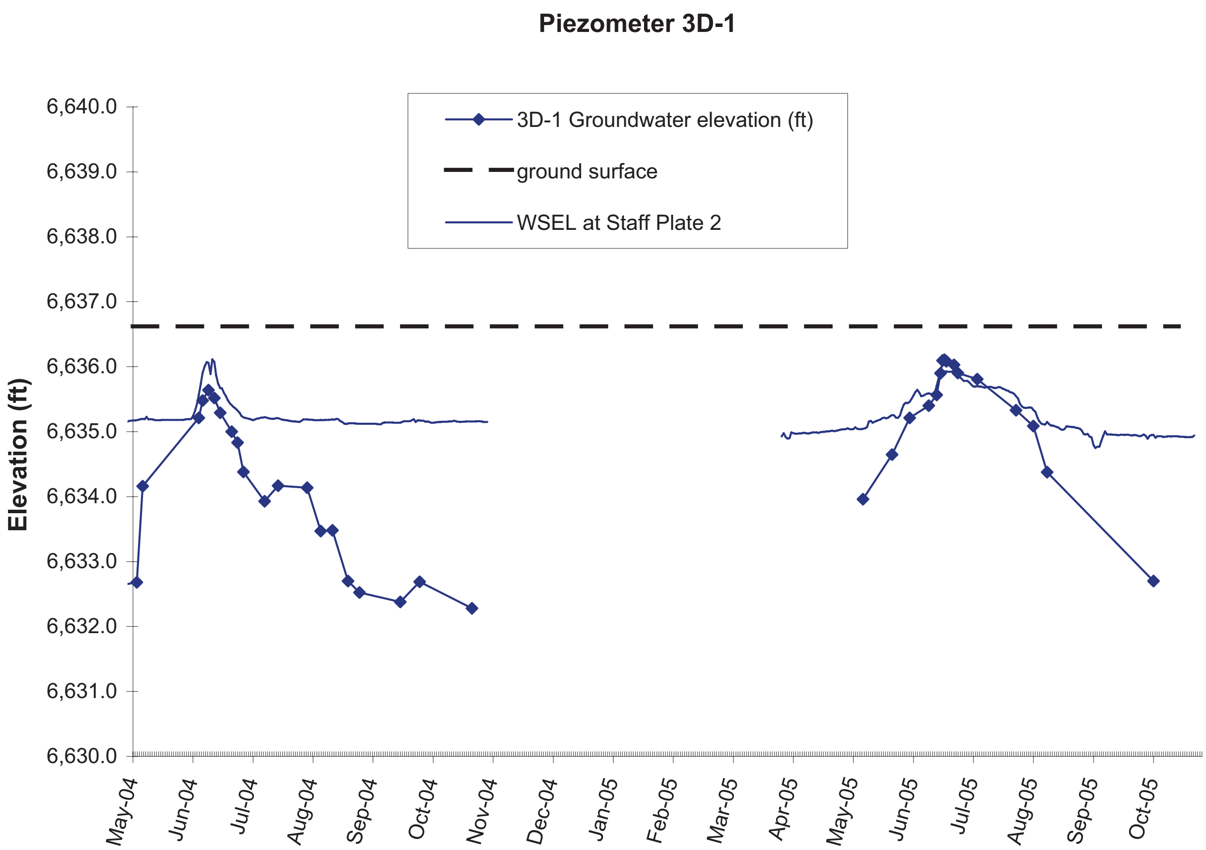
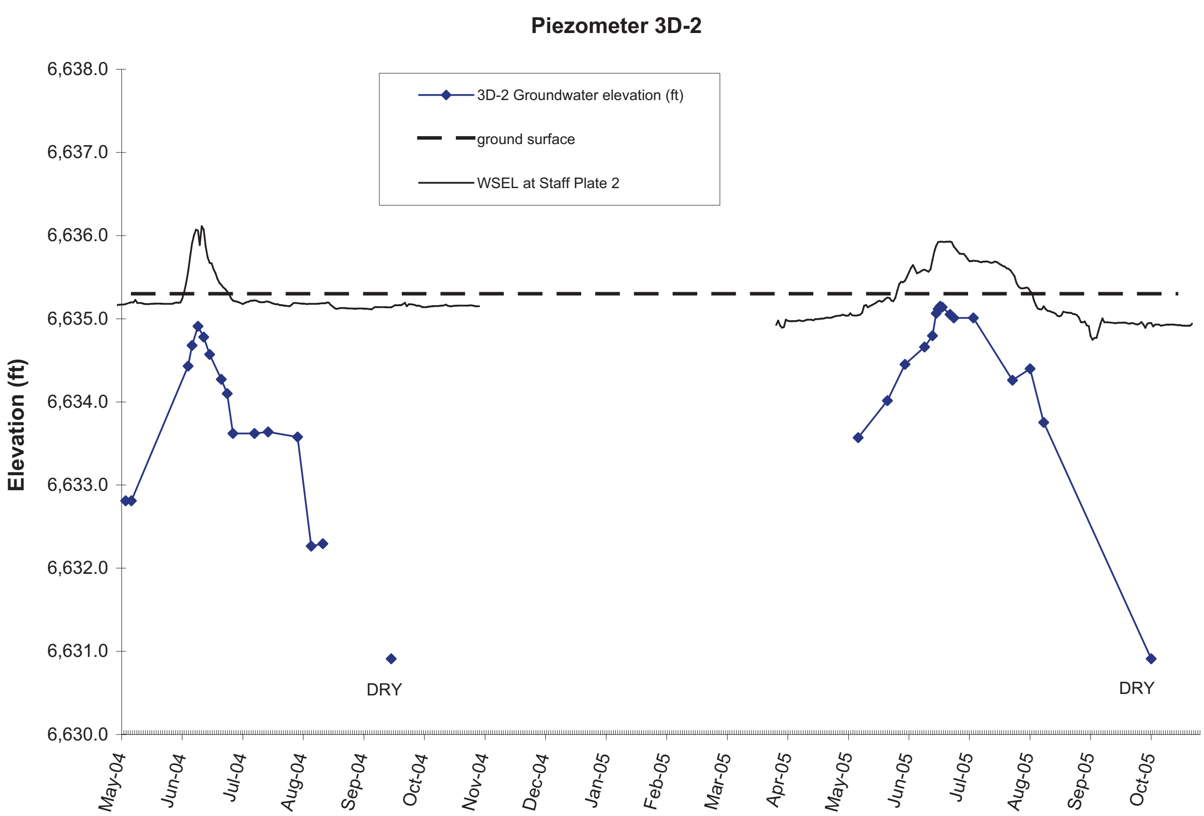
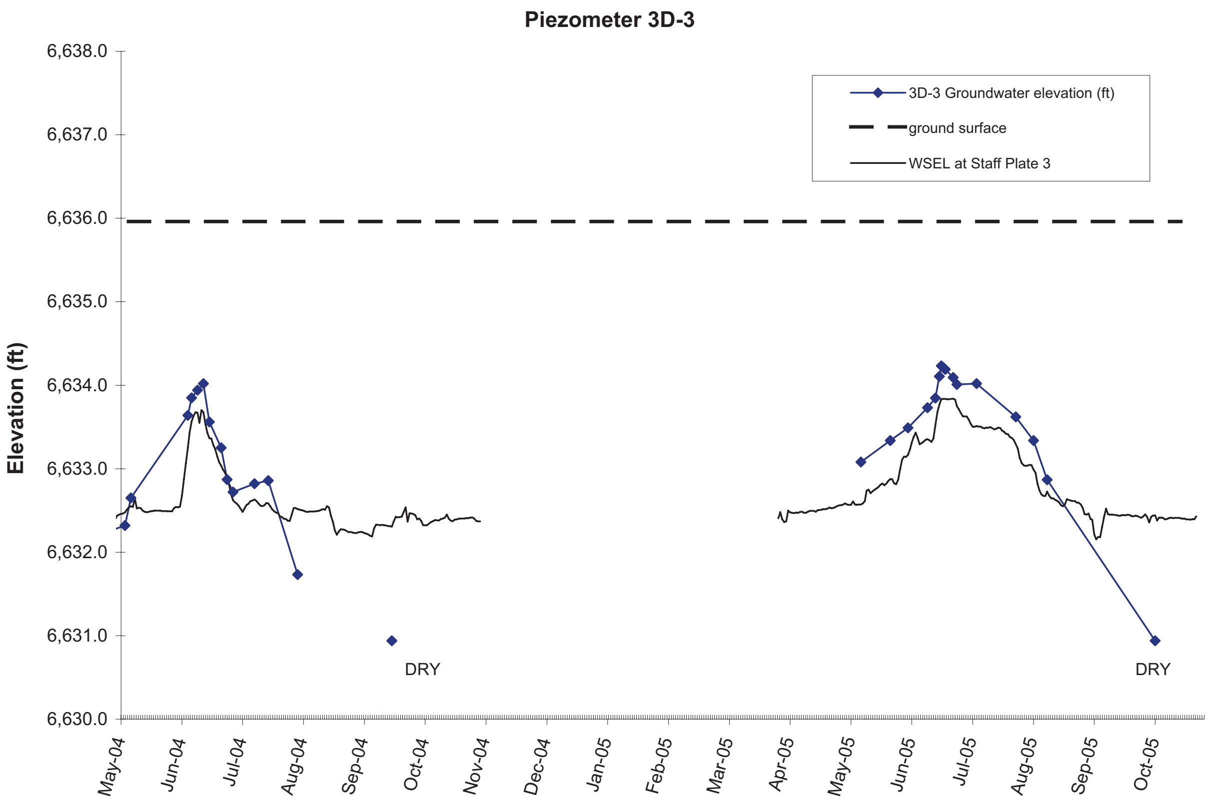
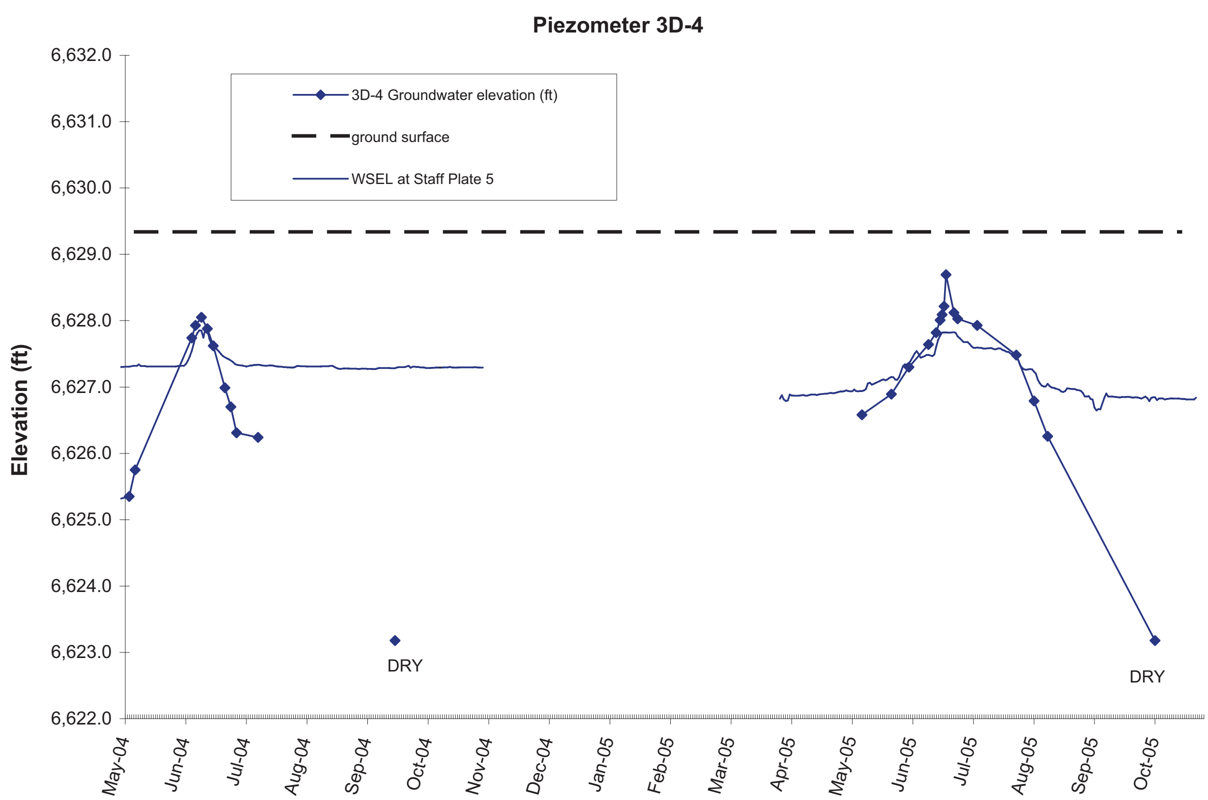


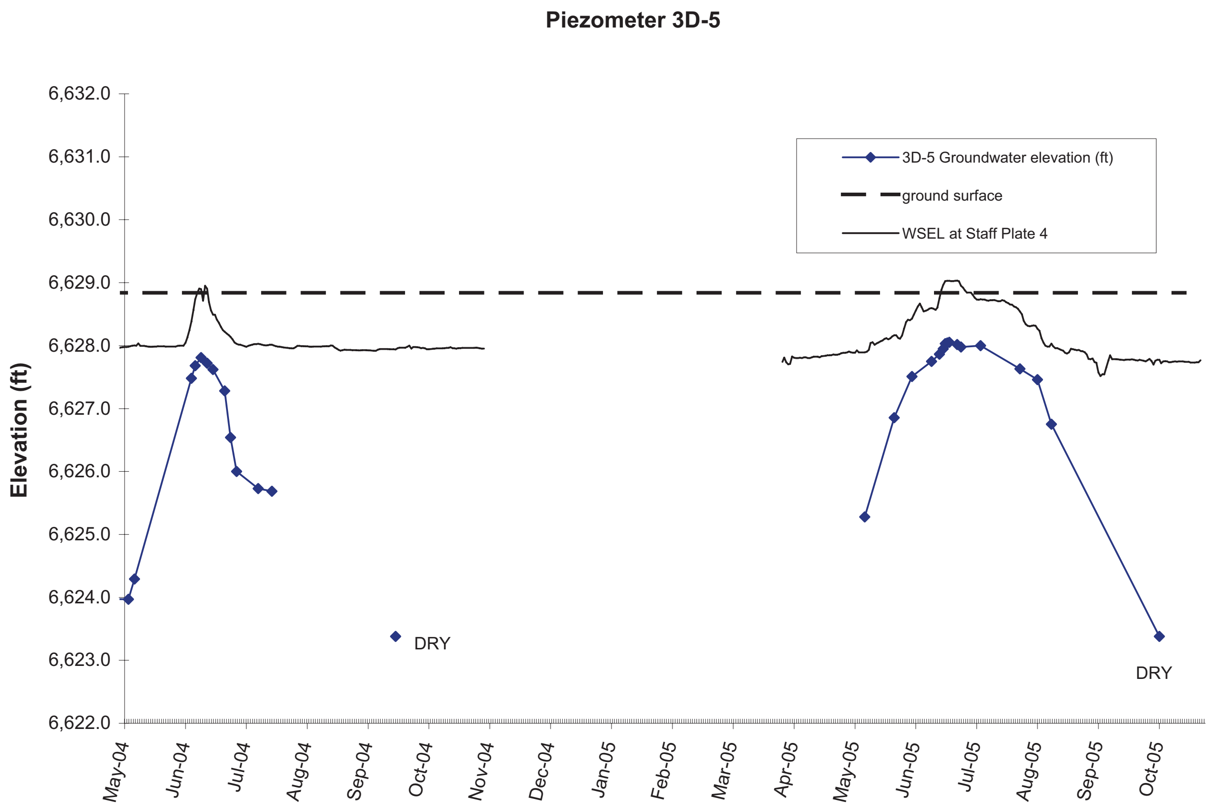
Figure C1. Locations of 3D Channel piezometers and staff plates used for groundwater monitoring during RY 2004 and 2005.

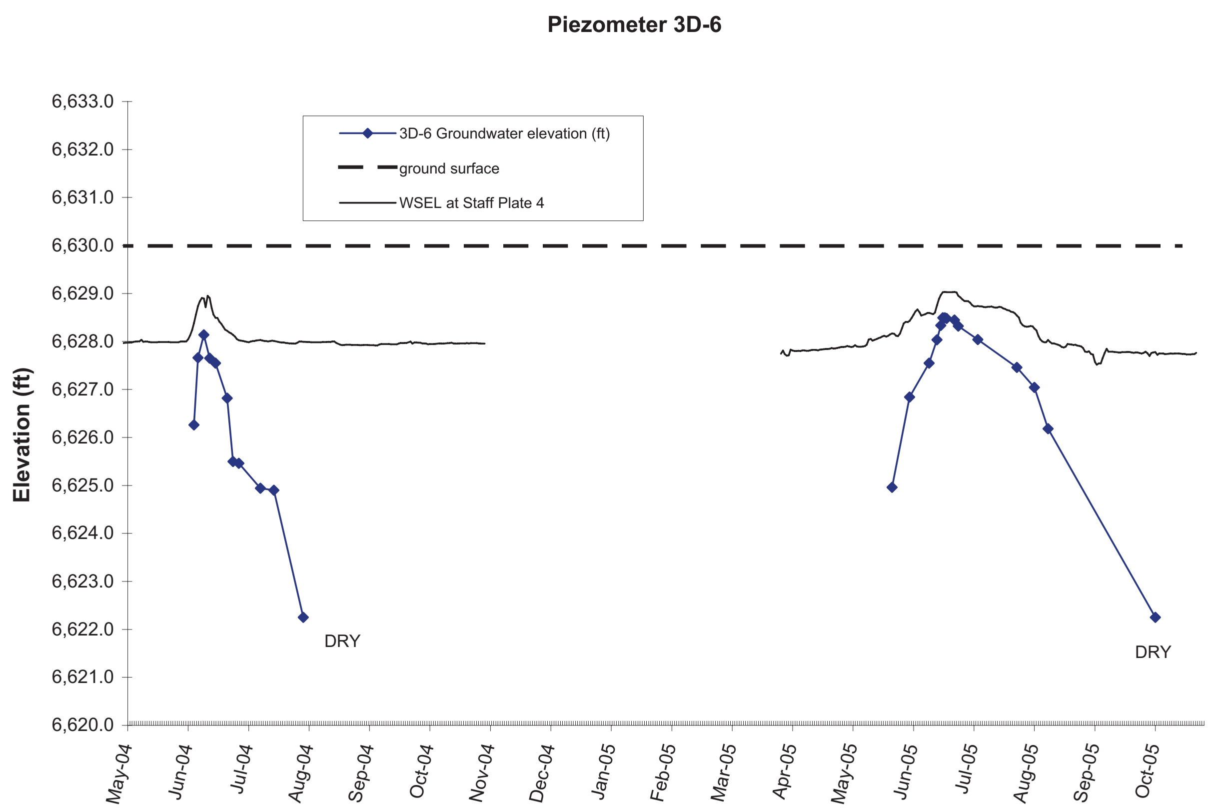

Piezometer 3D-1
3D-1 Groundwater elevation (ft)
ground surface
WSEL at Staff Plate 2
Elevation (ft)
6,640.0
6,639.0
6,638.0
6,637.0
6,636.0
6,635.0
6,634.0
6,633.0
6,632.0
6,631.0
6,630.0
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05

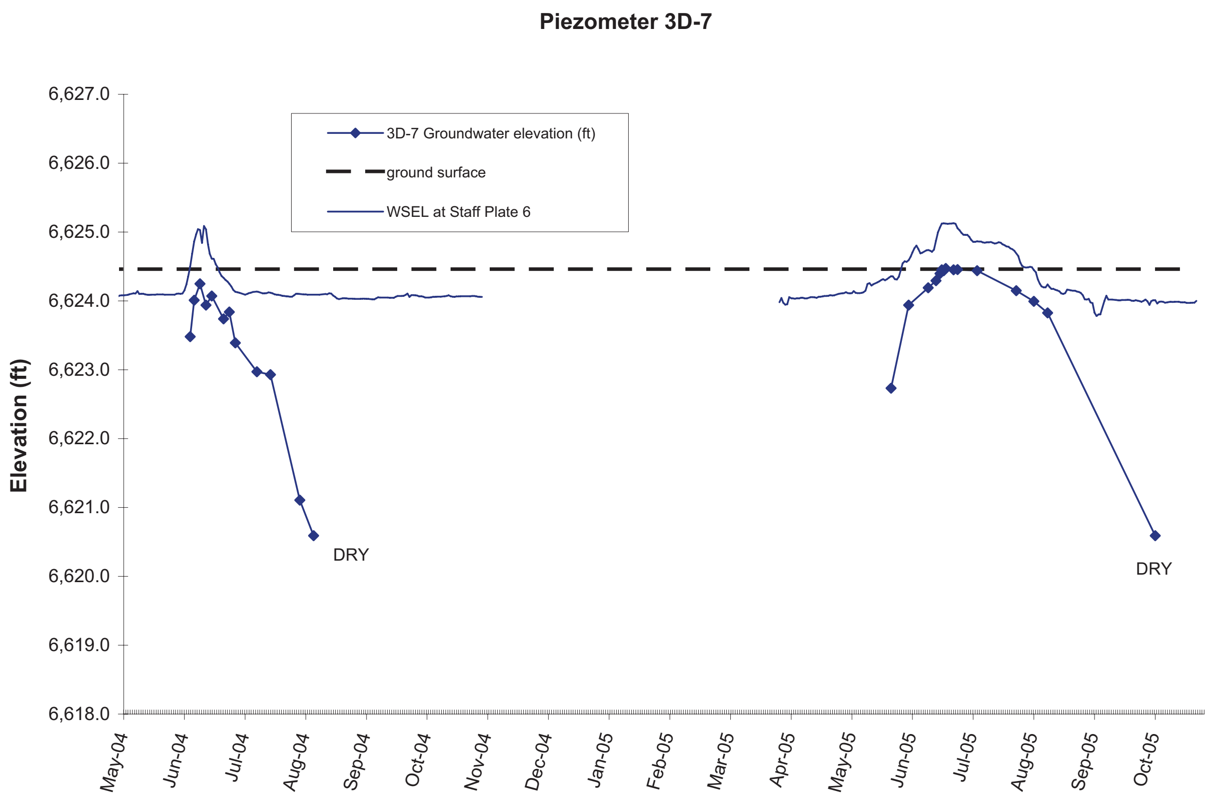

Piezometer 3D-2
3D-2 Groundwater elevation (ft)
ground surface
WSEL at Staff Plate 2
Elevation (ft)
6,638.0
6,637.0
6,636.0
6,635.0
6,634.0
6,633.0
6,632.0
6,631.0
6,630.0
DRY
DRY
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05

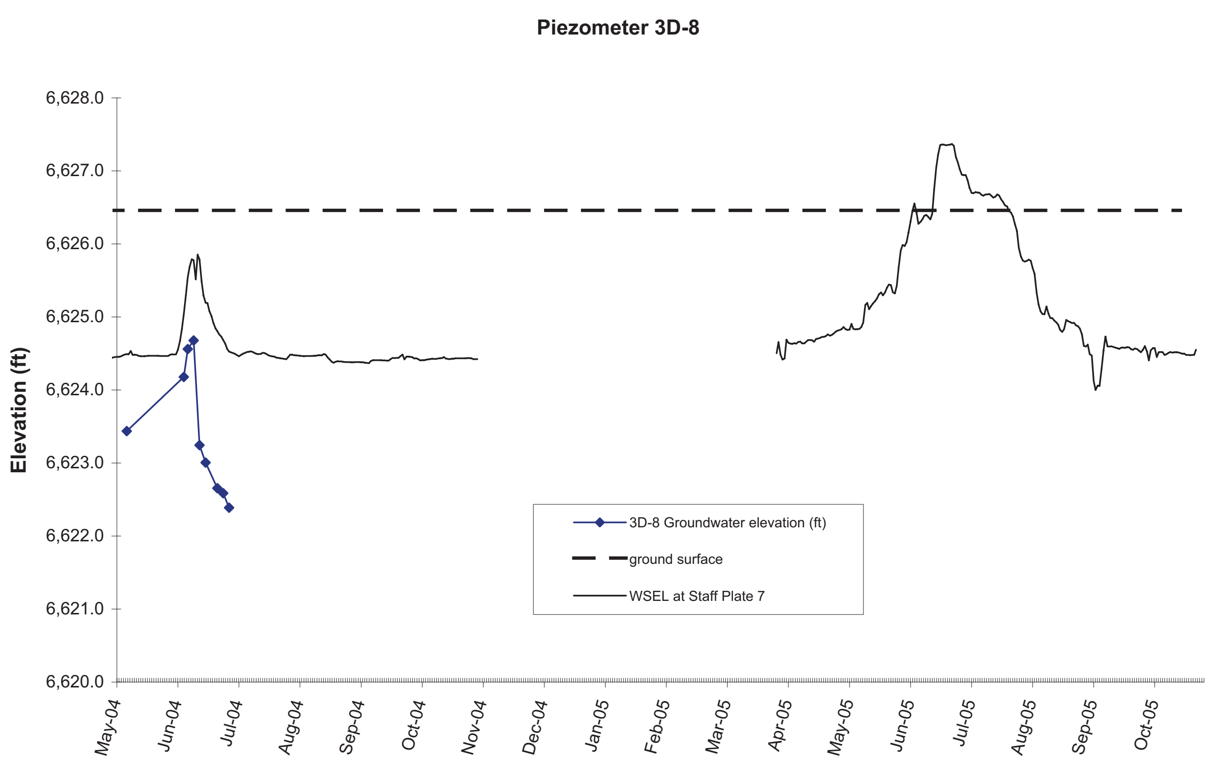

Piezometer 3D-3
3D-3 Groundwater elevation (ft)
ground surface
WSEL at Staff Plate 3
Elevation (ft)
6,638.0
6,637.0
6,636.0
6,635.0
6,634.0
6,633.0
6,632.0
6,631.0
6,630.0
DRY
DRY
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05

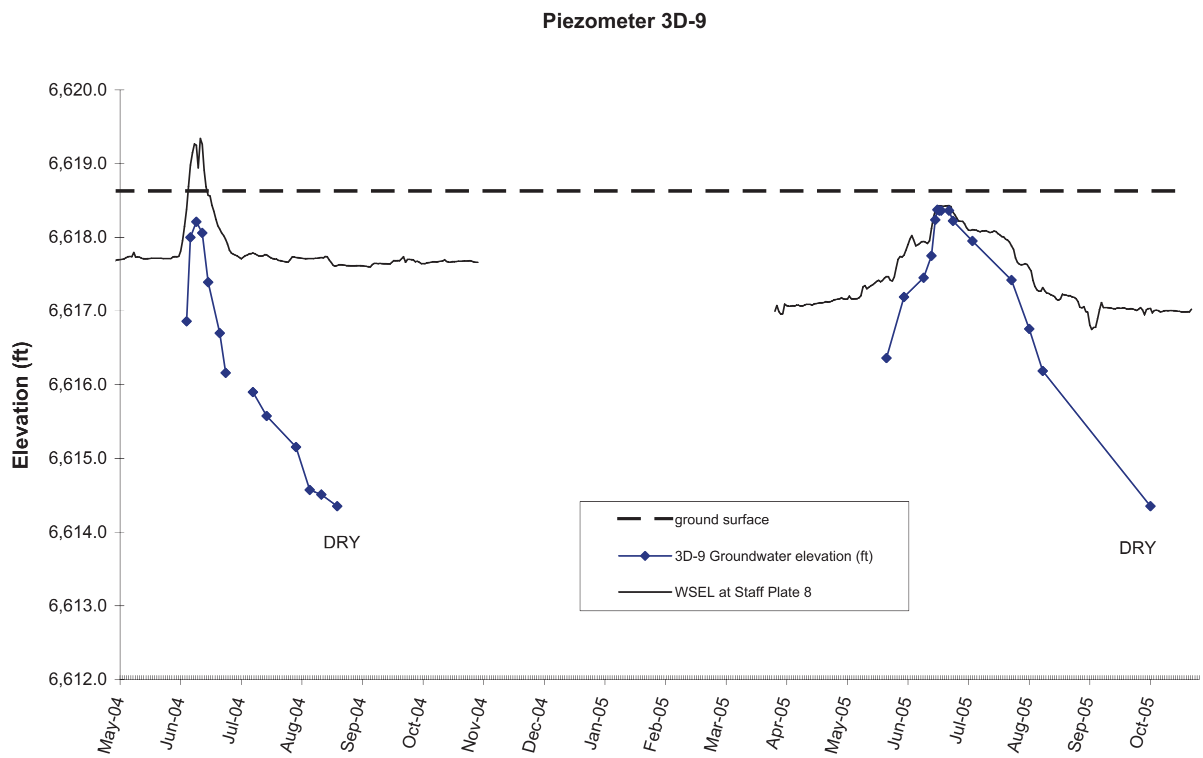

Piezometer 3D-4
3D-4 Groundwater elevation (ft)
ground surface
WSEL at Staff Plate 5
Elevation (ft)
6,632.0
6,631.0
6,630.0
6,629.0
6,628.0
6,627.0
6,626.0
6,625.0
6,624.0
6,623.0
6,622.0
DRY
DRY
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05


Piezometer 3D-5
3D-5 Groundwater elevation (ft)
ground surface
WSEL at Staff Plate 4
Elevation (ft)
6,632.0
6,631.0
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
DRY
DRY
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05


Piezometer 3D-6
3D-6 Groundwater elevation (ft)
ground surface
WSEL at Staff Plate 4
Elevation (ft)
6,633.0
6,632.0
6,631.0
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
DRY
DRY
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05


Piezometer 3D-7
Elevation (ft)
6,627.0
6,626.0
6,625.0
6,624.0
6,623.0
6,622.0
6,621.0
6,620.0
6,619.0
6,618.0
3D-7 Groundwater elevation (ft)
ground surface
WSEL at Staff Plate 6
DRY
DRY
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05


Piezometer 3D-8
Elevation (ft)
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
3D-8 Groundwater elevation (ft)
ground surface
WSEL at Staff Plate 7
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05


Piezometer 3D-9
6,620.0
6,619.0
6,618.0
6,617.0
6,616.0
6,615.0
6,614.0
6,613.0
6,612.0
Elevation (ft)
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
DRY
DRY
ground surface
3D-9 Groundwater elevation (ft)
WSEL at Staff Plate 8

APPENDIX D

Bed Mobility and Scour Data

Table D1. Mobility of tracer rocks at various discharges at monitored cross sections on Lee Vining Creek.

Cross Section	Geomorphic Unit	Observation Date	Discharge at Cross Section	Percent D_{84} Moved	Percent D_{50} Moved	Percent D_{31} Moved
13+92	Riffle	10/3/1997	17 cfs	0%	0%	0%
		6/2/1998	90 cfs	0%	0%	0%
		6/18/1998	193 cfs	0%	0%	8%
		9/10/1998	242 cfs	0%	25%	42%
		6/5/1999	162 cfs	0%	0%	17%
		7/24/1999	170 cfs	0%	8%	25%
		6/4/2000	204 cfs	0%	0%	0%
		8/3/2001	66 cfs	0%	9%	18%
		4/24/2002	164 cfs	0%	18%	9%
		6/27/2004	45 cfs	0%	9%	9%
		8/18/2005	289 cfs	36%	36%	64%
			maximum mobility =	36%	36%	64%
03+45	Pool Tail	10/3/1997	17 cfs	0%	0%	0%
		6/2/1998	90 cfs	0%	0%	0%
		7/2/1998	193 cfs	8%	17%	80%
		9/10/1998	242 cfs	47%	60%	80%
		6/5/1999	162 cfs	7%	27%	40%
		7/24/1999	170 cfs	7%	33%	60%
		6/4/2000	204 cfs	21%	14%	7%
		8/3/2001	152 cfs	7%	13%	20%
		4/24/2002	164 cfs	13%	7%	13%
		6/27/2004	105 cfs	0%	0%	0%
		8/18/2005	289 cfs	80%	80%	87%
			maximum mobility =	80%	80%	87%
06+61	Point Bar	10/3/1997	17 cfs	0%	0%	0%
		6/2/1998	90 cfs	0%	0%	0%
		7/2/1998	193 cfs	0%	0%	8%
		9/10/1998	242 cfs	0%	0%	17%
		6/5/1999	162 cfs	0%	0%	0%
		7/24/1999	170 cfs	0%	0%	0%
		6/4/2000		0%	0%	0%
		8/3/2001	152 cfs	0%	0%	0%
		4/24/2002	164 cfs	0%	0%	0%
		6/27/2004	105 cfs	0%	0%	0%
		8/18/2005	289 cfs	0%	0%	0%
			maximum mobility =	0%	0%	17%
09+31	Riffle	10/3/1997	17 cfs	0%	0%	0%
		6/2/1998	90 cfs	0%	0%	0%
		9/10/1998	242 cfs	45%	82%	91%
		6/5/1999	162 cfs	27%	36%	36%
		7/24/1999	170 cfs	45%	64%	55%
		6/4/2000	204 cfs	0%	18%	18%
		8/3/2001	152 cfs	0%	0%	18%
		4/24/2002	164	27%	82%	82%
		6/27/2004	105 cfs	0%	0%	0%
		8/18/2005	289 cfs	100%	100%	100%
			maximum mobility =	100%	100%	100%
09+31	Floodplain	10/3/1997	17 cfs	0%	0%	0%
		6/2/1998	90 cfs	0%	0%	0%
		7/2/1998	193 cfs	0%	0%	0%
		9/10/1998	242 cfs	0%	0%	0%
		6/5/1999	162 cfs	0%	0%	0%
		7/24/1999	170 cfs	0%	0%	25%
		6/4/2000	204 cfs	0%	45%	55%
		8/3/2001	152 cfs	18%	27%	55%
		4/24/2002	164 cfs	0%	0%	0%
		6/27/2004	105 cfs	0%	0%	0%
		8/18/2005	289 cfs	no recovery data	0%	0%
			maximum mobility =	18%	45%	55%
06+80	Riffle	10/3/1997	12 cfs	0%	0%	0%
		6/2/1998	37 cfs	0%	0%	0%
		7/2/1998	118 cfs	17%	83%	100%
		9/10/1998	149 cfs	17%	100%	100%
		6/5/1999	100 cfs	33%	33%	83%
		7/24/1999	104 cfs	20%	60%	80%
		6/4/2000	109 cfs	0%	0%	38%
		8/3/2001	66 cfs	0%	0%	0%
		4/24/2002	82 cfs	13%	0%	13%
		6/27/2004	45 cfs	0%	0%	0%
		8/18/2005	83 cfs	25%	75%	63%
			maximum mobility =	33%	100%	100%

Table D1. Mobility of tracer rocks at various discharges at monitored cross sections on Lee Vining Creek. Continued.

Cross Section	Geomorphic Unit	Observation Date	Discharge at Cross Section	Percent D_{84} Moved	Percent D_{50} Moved	Percent D_{31} Moved
05+15	Point Bar	10/3/1997	12 cfs	0%	0%	0%
		6/2/1998	37 cfs	10%	40%	40%
		7/2/1998	118 cfs	50%	50%	70%
		9/10/1998	149 cfs	50%	50%	70%
		6/5/1999	100 cfs	10%	30%	83%
		7/24/1999	104 cfs	25%	63%	63%
		6/4/2000	109 cfs	0%	9%	36%
		8/3/2001	66 cfs	0%	0%	10%
		4/24/2002	82 cfs	0%	20%	40%
		6/27/2004	45 cfs	0%	10%	10%
		8/18/2005	83 cfs	70%	70%	90%
			maximum mobility =	70%	70%	90%
04+04	Riffle	10/3/1997	12 cfs	0%	0%	0%
		6/2/1998	37 cfs	0%	0%	0%
		7/2/1998	118 cfs	10%	40%	40%
		9/10/1998	149 cfs	50%	40%	40%
		6/5/1999	100 cfs	30%	30%	0%
		7/24/1999	104 cfs	40%	40%	20%
		6/4/2000	109 cfs	20%	30%	40%
		8/3/2001	66 cfs	0%	20%	0%
		4/24/2002	82 cfs	40%	40%	50%
		6/27/2004	45 cfs	0%	0%	10%
		8/18/2005	83 cfs	10%	20%	50%
			maximum mobility =	50%	40%	50%
01+15	Riffle	10/3/1997		0%	0%	0%
		6/2/1998				
		7/2/1998				
		9/10/1998		50%	63%	75%
		6/5/1999	100 cfs	0%	13%	13%
		7/24/1999	104 cfs	14%	14%	29%
		6/4/2000	109 cfs	10%	20%	60%
		8/4/2001	131 cfs	0%	0%	20%
		4/24/2002	131 cfs	10%	30%	50%
		6/27/2004	89 cfs	0%	0%	0%
		8/18/2005	272 cfs	80%	90%	100%
			maximum mobility =	80%	90%	100%
06+08	Riffle	10/3/1997	17 cfs	0%	0%	0%
		6/2/1998	48 cfs	0%	0%	0%
		7/2/1998	152 cfs	40%	100%	100%
		9/10/1998	192 cfs	60%	100%	100%
		6/5/1999	100 cfs	40%	20%	100%
		7/24/1999	104 cfs	40%	80%	60%
		6/4/2000	109 cfs	0%	13%	100%
		8/3/2001	66 cfs	0%	13%	0%
		4/24/2002	105 cfs	0%	0%	0%
		6/27/2004	45 cfs	0%	0%	0%
		8/18/2005	100 cfs	38%	50%	88%
			maximum mobility =	60%	100%	100%
00+87	Point Bar	5/4/1999	23 cfs	0%	0%	0%
		6/5/1999	100 cfs	50%	75%	75%
		7/24/1999	104 cfs	67%	83%	75%
		6/4/2000	109 cfs	0%	20%	50%
		8/4/2001	86 cfs	10%	10%	20%
		4/24/2002	105 cfs	20%	10%	40%
		6/27/2004	61 cfs	0%	0%	0%
		8/18/2005	100 cfs	20%	40%	50%
			maximum mobility =	67%	83%	75%
01+80	Riffle	5/4/1999	23 cfs	0%	0%	0%
		6/5/1999	100 cfs	0%	33%	100%
		7/24/1999	104 cfs	17%	83%	100%
		6/4/2000	109 cfs	60%	30%	80%
		8/4/2001	86.43	20%	20%	50%
		4/24/2002	105	10%	60%	70%
		6/27/2004	60.63	0%	10%	0%
		8/18/2005	100	70%	70%	100%
			maximum mobility =	60%	83%	100%

Table D2. Scour and redeposition depths of scour cores at monitored cross sections on Lee Vining Creek.

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	
		2005	100	1	0.10	0.00	Point bar, pea gravels
				2	not installed		
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
		2005	289	1	0.03	0.19	Eddy deposit, coarse sand
				2	0.14	0.14	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
		2005	289	1	0.42	0.64	Eddy deposit - exposed bar
				2	0.37	1.11	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	0.09	0.30	Point bar - pea gravels
				2	0.14	0.24	Point bar - pea gravels
		2005	289	1	0.03	0.06	Point bar - pea gravels
				2	0.32	0.19	Point bar - pea gravels

Table D3. Mobility of tracer rocks at various discharges at monitored cross sections on Rush Creek.

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	10/3/1997	54 cfs	0%	0%	0%
			6/1/1998	65 cfs	0%	10%	10%
			7/3/1998	224 cfs	90%	80%	80%
			9/10/1998	387 cfs	100%	100%	100%
			7/20/1999	151 cfs	20%	30%	50%
			8/12/2000	153 cfs	23%	62%	77%
			8/5/2001	102 cfs	0%	38%	63%
			6/8/2002	142 cfs	60%	100%	100%
			6/11/2004	224 cfs	80%	90%	90%
			8/19/2005	286 cfs	90%	100%	100%
				maximum mobility =	100%	100%	100%
Lower Rush Creek	07+70	Riffle	10/3/1997	54 cfs	0%	0%	0%
			6/1/1998	65 cfs	0%	0%	0%
			7/3/1998	224 cfs	88%	100%	100%
			9/10/1998	387 cfs	100%	100%	100%
			7/20/1999	151 cfs	43%	71%	86%
			8/12/2000	153 cfs	50%	70%	100%
			8/5/2001	102 cfs	0%	20%	50%
			6/8/2002	142 cfs	40%	10%	60%
			6/11/2004	224 cfs	90%	90%	90%
			8/19/2005	286 cfs	80%	80%	90%
				maximum mobility =	100%	100%	100%
Lower Rush Creek	07+70	Floodplain	10/3/1997	54 cfs	0%	0%	0%
			6/1/1998	65 cfs	0%	0%	0%
			7/3/1998	224 cfs	0%	0%	0%
			9/10/1998	387 cfs	0%	14%	29%
			7/20/1999	151 cfs	0%	0%	0%
			8/12/2000	153 cfs	0%	0%	0%
			8/5/2001	102 cfs	0%	0%	0%
			6/8/2002	142 cfs	0%	0%	0%
			6/11/2004	224 cfs	0%	0%	0%
			8/19/2005	286 cfs	0%	0%	0%
				maximum mobility =	0%	14%	29%
Lower Rush Creek	07+25	Riffle	10/3/1997	54 cfs	0%	0%	0%
			6/1/1998	65 cfs	0%	0%	14%
			9/10/1998	387 cfs	0%	14%	29%
			7/21/1999	151 cfs	13%	75%	75%
			8/12/2000	153 cfs	0%	13%	13%
			8/5/2001	102 cfs	20%	50%	60%
			6/8/2002	142 cfs	40%	70%	40%
			6/11/2004	224 cfs	60%	60%	100%
			8/19/2005	286 cfs	90%	100%	100%
				maximum mobility =	90%	100%	100%
Lower Rush Creek	07+25	Floodplain	10/3/1997	54 cfs	0%	0%	0%
			6/1/1998	65 cfs	0%	0%	0%
			7/3/1998	224 cfs	0%	0%	0%
			9/10/1998	387 cfs	0%	0%	0%
			7/21/1999	151 cfs	0%	0%	0%
			8/12/2000	153 cfs	0%	0%	0%
			8/5/2001	102 cfs	0%	0%	0%
			6/8/2002	142 cfs	0%	0%	0%
			6/11/2004	224 cfs	0%	0%	0%
			8/19/2005	286 cfs	0%	0%	0%
				maximum mobility =	0%	0%	0%
Lower Rush Creek	04+08	Pool Tail	10/3/1997	54 cfs	0%	0%	0%
			6/1/1998	65 cfs	0%	0%	14%
			7/3/1998	224 cfs	100%	100%	100%
			9/10/1998	387 cfs	100%	100%	100%
			7/20/1999	151 cfs	29%	43%	57%
			8/12/2000	153 cfs	20%	20%	60%
			8/5/2001	102 cfs	0%	0%	10%
			6/8/2002	142 cfs	20%	40%	40%
			6/11/2004	224 cfs	100%	100%	100%
			8/19/2005	286 cfs	90%	90%	100%
				maximum mobility =	100%	100%	100%
Lower Rush Creek	-05+07	Point Bar	6/4/1998	56 cfs	0%	0%	0%
			7/3/1998	224 cfs	36%	57%	71%
			9/10/1998	387 cfs	93%	93%	93%
			7/20/1999	151 cfs	14%	36%	29%
			8/12/2000	255 cfs	0%	20%	30%
			8/5/2001	102 cfs	0%	0%	20%
			6/8/2002	142 cfs	10%	20%	40%
			6/11/2004	224 cfs	30%	30%	40%
			8/19/2005	286 cfs	30%	70%	90%
				maximum mobility =	93%	93%	93%

Table D3. Mobility of tracer rocks at various discharges at monitored cross sections on Rush Creek. Continued.

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	-09+82	Riffle	10/3/1997	68 cfs	0%	0%	0%
			9/10/1998	635 cfs	100%	100%	100%
			7/20/1999	247 cfs	38%	54%	85%
			8/12/2000	255 cfs	9%	64%	91%
			8/5/2001	170 cfs	0%	0%	38%
			6/8/2002	225 cfs	25%	50%	75%
			6/11/2004	413 cfs	67%	100%	92%
			8/19/2005	467 cfs	100%	92%	100%
				maximum mobility =	100%	100%	100%
Lower Rush Creek	1+10	Riffle	8/12/2000	102 cfs	17%	17%	33%
			8/5/2001	75 cfs	8%	0%	17%
			6/8/2002	83 cfs	20%	60%	70%
			6/11/2004	189 cfs	60%	80%	100%
			8/19/2005	181 cfs	100%	90%	100%
				maximum mobility =	100%	90%	100%
Upper Rush Creek	12+95	Pool tail	6/3/1998	55 cfs	0%	0%	0%
			7/1/1998	273 cfs	25%	42%	42%
			9/10/1998	538 cfs	75%	83%	100%
			7/20/1999	201 cfs	0%	22%	33%
			8/13/2000	204 cfs	0%	22%	22%
			8/5/2001	162 cfs	0%	0%	0%
			6/8/2002	168 cfs	10%	0%	20%
			6/11/2004	384 cfs	50%	70%	70%
			8/19/2005	403 cfs	70%	60%	70%
				maximum mobility =	75%	83%	100%
Upper Rush Creek	05+45	Riffle	6/3/1998	55 cfs	0%	0%	0%
			7/1/1998	273 cfs	60%	100%	100%
			9/10/1998	538 cfs	100%	100%	100%
			7/20/1999	201 cfs	10%	30%	50%
			8/13/2000	204 cfs	0%	20%	30%
			8/4/2001	162 cfs	10%	20%	20%
			6/8/2002	168 cfs	10%	20%	20%
			6/11/2004	384 cfs	60%	60%	60%
			8/19/2005	403 cfs	60%	80%	70%
				maximum mobility =	100%	100%	100%
Upper Rush Creek	00+74	Riffle	6/3/1998	55 cfs	0%	0%	0%
			7/2/1998	273 cfs	0%	0%	6%
			9/10/1998	538 cfs	31%	88%	94%
			7/20/1999	201 cfs	0%	12%	6%
			8/13/2000	204 cfs	0%	12%	12%
			8/5/2001	162 cfs	0%	0%	0%
			6/8/2002	168 cfs	24%	6%	0%
			6/11/2004	384 cfs	18%	35%	53%
			8/19/2005	403 cfs	47%	82%	76%
				maximum mobility =	47%	88%	94%
Rush Creek County Rd	15+19	Riffle	8/13/2000	255 cfs	8%	58%	75%
			8/6/2001	202 cfs	0%	17%	58%
			6/8/2002	225 cfs	0%	67%	83%
			6/11/2004	413 cfs	67%	92%	100%
			8/19/2005	467 cfs	100%	83%	100%
				maximum mobility =	100%	92%	100%
Rush Creek County Rd	6+85	Point Bar	8/13/2000	255 cfs	0%	0%	0%
			8/5/2001	202 cfs	0%	0%	0%
			6/8/2002	225 cfs	0%	0%	0%
			6/11/2004	413 cfs	0%	10%	10%
			8/19/2005	467 cfs	100%	100%	100%
				maximum mobility =	0%	10%	10%

Table D4. Scour and redeposition depths of scour cores at monitored cross sections on Rush Creek.

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
		2005	286	5	N/A	NO DATA	Upper point bar / floodplain
				4	0.05	0.11	Middle of point bar
				3	0.03	0.00	Point bar within low water channel
				2	0.02	0.07	Point bar within low water channel
				1	0.01	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
		2005	286	1	0.10	0.12	Pool tail at low flow, transverse bar at high flow
				2	0.05	0.06	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
		2005	286	1	0.30	0.25	Low-gradient riffle
				2	0.09	0.16	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
		2005	286	1	0.43	0.34	Riffle (transverse bar), within low water channel
				2	0.33	0.52	Riffle (transverse bar), within low water channel
				3	0.57	0.60	Riffle (transverse bar), within low water channel
				4	0.31	0.60	Riffle (transverse bar), within low water channel
Lower Rush Creek	07+25	1998	396	1	0.00	0.00	Upper point bar / floodplain
		1999	155	1	0.01	0.00	Upper point bar / floodplain
		2000	161	1	0.00	0.00	Upper point bar / floodplain

Table D4. Scour and redeposition depths of scour cores at monitored cross sections on Rush Creek. Continued.

Reach	Cross Section	Year	Discharge at Cross Section (cfs)	Core #	Scour depth (ft)	Redeposition depth (ft)	Geomorphic feature
		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
		2005	286		0.00	0.00	
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	0.00	0.00	Upper point bar / floodplain
		2005	286	1	0.00	0.00	
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	0.00	Pool tail
				2	unknown	NO DATA	Pool tail
		2005	286	1	0.35	0.52	
				2	not recovered	0.55	
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
		2005	403	1	0.33	0.28	Constructed pool tail
				2	0.13	0.46	Constructed pool tail
				3	0.20	0.08	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
		2005	403	1	0.33	0.28	Eddy deposit
				2	0.13	0.46	Lee deposit
				3	0.20	0.08	Eddy deposit
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
		2005	403	1	0.08	0.52	Riffle
				2	0.01	0.12	Riffle
Rush Creek at County Road	6+85	2004	354 (413)	1	0.06	1.38	point bar edge
		2005			not recovered	0.40	point bar edge

APPENDIX E

Large Woody Debris Mapping

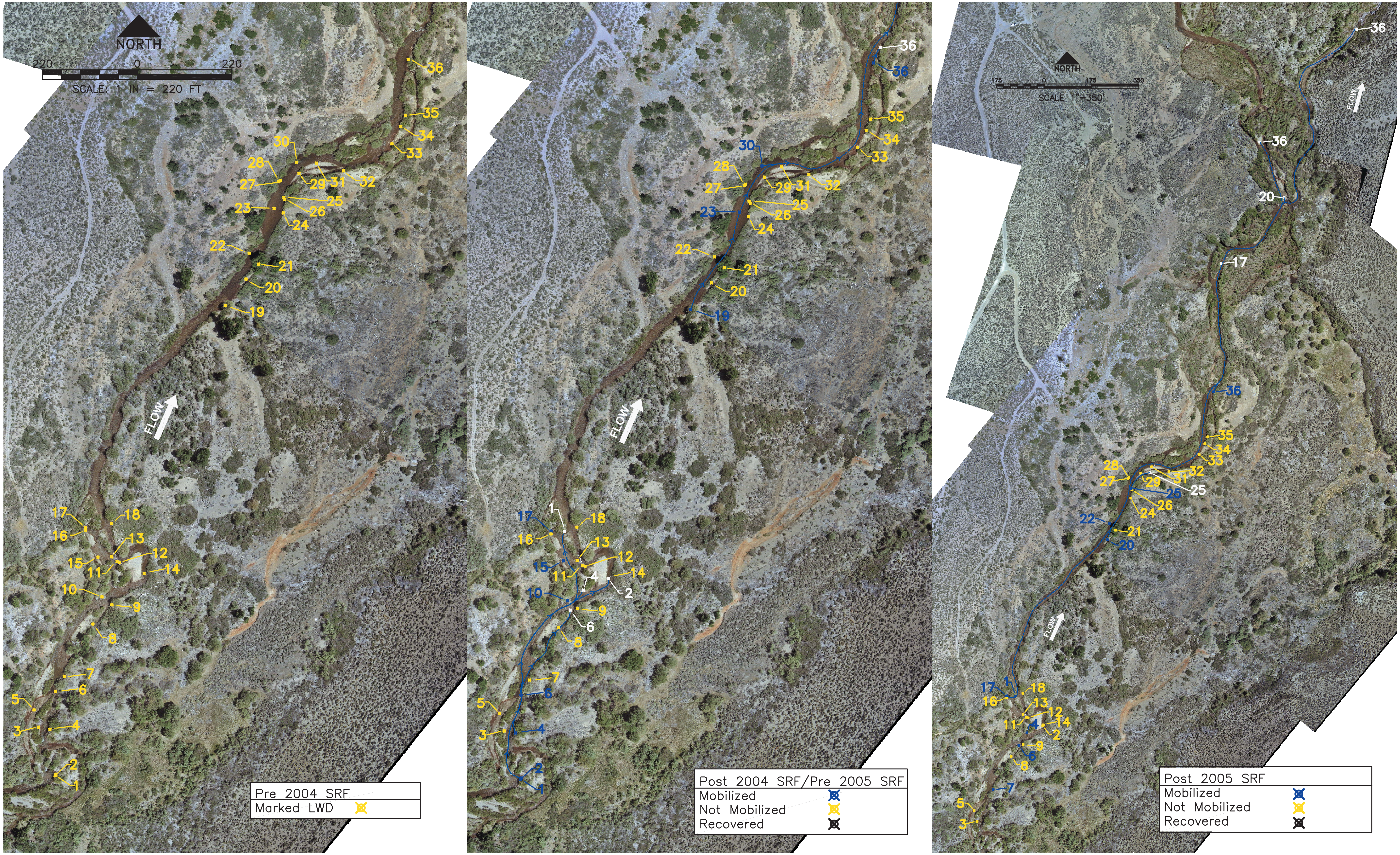


Figure E1. Large woody debris marked and relocated on Lower Rush Creek before and after the RY 2004 and 2005 SRF releases.

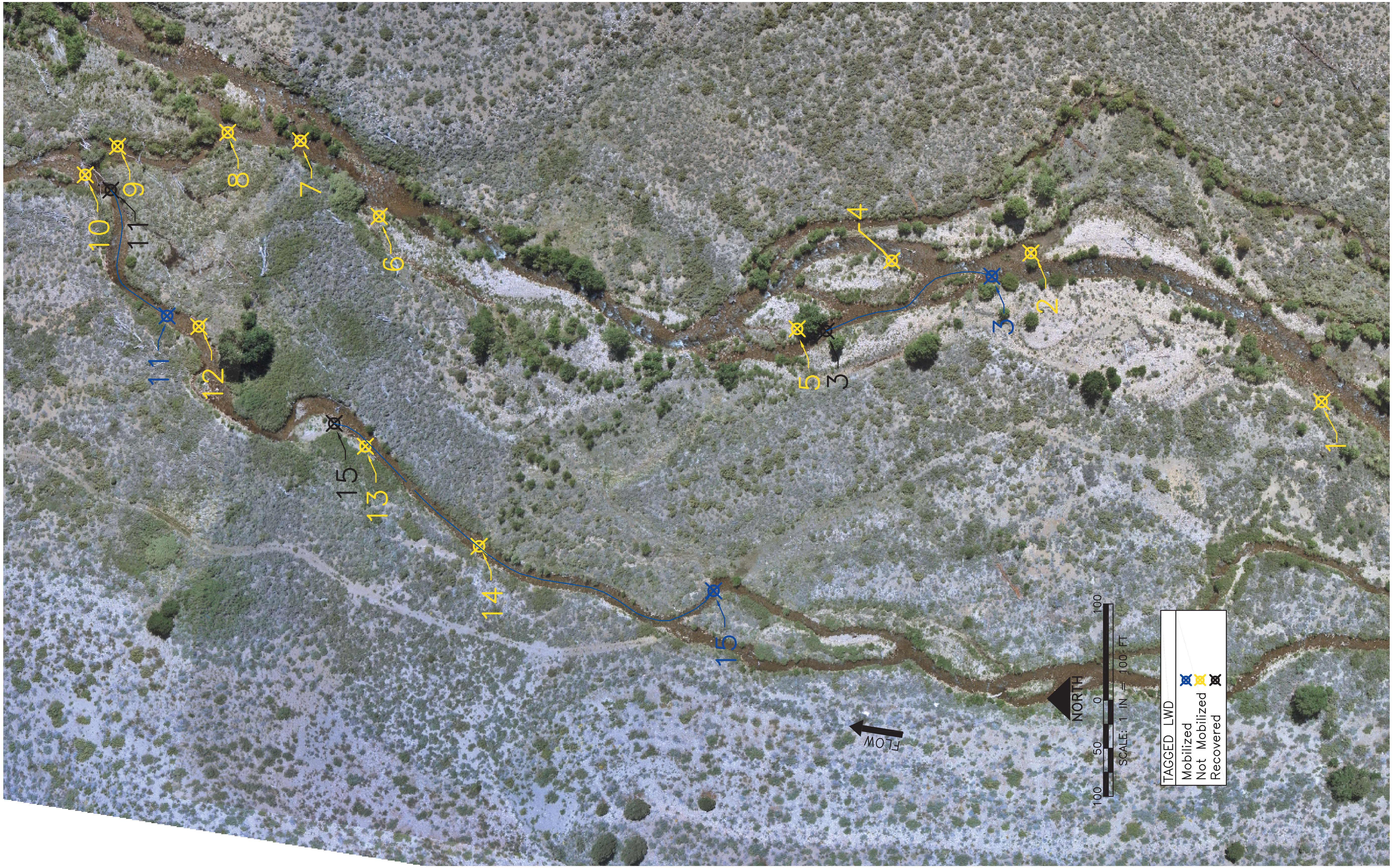


Figure E2. Large woody debris marked and relocated on Lee Vining Creek before and after the RY 2005 snowmelt peak.

APPENDIX F

Lee Vining Creek Planmaps

Table F1. 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 F2. 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 2
LOWER LEE VINING CREEK
2004 PLANFORM
LEGEND
MAPPED CHANNEL THALWEG
GEOMORPHIC UNIT
REACH BOUNDARY
CROSS SECTION
NOTE: SEE APPENDIX F, TABLES F1 & F2
FOR MAP UNIT SYMBOL TERMINOLOGY
NORTH
McBain & Trush 2005
MAIN CHANNEL
FLOW
B-1 CHANNEL
FLOW
VALLEY WIDE CROSS SECTION


PLATE 1.
UPPER LEE VINING CREEK
2004 PLANFORM
LEGEND
MAPPED CHANNEL THALWEG
GEOMORPHIC UNIT
REACH BOUNDARY
CROSS SECTION
NOTE: SEE APPENDIX F, TABLES F1 & F2
FOR MAP UNIT SYMBOL TERMINOLOGY
SCALE: 1 IN = 100 FT
100 50 0 100
NORTH
McBain & Trush 2005
MAIN CHANNEL
A-4 CHANNEL
FLOW
FLOW
B1-CONNECTOR
XS 00+26
XS 03+45
XS 03+73
XS 06+61
XS 03+91
XS 10+44
XS 13+92
XS 03+29
XS 03+75
XS 04+04
XS 05+15
XS 06+80

APPENDIX G

Floodplain Deposition Data

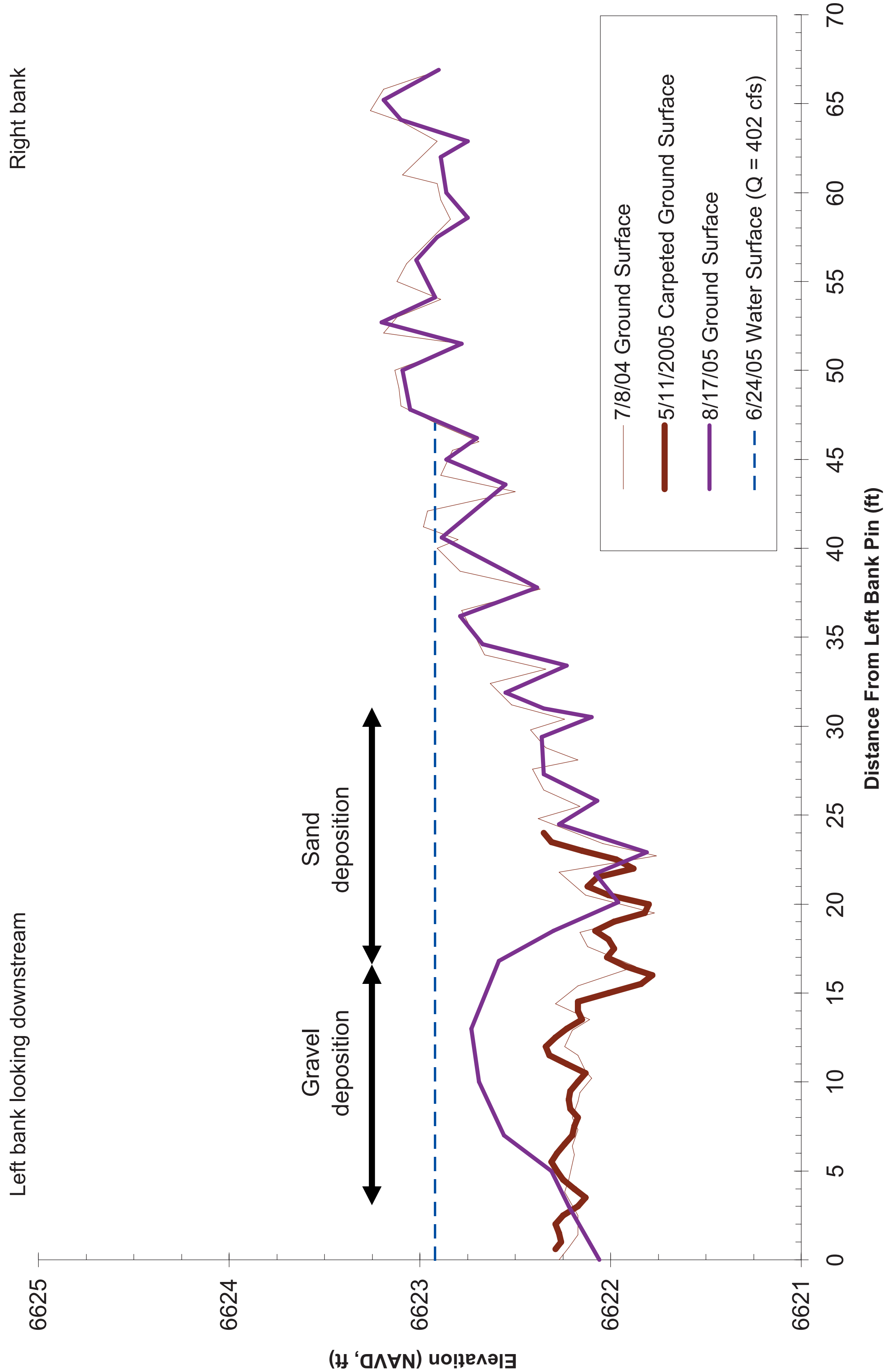


Figure G-1. Rush Creek floodplain deposition cross section 239+00.

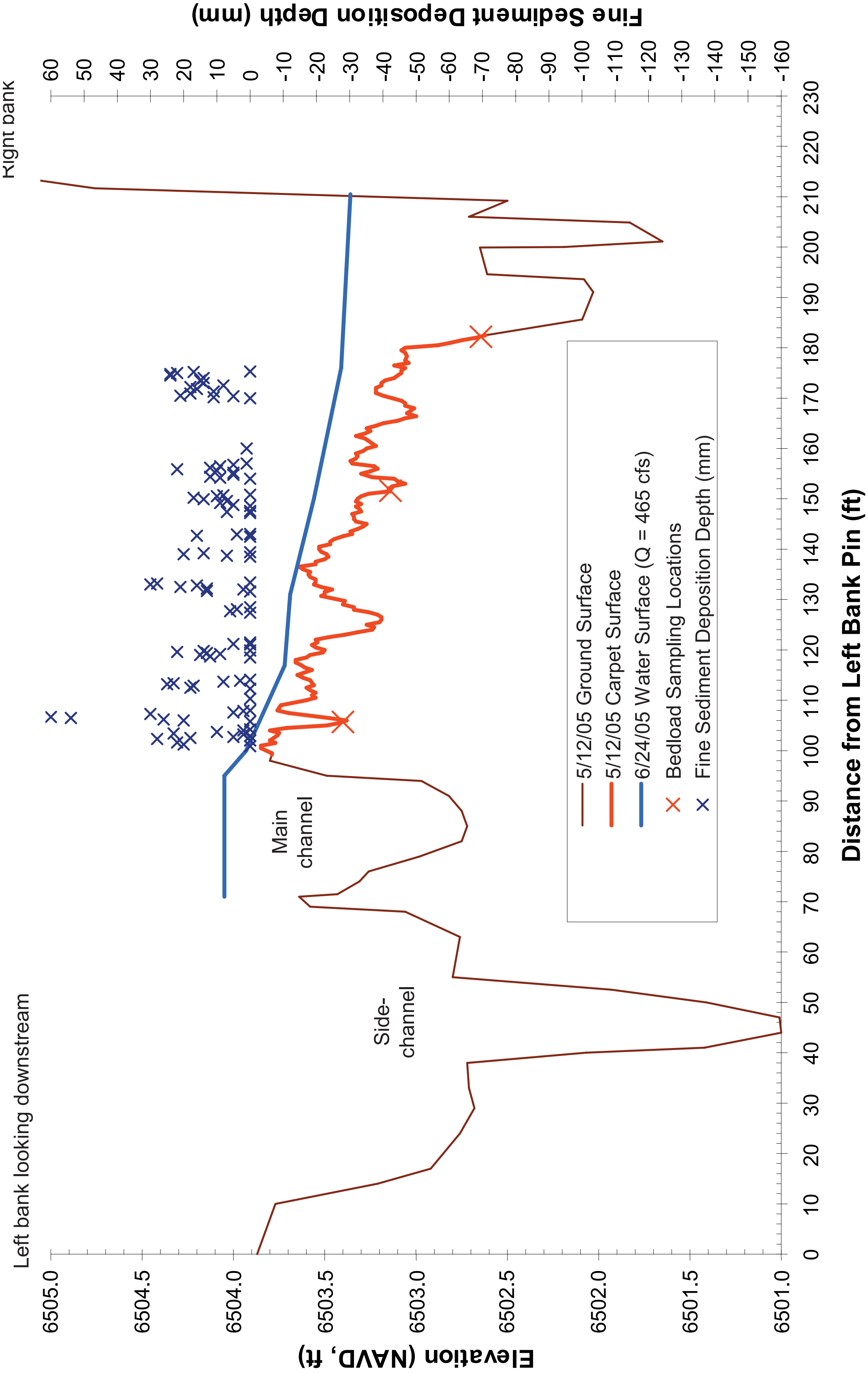


Figure G-2. Rush Creek floodplain deposition cross section 319+62 showing local deposition depths.

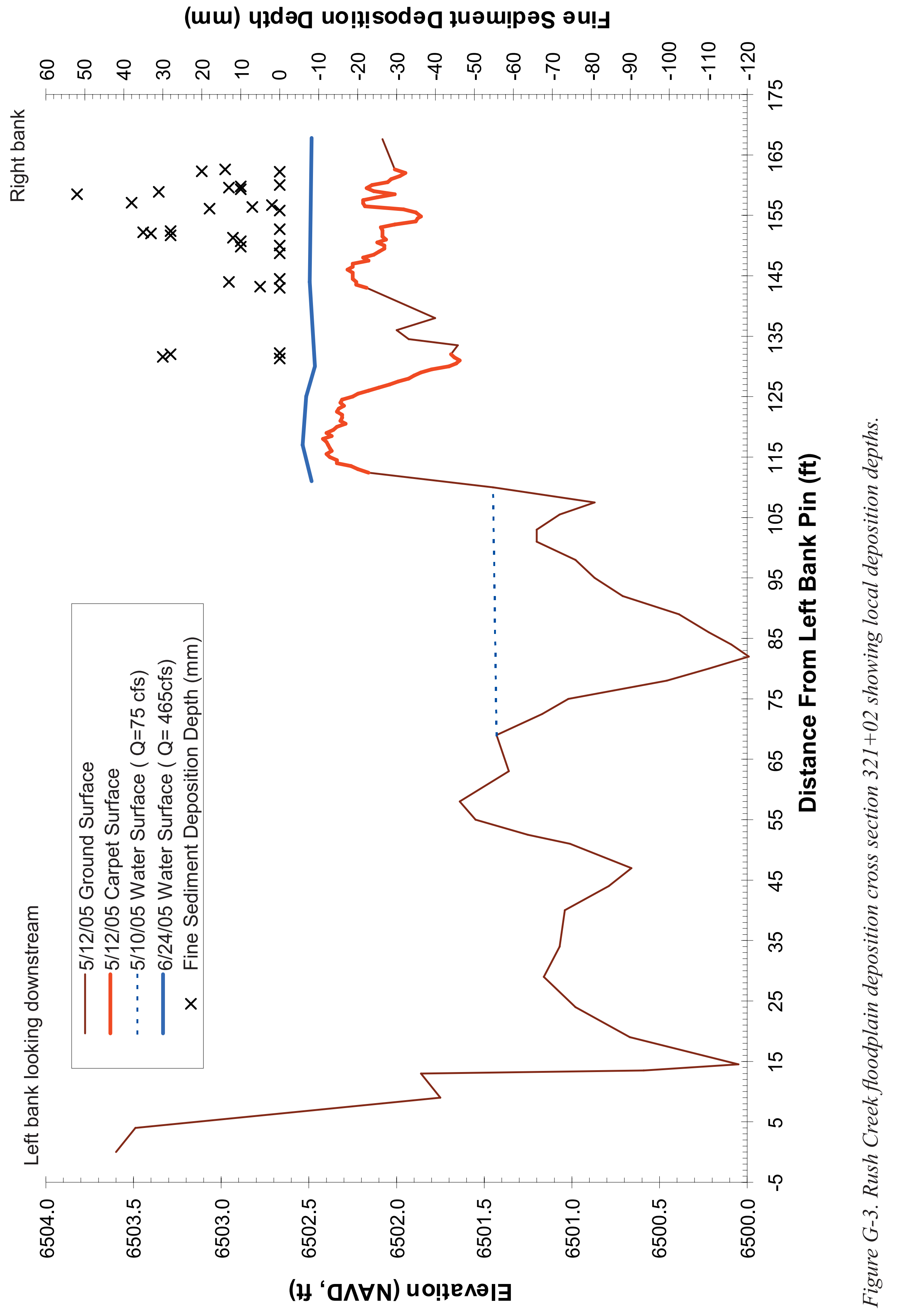


Figure G-3. Rush Creek floodplain deposition cross section 321+02 showing local deposition depths.

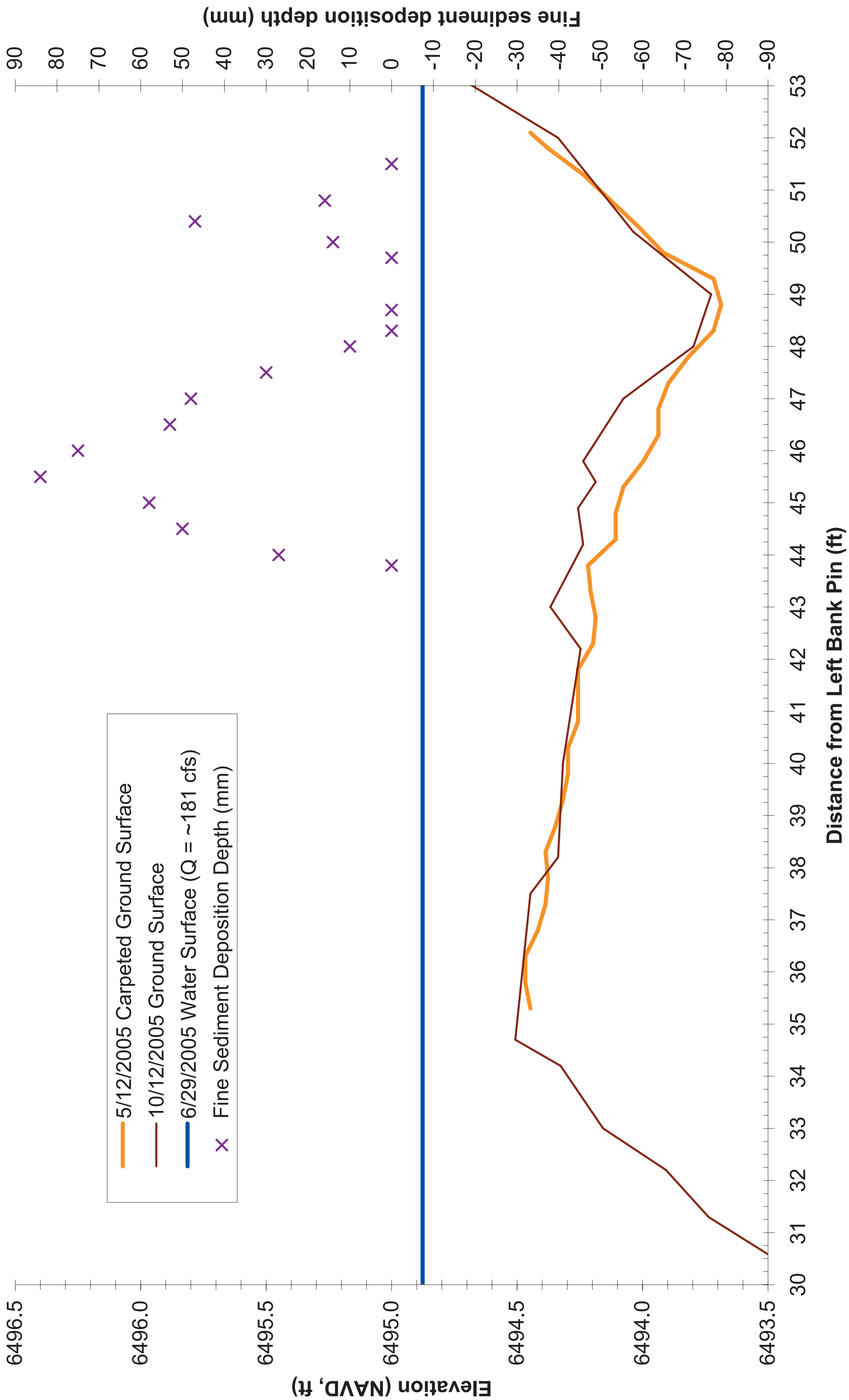


Figure G-4. Rush Creek floodplain deposition cross section 1+10 showing local deposition depths.

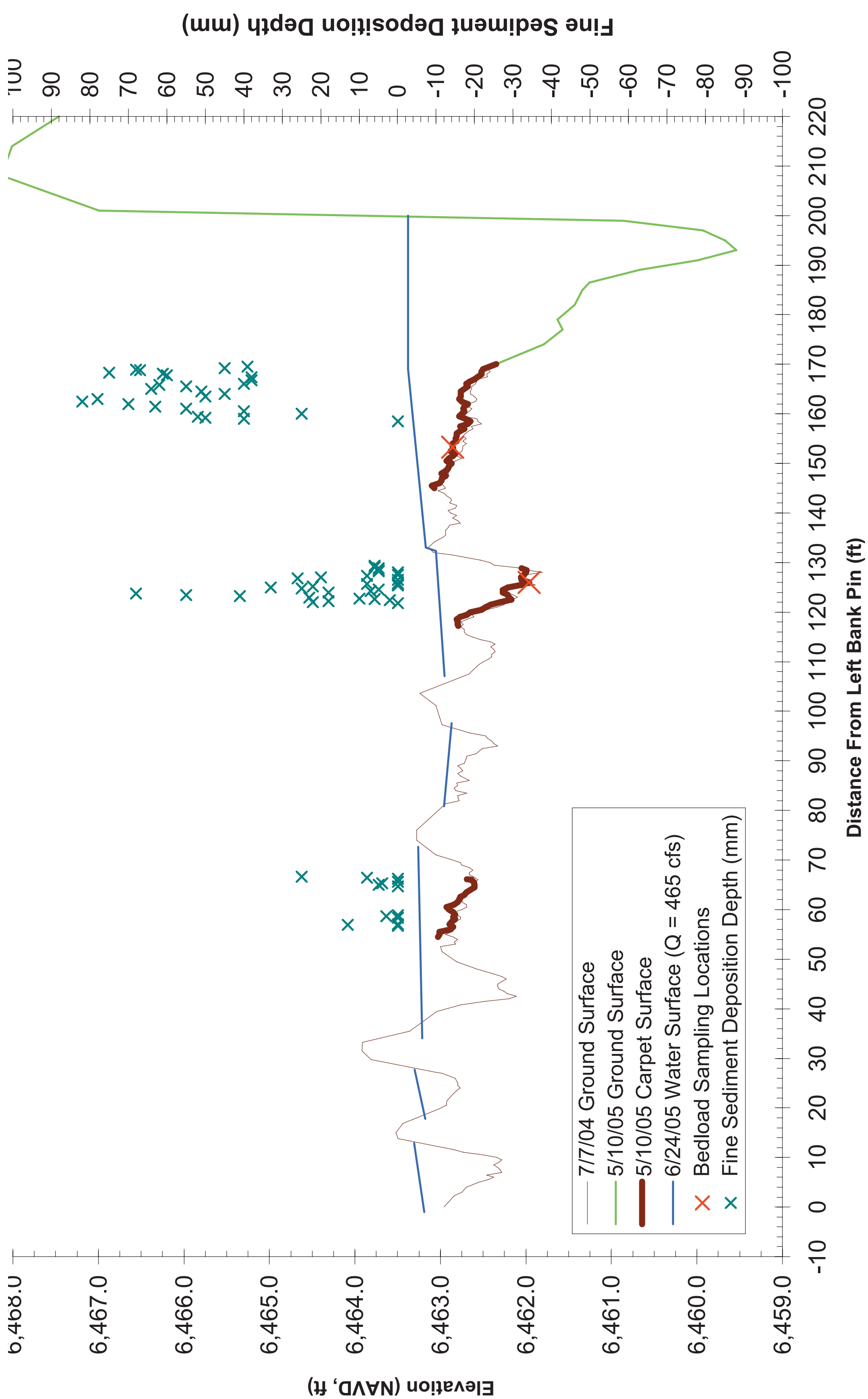


Figure G-5. Rush Creek floodplain deposition cross section -25+00 showing local deposition depths.

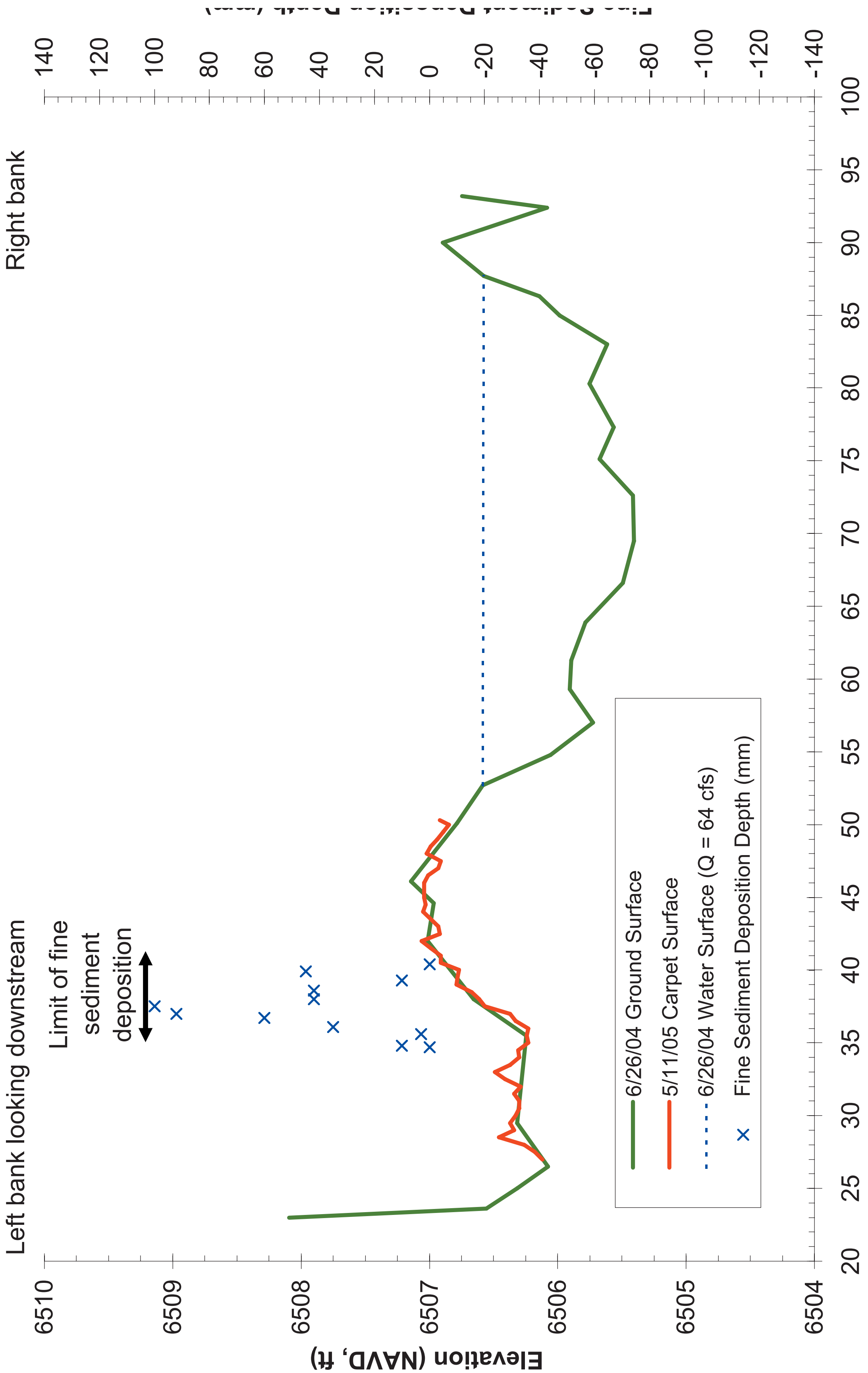


Figure G-6. Upper Lee Vining Creek main channel floodplain deposition cross section 3+45 showing local deposition depths.

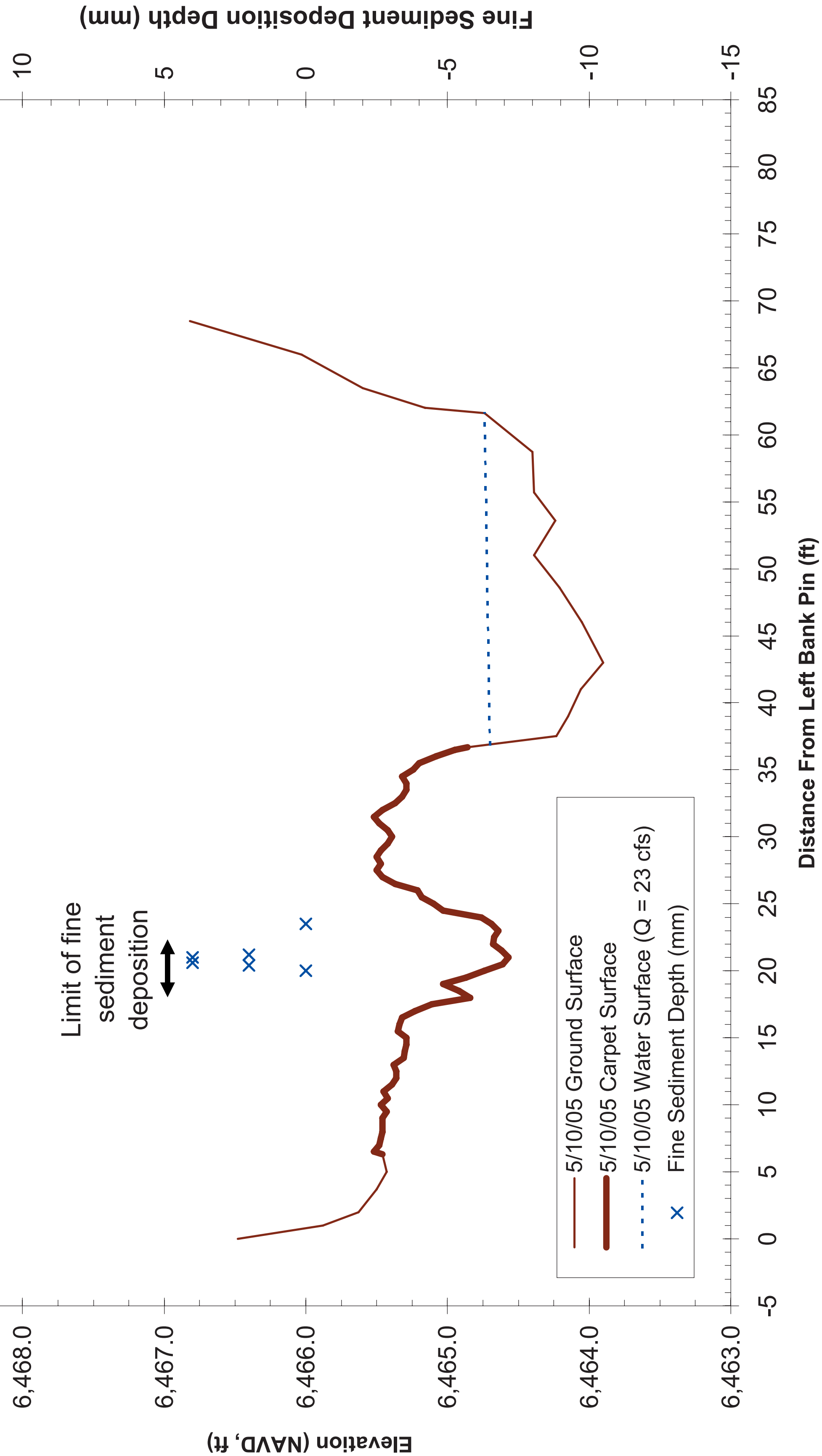


Figure G-7. Lower Lee Vining Creek B-1 Channel floodplain deposition cross section 04+31 showing local deposition depths.

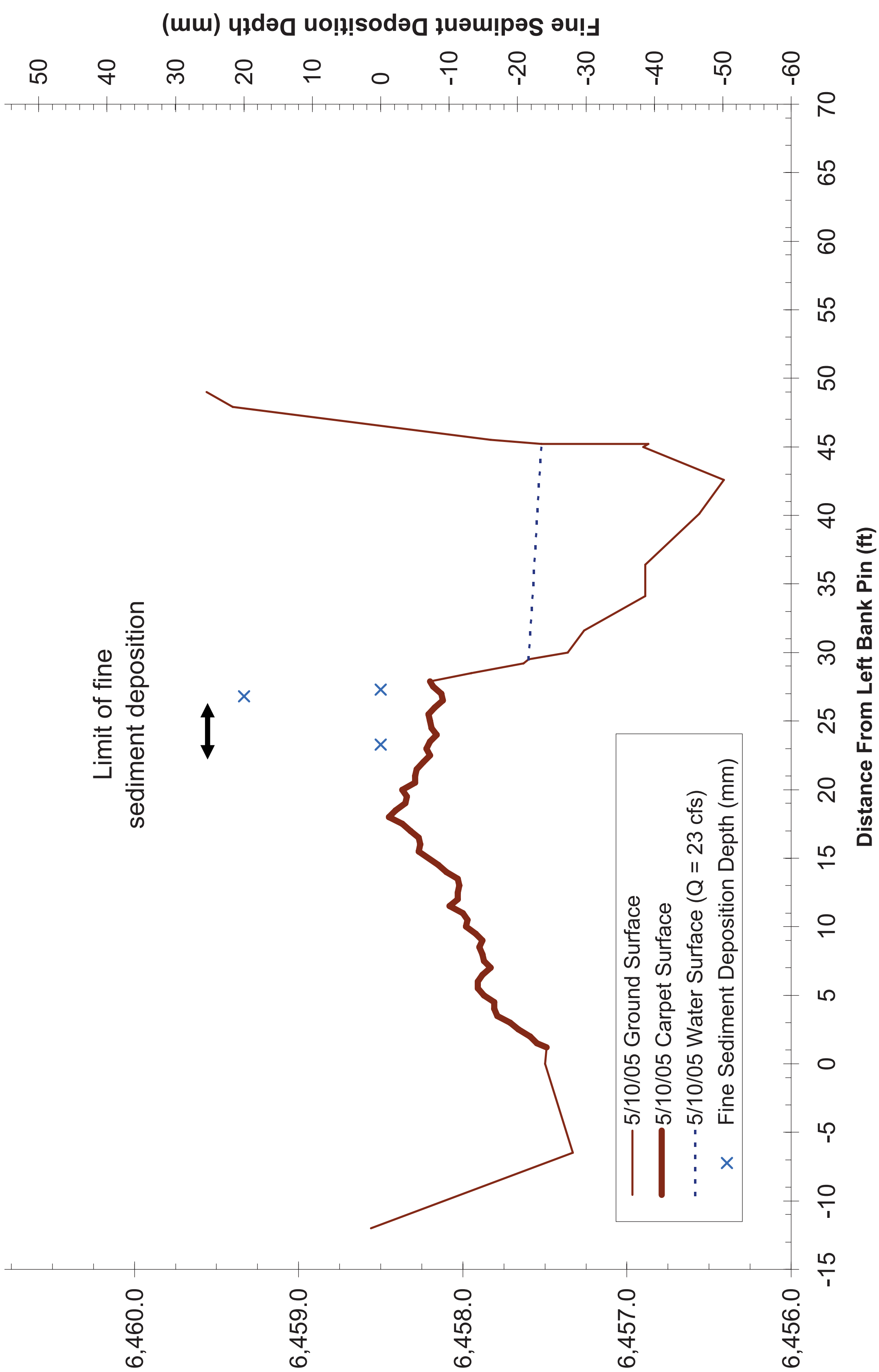


Figure G-8. Lower Lee Vining Creek main channel floodplain deposition cross section 01+28 showing local deposition depths.

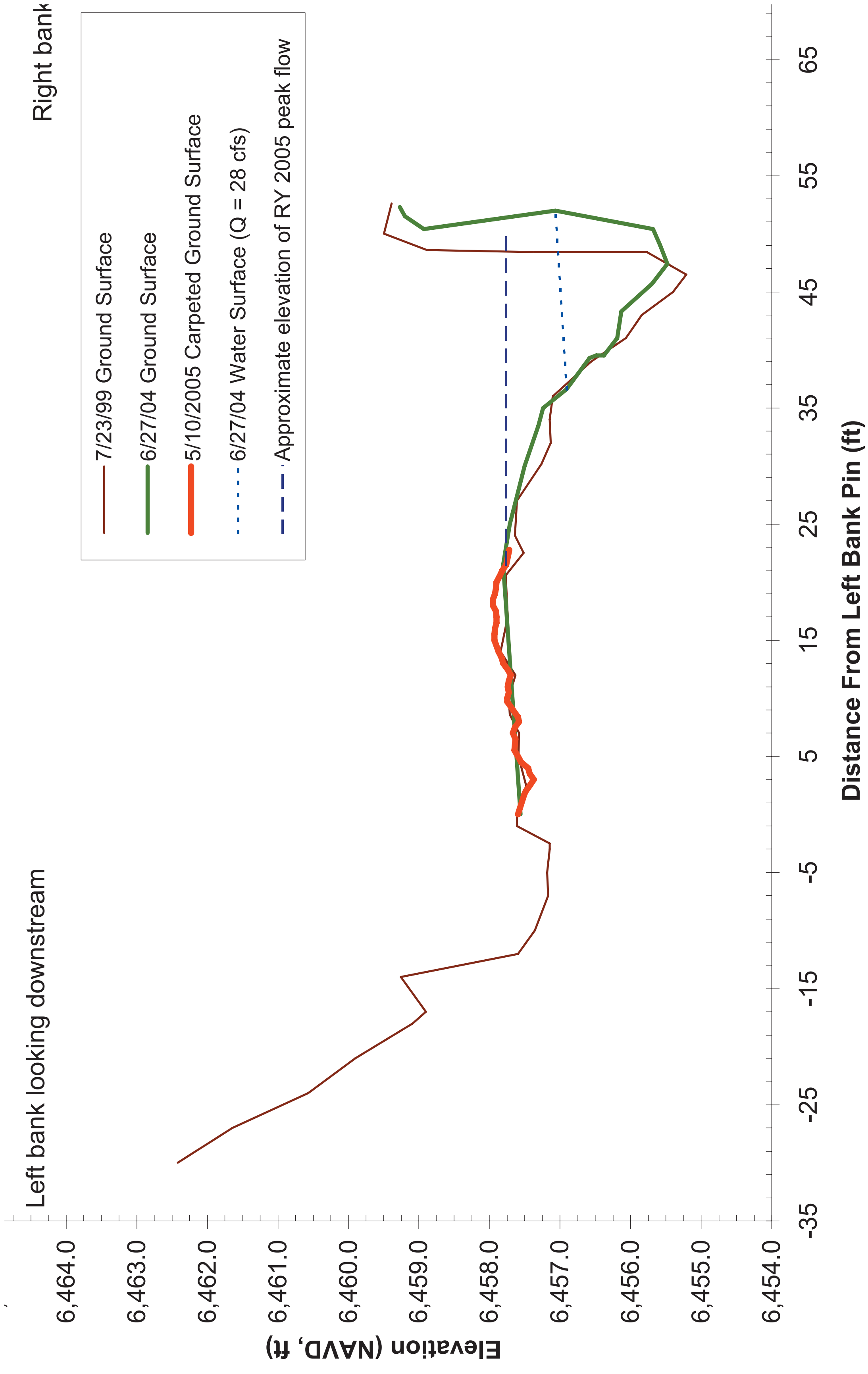


Figure G-9. Lower Lee Vining Creek B1 Channel floodplain deposition cross section 00+87 showing local deposition depths.

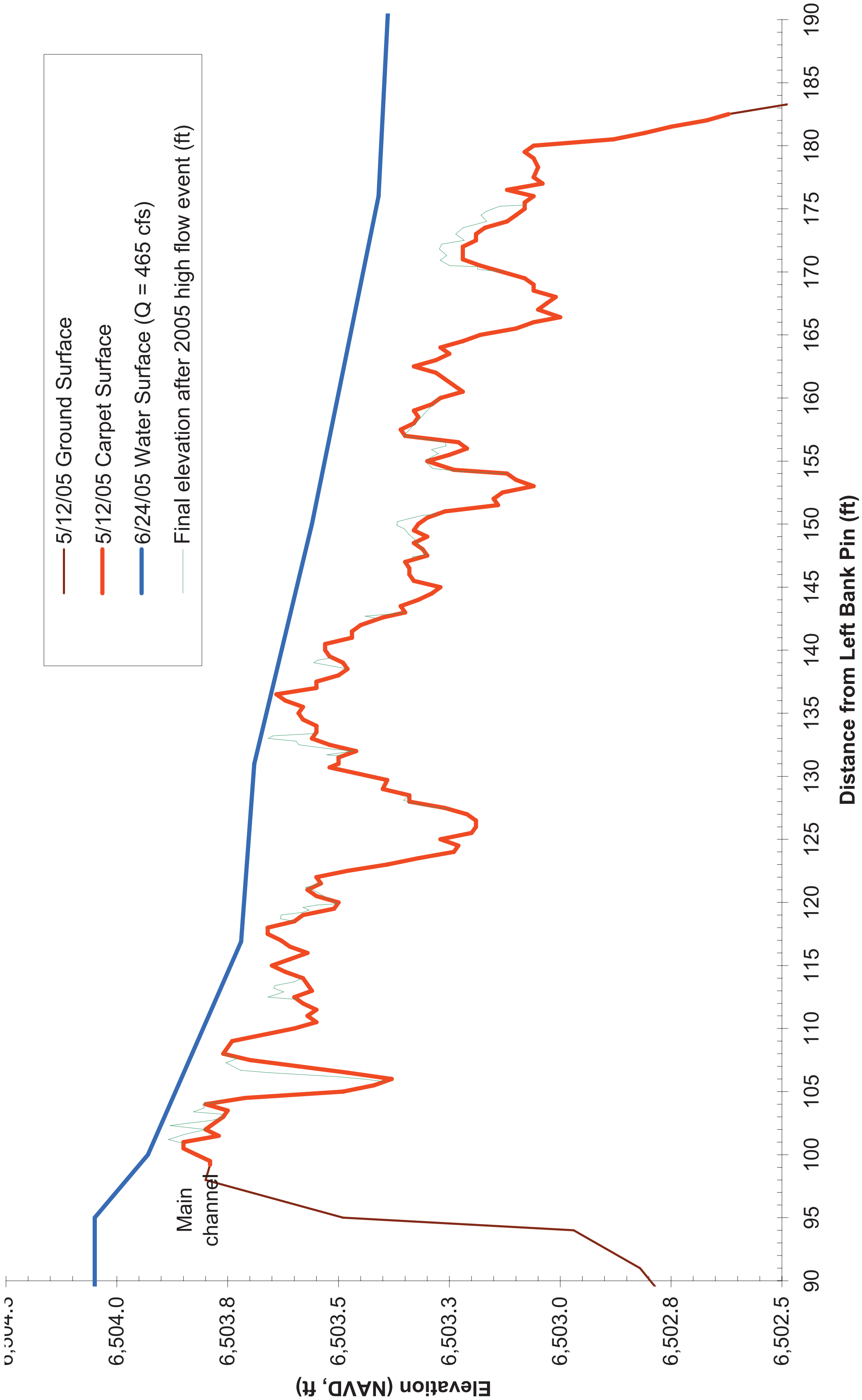


Figure G-10. Rush Creek floodplain deposition cross section 319+62 showing net deposition from RY2005 peak flow release.

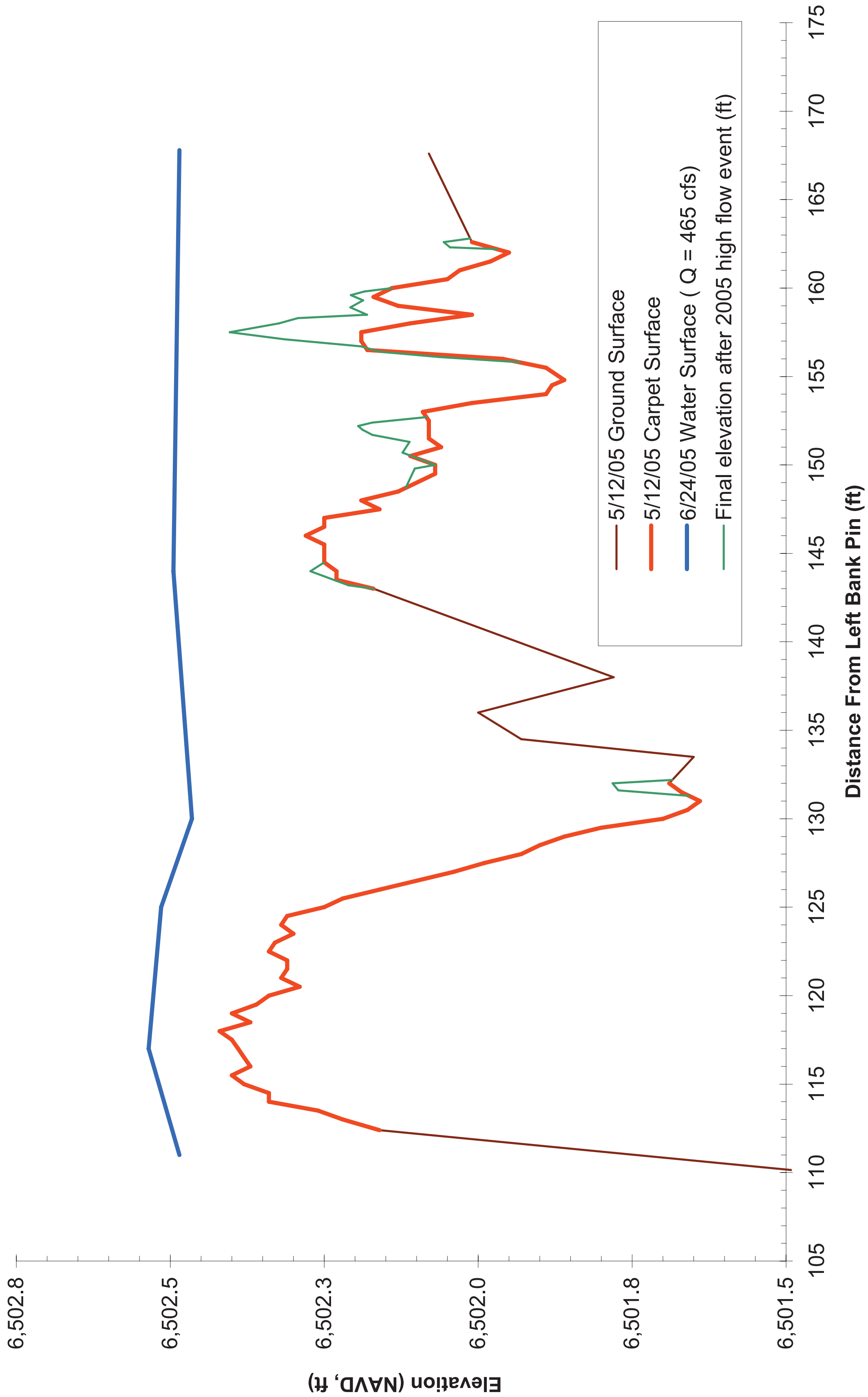


Figure G-11. Rush Creek floodplain deposition cross section 321+02 showing net deposition from RY2005 peak flow release.

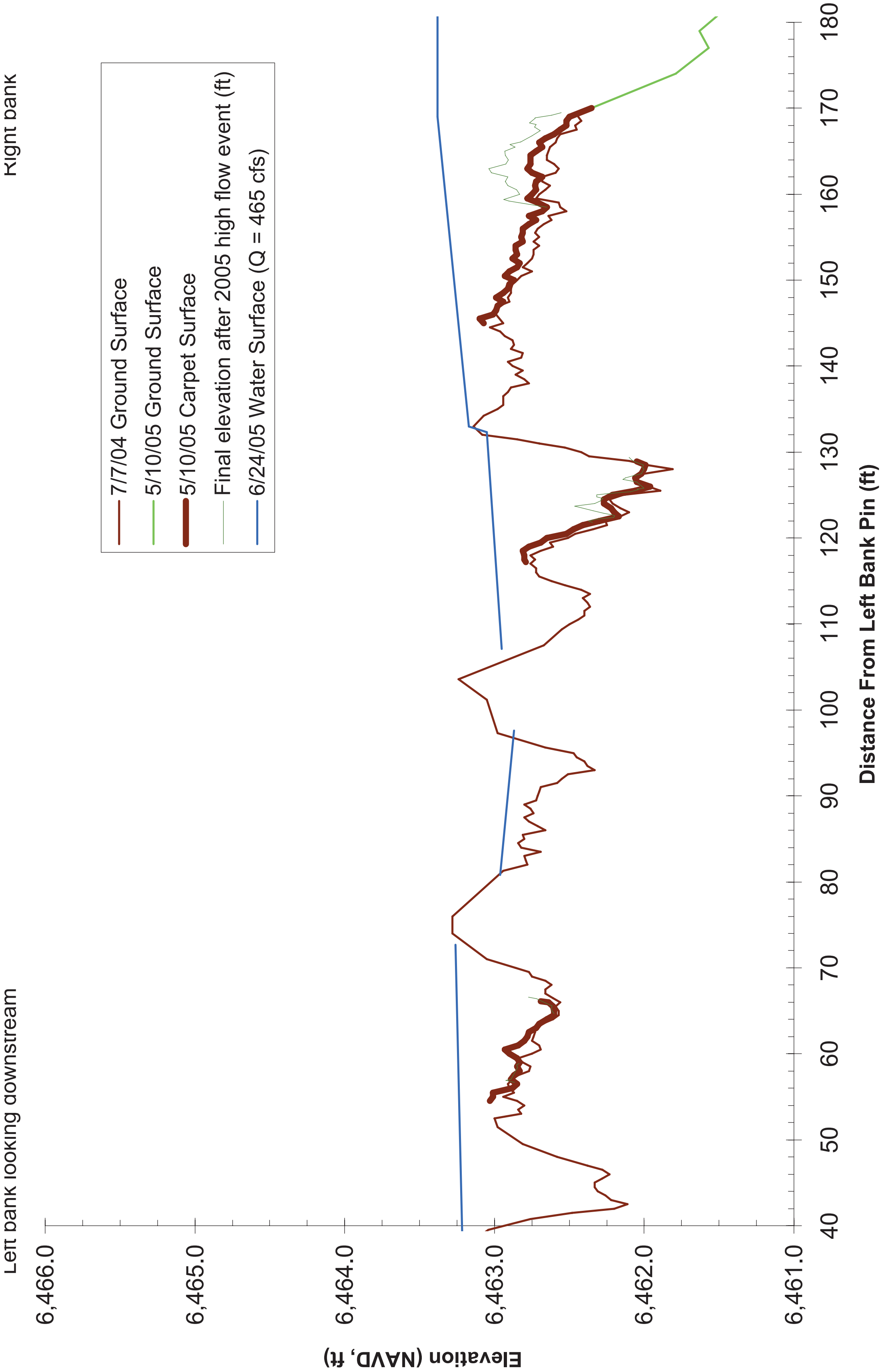


Figure G-12. Rush Creek floodplain deposition cross section -25+00 showing net deposition from RY2005 peak flow release.

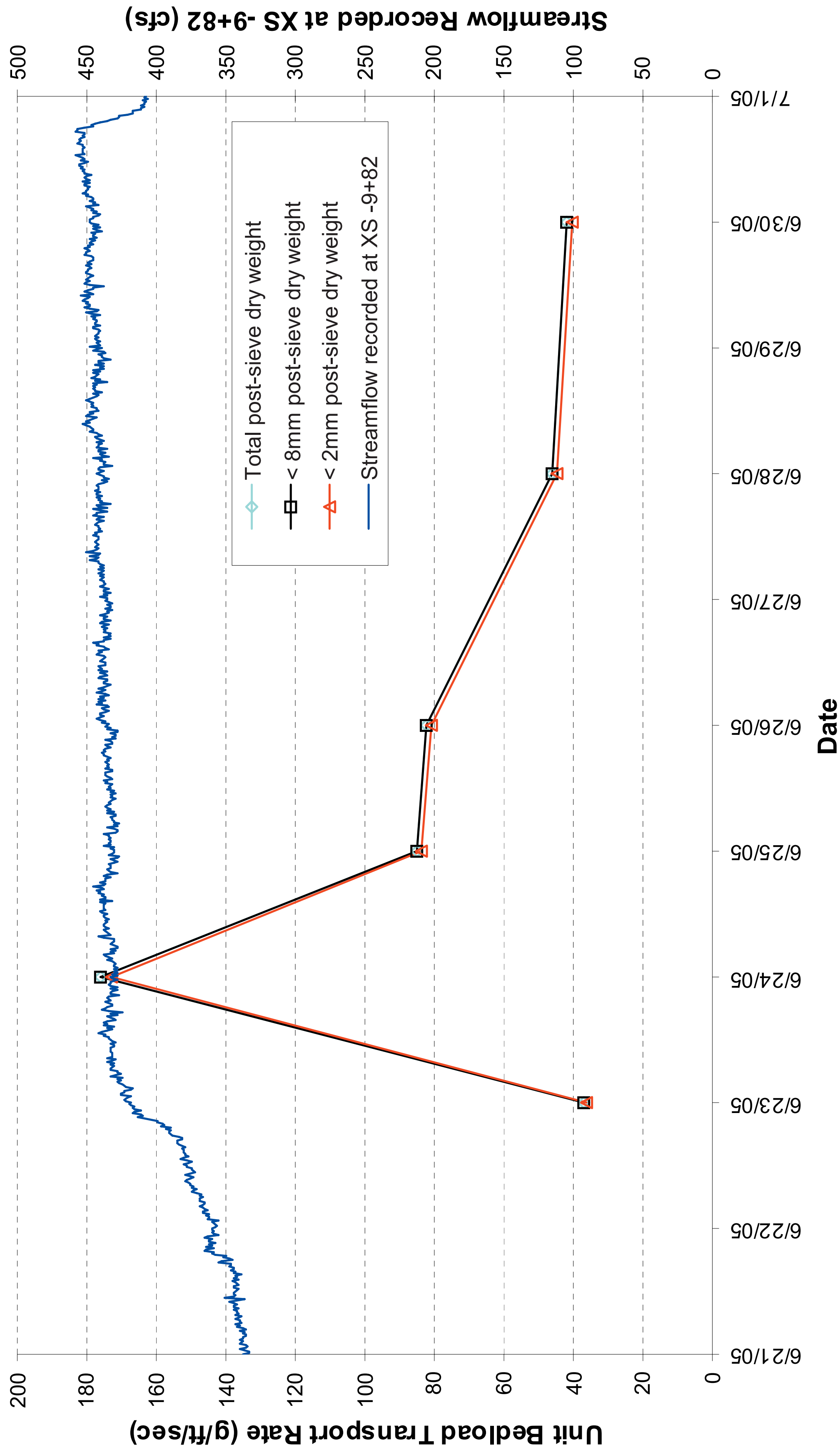


Figure G-13. Bedload transport rates on Rush Creek cross section 319+62 Station 183.2 during RY2005 peak flow release.

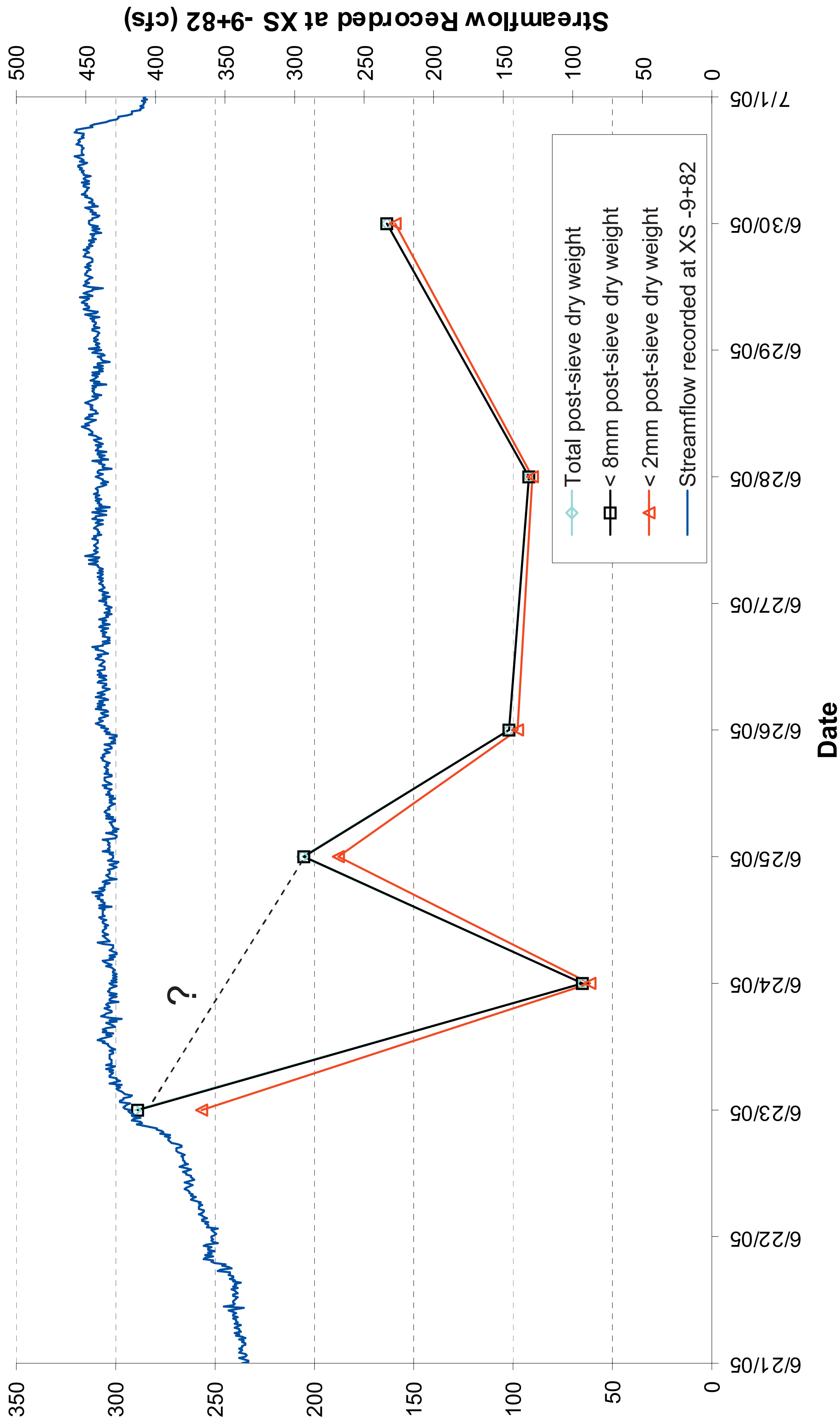


Figure G-14. Bedload transport rates on Rush Creek cross section 319+62 Station 152.6 during RY2005 peak flow release.

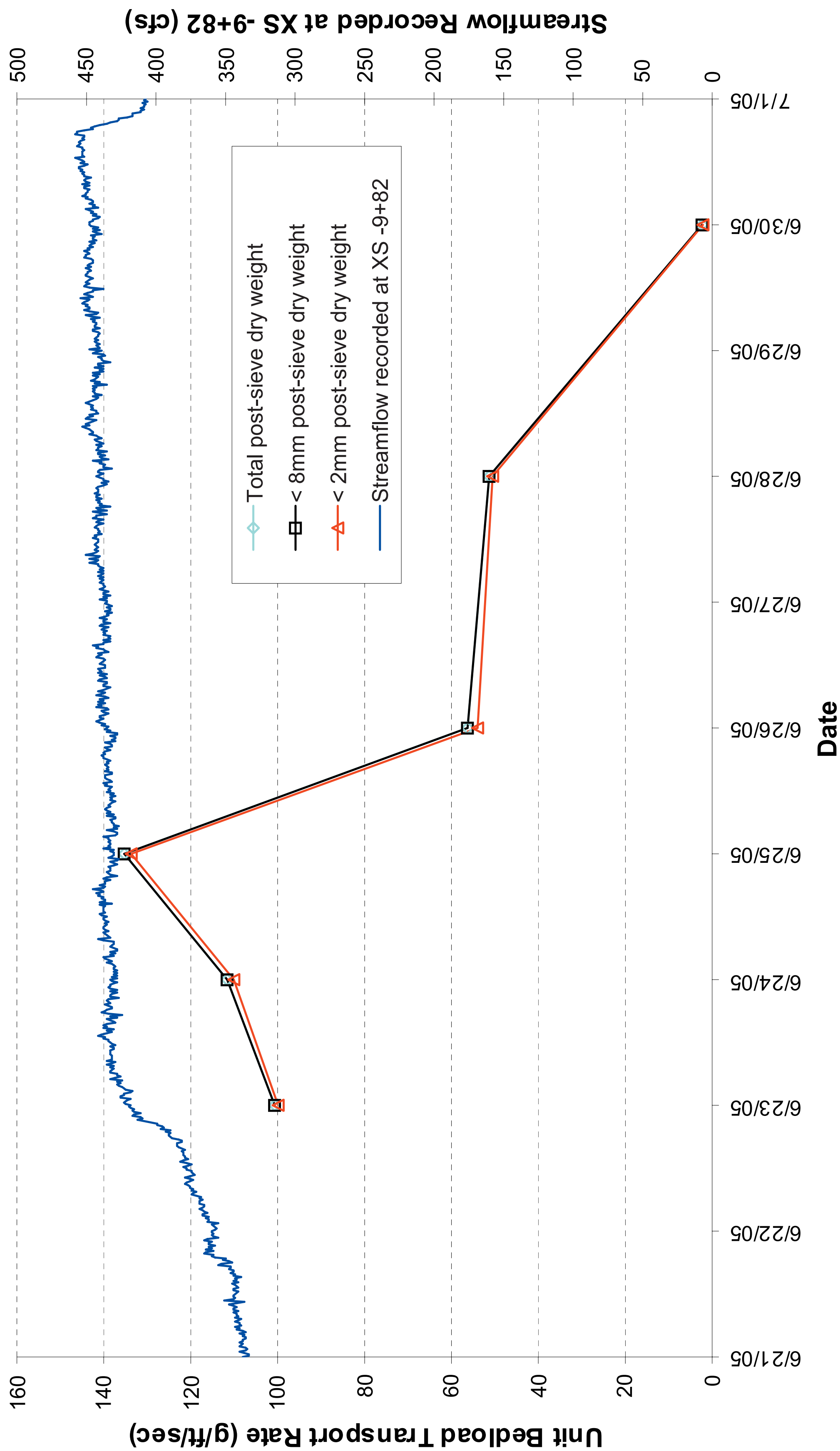


Figure G-15. Bedload transport rates on Rush Creek cross section 319+62 Station 106.7 during RY2005 peak flow release.

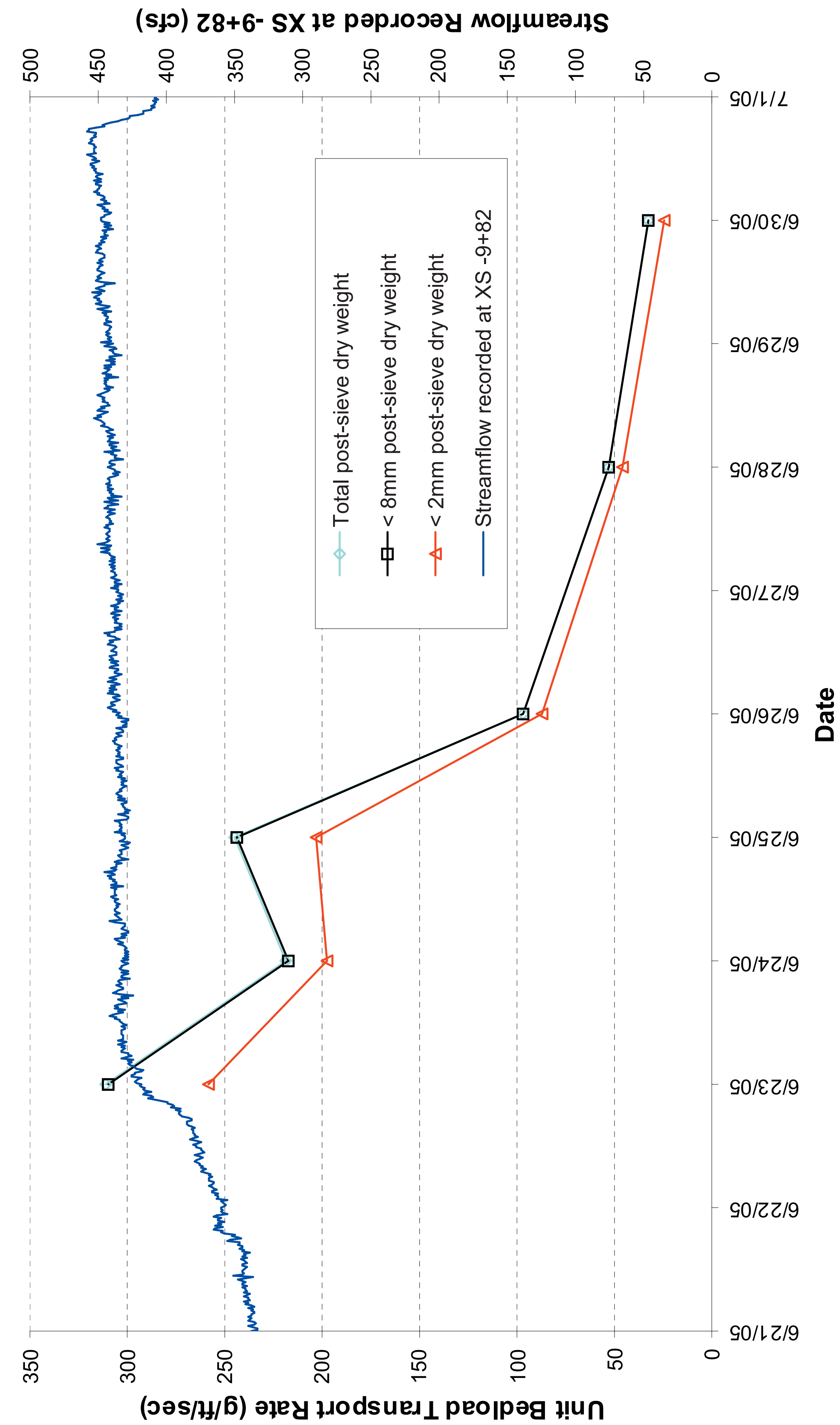


Figure G-16. Bedload transport rates on Rush Creek cross section -25+00 Station 153.3 during RY2005 peak flow release.

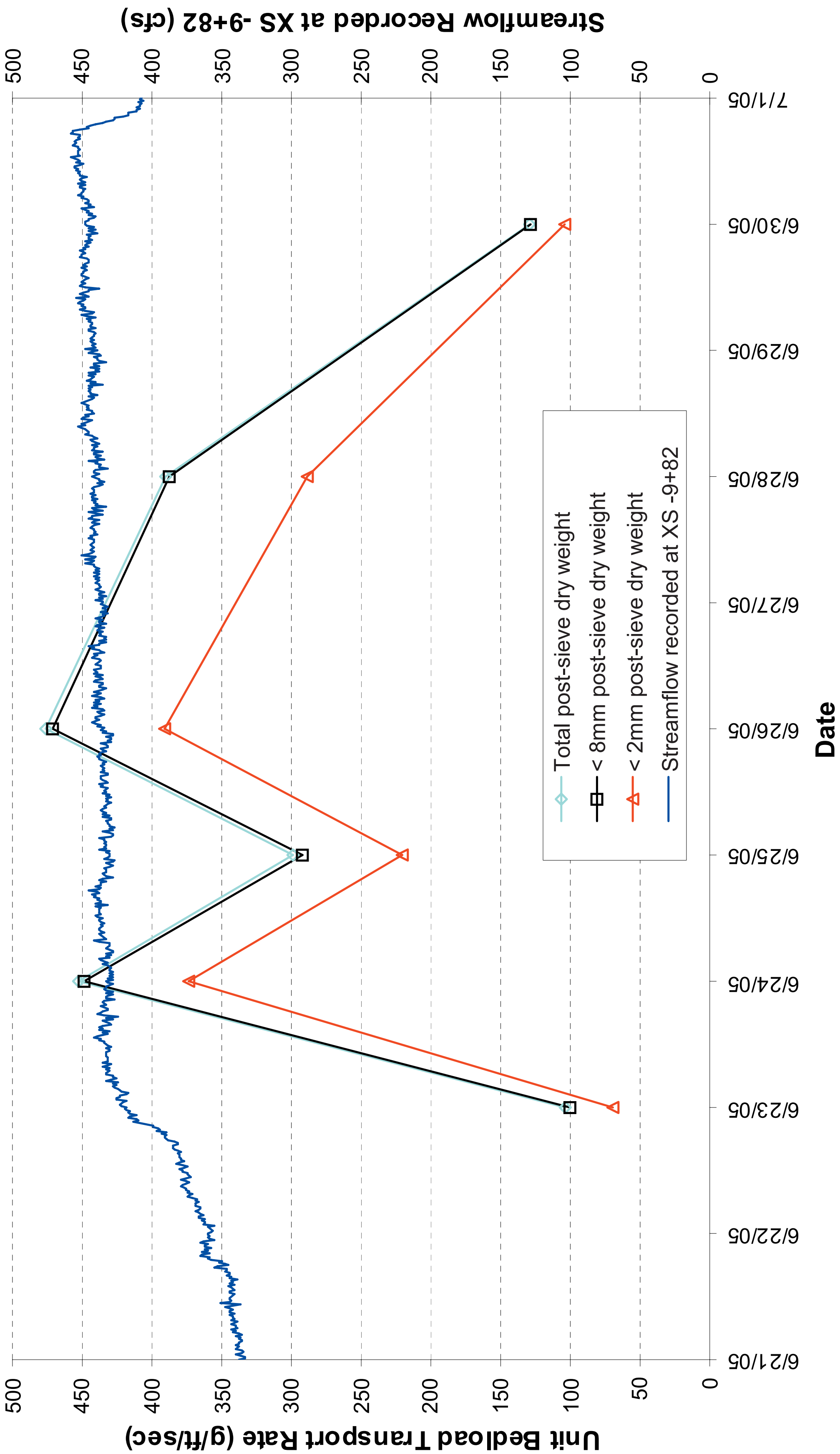


Figure G-17. Bedload transport rates on Rush Creek cross section -25+00 Station 126.0 during RY2005 peak flow release.

APPENDIX H

Riparian Vegetation Composition Data

Figure H-1. Percent of transects whose tallest species fall into the herb (<1.5m), shrub (1.5m<plant size <5m), or tree (>5m) vegetation layers.

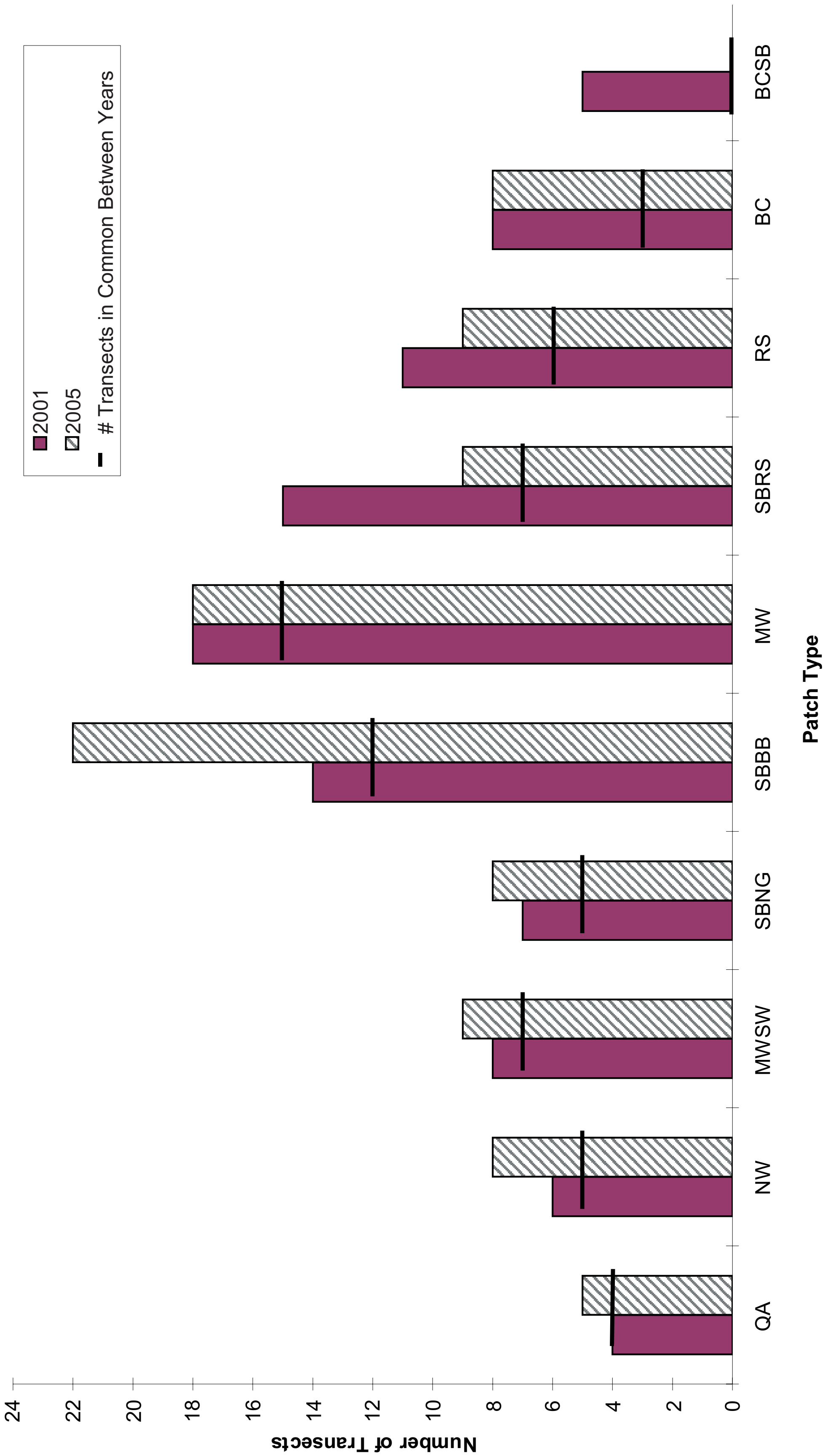


Figure H-2. Comparison of patch types derived from cluster analysis of nested frequency transects along Lee Vining Creek. Black horizontal lines represent the number of transects classified in the same patch type by both cluster analyses. For instance, every transect that was classified as quaking aspen in 2001 was also classified as quaking aspen in 2005. Note that an additional transect was classified as quaking aspen in 2005. See Figure H-4 for patch type definitions.

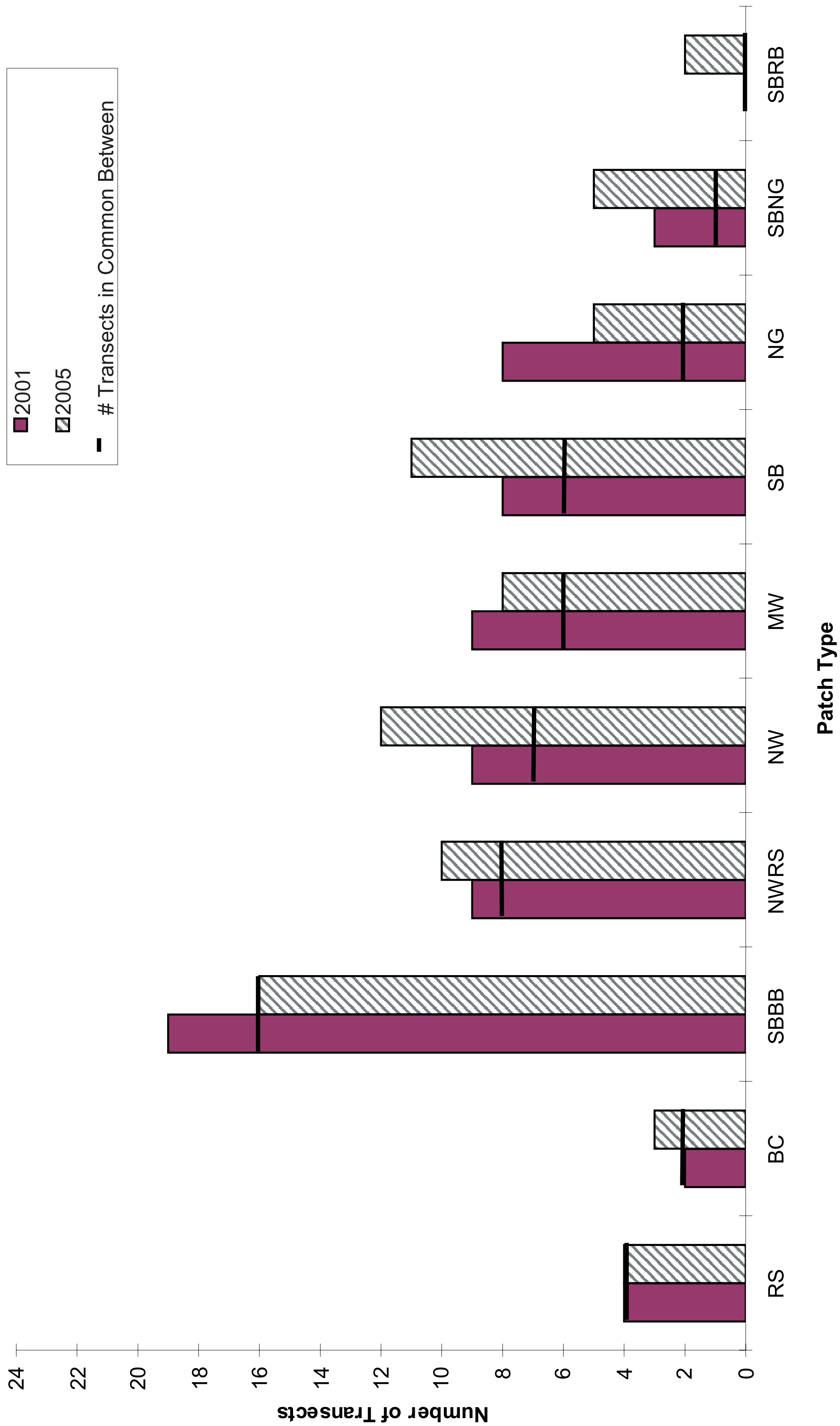


Figure H-3. Comparison of patch types derived from cluster analysis of nested frequency transects along Rush Creek. Black horizontal lines represent the number of transects classified in the same patch type by both cluster analyses. For instance, every transect that was classified as sagebrush-bitterbrush in 2005 was also classified as sagebrush-bitterbrush in 2001. The additional transects included in the 2001 sagebrush-bitterbrush patch were classified elsewhere in the 2005 analysis. See Figure H-6 for patch type definitions.

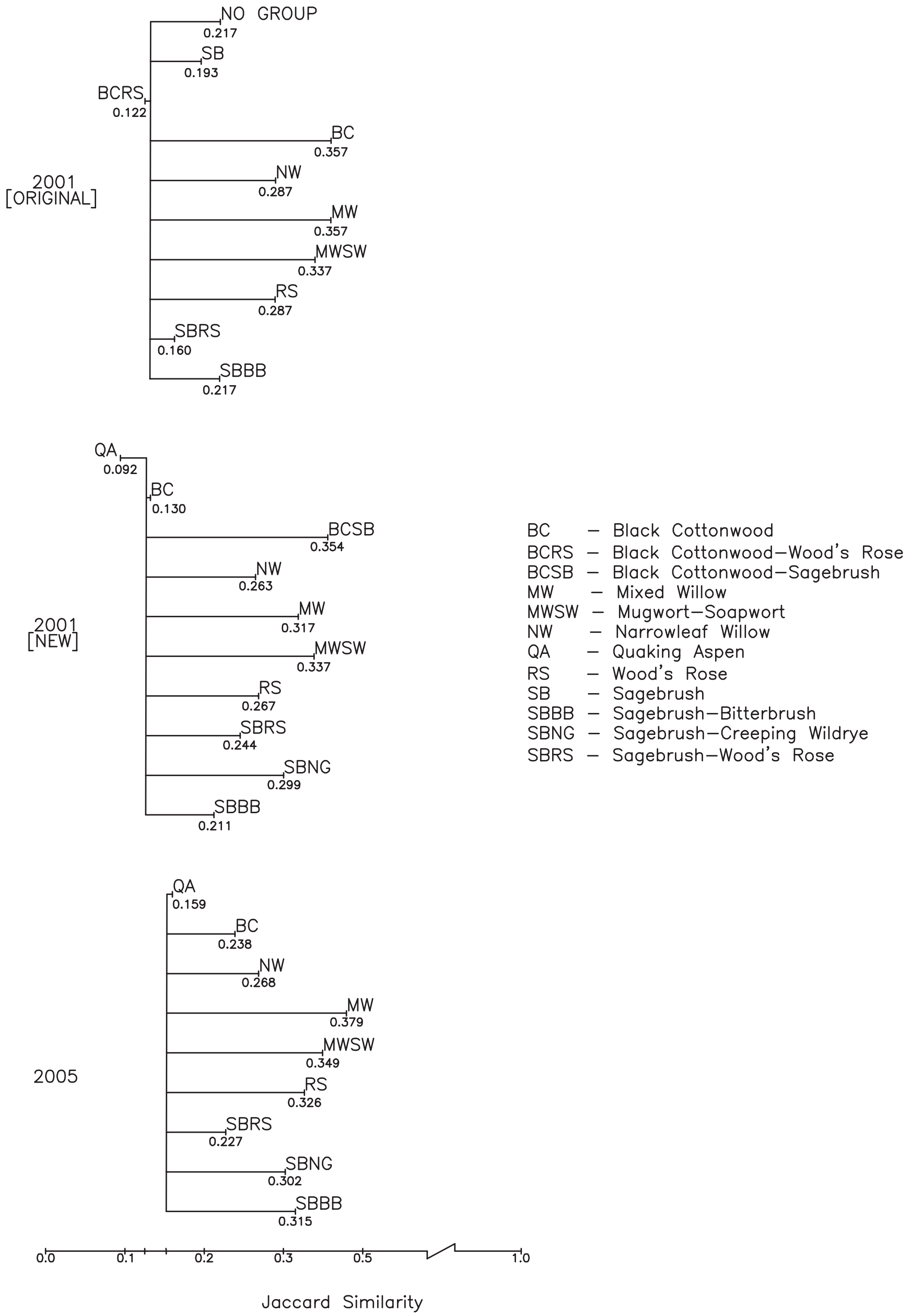


Figure H-4. Mean similarity dendrograms used to compare vegetation classifications between years for Lee Vining Creek. A dendrogram was produced for each year. Each branch represents a patch type resulting from cluster analysis. The length of each branch indicates the within-patch similarity; longer branches indicate patch types where the members are more similar to each other. Note the different lengths of black cottonwood patches in each dendrogram.

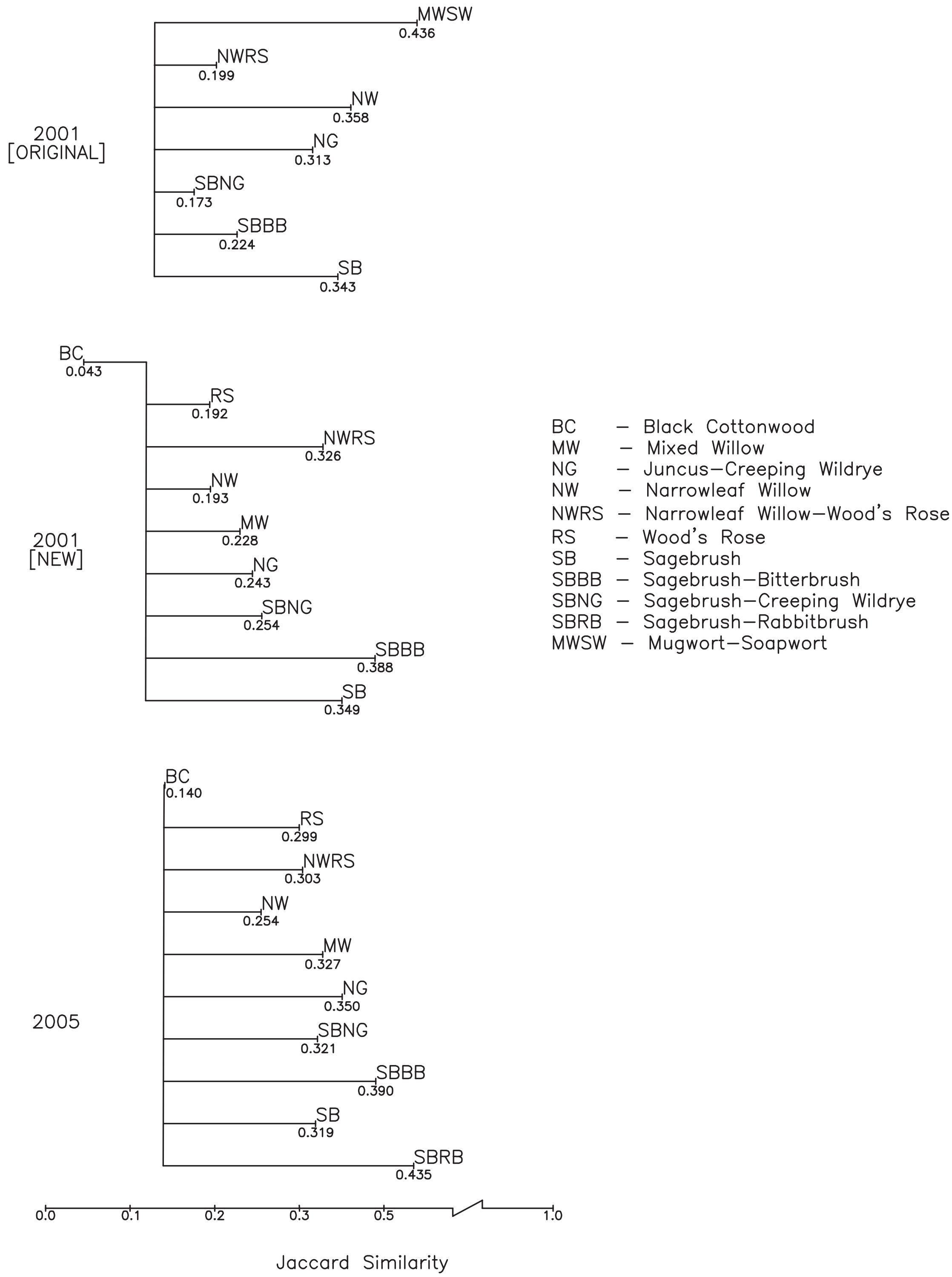


Figure H-5. Mean similarity dendrograms used to compare vegetation classifications between years for Rush Creek. A dendrogram was produced for each year. Each branch represents a patch type resulting from cluster analysis. The length of each branch indicates within-patch similarity; longer branches indicate patch types where the members are more similar to each other.

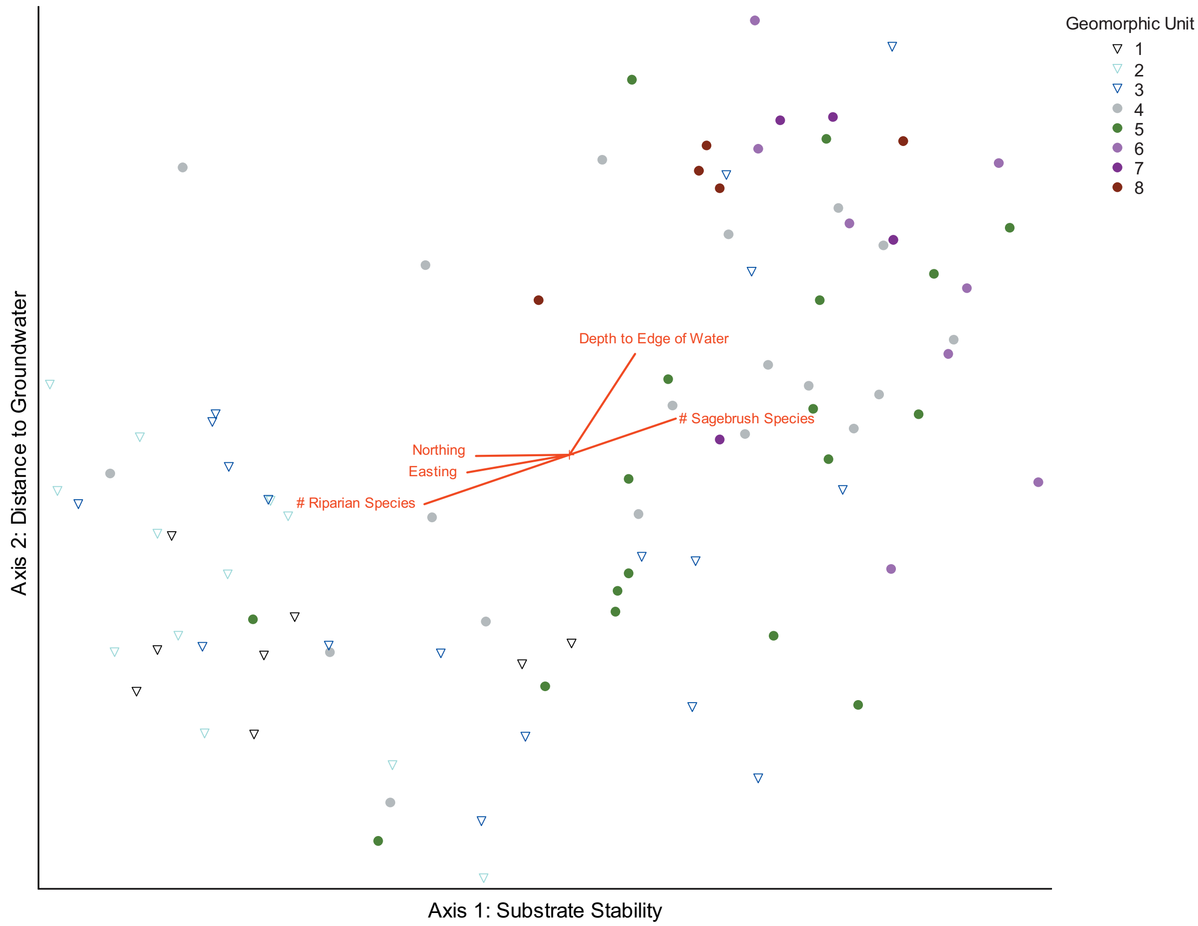


Figure H-6. Two of three environmental gradients revealed by indirect ordination of 96 transects on Lee Vining Creek. Transects are arranged such that transects with similar species composition and abundance are closer together, and transects with less similar species composition and abundance are farther apart. Transects are coded by the geomorphic unit upon which they occurred. Lines emerging from the center of the graph represent the measured environmental variables that were strongly correlated to the axes, which were used to interpret the environmental gradients. See text for complete explanation.

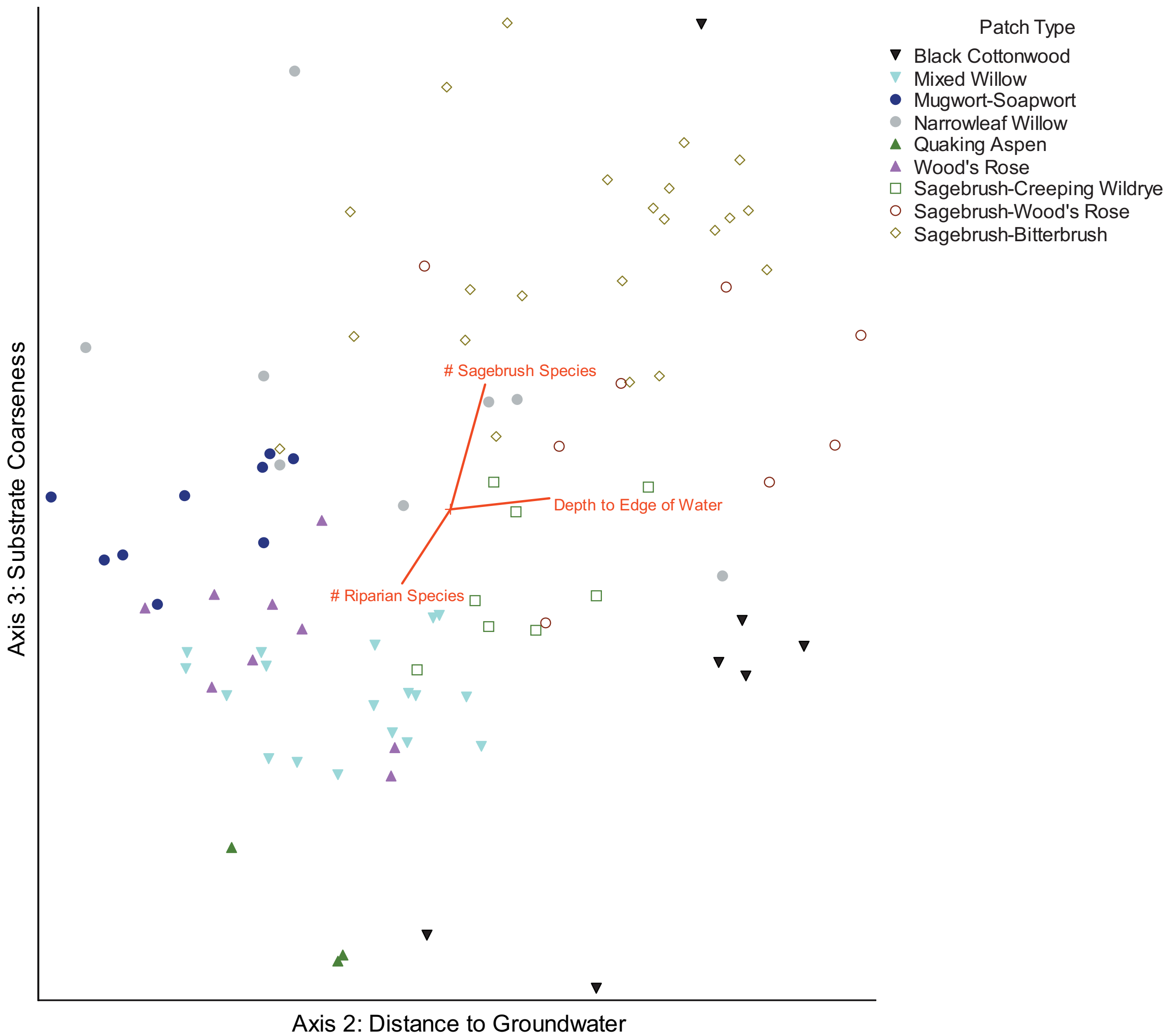


Figure H-7. Two of three environmental gradients revealed by indirect ordination of 96 transects on Lee Vining Creek. Transects are arranged such that transects with similar species composition and abundance are closer together, and transects with less similar species composition and abundance are farther apart. Transects are coded by the patch type in which they were classified by the 2005 cluster analysis. Lines emerging from the center of the graph represent the measured environmental variables that were strongly correlated to the axes, which were used to interpret the environmental gradients. See text for complete explanation.

APPENDIX I

Riparian Vegetation Structure Data

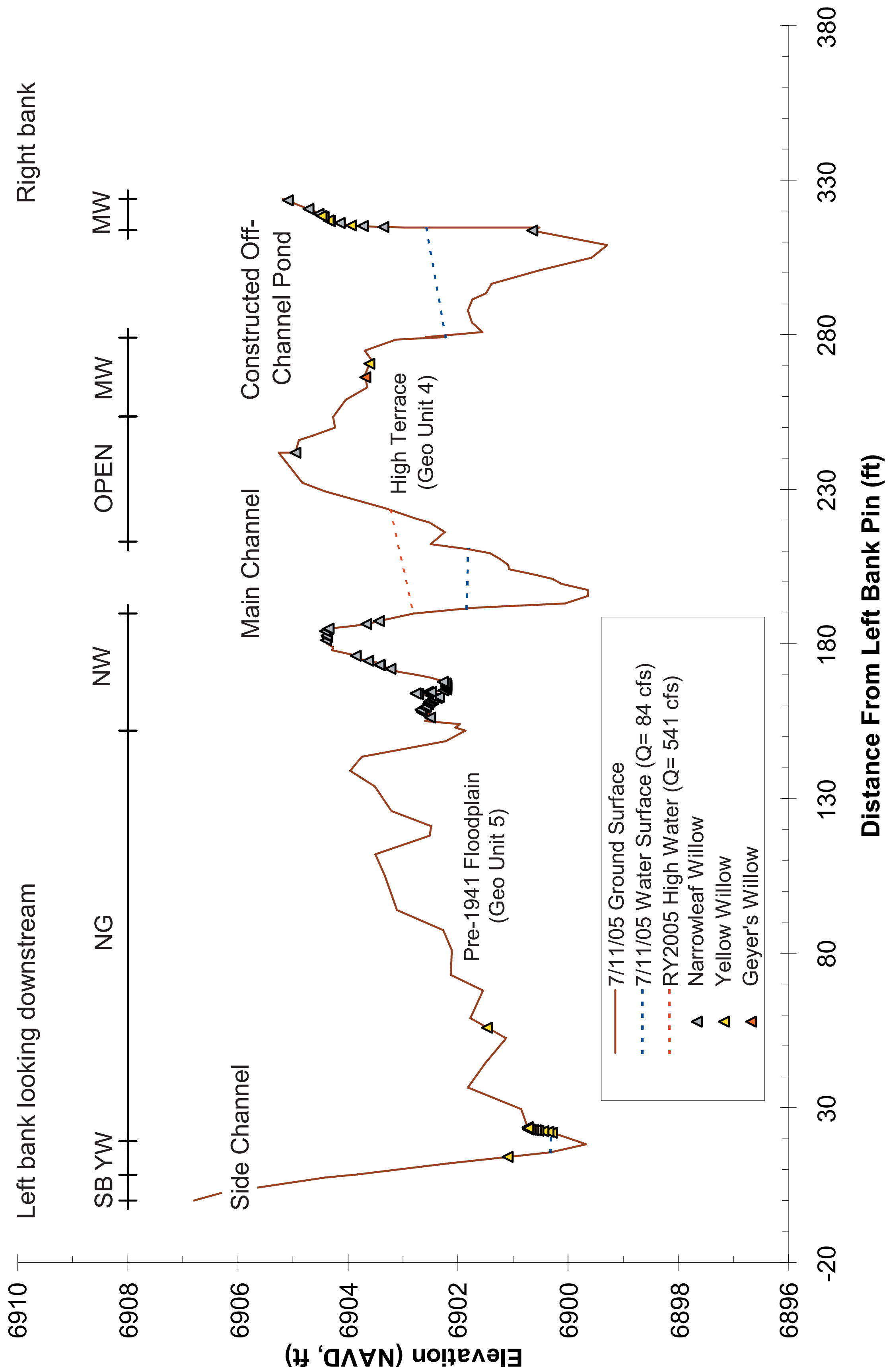


Figure I-1. Upper Rush Creek cross section 13+36 location and elevation of riparian hardwood plants along the valley wide band transect. The black line shows where each patch type occurred along the transect.

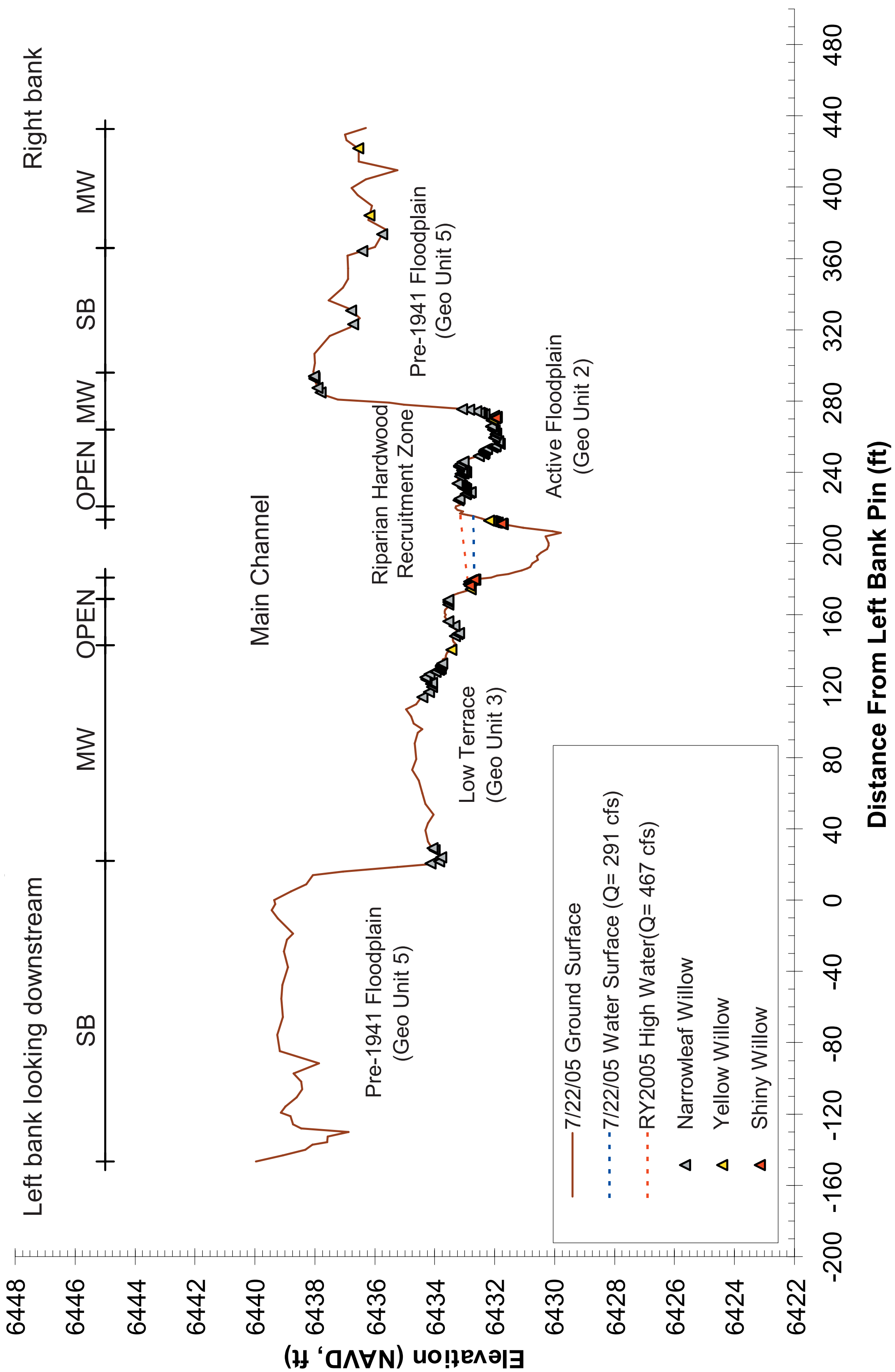


Figure I-2. County Road Rush Creek cross section 08+30 location and elevation of riparian hardwood plants along the valley wide band transect. The black line shows where each patch type occurred along the transect.

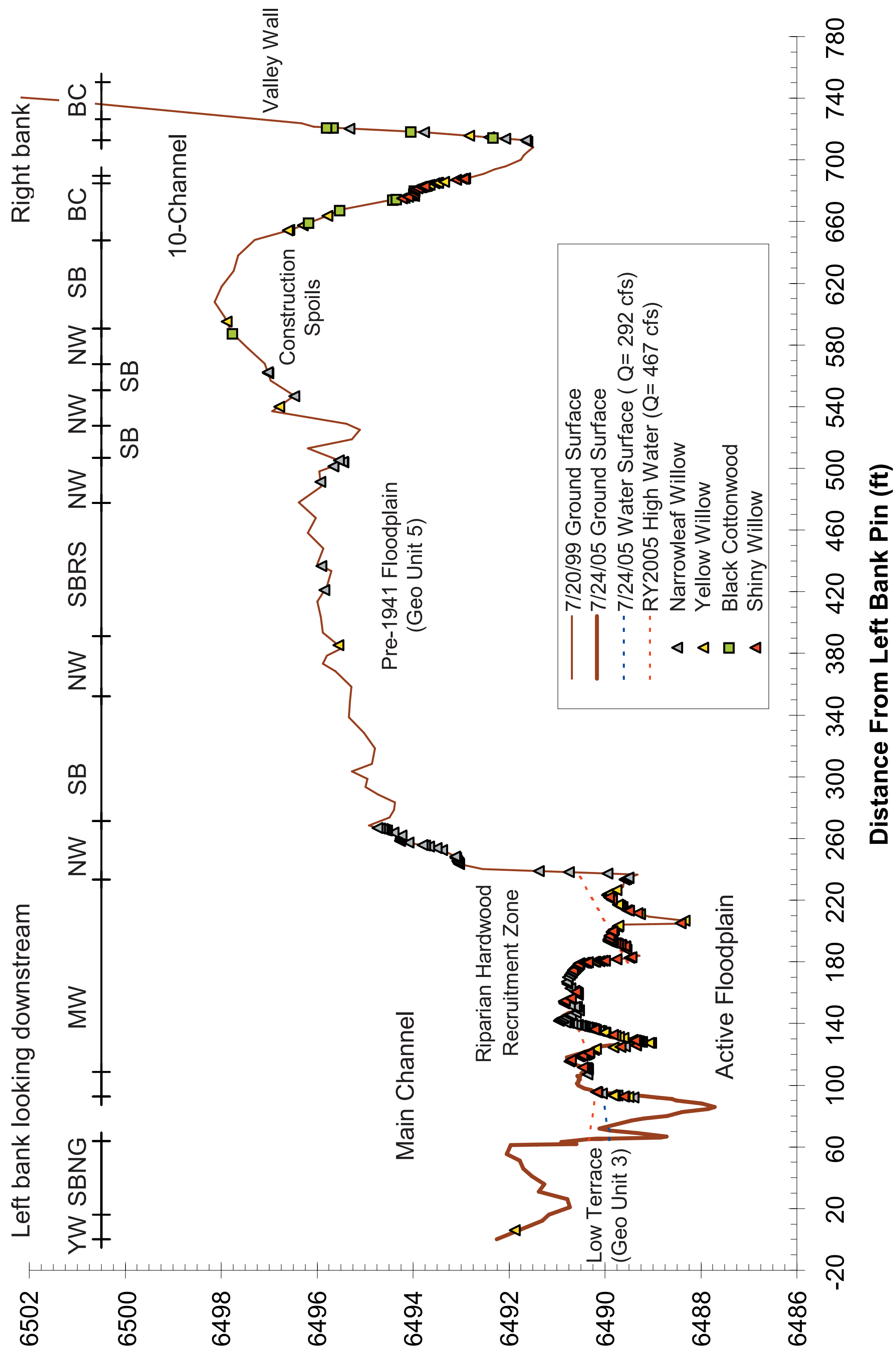


Figure I-3. Lower Rush Creek cross section 07+25 location and elevation of riparian hardwood plants along the valley wide band transect. The black line shows where each patch type occurred along the transect.

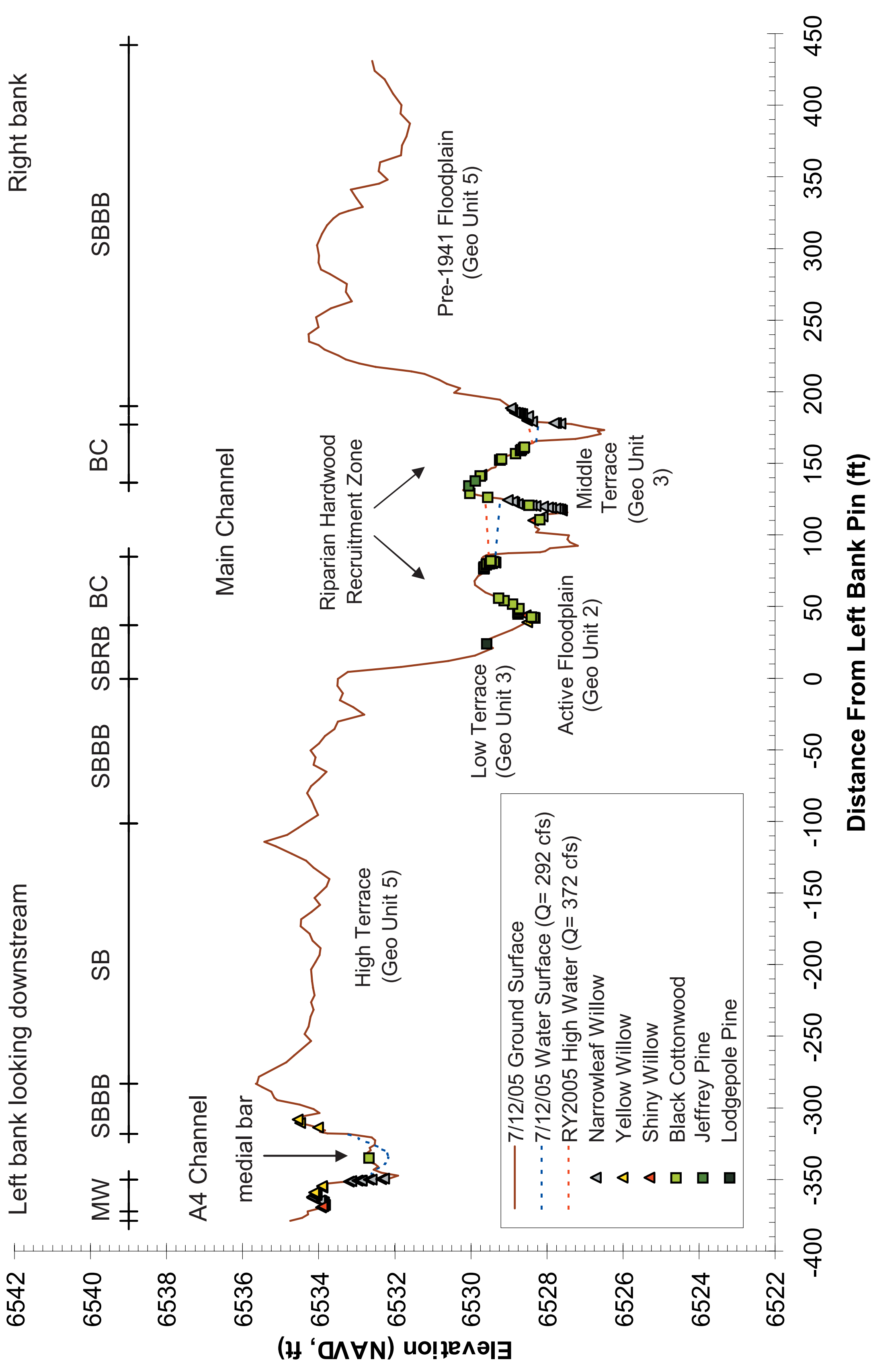


Figure I-4. Upper Lee Vining Creek cross section 10+44 location and elevation of riparian hardwood plants along the valley wide band transect. The black line shows where each patch type occurred along the transect.

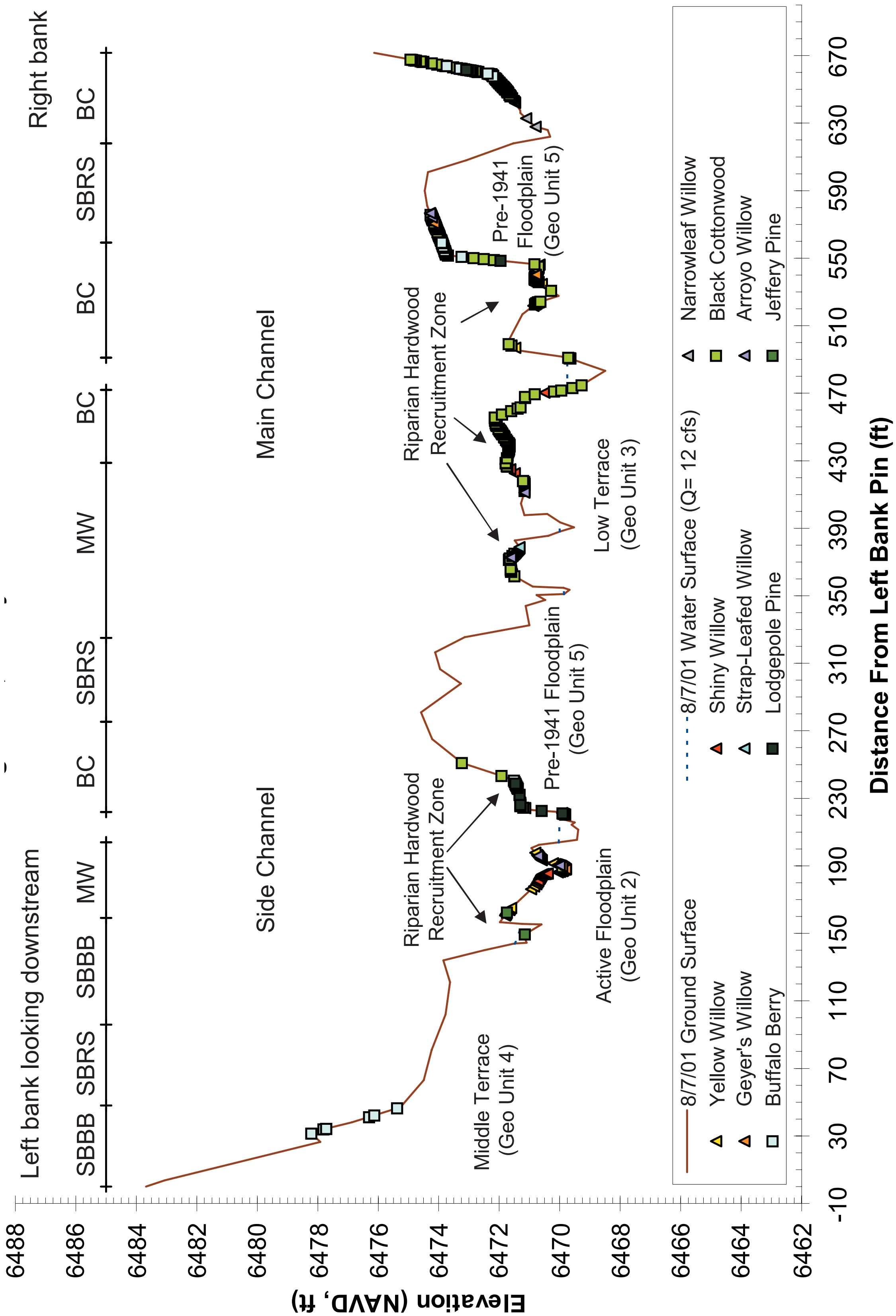


Figure I-5. Lower Lee Vining Creek Valleywide cross section 05+68 location and elevation of riparian hardwood plants along the valley wide band transect. The black line shows where each patch type occurred along the transect.

APPENDIX J

Riparian Phenology Data

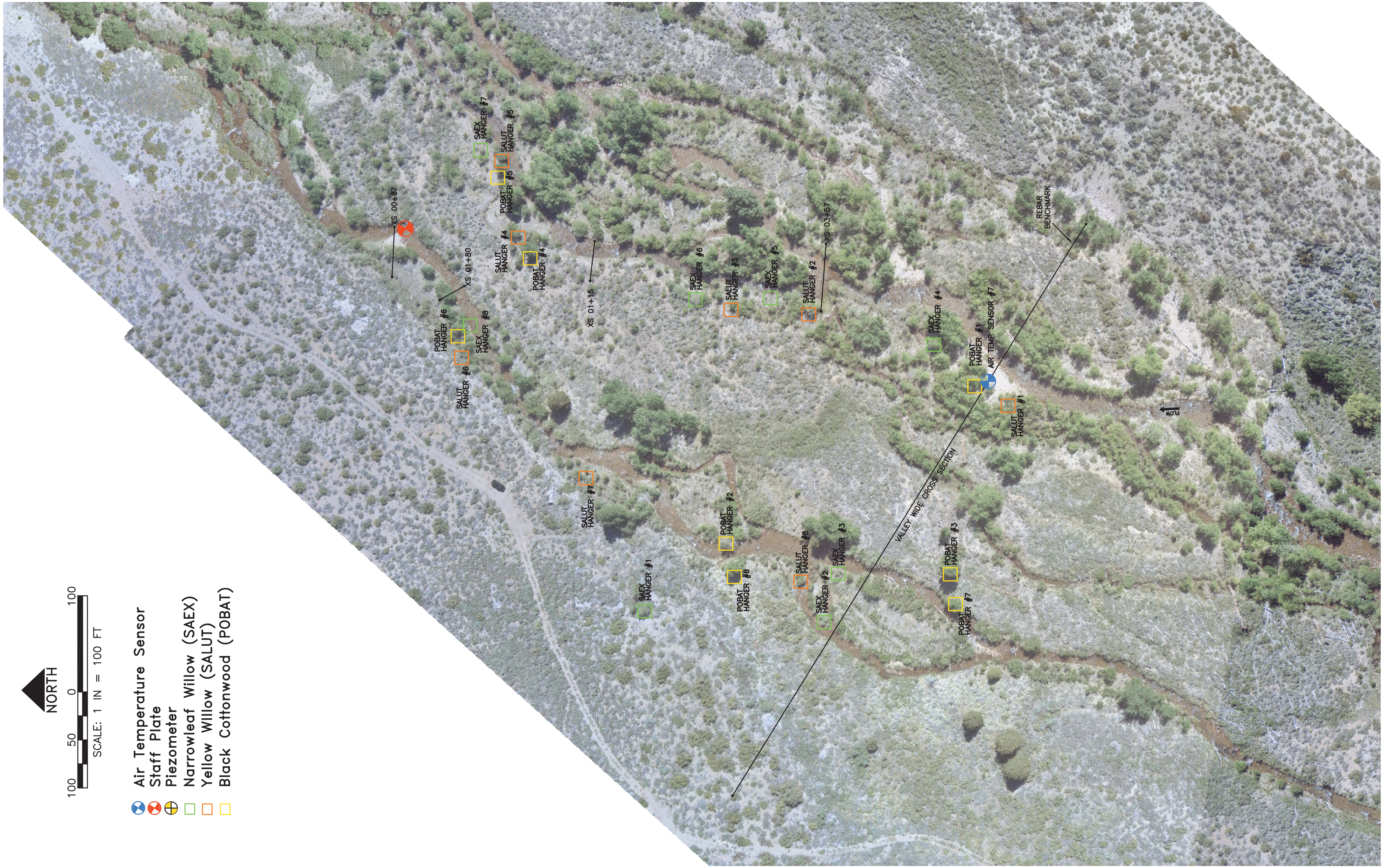


Figure J-1. Lower Lee Vining phenology study site at the lower planmap site.

Figure J-2. Upper Lee Vining phenology study site at the upper planmap site.

Figure J-3. Lower Rush Creek phenology study site at the 8 Channel.

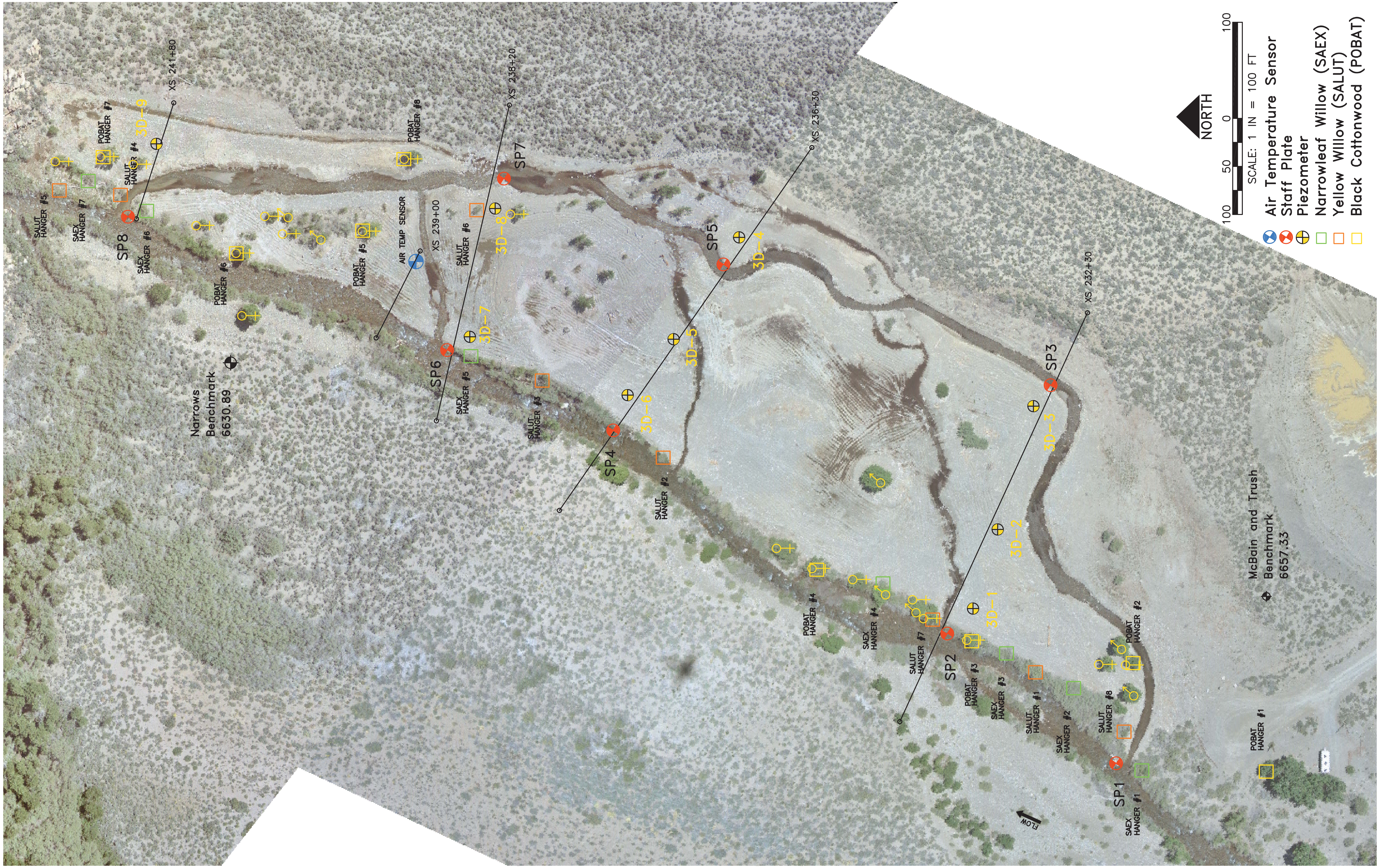


Figure J-4. Upper Rush Creek phenology study site at the 3D Channel.

Figure J-5. Seed trap in black cottonwood at the lower Rush Creek phenology site.

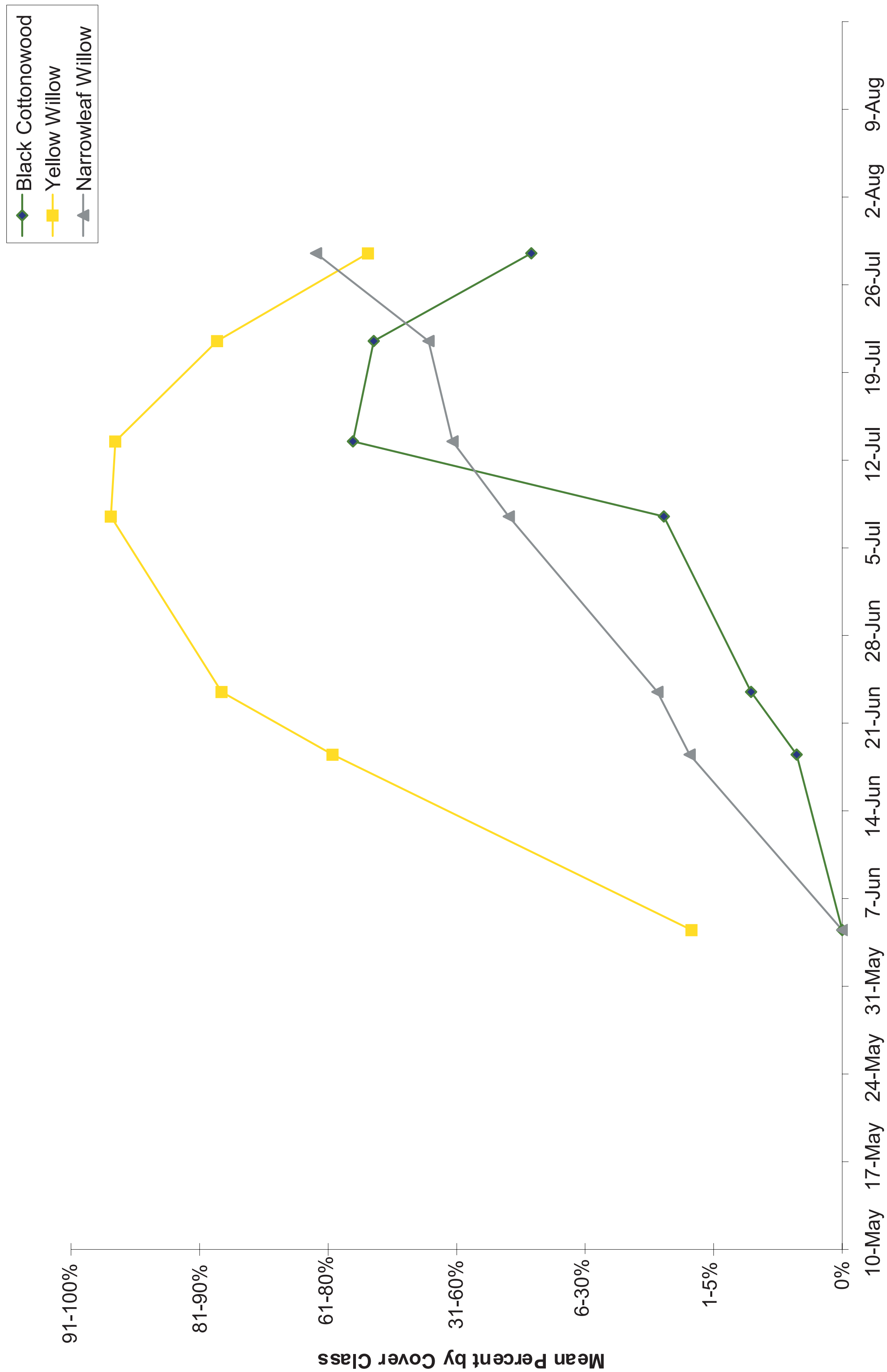


Figure J-6. Percent of yellow willow, narrowleaf willow and black cottonwood canopy area with catkins dispersing seeds during the 2005 growing season.

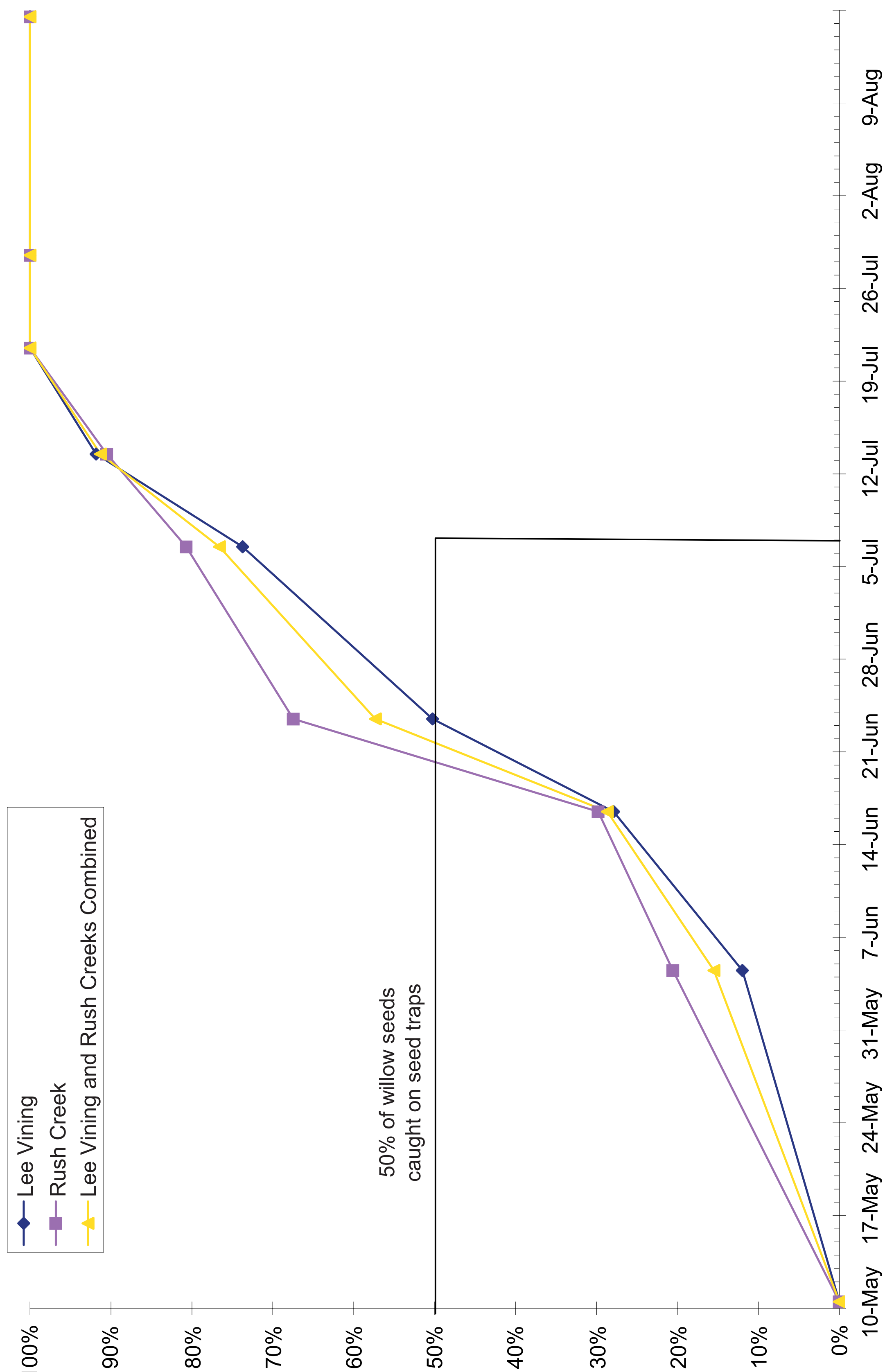


Figure J-7. Cumulative percent of willow seeds caught on seed traps during the 2005 growing season on Rush and Lee Vining creeks.

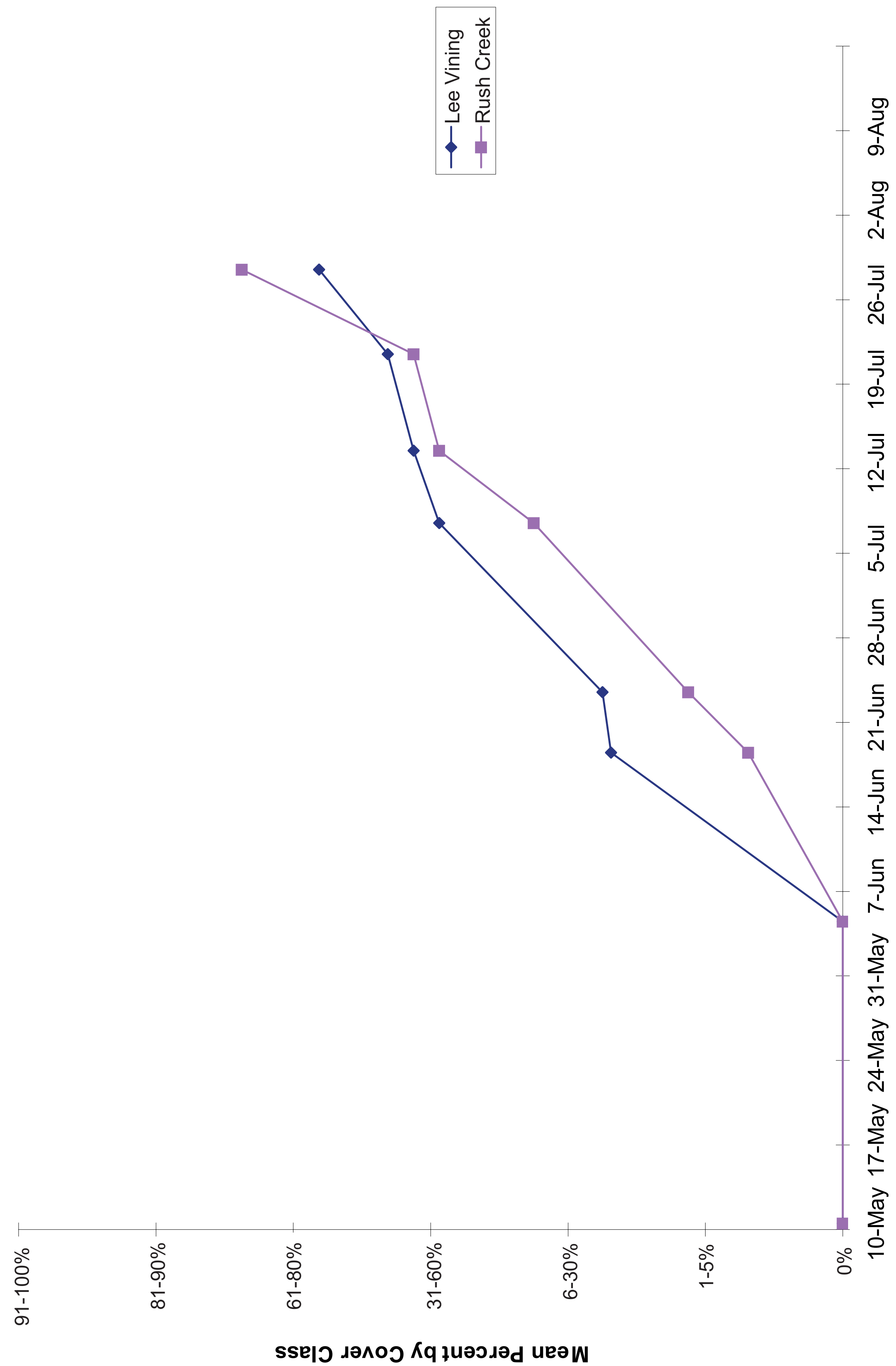


Figure J-8. Percent of yellow willow canopy area with catkins dispersing seeds during the 2005 growing season on Rush and Lee Vining creeks.

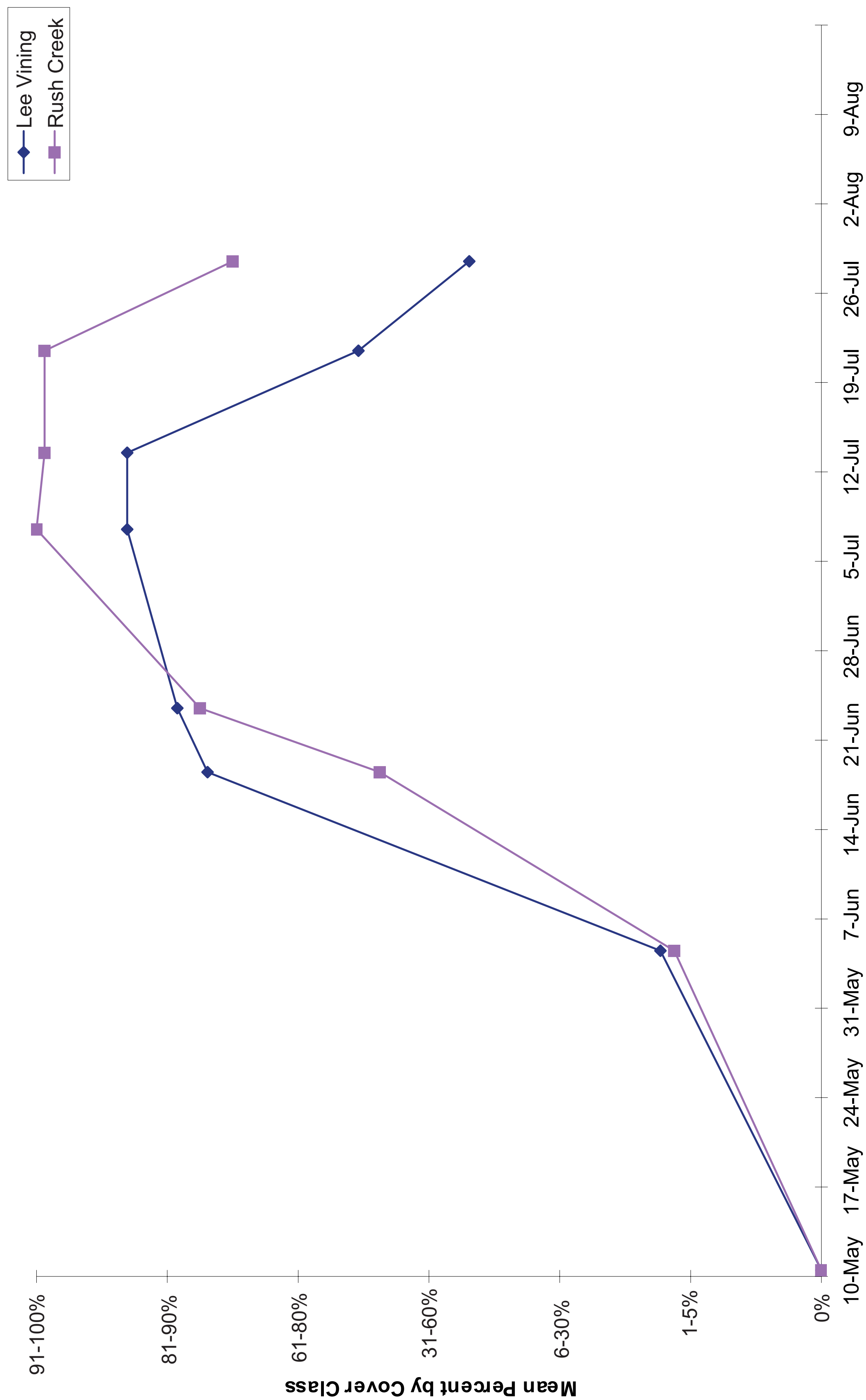


Figure J-9. Percent of narrowleaf willow canopy area with catkins dispersing seeds during the 2005 growing season on Rush and Lee Vining creeks.

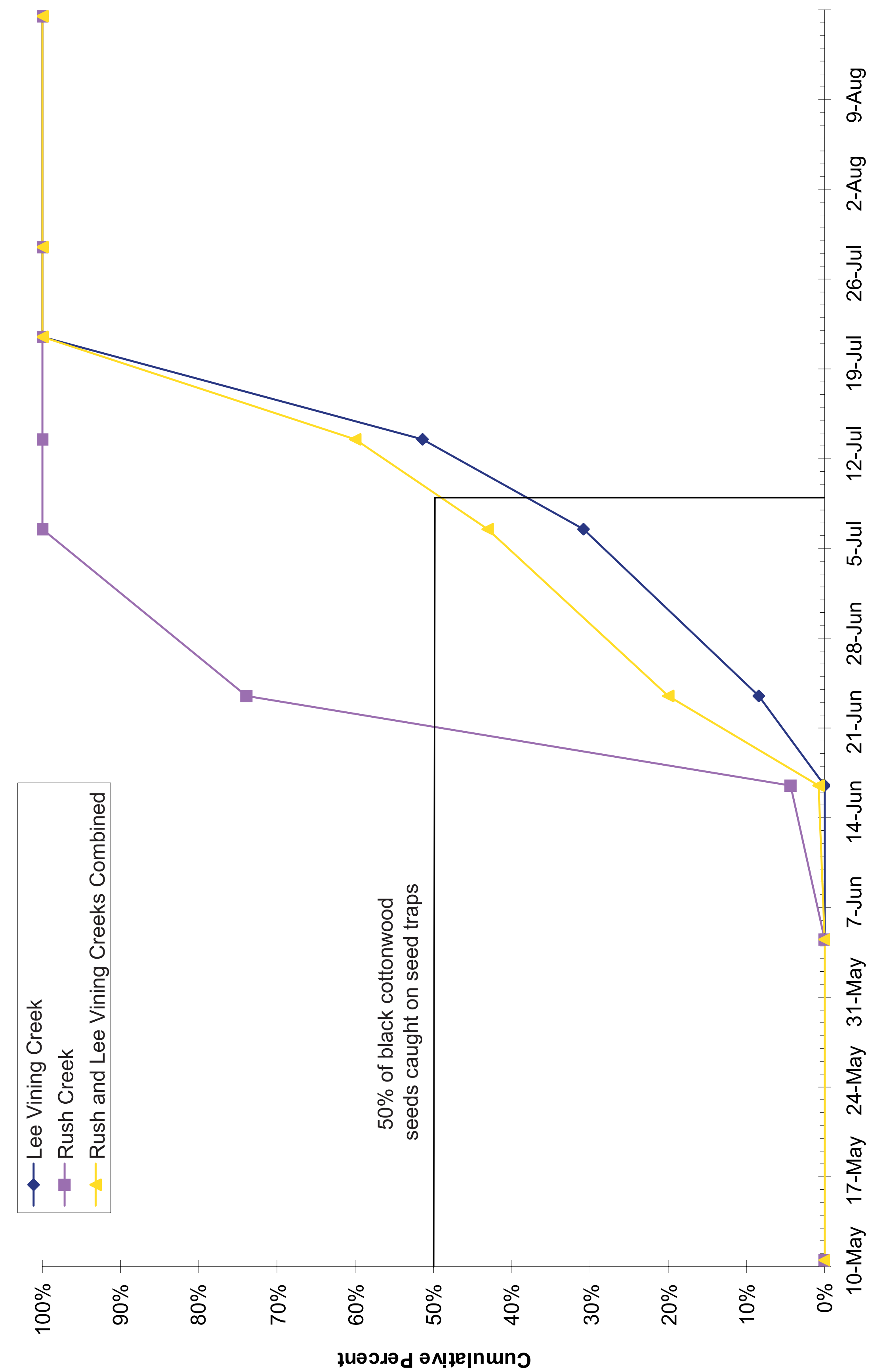


Figure J-10. Cumulative percent of black cottonwood seeds caught on seed traps during the 2005 growing season on Rush and Lee Vining creeks.

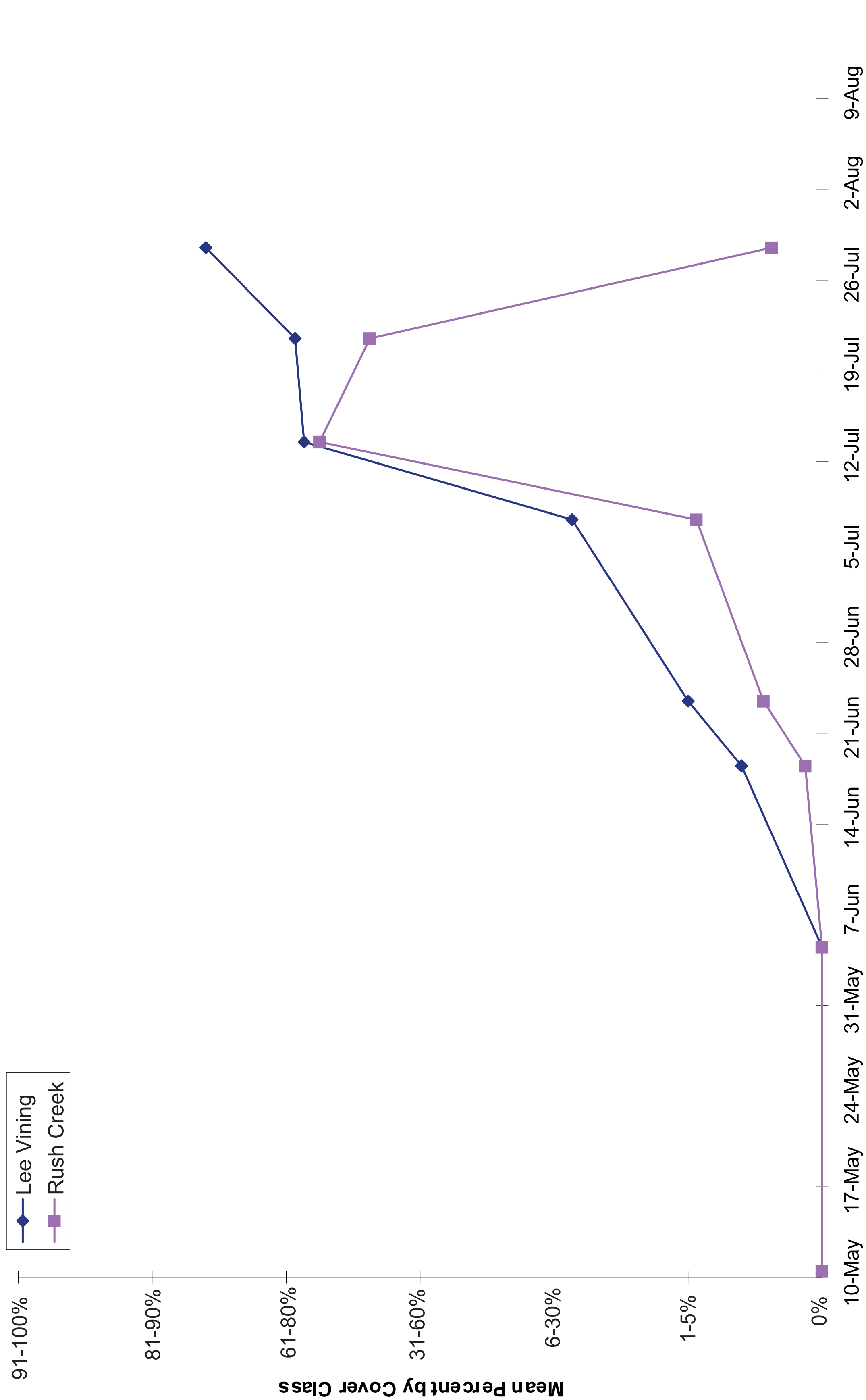


Figure J-11. Percent of black cottonwood canopy area with catkins dispersing seeds during the 2005 growing season on Rush and Lee Vining creeks.

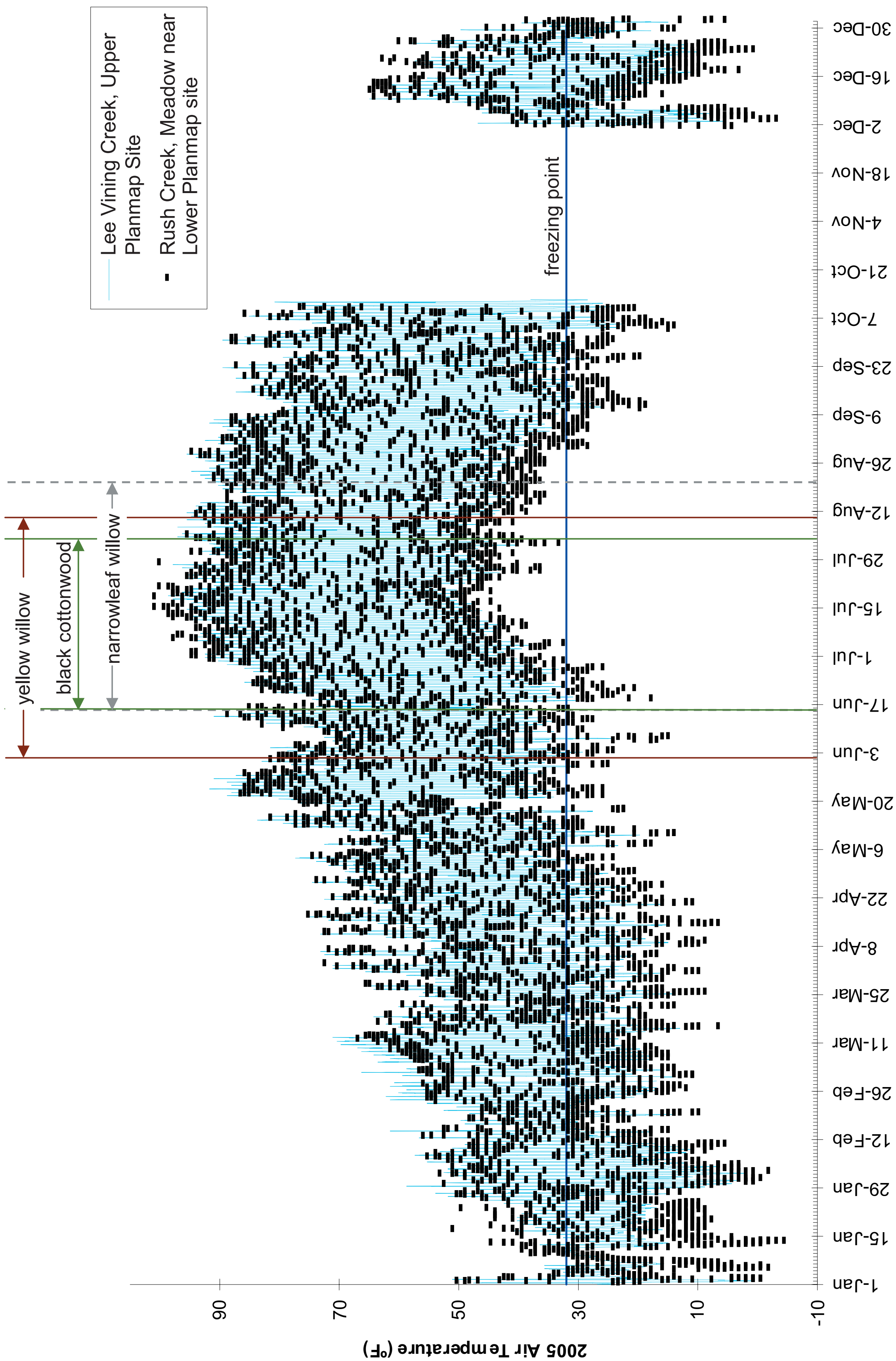


Figure J-12. Hourly air temperatures during the 2005 growing season in upper Lee Vining and Lower Rush Creeks, and seed dispersal periods for yellow willow, narrowleaf willow, and black cottonwood.

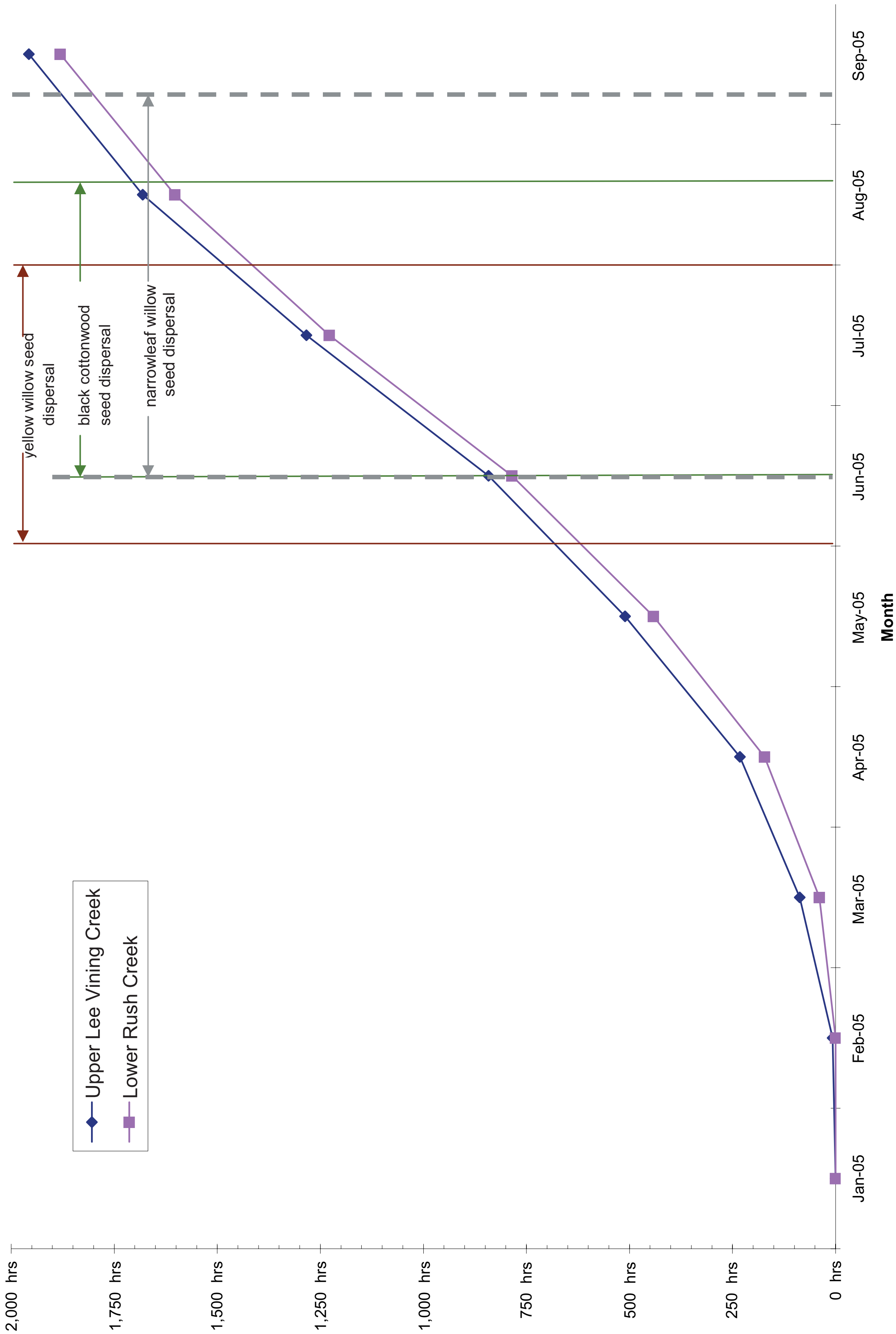


Figure J-13. Cumulative number of hours in each month during the growing season that air temperatures were over 60°F on Lee Vining and Rush creeks.

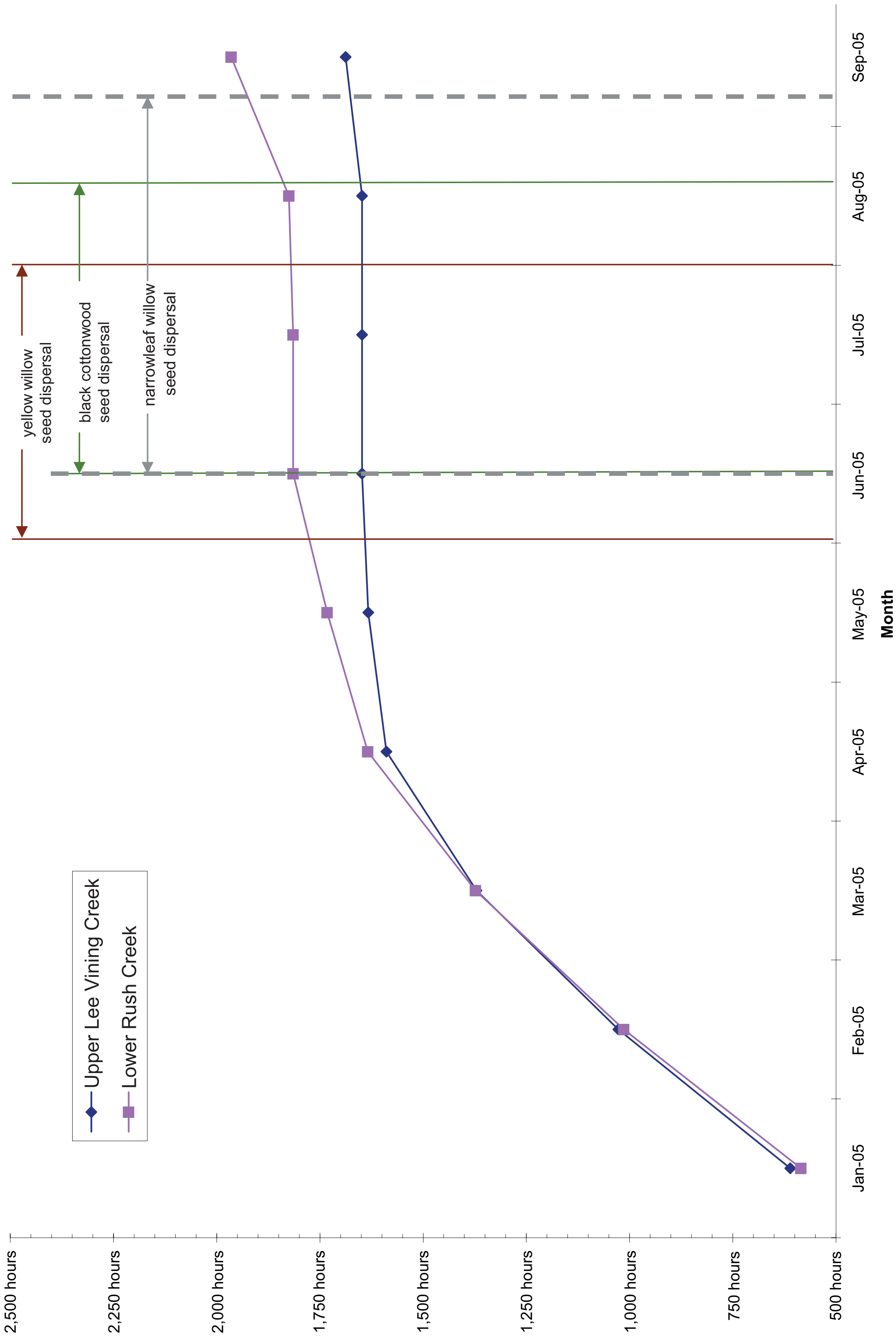


Figure J-14. Cumulative number of hours in each month during the growing season that air temperatures were under 32°F on Lee Vining and Rush creeks.

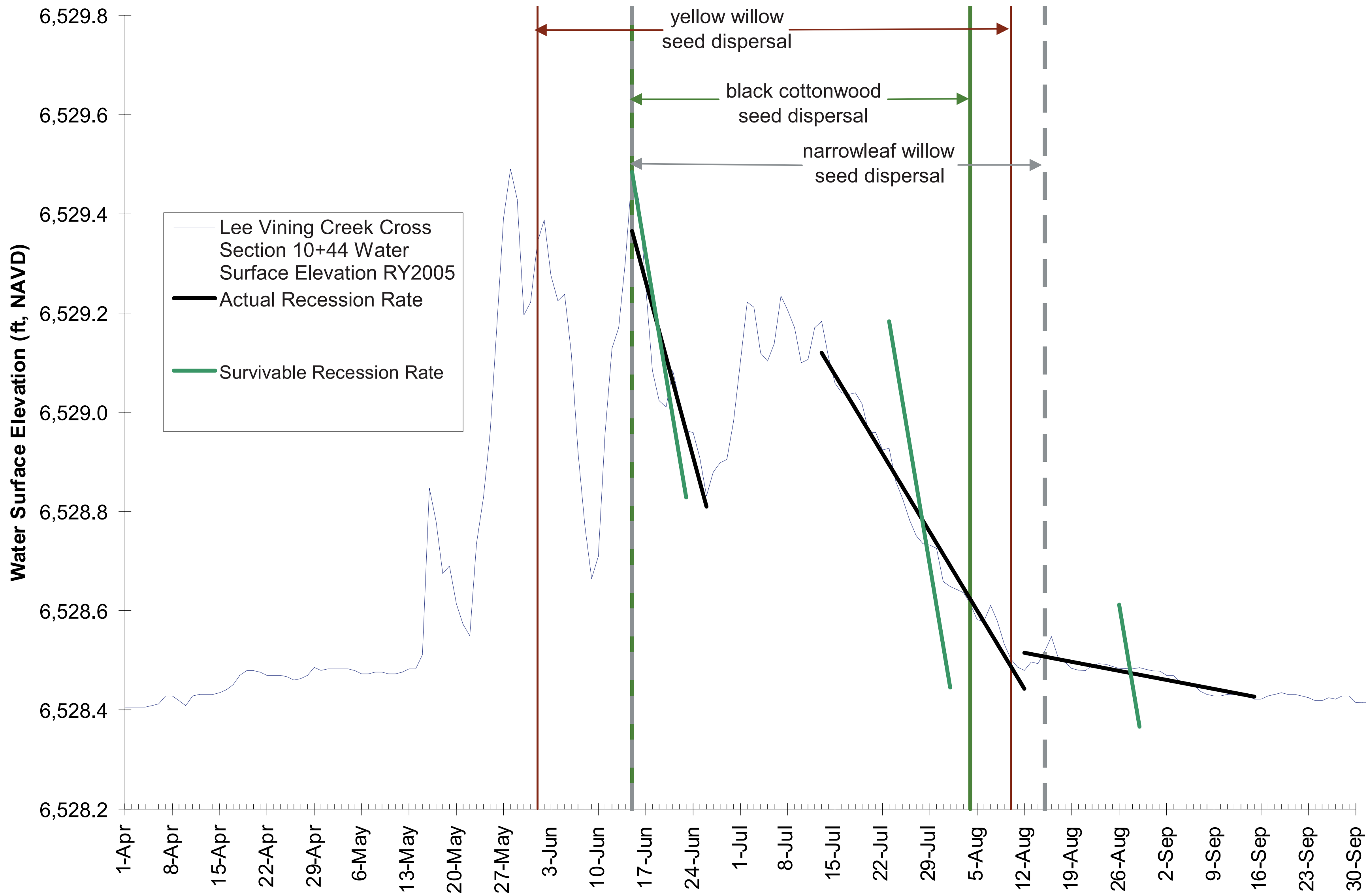


Figure J-15. RY2005 water surface elevations at upper Lee Vining Creek cross section 10+44 during and after seed dispersal periods for three riparian woody plants. Bold black lines indicate the slope of actual streamflow recession. Bold green lines indicate the survivable streamflow recession slope and are overlaid where the actual recession does not exceed survivability.

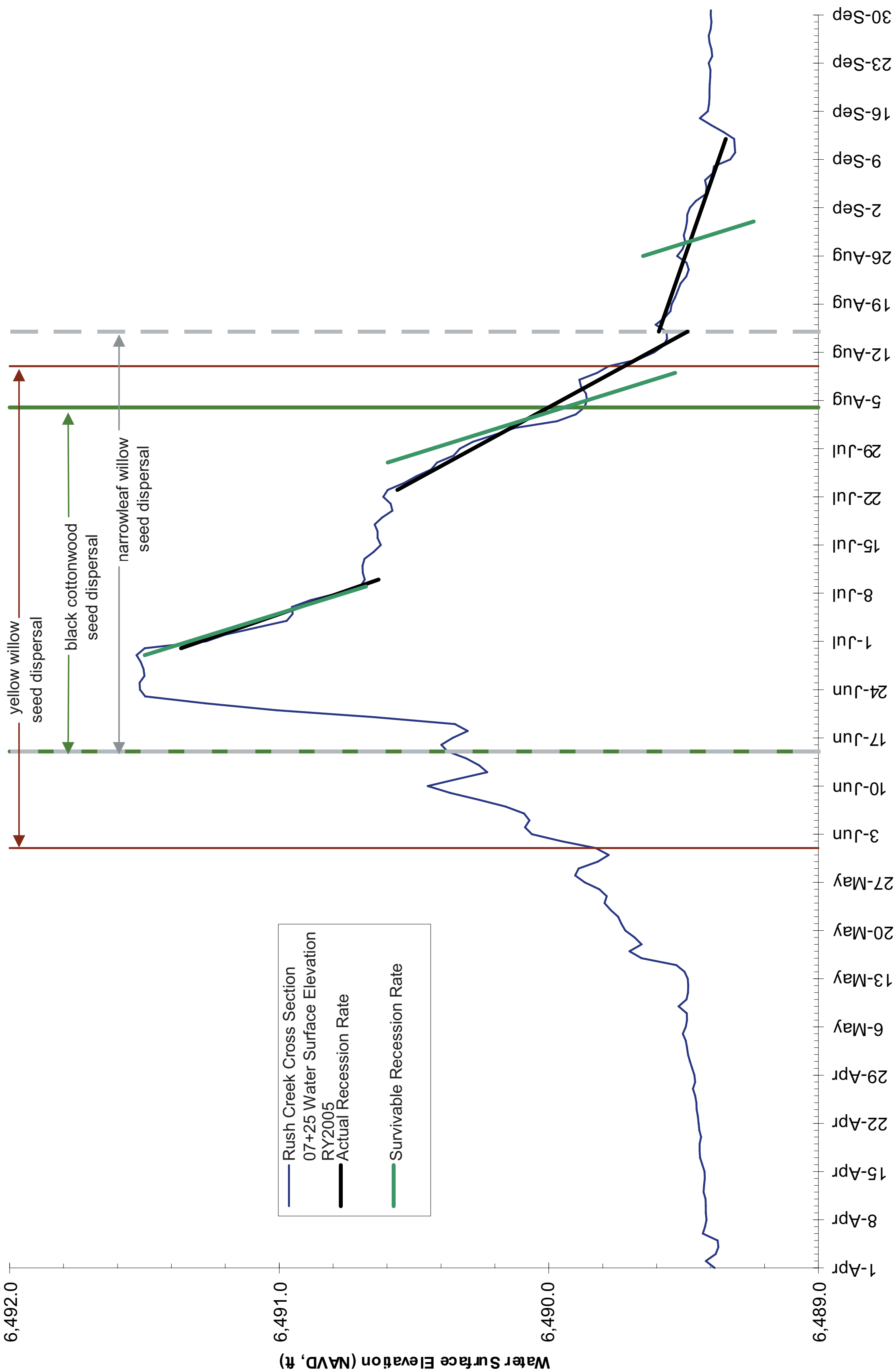


Figure J-16. RY2005 water surface elevations at Lower Rush Creek cross section 07+25 during and after seed dispersal periods for three riparian woody plants. Bold black lines indicate the slope of actual streamflow recession. Bold green lines indicate the survivable streamflow recession slope and are overlaid where the actual recession does not exceed survivability.

APPENDIX K

Jeffrey Pine and Black Cottonwood Planting Areas

BLACK COTTONWOOD AND JEFFERY PINE PLANTING RECOMMENDATIONS

We have monitored natural recovery of riparian hardwood and conifer species along Rush and Lee Vining Creeks since 1999. Given the slow recovery of some species in isolated patches within the riparian corridors (see Report Section 4), manually planting trees may be beneficial. A planting program would (1) accelerate recovery of woody riparian acreage to meet Termination Criteria, and (2) provide a future source of large woody debris (LWD) in the channel.

We developed a planting suitability model to assess suitable locations for planting black cottonwood and Jeffery pine. The model portrays the ground surface across the Rush and Lee Vining Creek valleys as a distance above a projected groundwater surface. A plane was projected out from the June 2003 main channel water surface elevation (captured in the 2003 air photos) across the valley floors, under the ground surface topography (i.e., the DTM surface) derived from photogrammetry. The projected water surface elevation was then subtracted from the ground surface to determine distance of the ground surface above the projected water surface plane. The primary model assumption is that the ground surface height above the water surface is an acceptable proxy for proximity to groundwater, a variable that often determines revegetation success or failure.

To assess whether existing black cottonwood and Jeffery pine patches exhibited a preferential pattern relative to predicted ground water distance, the 2003 vegetation maps identifying existing Jeffery Pine and black cottonwood patches were overlaid on the relative elevation model. The cumulative area of black cottonwood and Jeffery pine patches were summed relative to the distance to groundwater in 2 ft increments (i.e., zones). Most mapped black cottonwood patches occurred where the distance to groundwater was less than 4 ft (69.2% on Rush Creek; 83.4% on Lee Vining Creek), and 80.7% of the Jeffery pine patches occurred where the distance to ground water was less than 6 ft on Rush Creek and 59.8% of the Jeffery pine patches occurred between 0 and 8 feet of the predicted groundwater on Lee Vining Creek. We concluded that Jeffery pines could be planted within any of the patches selected for black cottonwoods and even a little higher in elevation. However, black cottonwood planting should be limited to patches with distance to ground water less than 4 ft.

A final combination of GIS layers was used in developing the planting suitability model. The 2003 vegetation maps classifying woody and herbaceous riparian, open and desert patches were overlaid onto the relative elevation model with slope and aspect layers derived in ERDAS (using prefabricated DTM analysis tools). Then using the combination of layers, the planting suitability model considered sites suitable using the following criteria:

- Distance from ground surface to projected water surface must be less than 6 ft for Jeffery pine or less than 4 ft for black cottonwood
- Aspect must range from 50-310 degrees (south facing) and 361 (flat areas)
- Slope ranges must be less than 8% (low gradient slopes and bottomlands)
- Existing open or desert patches (these are higher priority areas to convert to riparian woody vegetation).

Potential planting areas were located within the valley-wide riparian corridors of both Rush and Lee Vining creeks (maps showing planting areas available upon request). Priority was placed on open and desert patch types occurring within 4 ft and 6 ft of predicted groundwater. If the acreage available to plant using desert and open patches was still not sufficient to meet the Termination Criteria, riparian herbaceous patches within the same distances to groundwater were considered. In some reaches of Lee Vining and Rush Creek, there were not enough desert, open, or riparian patches in close proximity to groundwater that, if planted successfully, could meet the Termination Criteria. In these reaches other methods may be necessary to meet riparian acreage Termination Criteria.

There are additional considerations in terms of selecting Jeffrey pine for planting. The acreage planted with Jeffery pines could be used as an approach to meet deficits in the Termination Criteria for either creek; however those trees will require 10 to 15 years before they are accounted in the riparian acreage resulting from our field maps. Planted cottonwood patches would likely be accounted much sooner, as quickly as 5-7 years after planting. Furthermore the Point Reyes Bird Observatory (PRBO) has expressed concerns about Jeffery Pine plantings in their reports. They have observed that within the Eastern Sierra, riparian sites with a higher percentage Jeffrey Pine cover had lower breeding bird diversity, and sites with higher tree species richness (number of tree species) had higher bird diversity. They conclude that some pines in the riparian zone are beneficial, but that there is a threshold of pine encroachment that, when passed, begins to reverse the benefits that pine may provide. (Heath and Ballard 2003).

The inclusion of Jeffery pines in the corridor would increase structural diversity, but should not replace other woody riparian species as the sole dominant species in the canopy. Because of concerns regarding over-planting of Jeffery pine, we recommend Jeffery pine plantings be restricted to patches with 4-6 ft predicted distance to groundwater. Constraining the Jeffery pine plantings to these higher elevation patches (i.e., the 4-6 ft zone) will result in a much smaller area available for planting, and will provide an ecotone between black cottonwood plantings and Jeffrey pine plantings which could be beneficial as trees mature. Furthermore, the density of Jeffery pine plantings next to the stream should be minimized to allow greater structural diversity through natural recruitment of riparian hardwood species. Conifers are becoming more apparent in the riparian canopies of Rush and Lee Vining creeks. After fulfilling Order 98-05 for Jeffrey pine planting requirements, additional planting should be reviewed to assess long term ecological benefits. There should be no restrictions on the locations of cottonwood planting within the patches prioritized by our model.

Summary of Planting Recommendations By Reach

The planting suitability model selected black cottonwood and Jeffery pine planting locations based solely on the criteria described above (i.e., distance to groundwater, aspect, slope, etc.). Planting locations were summed up within each reach (Table K1). Additional future prioritization for planting location may be based on a reach-by-reach evaluation of the riparian Termination Criteria

Heath, S. K. and Ballard, G. 2003. Patterns of Breeding Songbird Diversity and Occurrence in Riparian Habitats of the Eastern Sierra Nevada. *in* California Riparian Systems: Processes and Floodplain Management, Ecology, and Restoration, P. M. Faber (Ed.), Riparian Habitat and Floodplains Conference Proceedings, Riparian Habitat Joint Venture, Sacramento, CA. pp 21 – 34.

Table K-1. Comparison of black cottonwood and Jeffrey pine planting suitability areas within reaches of the Rush and Lee Vining Creek to the woody riparian vegetation coverage established in the termination criteria, 1989 acreages quantified by JSA, 1999 acreages and 2004 acreages quantified by McBain and Trush.

RUSH CREEK								
	Woody Riparian Vegetation (Acres)							
Stream Segment	***Termination Criteria (SWRCB D1631)***	***1989 Vegetation (JSA 1993)***	***1999 Vegetation (McBain & Trush)***	***2004 Vegetation (McBain & Trush)***	***Acreage needed to meet Termination Criteria***	***Acreage available to plant black cottonwood***	***Acreage available to plant Jeffrey pine***	***Total Acreage recoverable through woody plantings***
1	6.2	1.7	N/A	1.9	4.3			
2	5.0	5.9	5.6	6.5	CRITERIA MET	0.1 acres	0.1 acres	0.2 acres
3a	21.5	12.7	13.2	14.3	7.2 acres	5.1 acres	1.2 acres	6.3 acres
3b	2.9	0.1	1.3	2.8	0.1 acres	4.4 acres	1.2 acres	5.6 acres
3c	11.2	4.1	8.4	9.7	1.5 acres	3.2 acres	2.4 acres	5.6 acres
3d	10.0	4.0	4.0	5.2	4.8 acres	3.0 acres	1.3 acres	4.3 acres
4a	26.3		22.5	26.2	CRITERIA MET	4.1 acres	3.4 acres	7.5 acres
4b	80.2 $\boxed{145.2}$	90.0	61.4 $\boxed{113.4}$	66.8 $\boxed{124.3}$	13.4 acres $\boxed{-20.8}$	21.1 acres $\boxed{26.7}$	3.4 acres $\boxed{7.1}$	24.5 acres $\boxed{33.8}$
4c	38.7		29.5	31.3	7.4 acres	1.4 acres	0.4 acres	1.8 acres
5a	37.8	11.0	26.4	29.3	8.5 acres	3.8 acres	2.5 acres	6.2 acres
5b	N/A	*combined with 5a*	4.6	7.7	N/A	1.3 acres	0.0 acres	1.3 acres

LEE VINING CREEK								
	Woody Riparian Vegetation (Acres)							
Stream Segment	***Termination Criteria (SWRCB D1631)***	***1989 Vegetation (JSA 1993)***	***1999 Vegetation (McBain & Trush)***	***2004 Vegetation (McBain & Trush)***	***Acreage needed to meet Termination Criteria***	***Acreage available to plant black cottonwood***	***Acreage available to plant Jeffrey pine***	***Total Acreage recoverable through woody plantings***
1	20.0	19.8	N/A	27.9	CRITERIA MET	N/A	N/A	N/A
2a	30.0	13.4	N/A	16.7	3.1 acres	N/A	N/A	N/A
2b	*Combined with 2a*	10.9	10.6	10.2	*Combined with 2a*	0.2 acres	0.0 acres	0.3 acres
3a	22.2	6.9	12.5	12.5	9.7 acres	3.8 acres	0.3 acres	4.1 acres
3b	32.9	7.5	24.6	25.0	7.9 acres	5.3 acres	1.4 acres	6.7 acres
3c	4.0	3.3	5.5	5.7	CRITERIA MET	1.1 acres	0.6 acres	1.6 acres
3d	N/A	8.6	12.8	13.2	N/A	1.1 acres	1.0 acres	2.0 acres

APPENDIX L

Side Channel Profiles

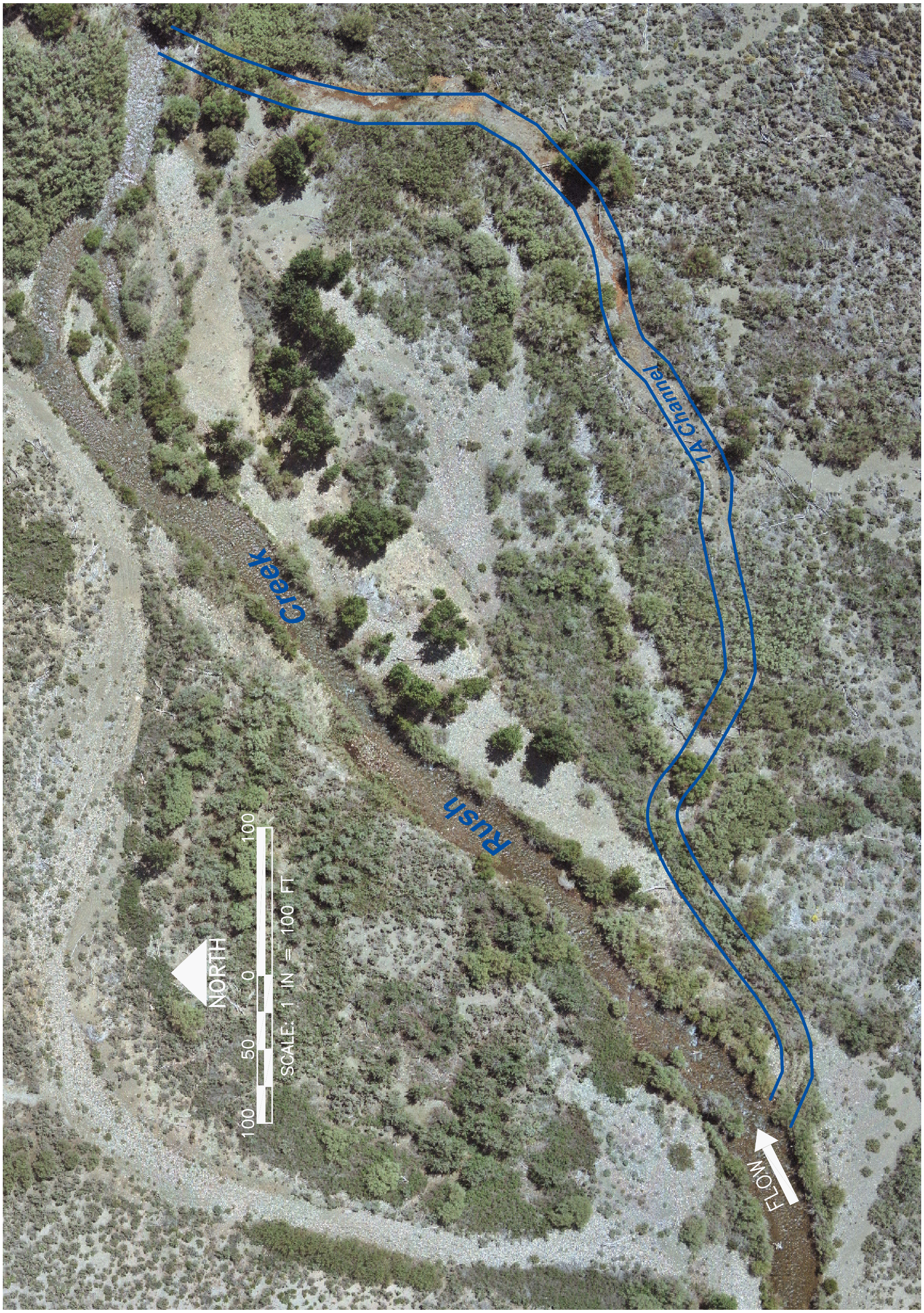
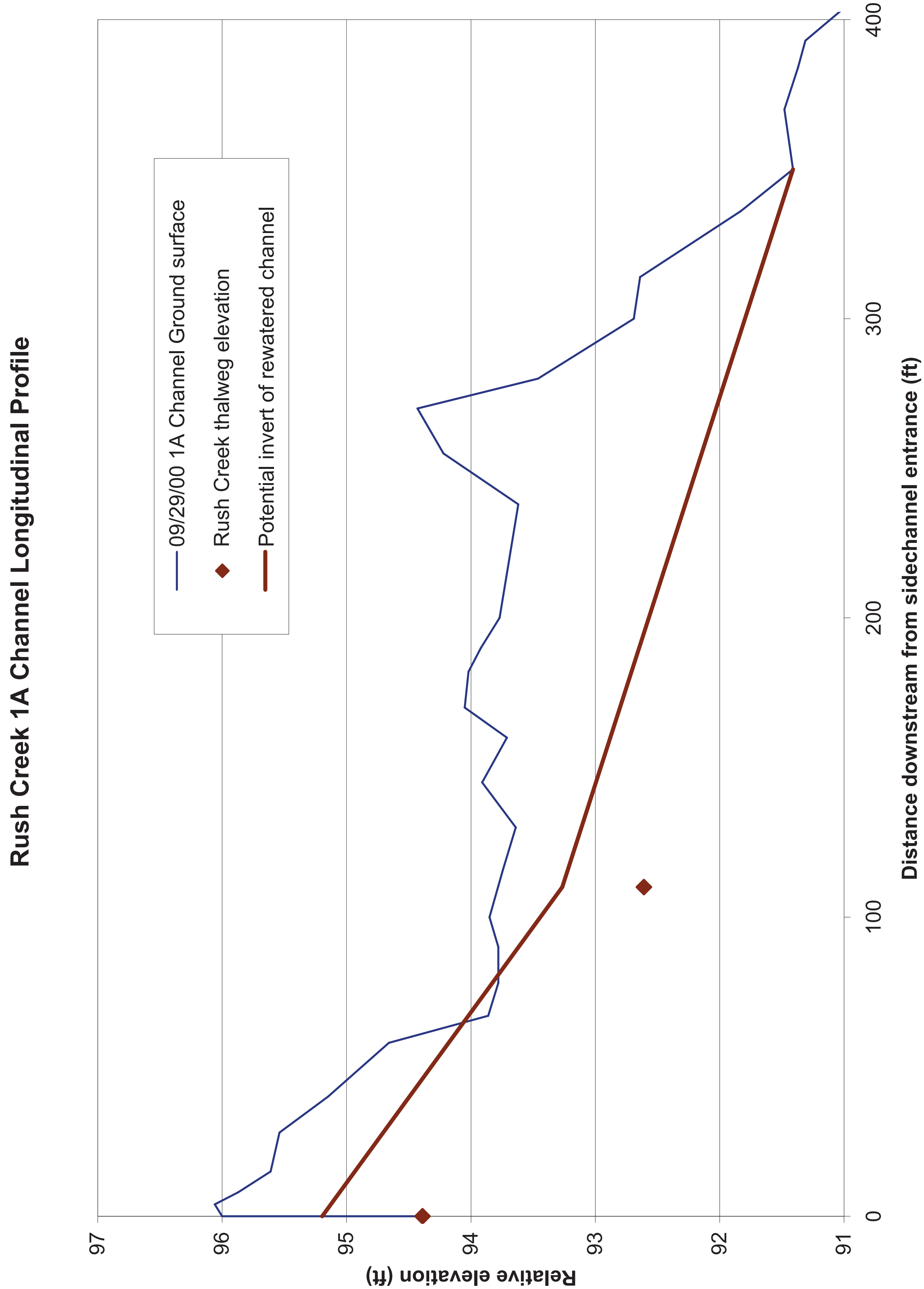


Figure L1. Location of Rush Creek Channel 1A below the Narrows in 2003 aerial photograph, and longitudinal profile surveyed 9-29-00.


Rush Creek 1A Channel Longitudinal Profile
09/29/00 1A Channel Ground surface
Rush Creek thalweg elevation
Potential invert of rewatered channel
Relative elevation (ft)
97
96
95
94
93
92
91
Distance downstream from sidechannel entrance (ft)
0
100
200
300
400

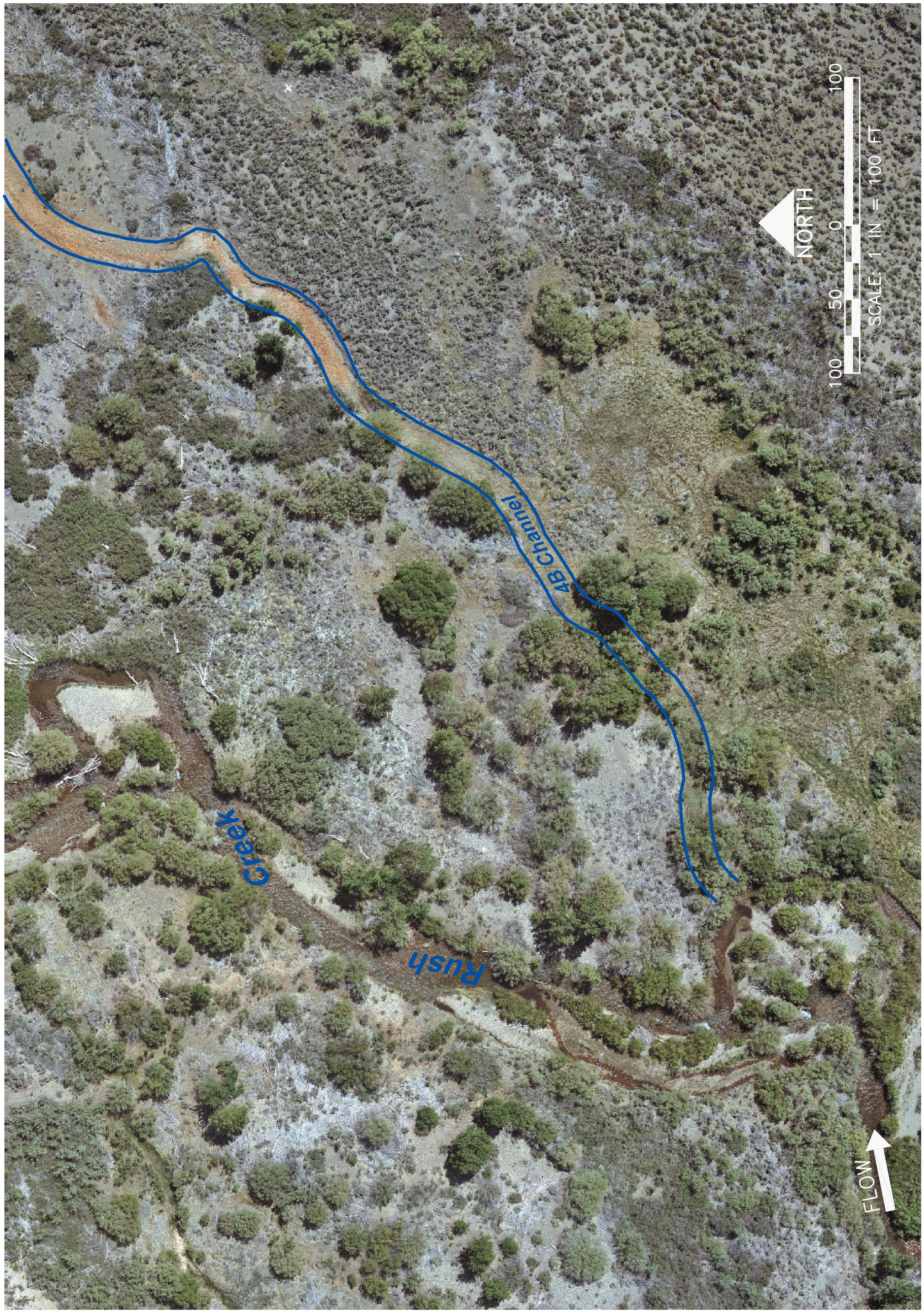
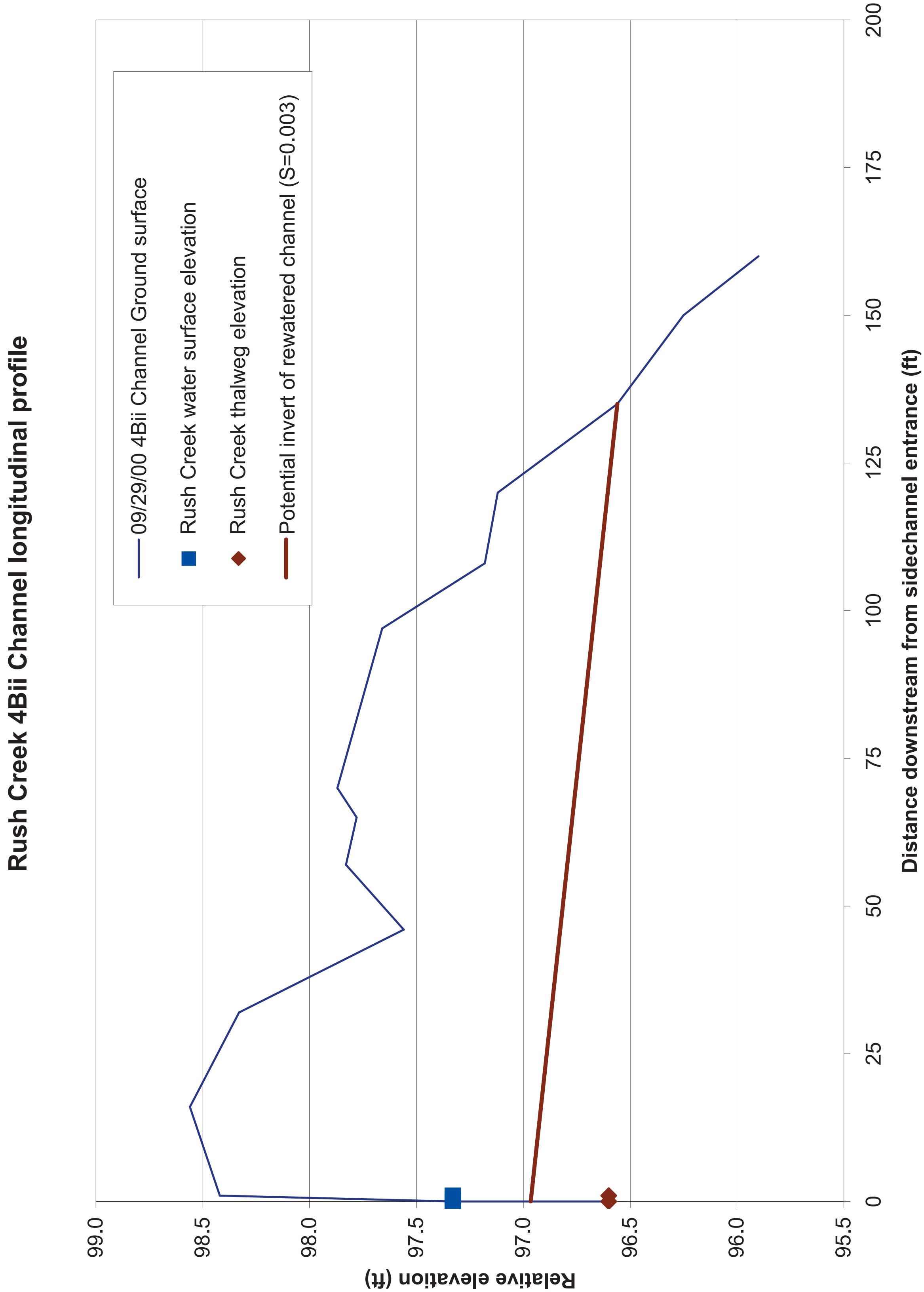


Figure L2. Location of Rush Creek 4Bii Channel entrance in the bottomlands in 2003 aerial photograph, and longitudinal profile surveyed 9-29-00.


Rush Creek 4Bii Channel longitudinal profile
09/29/00 4Bii Channel Ground surface
Rush Creek water surface elevation
Rush Creek thalweg elevation
Potential invert of rewatered channel (S=0.003)
Relative elevation (ft)
99.0
98.5
98.0
97.5
97.0
96.5
96.0
95.5
Distance downstream from sidechannel entrance (ft)
0
25
50
75
100
125
150
175
200

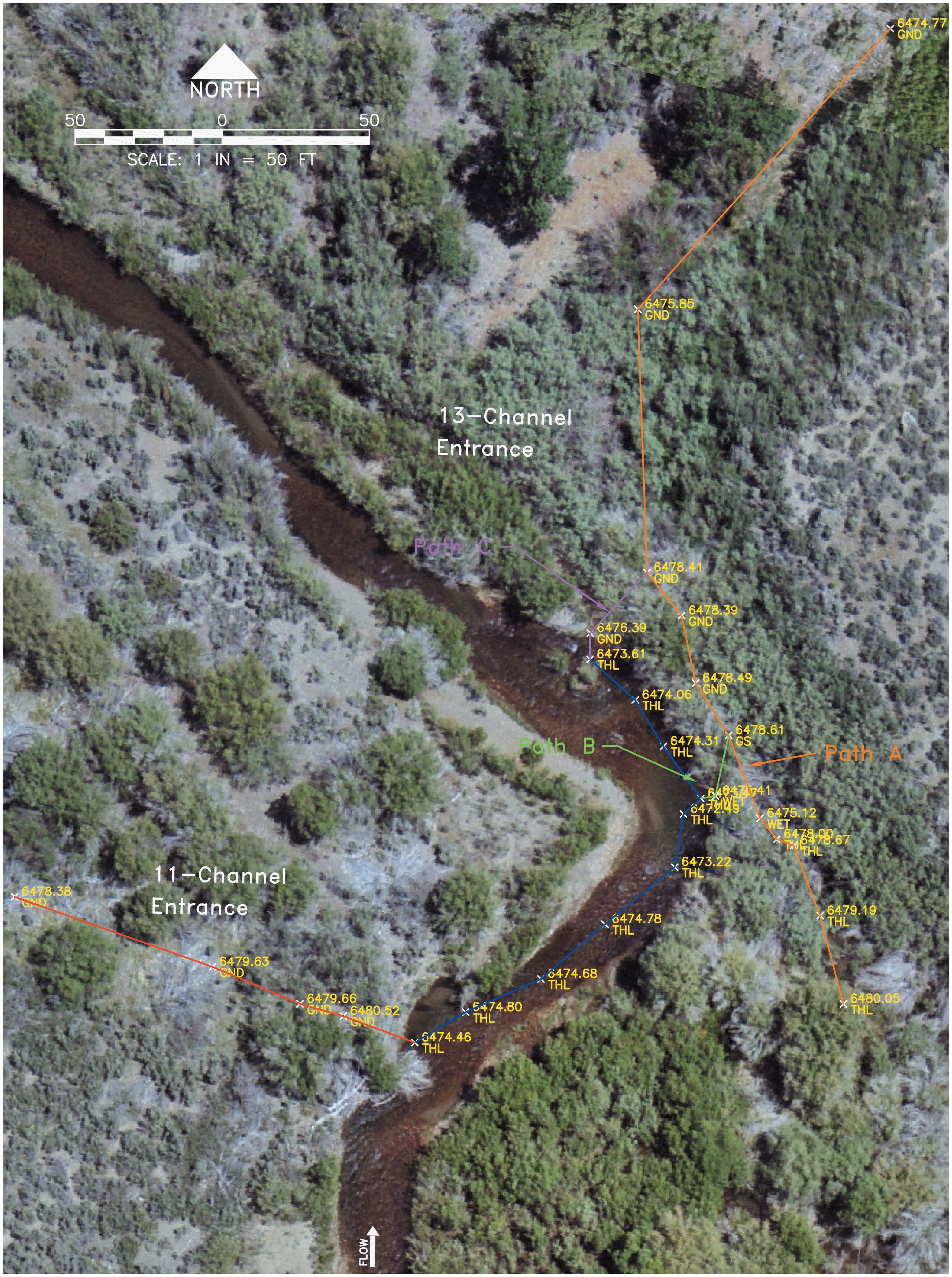
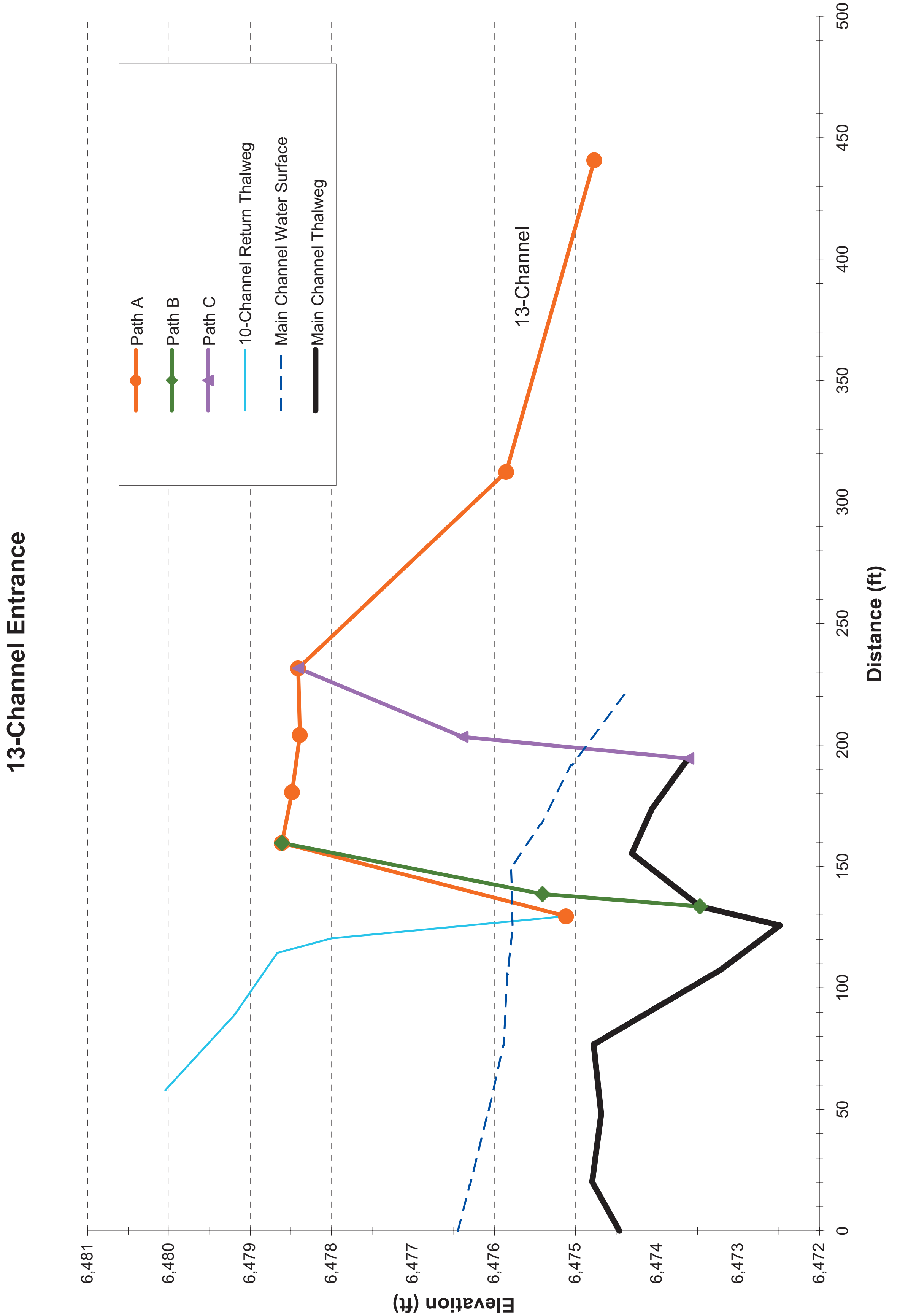


Figure L3. Location of Rush Creek 11 Channel and 13 Channel entrances in 2003 aerial photograph, and longitudinal profile surveyed in October 2005.


13-Channel Entrance
Path A
Path B
Path C
10-Channel Return Thalweg
Main Channel Water Surface
Main Channel Thalweg
13-Channel
Elevation (ft)
6,481
6,480
6,479
6,478
6,477
6,476
6,475
6,474
6,473
6,472
Distance (ft)
0
50
100
150
200
250
300
350
400
450
500

Section 5

Mono Basin Waterfowl
Habitat and Population Monitoring
2005-2006

Waterfowl Habitat Restoration Project
Annual Report
2005

Mono Lake Hydrology

- The Mono Lake elevation reads from Runoff Year 2005-2006 are reported in Appendix 1.
- Also included in Appendix 1 is the Mono Basin Operations Update letter from LADWP to the SWRCB, dated January 20, 2006, along with the SWRCB response letter dated February 15, 2006.

Lake Limnology

- The Mono Lake Limnological Monitoring 2005 Annual Report is presented in Appendix 3.

Waterfowl Surveys

- The Mono Lake Waterfowl Population Monitoring 2005 Annual Report is presented in Appendix 3.

Vegetation

- The Mono Lake Vegetation Monitoring 2005 Report is presented in Appendix 4.

Mono Lake Waterfowl Restoration Project
Compliance Checklist
2005

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 Photos	☑
Time Activity Budget	Required at Stabilization
Vegetation	**Appendix 4**
Lake-Fringing Wetland Transects	☑
Creek Delta Transects	☑
Ground/Aerial Photos	☑

Brian White

Brian White
Waterfowl Coordinator

† Several weekly elevation reads missed due to inclement weather.

‡ February lake survey and data collection by the UCSB meteorological station on Paoha Island between January 11 and March 24 missed due to inclement weather.

APPENDIX 1

Hydrology

January 20, 2006

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 2005-06

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 2005-06 (RY2005-06). The preliminary operations plan was submitted to the SWRCB and the Mono Basin parties in a letter submitted on May 11, 2005, which was also included in the "Compliance Reporting" submitted on May 12, 2005.

The April through September runoff for Mono Basin RY 2005-06 is typical in some respects and atypical in others. Most interestingly is the 45-day lag between peak flows on Walker and Parker Creeks. After heavy rainfall, followed by above normal temperatures, Walker Creek peaked on May 29 at 53 cubic feet per second (cfs) whereas the Parker Creek watershed held much of its snowpack into July, finally peaking on July 8 at 80 cfs. Lee Vining Creek demonstrated its historical bimodal nature, with two peaks of similar magnitude occurring approximately two weeks apart; the first one on May 28 at 396 cfs and the second on June 15 at 400 cfs. Rush Creek above Grant Lake Reservoir peaked on June 16 at 449 cfs. LADWP's releases to lower Rush Creek, operating under the SWRCB issued variance, peaked from June 23 through June 30 at 400 cfs.

The flow variance for Rush Creek, issued by the SWRCB on June 3, 2005, authorized changes to the Rush Creek hydrograph to allow for experimentation. The components of the Rush Creek hydrograph that were altered by the variance were:

1. an increase in the ramping rate on the ascending limb of the hydrograph;
2. an extended duration of the peak flow magnitude; and
3. the subsequent elimination of the secondary peak.

The increased ramping rate was requested to allow LADWP to better coordinate peak flows on Rush Creek to coincide with the peak flows on Walker and Parker Creeks and peak seed dispersal of the cottonwoods. The extended duration and subsequent elimination of the secondary peak was requested to monitor the effects of peak flow duration on the streams by eliminating as much "noise" as possible in the data. With the granting of the flow variance, the monitoring team increased their efforts to capture the data necessary to understand the effects of flow duration. This increased effort, however, reduced LADWP's flexibility to time the peak flows on Rush Creek with the above-mentioned environmental factors.

Attachment A contains a graph of the peak flows on Rush, Parker, and Walker Creeks from May 1 to August 31, 2005, along with the nighttime low temperatures at Cain Ranch plotted on the secondary axis. Coinciding with the nighttime temperatures (dashed line) after June 12 are the flows on Parker and Walker Creeks (light green and blue lines). From June 16 to June 17, the nighttime low temperatures dropped from 43 degrees to 24 degrees (red dash). Had this been a year without extensive monitoring efforts, LADWP could have delayed Rush Creek peak operations until the temperatures recovered to normal in early July and hence taken advantage of the extra flows in Walker and Parker Creeks.

Operations Summary

The following is a summary of LADWP's operations for the Mono Basin for RY2005-06, April through September 2005:

- Mono Basin Exports: Exports were delayed slightly allowing for Grant Lake Reservoir to gain a surface elevation conducive to recreation. Exports began on July 5, immediately following the peak flow operations on Rush Creek. Exports will continue through March 31, 2006, when a total of 16,000 acre-feet will be exported from the Mono Basin. The value of 16,000 acre-feet is the maximum export amount allowed under Decision 1631. The final storage for Grant Lake Reservoir is expected to be approximately 38,000 acre-feet, translating to a surface elevation of approximately 7,120 feet above mean sea level.

- Rush Creek: Grant Lake Reservoir's storage was approximately 15,500 acre-feet on April 1st, translating to a surface elevation of approximately 7,095.3 feet above mean sea level, 34.7 feet below the lip of the spillway. The low elevation of the reservoir made it difficult to predict if and when the reservoir could spill. Because of this, and the fact that the monitoring program was lacking some important data, an altered peak flow schedule was performed following approval from the SWRCB. A peak inflow into Grant Lake Reservoir (Rush Creek @ Damsite) of 441 cfs was experienced on June 16.

  Rush Creek below the confluence of the return ditch experienced a flow of approximately 400 cfs for eight days, beginning June 23 and continuing through July 2. The 400 cfs was achieved by releasing 350 cfs from Grant Lake Reservoir through the return ditch, and augmenting that flow with 50 cfs from the Lee Vining Counduit and the 5-Siphon Bypass.

- Parker Creek: There have been no diversions for export during the year. Parker Creek experienced its peak of a magnitude of 80 cfs on July 8, 2005. The peak was greater than the forecasted magnitude of 59 cfs, and it occurred 18 days later than the forecasted date of June 18.

- Walker Creek: There have been no diversions for export during the year. Walker Creek experienced its peak magnitude of 53 cfs on May 29. The peak was nine cfs greater than the forecasted magnitude of 44 cfs, and it occurred 15 days earlier than the forecasted date of June 13.

- Lee Vining Creek: Lee Vining Creek experienced two peak flows at approximately 400 cfs. The first peak arrived on May 29 at a magnitude of 396 cfs, and the second arrived on June 15 with a magnitude of 400 cfs. Both of these peaks passed through LADWP's diversion facility to Lower Lee Vining Creek. The peak of 400 cfs was 77 cfs greater than the expected peak of 323 cfs, and it occurred 6 days later than the expected date of June 9.

  As of September 30 diversions from Lee Vining Creek to Grant Lake Reservoir total approximately 4,400 acre-feet. By the end of RY2005-06 total diversions from Lee Vining Creek are expected to be approximately 5,500 acre-feet.

- Grant Lake Reservoir: Flow releases from the reservoir to Rush Creek were maintained slightly above the minimum and exports were suspended until early July 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,

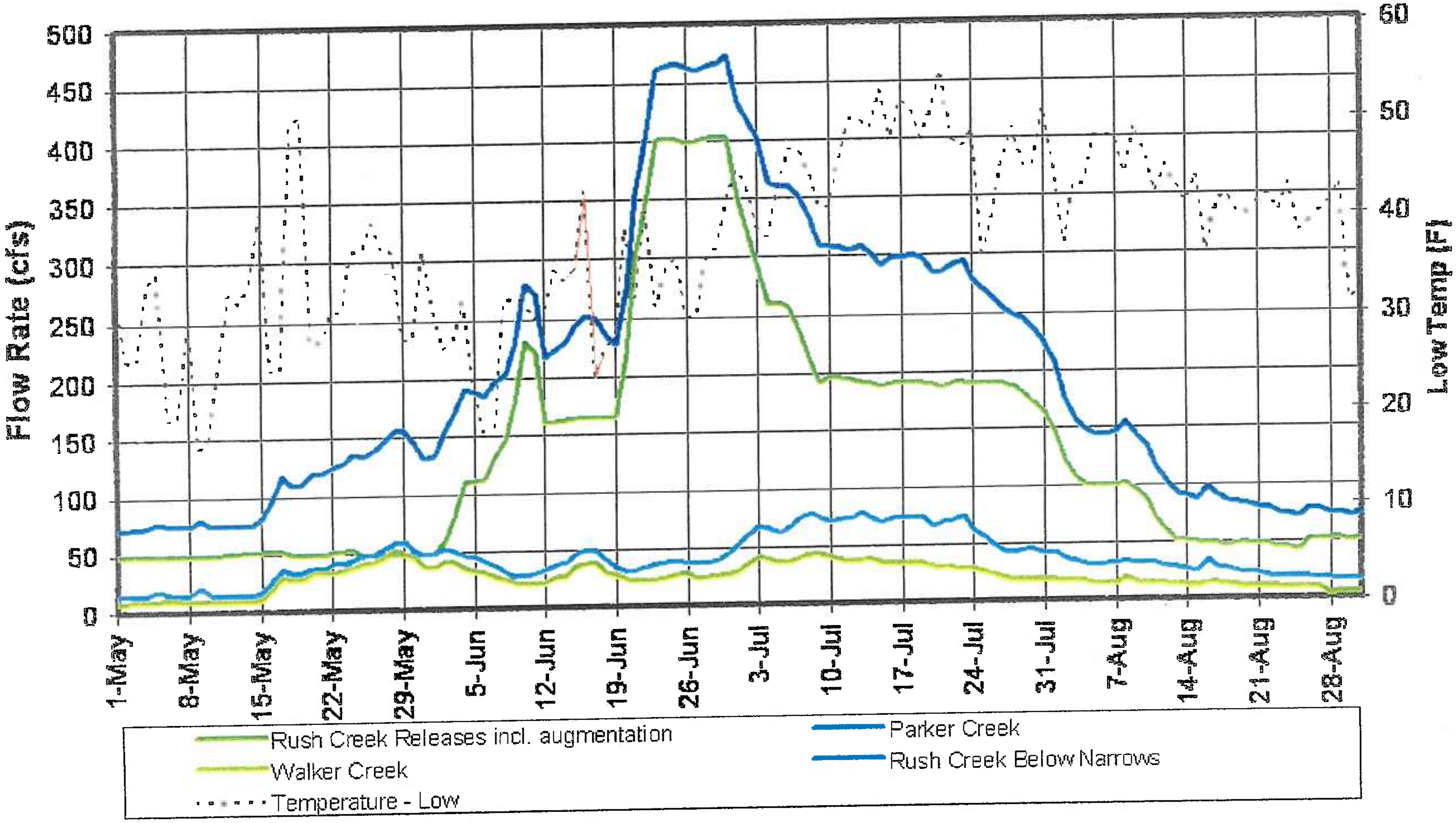
ORIGINAL SIGNED BY
GENE L. COUFAL

Gene L. Coufal
Manager
Aqueduct Business Group
MH:lge
Enclosure
c: enclosed mailing list
Dr. Mark Hanna

ATTACHMENT A

Rush Creek Flows: RY 2005-06

(May - August)



Mono Basin Distribution List
January 2006

Ms. Victoria Whitney, Chief Division of Water Rights State Water Resources Control Board 1001 I Street Sacramento, CA 95812	Mr. Jim Canaday Division of Water Rights State Water Resources Control Board P.O. Box 2000 Sacramento, CA 95812-02000 (916) 341-5308
Ms. Lisa Cutting Mono Lake Committee P.O. Box 29 Lee Vining, CA 93541 (760) 647-6595	Mr. Rob Lusardi California Trout Inc. Box 3442 Mammoth Lakes, CA 93546 (760) 924-1008
Marshall S. Rudolph Mono County Counsel P.O. Box 2415 Mammoth Lakes, CA 93546 (760) 934-7616	Board of Supervisors Mono County P.O. Box 715 Bridgeport, CA 93517 (760) 932-5534
Mr. Gary Smith, NAFWB Department of Fish and Game 1416 Ninth Street Sacramento, CA 95814	Mr. Steve Parmenter Department of Fish and Game 407 West Line Street, #8 Bishop, CA 93514 (760) 872-1171
Dr. William Trush McBain & Trush P.O. Box 663 Arcata, CA 95518 (707) 826-7794	Mr. Chris Hunter 616 Wintergreen Court Helena, Montana 59601 (406) 449-6561
Mr. James Barry Department of Parks and Recreation P.O. Box 942896 Sacramento, CA 94296-0001 (916) 653-9408	Mr. Doug Smith Grant Lake Reservoir Marina P.O. Box 21 June Lake, CA 93529 (760) 648-7512
Mr. Bill Bramlette U.S. Forest Service 351 Pacu Lane, Suite 200 Bishop, CA 93514 (760) 873-2400	Mr. Ken Anderson Department of Parks and Recreation P.O. Box 266 Tahoma, CA 96142
Ms. Molly Brown Deputy District Ranger/ Scenic Area Manager USDA Forest Service Mono Lake Ranger District P.O. Box 429 Lee Vining, CA 93541 (760) 647-3033	Mr. Larry Ford Scenic Area Assistant USDA Forest Service Region 5, Inyo National Forest P.O. Box 429 Lee Vining, CA 93541 (760) 647-3004

State Water Resources Control Board

Division of Water Rights
1001 I Street, 14th Floor ♦ Sacramento, California 95814 ♦ 916.341.5300
P.O. Box 2000 ♦ Sacramento, California 95812-2000
Fax: 916.341.5400 ♦ www.waterrights.ca.gov

Alan C. Lloyd, Ph.D.
Agency Secretary

Arnold Schwarzenegger
Governor

FEB 15 2006

W. MARK HANNA
FEB 22 2006
RECEIVED

Mr. Gene L. Coufal, Manager
Aqueduct Business Group
Los Angeles Department of Water & Power
300 Mandich Street
Bishop, CA 93514-3449

Dear Mr. Coufal:

UPDATE ON MONO BASIN OPERATIONS DURING RUNOFF YEAR 2005-06

Thank you for your recent letter describing Los Angeles Department of Water and Power's (LADWP) Mono Basin Operations for the water year 2005-06. State Water Resources Control Board (State Water Board) staff has reviewed the information in your letter. We look forward to reviewing the results of the flow experiments on Rush Creek last year that included increasing the ascending limb of the channel maintenance flow ramping rate and extending the duration of the peak flow magnitude while eliminating the secondary peak event.

I appreciate LADWP deferring diversions out of basin until later in the summer-fall to help raise Grant Lake elevations to assist the Grant Lake recreation concessionaire and to facilitate recreational opportunities for the public earlier than would have occurred with LADWP diversions.

I hope this spring's runoff will raise Mono Lake and provide flows to further restore the streams while affording LADWP opportunities to divert water for its customers. I look forward to continued cooperation between LADWP and the State Water Board. If you have any questions regarding the State Water Board's orders or need assistance regarding future LADWP restoration efforts please contact Jim Canaday at 916-341-5308 or by email at jcanaday@waterboards.ca.gov.

Sincerely,

Victoria A. Whitney

Victoria A. Whitney
Division Chief

cc: See next page.

cc: Ms. Mary Nichols - President
City of Los Angeles
Board of Water and Power Commissioners
111 North Hope Street
Room 1555-H, 15th Floor
Los Angeles, CA 90012

Dr. Mark Hanna
Los Angeles Department of Water & Power
Eastern Sierra Environmental Issues
111 North Hope Street, Room 1468
Los Angeles, CA 90012

2005 Mono Lake Elevation Reads

DATE	ELEVATION
2/3/2005	6,381.1
2/15/2005	6,381.2
3/17/2005	6,381.5
4/7/2005	6,381.6
4/21/2005	6,381.6
4/28/2005	6,381.6
5/5/2005	6,381.6
5/12/2005	6,381.6
5/19/2005	6,381.7
5/26/2005	6,381.8
6/2/2005	6,381.8
6/9/2005	6,381.8
6/15/2005	6,381.9
6/16/2005	6,381.9
6/24/2005	6,382.0
7/1/2005	6,382.1
7/7/2005	6,382.2
7/14/2005	6,382.4
7/22/2005	6,382.6
7/28/2005	6,382.6
8/4/2005	6,382.6
8/11/2005	6,382.6
8/19/2005	6,382.5
9/1/2005	6,382.4
9/15/2005	6,382.2
9/22/2005	6,382.1
9/29/2005	6,382.1
10/7/2005	6,382.0
10/14/2005	6,382.0
10/20/2005	6,381.9
10/27/2005	6,381.9
11/3/2005	6,381.9
11/10/2005	6,381.9
11/17/2005	6,381.9
12/1/2005	6,381.9
12/8/2005	6,382.0
12/15/2005	6,382.0
12/22/2005	6,382.1
12/30/2005	6,382.2

APPENDIX 2

Limnology

2005 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 2006

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EXECUTIVE SUMMARY

Limnological monitoring of the plankton dynamics in Mono Lake was continued during 2005 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 2004, 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 2005 limnological monitoring program. The breakdown of an 8-yr period of meromixis in November 2003 mixed nutrient-rich bottom waters throughout the water column and led to above average primary and secondary productivity in 2004. On the March 2005 survey, nutrient levels were similar to those observed in 2004, with ammonia concentrations <1 µM in the near-surface mixed layer and 30–40 µM in the hypolimnion. However, the spring algal bloom was somewhat smaller in 2005, with chlorophyll concentrations at 2 and 8 m depth of 57–59 µg chl *a* liter^{-1} compared to 91–105 µg chl *a* liter^{-1} in 2004. The March survey indicated the spring *Artemia* hatch was well underway with abundance across 12 stations ranging from 18,000 to 57,000 m^{-2} with a lakewide mean of 31,800 m^{-2}. While not as large as 2004

(75,500 m^{-2}), abundant food and above average water temperatures in 2005 led to the third largest 1st generation of adults (45,400 m^{-2}) observed during the entire 27-yr period (1979-2005). Although ovoviviparous reproduction was 25 % above the long-term mean, the large 1st generation of adults depleted food availability and reduced recruitment into the second generation resulting in a rapid late summer decline in adults. Although less dramatic, similar to that observed in 2004.

In 2005, annual primary production was 1,111 g C m^{-2} or double the long-term mean of 573 g C m^{-2}. Average *Artemia* biomass, a measure of secondary production, was 11.8 g m^{-2}, 25 % above the long-term mean. Total annual cyst production was 3.8 million m^{-2} or 15 % below the long-term mean of 4.4 million m^{-2}. However, secondary productivity is not limited by cyst production and there is little correlation between annual cyst production and the subsequent year's population of *Artemia*.

Seasonally-filtered mixed-layer chlorophyll *a* concentration and adult *Artemia* abundance provide two measures of long-term ecological trends. They both 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 1982–2005. Neither provide any evidence of a long-term trend.

Snowmelt runoff into the epilimnion of Mono Lake causes seasonal salinity stratification which typically breaks down in November following a period of evaporative concentration, epilimnetic cooling, and declining lake levels. In 2005, above average snowmelt runoff led to a 1.8 ft seasonal rise in surface elevation. While evaporative concentration of the upper mixed-layer and cooling was leading holomixis, freshwater inputs late in the year strengthened salinity stratification and prevented winter holomixis and initiated a third period of meromixis. Overall, surface elevation increased 1.4 ft to 6382.17 ft asl (USGS Datum) in 2005.

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. Kimberly Rose assisted with all aspects of the monitoring program including field sampling, laboratory analyses, and data analysis. K. Rose also assisted with presenting data and reviewing text of this report. J. M. Melack reviewed 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 monthly surveys (except January) supplemented by additional surveys as conditions warrant. 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 2005 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		64
Wind Direction	21		
Air Temperature	22		65
Incident Radiation	22		66
Humidity	22		67
Precipitation	22		68
Physical/Chemical			
Water Temperature	23-24	39,42	70,72
Transparency	25-26	43	73,74
Underwater light	25-26		71
Dissolved Oxygen	26	44	72
Conductivity	24-25	40 42	71,72
Nutrients (ammonia and phosphate)	26-27	43	77,78
Plankton			
Chlorophyll *a*	27-28	47,48	79,80, 94
Primary production	31-33	55	87-90
Artemia Abundance	28-31	49-51	82,83,95
Artemia Instar distribution	28-31	52	
Artemia Fecundity/Length	28-31	56	
Artemia Reproductive parameters	28-31	53-55	84
Artemia Biomass	33-34	55	95

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CHAPTER 1
INTRODUCTION

Background

Saline lakes are widely recognized as highly productive aquatic habitats, which in addition to harboring distinctive 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 (6391 ft) 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 27-yr period, 1979–2005, 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, 2003; Jellison and Melack 2000; Jellison 2004, 2005) 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

<u>1995</u>

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.

<u>1996</u>

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 x 10^6 m^{-2} compared to 4.03 x 10^6 m^{-2} in 2000. While this is 37% below the long-term mean of 4.77 x 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 x 10^6 m^{-2}), along with abundance of ovigerous females, was less than in the previous three years (3.0-4.2 x 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 x 10^6 m^{-2}.

Response to the breakdown of an 8-yr period of meromixis (2003–2004)

<u>2003</u>

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 x 10^6 m^{-2}, close to the long-term (1983-2003) mean of 4.5 x 10^6 m^{-2}.

<u>2004</u>

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 was 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 was among the lowest estimates of annual cyst production, there is little correlation between cyst production and the subsequent year's population of *Artemia*.

Two measures of long-term ecological trends, seasonally-filtered mixed-layer chlorophyll *a* concentration and adult *Artemia* abundance, 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.

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 (restarted in 2002), 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 (1983-2005) mean of 9.5 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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Miller, L. G., R. Jellison, R. S. Oremland, and C. W. Culbertson. 1993. Meromixis in hypersaline Mono Lake, California III. Breakdown of stratification and biogeochemical response to overturn. Limnol. Oceanogr. 38:1040–1051.

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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 monthly surveys from February through December. Additional lakewide *Artemia* surveys are taken when warranted to better characterize the seasonal development of the *Artemia* population. Surveys are conducted over one or two days depending on the weather conditions, the number of depths at which productivity is being estimated, and meteorological station maintenance requirements. When conducted over two days, every effort is made to collect the lakewide survey and the station 6 profiles including productivity data on consecutive days.

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:

$$\rho(t, C_{25}) = 1.0034 + 1.335 \times 10^{-5} t - 6.20 \times 10^{-6} t^2 + 4.897 \times 10^{-4} C_{25} + 4.23 \times 10^{-6} C_{25}^2 - 1.35 \times 10^{-6} t C_{25}.$$

The relationship between total dissolved solids and conductivity for Mono Lake water was given by:

$$TDS\left(g\ kg^{-1}\right) = 3.386 + 0.564 \times C_{25} + 0.00427 \times C_{25}^2.$$

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. When adults were present, an additional net tow is taken from Stations 1, 2, 5, 6, 7, 8 and 11 to collect adult females for brood size and length analysis.

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). 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 are kept cool and in low densities during transport to the laboratory. Immediately on return to the laboratory, females are 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 $\mu E\ m^{-2}\ s^{-1}$. 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: $P^B = P_m{}^B \tanh\left(\frac{\alpha^B I}{P_m{}^B}\right)$ 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.

Long-term trends in annual algal biomass and adult Artemia abundance

The seasonality in algal biomass and adult *Artemia* abundance can be removed by calculating yearly moving averages. Because the intervals between sampling dates varied among years, daily values are 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 each sample. This seasonally-filtered data can be used to detect long-term trends in algal biomass and adult *Artemia.*

CHAPTER 3

RESULTS AND DISCUSSION

Overview

The plankton dynamics during 2003 and 2004 are illustrative of the transition from extended meromixis (persistent chemical stratification) to a monomictic (annual mixing regime with one period of holomixis) mixing regime. During the transition, nutrients previously accumulated beneath the chemocline are mixed upward into the euphotic zone and productivity is increased.

In 2005, monthly lakewide surveys were conducted from March through December (March 24, April 14-15, May 23-24, June 14-15, July 13-14, August 17-18, September 14-15, October 20, November 16, and December 14). The February survey was prevented by road and weather conditions. In addition to the monthly surveys, three additional lakewide surveys were conducted June 3, July 1, and August 1 to better characterize ovoviviparous reproduction and the seasonal *Artemia* population dynamics.

In 2005, plankton dynamics were fairly typical of monomictic conditions with all measures lying within the extremes observed during the past 25 years. Two notable aspects of 2005 were the large spring generation of *Artemia* caused by warmer than average water temperatures and the absence of holomixis in late autumn or early winter. The February 2006 survey indicated the lake did not fully mix during winter 2005–06.

Here, we describe the limnological conditions observed during 2005 and calculate several long-term integrative measures of ecosystem productivity.

Meteorological Data

The Mono Lake limnological monitoring program includes collection of a full suite of meteorological data at a station located on the southern tip of Paoha Island and radiation (shortwave, longwave, and photosynthetically available radiation) at Cain Ranch. Maintenance of the Paoha meteorological station is problematic due to the difficulty of access during winter or during periods of poor weather conditions. At the Paoha station data is collected at 10-min intervals and an incomplete number of wind readings were recorded during 4-10 January 2005 after which the station failed entirely. We were unable to visit and restore service at the station until 24 March 2005. Also, RF telemetry failures resulted in the loss of data from midday 24 Oct to 6 November. Therefore, unless stated otherwise, results reported here do not include data from these periods of time.

Wind Speed and Direction

Mean daily wind speed varied from 1.0-10.1 m s^{-1} over the year, with an overall annual mean of 3.5 m s^{-1} (Fig. 2). This annual mean is slightly higher than the 3.2 m s^{-1} annual mean observed in 2001, 2002, and 2003 and 3.1 m s^{-1} observed in 2004. The daily maximum 10-min averaged wind speeds averaged 2.3 times mean daily wind speeds. The maximum recorded gust (31.8 m s^{-1}, 71 mph) was during an early morning storm on 1 Dec with sustained winds (10-min mean) of 21 m s^{-1}(Fig. 2). The mean monthly wind speed varied from 3.0 to 4.5 m s^{-1} (coefficient of variation, 14 %). This was similar to 2004 when the mean monthly wind speed varied only from 2.1 to 4.1 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 (mean, 189.4 deg).

Air Temperature

Mean daily air temperatures ranged from a minimum of –8.1°C on 6 January to a maximum of 24.8°C on 18 July (Fig. 3). Air temperatures ranged from 0.6°C to 33°C during the summer (June through August) with a mean daily range of 9.1°C to 24.8°C and from –10°C to 14.3°C during the winter (December through February) with a mean daily range of -8.1°C to 9.6°C.

Incident Photosynthetically Available Radiation (PAR)

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 2005, the annual mean was 39.0 Einsteins m^{-2} day^{-1}, with daily values ranging from 1.48 Einsteins m^{-2} day^{-1} on 31 December to 68.9 Einsteins m^{-2} day^{-1} on 22 July. The 2005 annual mean was between those observed in 2002, 2003, and 2004 (39.9, 35.0, 37.5 Einsteins m^{-2} day^{-1}) respectively. PAR values collected at Cain Ranch supplemented missing data points in January, October 24 - November 6 and December 14-31.

Relative Humidity and Precipitation

Mean daily relative humidity followed a general pattern of high values (mostly 70-90 %) in January, decreasing to lows (mostly 40-60 %) in April through August, and increasing to 60-80 % through December (Fig. 5). The yearly mean was 57.9 %, slightly higher than 54.3 % observed in 2004 and 54 % in 2003.

During 2005, annual precipitation, collected at Paoha meteorological station was 230.9 mm (9.09 in) (Fig. 6). Total precipitation was higher than in 2001, 2002, 2003 and 2004 (87.9 mm, 69.1 mm, 101.1 mm and 102.7 mm, respectively). The largest precipitation events occurred on 26 May (30.6 mm) and, 1 and 31 December (34.4 and 24 mm, respectively). 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 2005, above average snowmelt runoff has led to a 1.8 ft rise in surface elevation from 6380.8 ft asl (USGS Datum) at the beginning to January to 6382.6 ft by August (Fig. 7). Following this seasonal peak, evaporation and reduced inflows led to a 0.7 ft decline to 6381.9 ft by mid November. Although further evaporative concentration of the upper mixed-layer would certainly have resulted in complete mixing, a late season

0.3 ft rise strengthened salinity stratification and prevented holomixis. Although increased inflows and decreased evaporation often lead to surface elevation rise early in the year, this most often occurs after a period of holomixis in late November or early December.

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.

The annual period of holomixis typically extends from late November to early February after which seasonal thermal and salinity stratification are initiated due to warming air temperatures, increased insolation, and increased inflows. January represents a period of low biological activity due to cold water temperatures, low light levels, and absence of *Artemia* and January surveys are only conducted when unusual circumstances warrant it and weather permitting. Monthly surveys are typically initiated in February. In 2005, heavy snow and road closures prevented sampling until March.

A lakewide survey and deep station profiles were conducted on 24 March. Seasonal thermal stratification was already present by the survey date with a gradual thermal gradient between 7 and 15 m (Table 1, Fig. 8). Upper mixed-layer (<8 m) temperatures mostly varied between 4.9 to 5.4 °C with slightly higher temperatures (~6 °C) very near the surface. Temperatures decreased from 4.6 °C at the bottom of the mixed layer to 2-2.3 °C at the bottom (~15 m) of the metalimnion (mid-depth region of thermal gradient). Temperatures were near isothermal below the metalimnion.

During the April and May surveys, multiple small thermoclines indicative of a series of heating and mixing events were present. This is a typical observation during the onset of seasonal thermal stratification. On 15 April near-surface (0-4 m) water temperatures ranged from 6.8-7.6 °C. Below this water temperatures decreased in a series of small steps to 2.9 °C at 20 m. Deep water temperatures (>25 m) were near isothermal at 2.2 °C. By 24 May, near-surface water temperatures had warmed to almost 16 °C and decreased only slightly to 14 °C at 3.8 m where the first thermal step of a 0.5 °C decrease occurred over 16 cm. Another step occurred at 7.5 m and the main or seasonal thermocline occurred at 14.7 m where the temperature dropped from 5.8 °C to 4.5 °C in 0.5 m. Near-bottom temperatures, 2.4–2.5 °C, were only slightly higher than observed in April (2.1–2.2 °C). The above normal near-surface temperatures resulted in a large spring generation of Artemia (see *Artemia* section below)

Summer epilimnetic water temperatures were near or slightly above the long-term mean. Thermal stratification continued to increase as the temperature of the upper well-mixed layer increased from 16-17 °C in mid-June to 18.0–19.3 °C by 1 July and further to 22.6–23.3 °C on 13 July. Due to above normal runoff and continuing inputs of freshwater to the surface, the upper water column was salinity stratified and well-mixed only to 4.5 m depth. On 13 July, a 3.5 °C temperature drop occurred between 4 and 6 m, followed by a decline to 4.5 °C at 17 m and 3 °C near the bottom (35 m).

By mid-August, the upper water column was well-mixed to 7 m at the mid-lake station 6 and had warmed to 21.4-21.6 °C. Below this, water temperature decreased almost linearly to 5.0 °C at 17.5 m and then more slowly to 3.2 °C near the bottom (34–27 m). In mid-July, near bottom water temperatures were 3.0 °C. The absence of significant warming in near-bottom waters indicates low rates of vertical mixing.

Convective mixing associated with seasonal cooling and evaporative concentration of surface waters leads to deepening of the thermocline and a well-mixed epilimnion. By mid-September water temperatures in the epilimnion (upper mixed layer; <11 m) were 17.6–17.8 °C. Below this, water temperature decreased almost linearly to 5.4 °C at 17.5 m and then more gradually to 3.3 °C near the bottom (36 m). On 20 October, the upper water column was well-mixed down to 14.5 m with water temperatures ranging only from 12.3 to 13.1 °C in the epilimnion. A sharp thermocline extended from 14.5 to 20 m with water temperature decreasing to 5.1 °C at 20 m. Temperatures decreased gradually below this to 3.7°C near the bottom (37 m). This vertical thermal structure is typical for this time of year. On 16 November the upper mixed-layer had deepened from 14 to 16 m and epilimnetic water temperatures were 9.3–9.8 °C. Near-bottom temperatures were 4.0 °C or 0.3 °C warmer than observed in mid-October.

On 14 December mixed-layer water temperatures were 5.6–5.9 °C while temperatures were 4.4 °C near the bottom (37 m). The 0.4 °C increase in hypolimnetic temperatures indicates increased mixing and given the small temperature gradient, holomixis would be expected to occur with further epilimnetic cooling. However, increased salinity stratification due to increased inflows during December prevented the winter period of meromixis as indicated by profiles collected in February 2006.

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.

Winter storms and snowmelt runoff had already resulted in significant seasonal salinity stratification by the 24 March 2005 (Table 2, Fig. 9). Standardized (25 °C) conductivities were 82.1 mS cm^{-1} near the surface (1m), 82.2–83.4 mS cm^{-1} between 2 and 25 m, and 83.5 mS cm^{-1} near the bottom. In mid-April conductivities were 82.3–82.4 mS cm^{-1} at 1-2 m and increased nearly linearly to 83.2 mS cm^{-1} at 22 m..

Salinity stratification continued to increase as snowmelt runoff increased and epilimnetic conductivity declined during May through July. May conductivities were 81.5 mS cm^{-1} near the surface, 82.2–82.5 mS cm^{-1} between 3 and 15 m, and uniformly

83.3 mS cm^{-1} throughout much of the hypolimnion (25–36 m). June conductivities were 80.4–82.5 mS cm^{-1} from the surface to 14 m at which depth it increased 0.5 mS cm^{-1} to 83.0 mS cm^{-1} at 19 m. Below this chemocline conductivities remained nearly constant at 83.0–83.2 mS cm^{-1} indicating a well-mixed hypolimnion. July conductivities were 79–80 mS cm^{-1} near the surface and gradually increased to 83.1 mS cm^{-1} near the bottom (35 m). August conductivities were 80.1, 81.9–82.2, and 82.8–83.3 mS cm^{-1} in the upper (0-5 m), mid (9-14 m), and lower water column (18–38 m).

Decreased runoff and little precipitation resulted in a 0.4 ft drop in surface elevation during September. Evaporative concentration led to ~1.5 mS cm^{-1} increase in mixed-layer conductivities (or 1.9 g kg^{-1} increase in salinity). Conductivity increased from 81.4–81.6 mS cm^{-1} in the epilimnion (<11 m) to 82.9 mS cm^{-1} at 17.5 m and then more slowly to 83.4 mS cm^{-1} near the bottom (36 m).

Surface elevation declined only 0.1 ft during October and thus standardized (to 25°C) conductivities increased only slightly in the epilimnion to 82.1–82.4 mS cm^{-1}. Near-bottom conductivities remained nearly constant at 83.4 mS cm^{-1}.

Slight salinity stratification remained in November and then increased in December as the surface elevation rose and lake volume increased. In December, conductivity was 82.0 mS cm^{-1}above 6 m depth and 83.5 mS cm^{-1} near the bottom.

Over the year, conductivities between 1 and 37 m ranged from 79.0 mS cm^{-1} to 83.5 mS cm^{-1}. This corresponds to 74.6 to 80.3 g kg^{-1} salinity.

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 and its affect on nutrient cycling.

In 2005, excess density varied from 63.1 to 73.6 g l^{-1} over the course of the year (Table 3).

By the 24 March survey, seasonal stratification had already been initiated with a difference in density due to salinity and temperature of 1.51 and 0.41 kg m^{-3}, respectively, between upper and bottom waters (Table 4, Fig 10). Temperature and salinity gradients contributed almost equally to overall stratification at its peak of 9.76 kg m^{-3} on 1 August. Density stratification decreased due to evaporative concentration and cooling to 1.86 kg m^{-3} on 14 December at which time salinity stratification accounted for 91 % of the overall density stratification. Accompanied by further rises in level this was enough to prevent a winter period of holomixis.

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 2005, average lakewide transparency during spring was close to the lowest observed (Fig. 11, Table 5) indicating high algal biomass. The average lakewide Secchi depth was 0.7 m during March and April and reached a maximum of 8.0 m during mid July before decreasing to 0.9–1.0 during November and December. As observed in most years, the midsummer transparencies at western stations (mean, 9.08±0.31 m, SE) were generally higher than eastern stations (mean, 7.03±0.16 m, SE).

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 2005, the depth of the euphotic zone, operationally defined as the depth at which only 1 % of the surface insolation is present, increased from a low of 6 m during the spring, to 14 m during midsummer, and then to 7 m during the autumn phytoplankton bloom (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.

In 2005, epilimnetic dissolved oxygen concentrations ranged from 2.3 to 7.7 mg l^{-1} (Table 6, Fig. 14)) with the highest concentrations occurring during the spring phytoplankton bloom. On the March survey, near bottom concentrations had already declined to 0.5 mg l^{-1}. The anoxic zone (depth below which dissolved oxygen concentrations are <0.5 mg l^{-1}) varied from below 26 m in April to as high as 14 m in June. The absence of autumn turnover and holomixis is indicated by anoxic conditions below 21 m observed during the 14 December survey.

Nutrients (ammonia/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.

As observed in most years, epilimnetic ammonium concentrations were already significantly depleted by the 24 March 2005 survey due to phytoplankton uptake (Table 7, Fig. 15). Ammonium in the upper 9-m integrated samples ranged from 1.4 to 2.5 µM across 8 lakewide stations (Table 8, Fig. 16). Also, ammonium had begun to accumulate in the hypolimnion as indicated by the increase to 14.7 µM at 16 m and further to 38 µM at 35 m.

At the centrally-located station 6, ammonium concentrations at 2 & 8 m were low (0.9–1.3) throughout the rest of the year except for a pronounced peak of 11.0 µM at 2 m depth on 14 July and a slightly elevated value of 2.7 µM on 18 August. Higher midsummer ammonium concentrations in the euphotic zone 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. This causal connection to grazing is highlighted by the variation in the prominence of this feature across the lake which shows an inverse correlation with adult *Artemia* abundance. The peak is much more prominent at stations 1, 2, 5, and 6 where larger midsummer peaks of *Artemia* occurred compared to stations in the eastern basin (7, 8, and 11).

Hypolimnetic ammonium concentration increased to 101 µM at 35 m depth at the central station 6. An 80–100 µM seasonal increase in hypolimnetic ammonium concentrations appears typical for Mono Lake and has been observed in most monomictic years. Hypolimnetic ammonium concentrations decreased slightly to 75 µM at 28 m and 85 µM at 35 m on December 14. While the decline indicates some vertical mixing it is clear that autumn turnover or holomixis had not occurred.

Phytoplankton (algal biomass and fluorescence)

The phytoplankton community, as characterized by chlorophyll *a* concentration, shows pronounced seasonal variation (Table 9, Fig. 17).

A pronounced spring algal bloom was present during March and April. On the 24 March survey, chlorophyll *a* concentrations ranged from 54.3 to 67.5 µg chl l^{-1} in the upper 9-m integrated samples (Table 10, Fig. 18) and a mid-depth increase to 87.0 µg chl l^{-1}at 12 m was observed at station 6 (Table 9, Fig. 17). The slightly lower concentrations at the eastern stations 7, 8, and 11 most likely reflect higher grazing associated with the higher abundance of early instar *Artemia* in the east. The spring hatch of *Artemia* is almost always larger in the eastern portion of the lake and thought to be related to the larger extent of oxygenated sediments due to the more gently sloped bathymetry compared to the western half of the lake. The spring bloom continued to develop with chlorophyll concentrations in the upper 9-m integrated samples ranging from 65.3 to 77.7 µg chl a l^{-1} with an eight station lakewide mean of 73.5 (±1.7) µg chl a l^{-1} on 15 April.

Maturation of the spring generation *Artemia* results in a rapid decrease in phytoplankton abundance. By 24 May, lakewide mean algal biomass in the upper-9 m decreased to 18.8 µg $liter^{-1}$ ranging from 11.7 to 25.3 µg $liter^{-1}$ across the lake. At the mid-lake station, chlorophyll increased from 10.6 µg $liter^{-1}$ at 2 m to a mid-depth maximum of 73 µg $liter^{-1}$ at 16 m, before declining to 46.5-54 µg $liter^{-1}$ in the hypolimnion. The in-situ fluorescence profile indicated the mid-depth maximum was broad and not associated with a narrow peak population as often observed later in the season (Fig. 19). Algal biomass declined further to 4.1 µg $liter^{-1}$ the upper-9 m by 14 June ranging from 2.7 to 5.3 µg $liter^{-1}$ across the lake. At the mid-lake station, chlorophyll increased from 2.6 µg $liter^{-1}$ at 2 m to a mid-depth maximum of 57.9 µg $liter^{-1}$ at 16 m, before declining slightly to 49–55 µg $liter^{-1}$ in the hypolimnion. The in-situ fluorescence profile exhibited a minor peak at the top of the oxycline (14 m).

Lakewide mean algal biomass reached seasonal minimum during July, when upper-9 m chlorophyll was 1.0 µg $liter^{-1}$ ranging from 0.3 to 1.4 µg $liter^{-1}$ across the lake. At the mid-lake station, chlorophyll increased from 0.7 µg $liter^{-1}$ at 2 m to 15.5 µg $liter^{-1}$ at 14 m depth. Beneath this at 16 m depth, a pronounced mid-depth maximum of 57.8 µg $liter^{-1}$ was present. Epilimnetic chlorophyll remained low through August and September and the vertical distribution similar to that observed in July.

Decreasing *Artemia* abundance and increasing nutrient supply initiated the autumn bloom with chlorophyll *a* concentrations increasing to 17.8–20.6 µg l^{-1} in mid-October in the 9-m integrated samples. In absence of significant numbers of *Artemia* the autumn phytoplankton bloom continued to develop with epilimnetic mid-November chlorophyll *a* concentrations increasing to 36.6–43.5 µg l^{-1}. Hypolimnetic concentrations (20, 24, 28 m) were slightly higher (45.5–46.1 µg l^{-1}). By the 14 December survey, mixed-layer chlorophyll ranged from 53 to 65.6 µg l^{-1}.

In general, the 9-m integrated samples collected from 7 stations showed lower epilimnetic chlorophyll concentrations in the eastern half of the lake during the spring. This is most likely due to the more abundant hatch observed at stations overlying shallow or gently sloping sediments. During the rest of the year, consistent lakewide variation was much less or absent.

Artemia Population Dynamics

Zooplankton populations in temperate lakes are highly variable across several spatial and temporal scales. The Mono Lake monitoring program collects samples from 12 stations distributed across the lake and the relative standard errors of lakewide estimates are typically 10-20 %. However, on a given sample date the standard error of a lakewide estimate may be smaller or larger depending on the observed spatial variability occurring on that date. In extreme cases, local convergences of water masses may concentrate shrimp to well above the overall mean. For these reasons, a single level of significant figures in presenting data (e.g. rounding to 10s, 100s, 1000s or even 10,000s) is inappropriate and we include the standard error of each lakewide estimate using the "±" notation. The reader is cautioned to always consider the standard errors when making inferences from the data.

Hatching of over-wintering cysts, and maturation and decline of 1st generation

Hatching of over-wintering cysts is initiated by warming water temperatures and oxic conditions. The peak of hatching usually occurs during March but significant hatching may also occur during February. A small amount of hatching may even occur during January in shallow nearshore regions during periods of above normal air temperatures. By the 24 March survey the spring *Artemia* hatch was well underway with abundance across 12 stations ranging form 18,000 to 57,000 m^{-2} with a lakewide mean of 31,794±3925 m^{-2} (Table 11a, b, c, Fig. 20). The population consisted mostly of instars 1 (31.9 %), 2 (46.7 %), and 3 (19.9 %), but some instar 4 (1.5 %) were present (Table 12). The spring *Artemia* hatch was still in progress during the 15 April survey with total naupliar abundance ranging form 6,200 at the nearshore southern station (Station 5) to 84,000 m^{-2} at the northwestern station (Station 11). The overall lakewide naupliar mean was 33,588±5960 m^{-2}, almost identical to that observed in March. The population consisted entirely of naupliar instars with instars 1 through 5 each contributing 16-21 % to the total population with lesser instars 6 present (4.8 %) and few instars 7 (0.6 %) present.

Larval development continued with 66 % of population on the 24 May survey having reached the adult stage. The may lakewide mean *Artemia* abundance (12 stations) was 39,262±5258 m^{-2}, with all age classes about twice as abundant in the eastern sector of the lake (stations 7-12) versus the western sector (stations 1-6). All instars were present, but instars 4-7 constituted 77 % of the total thus indicating that the spring hatch was mostly over.

Recruitment into the adult population continued during early June and the annual peak was observed on 14 June when lakewide adult abundance was 45,419±3810 m^{-2}. This June 2005 adult *Artemia* abundance was the third largest spring generation observed in the 27-yr (1979 to 2005) record (Fig. 21). While the total *Artemia* abundance declined from 66,184±4641 m^{-2} on 14 June to 54635±5368 m^{-2} on 1 July, the number of adults was nearly the same; 41,221±5,262 m^{-2} as observed in mid-June. However, 1st generation adults declined to 34,460±5,536 m^{-2} by 13 July. This mid-July adult abundance is slightly above the observed long-term mean.

Ovoviviparous reproduction and the second generation

Ovoviviparous reproduction depends on the ambient food levels and the age of the individual. *Artemia* produce multiple broods and ovoviviparous reproduction in the lake occurs, if at all, almost exclusively with the first brood, rarely occurring in an individual's second and subsequent broods.

While adult females were abundant on the 24 May survey, only 6.3 % of the adult females were carrying eggs and nearly all these (91.2 %) were still undifferentiated (Table 13a, b, c, Fig. 22). Of the eggs that had differentiated, 81.8 % were naupliar eggs (as opposed to encapsulated cysts). As a large number of adult female *Artemia* were just maturing during the mid-May survey, a survey was conducted two weeks later on 3 June so that more accurate estimates of egg production could be made. Ovigery increased from 6.3 % in mid-May to 30 % by 3 June. While most (60.9 %) of the egg masses were undifferentiated, 28.9 % were carrying cysts and 10.2 % were reproducing ovoviviparously. The naupliar instars (instars 1-7) were dominated (67 %) by 1st instars produced by this 1st generation of adults. June mean fecundity was 42.9 eggs $brood^{-1}$ Table 14).

While ovigerity increased to 47 % by 14 June, a smaller proportion of females were reproducing ovoviviparously (7.4 %) and cyst production had increased to 92.6 % of the ovigerous females (21 % had undifferentiated egg masses). Also, fecundity had decreased slightly to 37.1 eggs brood^{-1}. The lower fecundity and switch to cyst production accompanies declining food levels (decreasing algal biomass).

Ovigery increased from 47 % in mid-June to 63 % by mid-July with 96 % of ovigerous females with differentiated egg masses producing cysts. Mid-July fecundity was 21 eggs brood^{-1}. On both the 1 July and 13 July surveys, naupliar instars consisted primarily (>51 %) of 1st instars, and 5th through 7th instars were virtually absent (<2 % of naupliar instars) indicating the lack of recruitment into the adult population during July.

Lakewide adult *Artemia* abundance declined 34,460±5,536 m^{-2} on 13 July to 28,256 ±5,626 m^{-2} on 1 August and 25,419±2373 m^{-2} on 17 August. The August adult abundance is in the center of the observed range from previous years. Reflecting higher food levels, both ovigery and individual fecundity increased from values observed in mid-July to 80.3 % and 34.0 eggs individual^{-1}, respectively, by mid-August. While all life stages were represented, adults constituted 83.4 % of the total population. Naupliar instars were dominated by 1st (24 %), 2nd (44 %) and 3rd (23 %) instars.

Lakewide adult *Artemia* abundance continued its late summer decline to 13,058±1739 m^{-2} on 14 September. The mid-September population was dominated by adults (82 % of total). Females accounted for 22 % of the adults and both ovigery (96 %) and fecundity (60.3 eggs female^{-1}) were markedly higher than in August. Ovoviparous reproduction was still occurring, albeit at a low rate (3.3 % of ovigerous females), and some recruitment of young occurring as evidenced by the presence of all naupliar instars.

Artemia abundance continued to decline despite the observed ovoviviparous reproduction in September. By 20 October, lakewide adult *Artemia* abundance had decreased to 3,073 (±743 m^{-2}) this is almost identical to 2004 when October lakewide abundance was 2,245 m^{-2}. All naupliar instars and juveniles were present and they represented 46 % of the total population. Thus, recruitment into the adult population was occurring. While females were only one quarter as abundant as adult males, 80 % were ovigerous and fecundity was high (82.7 eggs female^{-1}). A small proportion (3.2 %) of ovigerous females were reproducing ovoviviparously.

Artemia adult abundance declined further to 189 (±50 m^{-2}) on 16 November and constituted only 12 % of the total population. Only 3 % of adult females were ovigerous. While all instars and juveniles were present and food abundant, cold water temperatures limit development and recruitment into the adult population at this time of the year.

Adults were virtually absent in mid-December with only four adult shrimp collected in vertical net tows taken at station 6 and 3 yielding an estimated lakewide abundance of 40 m^{-2}. None of the three adult females collected were ovigerous. Naupliar instars were slightly more abundant (282 m^{-2}, range 210-363) but still virtually absent and only 1 juvenile was present in the net tows.

During 2005, the length of adult females varied from 9.8±0.1 (±1 SE) mm on 13 July to 12.0±0.2 on 20 October (Table 14). These are well within the range observed in other years.

Artemia Spatial Variability

Artemia abundance is often spatially heterogeneous across the lake. Although the temporal and spatial patterns of *Artemia* abundance at individual stations vary among years, a tendency for greater abundance early in the year in the eastern half of the lake has been noted. While the bathymetry of the lake is complex and defies a simple grouping scheme, this trend is often apparent by splitting the stations into western (Stations 1-6) and eastern (Station 7-12) sectors. During 2005, adult abundance was twice as high at the eastern stations (Stations 7-12) as at the western stations (Stations 1-6) on 24 May.

Artemia Population Statistics, 1979–2005

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 15, Fig. 23). 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 varied less within a range of 14–37,000 m^{-2}. The overall mean seasonal abundance of adult *Artemia* from 1979 to 2005 was ~19,100 m^{-2}. During this 27-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 2005, mean seasonal abundance was ~17,900 m^{-2} slightly below the long-term mean.

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 2005 (Table 15, Fig. 24). 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. The 3rd largest spring generation of adults was observed in 2005 and the overall temporal occurrence of adults was also the 3rd earliest at 11 July.

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 ammonium concentrations due to the breakdown of meromixis, regressions were performed on just 1991 and 1992 for use in subsequent years. The exponential equation:

$$P_m^B = 0.237 \times 1.183^T \qquad n=42, r^2=0.86$$

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 2005, fourteen carbon uptake experiments were conducted with natural phytoplankton assemblages from either the mixed-layer or near the bottom of the epilimnion (Table 16). 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 for samples collected at 2 m depth ranged from 1.67 g C g Chl a^{-1} h^{-1} on 16 November to 24.6 g C g Chl a^{-1} h^{-1} on 14 July (Table 16, Fig. 25), while light-limited rates (α^B) for these samples ranged from 5.4 to 40.1 g C g Chl a^{-1}

Einst^{-1} m^{2} (Table 16). Chlorophyll specific rates for samples collected from the mid-depth maxima during June through September were always much lower.

Using the interpolative model to integrate the photosynthetic parameters with in situ temperature, chlorophyll, and light resulted in an annual productivity estimate of 1111 g C m^{-2} during 2005 (Table 17, Fig. 26). The maximum uptakes rates are primarily a function of temperature and thus the seasonal pattern and magnitudes were roughly similar during 2002–2005 (Fig. 27, 28). 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. 27, Fig. 28) 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 2005 was 94 % higher than the long-term mean (1982–2005) of 573 g C m^{-2} (Table 17, Fig. 29). 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 ammonium 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 2005, *Artemia* biomass was 0.18 g dry weight m^{-2} on 24 March and increased to the yearly peak of 30.5 g dry weight m^{-2} on 14 June. *Artemia* biomass remained fairly high through September but then declined to 3.92 g m^{-2} in mid-October, 0.14 g m^{-2} in mid-November and virtually zero in December. The 2005 mean annual biomass of 11.8 g m^{-2} was 7 % higher than observed in 2004 and 25 % above the long-term (1982-2005) mean of 9.46 g m^{-2} (Table 17, Fig. 30)

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. 31, Table 17). In 2004, total annual naupliar production (0.04×10^6 m^{-2}) was much lower than the long-term mean of 0.24×10^6 m^{-2} and among the lowest observed. In 2005, total annual naupliar production (0.31×10^6 m^{-2}) is slightly above the long-term mean of 0.25×10^6 m^{-2}. Total annual cyst production in 2004 (2.62×10^6 m^{-2}) and 2005 (3.8×10^6 m^{-2}) are both below the long-term mean of 4.1×10^6 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. 32-33). 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 2005.

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. 32, 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. 33) 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, March – December 2005.

Depth (m)	3/24	4/15	5/24	6/14	7/13	8/17	9/14	10/20	11/16	12/14
1	5.2	7.6	15.9	-	23.1	21.5	17.7	13.1	9.6	5.6
2	4.9	7.1	15.7	17.6	23.3	21.4	17.8	12.8	9.5	5.6
3	5.0	7.0	14.4	16.9	23.0	21.4	17.8	12.5	9.4	5.6
4	5.0	6.8	13.8	16.6	22.6	21.4	17.7	12.4	9.3	5.6
5	5.0	6.4	12.8	16.5	20.3	21.5	17.7	12.3	9.3	5.6
6	5.1	5.9	12.5	16.5	19.1	21.5	17.7	12.4	9.5	5.6
7	5.2	5.6	12.2	15.5	18.4	21.6	17.7	12.6	9.7	5.7
8	5.4	5.6	11.7	14.4	17.8	19.9	17.6	12.9	9.8	5.9
9	4.6	5.5	11.2	13.9	16.9	18.2	17.6	12.9	9.8	5.7
10	3.8	5.3	10.7	12.0	15.9	17.1	17.6	12.9	9.7	5.7
11	3.0	5.2	9.6	10.2	14.3	15.7	16.6	12.9	9.7	5.7
12	2.7	5.0	7.9	9.0	12.3	14.3	15.0	12.9	9.6	5.8
13	2.4	4.6	7.0	7.8	9.9	12.7	11.6	12.8	9.6	5.8
14	2.3	4.3	6.2	6.4	6.9	11.0	10.3	12.6	9.5	5.9
15	2.2	4.0	4.7	5.1	5.3	8.1	8.8	11.7	9.4	5.9
16	2.2	3.8	3.9	4.6	5.0	6.2	7.0	8.8	9.4	5.9
17	2.1	3.5	3.7	4.2	4.5	5.2	5.6	7.3	9.0	5.9
18	2.1	3.4	3.4	3.9	4.4	4.8	5.2	6.5	8.6	5.9
19	2.0	3.1	3.1	3.6	4.1	4.5	4.8	5.5	7.4	5.8
20	2.0	2.9	3.0	3.5	3.9	4.0	4.5	5.1	6.3	5.7
21	2.0	2.6	2.9	3.4	3.6	3.9	4.4	4.9	5.5	5.7
22	2.0	2.5	2.9	3.2	3.5	3.8	4.2	4.7	5.1	5.9
23	2.0	2.4	2.8	3.1	3.5	3.8	4.1	4.5	4.7	5.7
24	2.0	2.3	2.8	3.1	3.5	3.7	4.0	4.3	4.5	5.2
25	2.0	2.3	2.7	3.1	3.4	3.6	3.9	4.2	4.4	5.1
26	2.0	2.2	2.7	3.1	3.4	3.6	3.8	4.2	4.3	5.0
27	2.0	2.2	2.6	2.9	3.3	3.5	3.7	4.0	4.3	4.9
28	2.0	2.2	2.6	2.9	3.2	3.4	3.7	4.0	4.2	4.8
29	2.1	2.2	2.5	2.9	3.1	3.4	3.6	4.0	4.2	4.7
30	2.1	2.2	2.5	2.8	3.1	3.4	3.5	3.9	4.2	4.6
31	2.1	2.1	2.5	2.8	3.1	3.4	3.4	3.8	4.1	4.6
32	2.1	2.1	2.5	2.8	3.0	3.3	3.4	3.8	4.1	4.6
33	2.1	2.1	2.5	2.8	3.0	3.3	3.4	3.8	4.0	4.5
34	2.1	2.1	2.5	2.7	3.0	3.2	3.4	3.8	4.0	4.5
35	2.1	2.1	2.5	2.7	3.0	3.2	3.4	3.8	4.0	4.4
36	2.1	2.1	2.4	2.7	3.0	3.2	3.3	3.7	4.0	4.4
37	2.1	2.1	2.4	2.7	-	3.2	3.3	3.7	4.0	4.4

Table 2. Conductivity (mS cm^{-1} at 25ºC) at Station 6, March – December 2005.

Depth (m)	3/24	4/15	5/24	6/14	7/13	8/17	9/14	10/20	11/16	12/14
1	82.1	82.3	81.5	-	79.0	80.1	81.4	82.1	82.1	82.0
2	82.2	82.4	81.9	80.4	80.0	80.1	81.6	82.1	82.1	82.0
3	82.2	82.5	82.2	81.9	80.4	80.1	81.6	82.1	82.2	82.0
4	82.2	82.5	82.4	81.9	80.7	80.1	81.6	82.1	82.2	82.0
5	82.2	82.5	82.4	82.1	81.2	80.1	81.6	82.1	82.3	82.0
6	82.3	82.5	82.5	82.2	81.6	80.2	81.6	82.2	82.4	82.0
7	82.3	82.5	82.4	82.1	81.8	81.4	81.6	82.3	82.4	82.1
8	82.3	82.6	82.2	81.9	81.8	81.8	81.6	82.4	82.4	82.2
9	82.5	82.6	82.3	82.2	81.9	81.9	81.6	82.4	82.4	82.1
10	83.0	82.6	82.4	82.3	82.0	81.9	81.6	82.4	82.5	82.2
11	83.2	82.6	82.3	82.3	82.0	82.1	81.6	82.4	82.5	82.3
12	83.3	82.6	82.3	82.5	81.9	81.9	81.9	82.4	82.5	82.3
13	83.3	82.6	82.5	82.1	81.9	82.2	81.8	82.4	82.5	82.3
14	83.4	82.8	82.4	82.3	82.3	82.1	82.1	82.4	82.5	82.3
15	83.4	82.8	82.5	82.6	82.3	82.5	82.3	82.2	82.5	82.3
16	83.4	82.9	82.9	82.7	82.7	82.7	82.5	82.1	82.5	82.3
17	83.4	83.0	82.9	82.8	82.7	82.9	82.7	82.7	82.5	82.3
18	83.4	83.1	83.0	82.9	82.8	82.8	82.8	82.7	82.5	82.3
19	83.4	83.1	83.1	83.0	82.8	82.9	83.1	83.1	82.7	82.3
20	83.4	83.1	83.2	83.0	82.8	82.9	83.2	83.1	82.6	82.4
21	83.4	83.2	83.2	83.0	82.9	83.0	83.2	83.2	82.9	82.4
22	83.4	83.2	83.2	83.0	83.0	83.0	83.3	83.2	83.0	83.0
23	83.4	83.3	83.2	83.1	82.9	83.0	83.3	83.2	83.1	83.1
24	83.4	83.3	83.2	83.1	83.0	83.1	83.3	83.4	83.2	83.2
25	83.4	83.3	83.3	83.1	83.0	83.1	83.3	83.4	83.2	83.3
26	83.5	83.3	83.3	83.1	83.0	83.1	83.4	83.4	83.3	83.4
27	83.5	83.3	83.3	83.1	83.0	83.2	83.3	83.4	83.3	83.3
28	83.5	83.4	83.3	83.1	83.0	83.2	83.4	83.4	83.3	83.4
29	83.5	83.4	83.3	83.1	83.0	83.2	83.4	83.4	83.3	83.4
30	83.5	83.4	83.3	83.2	83.1	83.2	83.4	83.4	83.3	83.4
31	83.5	83.4	83.3	83.2	83.1	83.2	83.4	83.4	83.3	83.5
32	83.5	83.4	83.3	83.2	83.1	83.3	83.4	83.4	83.3	83.5
33	83.5	83.4	83.3	83.2	83.1	83.3	83.4	83.4	83.3	83.5
34	83.5	83.4	83.3	83.2	83.1	83.3	83.4	83.4	83.3	83.5
35	83.5	83.4	83.3	83.2	83.1	83.3	83.4	83.4	83.3	83.5
36	83.5	83.4	83.3	83.2	83.1	83.3	83.4	83.4	83.3	83.5
37	83.5	83.4	83.4	83.2	-	83.3	83.4	83.4	83.3	83.5

Table 3. Excess density (g l^{-1}) at Station 6, March – December 2005.

Depth (m)	Dates 3/24	4/15	5/24	6/14	7/13	8/17	9/14	10/20	11/16	12/14
1	71.4	71.3	68.3	-	63.1	64.8	67.7	69.7	70.5	71.3
2	71.6	71.5	68.8	66.5	64.0	64.9	67.8	69.8	70.7	71.3
3	71.6	71.6	69.5	68.5	64.7	64.9	67.8	69.9	70.7	71.3
4	71.6	71.7	69.9	68.6	65.2	64.8	67.8	69.9	70.8	71.3
5	71.6	71.7	70.2	68.8	66.6	64.9	67.8	70.0	70.9	71.3
6	71.7	71.8	70.4	68.9	67.4	65.0	67.8	70.0	70.9	71.3
7	71.7	71.9	70.4	69.0	67.9	66.3	67.8	70.1	70.9	71.4
8	71.7	72.0	70.2	69.2	68.1	67.4	67.8	70.2	71.0	71.5
9	72.0	72.0	70.5	69.6	68.5	68.0	67.9	70.1	71.0	71.4
10	72.7	72.0	70.7	70.3	68.9	68.4	67.9	70.1	71.0	71.5
11	73.0	72.0	70.8	70.8	69.3	69.0	68.2	70.1	71.0	71.5
12	73.2	72.1	71.2	71.2	69.8	69.2	69.1	70.2	71.0	71.6
13	73.3	72.2	71.6	71.0	70.3	70.0	69.8	70.2	71.1	71.6
14	73.3	72.4	71.6	71.5	71.3	70.3	70.4	70.2	71.1	71.6
15	73.4	72.5	72.0	72.1	71.7	71.4	71.0	70.2	71.1	71.6
16	73.4	72.6	72.6	72.2	72.1	72.0	71.6	70.8	71.1	71.6
17	73.4	72.8	72.7	72.4	72.3	72.4	72.1	71.8	71.2	71.6
18	73.4	72.8	72.8	72.6	72.4	72.4	72.3	71.9	71.3	71.6
19	73.5	72.9	72.9	72.7	72.5	72.4	72.7	72.5	71.8	71.6
20	73.5	73.0	73.0	72.8	72.5	72.6	72.9	72.7	71.9	71.7
21	73.5	73.1	73.1	72.8	72.6	72.7	72.9	72.8	72.3	71.7
22	73.5	73.2	73.1	72.9	72.7	72.8	73.0	72.8	72.6	72.3
23	73.5	73.2	73.1	72.9	72.7	72.8	73.1	72.9	72.7	72.5
24	73.5	73.3	73.1	72.9	72.7	72.9	73.1	73.1	72.9	72.8
25	73.5	73.3	73.2	72.9	72.8	72.9	73.1	73.1	72.9	72.9
26	73.5	73.3	73.2	73.0	72.8	72.9	73.1	73.1	73.0	73.0
27	73.5	73.3	73.2	73.0	72.8	73.0	73.1	73.1	73.0	73.0
28	73.5	73.4	73.2	73.0	72.8	73.0	73.2	73.2	73.0	73.0
29	73.5	73.4	73.2	73.0	72.9	73.0	73.2	73.1	73.0	73.1
30	73.5	73.4	73.3	73.0	72.9	73.1	73.2	73.1	73.0	73.1
31	73.6	73.4	73.3	73.1	72.9	73.1	73.2	73.2	73.0	73.2
32	73.6	73.4	73.3	73.1	72.9	73.1	73.2	73.2	73.0	73.1
33	73.6	73.4	73.3	73.1	73.0	73.1	73.3	73.2	73.0	73.2
34	73.6	73.4	73.3	73.1	73.0	73.1	73.2	73.1	73.1	73.2
35	73.6	73.4	73.3	73.1	73.0	73.1	73.2	73.2	73.0	73.2
36	73.6	73.4	73.3	73.1	73.0	73.2	73.3	73.2	73.1	73.2
37	73.6	73.5	73.3	73.1	-	73.1	73.2	73.2	73.1	73.2

Table 4. Temperature, conductivity, and density stratification (kg m^{-3}) at Station 6, March – December 2005.

Date	Temperature		Conductivity		Density Difference due to		
	2 m	32 m	2 m	32 m	Temperature	Conductivity	Both
3/24	4.93	2.06	82.23	83.50	0.407	1.513	1.920
4/14	6.57	2.19	82.51	83.36	0.670	1.008	1.677
5/23	14.42	2.47	81.93	83.54	2.426	1.889	4.314
6/3	16.66	2.59	81.77	83.26	3.058	1.752	4.810
6/15	17.01	2.78	81.64	83.20	3.140	1.830	4.969
7/1	18.88	2.99	81.11	83.10	3.704	2.320	6.025
7/14	22.50	3.10	80.05	83.07	4.957	3.513	8.469
8/1	22.94	3.22	79.01	83.04	5.092	4.664	9.756
8/18	21.70	3.27	79.89	83.36	4.639	4.039	8.679
9/15	17.65	3.44	81.35	83.44	3.250	2.445	5.695
10/20	12.76	3.81	82.07	83.39	1.800	1.555	3.356
11/16	9.48	4.08	82.15	83.29	0.984	1.352	2.336
12/14	5.56	4.55	82.02	83.46	0.162	1.693	1.855

Table 5. Secchi Depths (m), March – December 2005.

	Dates									
Station	3/24	4/15	5/24	6/14	7/13	8/17	9/14	10/20	11/16	12/14
Western Sector										
1	0.70	0.60	0.80	5.60	9.90	7.60	6.50	1.80	0.90	-
2	0.68	0.60	0.80	5.10	9.60	7.00	5.60	1.80	0.85	-
3	0.70	0.70	1.20	4.20	9.10	6.90	5.70	1.40	0.80	1.00
4	0.70	0.70	1.20	4.40	8.40	7.00	6.30	1.30	0.80	-
5	0.70	0.70	1.50	4.60	8.40	7.40	5.60	1.50	0.90	-
6	0.80	0.70	1.30	4.30	8.00	7.40	4.20	1.45	1.10	1.00
Avg.	0.70	0.66	1.10	4.78	9.08	7.18	5.94	1.56	0.85	1.00
S.E.	0.02	0.02	0.11	0.22	0.31	0.12	0.33	0.09	0.05	0.00
n	6	6	6	6	6	6	6	6	6	2
Eastern Sector										
7	0.60	0.65	1.20	4.80	7.60	6.50	4.00	1.50	0.80	-
8	0.60	0.70	1.70	4.60	7.40	6.40	4.10	1.30	0.95	-
9	0.70	0.70	2.00	4.80	6.70	6.70	5.20	1.40	0.80	-
10	0.70	0.70	1.50	4.20	6.60	6.00	5.20	1.40	0.90	-
11	0.70	0.70	1.40	5.20	6.80	6.00	3.50	1.35	0.85	-
12	0.70	0.70	1.40	4.80	7.10	6.10	4.20	1.40	0.95	-
Avg.	0.67	0.69	1.53	4.73	7.03	6.28	4.37	1.39	0.88	-
S.E.	0.02	0.01	0.11	0.13	0.16	0.12	0.28	0.03	0.03	-
n	6	6	6	6	6	6	6	6	6	0
Total Lakewide										
Avg.	0.69	0.68	1.33	4.72	7.97	6.75	5.01	1.47	0.88	1.00
S.E.	0.01	0.01	0.10	0.12	0.33	0.16	0.28	0.05	0.03	0.00
n	12	12	12	12	12	12	12	12	12	2

Table 6: Dissolved Oxygen (mg l^{-1}) at Station 6, March – December 2005.

	Dates									
Depth (m)	3/24	4/14	5/23	6/15	7/14	8/18	9/15	10/20	11/16	12/14
0	7.1	6.8	5.0	4.3	3.2	3.8	5.2	5.0	5.9	5.4
1	7.0	7.2	5.2	4.3	3.1	3.7	5.2	5.2	6.2	5.2
2	7.0	7.2	5.2	4.2	2.7	3.7	5.5	5.2	6.5	5.2
3	7.5	7.2	5.3	4.1	2.6	3.7	5.5	5.2	6.8	5.1
4	7.6	6.8	5.3	4.1	2.3	3.8	5.3	5.2	6.9	5.1
5	7.6	5.8	4.9	4.2	2.5	3.8	5.3	5.0	6.9	5.1
6	7.7	5.7	4.8	4.2	3.6	3.9	5.4	5.0	5.4	5.1
7	7.7	5.6	4.7	4.1	3.8	3.9	5.4	5.0	4.7	4.7
8	7.7	5.4	4.6	4.4	4.0	3.9	5.3	5.0	4.5	4.6
9	7.5	5.1	4.6	4.7	3.9	6.1	5.3	4.7	4.0	4.7
10	6.4	4.8	4.2	5.0	3.8	6.1	5.3	4.7	3.8	4.7
11	5.1	4.7	3.9	4.2	3.3	4.8	5.2	4.7	3.5	4.7
12	4.6	4.7	3.4	3.1	3.7	3.2	5.6	4.8	3.3	4.5
13	4.0	4.5	2.4	1.1	2.1	3.8	4.1	4.6	2.7	4.6
14	3.4	4.0	1.8	<0.5	1.7	2.3	2.7	4.1	2.5	4.7
15	3.2	3.7	<0.5	<0.5	1.3	0.8	1.3	3.1	1.6	4.6
16	3.1	3.1	<0.5	-	<0.5	<0.5	<0.5	<0.5	1.7	4.4
17	3.1	2.7	<0.5	-	<0.5	<0.5	<0.5	<0.5	0.5	4.3
18	3.1	2.2	<0.5	-	<0.5	<0.5	<0.5	<0.5	0.5	4.3
19	3.0	1.7	<0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	4.3
20	2.7	1.4	<0.5	-	<0.5	<0.5	<0.5	-	<0.5	4.3
21	2.7	1.2	<0.5	-	<0.5	-	-	-	<0.5	4.0
22	2.5	0.9	<0.5	-	-	-	-	-	<0.5	<0.5
23	2.4	0.7	<0.5	-	-	-	-	-	0.5	<0.5
24	2.5	0.6	<0.5	-	-	-	-	-	0.5	<0.5
25	2.5	0.5	<0.5	-	-	-	-	-	0.5	-
26	2.4	<0.5	<0.5	-	-	-	-	-	0.5	-
27	2.5	<0.5	<0.5	-	-	-	-	-	0.5	-
28	2.4	<0.5	-	-	-	-	-	-	<0.5	-
29	2.0	<0.5	-	-	-	-	-	-	-	-
30	1.1	<0.5	-	-	-	-	-	-	-	-
31	0.6	<0.5	-	-	-	-	-	-	-	-
32	0.6	<0.5	-	-	-	-	-	-	-	-
33	0.6	<0.5	-	-	-	-	-	-	-	-
34	0.5	<0.5	-	-	-	-	-	-	-	-
35	0.5	<0.5	-	-	-	-	-	-	-	-
36	0.5	<0.5	-	-	-	-	-	-	-	-

Table 7. Ammonium (µM) at Station 6, March – December 2005.

	Dates									
Depth (m)	3/24	4/14	5/23	6/15	7/14	8/18	9/15	10/20	11/16	12/14
1	-	-	-	-	-	-	-	-	-	-
2	0.8	1.0	1.1	1.0	11.0	2.7	1.1	0.9	1.2	1.1
3	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-
8	1.1	1.1	1.3	1.0	1.3	0.9	1.1	1.0	1.2	1.1
9	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-
12	1.9	1.3	1.3	1.2	1.3	3.5	1.1	1.0	5.6	1.0
13.5	-	-	-	2.1	-	-	-	-	-	-
14	-	-	-	-	4.2	4.2	9.4	-	-	-
15	-	-	-	-	-	-	-	-	-	-
16	14.7	3.1	6.5	20.8	17.6	17.3	19.6	3.9	12.2	1.1
17	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-
20	25.5	21.4	25.9	40.7	55.6	50.2	59.5	49.9	52.3	0.9
21	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-
24	25.0	30.0	30.6	41.2	59.4	60.8	67.5	74.5	86.4	40.9
25	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-
28	25.9	32.2	41.9	44.0	66.5	71.1	70.5	75.3	82.8	75.2
29	-	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-	-
35	38.0	35.2	47.0	49.2	67.9	68.3	72.6	85.5	101.0	84.8

Table 8. Ammonium (μM) at 7 stations in upper 9 m of water column, March – November 2005.

Station	3/24	4/15	5/24	6/14	7/13	8/17	9/14	10/20	11/16
1	1.8	1.3	1.4	2.8	12.4	2.6	1.5	1.3	1.1
2	2.5	1.3	1.4	1.9	10.5	2.2	1.1	1.5	1.2
5	2.2	1.5	1.5	1.3	8.1	2.0	1.1	1.3	1.2
6	1.8	1.1	0.7	1.1	7.9	1.9	1.1	0.9	1.2
7	1.8	1.1	0.3	1.2	5.1	1.6	1.1	0.9	1.1
8	1.6	1.1	0.4	1.0	5.1	1.0	1.2	1.1	1.2
11	1.4	0.9	0.2	2.2	5.6	1.7	1.1	0.9	1.1
Mean	1.9	1.2	0.8	1.6	7.8	1.9	1.2	1.1	1.2
SE	0.14	0.08	0.22	0.26	1.06	0.19	0.06	0.08	0.02

Table 9. Chlorophyll *a* (μg l^{-3}) at Station 6, March – December 2005.

Depth (m)	3/24	4/14	5/23	6/15	7/14	8/18	9/15	10/20	11/16	12/14
	Dates									
1	-	-	-	-	-	-	-	-	-	-
2	58.7	72.5	10.6	2.6	0.7	1.3	2.0	14.9	42.3	65.6
3	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-
8	57.4	76.5	23.7	8.1	1.6	2.7	2.5	20.6	38.6	61.0
9	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-
12	87.0	78.1	45.9	27.6	6.4	2.7	6.1	17.8	34.1	56.7
13.5	-	-	-	45.6	-	-	-	-	-	-
14	-	-	-	-	15.5	9.2	46.8	-	-	-
15	-	-	-	-	-	-	-	-	-	-
16	50.6	69.9	73.0	57.9	57.8	54.4	62.1	21.3	34.8	53.0
17	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-
20	43.9	61.4	54.0	53.6	41.0	41.0	48.2	51.6	45.6	52.8
21	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-
24	34.8	50.1	53.1	49.3	40.2	45.6	47.6	50.3	46.1	47.7
25	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-
28	36.9	51.0	46.5	55.1	39.6	47.0	45.0	46.9	45.5	47.3

Table 10. Chlorophyll *a* ($\mu g\ l^{-3}$) at 7 stations in upper 9 m of water column, March – November 2005.

Stations	3/24	4/15	5/24	6/14	7/13	8/17	9/14	10/20	11/16
1	63.5	72.5	22.7	2.7	0.3	2.3	2.8	19.9	41.9
2	63.4	75.7	25.3	5.1	0.6	2.4	2.9	19.8	43.5
5	61.3	77.7	20.1	5.3	1.0	2.1	2.6	18.5	41.7
6	67.5	77.0	16.5	4.7	1.3	2.0	2.7	17.4	39.3
7	54.3	70.3	18.5	3.7	1.0	2.1	3.8	17.4	40.6
8	57.7	65.3	16.5	4.2	1.2	2.2	4.8	17.4	41.7
11	55.2	76.2	11.7	3.1	1.4	2.1	4.8	16.5	36.6
Mean	60.4	73.5	18.8	4.1	1.0	2.2	3.5	18.1	40.7
SE	1.83	1.70	1.69	0.38	0.15	0.05	0.37	0.50	0.84

Table 11a. *Artemia* lake and sector means, 2005.

	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:										
3/24	31,791	0	3	0	0	0	0	0	3	31,794
4/15	33,588	0	0	0	3	0	0	3	3	33,592
5/24	9,893	3,467	12,575	765	12,488	13	60	13,327	25,902	39,262
6/3	11,294	1,985	19,396	3,219	12,394	1,529	537	17,679	37,076	50,355
6/14	19,665	1,100	23,689	2,146	11,590	7,404	590	21,730	45,419	66,184
7/1	13,239	174	21,731	1,020	7,860	9,993	617	19,491	41,221	54,635
7/13	9,805	161	20,993	1,006	4,923	7,217	322	13,467	34,460	44,427
8/1	8,853	208	16,626	993	3,192	7,009	436	11,630	28,256	37,317
8/17	4,936	107	16,177	671	1,824	6,385	362	9,242	25,419	30,463
9/14	2,881	59	9,561	136	134	3,120	107	3,498	13,058	15,998
10/20	2,559	109	2,460	23	121	454	15	614	3,073	5,741
11/16	1,261	159	72	2	114	2		117	189	1,610
12/14	282	10	10	0	30	0	0	30	40	332
Western Sector Mean:										
3/24	31,911	0	3	0	0	0	0	0	3	31,915
4/15	28,330	0	0	0	7	0	0	7	7	28,337
5/24	6,157	1,355	8,249	832	8,343	27	13	9,215	17,465	24,977
6/3	9,819	1,556	19,691	4,078	11,107	1,556	805	17,545	37,237	48,612
6/14	19,584	1,180	26,023	2,146	11,268	7,834	805	22,052	48,075	68,840
7/1	11,751		27,686	1,395	9,497	12,394	751	24,038	51,724	63,474
7/13	10,302	107	31,496	1,127	6,653	9,175	429	17,384	48,880	59,289
8/1	6,868	80	25,057	1,583	5,741	9,443	510	17,277	42,334	49,282
8/17	3,488	80	20,496	778	2,495	5,848	268	9,390	29,886	33,454
9/14	3,032	54	12,757	174	215	4,172	134	4,695	17,451	20,537
10/20	2,569	124	3,964	47	127	805	30	1,009	4,973	7,666
11/16	376	64	57	3	77	0	0	80	137	577
12/14	282	10	10	0	30	0	0	30	40	332
Eastern Sector Mean:										
3/24	31,670	0	3	0	0	0	0	0	3	31,673
4/15	38,846	0	0	0	0	0	0	0	0	38,846
5/24	13,628	5,580	16,901	698	16,633	0	107	17,438	34,339	53,548
6/3	12,770	2,414	19,101	2,361	13,682	1,502	268	17,814	36,915	52,099
6/14	19,745	1,019	21,355	2,146	11,911	6,975	376	21,408	42,763	63,528
7/1	14,728	349	15,775	644	6,224	7,592	483	14,943	30,718	45,795
7/13	9,309	215	10,490	885	3,192	5,258	215	9,551	20,040	29,564
8/1	10,838	335	8,196	402	644	4,574	362	5,983	14,178	25,352
8/17	6,385	134	11,858	563	1,154	6,922	456	9,095	20,952	27,471
9/14	2,730	64	6,365	97	54	2,069	80	2,300	8,665	11,459
10/20	2,549	94	956	0	114	104	0	218	1,174	3,816
11/16	2,146	255	87	0	151	3	0	154	241	2,643
12/14	31,670	0	3	0	0	0	0	0	3	31,673

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

Table 11b. Standard errors of *Artemia* sector means (Table 11a), 2005.

	Instars 1-7	Instars 8-11	adult male	adult fem ?	adult fem e	adult fem c	adult fem n	adult fem tot	adult total	total
SE of Lakewide Mean:										
3/24	3,925	0	2	0	0	0	0	0	2	3,925
4/15	5,960	0	0	0	3	0	0	3	3	5,960
5/24	1,419	978	1,796	103	1,584	13	53	1,603	3,331	5,258
6/3	1,194	307	1,562	563	1,057	327	170	1,628	2,799	3,416
6/14	1,769	276	2,177	332	1,101	1,210	118	2,158	3,810	4,641
7/1	1,663	73	2,950	202	910	1,454	101	2,353	5,262	5,368
7/13	1,317	63	4,090	177	709	1,028	89	1,643	5,536	5,562
8/1	1,715	58	3,198	374	942	1,356	81	2,479	5,626	5,364
8/17	1,118	36	1,658	134	314	853	60	1,141	2,373	2,523
9/14	371	17	1,347	26	36	515	32	558	1,739	1,737
10/20	297	17	610	13	31	142	9	156	743	876
11/16	460	59	19	2	33	2	0	33	50	545
12/14	80	10	10	0	10	0	0	10	20	111
SE of Western Sector Mean:										
3/24	6,063	0	3	0	0	0	0	0	3	6,066
4/15	11,601	0	0	0	7	0	0	7	7	11,600
5/24	916	234	1,671	146	1,204	27	13	1,214	2,757	3,461
6/3	1,557	419	2,201	898	1,645	602	273	3,190	5,026	5,917
6/14	1,985	503	4,167	359	1,473	2,221	161	3,451	7,014	8,075
7/1	709		4,456	339	1,342	2,549	180	3,758	8,199	8,439
7/13	1,949	68	5,059	297	791	1,561	136	1,946	6,489	5,269
8/1	560	55	3,799	671	1,130	2,255	134	3,618	7,320	7,237
8/17	1,407	36	1,415	214	100	924	99	1,222	1,924	3,120
9/14	667	34	1,435	44	54	602	49	620	1,391	1,094
10/20	407	31	810	24	51	196	16	199	946	1,169
11/16	82	18	17	3	23	0	0	23	34	119
12/14	80	10	10	0	10	0	0	10	20	111
SE of Eastern Sector Mean:										
3/24	5,568	0	3	0	0	0	0	0	3	5,566
4/15	3,265	0	0	0	0	0	0	0	0	3,265
5/24	1,563	1,539	1,979	154	1,649	0	107	1,752	3,571	5,294
6/3	1,725	405	2,420	543	1,243	329	154	1,215	3,033	3,888
6/14	3,134	281	1,145	597	1,767	1,201	129	2,922	3,442	5,171
7/1	3,282	105	2,061	93	878	701	72	1,402	3,234	4,929
7/13	1,932	107	1,973	211	621	826	107	1,398	3,092	4,474
8/1	3,324	73	1,462	165	181	798	92	1,089	2,528	4,118
8/17	1,638	65	1,620	170	494	1,494	49	2,055	3,619	3,832
9/14	391	13	1,356	22	17	601	42	643	1,910	1,961
10/20	471	16	277	0	40	38	0	71	298	726
11/16	781	106	35	0	61	3	0	62	94	930
12/14	5,568	0	3	0	0	0	0	0	3	5,566

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii

Table 11c. Percentage in different classes for *Artemia* sector means (Table 11a), 2005.

	Instars 1-7	8-11	adult male	adult fem ?	adult fem e	adult fem c	adult fem n	adult fem tot	adult total	total
Lakewide (%):										
3/24	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4/15	100.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0
5/24	25.2	8.8	32.0	5.7	93.7	0.1	0.5	33.9	66.0	100.0
6/3	22.4	3.9	38.5	18.2	70.1	8.6	3.0	35.1	73.6	100.0
6/14	29.7	1.7	35.8	9.9	53.3	34.1	2.7	32.8	68.6	100.0
7/1	24.2	0.3	39.8	5.2	40.3	51.3	3.2	35.7	75.4	100.0
7/13	22.1	0.4	47.3	7.5	36.6	53.6	2.4	30.3	77.6	100.0
8/1	23.7	0.6	44.6	8.5	27.5	60.3	3.7	31.2	75.7	100.0
8/17	16.2	0.4	53.1	7.3	19.7	69.1	3.9	30.3	83.4	100.0
9/14	18.0	0.4	59.8	3.9	3.8	89.2	3.1	21.9	81.6	100.0
10/20	44.6	1.9	42.8	3.8	19.7	74.0	2.5	10.7	53.5	100.0
11/16	78.3	9.9	4.5	1.4	97.1	1.4	0.0	7.3	11.8	100.0
12/14	84.8	3.0	3.0	0.0	100.0	0.0	0.0	9.1	12.1	100.0
Western Sector (%):										
3/24	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4/15	100.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	100.0
5/24	24.7	5.4	33.0	9.0	90.5	0.3	0.1	36.9	69.9	100.0
6/3	20.2	3.2	40.5	23.2	63.3	8.9	4.6	36.1	76.6	100.0
6/14	28.4	1.7	37.8	9.7	51.1	35.5	3.6	32.0	69.8	100.0
7/1	18.5		43.6	5.8	39.5	51.6	3.1	37.9	81.5	100.0
7/13	17.4	0.2	53.1	6.5	38.3	52.8	2.5	29.3	82.4	100.0
8/1	13.9	0.2	50.8	9.2	33.2	54.7	3.0	35.1	85.9	100.0
8/17	10.4	0.2	61.3	8.3	26.6	62.3	2.9	28.1	89.3	100.0
9/14	14.8	0.3	62.1	3.7	4.6	88.9	2.9	22.9	85.0	100.0
10/20	33.5	1.6	51.7	4.7	12.6	79.7	3.0	13.2	64.9	100.0
11/16	65.1	11.0	9.9	4.2	95.8	0.0	0.0	14.0	23.8	100.0
12/14	84.8	3.0	3.0	0.0	100.0	0.0	0.0	9.1	12.1	100.0
Eastern Sector (%):										
3/24	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4/15	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
5/24	25.5	10.4	31.6	4.0	95.4	0.0	0.6	32.6	64.1	100.0
6/3	24.5	4.6	36.7	13.3	76.8	8.4	1.5	34.2	70.9	100.0
6/14	31.1	1.6	33.6	10.0	55.6	32.6	1.8	33.7	67.3	100.0
7/1	32.2	0.8	34.4	4.3	41.7	50.8	3.2	32.6	67.1	100.0
7/13	31.5	0.7	35.5	9.3	33.4	55.1	2.2	32.3	67.8	100.0
8/1	42.8	1.3	32.3	6.7	10.8	76.5	6.1	23.6	55.9	100.0
8/17	23.2	0.5	43.2	6.2	12.7	76.1	5.0	33.1	76.3	100.0
9/14	23.8	0.6	55.5	4.2	2.3	89.9	3.5	20.1	75.6	100.0
10/20	66.8	2.5	25.0	0.0	52.3	47.7	0.0	5.7	30.8	100.0
11/16	81.2	9.6	3.3	0.0	97.8	2.2	0.0	5.8	9.1	100.0
12/14	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0

(?): undifferentiated egg mass (e): empty ovisac (c): cysts (n): nauplii
The fem-?, e, c, n, percentages are of the total females

Table 12. Lakewide *Artemia* instar analysis, 2005

	Instars									
	1	2	3	4	5	6	7	8-11	adults	total
Mean:										
3/24	9,175	13,395	5,714	425	0	0	0	0	0	28,709
4/15	7,680	7,393	5,800	7,796	5,685	1,736	230	0	0	36,321
5/24	851	460	770	1,978	1,863	1,920	2,058	3,668	26,306	39,874
6/3	8,646	368	46	690	966	782	644	2,162	39,322	53,625
6/14	14,211	5,979	46	322	92	276	138	1,426	47,968	70,457
7/1	7,473	4,806	368	69	92	138	46	115	47,071	60,178
7/13	4,622	2,507	1,196	690	46	0	0	184	38,977	48,221
8/1	3,472	2,357	471	724	172	126	34	241	26,916	34,516
8/17	1,242	2,276	1,173	276	115	46	23	115	28,836	34,102
9/14	446	943	609	434	201	144	172	43	12,015	15,007
10/20	391	497	445	650	345	216	138	86	3,561	6,329
11/16	296	239	95	109	118	112	98	118	147	1,331
12/14	121	80	40	101	20	0	0	20	60	443
Standard error of mean:										
3/24	1,506	1,966	685	109	0	0	0	0	0	3,812
4/15	1,613	2,072	2,124	2,302	1,345	615	85	0	0	9,193
5/24	278	174	310	408	512	562	717	1,686	5,393	8,790
6/3	1,218	204	46	130	99	119	211	459	4,470	5,461
6/14	2,117	1,605	46	122	92	110	96	377	5,839	7,042
7/1	1,072	1,179	276	48	92	96	46	91	8,333	8,253
7/13	639	897	591	318	46	0	0	96	7,811	7,694
8/1	623	532	202	248	57	55	24	88	6,686	6,788
8/17	503	828	567	227	58	30	23	46	3,041	3,593
9/14	112	218	186	149	60	62	77	23	2,254	2,259
10/20	170	105	72	137	73	78	47	13	1,137	1,340
11/16	187	163	44	48	41	35	22	35	32	539
12/14	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Percentage in different age classes:										
3/24	32.0	46.7	19.9	1.5	0.0	0.0	0.0	0.0	0.0	100.0
4/15	21.1	20.4	16.0	21.5	15.7	4.8	0.6	0.0	0.0	100.0
5/24	2.1	1.2	1.9	5.0	4.7	4.8	5.2	9.2	66.0	100.0
6/3	16.1	0.7	0.1	1.3	1.8	1.5	1.2	4.0	73.3	100.0
6/14	20.2	8.5	0.1	0.5	0.1	0.4	0.2	2.0	68.1	100.0
7/1	12.4	8.0	0.6	0.1	0.2	0.2	0.1	0.2	78.2	100.0
7/13	9.6	5.2	2.5	1.4	0.1	0.0	0.0	0.4	80.8	100.0
8/1	10.1	6.8	1.4	2.1	0.5	0.4	0.1	0.7	78.0	100.0
8/17	3.6	6.7	3.4	0.8	0.3	0.1	0.1	0.3	84.6	100.0
9/14	3.0	6.3	4.1	2.9	1.3	1.0	1.1	0.3	80.1	100.0
10/20	6.2	7.9	7.0	10.3	5.4	3.4	2.2	1.4	56.3	100.0
11/16	22.2	17.9	7.1	8.2	8.8	8.4	7.3	8.9	11.0	100.0
12/14	27.3	18.1	9.0	22.8	4.5	0.0	0.0	4.5	13.6	100.0

All data in this table are from stations 1, 2, 5, 6, 7, 8, and 11 only.

Table 13a. *Artemia* reproductive summary, lake and sector means, 2005.

	Adult Females					
	Total	Ovigery	e	?	c	n
Lakewide Mean:						
3/24	0	0	0	0	0	0
4/15	3	0	3	0	0	0
5/24	13,327	838	12,488	765	13	60
6/3	17,679	5,285	12,394	3,219	1,529	537
6/14	21,730	10,141	11,590	2,146	7,404	590
7/1	19,491	11,630	7,860	1,020	9,993	617
7/13	13,467	8,545	4,923	1,006	7,217	322
8/1	11,630	8,437	3,192	993	7,009	436
8/17	9,242	7,418	1,824	671	6,385	362
9/14	3,498	3,364	134	136	3,120	107
10/20	614	493	121	23	454	15
11/16	117	3	114	2	2	0
12/14	30	0	30	0	0	0
Western Sector Mean:						
3/24	0	0	0	0	0	0
4/15	7	0	7	0	0	0
5/24	9,215	872	8,343	832	27	13
6/3	17,545	6,439	11,107	4,078	1,556	805
6/14	22,052	10,785	11,268	2,146	7,834	805
7/1	24,038	14,541	9,497	1,395	12,394	751
7/13	17,384	10,731	6,653	1,127	9,175	429
8/1	17,277	11,536	5,741	1,583	9,443	510
8/17	9,390	6,895	2,495	778	5,848	268
9/14	4,695	4,480	215	174	4,172	134
10/20	1,009	882	127	47	805	30
11/16	80	3	77	3	0	0
12/14	30	0	30	0	0	0
Eastern Sector Mean:						
3/24	0	0	0	0	0	0
4/15	0	0	0	0	0	0
5/24	17,438	805	16,633	698		107
6/3	17,814	4,131	13,682	2,361	1,502	268
6/14	21,408	9,497	11,911	2,146	6,975	376
7/1	14,943	8,719	6,224	644	7,592	483
7/13	9,551	6,358	3,192	885	5,258	215
8/1	5,983	5,339	644	402	4,574	362
8/17	9,095	7,941	1,154	563	6,922	456
9/14	2,300	2,247	54	97	2,069	80
10/20	218	104	114	0	104	0
11/16	154	3	151	0	3	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 13b. Standard errors of *Artemia* reproductive summary (Table 13a), 2005.

	Adult Females					
	Total	Ovigery	e	?	c	n
Standard Error of Lakewide Mean:						
3/24	3	0	3	0	0	0
4/15	1,603	98	1,584	103	13	53
5/24	1,628	982	1,057	563	327	170
6/3	2,158	1,326	1,101	332	1,210	118
6/14	2,353	1,563	910	202	1,454	101
7/1	1,643	1,075	709	177	1,028	89
7/13	2,479	1,696	942	374	1,356	81
8/1	1,141	977	314	134	853	60
8/17	558	545	36	26	515	32
9/14	156	157	31	13	142	9
10/20	33	2	33	2	2	0
11/16	10	0	10	0	0	0
12/14	0	0	0	0	0	0
Standard Error of Western Sector Mean:						
3/24	7	0	7	0	0	0
4/15	1,214	150	1,204	146	27	13
5/24	3,190	1,724	1,645	898	602	273
6/3	3,451	2,406	1,473	359	2,221	161
6/14	3,758	2,613	1,342	339	2,549	180
7/1	1,946	1,482	791	297	1,561	136
7/13	3,618	2,793	1,130	671	2,255	134
8/1	1,222	1,140	100	214	924	99
8/17	620	610	54	44	602	49
9/14	199	215	51	24	196	16
10/20	23	3	23	3	0	0
11/16	10	0	10	0	0	0
12/14	0	0	0	0	0	0
Standard Error of Eastern Sector Mean:						
3/24	0	0	0	0	0	0
4/15	1,752	138	1,649	154	0	107
5/24	1,215	861	1,243	543	329	154
6/3	2,922	1,337	1,767	597	1,201	129
6/14	1,402	732	878	93	701	72
7/1	1,398	988	621	211	826	107
7/13	1,089	1,005	181	165	798	92
8/1	2,055	1,672	494	170	1,494	49
8/17	643	659	17	22	601	42
9/14	71	38	40	0	38	0
10/20	62	3	61	0	3	0
11/16	0	0	0	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 13c. *Artemia* percentages in different reproductive categories (Table 13a), 2005.

	Total	Adult Females Ovig	e	?	c	n
Lakewide Mean (%):						
3/24	100	0.0	100.0	0.0	0.0	0.0
4/15	100	0.0	100.0	0.0	0.0	0.0
5/24	100	6.3	93.7	91.2	18.2	81.8
6/3	100	29.9	70.1	60.9	74.0	26.0
6/14	100	46.7	53.3	21.2	92.6	7.4
7/1	100	59.7	40.3	8.8	94.2	5.8
7/13	100	63.4	36.6	11.8	95.7	4.3
8/1	100	72.5	27.5	11.8	94.1	5.9
8/17	100	80.3	19.7	9.0	94.6	5.4
9/14	100	96.2	3.8	4.0	96.7	3.3
10/20	100	80.3	19.7	4.8	96.8	3.2
11/16	100	2.9	97.1	50.0	100.0	0.0
12/14	100	0.0	100.0	0.0	0.0	0.0
Western Sector Mean (%):						
3/24	100	0.0	100.0	0.0	0.0	0.0
4/15	100	0.0	100.0	0.0	0.0	0.0
5/24	100	9.5	90.5	95.4	66.7	33.3
6/3	100	36.7	63.3	63.3	65.9	34.1
6/14	100	48.9	51.1	19.9	90.7	9.3
7/1	100	60.5	39.5	9.6	94.3	5.7
7/13	100	61.7	38.3	10.5	95.5	4.5
8/1	100	66.8	33.2	13.7	94.9	5.1
8/17	100	73.4	26.6	11.3	95.6	4.4
9/14	100	95.4	4.6	3.9	96.9	3.1
10/20	100	87.4	12.6	5.3	96.4	3.6
11/16	100	4.2	95.8	100.0	0.0	0.0
12/14	100	0.0	100.0	0.0	0.0	0.0
Eastern Sector Mean (%):						
3/24	100	0.0	100.0	0.0	0.0	0.0
4/15	100	0.0	100.0	0.0	0.0	0.0
5/24	100	4.6	95.4	86.7	0.0	100.0
6/3	100	23.2	76.8	57.1	84.8	15.2
6/14	100	44.4	55.6	22.6	94.9	5.1
7/1	100	58.4	41.7	7.4	94.0	6.0
7/13	100	66.6	33.4	13.9	96.1	3.9
8/1	100	89.2	10.8	7.5	92.7	7.3
8/17	100	87.3	12.7	7.1	93.8	6.2
9/14	100	97.7	2.3	4.3	96.3	3.7
10/20	100	47.7	52.3	0.0	100.0	0.0
11/16	100	2.2	97.8	0.0	100.0	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.

Table 14. *Artemia* fecundity summary, 2005.

	#eggs/brood				female length		
	mean	SE	%cyst	%intended	mean	SE	n
Lakewide Mean:							
6/3	42.9	2.4	0.8	0.4	10.5	0.2	7
6/14	37.1	1.7	0.9	0.6	10.3	0.1	7
7/1	28.6	1.4	1.0	0.7	10.0	0.1	7
7/13	21.0	1.0	0.9	0.6	9.8	0.1	7
8/1	44.1	4.1	1.0	0.6	11.0	0.2	7
8/17	34.0	3.3	1.0	0.5	10.8	0.2	7
9/14	60.3	3.1	0.9	0.6	11.9	0.1	7
10/20	82.7	5.6	1.0	0.6	12.0	0.2	6
Western Sector Mean:							
6/3	45.2	2.0	0.7	0.3	10.7	0.1	4
6/14	37.5	2.9	0.9	0.6	10.3	0.1	4
7/1	30.5	1.3	1.0	0.6	9.9	0.1	4
7/13	20.7	1.2	1.0	0.6	9.8	0.1	4
8/1	38.5	3.1	1.0	0.7	10.9	0.2	4
8/17	31.5	4.8	1.0	0.6	10.5	0.2	4
9/14	57.1	3.9	1.0	0.7	12.0	0.2	4
10/20	90.9	3.1	1.0	0.7	12.2	0.2	4
Eastern Sector Mean:							
6/3	39.7	4.9	0.8	0.6	10.2	0.4	3
6/14	36.6	2.1	0.9	0.6	10.4	0.1	3
7/1	26.1	2.1	0.9	0.7	10.2	0.2	3
7/13	21.4	2.1	0.9	0.6	9.9	0.1	3
8/1	51.5	6.9	0.9	0.6	11.1	0.3	3
8/17	37.2	4.5	1.0	0.5	11.1	0.2	3
9/14	64.5	4.7	0.9	0.6	11.9	0.1	3
10/20	66.3	2.9	1.0	0.5	11.7	0.1	2

'n' in last column refers to number of stations averaged.
Ten females were collected and measured from each station.

Table 15. Summary Statistics of Adult *Artemia* Abundance from 1 May through 30 November, 1979–2005.

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
2005	17,888	15,824	45,419	192
Mean	19,828	19,065	44,400	217

*Centroid calculated as the abundance-weighted mean day of occurrence.

Table 16. Photosynthetic parameters for 2005.

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)
4/15/2005	2	6.3	7.15	2.05
5/23/2005	2	14.5	12.38	3.49
6/15/2005	2	16.6	12.66	5.09
6/15/2005	12	9.5	5.73	1.04
7/14/2005	2	22.5	33.45	24.58
7/14/2005	14	8.5	1.65	0.37
8/18/2005	2	21.2	40.14	15.72
8/18/2005	14	10.2	17.26	1.01
9/15/2005	2	17.8	10.09	9.62
9/15/2005	14	10	5.57	1.08
10/20/2005	2	12.8	5.39	2.37
11/16/2005	2	9.5	5.35	1.67
12/14/2005	2	5.2	6.92	1.71

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 17. Long term Integrative Measures of Productivity: Annual Primary Production, *Artemia* biomass and egg production (see Chapter 2 for methods), 1982-2005.

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
2005	1,111	11.8	0.31	3.8
Mean	573	9.46	0.25	4.41

*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).

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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, 2005.

Fig. 3. Daily air temperature; mean, maximum, and minimum, 2005.

Fig. 4. Daily photosynthetically available radiation, 2005.

Fig. 5. Mean daily relative humidity, 2005.

Fig. 6. Daily precipitation, 2005.

Fig. 7. Mono Lake surface elevation (ft asl), 1979–05, USGS datum.

Fig. 8. Temperature (°C) at station 6, 2005.

Fig. 9. Conductivity (mS cm^{-1} corrected to 25°C) at station 6, 2005.

Fig.10. Density difference (kg m^{-3}) between 2 and 32 m at station 6 due to temperature and chemical stratification from 1991–2005.

Fig. 11. Transparency as measured by mean lakewide Secchi depth (m), 1994–05. Error bars show standard errors of the lakewide estimate based on 12-20 stations.

Fig. 12. Mean lakewide Secchi depth ($\log_{10}$ m) 1979–05.

Fig. 13. Light attenuation (% of surface) at station 6, 2005.

Fig. 14. Dissolved oxygen (mg O_2 l^{-1}) at station 6, 2005. Dots denote the dates and depths of samples.

Fig. 15. Ammonium (µM) at station 6, 2005. Dots denote the dates and depths of samples.

Fig. 16. Ammonium (µM) in upper 9 m of the water column at 7 stations, 2005.

Fig. 17. Chlorophyll *a* (µg chl *a* l^{-1}) at station 6, 2005. Dots denote the dates and depths of samples.

Fig. 18. Chlorophyll *a* (µg chl *a* l^{-1}) in upper 9 m of the water column at 7 stations, 2005.

Fig. 19. Seasonal fluorescence profiles at station 6, 2005.

Fig. 20. Lakewide *Artemia* abundance during 2005: nauplii (instars 1-7), juveniles (instars 8-11), and adults (instars 12+).

Fig. 21. Lakewide estimates of adult *Artemia* based on 3-20 stations, 1982–05 (see Methods).

Fig. 22. Reproductive characteristics of *Artemia* during 2005: 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. 23. Summary statistics of the seasonal (1 May through 30 November) lakewide abundance of adult *Artemia*, 1979–05. Values are based on interpolated daily abundances.

Fig. 24. Temporal center of abundance-weighted centroid of the seasonal (1 May through 30 November) distribution of adult *Artemia*, 1979–05. Centroid is based on interpolated daily abundances of adult *Artemia*.

Fig. 25. Chlorophyll-specific uptake rates during March, August, and December 2005 for samples collected from the surface mixed layer and the deep chlorophyll maximum.

Fig. 26. 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}), 2005.

Fig. 27. Comparison of 2002–05 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. 28. Comparison of 2002–05 daily primary production (g C m^{-2} y^{-1}) calculated with a numerical interpolative model of chlorophyll, temperature, insolation, attenuation, and photosynthetic parameters.

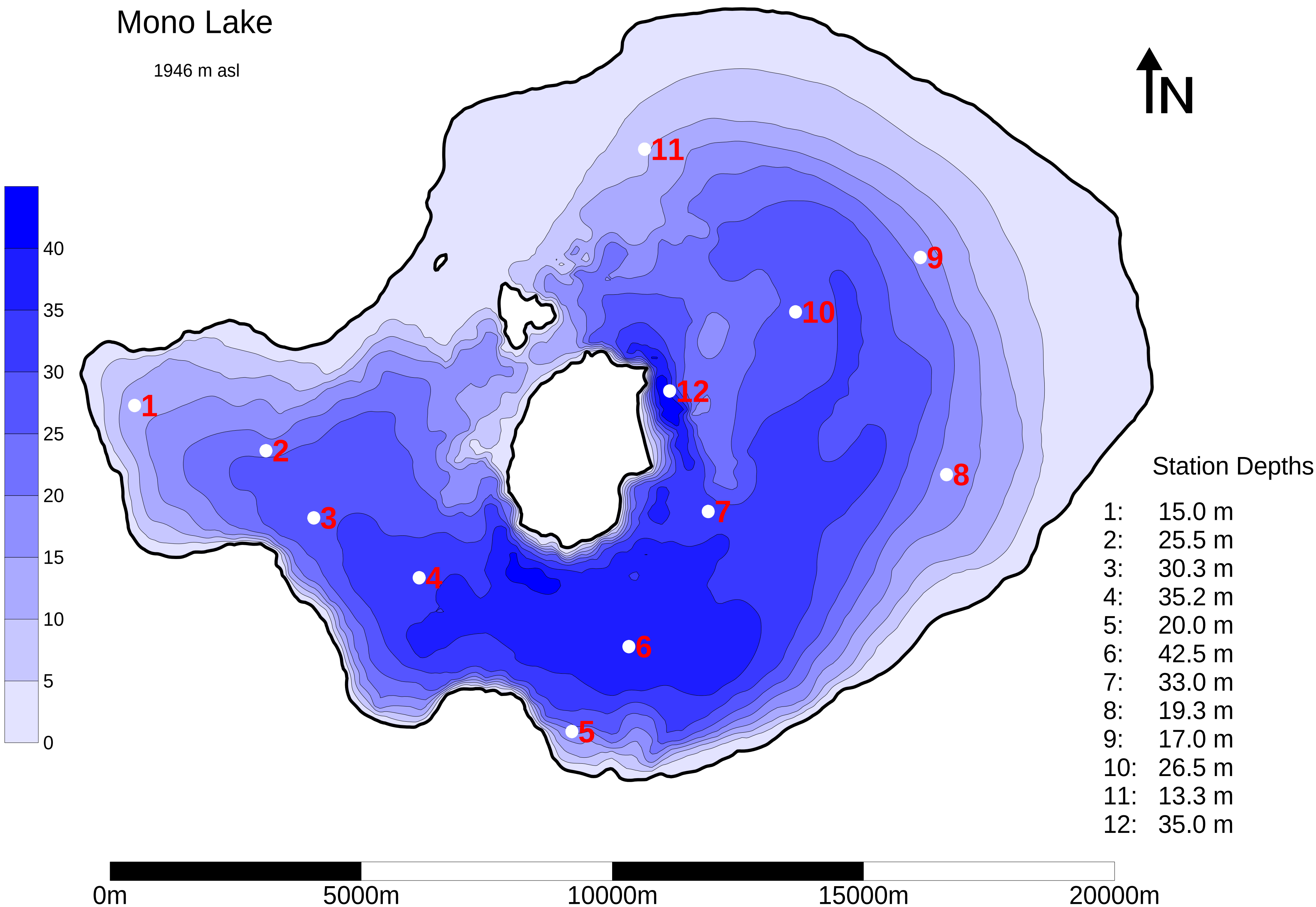
Fig. 29. Annual phytoplankton production estimates (g C m^{-2}), 1982–05.

Fig. 30. 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 2000–05, *Artemia* biomass was measured directly by determining dry weights of plankton tows.

Fig. 31. Annual *Artemia* reproduction, ovoviviparous (live-bearing) and oviparous (cyst-bearing), 1983–05.

Fig. 32. Lakewide mean of mixolimnetic (<10 m) chlorophyll *a*, 1982–05. 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. 33. Lakewide mean of adult *Artemia* abundance, 1982–05. Heavy line shows seasonally filtered data formed by linearly interpolating between sampling dates to daily values and then calculating a 365-day running mean.


Mono Lake
1946 m asl
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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
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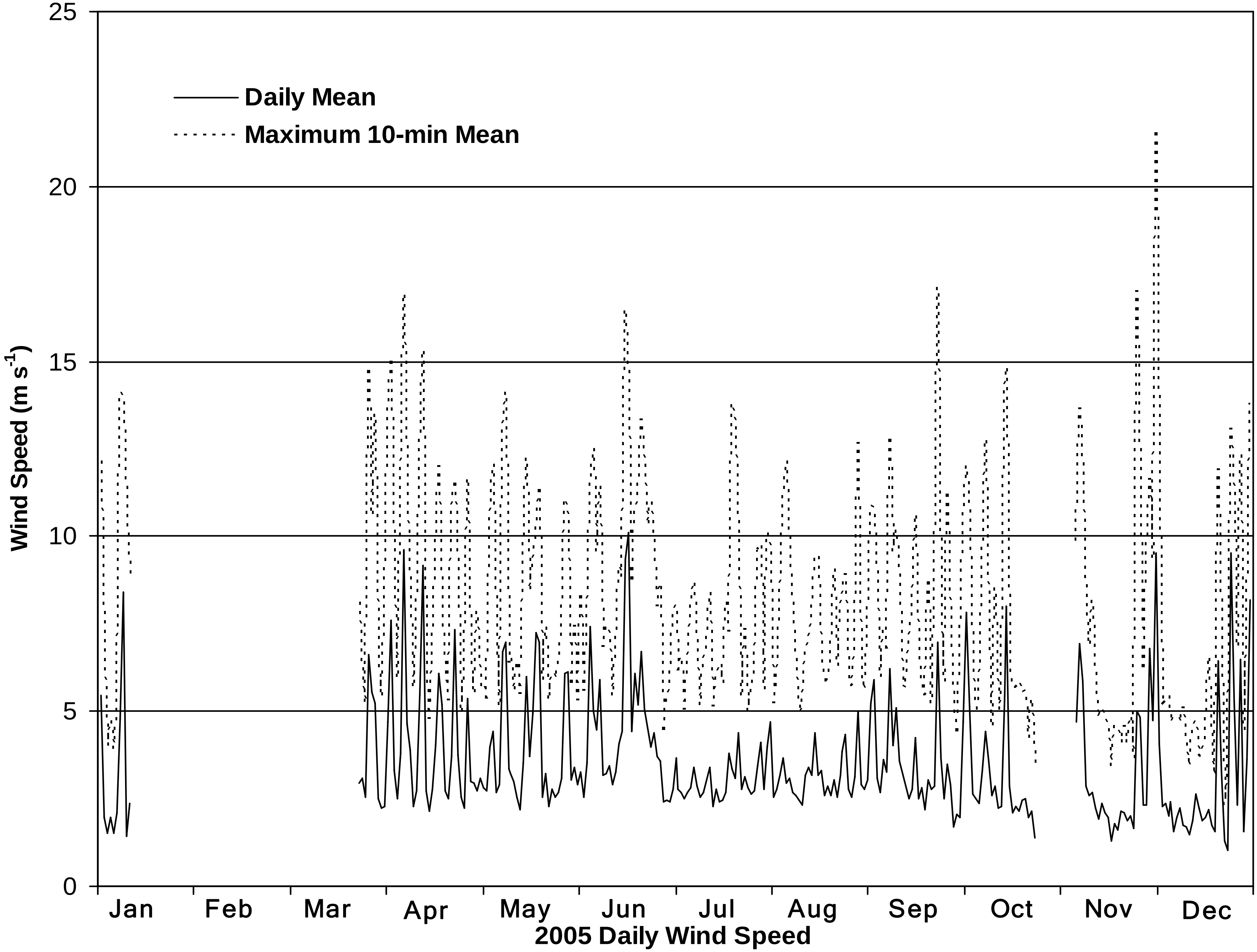
Figure 1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Maximum 10-min Mean
Wind Speed (m s-1)
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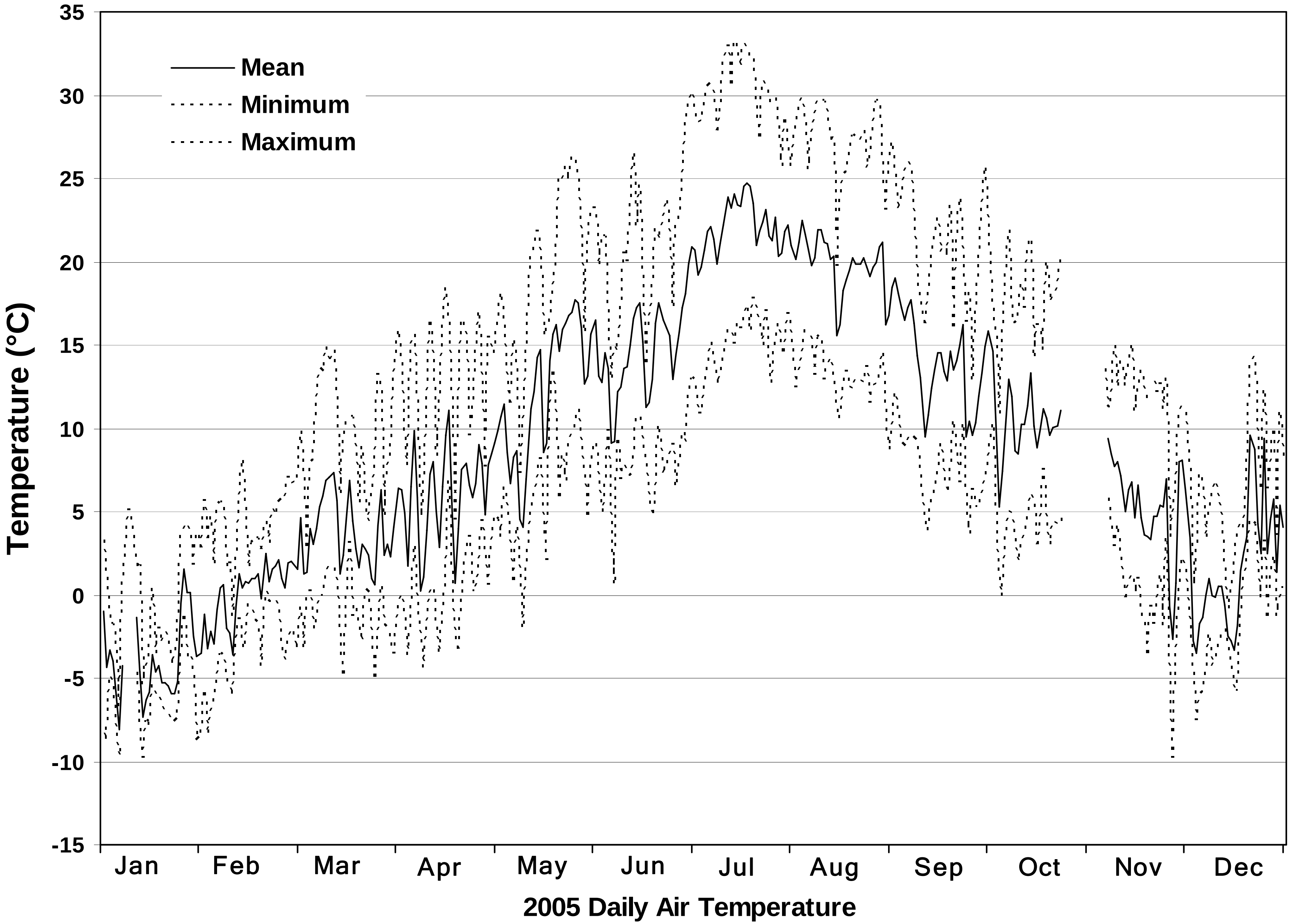
2005 Daily Wind Speed

Figure 2


Mean
Minimum
Maximum
Temperature (°C)
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30
25
20
15
10
5
0
-5
-10
-15
Jan
Feb
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Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2005 Daily Air Temperature

Figure 3

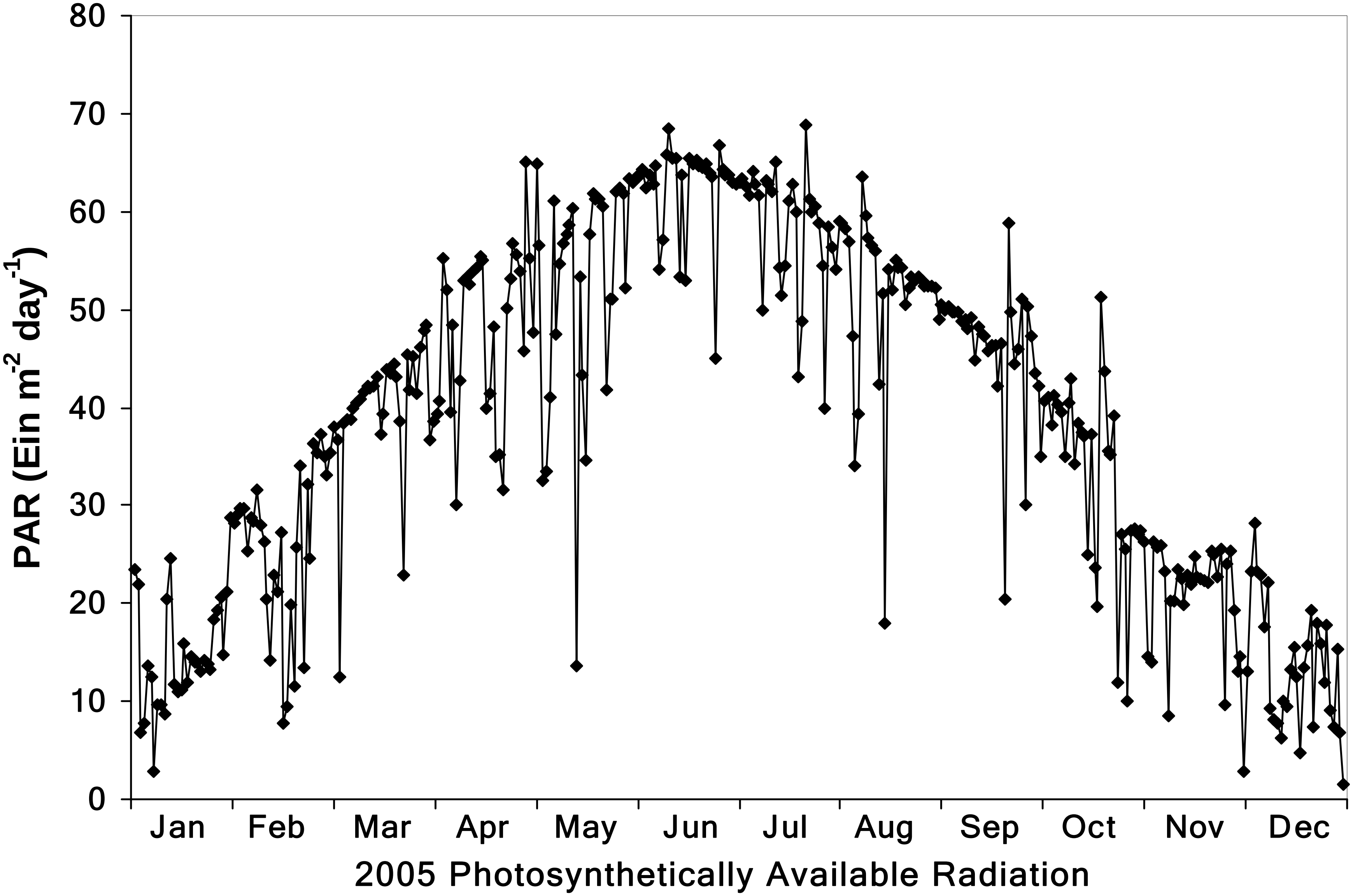

PAR (Ein m-2 day-1)
80
70
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2005 Photosynthetically Available Radiation

Figure 4

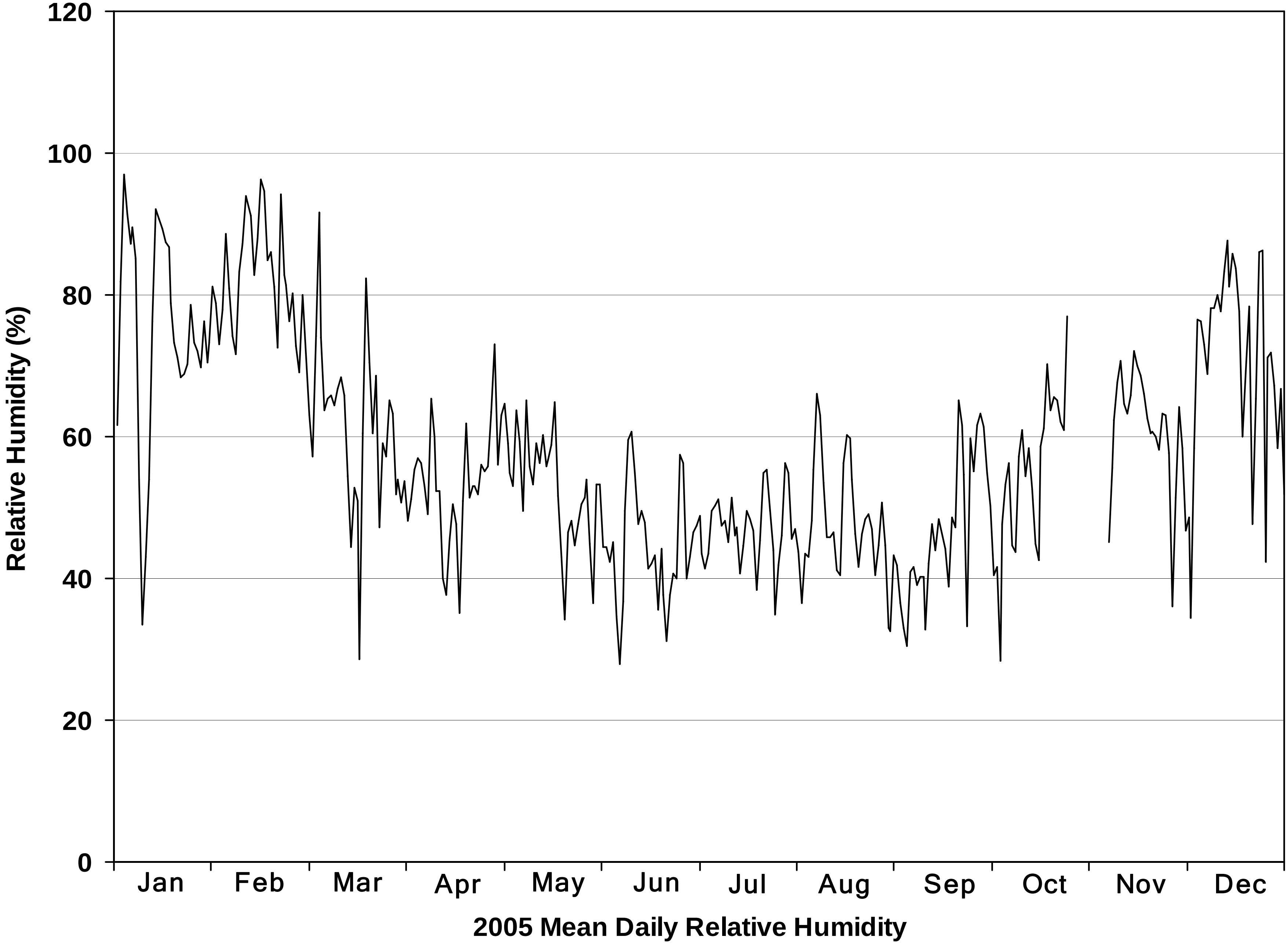

Relative Humidity (%)
120
100
80
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2005 Mean Daily Relative Humidity

Figure 5

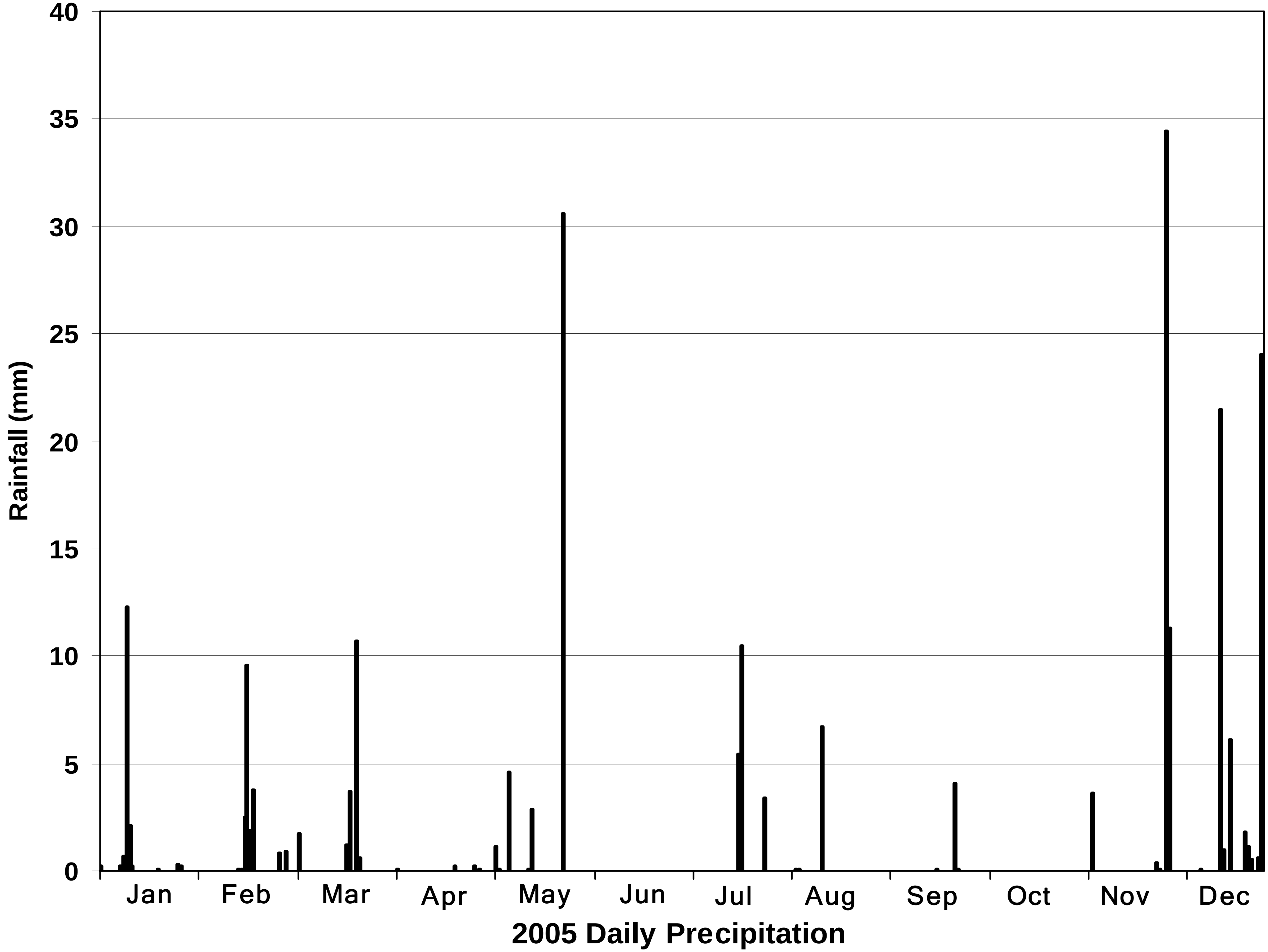
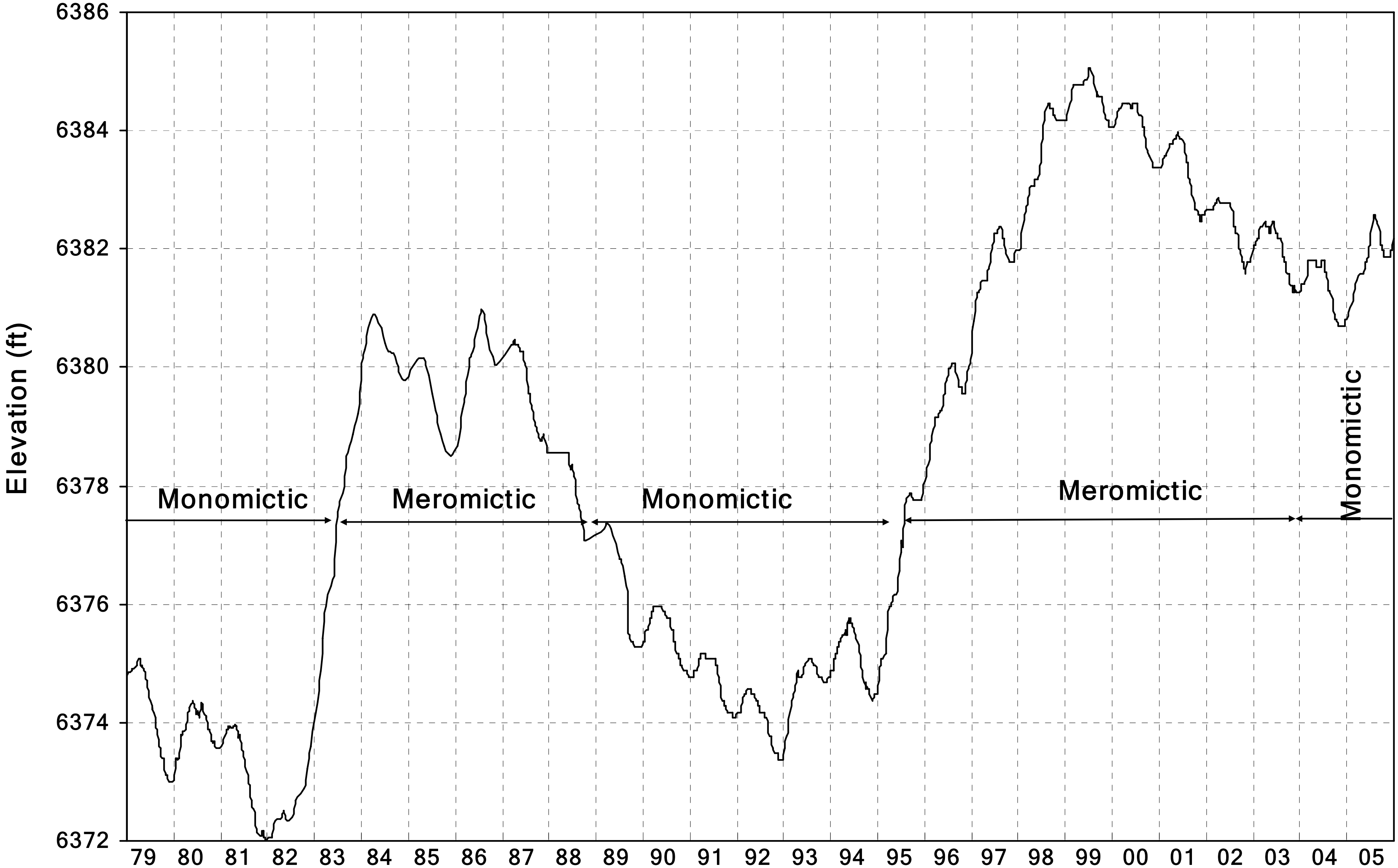
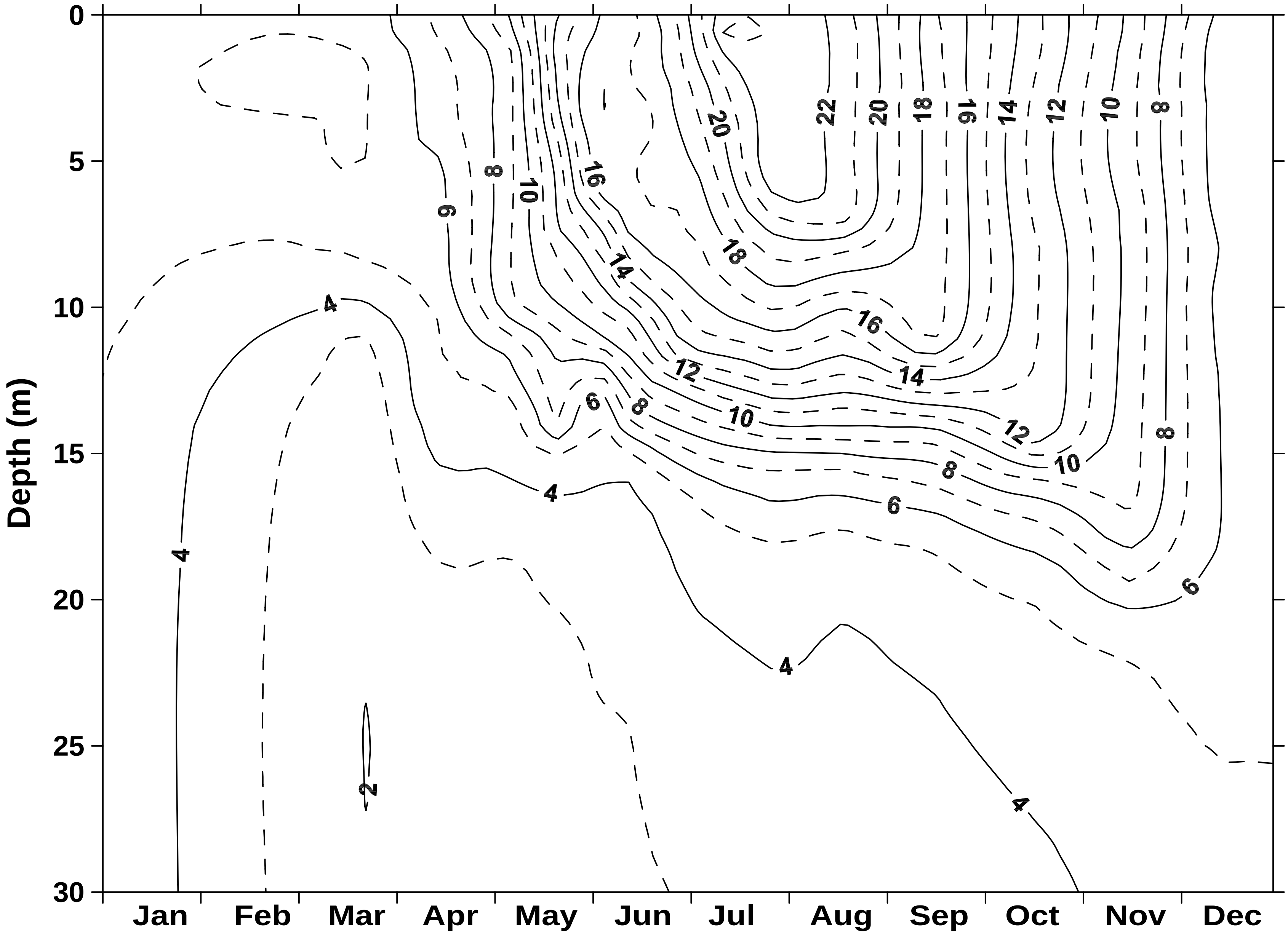

40
35
30
25
20
15
10
5
0
Rainfall (mm)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2005 Daily Precipitation

Figure 6



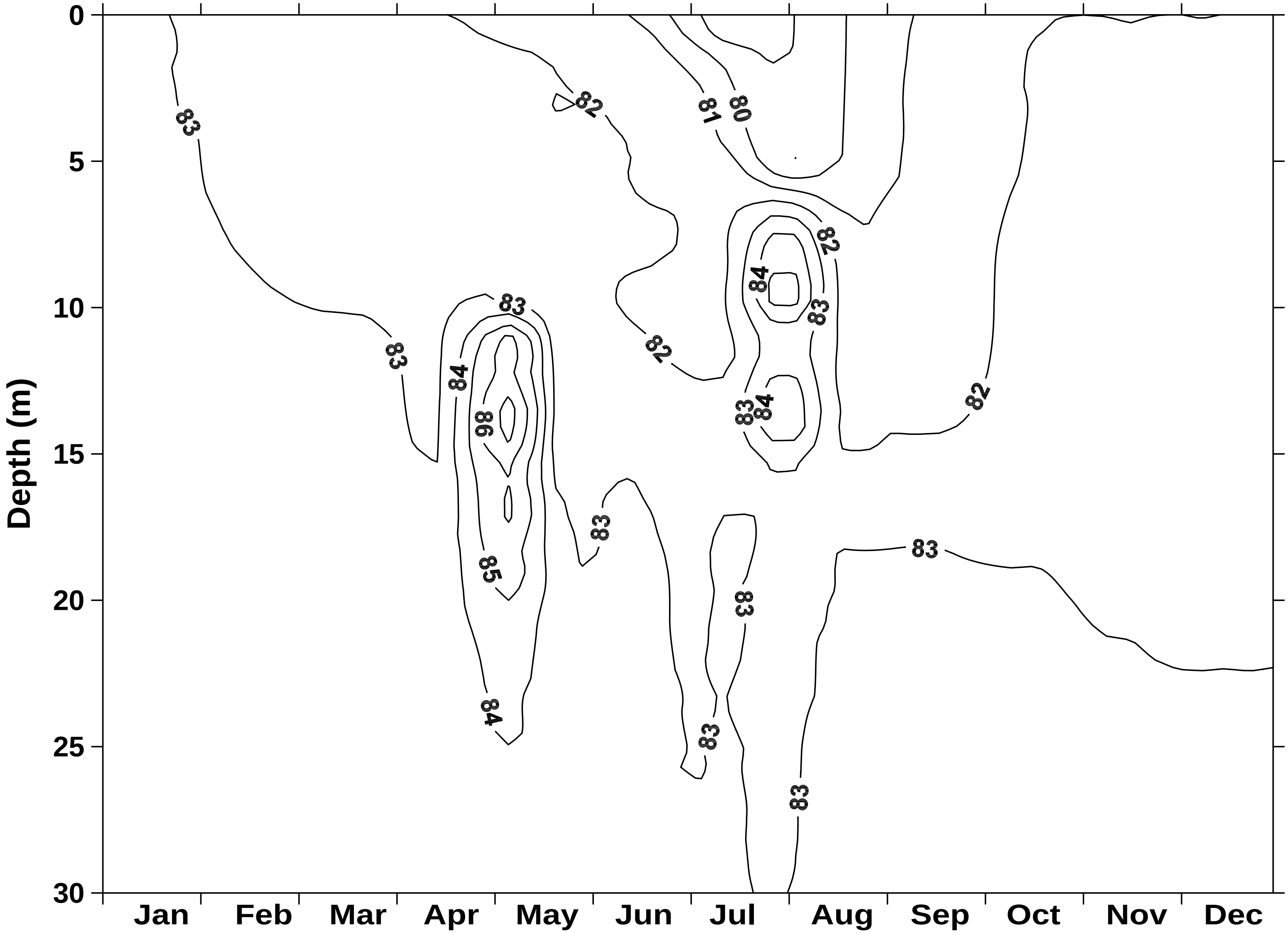
Mono Lake Surface Elevation

Figure 7



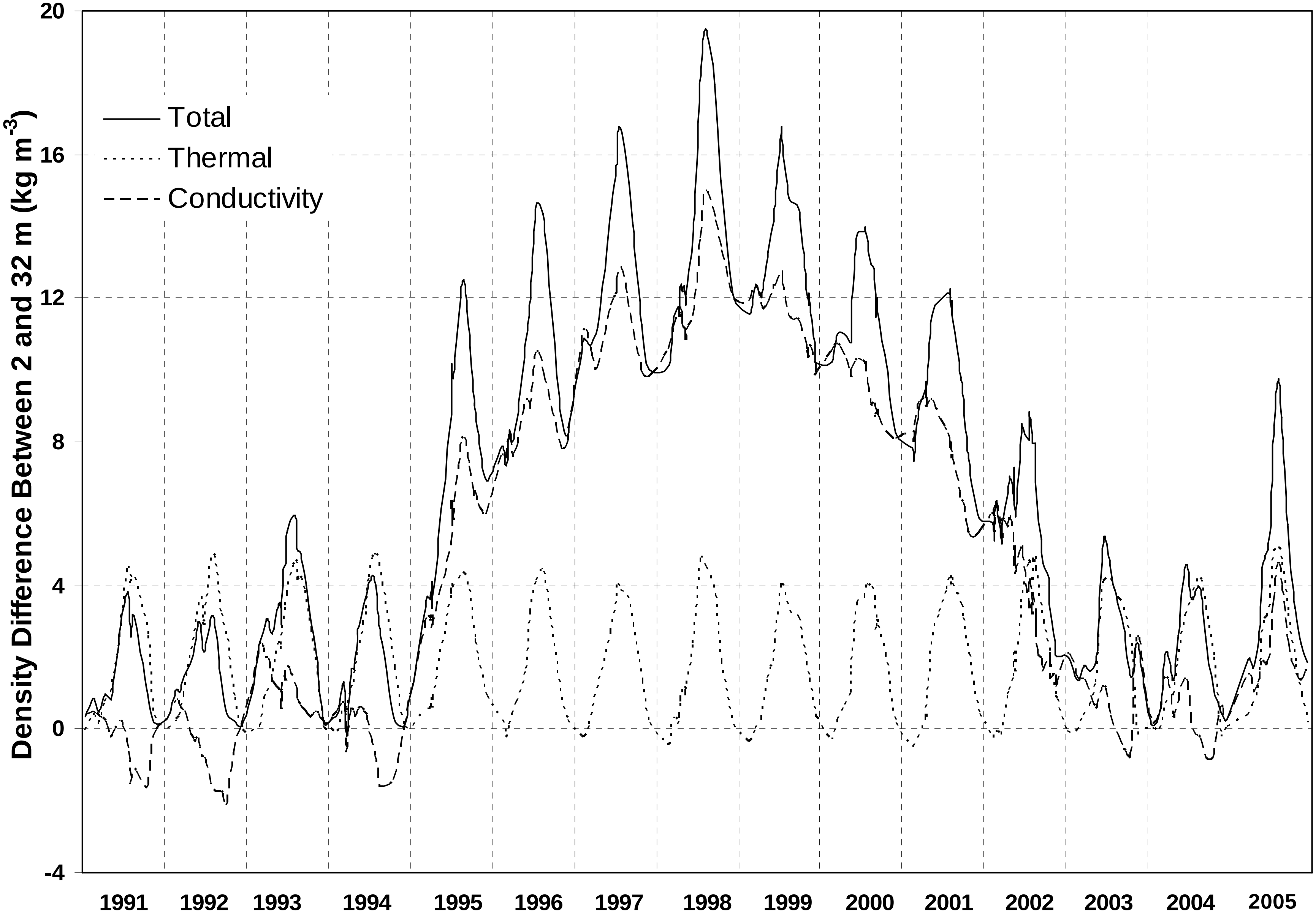
Temperature (°C) at Station 6

Figure 8



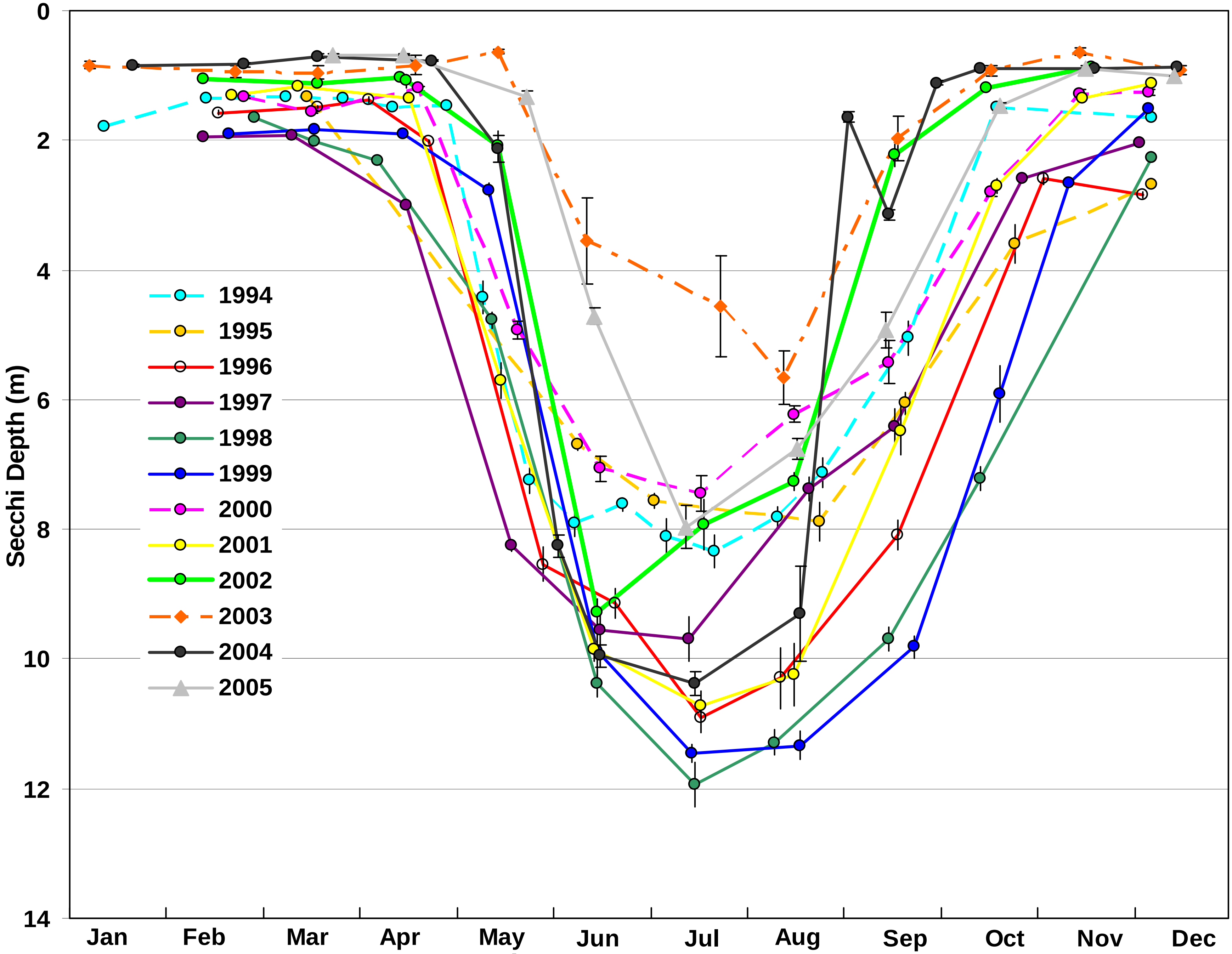
Conductivity (mS/cm) at Station 6

Figure 9



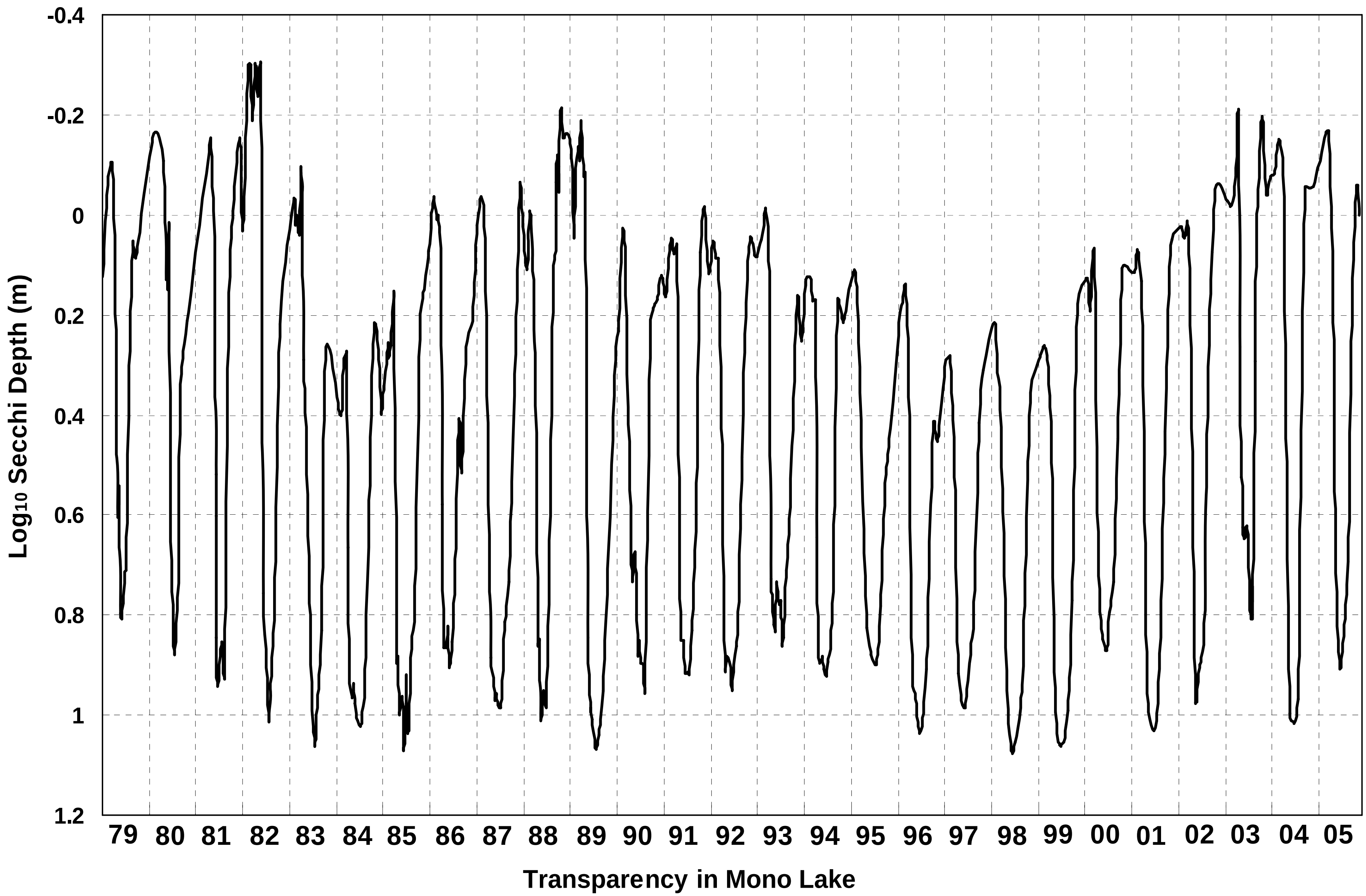
Density Stratification (2-32 m), 1991 - 2005

Figure 10



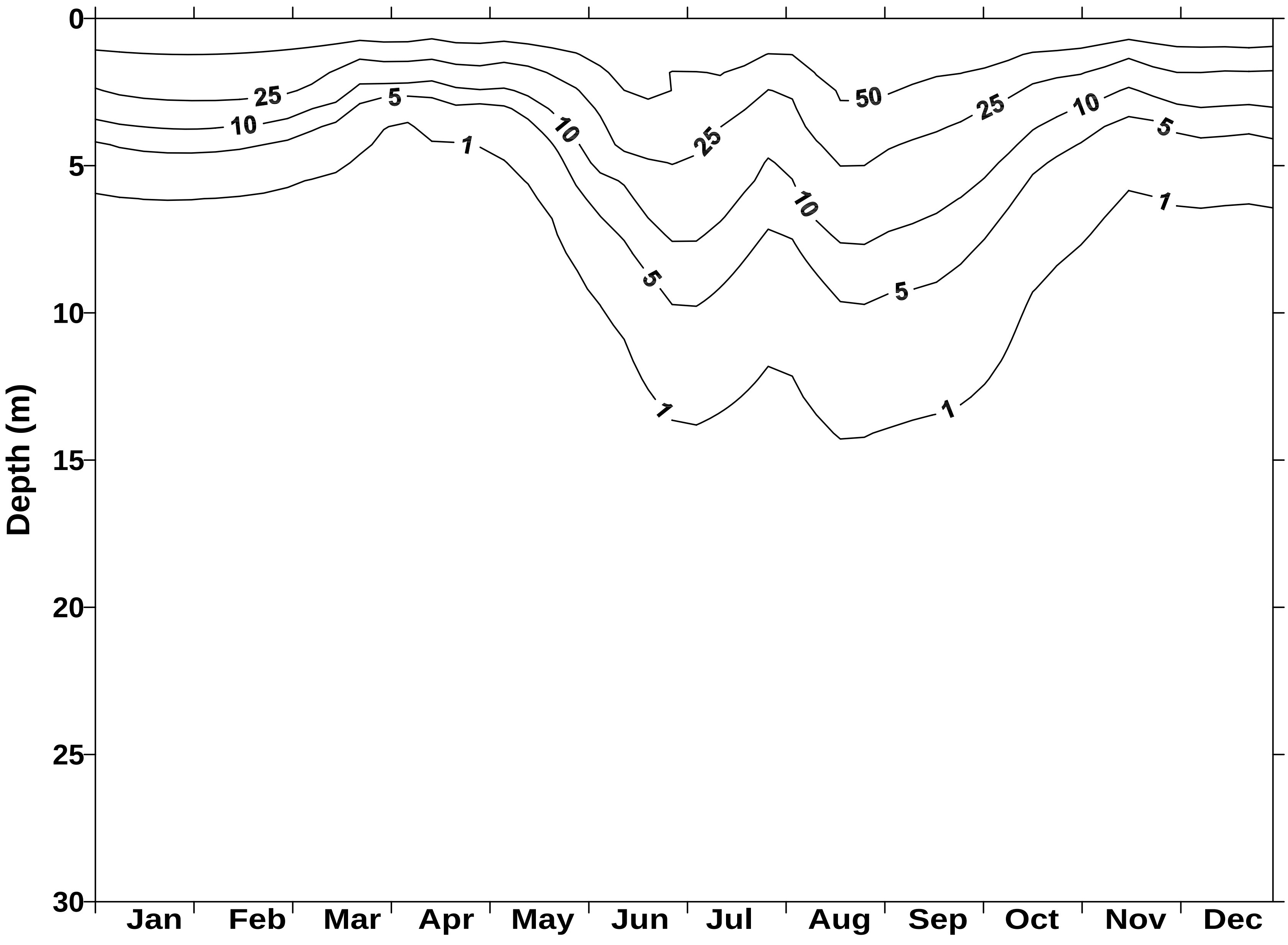
Mono Lake Transparency

Figure 11



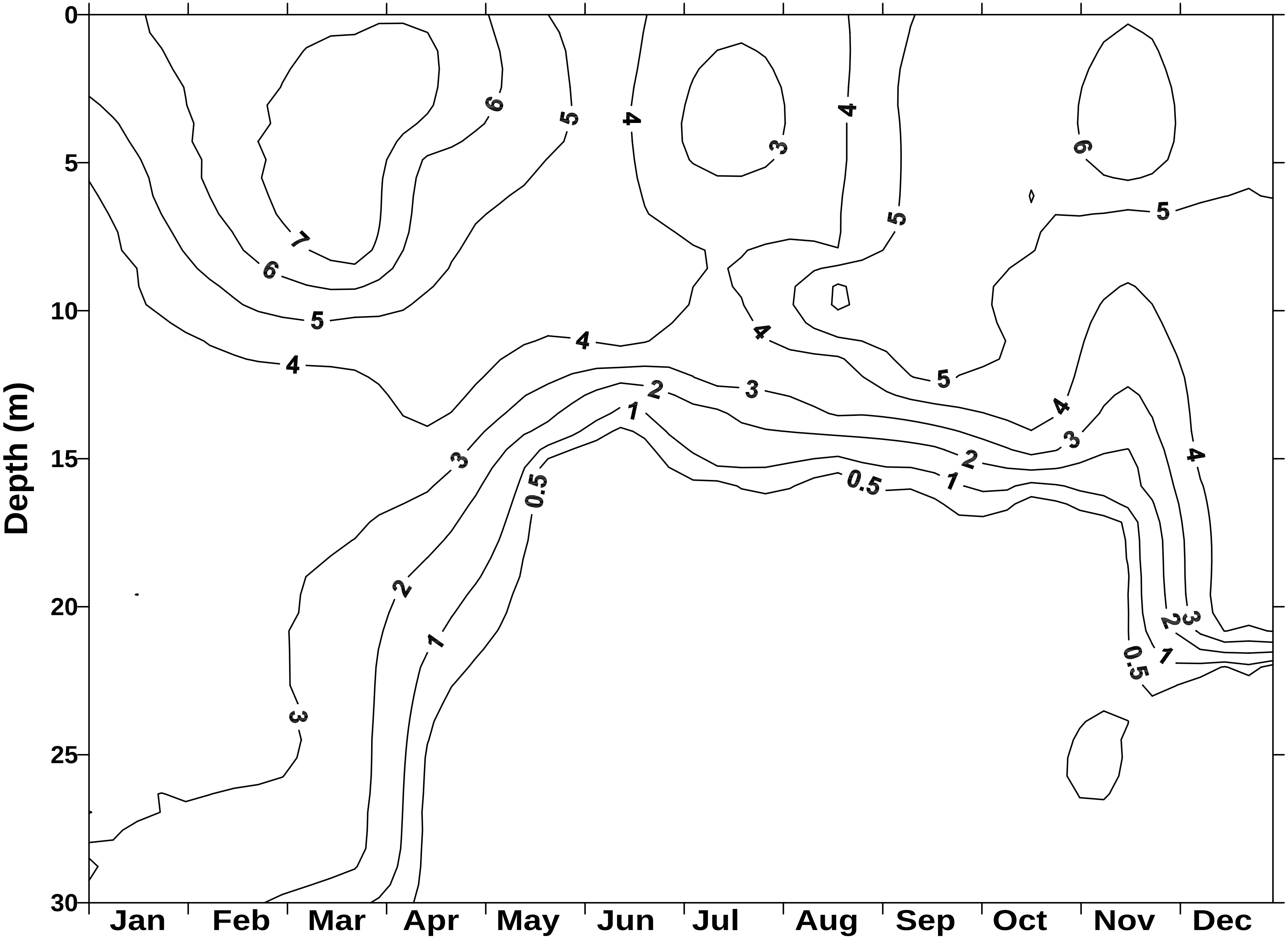
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
Log10 Secchi Depth (m)
79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05
Transparency in Mono Lake

Figure 12



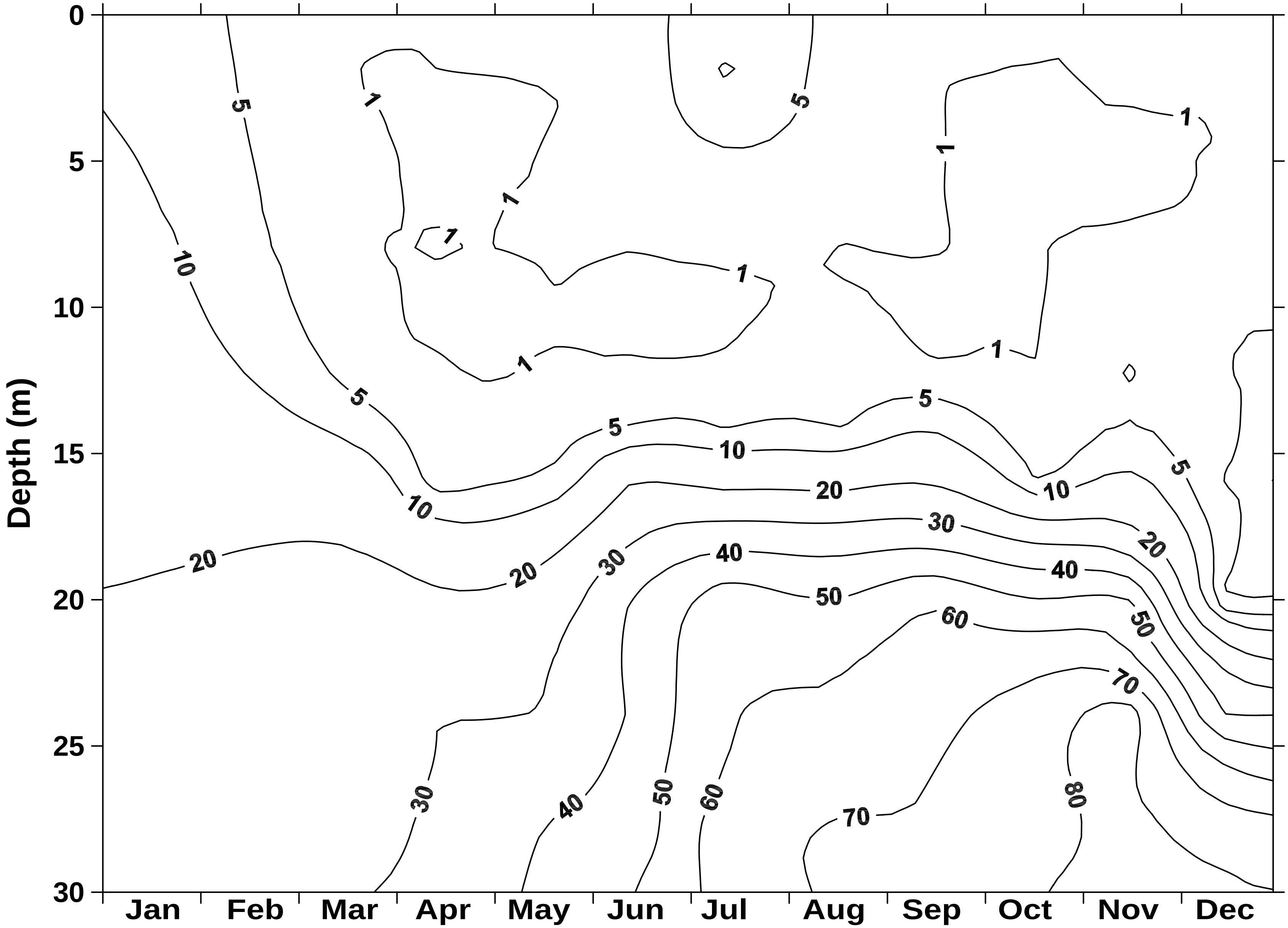
Light Attenuation (% of Surface) at Station 6

Figure 13



Dissolved Oxygen (mg/l) at Station 6, 2005

Figure 14



Ammonia (µM) at Station 6, 2005

Figure 15

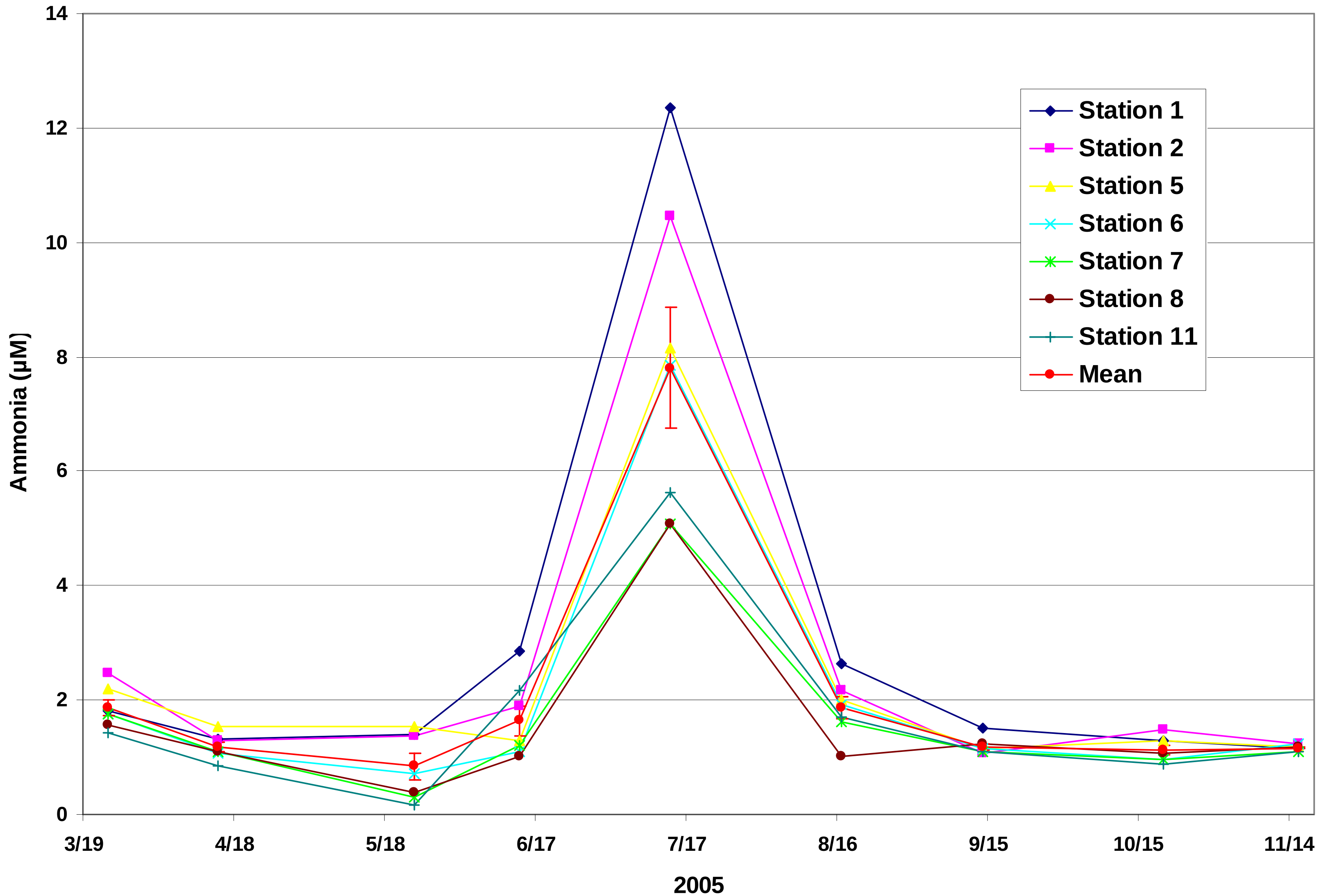
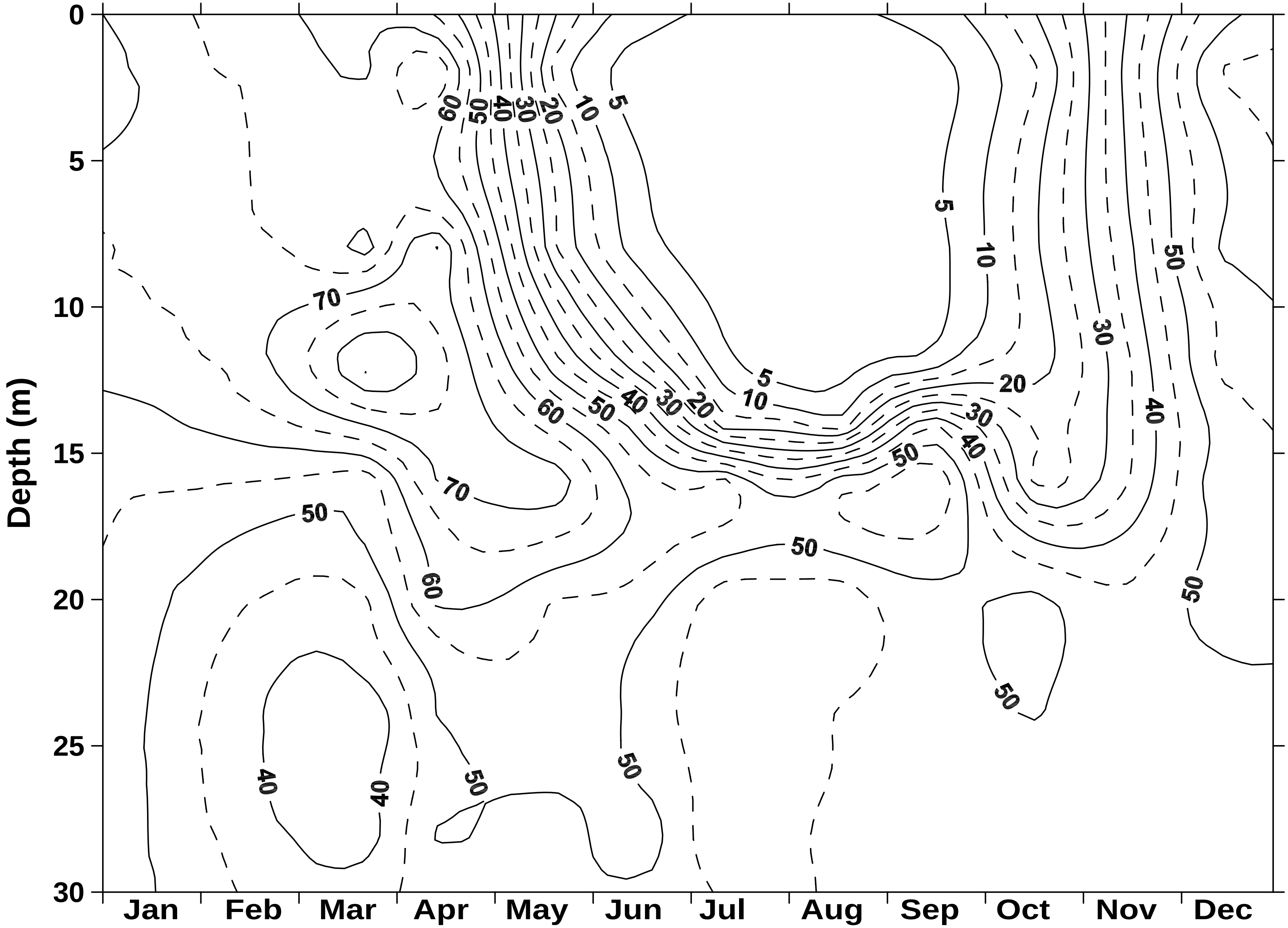
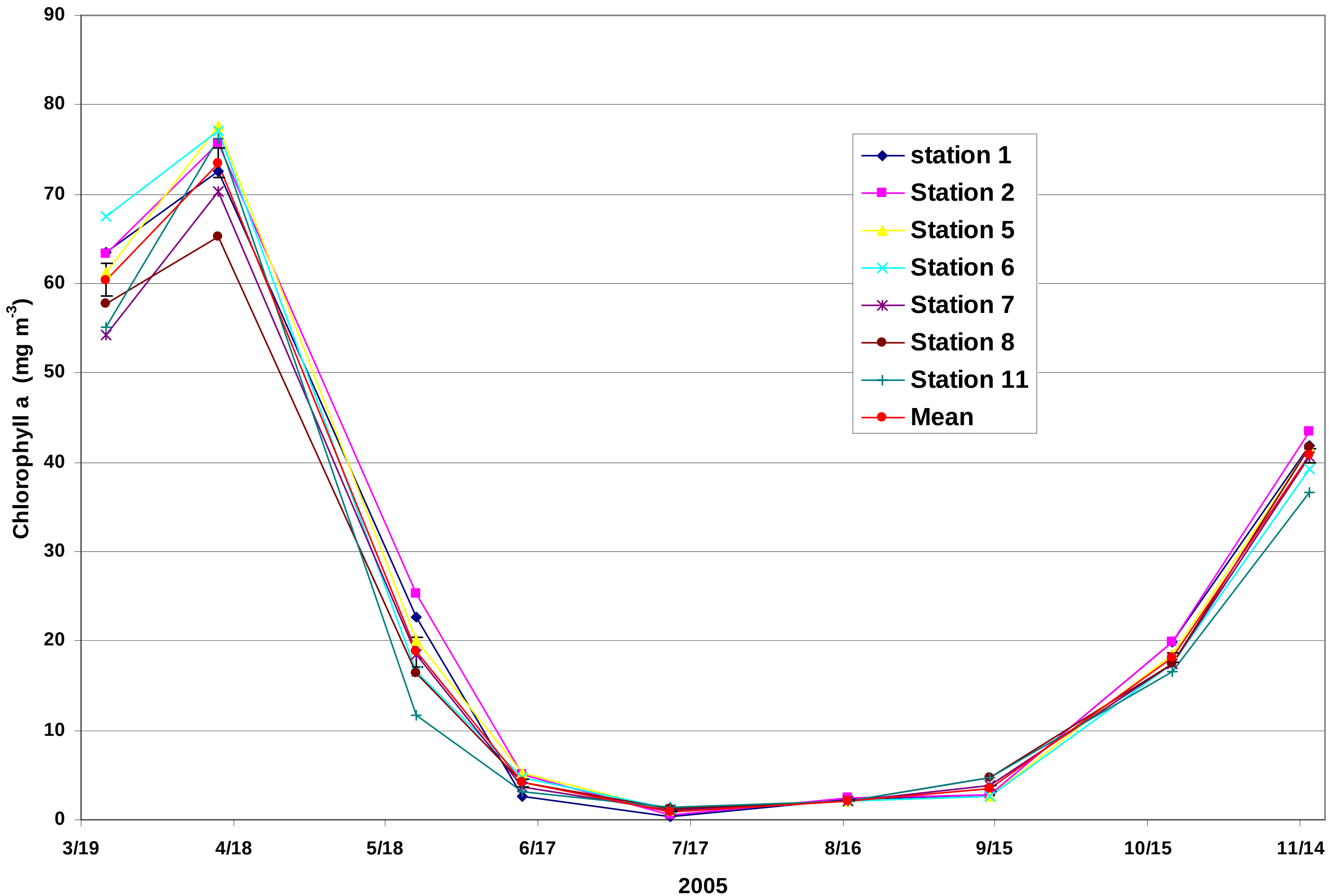

Ammonia (µM)
0
2
4
6
8
10
12
14
3/19
4/18
5/18
6/17
7/17
8/16
9/15
10/15
11/14
2005
Station 1
Station 2
Station 5
Station 6
Station 7
Station 8
Station 11
Mean

Figure 16



Chlorophyll a (μg/l) at Station 6, 2005

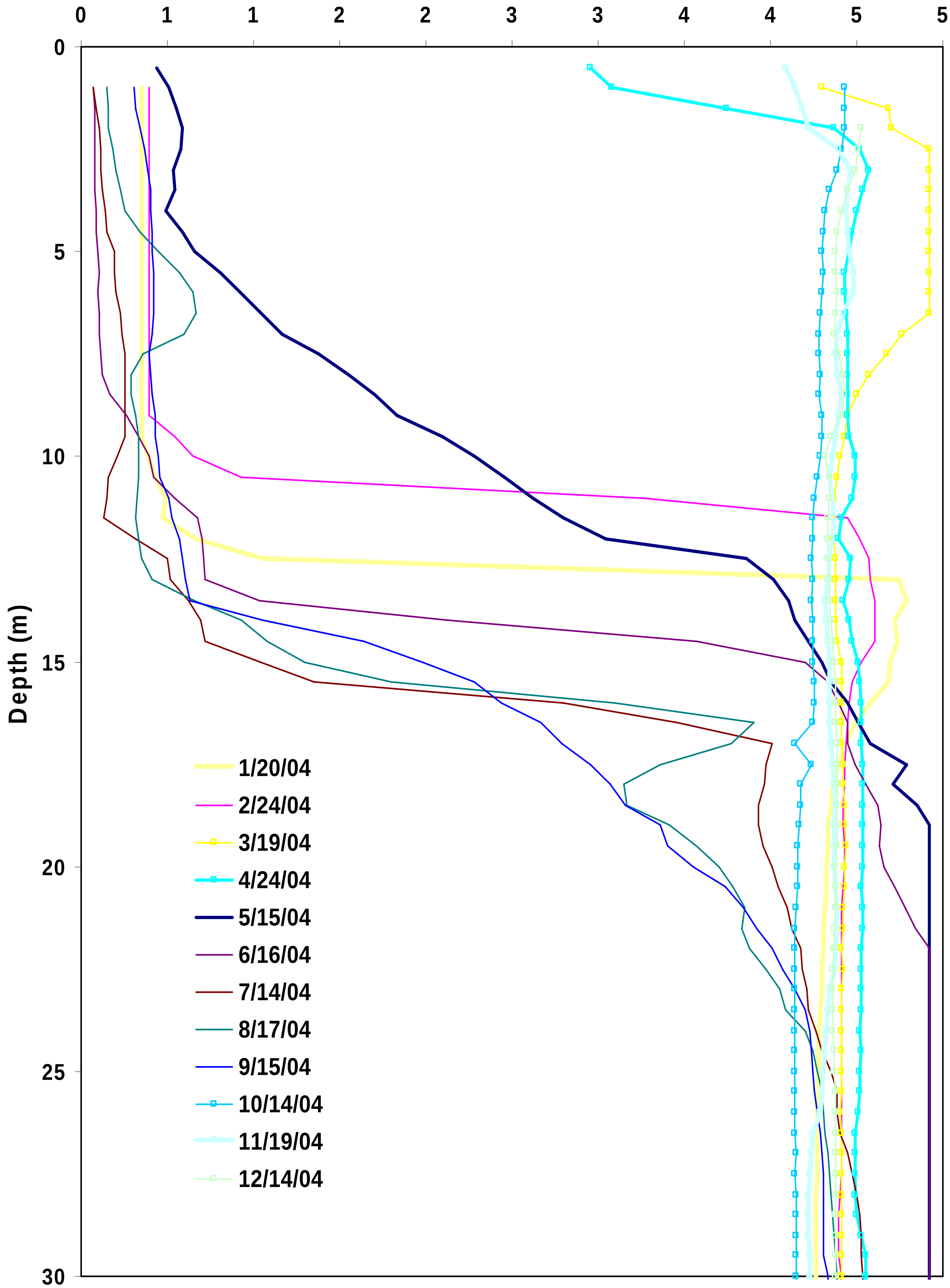
Figure 17



90
80
70
60
50
40
30
20
10
0
Chlorophyll a (mg m-3)
3/19
4/18
5/18
6/17
7/17
8/16
9/15
10/15
11/14
2005
station 1
Station 2
Station 5
Station 6
Station 7
Station 8
Station 11
Mean

Figure 18

Figure 19



2004 Seasonal fluorescence profiles at Station 6

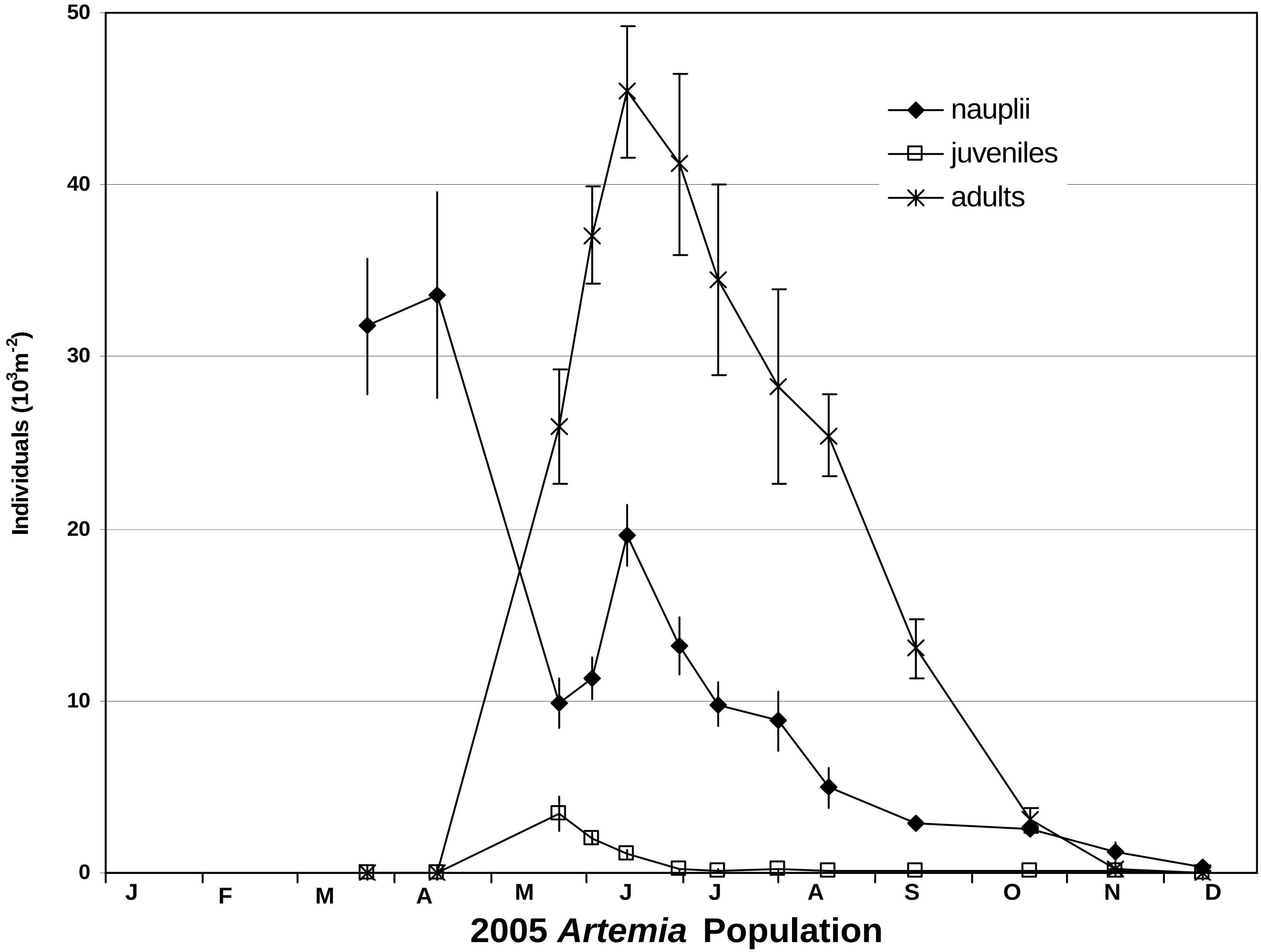

Individuals (10^3 m^-2)
50
40
30
20
10
0
nauplii
juveniles
adults
J
F
M
A
M
J
J
A
S
O
N
D
2005 Artemia Population

Figure 20

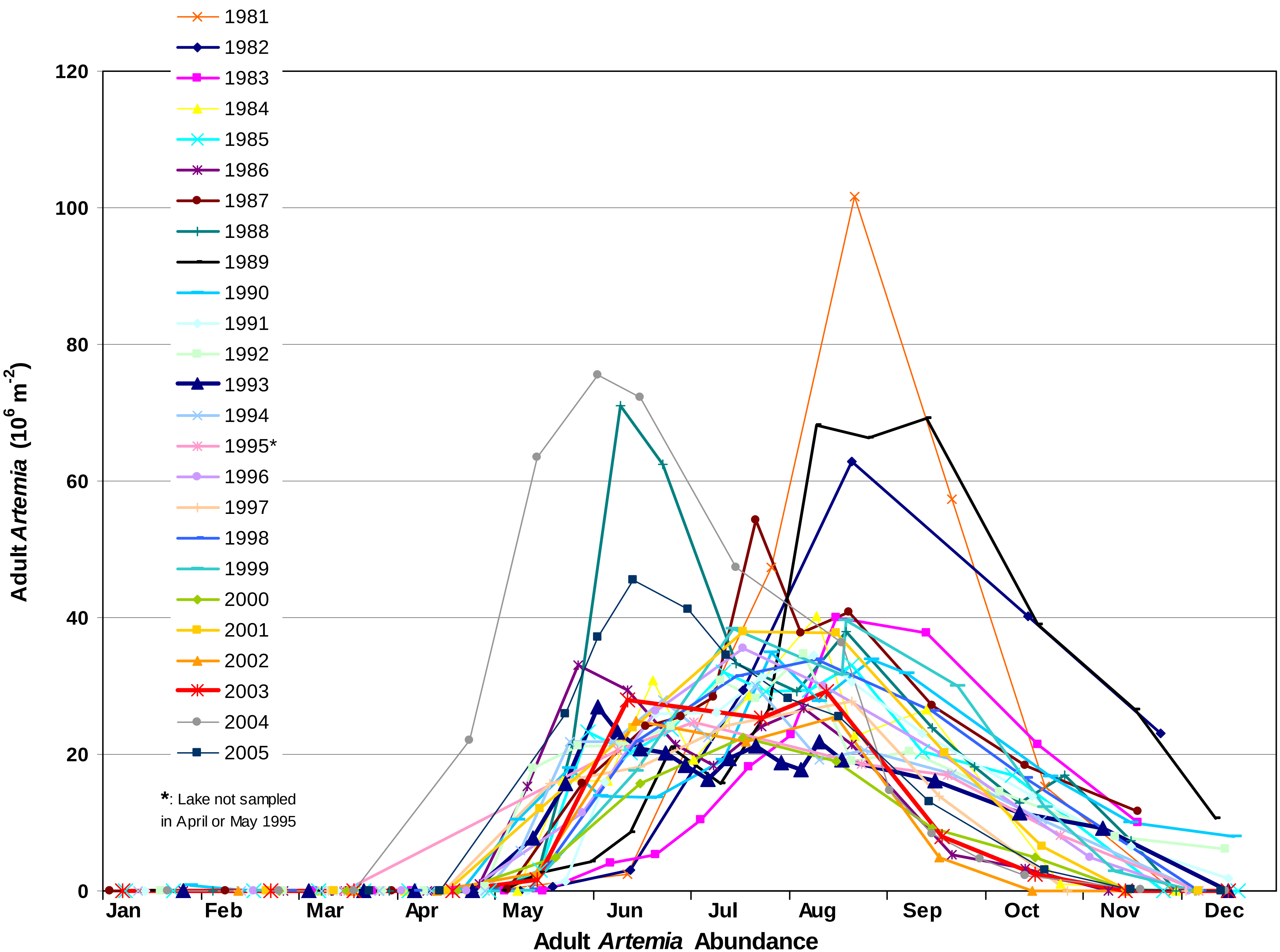
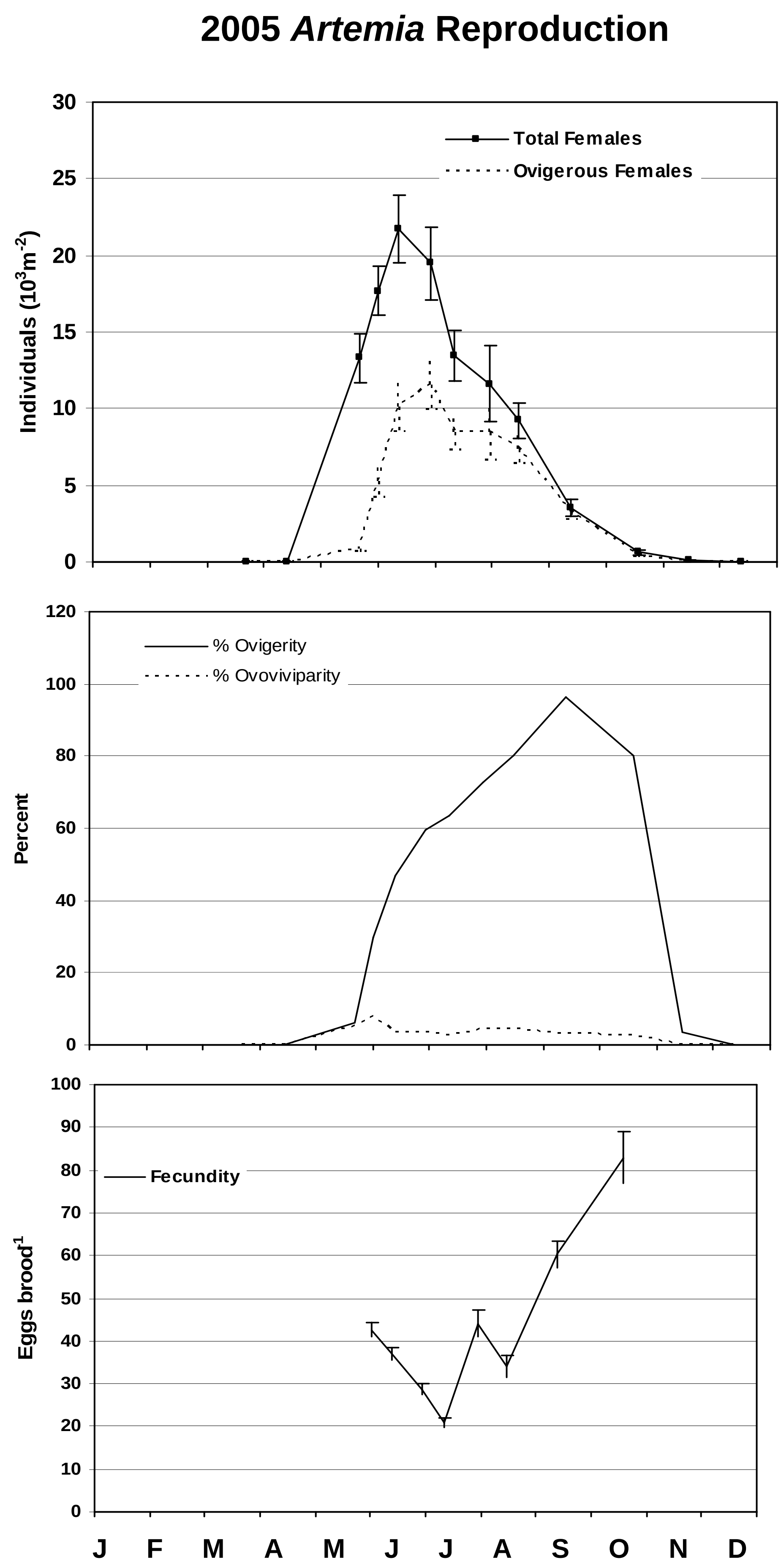
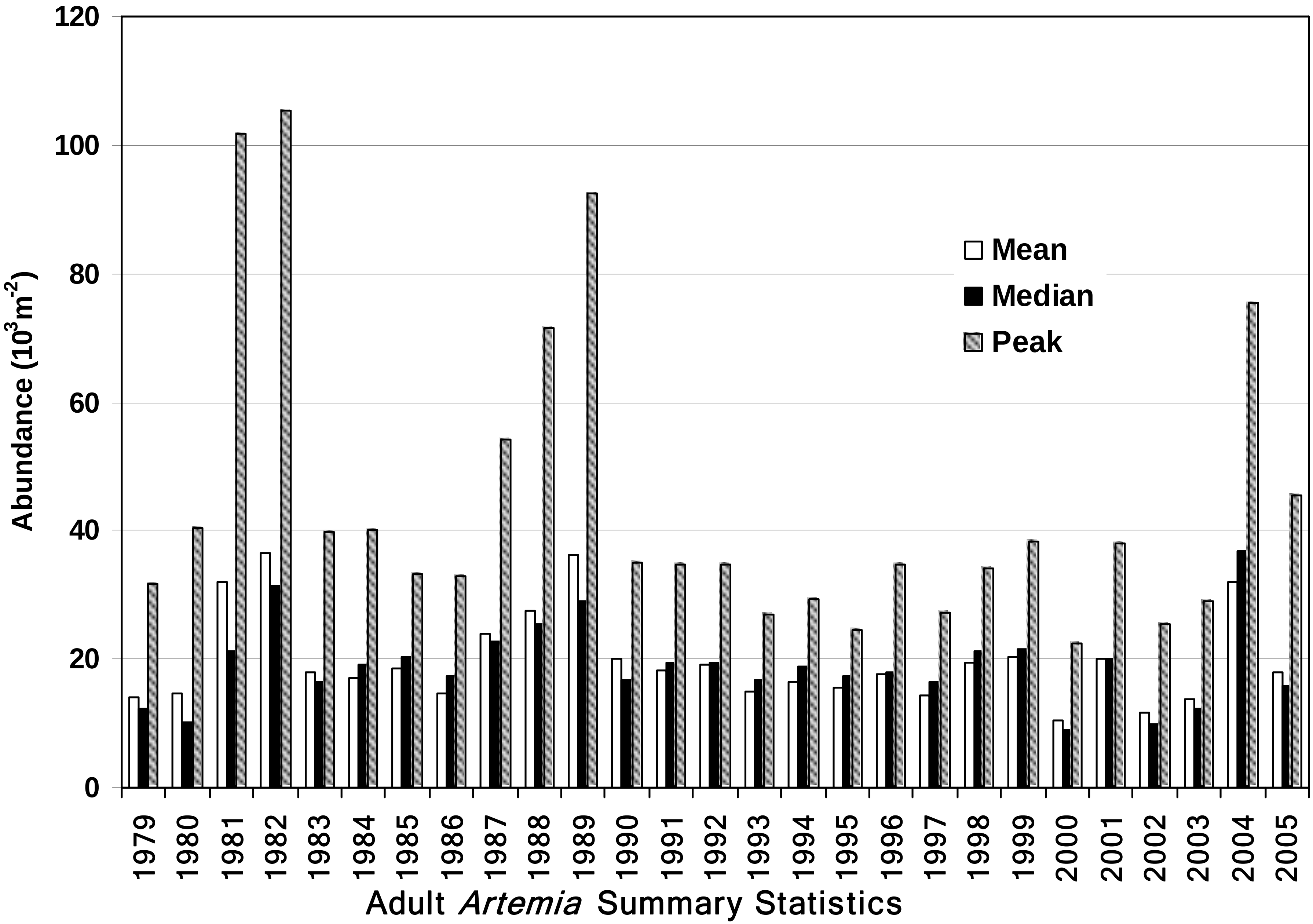

Adult *Artemia* (10^6 m^{-2})
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Adult *Artemia* Abundance
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995*
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
*: Lake not sampled
in April or May 1995

Figure 21

Figure 22



2005 Artemia Reproduction
Total Females
Ovigerous Females
Individuals ($10^3 m^{-2}$)
30
25
20
15
10
5
0
% Ovigerity
% Ovoviviparity
Percent
120
100
80
60
40
20
0
Fecundity
Eggs brood^{-1}
100
90
80
70
60
50
40
30
20
10
0
J F M A M J J A S O N D



120
100
80
60
40
20
0
Abundance ($10^3 m^{-2}$)
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
2005
Adult *Artemia* Summary Statistics

Figure 23

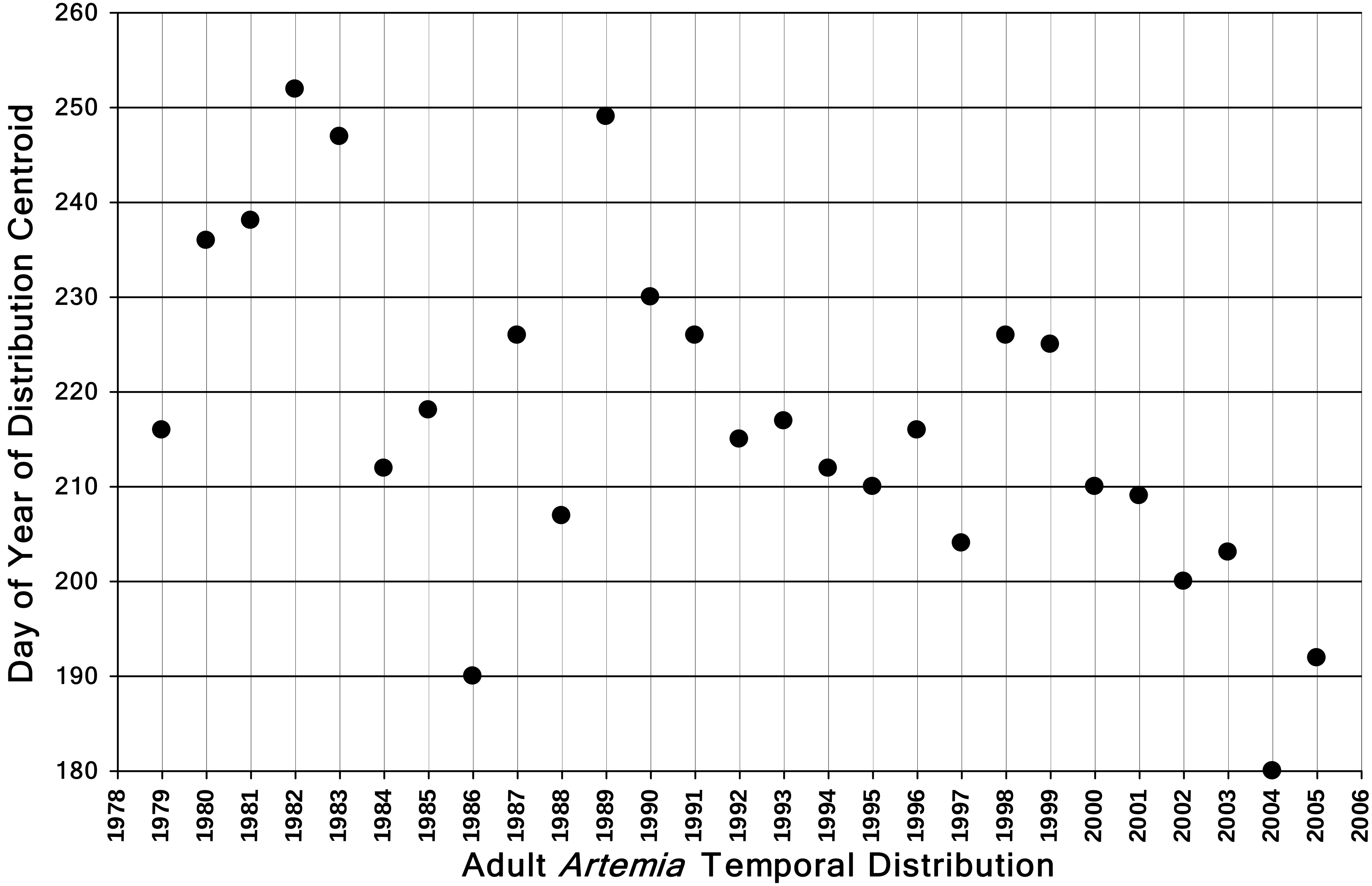
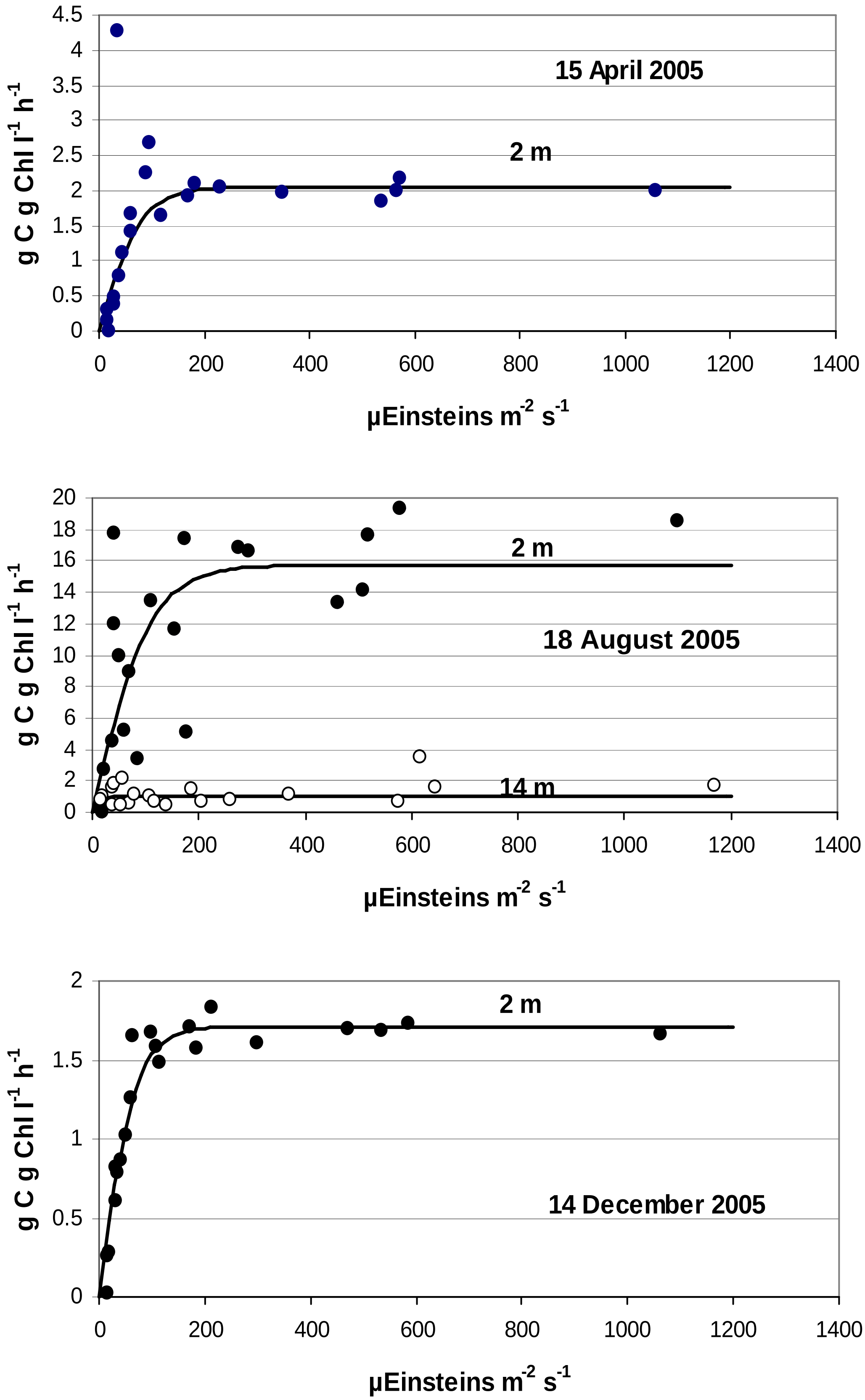

Day of Year of Distribution Centroid
260
250
240
230
220
210
200
190
180
1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
Adult *Artemia* Temporal Distribution

Figure 24

Figure 25



15 April 2005
2 m
g C g Chl l-1 h-1
µEinsteins m-2 s-1
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
0
200
400
600
800
1000
1200
1400
18 August 2005
2 m
14 m
g C g Chl l-1 h-1
µEinsteins m-2 s-1
0
2
4
6
8
10
12
14
16
18
20
0
200
400
600
800
1000
1200
1400
14 December 2005
2 m
g C g Chl l-1 h-1
µEinsteins m-2 s-1
0
0.5
1
1.5
2
0
200
400
600
800
1000
1200
1400

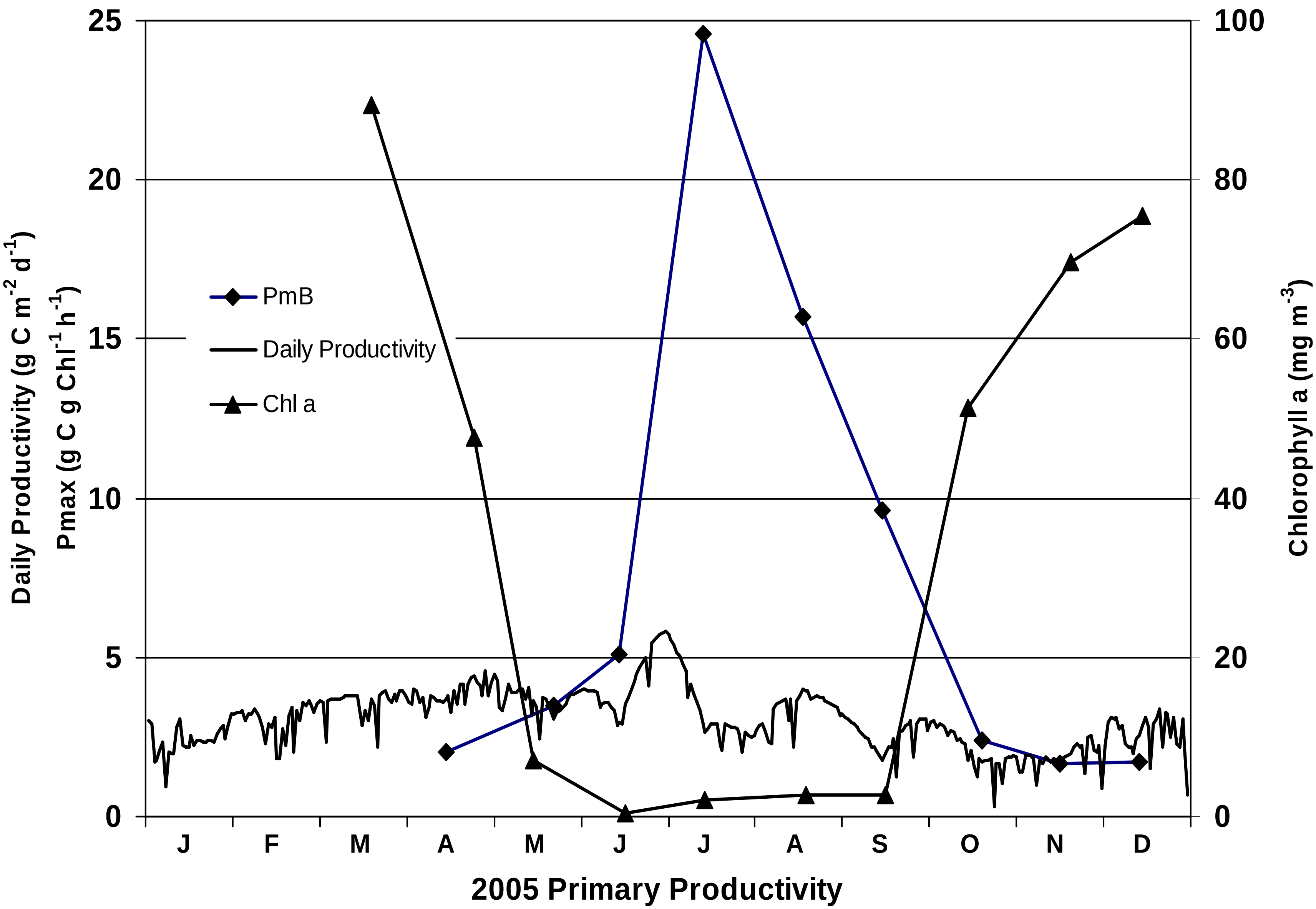
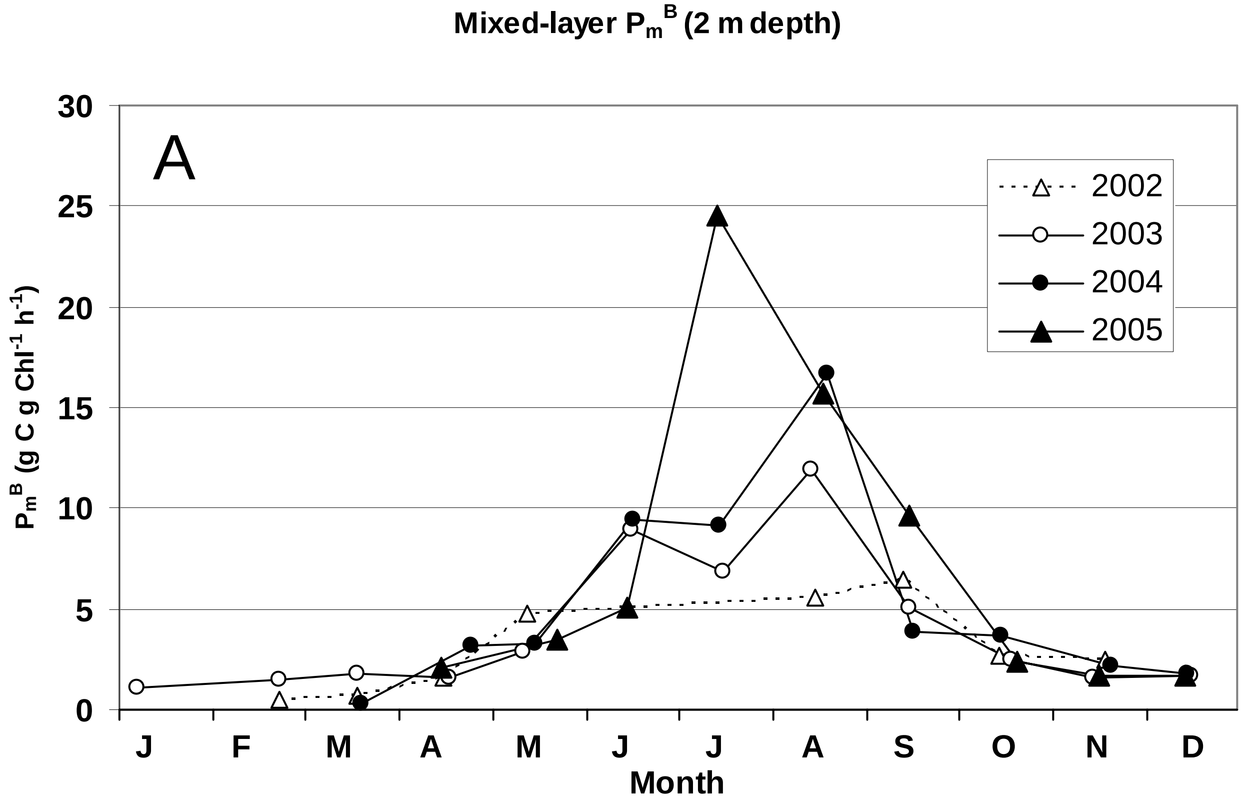
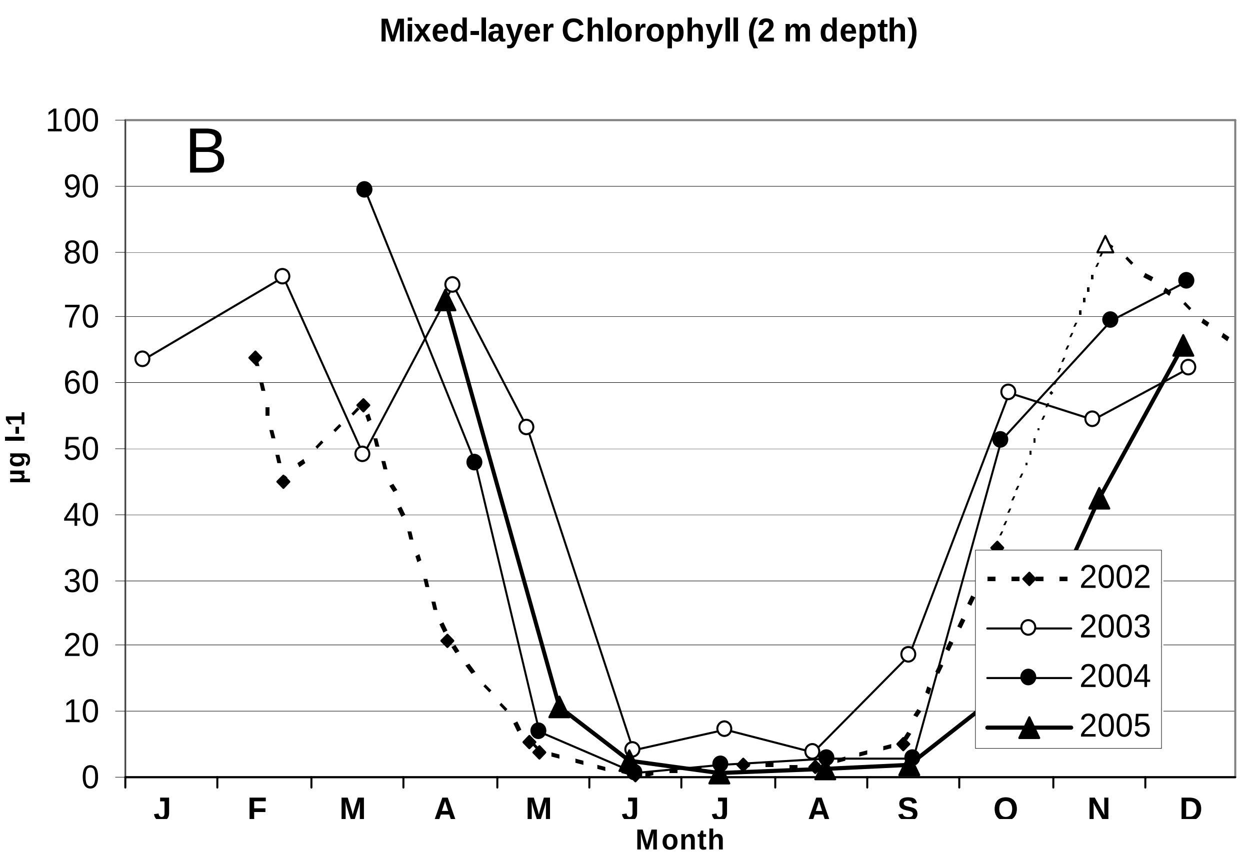
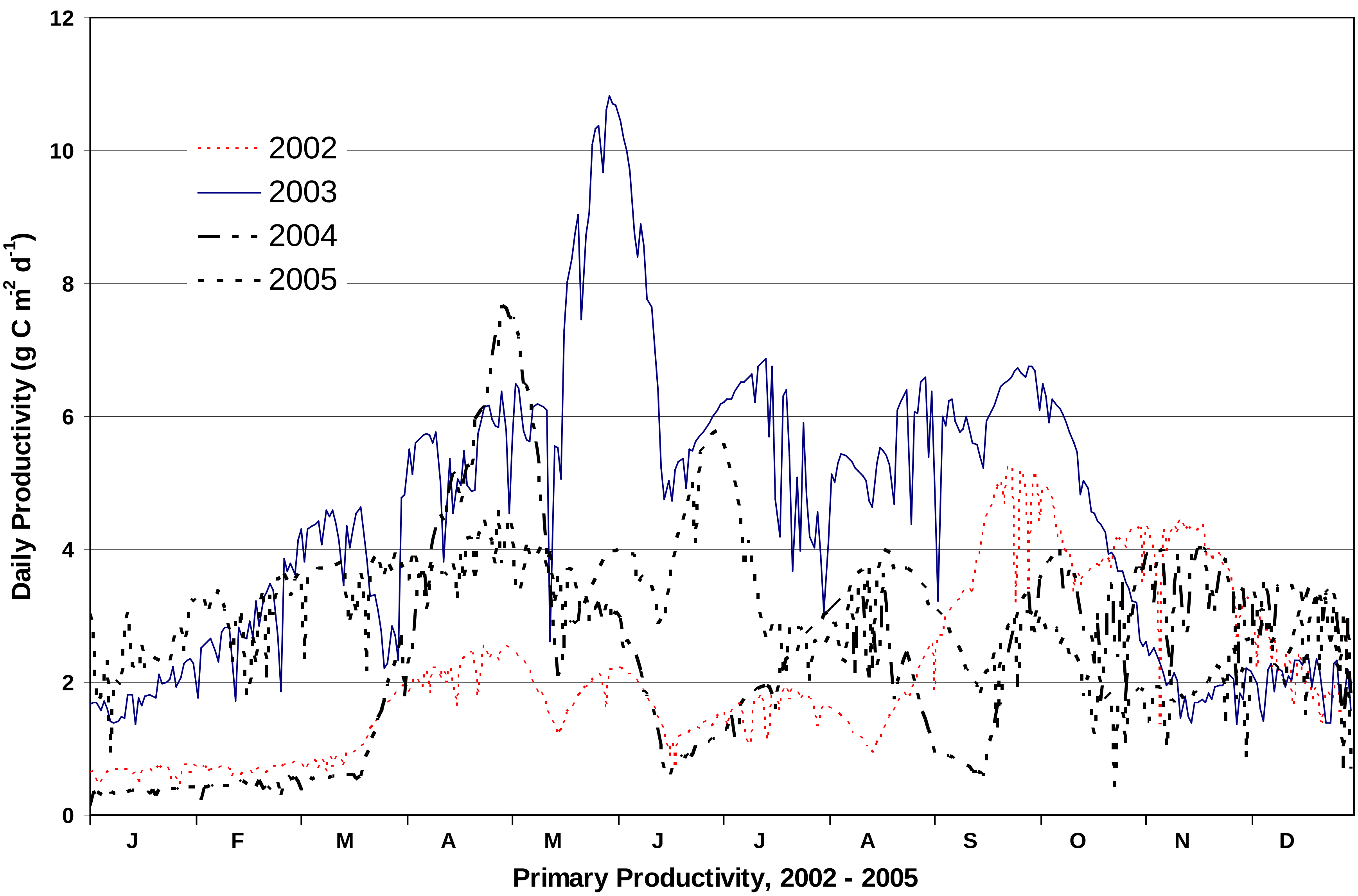

25
20
15
10
5
0
100
80
60
40
20
0
Daily Productivity (g C m-2 d-1)
Pmax (g C g Chl-1 h-1)
Chlorophyll a (mg m-3)
PmB
Daily Productivity
Chl a
J
F
M
A
M
J
J
A
S
O
N
D
2005 Primary Productivity

Figure 26

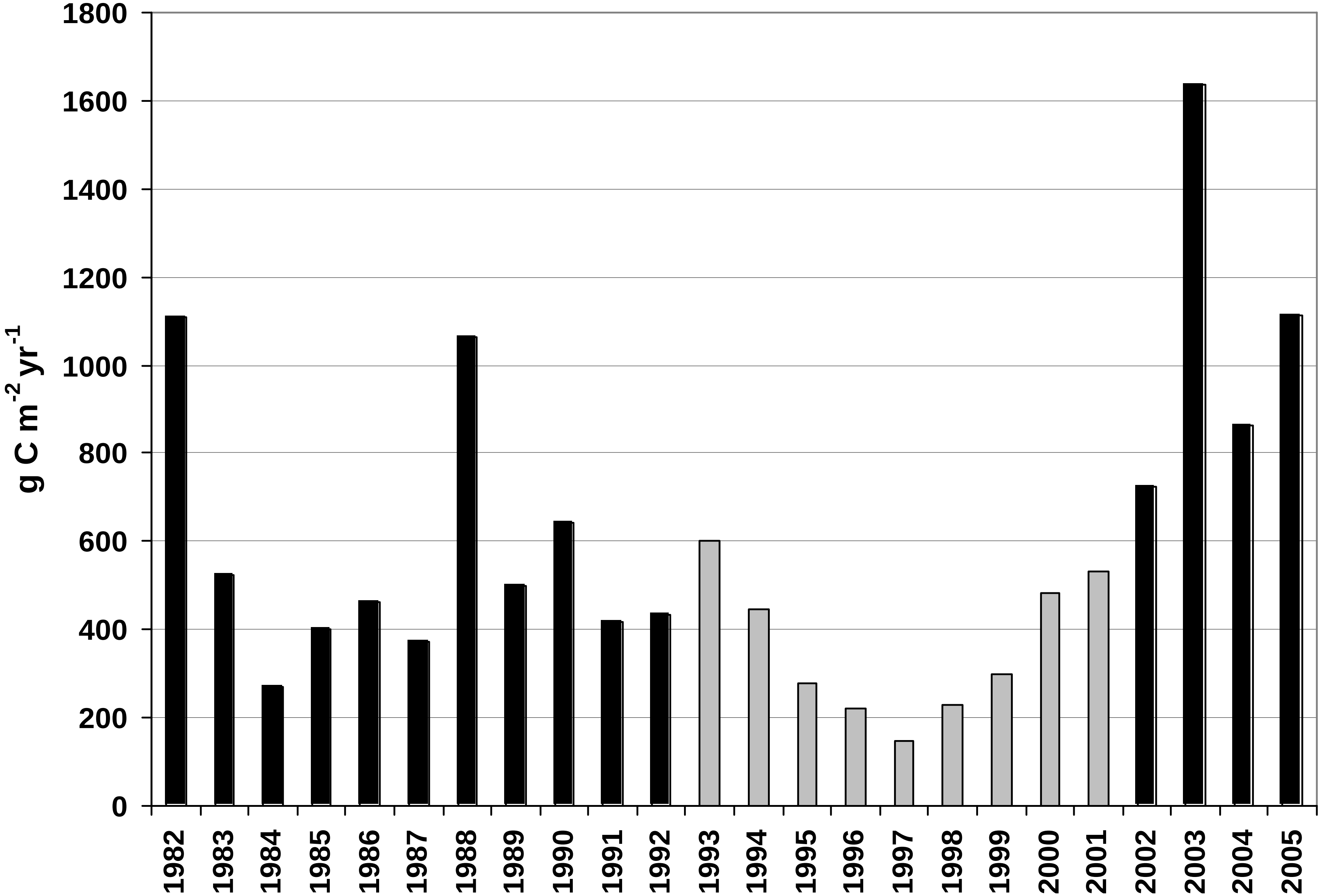

Mixed-layer P_m^B (2 m depth)
A
P_m^B (g C g Chl^{-1} h^{-1})
30
25
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D
Month
2002
2003
2004
2005


Mixed-layer Chlorophyll (2 m depth)
B
µg l-1
100
90
80
70
60
50
40
30
20
10
0
J
F
M
A
M
J
J
A
S
O
N
D
Month
2002
2003
2004
2005



Daily Productivity (g C m-2 d-1)
0
2
4
6
8
10
12
2002
2003
2004
2005
J
F
M
A
M
J
J
A
S
O
N
D
Primary Productivity, 2002 - 2005

Figure 28



Annual Primary Productivity

Figure 29

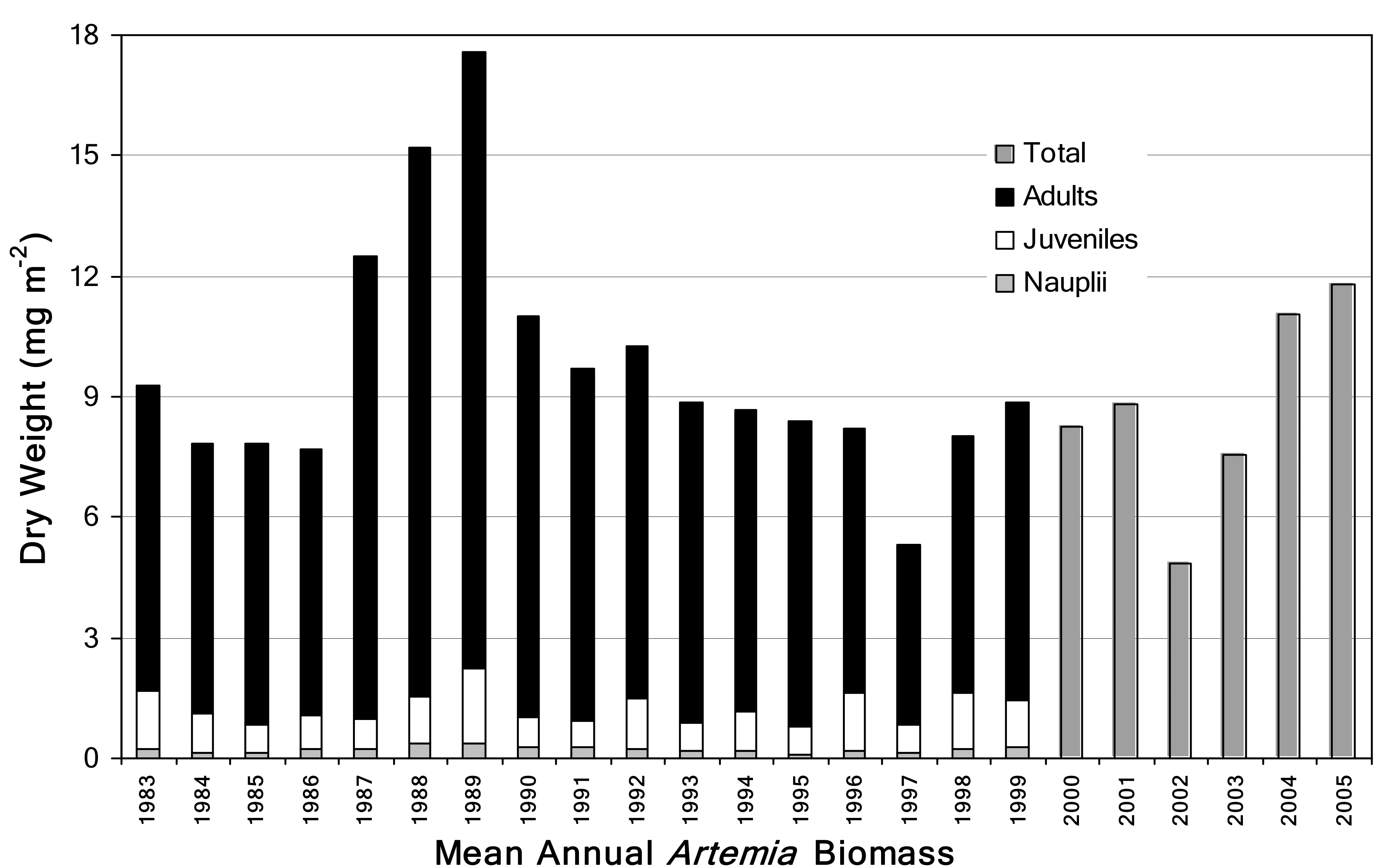

Dry Weight (mg m^{-2})
0
3
6
9
12
15
18
Total
Adults
Juveniles
Nauplii
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Mean Annual *Artemia* Biomass

Figure 30

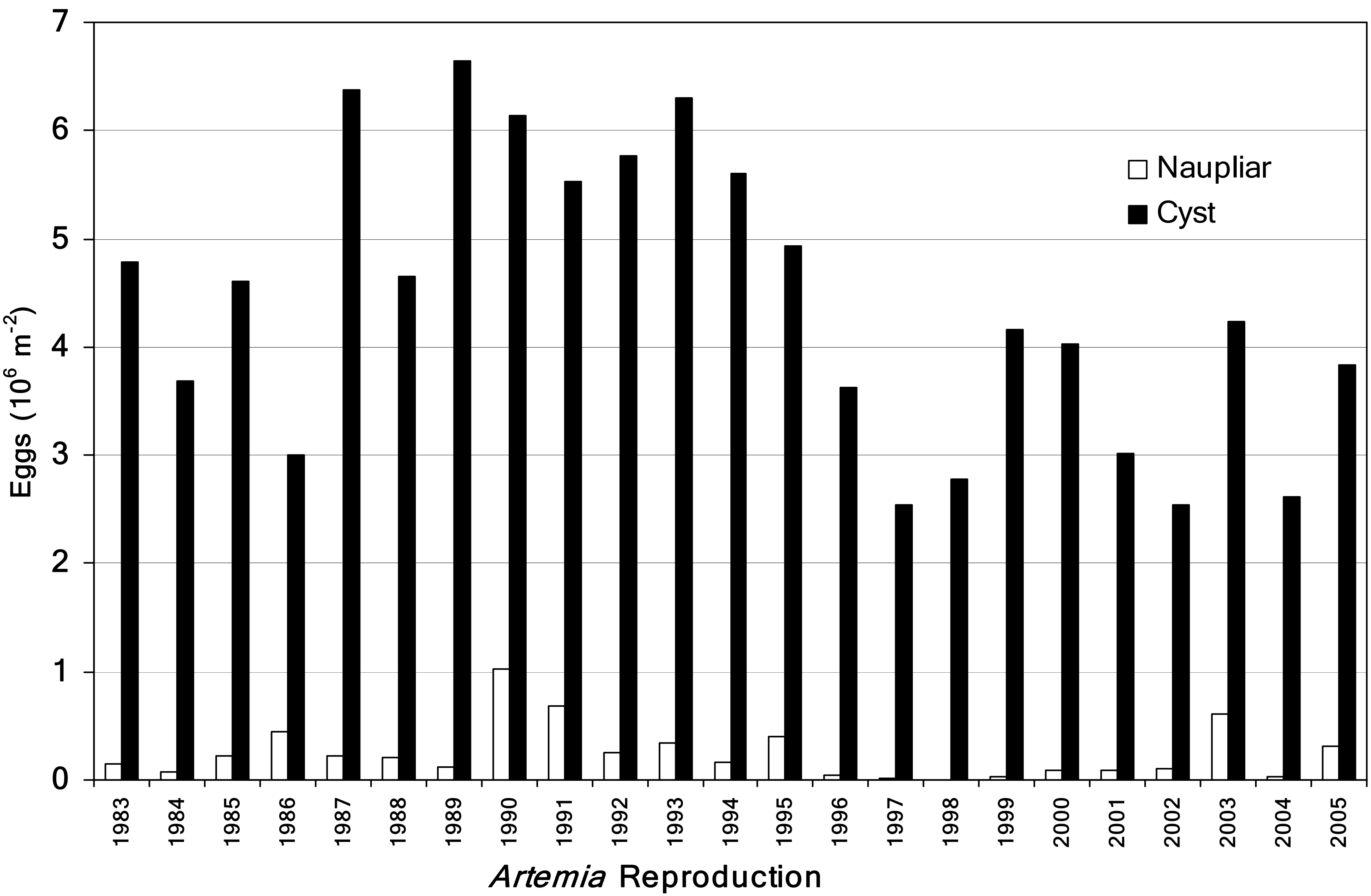

Naupliar
Cyst
Eggs (10^6 m^-2)
0
1
2
3
4
5
6
7
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Artemia Reproduction

Figure 31

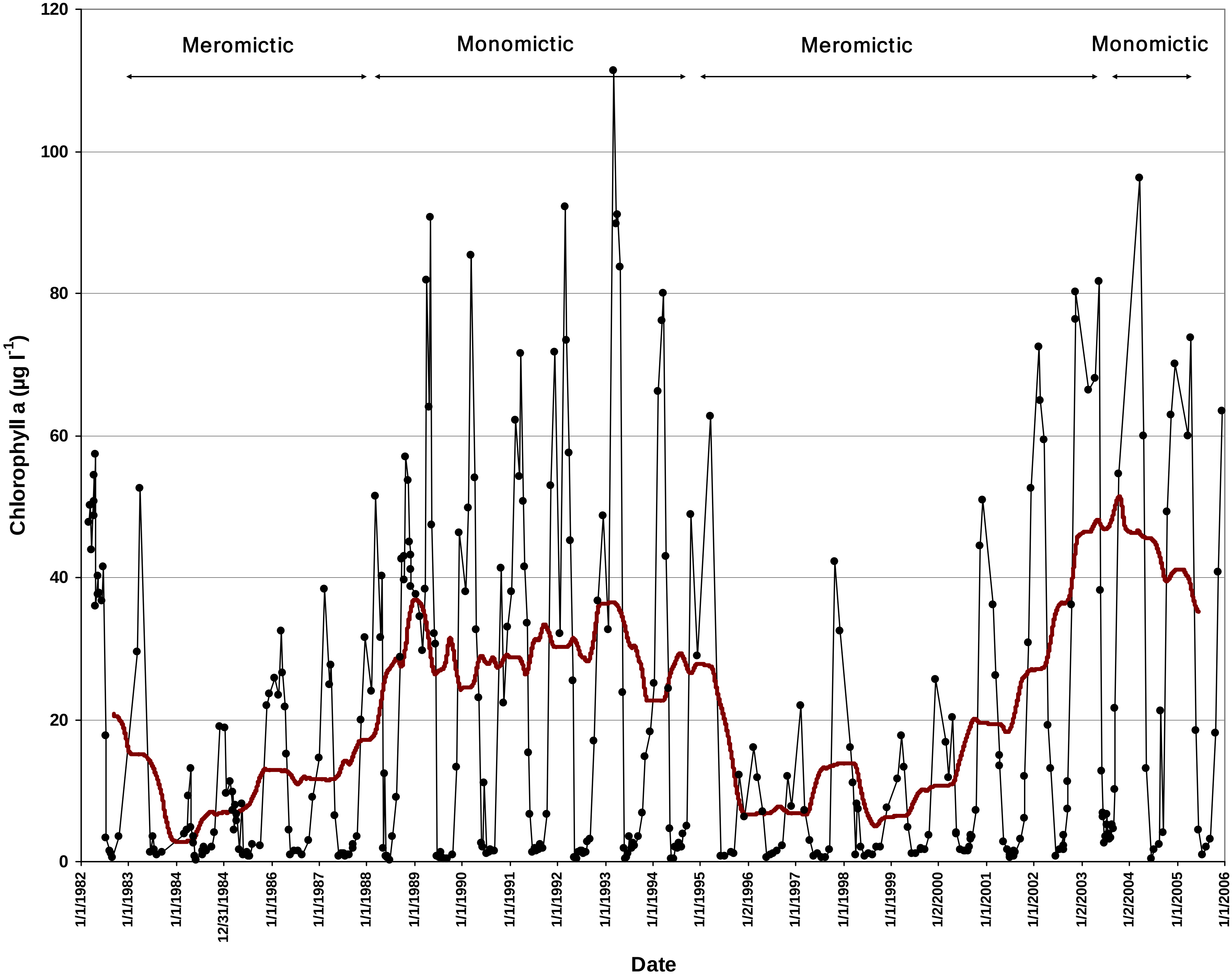
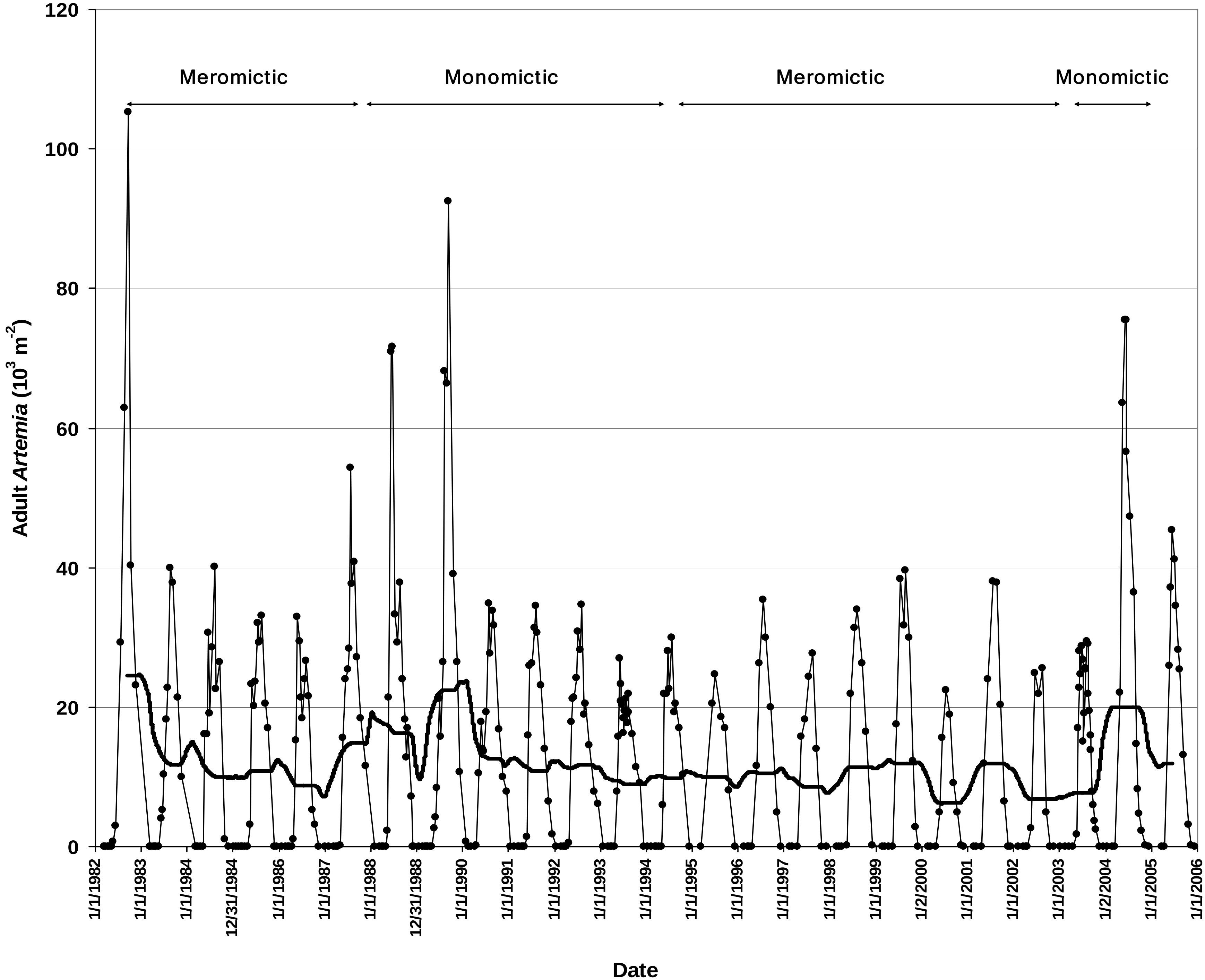

Meromictic
Monomictic
Meromictic
Monomictic
Chlorophyll a (µg l-1)
0
20
40
60
80
100
120
1/1/1982
1/1/1983
1/1/1984
12/31/1984
1/1/1986
1/1/1987
1/1/1988
1/1/1989
1/1/1990
1/1/1991
1/1/1992
1/1/1993
1/1/1994
1/1/1995
1/2/1996
1/1/1997
1/1/1998
1/1/1999
1/2/2000
1/1/2001
1/1/2002
1/2/2003
1/2/2004
1/1/2005
1/1/2006
Date

Figure 32



Meromictic
Monomictic
Meromictic
Monomictic
Adult Artemia (10^3 m^-2)
0
20
40
60
80
100
120
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
1/1/2006
Date

Figure 33

APPENDIX 3

Ornithology

MONO LAKE WATERFOWL POPULATION MONITORING

2005 ANNUAL REPORT

LOS ANGELES DEPARTMENT OF WATER AND POWER
PREPARED BY DEBBIE HOUSE
WATERSHED RESOURCES SPECIALIST
BISHOP, CA 93514
April 2006

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Executive Summary

Waterfowl populations were monitored in 2005 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. In order to determine whether or not long-term trends observed at Mono Lake are mirrored at other Eastern Sierra water bodies, fall aerial surveys were also conducted at Bridgeport and Crowley Reservoirs.

A total of nine waterfowl species were encountered at Mono Lake while conducting summer surveys. The five species that used the Mono Lake shoreline habitats and Restoration Ponds (DeChambeau and County Ponds) for brooding were Gadwall, Canada Goose, Mallard, Cinnamon Teal, and Green-winged Teal. Gadwall was the most abundant waterfowl species breeding at Mono Lake. This species also had the greatest spatial distribution of all waterfowl that use Mono Lake shoreline habitats for breeding.

A minimum of 46 unique broods were observed using Mono Lake shoreline habitats and Restoration Ponds in the summer. These 46 broods included 32 Gadwall, seven Canada Goose, five Mallard, one Cinnamon Teal and one Green-winged Teal brood. Wilson Creek and the South Shore Lagoons areas supported the greatest number of waterfowl broods.

A total of 19 shorebird species were encountered during the summer surveys. The most abundant summering species was American Avocet. Shorebird species for which evidence of breeding was detected included: American Avocet, Wilson's Phalarope, Killdeer, Spotted Sandpiper, and Snowy Plover. The Warm Springs, Sammann's Springs and South Shore Lagoons areas of Mono Lake attracted the greatest number of shorebird species throughout the summer season.

A total of eleven waterfowl species were recorded at Mono Lake during fall aerial surveys. In terms of total waterfowl detections, 22,566 individuals were detected on the lake during these surveys, while 327 individuals were detected using the Restoration Ponds. The peak number of waterfowl detected on any one survey at Mono Lake in 2005 was 8,247, which occurred on the September 27 survey.

The primary areas of waterfowl use (excluding Ruddy Ducks) during the fall of 2005 were the Mill Creek, Wilson Creek, and Sammann's Spring areas. Ruddy Ducks exhibited a shift in distribution through the fall survey period, occurring in a fairly concentrated area off-shore early in the fall, but then being detected close to shore as fall progressed.

A total of 13 waterfowl species were recorded at Bridgeport Reservoir during the fall 2005 aerial surveys. The peak number of waterfowl detected at Bridgeport Reservoir was 23,644 individuals, and occurred during the September 27th survey. A total of 83,630 waterfowl were detected during the six surveys at Bridgeport Reservoir during the fall season. The most abundant species were Northern Shoveler, Mallard, Gadwall, and Northern Pintail. The primary area of waterfowl concentration was the West Bay area.

A total of 16 waterfowl species were recorded at Crowley Reservoir during the 2005 fall aerial surveys. The peak number detected at Crowley Reservoir was 18,219, which occurred during the October 27th survey. A total of 58,349 waterfowl were detected at Crowley Reservoir over the six fall season surveys. The most abundant species were Mallard, Northern Pintail, and Gadwall. The primary areas of waterfowl concentration were McGee Bay and the Upper Owens River.

Comparison counts conducted at Bridgeport Reservoir and Crowley Reservoir indicate a large disparity between Mono Lake and the other two bodies of water with regard to the dominant species present. The data indicate that utilization by Ruddy Ducks and Northern Shovelers was proportionally higher at Mono Lake than either the Bridgeport or Crowley Reservoirs. Conversely, utilization by Mallards, Gadwalls, and Northern Pintails, Green-winged Teals was proportionally higher at both Bridgeport Reservoir and Crowley Reservoir than at Mono Lake.

An analysis of the trend in peak waterfowl numbers indicates a significant, positive trend in the peak number of waterfowl detected at Mono Lake since 1996.

Waterfowl Monitoring Compliance

This report fulfills the Mono Lake waterfowl population survey and study 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 2005. 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 22, 2005.

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2005 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 Orders 98-05 and 98-07]. 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 (6,392 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, 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 proper flow and land management in the tributaries designed to achieve healthy, functional riparian systems, and a rise in lake elevation from reduced water diversions.

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. In order to determine whether long-term trends observed at Mono Lake are being mirrored at other Eastern Sierra water bodies, or are specific to Mono Lake and any changes which may be occurring there, 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-count surveys were conducted at Mono Lake at three-week intervals beginning in early June. These were conducted as either transect surveys, or by making observations from a stationary point. Three days were required to complete each ground survey of Mono Lake. The date and time of day that surveys were done in each area around Mono Lake during 2005 have been provided in Appendix 1.

The locations surveyed were those identified in the Waterfowl Restoration Plan (LADWP 1996) 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 ground 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. Transect surveys were conducted by walking at an average rate of approximately 2 km/hr and recording waterfowl and shorebird species as they were encountered. 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 and the flushing of waterfowl ahead of the observer. In Lee Vining Creek, surveys of the creek channel were conducted by walking along the north bank 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 earthen 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 observed within 100 meters on either side of the deltas were also recorded.

At the DeChambeau Pond complex, observations were taken from a single stationary point at each of the five ponds. The observation points were selected so as to provide a full view of each pond. However, at the County Ponds, observations were taken from a single location that allowed full viewing of both ponds simultaneously. At all observation points at the DeChambeau and County ponds, a minimum of 5 minutes was spent at each observation 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 all waterfowl and shorebird species, the following data were recorded when the individual or group was first detected: the time of the observation, the habitat type the individual or group 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 each species mentioned in the document can be found in Appendix 2.

When 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 aerial photograph while in the field. Each brood was also assigned to an age class based on its plumage and body size (Gollop and Marshall 1954). Since the summer surveys were conducted at three-week intervals, any brood assigned to Class I using the Gollop and Marshall age classification scheme (which includes subclasses Ia, Ib, and Ic), would be a brood that had hatched since the previous visit. Assigning broods to an age class allowed for the determination of the minimum number of “unique broods” using the Mono Lake wetland and shoreline habitats.

The habitat categories used generally follow 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 in 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 of shore), and open-water offshore (>50 meters offshore), were added to the existing classification system in order to more completely represent areas used by waterfowl and shorebirds. Although a “>50 meter” category was used at the time of data collection, these observations will not be included in the final calculations unless the presence of waterfowl in the open-water offshore zone was determined to be 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 using a small high-winged airplane. A total of six surveys were conducted at two-week intervals, with the first survey beginning during the first week of September, and the last occurring in the middle of November. A summary of the fall survey schedule has been provided as Appendix 4.

Each aerial survey began at Mono Lake at approximately 0900 hrs. Mono Lake was surveyed in approximately one and one-half hours. Bridgeport Reservoir was surveyed next, and Crowley Reservoir was surveyed last. All three surveys were completed in a single flight by 1200 hrs on the day of the survey. No flights needed to be rescheduled due to inclement weather.

Observations were verbally recorded onto a handheld digital audio recorder, and later transcribed by the observer.

A second observer was present on all six flights. At Mono Lake, the second observer sat on the same side of the plane as the primary observer 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 all 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 at that lake, the 2005 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 a set of fixed cross-lake transects. The shoreline was divided into 15 lakeshore segments (Figure 2) in order to document the spatial use patterns of fall migrant waterfowl. Coordinates forming the beginning of each segment were derived from the 2002 aerial photo of Mono Lake (2002 aerial image taken by I. K. Curtis, and processed by Air Photo, USA) and can be found in 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 easily seen from the air.

Eight parallel cross-lake transects were conducted over the open water at Mono Lake. The eight transects are spaced at one-minute (1/60 of a degree, approximately 1 nautical mile) intervals and correspond to those used by Boyd and Jehl (1998) for the monitoring of Eared Grebes during fall migration. The latitudinal alignment of each transect is provided in Appendix 6.

Each of the eight transects is further divided into two to four sub-segments of approximately equal length (see Figure 2). The total length of each cross-lake transect was first determined from the 2002 aerial photo. These lengths were then sub-divided into the appropriate number of subsections to a total of twenty-five sub-segments, each approximately 2-km in length. This approach creates a grid-like sampling system that allows for the evaluation of the spatial distribution of Ruddy Ducks offshore. Since the survey aircraft's airspeed was carefully controlled, and the approximate length of each subsection was known, it was possible to use a stopwatch to determine the beginning and ending points 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 over water 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 with the southernmost transect and working northwards.

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. Even though the flight path of the aircraft along the latitudinal transects effectively alternated the observer's hemisphere of observation in a North-South fashion due to the aircraft's heading on successive transects, the one-nautical-mile spacing between the transects worked in conjunction with the limited detection distance of the waterfowl (<< 0.5 nautical mile) to effectively prevent double-counting of birds on two adjacent transects.

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. Survey 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 employed at Mono Lake. When flying over fishermen on the water, the pilot temporarily increased the aircraft's altitude. 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 pass around the reservoir allowed for the confirmation of both the number of birds counted and the 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 I. K. Curtis, and processed by Air Photo, USA) and can be found in 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 over water in a counterclockwise direction along the shoreline. The distance from shore, flight speed, and height above the water were the same as at Mono Lake during most of each flight. On occasion, there were large numbers of boats or float-tubers on the water. This required the pilot to temporarily increase the aircraft's altitude while over some areas of the lake. The reservoir was circumnavigated twice during each survey, due to presence of large concentrations of waterfowl. The second pass allowed for the confirmation of both the number of birds counted and the species composition.

Ground verification counts

Ground verification counts were conducted whenever flight conditions (e.g. lighting, background water color, etc.) did not allow the positive identification of a significant percentage of the waterfowl encountered, or to confirm the species or number of individuals present. During a ground validation count, the total number of waterfowl present in an area was recorded first, followed by a count of the number of individuals of each species present.

<u>Statistical Analysis</u>

Summer Ground Counts – waterfowl distribution; shorebird distribution and species richness

Single-factor Repeated Measures Analysis of Variance (RM ANOVA) was used to determine if the mean total waterfowl detections differed between lakeshore segments. (Detections at the Restoration Ponds were not included in this analysis; as the water levels of these ponds are managed, and therefore do not accurately reflect water levels, shoreline changes, or waterfowl responses to these factors at Mono Lake.) For shorebirds, single-factor RM ANOVAs were used to determine if either the mean total detections or mean species richness differed among lakeshore segments. The Tukey test (Zar 1996) was used whenever the ANOVA test found a significant difference among sites in the mean number of waterfowl or shorebirds detected. The Tukey Test is a multiple comparison test that identifies which lakeshore segments differ significantly from one another.

Summer Ground Counts - Habitat Use

Chi-square goodness-of-fit analysis was used to determine if individual waterfowl and shorebird species used any of the various habitats in a disproportionate manner. This analysis was done for the most abundant summering species, provided that the behavior of at least 30 individuals had been recorded. For waterfowl, all observations (foraging, resting, brooding, etc.) except those of flyovers were included in this analysis. The waterfowl species for which habitat use data were analyzed were Gadwall, Mallard, Cinnamon Teal, and Canada Goose. 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 with respect to the others.

Shorebird habitat use was analyzed in the same manner, except that analysis was confined to foraging observations only. Analysis was done for American Avocet, Killdeer, Least Sandpiper, Red-necked Phalarope, Snowy Plover, Western Sandpiper, and the Wilson's Phalarope.

Fall Counts – Data Summary and Analysis

Waterfowl counts were summed over all six fall counts to determine the total detections of each species and total detections for all waterfowl species. The total detections of all waterfowl or of individual waterfowl species provides an index as to the overall use. The fall aerial survey data was also summed by lakeshore segment for each body of water. Single-factor Repeated Measures Analysis of Variance (RM ANOVA) was used to determine if the mean waterfowl detections for the entire fall season differed between lakeshore segments at each site. The Tukey test (Zar 1996) was used to determine which lakeshore segments differed from one another whenever the ANOVA test found a significant difference in the mean number of waterfowl detected.

The counts of waterfowl detections at Bridgeport and Crowley were compared with counts of waterfowl at Mono for the all comparison counts conducted from 2002 through 2005. Single-factor RM ANOVA was used to evaluate whether the mean number of waterfowl detected differed between the three bodies of water.

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, i.e. "Is the slope significantly different from zero?" (Zar 1996).

Photo Documentation

As required by the Order 98-05, photo documentation of lake-fringing waterfowl habitats was completed in 2005. Photos were taken from a helicopter at all bodies of water on September 22, 2005.

Photos at Mono Lake are provided as Figures 5a -5m. The photos of Mono Lake were geo-referenced 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, and are shown on each photo. The general shoreline area depicted in each photo is also indicated on an outline diagram of Mono Lake that has been provided along with the photos.

Photos of Bridgeport Reservoir are provided as Figure 6a – 6b. The general shoreline area depicted in each photo is indicated on an outline diagram of the reservoir.

Photos of shoreline habitats at Crowley Reservoir are provided as Figures 7a – 7d. The general shoreline area depicted in each photo is indicated on an outline diagram of the reservoir.

Data Summary

<u>2005 Conditions - Mono Lake</u>

The 2004-2005 water year in the Mono Basin was "Wet-Normal" or one in which runoff during 2005 was predicted to be between 107% and 136.5% of normal. As a result, during the summer survey period of 2005, the level of Mono Lake was between 0.1 foot and 1.0 foot higher than during the same period in 2004. The lake reached its maximum level in July (elevation 6382.2 feet), and remained at this level until mid-August, at which point the lake level started to slowly decline through the fall months. The increased lake elevation resulted in qualitative differences in lake-fringing habitats during the 2005 monitoring period, some of which are discussed below.

South Shoreline Areas (South Tufa, South Shore Lagoons, and Sammann's Spring)

One of the most obvious changes seen along the south shoreline of the lake was the development of an extensive littoral bar system. In some south shoreline areas a littoral bar developed offshore of an existing littoral bar, creating a "double" littoral bar system. The formation and breakdown of littoral bars in some areas such as the south shoreline are likely influenced by the prevailing winds interacting with lake elevation changes. Figure 8 shows the littoral bar that had developed in the Sammann's Spring area since the fall of 2004. Also apparent in Figure 8, is that the increase in lake level resulted in a decrease in the width of the unvegetated area between the shoreline and lake-fringing wetland vegetation. Because of the development of the extensive littoral bar system, it appeared that hypersaline lagoon habitats were also more extensive along the south shore in 2005.

Local changes in the condition of some of the more permanent lagoons in the south shoreline area were also noted. For example, the first lagoon at the western boundary of the South Shore Lagoons shoreline area had dried considerably since 2002. This lagoon is one that typically gets used by waterfowl and shorebirds, but has received little use in the last few years as it has decreased in size, and presumably, has become increasingly saline. Due to above-normal precipitation, and/or increases in lake elevation, the water level in this lagoon recovered markedly in 2005 as compared to its condition in 2004. Figure 9 shows how the condition of this lagoon changed from the fall of 2004 to the fall of 2005.

Warm Springs

The major changes noted in the Warm Springs area were that the water level in north and south lagoons was initially higher than in 2004, and the area of exposed playa was reduced (Figure 10). As was the case in the south shoreline area, a littoral bar developed along the shoreline in the Warm Springs area. The littoral bar system in the Warm Springs area seemed less extensive and more ephemeral than that which developed along the south shore.

The north lagoon at Warm Springs, which has had water in all years since 2002, is where almost all waterfowl are recorded in the Warm Springs area. Only on rare occasions are waterfowl on shore or near shore in this area. This north lagoon is also very attractive to shorebirds, as is the shoreline in the Warm Springs area. A family of Coyote (*Canis latrans*) began frequenting the area around the north lagoon in 2005. Numerous piles of feathers were encountered adjacent to the north lagoon during the summer, indicating that the Coyotes were frequently preying on the birds in this area. The majority of the feathers found were from California Gulls (*Larus californicus*), but a few shorebird carcasses were also encountered.

The south lagoon at Warm Springs started to dry out by the end of summer. The south lagoon has not been used by waterfowl in any year since 2002, and has rarely been used by shorebirds.

Northwest Shore (DeChambeau Creek, Mill Creek, and Wilson Creek)

Qualitative changes were also noted along the northwest shore of the lake, from DeChambeau Creek area to the Wilson Creek area. Due to the rise in lake level, there was little to no exposed unvegetated area or mudflat area between the wetland vegetation adjacent to the creek and springs, and the lake. These mudflat areas had previously been where waterfowl would typically sit, preen, or sleep. In the Mill Creek area, some willow die-off was noted at the edge of the lake since the increased lake level was resulting in saline toxicity to the willows.

The 2005 flows in Mill Creek and Wilson Creek were well above those seen in 2004. During early June, there was sheet flow of the water over the entire delta area of Mill Creek. High flows from Mill Creek continued through the summer. In Wilson Creek, the high flows began cutting a deeper and more well-defined channel near shore. By the end of June, there was a 1.5- to 2-foot deep channel along Wilson Creek near the delta. By the end of June however, flows out of Wilson Creek had dropped to a point that there was little actual outflow from the delta.

It is important to note that flows from Wilson Creek currently enter Mill Creek Bay, and not Wilson Bay. East of Wilson Creek and Wilson Bay, the meadows appear to be continuing a slow trend of increasing dryness.

Rush Creek

Since the 2004-2005 runoff year was “Wet-Normal”, Rush Creek received a peak flow which was greater than has been observed since 2002. During the initial visit to Rush Creek delta in early June (before peak flows), it was noted that the mouth of the creek had changed noticeably since the fall of 2004. A littoral bar had developed that extended from the north bank of the main channel, and continued south across the mouth of the delta area. This sandbar deflected flows southward from the main channel of the creek (along the north embankment). The peak flow in Rush Creek of 357 cfs occurred from June 23 through June 26. This high flow appeared to inundate much of the wetland vegetation in the bottomlands of lower Rush Creek. On the June 27th visit, it was noted that the sandbar had eroded just downstream of the mouth of the creek, so that the entire flow was no longer being diverted to the south.

Lee Vining Creek

As was the case with Rush Creek, Lee Vining Creek also received flows which were greater than have been observed since 2002. The peak flow in Lee Vining Creek of 372 cfs occurred on May 28. Throughout June, water was seen flowing in many small channels which have otherwise remained dry for the last few years. During the early June visit, water was spread across the entire vegetated delta area of the south arm of the creek.

2005 Conditions – Bridgeport Reservoir

The water level at Bridgeport Reservoir was considerably higher than in 2004, when the reservoir level was very low all season. Figure 11 shows photos comparing conditions and lake level in 2004 versus 2005. Due to the topography of this area, this increase in reservoir level appeared to increase the amount of shallow-water habitat available for foraging by dabbling ducks.

2005 Conditions – Crowley Reservoir

As was the case at Bridgeport Reservoir, the water level at Crowley Reservoir had also increased over that seen in 2004. Similar to Mono Lake, this increase in lake level resulted in local decreases or elimination of mudflat areas for ducks to sleep or rest, especially in the McGee Bay area (Figure 12). At the mouth of the Owens River, the increased reservoir level may have resulted in increased shallow-water habitats available for foraging by dabbling ducks.

Fall Aerial Survey Weather Conditions

Relatively mild conditions prevailed throughout the fall survey period. Weak cold fronts passed through the area September 26 and October 27, but temperatures continued to remain mild. The first significant winter storm of the season in the area occurred November 8, the day before the final fall survey.

Summer Ground Counts

Shoreline Count - Waterfowl

The number of waterfowl detected in each survey area during each visit can be found in Tables 1 through 3. Table 4 provides a summary of the number of detections for each species during each survey.

A total of nine waterfowl species were encountered during summer surveys, seven of which were present throughout the summer. Evidence of breeding was documented for five of these species (Gadwall, Mallard, Canada Goose, Cinnamon Teal, and Green-Winged Teal). Breeding was not confirmed for Northern Pintail or Ruddy Duck. As in previous years, Gadwall was the most abundant and widespread species during the summer.

There was a significant difference between lakeshore segment areas in terms of the mean number of waterfowl detected during summer ground counts ($p = 0.004$, $F = 4.748$, $df = 26$). The number of waterfowl detected at Mill Creek was significantly greater than at Lee Vining Creek, South Tufa, Warm Springs, and Sammann's Spring (Tukey test, $p < 0.05$). The results of the Tukey test also indicated that 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 summer. The water levels in Ponds 1 and 5 were lower than they had been in 2004, and these two ponds remained partly covered with algal mats through the summer. The water level in the County Ponds was noticeably higher than in 2004, and the area between the ponds was also flooded during the summer.

A total of five 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 four American Coot broods were raised at the DeChambeau Pond complex. Five waterfowl broods were seen at the County Ponds. At least five American Coot broods were seen at the County Ponds.

Brood Summary

A total of 55 broods were detected during summer counts, with 46 of those categorized as "unique". The number of unique broods represents the minimum number of broods observed using the lake and restoration ponds. The number of unique broods was determined by eliminating broods of age Class II or older that may 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 13 shows the locations of all of the broods detected in 2005. The most unique broods (9) were detected in the Wilson Creek and South Shore Lagoons areas, followed by the DeChambeau Ponds with 7 unique broods. Five broods were detected at DeChambeau Creek, Mill Creek, and the County Ponds each. Three broods were detected in the Rush Creek delta and another three were detected in the Sammann's Spring area. As was the case last year, no broods were detected in the Warm Springs or South Tufa areas. Although a small number of broods are usually detected in Lee Vining Creek, none were detected in 2005.

Five species of waterfowl used Mono Lake shoreline habitats for brooding. Gadwall was the most abundant and widespread breeding species at Mono Lake. A minimum of 32 Gadwall broods were detected in the areas surveyed, with the majority of these broods being detected at Wilson Creek, DeChambeau Ponds, and the South Shore Lagoon area. Gadwall broods were also detected at Mill Creek, the County Ponds, and Sammann's Spring. Mallard broods (five total) were seen at Rush Creek delta, Wilson Creek, and along the south shore in the South Shore Lagoons and Sammann's Springs areas. A Cinnamon Teal brood was seen at the DeChambeau Ponds. Cinnamon Teal also attempted to nest in the Sammann's Spring area, but this nest was predated. This predated nest with two eggs was found in the Sammann's Spring area on June 8. The nest was near a spring-fed pond in alkali wet meadow habitat and was located in a dense growth of *Juncus*. Seven Canada

Goose broods were detected, with the majority of these (5) in the DeChambeau Creek area. Only one Green-winged Teal brood was seen, and this brood was in the Rush Creek delta area.

Waterfowl Habitat Use

All four waterfowl species analyzed showed a disproportionate use of the various shoreline habitats in 2005. Differences in habitat use between 2004 and 2005 were also evident. Table 6 provides the tabulated habitat use data, the chi-squared goodness-of-fit results, and the Bonferonni test results for Gadwall, Mallard, Cinnamon Teal and Canada Goose. Figure 14 is a bar graph depicting the proportional use of habitats by each of these species.

In 2005, Gadwall were seen using ria, open-water habitats close to shore (<50 meters) and unvegetated areas significantly more than expected (Bonferonni test, $p < 0.05$). All other habitats were used less than expected. The observations of Gadwall using ria were primarily of birds foraging at the mouths of Mill Creek and Rush Creek. As compared to 2004, Gadwall were observed using ria proportionally more and open-water habitats proportionally less in 2005.

Mallards also used the various habitat types out of proportion to one another. Mallards were observed using brackish lagoons proportionally more than the other habitat types (Bonferonni test, $p < 0.05$). Ria, freshwater ponds, hypersaline lagoons, unvegetated areas, and open-water areas close to shore were not used more or less than expected. As compared to 2004, Mallards were observed using ria and brackish lagoons proportionally more in 2005, and unvegetated areas proportionally less.

Cinnamon Teal were seen using brackish and hypersaline lagoons proportionally more than other habitat types. Open water areas close to shore and wet meadow habitat were used less than expected. As compared to 2004, Cinnamon Teal were seen using ria and hypersaline lagoons proportionally more in 2005, and freshwater ponds proportionally less.

Canada Geese were seen using wet and alkaline meadow, unvegetated areas, ria, open-water (<50 meters from shore), and brackish lagoons. Canada Geese used open-water areas and wet meadow habitats proportionally more than all other habitats (Bonferonni test, $p < 0.05$). Observations of birds using ria and unvegetated areas was proportional, while alkali meadow habitats, and brackish lagoons were used less than expected. As compared to the combined habitat use data from 2002-2004, Canada Geese used wet meadows and open water proportionally more in 2005, and unvegetated areas proportionally less.

Shoreline Count – Shorebirds

A total of 19 shorebird species were encountered at Mono Lake during the summer surveys. The number of shorebirds detected in each survey area during each visit can be found in Tables 1 through 3, while Table 4 provides a summary of the number of detections for each species during each survey. Total shorebird species richness was highest in the Warm Springs area where a total of 13 species were detected in the summer. Other areas of high shorebird species richness include Sammann's Springs (12 species), and South Shore Lagoons (11 species).

Mean shorebird species richness differed among sites ($p = 0.016$, $F = 3.477$, $df = 26$), as the mean number of shorebird species detected throughout the summer was highest at Sammann's Springs, and significantly lower at Lee Vining Creek and South Tufa (Tukey test, $p < 0.05$). In terms of shorebird abundance, the majority of shorebird individuals detected were in the Sammann's Spring, DeChambeau Creek, and South Shore Lagoon areas. The mean number of individuals detected among the lakeshore segment areas differed ($p = 0.027$, $F = 3.068$, $df = 26$) as the number of shorebird individuals detected at

Sammann's Spring was significantly greater than all sites except DeChambeau Creek and South Shore Lagoons (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 the was most abundant of the summering shorebird species, although the total number of American Avocets detected during the summer (912) was noticeably below that encountered in previous years in which the total number of American Avocets detected in the summer has ranged from 1,503 to 3,683. The most widespread shorebird species was Killdeer which was detected at all survey areas, followed by Wilson's Phalaropes, American Avocet and Least Sandpiper.

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 through 3 represent only individuals seen within 50 meters of shore. Large rafts of phalaropes could also be seen offshore in some areas. In 2005, offshore staging areas were noted in the Sammann's Spring, South Shore Lagoon, and Wilson Creek areas.

Shorebird Habitat Use

All of the shorebird species showed disproportionate use of the various shoreline habitats. As was the case with waterfowl, differences in habitat use between 2004 and 2005 were also evident. Table 7 provides the tabulated foraging habitat use data, the chi-squared goodness-of-fit results, and the Bonferonni test results for American Avocet, Wilson's Phalarope, Killdeer, Spotted Sandpiper and Snowy Plover. Figure 15 depicts the proportional use of habitats by each of these species.

American Avocets foraged in hypersaline lagoons proportionally more than all other habitat types (Bonferonni test $p < 0.05$). The next most frequently-used habitat was open-water areas close to shore, but use of this habitat type was not greater than 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.

Wilson's Phalaropes used open-water areas close to shore, unvegetated areas, and hypersaline lagoons proportionally more than expected (Bonferonni test, $p < 0.05$). The next most frequently-used habitats were ria, brackish lagoon, and freshwater ponds, although these were used less than expected, as compared to use of other habitats. Marsh, meadow and vegetated riparian habitats were not used for foraging by Wilson's Phalaropes. Red-necked Phalaropes were only seen foraging in hypersaline lagoons and open-water areas close to shore, and showed no preference for either habitat.

Killdeer and Snowy Plovers foraged primarily on unvegetated areas and used all other habitats less than expected (Bonferonni test, $p < 0.05$). Least Sandpipers used hypersaline lagoons and unvegetated areas more than expected (Bonferonni test, $p < 0.05$). Least Sandpipers were also seen using brackish lagoons, open water areas close to shore and ria. Western Sandpipers used hypersaline lagoons more than expected and unvegetated areas and open water habitats close to shore less than expected.

<u>Fall Aerial Surveys</u>

Mono Lake

A total of eleven waterfowl species and 22,566 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 8,247 and occurred on the September 27 survey (Table 8, Figure 16). Compared to the 2004 counts, these numbers represent a 56% decrease in total detections and a 54% decrease in the one-day peak count at Mono Lake. As was the case in 2004, the peak number of both Northern Shovelers and Ruddy Ducks occurred on the same day. The peak count, exclusive of Ruddy Ducks, was 6,054 or approximately 33% lower than the peak count of 8,994 in 2004.

In terms of total detections, Ruddy Ducks and Northern Shovelers were the dominant species during fall migration (Figure 17) with Ruddy Ducks accounting for 28.8% (6,515) of all detections, and Northern Shovelers accounting for 61.1% (13,780) of all detections (Table 8). There was a 40% decrease in total detections of Northern Shovelers in 2005 as compared to 2004 (22,874), but this species made up a larger percentage of total detections in 2005 (61.1%) as compared to 2004 (44.5%) due to the decrease in the number of Ruddy Ducks detected at the lake. There was a 72% decrease in total detections of Ruddy Ducks in 2005 as compared to 2004 (23,465), and this species made up a smaller percentage of total detections in 2005 (28.8%) as compared to 2004 (45.7%).

Tables 9 through 14 provide the results of each of the six fall surveys in terms of the number of individuals 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 ($p = 0.046$, $F = 1.831$, $df = 95$), however, the ANOVA results explain only 30% of the variation in the data, and the power of the test was low. Although a majority of the waterfowl were detected in Wilson and Mill Creeks, there was enough variability in the distribution of waterfowl between surveys that the multiple comparison test failed to detect significant differences in the mean number of waterfowl detected at the different lakeshore segments or offshore areas. Figure 18 shows the relative percentage of use of each lakeshore segment by waterfowl during each fall survey. Note that Mill Creek attracted the largest proportion of the waterfowl during the first survey, but that Wilson Creek and Sammann's Spring attracted a greater proportion of waterfowl through the rest of September (Figure 18). The relative proportion of waterfowl using these areas decreased through the fall period. This is largely driven by the pattern of use of Northern Shovelers, which are the dominant species early in the fall and tend to concentrate in the Mill and Wilson Creek areas, and sometimes the Sammann's Spring area. During later surveys, the proportional use of offshore areas increased due the lingering presence of Ruddy Ducks, a significant proportion of which are often offshore.

A total of nine waterfowl species and 324 individuals (less than 2% of all fall detections) and 600 American Coots were detected at the DeChambeau and County Pond complexes during fall surveys (Table 15). Approximately 60% (193/324) of the waterfowl detected at the Restoration Ponds were seen in the DeChambeau Pond complex.

The most abundant shorebirds at Mono Lake during fall were phalaropes and American Avocets (Table 16). The majority of phalaropes were detected either offshore or on shore along the west side of the lake (DeChambeau Creek to Ranch Cove). During fall, the main concentration of American Avocets was along the southeast shore (Sammann's Springs to Warm Springs), and the north shoreline areas (Northeast Shore west to Wilson Creek) (see Tables 9-14).

Ruddy Duck Distribution – Mono Lake

The distribution of Ruddy Ducks varied throughout the fall migratory period (Figure 19). Table 17 provides the number and percent of total Ruddy Ducks detected along each cross-lake segment and in each lakeshore segment for each survey. The relative width of the lines in Figure 19 represents the percent of total detections on that survey. As seen in the Figure, Ruddy Ducks initially staged in areas offshore of DeChambeau Embayment, Bridgeport Creek, and the Northeast Shore areas and most of the individuals (74 to 99%) were detected on cross-lake transects. From October on, Ruddy Ducks were more dispersed and closer to shore, such that 44% to 60% of the Ruddy Ducks were detected during the shoreline count and were recorded in all shoreline areas except the Warm Springs, and Sammann's Spring areas.

Bridgeport Reservoir

A total of 13 waterfowl species and 83,680 individuals were recorded at Bridgeport Reservoir during the 2005 fall aerial surveys (Table 18). The peak number of waterfowl detected on any single count at Bridgeport Reservoir was 23,644 individuals, which occurred on September 27 (Table 18, Figure 16). Compared to the 2004 counts, these numbers represent a 174% increase in total detections and an approximate 100% increase in the one-day peak count at Bridgeport.

Figure 20 shows the number of each species detected per survey at Bridgeport for the seven most abundant species. The most abundant species (in terms of total detections) were Northern Shoveler followed by Mallard, Gadwall, and Northern Pintail. These four species comprised approximately 70% of all waterfowl identified at Bridgeport Reservoir. The total number of Northern Shovelers detected at Bridgeport in 2005 was approximately 84% more than in 2004. Northern Shovelers were proportionally less abundant at Bridgeport this year than in 2004 (~20% of identified birds as compared to ~30%). Tables 19 through 24 provide the results of each of the six fall surveys in terms of the number of each species detected in each lakeshore segment. There was a significant difference in the mean number of waterfowl detected at each of the lakeshore segments ($p < 0.001$, $F = 24.9$, $df = 17$). The greatest proportion of waterfowl were detected in the West Bay area (Tukey test, $p < 0.05$). 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 58,349 individuals were detected at Crowley Reservoir during the 2005 fall aerial surveys (Table 25). The peak number of waterfowl detected on any single count at Crowley Reservoir was 18,219 individuals and occurred on October 27 (Table 25, Figure 16). These numbers represent an 11% decrease in total detections and a 21% increase in the one-day peak count at Crowley as compared to 2004. The total waterfowl detections at Crowley were generally lower than usual early in the fall, and the peak count for Crowley, which did not occur until the October 27 count, is the latest that the peak count has occurred since regular surveys began in the fall of 2002.

The most abundant species, in terms of total detections, were Mallards, Northern Pintail, and Gadwall. Green-winged Teal, generally one of the most abundant species at Crowley Reservoir in the fall, was notably less abundant in 2005. A total of 5,684 green-winged Teal were detected at Crowley in 2005, as compared to 13,482 in 2003 and 16,920 in 2004. Figure 21 shows the number of each species detected per survey at Crowley for the seven most abundant species. Gadwall and Mallard were the dominant species early in September (Figure 17) while Mallard, Northern Pintail, and Green-winged Teal were the dominant species for remainder of fall.

Tables 26 through 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 ($p < 0.001$, $F = 7.2$, $df = 41$). 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.

<u>Comparison of Mono Lake with Bridgeport and Crowley Reservoirs</u>

As compared to Bridgeport Reservoir and Crowley Reservoir, Mono Lake received less use by waterfowl in the fall of 2005, when considering total fall detections. The index of total fall detections is only available for the years 2003 through 2005 – or years in which six counts were done at each body of water. Total fall waterfowl detections were lowest at Mono Lake in 2003 also. In 2004, a year in which the total waterfowl detections and the peak one-day counts were high at Mono, and relatively low at Bridgeport all season, the fewest total detections in 2004 were recorded for Bridgeport Reservoir. Since regular comparison counts began in 2002, the number of waterfowl detected on any single survey has been typically higher at Crowley Reservoir than Mono Lake, but the same has not been true when comparing Bridgeport Reservoir to Mono Lake, due to the annual and seasonal variability in waterfowl use of Bridgeport Reservoir ($p = 0.017$, $f = 4.532$, $df = 62$).

Mono Lake was used primarily by Northern Shovelers and Ruddy Ducks during fall migration. These two species accounted for approximately 90% of all waterfowl detected at Mono Lake in 2005, whereas these two species accounted for 21% of all detections at Bridgeport Reservoir and 11% of detections at Crowley Reservoir.

The absolute abundance of waterfowl species also differed greatly between Mono Lake and the two reservoirs. Figure 22 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 Northern Shovelers in 2005 was higher at Bridgeport Reservoir than either Mono Lake or Crowley Reservoir. The other dabbling duck species that are dominant at the reservoirs, namely Gadwall, Green-winged Teal, Northern Pintail, and Mallard, were only encountered in relatively small numbers at Mono Lake. Few Ruddy Ducks were detected at Bridgeport, while slightly more comparable numbers were detected at Mono Lake and Crowley Reservoir.

<u>Analysis of Trend – Mono Lake</u>

Figure 23 illustrates the trend in the peak number of waterfowl detected at Mono Lake from 1996-2005. The regression coefficient ($r = 0.7256$) indicates that there is a positive relationship between the peak number of waterfowl and the year. Analysis of variance indicates that this relationship is statistically significant ($p = 0.018$, $F = 8.897$, $df = 1,8$).

DISCUSSION

Summer waterfowl use was similar to previous years, although some local shifts in waterfowl use were noted. As has been the case in previous years, use of Mono Lake shoreline habitats in the summer was concentrated along the northwest shore, and along the south shoreline in the South Shore Lagoon area. The total number of waterfowl detections through the summer sampling period was comparable to the total number detected the previous three years.

No change in the total number of waterfowl broods was detected as compared to 2004, in spite of the qualitative changes noted as a result of the increased lake level. While Mill Creek had the highest use in terms of total detections, more broods were seen in the Wilson Creek area. The condition of high flows at the mouth of Mill Creek attracted ducks in the area to forage in the ria. It is typical to see ducks and broods gathered at the mouth of Mill Creek in the summer, often foraging or resting on exposed mudflats. This year, large groups of ducks were seen foraging at the mouth of the creek during summer surveys, possibly in response to increased flows. Conversely, relatively few broods were seen in Mill Creek in 2005 as compared to previous years. While it is not possible to state definitively why this was the case, the high flows may have been a contributing factor, if the preferred behavior of brooding females is to have their young near the freshwater outflow, yet the high water turbulence created unfavorable conditions for young broods. More broods were detected in the adjacent Wilson Creek delta, which receives outflow from nearby springs, but lacked the turbulent high flows the Mill Creek delta experienced in 2005.

The shoreline habitats used most frequently by waterfowl summering at Mono Lake included ria, open-water areas near shore, unvegetated areas, and brackish and hypersaline lagoons. Gadwall, Mallard and Cinnamon Teal were observed using ria proportionally more in 2005 as compared to 2004. The use of ria by these species was primarily at the mouths of Mill Creek and Rush Creek, and primarily involved birds foraging in these areas where flows from the creek mix with the lake water. Since both of these creeks also experienced increased flows, it is thus possible that local conditions created favorable foraging habitat for these species. The significant decrease in proportional use of unvegetated habitats by Mallard and Canada Goose as compared to 2004 may be a result of decreased availability of this habitat due increased lake level. In some areas typically used by these species, the increased lake level resulted in little to no exposed unvegetated areas for these species to rest or feed.

Spatial distribution patterns for shorebirds appeared different than waterfowl distribution patterns at Mono Lake during the summer. The main area of shorebird activity in 2005 was in the Sammann's Spring area. Of the shoreline areas sampled, the Sammann's Spring area has the most extensive and complex wetland habitats and typically attracts a large proportion of the summering and early migrant shorebirds. Some year-to-year variability has been seen in shorebird use, largely driven by the distribution of migrant phalaropes. In 2005, phalaropes staged primarily in the Sammann's Spring and DeChambeau Creek areas, whereas Wilson Creek and Sammann's Spring were the main lakeshore segment areas used in 2004. It is unclear what factors are contributing to the variation in use of lake-fringing habitats by phalaropes.

Shoreline habitats most frequently used by shorebird species in the summer were hypersaline lagoons, open-water areas near shore, and unvegetated areas. As was the case with use by waterfowl, the proportional use of ria and hypersaline lagoons for foraging by shorebirds was greater in 2005 than in 2004. Again, this may be due to the high runoff conditions at the mouths of some creeks which may have resulted in increased area of ria, and increases in hypersaline lagoons habitats due to the development of the extensive littoral bar system in the south shoreline areas.

The primary area of use of Northern Shovelers during fall migration were the Mill and Wilson Creek areas. While the Mill and Wilson Creek areas continue to be the main areas used by migrating Northern Shovelers, after their departure, few waterfowl are often detected in these areas. Areas used by dabbling ducks later in fall (after departure of the majority of Northern Shovelers) include the DeChambeau Creek, DeChambeau Embayment, South Shore Lagoons and Warm Springs. This shift in areas used by dabbling ducks could be due to differences in the habitat preferences of the species dominant later in the fall (Mallard and Green-winged Teal), or may be related to hunting pressure. The shift in use was seen after the opening of the waterfowl hunting season. While the surrounding vegetation in the Mill and Wilson Creek areas allows close approach to ducks in these areas, the areas used by ducks later in the fall are relatively open, and more difficult for the public to access.

There was a decrease in the total number but an increase in the proportional abundance of Northern Shovelers detected at Mono Lake in 2005 as compared to 2004. In contrast, the total number of Northern Shovelers detected at Bridgeport Reservoir in 2005 was well above that seen in 2004. Assuming that the Northern Shovelers that stop over at Bridgeport Reservoir continue on to Mono Lake, one possible explanation for the differences seen in use by Northern Shovelers relates to the differences in conditions the birds encountered in 2004 as compared to 2005. In the fall 2004, the level of Bridgeport Reservoir was extremely low. It is possible that conditions encountered by Northern Shovelers at Bridgeport Reservoir during fall migration in 2004 were not favorable for extensive or extended use, and the birds chose to continue to Mono Lake. In contrast, conditions appeared favorable at Bridgeport Reservoir in 2005, perhaps encouraging greater use by this species.

Another factor that may have played a role in the high use of Mono Lake by Northern Shovelers in 2004 is the dynamics of the lake in terms of plankton cycles and food availability. After an 8-year period of meromixis, Mono Lake entered a monomictic state in November 2003 (Jellison 2005) following a complete mixing of the water column. It is unclear if the changes in nutrient load or plankton populations in 2004 resulted in increased foraging opportunities for migrating waterfowl (and thus the high use by Northern Shovelers and Ruddy Ducks in 2004), and the specific mechanisms that might be involved.

Ruddy Ducks exhibited a shift in distribution throughout the fall, occurring in a fairly concentrated area primarily offshore 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 which is shallow, but is rarely used by Ruddy Ducks. 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 offshore 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.

Bridgeport Reservoir showed a substantial increase in use by waterfowl in the fall of 2005 as compared to 2004. The level of the water in the reservoir level had recovered noticeably above what it was in 2004. Given the available data, it is believed that the low use in 2004 was likely due to the low water level and resulting poor conditions encountered by migrating waterfowl at Bridgeport in 2004.

The comparison count data provided insight regarding the relative use of Mono Lake, Bridgeport Reservoir, and Crowley Reservoir by waterfowl during fall migration. The large disparity in total detections of Mallard, Gadwall, and Green-winged Teal 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 low use by species other than Northern Shoveler and Ruddy Duck may relate to a lack of physiological adaptations to saline and alkaline conditions at Mono Lake or a lack of suitable food resources.

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 6-8, 2005

Waterfowl	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
Canada Goose			39				6	6		14		**65**
Cinnamon Teal				6		4						**10**
Gadwall	10	17	15	9	3	6	3	22	7	150	32	**274**
Green-winged Teal		2	1					1				**4**
Mallard	2	8	2	3		16	11	8	1	8	4	**63**
Northern Pintail						3	4					**7**
Ruddy Duck				4						3		**7**
Anas sp.		2										**2**
Total waterfowl by area	**12**	**29**	**57**	**22**	**3**	**29**	**24**	**37**	**8**	**175**	**36**	**432**

Shorebirds	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
American Avocet			1			9	22	7	6	9	6	**60**
Killdeer	1	4	11	2	1	3	6	2	10	4	2	**46**
Red-necked Phalarope							20					**20**
Snowy Plover						5	17					**22**
Spotted Sandpiper	9	3	3							2	1	**18**
Willet						1						**1**
Wilson's Phalarope	1		5			12	47				4	**69**
Wilson's Snipe			4									**4**
Total shorebirds	**11**	**7**	**24**	**2**	**1**	**30**	**112**	**9**	**16**	**15**	**13**	**240**

Table 2. Summer ground data, Survey 2 – June 27- 29, 2005

Waterfowl	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
Canada Goose			31				6		4			**41**
Cinnamon Teal		2		4			5	4		1	3	**19**
Gadwall	4	32	19	8	3		3	5	2	142	33	**251**
Green-winged Teal		3										**3**
Mallard		7	4			2	9	12	2	3	2	**41**
Northern Pintail										2		**2**
Redhead										5		**5**
Ruddy Duck				2	2							**4**
Total waterfowl	**4**	**44**	**54**	**14**	**5**	**2**	**23**	**21**	**8**	**153**	**38**	**366**

Shorebirds	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	**Total**
American Avocet			31			4	114	39	12		24	**224**
Killdeer	3	4	10	3	1	2	4	5	5	6	5	**48**
Least Sandpiper						39	88	1				**128**
Long-billed Curlew		12					60	4				**76**
Red-necked Phalarope							22					**22**
Semipalmated Plover						1						**1**
Snowy Plover						16	39					**55**
Spotted Sandpiper	6	1								4		**11**
Western Sandpiper							3					**3**
White-faced Ibis							7	1	1			**9**
Wilson's Phalarope	216	3	1			11	5187	5		7	9	**5439**
Phalaropus spp.							620					**620**
Total shorebirds	**225**	**20**	**42**	**3**	**1**	**73**	**6144**	**55**	**18**	**17**	**38**	**6636**

Table 3. Summer ground data, Survey 3 – July 18-20, 2005

Waterfowl Species	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	Total
Canada Goose		30	12					25			9	**76**
Cinnamon Teal		4					4	15			1	**24**
Gadwall		14	4	5	6		2	34		29	32	**126**
Green-winged Teal		1								1	1	**3**
Mallard		6					1	9		2		**18**
Northern Pintail					1							**1**
Northern Shoveler										3		**3**
Redhead										4		**4**
Ruddy Duck				1						1	3	**5**
Total waterfowl	**0**	**55**	**16**	**6**	**7**	**0**	**7**	**83**	**0**	**40**	**46**	**260**

Shorebirds	LVCR	RUSC	DECR	DEPO	COPO	WASP	SASP	SSLA	SOTU	MICR	WICR	Total
American Avocet		44				43	23	428		90		**628**
Baird's Sandpiper						4						**4**
Greater Yellowlegs						7	3	5				**15**
Killdeer	7	2	4		1	5	10	8	3	7	1	**48**
Least Sandpiper		7	4			237	122	88	3	3	1	**465**
Long-billed Curlew						3	2	3				**8**
Long-billed Dowitcher						20	24					**44**
Marbled Godwit		6				3		4				**13**
Red-necked Phalarope				10			1241	97				**1348**
Sanderling							1					**1**
Semipalmated Plover		1				14	32		9			**56**
Short-billed Dowitcher							7	6				**13**
Snowy Plover						50	21					**71**
Spotted Sandpiper	10	7	3							5		**25**
Western Sandpiper		4				58	36	6				**104**
White-faced Ibis				1		7	2	10				**20**
Wilson's Phalarope	61	1	4793				265	1694	11	646	1071	**8542**
Calidris spp.						99						**99**
Limnodromus spp.							2					**2**
Phalaropus spp.							6680				350	**7030**
Total shorebirds	**78**	**72**	**4804**	**11**	**1**	**550**	**8471**	**2349**	**26**	**751**	**1423**	**18536**

Table 4. Summary of ground count data for Mono Lake, 2005

Waterfowl	Survey 1	Survey 2	Survey 3	Total Detections
Canada Goose	65	41	76	182
Cinnamon Teal	10	19	24	53
Gadwall	274	251	126	651
Green-winged Teal	4	3	3	10
Mallard	63	41	18	122
Northern Pintail	7	2	1	10
Northern Shoveler			3	3
Redhead		5	4	9
Ruddy Duck	7	4	5	16
Anas spp.	2			2
Total Waterfowl	432	366	260	1058
Shorebirds	Survey 1	Survey 2	Survey 3	Total Detections
American Avocet	60	224	628	912
Baird's Sandpiper			4	4
Greater Yellowlegs			15	15
Killdeer	46	48	48	142
Least Sandpiper		128	465	593
Long-billed Curlew		76	8	84
Long-billed Dowitcher			44	44
Marbled Godwit			13	13
Red-necked Phalarope	20	22	1348	1390
Sanderling			1	1
Semipalmated Plover		1	56	57
Short-billed Dowitcher			13	13
Snowy Plover	22	55	71	148
Spotted Sandpiper	18	11	25	54
Western Sandpiper		3	104	107
White-faced Ibis		9	20	29
Willet	1			1
Wilson's Phalarope	69	5439	8542	14050
Wilson's Snipe	4			4
Calidris spp.			99	99
Limnodromus spp.			2	2
Phalaropus spp.		620	7030	7650
Total Shorebirds	240	6636	18536	25412

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			4					2				6
	CITE												0
	GADW								1				1
	GWTE												0
	MALL								1				1
	NOPI												0
	Total broods	0	0	4	0	0	0	0	4	0	0	0	8
Survey 2													
	CAGO			1									1
	CITE				1								1
	GADW				3	1			1		1	1	7
	GWTE												0
	MALL											1	1
	NOPI												0
	Total broods	0	0	1	4	1	0	0	1	0	1	2	10
Survey 3													
	CAGO												0
	CITE												0
	GADW				3	4		2	4		4	7	24
	GWTE		1										1
	MALL		2					1					3
	NOPI												0
	Total broods	0	3	0	3	4	0	3	4	0	4	7	28
Total broods per area		0	3	5	7	5	0	3	9	0	5	9	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	12.1	6.8	-								
Wet Meadow	10	58.5	40.3	-	2	12.1	8.4	-	2	8.2	4.7	-	43	28.3	7.6	+
Alkaline Wet Meadow	1	58.5	56.6	-	5	12.1	4.2	-					9	28.3	13.2	-
Dry Meadow/Forb	2	58.5	54.6	-												
Riparian Scrub	1	58.5	56.6	-												
Great Basin Scrub																
Riparian Forest																
Freshwater Stream	5	58.5	49.0	-	4	12.1	5.4	-								
Ria	235	58.5	531.8	+	24	12.1	11.7	NS	7	8.2	0.2	NS	31	28.3	0.3	NS
Freshwater Pond	37	58.5	7.9	-	12	12.1	0.0	NS	8	8.2	0.0	NS				
Brackish Lagoon	50	58.5	1.2	-	34	12.1	39.6	+	16	8.2	7.5	+	4	28.3	20.9	-
Hypersaline Lagoon	39	58.5	6.5	-	17	12.1	2.0	NS	15	8.2	5.7	+				
Unvegetated	84	58.5	11.1	+	12	12.1	0.0	NS					25	28.3	0.4	NS
Open Water <50m	180	58.5	252.0	+	8	12.1	1.4	NS	1	8.2	6.3	-	58	28.3	31.1	+
Total	644		1067.5		121		79.6		49		24.3		170		73.4	

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				LESA				RNPH			
Habitat	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign
Marsh																
Wet Meadow																
Alkaline Wet Meadow																
Dry Meadow/Forb																
Riparian Scrub																
Great Basin Scrub																
Freshwater Stream					2	9.1	5.6	-								
Ria	75	131.4	24.2	-	2	9.1	5.6	-	4	101	93.2	-				
Freshwater Pond					1	9.1	7.3	-								
Brackish Lagoon	29	131.4	79.8	-	7	9.1	0.5	-	66	101	12.1	-				
Hypersaline Lagoon	501	131.4	1039.6	+	8	9.1	0.1	-	232	101	169.9	+	150	151	0.0	NS
Unvegetated	6	131.4	119.7	-	43	9.1	125.4	+	171	101	48.5	+				
Open Water <50m	46	131.4	55.5	-	1	9.1	7.3	-	32	101	47.1	-	151	151	0.0	NS
Total	657		1318.8		64		151.7		505		370.9		301		0.0	

	SNPL				WESA				WIPH			
Habitat	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign	Obs	Exp	χ^2	Sign
Marsh												
Wet Meadow												
Alkaline Wet Meadow												
Dry Meadow/Forb	5	29	19.9	-								
Riparian Scrub												
Great Basin Scrub												
Freshwater Stream												
Ria									491	538.0	4.1	-
Freshwater Pond									11	538.0	516.2	-
Brackish Lagoon	1	29	27.0	-					231	538.0	175.2	-
Hypersaline Lagoon	8	29	15.2	-	44	23.7	17.5	+	630	538.0	15.7	+
Unvegetated	102	29	183.8	+	13	23.7	4.8	-	681	538.0	38.0	+
Open Water <50m					14	23.7	3.9	-	1184	538.0	775.7	+
Total	116		245.9		71		26.2		3228		1524.9	

Table 8. Summary of fall aerial survey counts for 2005 – Mono Lake

Species	1-Sep	16-Sep	27-Sep	13-Oct	27-Oct	9-Nov	**Total Detections**	**%Total Detections**
American Wigeon			8				8	0.04
Bufflehead				1	1	7	9	0.04
Canada Goose	8	35		1	74	83	201	0.89
Cinnamon Teal	132	81	1	1			215	0.95
Gadwall	4	4	9		3		20	0.09
Green-winged Teal	160	3	58	124	241	96	682	3.02
Lesser Scaup			2				2	0.01
Mallard	52	46	36	112	19	48	313	1.39
Northern Pintail			9	49	142	6	206	0.91
Northern Shoveler	4100	3445	5683	463	67	22	13780	61.07
Ruddy Duck	81	593	2193	1757	1006	885	6515	28.87
Unidentified *Anas*	43	125	248	122	60	17	615	2.73
Total waterfowl	4580	4332	8247	2630	1613	1164	22566	

Table 9. Mono Lake - fall aerial survey, 1 September, 2005

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				8												8	8
Cinnamon Teal			120							3		9				132	132
Gadwall	4															4	4
Green-winged Teal	15		135		2							8				160	160
Mallard	2		20		25										5	52	52
Northern Shoveler			250						4	31	3800			12		4097	4100
Ruddy Duck									3						2	5	81
Anas spp.	4											39				43	43
Total Waterfowl	25	0	525	8	27	0	0	0	7	34	3800	56	0	12	7	**4501**	**4580**

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		70		367	250	250		548	550	350						2385	2430
American Coot				1												1	1
American White Pelican					1											1	1
Limnodromus spp.														25		25	25
Great Blue Heron													1			1	1
Phalaropus spp.	3							3				500	575	1160	268	2509	9625
Calidris spp.				15	12	20		34		30	10	6	20			147	147
Marbled Godwit/Curlew		8							3							11	11
White-faced Ibis				22					6							28	28
Total Waterbirds	3	78	0	405	263	270	0	585	559	380	10	506	596	1185	268	**5108**	**12269**

Table 10. Mono Lake - fall aerial survey, 16 September, 2005

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			30	5												35	35
Cinnamon Teal			40							6	30	5				81	81
Gadwall	4															4	4
Green-winged Teal												3				3	3
Mallard			12	12	12						10					46	46
Northern Shoveler	15			1400	25				18	1600	350	25				3433	3445
Ruddy Duck									2						2	4	593
Anas spp.	25		60									40				125	125
Total Waterfowl	44	0	142	1417	37	0	0	0	20	1606	390	73	0	0	2	**3731**	**4332**

Waterbird count	**Lakeshore segment**															Shoreline Total	Lakewide Total
	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
American Avocet	2	20		135	90	175	145	735	1200	250		200				2952	2964
Great Blue Heron															1	1	1
White-faced Ibis				10												10	10
Phalaropus spp.												600	170	150	70	990	990
Marbled Godwit									8							8	8
Total Waterbirds	2	20	0	145	90	175	145	735	1208	250	0	800	170	150	71	3961	3973

Table 11. Mono Lake - fall aerial survey, 27 September, 2005

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					7							1				8	8
Cinnamon Teal													1			1	1
Gadwall	3			2								2	2			9	9
Green-winged Teal	3	5	13		30							7				58	58
Lesser Scaup									2							2	2
Mallard				4	18							5	5	4		36	36
Northern Pintail			9													9	9
Northern Shoveler	13								15	4500	450	695		10		5683	5683
Ruddy Duck						188	15	44			305				32	584	2193
Anas spp.			220	28												248	248
Total Waterfowl	19	5	242	34	55	188	15	44	17	4500	755	710	8	14	32	**6638**	**8247**

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	12	11	7	55		4	25	450	1600			22	1	1		2188	2188
American Coot	27															27	27
Great Blue Heron	1												1			2	2
Greater Yellowlegs								2								2	2
Killdeer		2							4							6	6
Calidris spp.					5		3	25	4							37	37
Phalaropus spp.																0	1864
Total Waterbirds	40	13	7	55	5	4	28	477	1608	0	0	22	2	1	0	**2262**	**4126**

Table 12. Mono Lake - fall aerial survey, 13 October, 2005

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
Bufflehead											1					1	1
Canada Goose				1												1	1
Cinnamon Teal													1			1	1
Green-winged Teal			4	27	20				3	70						124	124
Mallard	2	8	52	18	30								1	1		112	112
Northern Pintail	8									40			1			49	49
Northern Shoveler			6					1	1	420		30	2		3	463	463
Ruddy Duck	6	36	33			4	4	251	180	80	45	20	165	37	40	901	1757
Anas spp.	3		10	10	5							90	1	3		122	122
Total Waterfowl	19	44	105	56	55	4	4	252	184	610	46	140	171	41	43	**1774**	**2630**

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		5	1		8	9	7							36	36
American Coot				220												220	260
Great Blue Heron													1			1	1
Long-billed Curlew		9														9	9
Red-necked Phalarope				8												8	8
Chalidris spp.									50							50	50
Total Waterbirds	0	15	0	233	1	0	8	9	57	0	0	0	1	0	0	**324**	**364**

Table 13. Mono Lake - fall aerial survey, 27 October, 2005

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
Bufflehead																0	1
Canada Goose								74								74	74
Gadwall												3				3	3
Green-winged Teal			22		120						4	95				241	241
Mallard					3							15			1	19	19
Northern Pintail												12	130			142	142
Northern Shoveler												17	50			67	67
Ruddy Duck	69	10	23					67			21	45	118	27	67	447	1006
Anas spp.	40			20												60	60
Total Waterfowl	109	10	45	20	123	0	0	141	0	0	25	187	298	27	68	**1053**	**1613**

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	5	65	65					64	12		8	28	1			248	262
American Avocet								2	4							6	6
Common Loon					1											1	1
Scolopacidae spp.								2	50							52	52
Total Waterbirds	5	65	65	0	1	0	0	68	66	0	8	28	1	0	0	**307**	**321**

Table 14. Mono Lake - fall aerial survey, 9 November, 2005

Waterfowl Count	**Lakeshore segment**															Shoreline Total	Lakewide Total
Species	RUCR	SOTU	SSLA	SASP	WASP	NESH	BRCR	DEEM	BLPO	WICR	MICR	DECR	WESH	LVCR	RACO		
Bufflehead										3						3	7
Canada Goose			47	7				29								83	83
Green-winged Teal	12			2	27			5				50				96	96
Mallard			14	3	3			28								48	48
Northern Pintail								6								6	6
Northern Shoveler												22				22	22
Ruddy Duck	28	138	1			40	20	48	5		5	6	163	55	23	532	885
Anas spp.			15	2												17	17
Total Waterfowl	40	138	77	14	30	40	20	116	5	3	5	78	163	55	23	807	1164

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	6			23								5			9	43	46
American Avocet				71				10	9							90	90
Calidris spp.				5												5	5
Scolopacidae spp.									3							3	3
Total Waterbirds	6	0	0	99	0	0	0	10	12	0	0	5	0	0	9	141	144

Table 15. Mono Lake Restoration ponds – Aerial waterfowl counts - 2005

Sept 7	CITE	NSHO	MALL	*Anas*	AMCO
COPO_1 E	7	5			8
COPO_2 W		8		4	
DEPO_1	5			7	
DEPO_2					3
DEPO_3					4
DEPO_4		2	12		
DEPO_5					
Total	12	15	12	11	15

Sept 16	GADW	MALL	NSHO	*Anas*	AMCO
COPO_1 E					
COPO_2 W	5				15
DEPO_1					4
DEPO_2					3
DEPO_3					3
DEPO_4		8	40	2	25
DEPO_5		6			
Total	5	14	40	2	50

Sept 27	GADW	GWTE	MALL	RUDU	*Anas*	AMCO
COPO_1 E			1			8
COPO_2 W	-	-		2	5	22
DEPO_1		4				
DEPO_2						3
DEPO_3	1					2
DEPO_4						35
DEPO_5			5			
Total	1	4	6	2	5	70

Oct 13	BWTE	GADW	MALL	RUDU	*Anas*	AMCO
COPO_1			2			40
COPO_2					4	20
DEPO_1						
DEPO_2						20
DEPO_3						
DEPO_4	2	9		5		58
DEPO_5						
Total	2	9	2	5	4	138

Oct 27	MALL	*Anas*	AMCO
COPO_1 E	25		30
COPO_2 W	3	42	72
DEPO_1			8
DEPO_2			12
DEPO_3			
DEPO_4	2	50	70
DEPO_5			
Total	30	92	192

Nov 9	BUFF	GWTE	LESC	MALL	*Anas*	AMCO
COPO_1	1	12	1			8
COPO_2				7		42
DEPO_1						
DEPO_2						85
DEPO_3						
DEPO_4				10	20	
DEPO_5						
Total	1	12	1	17	20	135

Total Detections	BWTE	BUFF	CITE	GADW	GWTE	LESC	MALL	NSHO	RUDU	*Anas*	Total Waterfowl	Total AMCO
	2	1	12	15	16	1	81	55	7	134	324	600

Table 16. Summary of shorebird/waterbird counts at Mono Lake during fall aerial counts - 2005

Survey Date	1-Sep	16-Sep	27-Sep	13-Oct	27-Oct	9-Nov	Total Detections
American Avocet	2430	2964	2188	36	6	90	7714
American Coot	1		27	260	262	46	596
American White Pelican	1						1
Common Loon					1		1
Great Blue Heron	1	1	2	1			5
Greater Yellowlegs			2				2
Killdeer			6				6
Marbled Godwit/Curlew	11	8		9			28
Red-necked Phalarope				8			8
Western Grebe					2		2
White-faced Ibis	28	10					38
Calidris spp.	147		37	50		5	239
Limnodromus spp.	25						25
Phalaropus spp.	9625	990	1864				12479
Scolopacidae spp.					52	3	55
Total	12269	3973	4126	364	323	144	**21199**

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	1-Sep	%Det	16-Sep	%Det	27-Sep	%Det	13-Oct	%Det	27-Oct	%Det	9-Nov	%Det
1a					1	0.05	4	0.23	2	0.20		
1b					1	0.05	5	0.28			3	0.34
2a			11	1.85	5	0.23	7	0.40			3	0.34
2b			12	2.02	9	0.41						
2c			71	11.97	9	0.41	5	0.28	3	0.30	1	0.11
3a					1	0.05	103	5.86	34	3.38	70	7.91
3b			5	0.84			5	0.28	4	0.40	1	0.11
3c			4	0.67			5	0.28				
3d			1	0.17	50	2.28	16	0.91	1	0.10	21	2.37
4a			23	3.88	4	0.18	18	1.02			2	0.23
4b			8	1.35	8	0.36	6	0.34				
4c			24	4.05	4	0.18	11	0.63			3	0.34
4d	1	1.23	17	2.87			5	0.28	8	0.80	9	1.02
5a			9	1.52	45	2.05	35	1.99	34	3.38	33	3.73
5b	5	6.17	2	0.34			12	0.68	3	0.30		
5c			4	0.67			0	0.00				
5d			8	1.35	4	0.18	61	3.47			11	1.24
6a	2	2.47			14	0.64	61	3.47	72	7.16	70	7.91
6b			30	5.06	8	0.36	7	0.40	98	9.74	1	0.11
6c			18	3.04	72	3.28	34	1.94	6	0.60	11	1.24
7a	16	19.75	8	1.35	79	3.60	53	3.02	53	5.27	35	3.95
7b			9	1.52	4	0.18			22	2.19	1	0.11
7c	3	3.70	13	2.19	6	0.27	110	6.26	3	0.30	8	0.90
8a	46	56.79	217	36.59	454	20.70	92	5.24	106	10.54	37	4.18
8b	3	3.70	95	16.02	831	37.89	201	11.44	110	10.93	33	3.73
RUCR							6	0.34	69	6.86	28	3.16
SOTU							36	2.05	10	0.99	138	15.59
SSLA							33	1.88	23	2.29	1	0.11
SASP												
WASP												
NESH					188	8.57	4	0.23			40	4.52
BRCR					15	0.68	4	0.23			20	2.26
DEEM					44	2.01	251	14.29	67	6.66	48	5.42
BLPO	3	3.70	2	0.34			180	10.24			5	0.56
WICR							80	4.55				
MICR					305	13.91	45	2.56	21	2.09	5	0.56
DECR							20	1.14	45	4.47	6	0.68
WESH							165	9.39	118	11.73	163	18.42
LVCR							37	2.11	27	2.68	55	6.21
RACO	2	2.47	2	0.34	32	1.46	40	2.28	67	6.66	23	2.60
Total	**81**		**593**		**2193**		**1757**		**1006**		**885**	

Table 18. Summary of 2005 fall aerial survey counts – Bridgeport Reservoir

Species	1-Sep	16-Sep	27-Sep	13-Oct	27-Oct	9-Nov	Total Detections	%Total Detections
American Wigeon		20	150				170	0.20
Bufflehead			2	5	26	93	126	0.15
Canada Goose	265	180	60	258	24	112	899	1.07
Cinnamon Teal	402	203	204				809	0.97
Common Merganser	33	21	24	21	15	1	115	0.14
Gadwall	502	3603	5710	2108	2019	110	14052	16.79
Green-winged Teal	3600	502	1130	2703	1213	700	9848	11.77
Lesser Scaup			2		25		27	0.03
Mallard	2102	1362	4552	3500	3082	863	15461	18.48
Northern Pintail	40	300	1301	6000	2330	1200	11171	13.35
Northern Shoveler	1265	6214	7907	1500	200	80	17166	20.51
Redhead			5	6	10	29	50	0.06
Ruddy Duck	2				68	22	92	0.11
Anas spp.	2230	5550	2597	1254	1105	958	13694	16.36
Total Waterfowl	10441	17955	23644	17355	10117	4168	83680	

Table 19. Bridgeport Reservoir - fall aerial survey, 1 September, 2005

Species	Lakeshore segment			Total
	NOAR	WEBA	EASH	
Canada Goose		250	15	265
Cinnamon Teal	2	400		402
Common Merganser	33			33
Gadwall	2	500		502
Green-winged Teal		3600		3600
Mallard	22	2080		2102
Northern Pintail		40		40
Northern Shoveler	25	1240		1265
Ruddy Duck		2		2
Unidentified	30	2200		2230
Total waterfowl	114	10312	15	10441

Table 20. Bridgeport Reservoir - fall aerial survey, 16 September, 2005

Species	Lakeshore segment			Total
	NOAR	WEBA	EASH	
American Wigeon	0	20	0	20
Canada Goose	0	180	0	180
Cinnamon Teal	3	200	0	203
Common Merganser	21	0	0	21
Gadwall	3	3600	0	3603
Green-winged Teal	0	500	2	502
Mallard	150	1200	12	1362
Northern Pintail	0	300	0	300
Northern Shoveler	11	6200	3	6214
Anas spp.	50	5500	0	5550
Total Waterfowl	238	17700	17	17955

Table 21. Bridgeport Reservoir - fall aerial survey, 27 September, 2005

Species	Lakeshore segment			Total
	NOAR	WEBA	EASH	
American Wigeon	0	150	0	150
Bufflehead	0	2	0	2
Canada Goose	0	60	0	60
Cinnamon Teal	0	200	4	204
Common Merganser	24	0	0	24
Gadwall	20	5680	10	5710
Green-winged Teal	5	1100	25	1130
Lesser Scaup	0	2	0	2
Mallard	0	4550	2	4552
Northern Pintail	1	1300	0	1301
Northern Shoveler	0	7900	7	7907
Redhead	0	5	0	5
Anas spp.	301	1850	446	2597
Total waterfowl	351	22799	494	**23644**

Table 22. Bridgeport Reservoir - fall aerial survey, 13 October, 2005

Species	Lakeshore segment			Total
	NOAR	WEBA	EASH	
Bufflehead	5	0	0	5
Canada Goose	0	258	0	258
Common Merganser	6	0	15	21
Gadwall	0	2100	8	2108
Green-winged Teal	3	2700	0	2703
Mallard	0	3500	0	3500
Northern Pintail	0	6000	0	6000
Northern Shoveler	0	1500	0	1500
Redhead	5	1	0	6
Anas spp.	254	500	500	1254
Total waterfowl	273	16559	523	**17355**

Table 23. Bridgeport Reservoir - fall aerial survey, 27 October, 2005

Species	Lakeshore segment			Total
	NOAR	WEBA	EASH	
Bufflehead	7	10	9	26
Canada Goose	0	24	0	24
Common Merganser	14	1	0	15
Gadwall	0	2008	11	2019
Green-winged Teal	0	1200	13	1213
Lesser Scaup	0	25	0	25
Mallard	0	3078	4	3082
Northern Pintail	30	2300	0	2330
Northern Shoveler	0	200	0	200
Redhead	0	10	0	10
Ruddy Duck	0	60	8	68
Anas spp.	5	1100	0	1105
Total waterfowl	56	10016	45	**10117**

Table 24. Bridgeport Reservoir - fall aerial survey, 9 November, 2005

Species	Lakeshore segment			Total
	NOAR	WEBA	EASH	
Bufflehead	11	60	22	93
Canada Goose	0	112	0	112
Common Merganser	0	1	0	1
Gadwall	0	100	10	110
Green-winged Teal	0	700	0	700
Mallard	0	860	3	863
Northern Pintail	0	1200	0	1200
Northern Shoveler	0	80	0	80
Redhead	0	27	2	29
Ruddy Duck	0	0	22	22
Anas spp.	0	928	30	958
Total Waterfowl	11	4068	89	**4168**

Table 25. Summary of 2005 fall aerial survey counts – Crowley Reservoir

Species	1-Sep	16-Sep	27-Sep	13-Oct	27-Oct	9-Nov	Total Detections	%Total Detections
American Wigeon	50	6	110	43	28	110	347	0.59
Bufflehead			2	19	153	275	449	0.77
Canada Goose	245	270	150	267	373	182	1487	2.55
Canvasback						3	3	0.01
Cinnamon Teal	499	437	68	1			1005	1.72
Common Merganser			20			10	30	0.05
Gadwall	666	1250	1050	968	2900	1730	8564	14.68
Green-winged Teal	108	241	244	1277	1678	2136	5684	9.74
Lesser Scaup			20	5	150	110	285	0.49
Mallard	196	763	3803	2053	6660	1679	15154	25.97
Northern Pintail	25	210	1320	1876	2672	4002	10105	17.32
Northern Shoveler	39	608	885	759	198	14	2503	4.29
Redhead		34		70	11	10	125	0.21
Ring-necked Duck	4			20	13	3	40	0.07
Ruddy Duck	5	114	34	725	1138	1775	3791	6.50
Snow Goose						4	4	0.01
Unidentified *Anas*	825	1872	964	1384	2245	1483	8773	15.04
Total Waterfowl	2662	5805	8670	9467	18219	13526	58349	

Table 26. Crowley Reservoir - fall aerial survey, 1 September, 2005

Species	Lakeshore segment							Total detections
	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	50	0	0	0	0	0	0	50
Canada Goose	75	0	0	0	50	0	120	245
Cinnamon Teal	250	50	0	60	50	0	89	499
Gadwall	300	120	0	100	20	0	126	666
Green-winged Teal	70	0	0	20	0	0	18	108
Mallard	100	0	0	20	5	0	71	196
Northern Pintail	5	0	0	20	0	0	0	25
Northern Shoveler	0	30	1	0	0	0	8	39
Redhead	3	0	1	0	0	0	0	4
Ruddy Duck	0	0	0	5	0	0	0	5
Anas spp.	522	0	0	198	105	0	0	825
Total Waterfowl	1375	200	2	423	230	0	432	2662

Table 27. Crowley Reservoir - fall aerial survey, 16 September, 2005

Species	Lakeshore segment							Total Detections
	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	3	0	0	3	0	0	0	6
Canada Goose	0	0	0	80	10	0	180	270
Cinnamon Teal	210	10	0	110	70	0	37	437
Gadwall	1000	0	0	250	0	0	0	1250
Green-winged Teal	30	20	0	180	0	1	10	241
Mallard	300	0	20	400	40	3	0	763
Northern Pintail	60	0	0	150	0	0	0	210
Northern Shoveler	600	0	0	0	0	8	0	608
Redhead	4	0	0	30	0	0	0	34
Ruddy Duck	12	0	82	20	0	0	0	114
Anas spp.	800	4	0	950	115	0	3	1872
Total Waterfowl	3019	34	102	2173	235	12	230	**5805**

Table 28. Crowley Reservoir - fall aerial survey, 27 September, 2005

Species	Lakeshore segment							Total Detections
	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	100	0	0	0	0	0	10	110
Bufflehead	0	0	2	0	0	0	0	2
Canada Goose	150	0	0	0	0	0	0	150
Cinnamon Teal	0	0	0	60	8	0	0	68
Common Merganser	0	0	0	20	0	0	0	20
Gadwall	480	8	20	160	0	0	382	1050
Green-winged Teal	0	0	0	230	14	0	0	244
Lesser Scaup	0	0	0	20	0	0	0	20
Mallard	650	0	5	3000	128	0	20	3803
Northern Pintail	200	0	0	1000	100	0	20	1320
Northern Shoveler	600	0	0	250	33	0	2	885
Ruddy Duck	0	2	15	10	7	0	0	34
Unidentified	220	10	208	290	70	0	166	964
Total Waterfowl	2400	20	250	5040	360	0	600	**8670**

Table 29. Crowley Reservoir - fall aerial survey, 13 October, 2005

Species	Lakeshore segment							Total Detections
	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	43	0	0	0	0	0	0	43
Bufflehead	0	0	2	17	0	0	0	19
Canada Goose	180	0	0	82	5	0	0	267
Cinnamon Teal	1	0	0	0	0	0	0	1
Gadwall	160	0	3	800	0	0	5	968
Green-winged Teal	120	5	2	1000	110	5	35	1277
Lesser Scaup	0	0	0	5	0	0	0	5
Mallard	240	0	0	1750	30	28	5	2053
Northern Pintail	300	0	1	1575	0	0	0	1876
Northern Shoveler	700	0	0	50	0	1	8	759
Redhead	7	0	0	63	0	0	0	70
Ring-necked Duck	0	0	0	20	0	0	0	20
Ruddy Duck	125	0	97	413	0	0	90	725
Unidentified	500	402	0	300	60	2	120	1384
Total Waterfowl	2376	407	105	6075	205	36	263	**9467**

Table 30. Crowley Reservoir - fall aerial survey, 27 October, 2005

Species	Lakeshore segment							Total Detections
	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	0	0	0	0	0	28	0	28
Bufflehead	10	22	30	10	46	27	8	153
Canada Goose	8	0	25	200	0	0	140	373
Gadwall	0	0	0	1400	0	1500	0	2900
Green-winged Teal	0	0	0	1010	80	8	580	1678
Lesser Scaup	0	0	50	100	0	0	0	150
Mallard	27	5	123	3000	275	3230	0	6660
Northern Pintail	100	0	20	1750	0	800	2	2672
Northern Shoveler	3	0	0	190	0	0	5	198
Redhead	0	0	0	11	0	0	0	11
Ring-necked Duck	0	0	3	10	0	0	0	13
Ruddy Duck	234	28	87	90	0	9	690	1138
Unidentified	0	0	0	1700	515	30	0	2245
Total Waterfowl	382	55	338	9471	916	5632	1425	18219

Table 31. Crowley Reservoir - fall aerial survey, 9 November, 2005

Species	Lakeshore segment							Total Detections
	UPOW	SAPO	NOLA	MCBA	HIBA	CHCL	LASP	
American Wigeon	80	25	0	5	0	0	0	110
Bufflehead	50	115	25	0	40	30	15	275
Canada Goose	0	0	0	150	20	0	12	182
Canvasback	3	0	0	0	0	0	0	3
Common Merganser	0	0	0	0	0	10	0	10
Gadwall	1500	18	0	200	2	0	10	1730
Green-winged Teal	0	350	22	1000	300	24	440	2136
Lesser Scaup	0	80	0	0	30	0	0	110
Mallard	200	410	219	750	100	0	0	1679
Northern Pintail	150	400	0	3000	350	22	80	4002
Northern Shoveler	4	5	0	5	0	0	0	14
Redhead	2	0	0	2	6	0	0	10
Ring-necked Duck	0	3	0	0	0	0	0	3
Ruddy Duck	500	105	150	0	520	0	500	1775
Snow Goose	0	0	0	0	4	0	0	4
Anas spp.	500	30	59	285	125	84	400	1483
Total Waterfowl	2989	1541	475	5397	1497	170	1457	**13526**

Figure 1. Summer ground survey areas

Figure 2. Lakeshore segments, segment boundaries, and cross-lake transects used for fall aerial surveys of Mono Lake

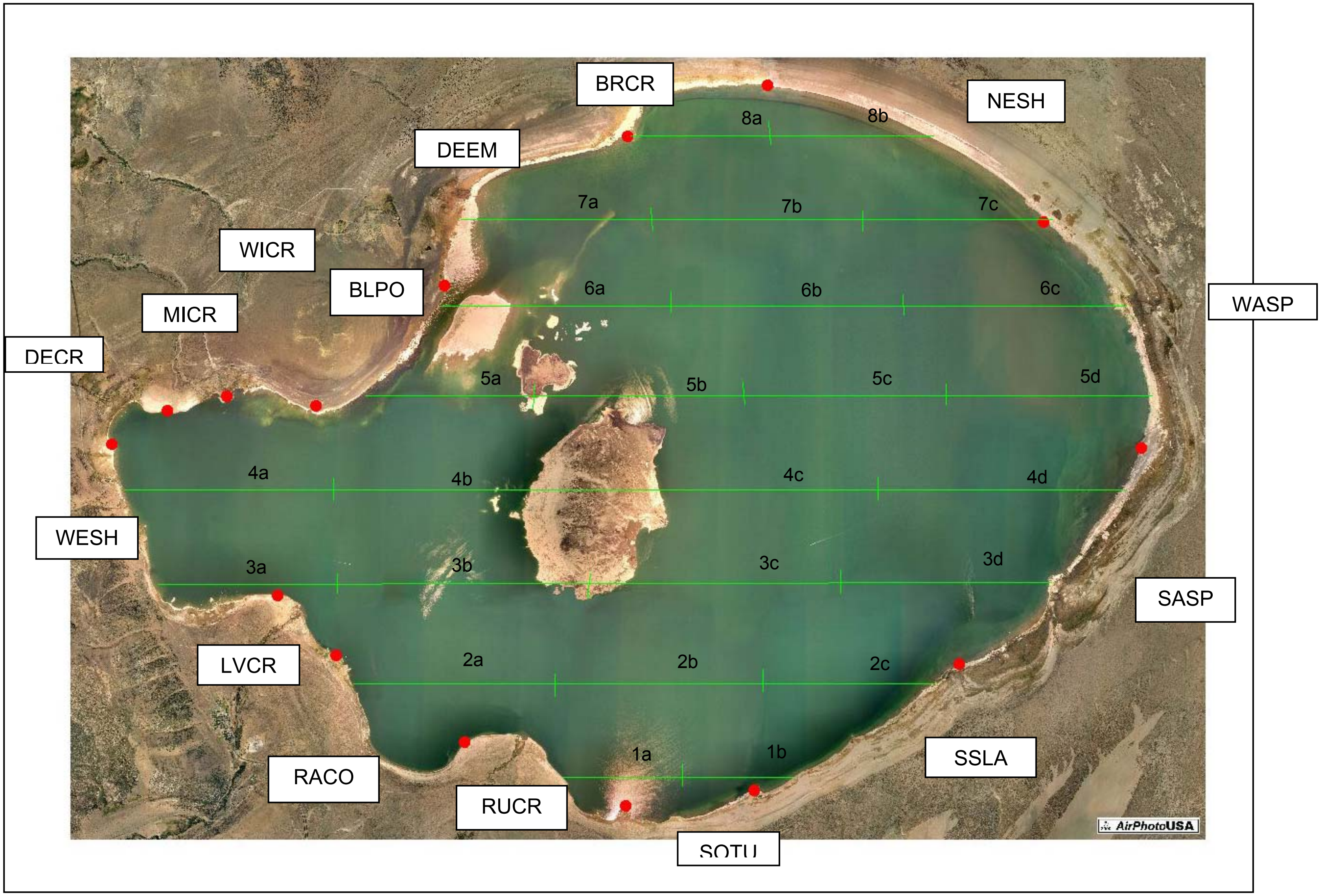


Figure 3. Lakeshore segments and segment boundaries used for fall aerial surveys of Bridgeport Reservoir

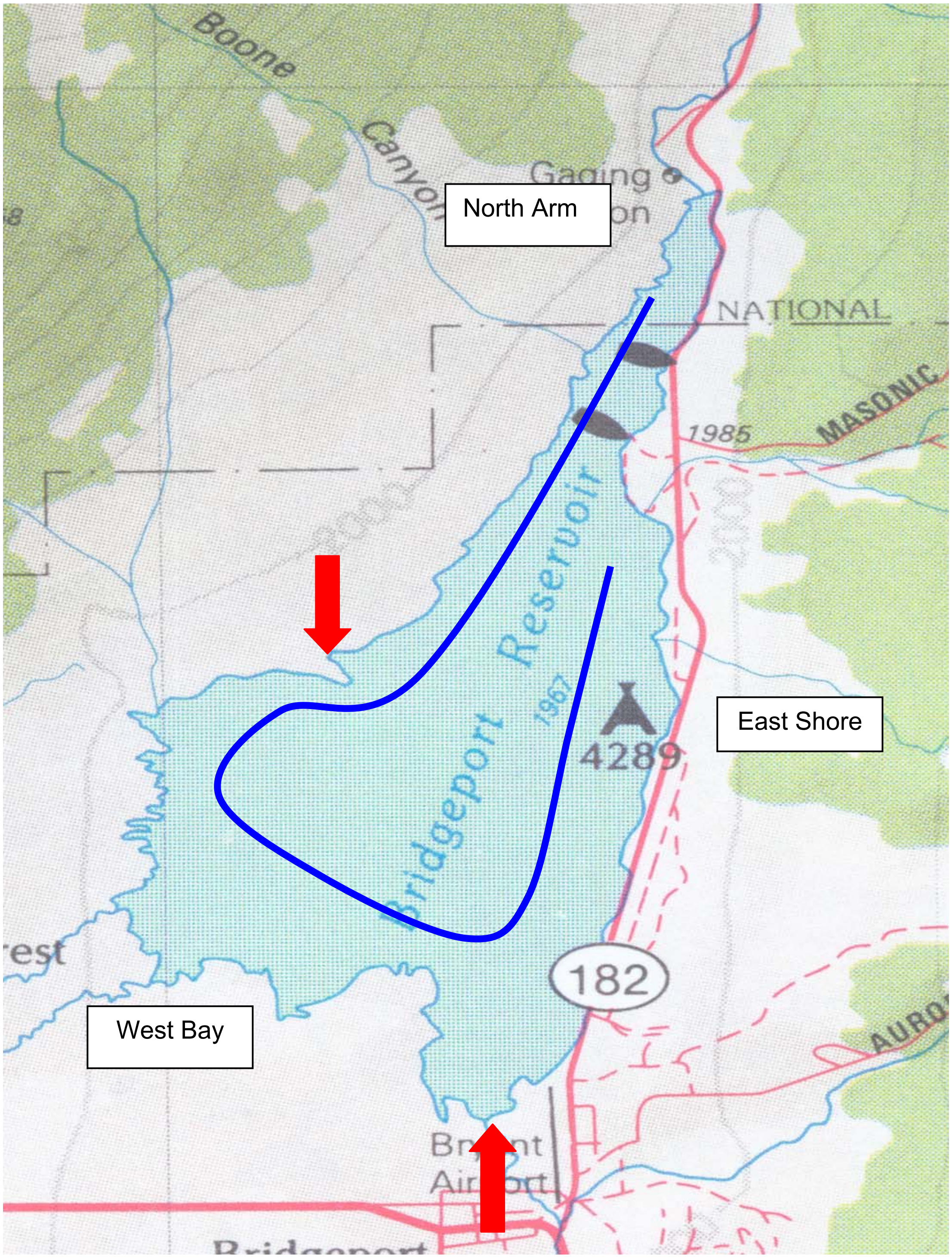


Figure 4. Lakeshore segments and segment boundaries used for fall aerial surveys of Crowley Reservoir

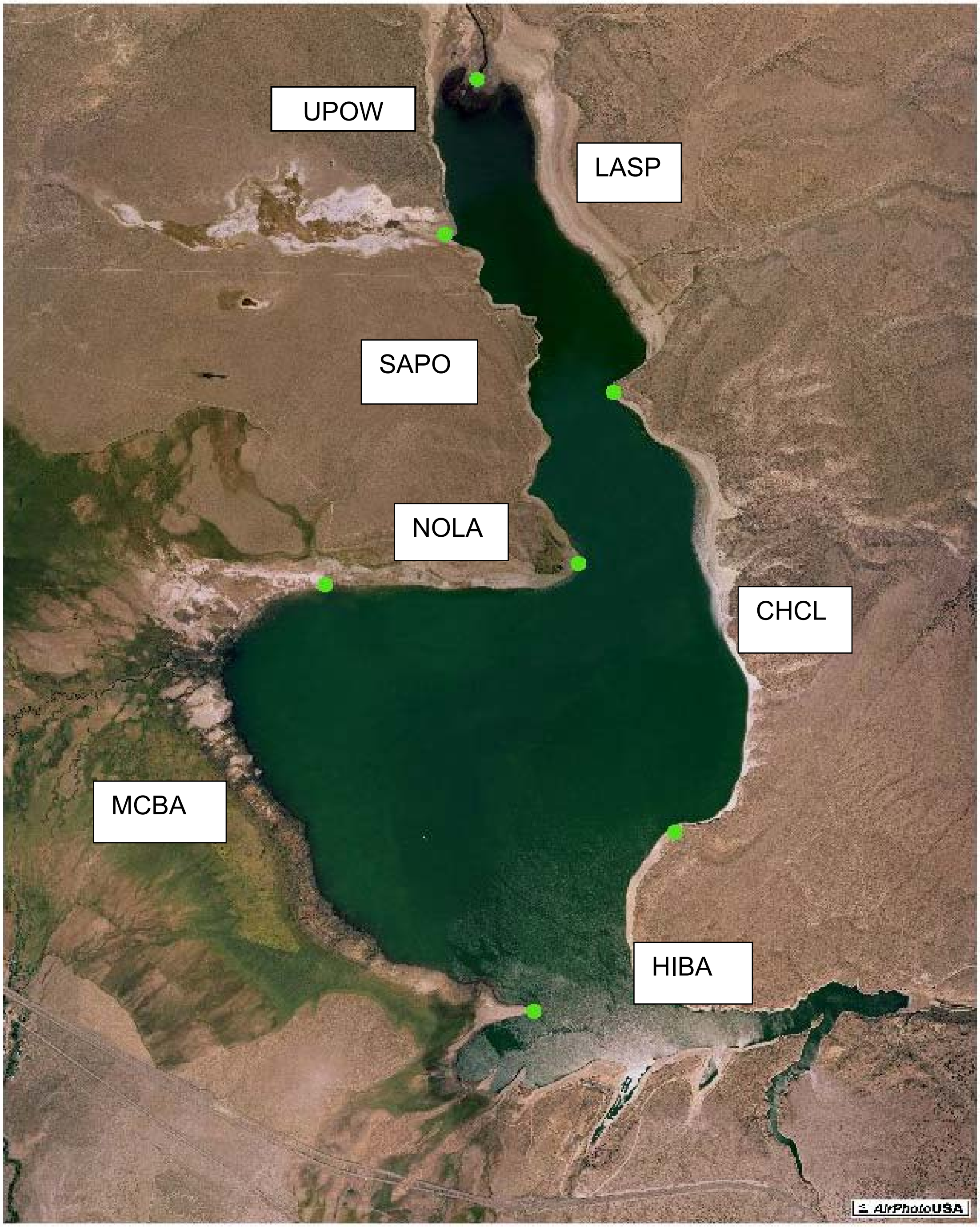


Figure 5. Photos of shoreline habitats at Mono Lake. Taken from a helicopter on September 22, 2005. The coordinates on each photo indicate the shoreline area depicted in the photo (NAD 27, Zone 11).

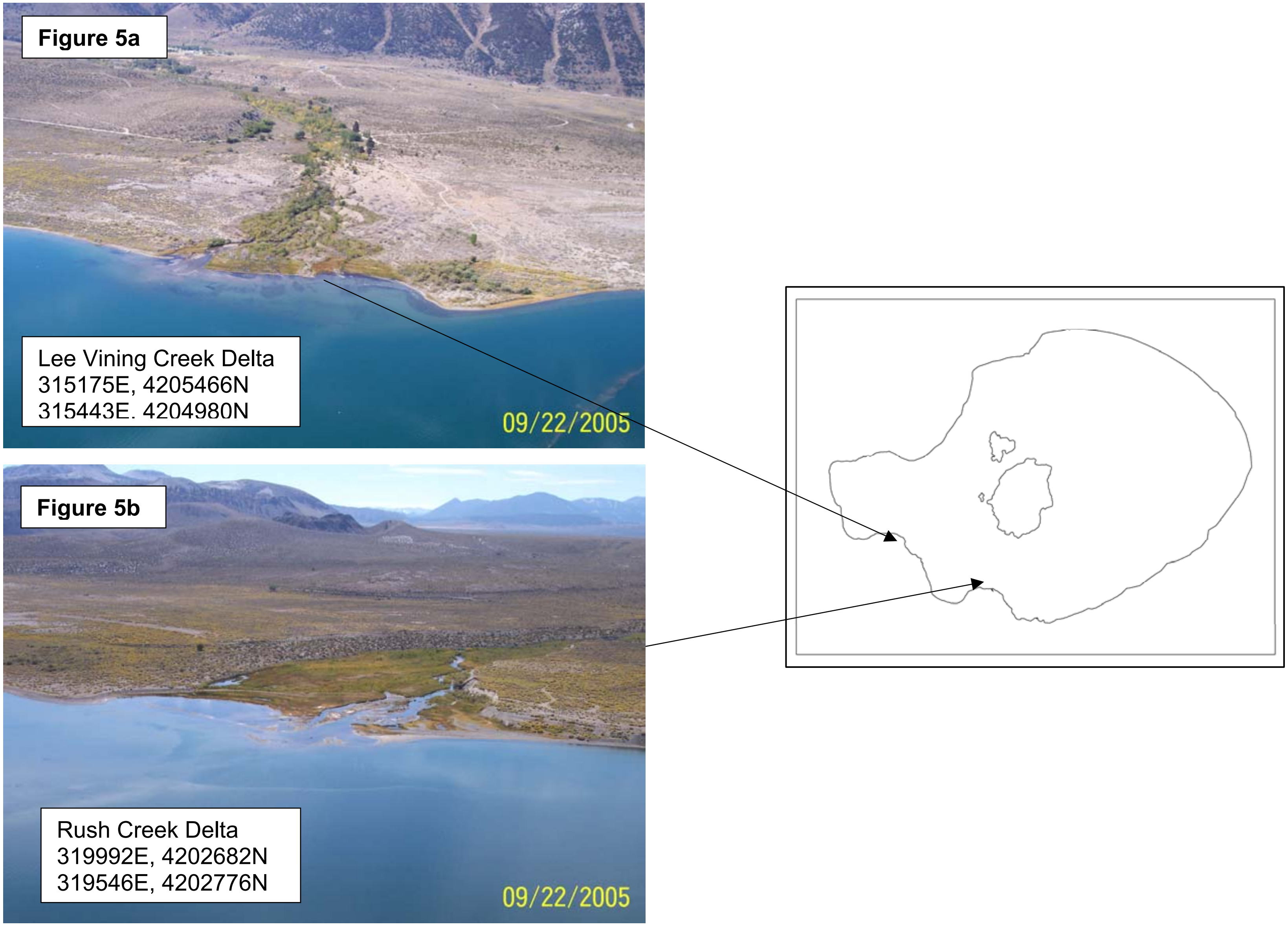


Figure 5. Continued - Mono Lake shoreline habitats

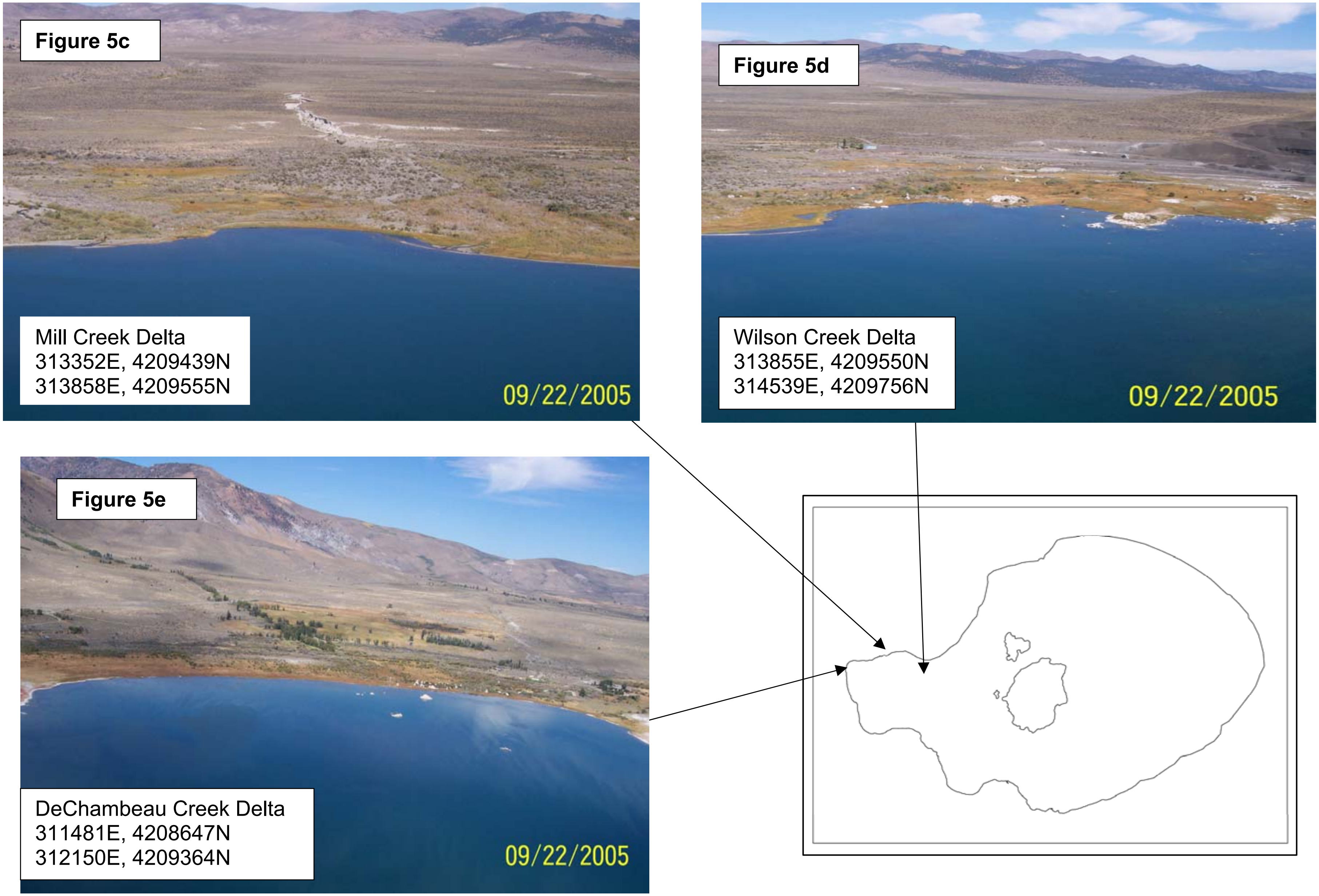
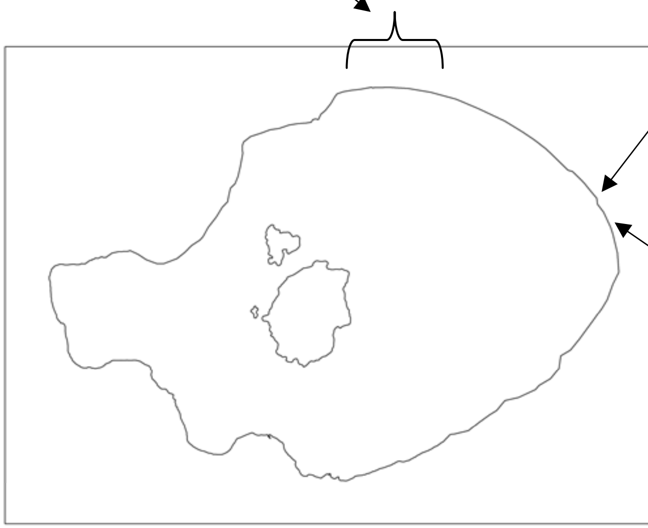


Figure 5. Continued - Mono Lake shoreline habitats



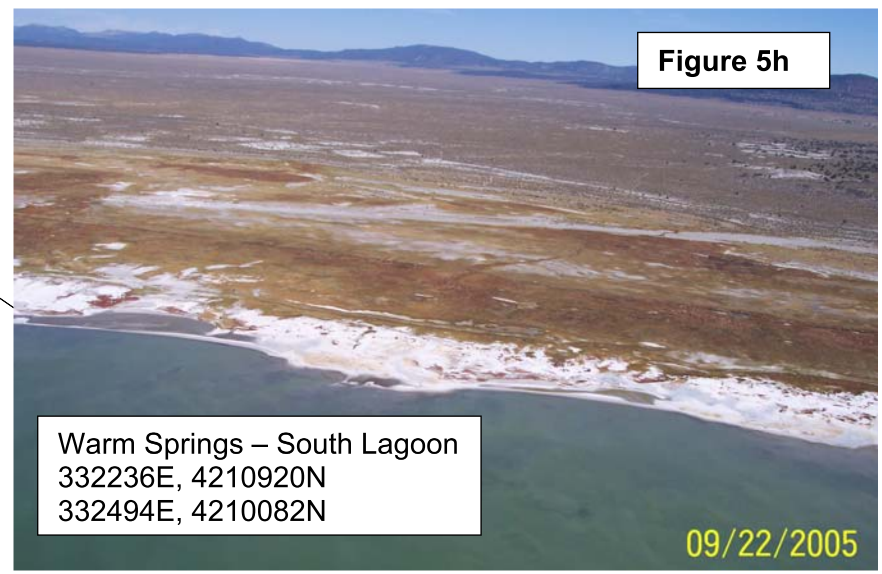
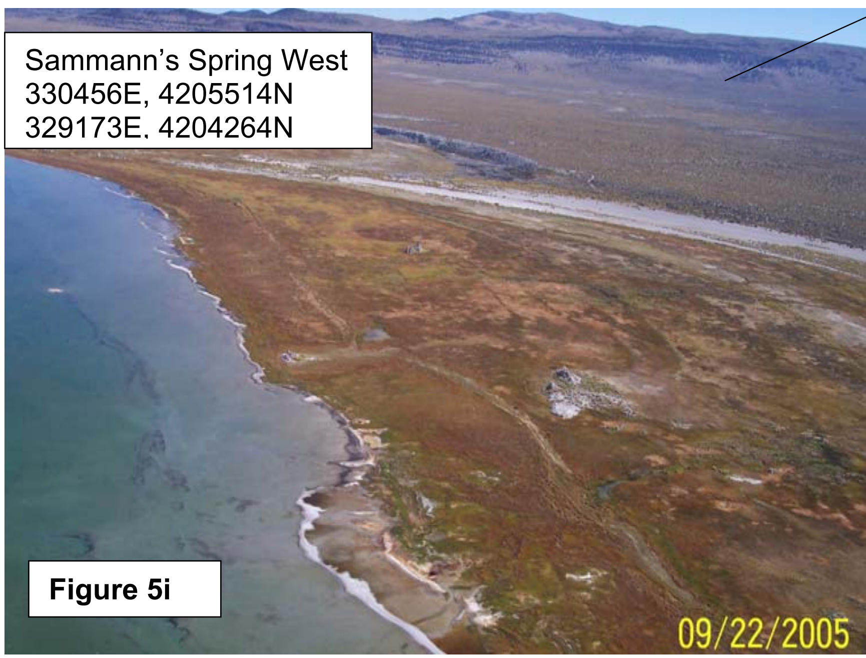
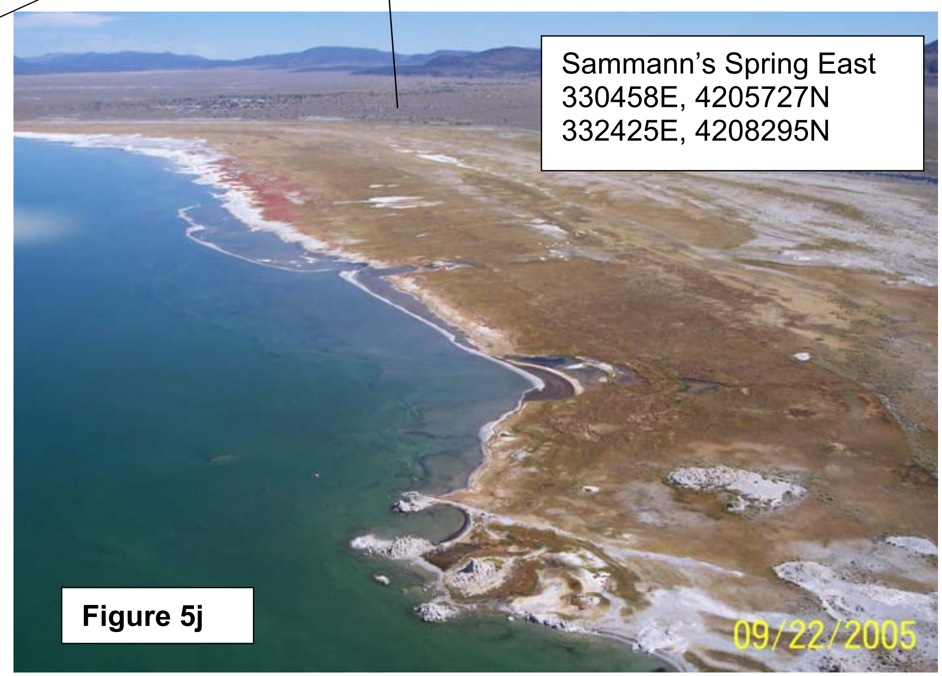


Figure 5. Continued - Mono Lake shoreline habitats



Sammann's Spring West
330456E, 4205514N
329173E, 4204264N

Figure 5i



Sammann's Spring East
330458E, 4205727N
332425E, 4208295N

Figure 5j

Figure 5. Continued - Mono Lake shoreline habitats

South Shore Lagoons – First Lagoon
324412E, 4201613N
324835E. 4201617N

Figure 5k

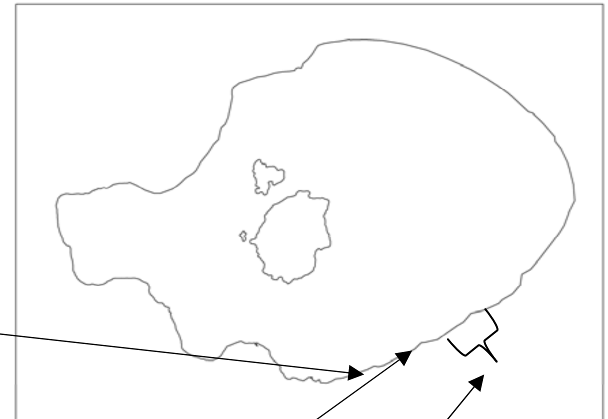


Figure 5l

Figure 5m

South Shore Lagoons – East End
328087E, 4203755N
328716E, 4204180N

**Figure 6. Photos of shoreline habitats at Bridgeport Reservoir.
Taken from a helicopter on September 22, 2005**

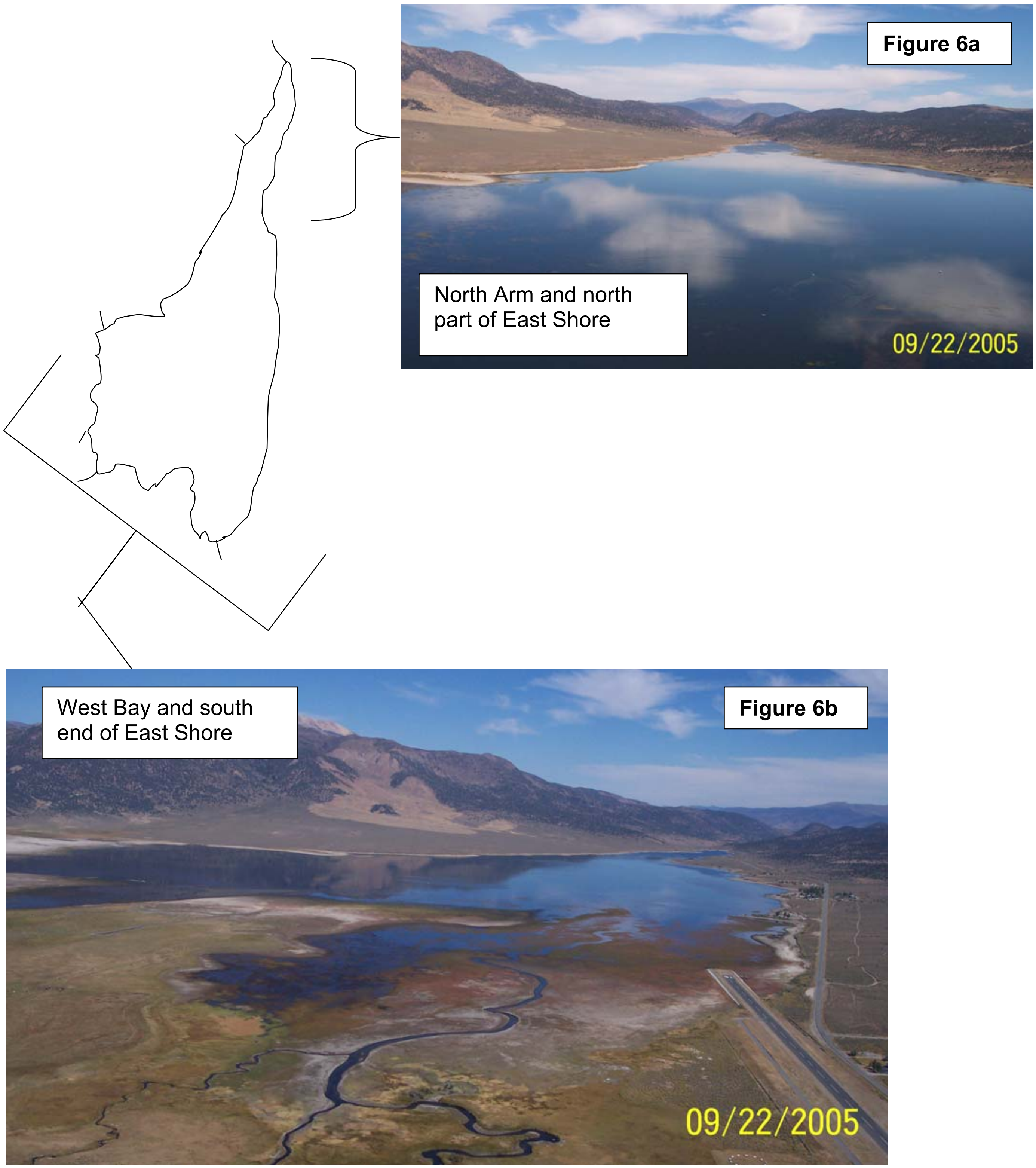


Figure 7. Photos of shoreline habitats at Crowley Reservoir. Taken from a helicopter on September 22, 2005

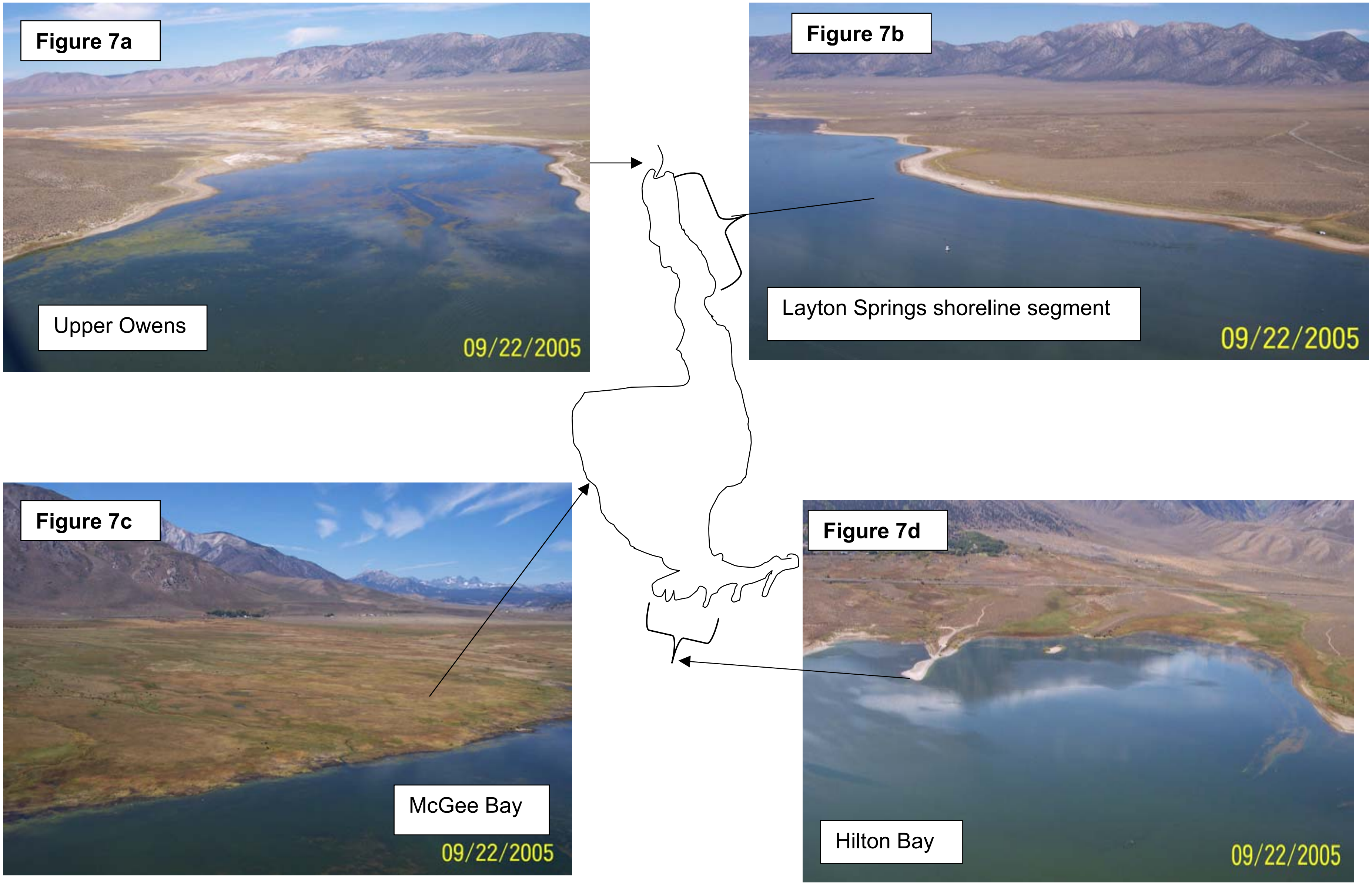


Figure 8. Changes in shoreline habitat in the Sammann's Springs area, Mono Lake, between 2004 and 2005. Note the reduction in exposed unvegetated areas and the development of an extensive littoral bar that created more hypersaline lagoon habitat in this area.

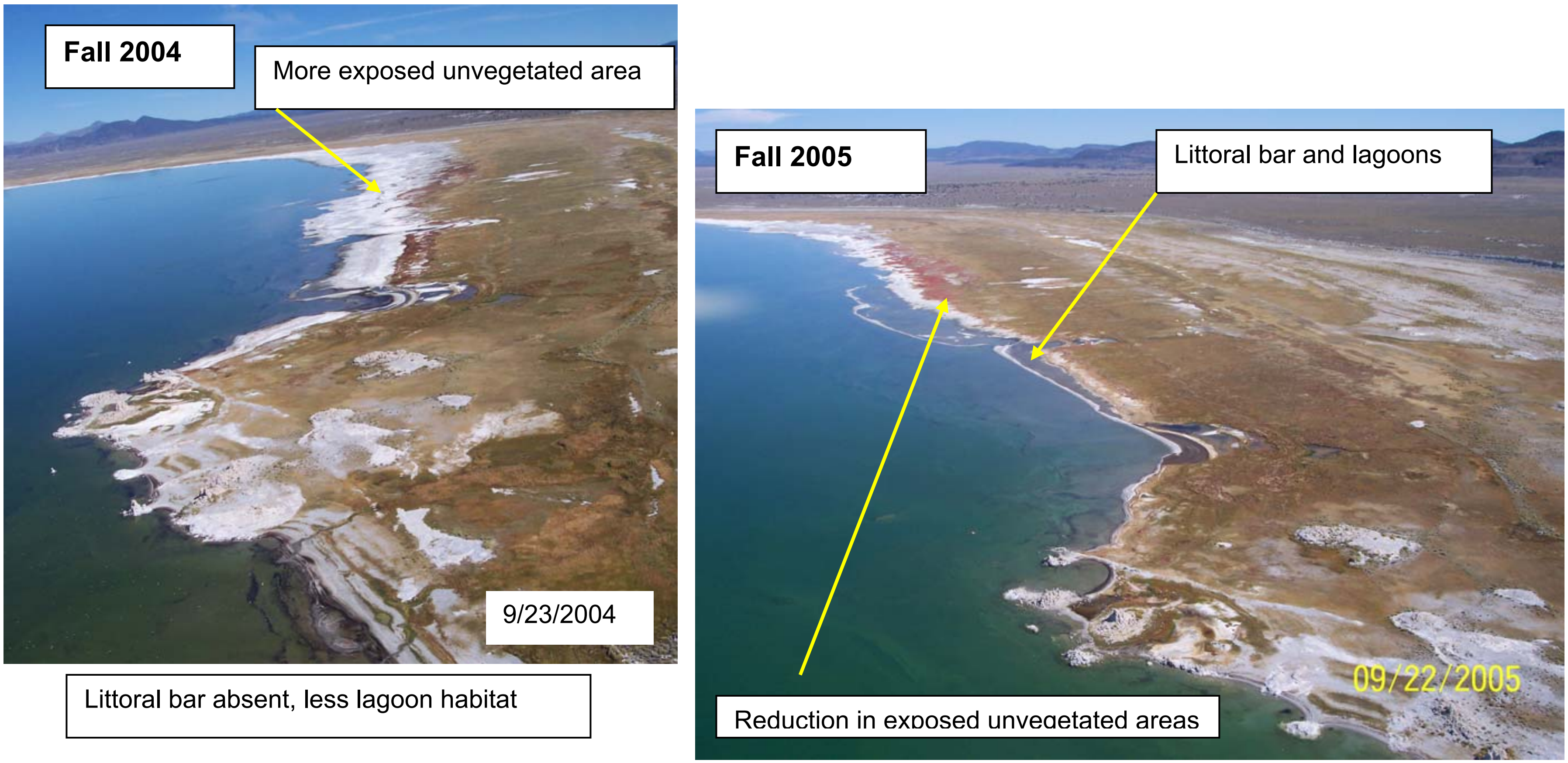
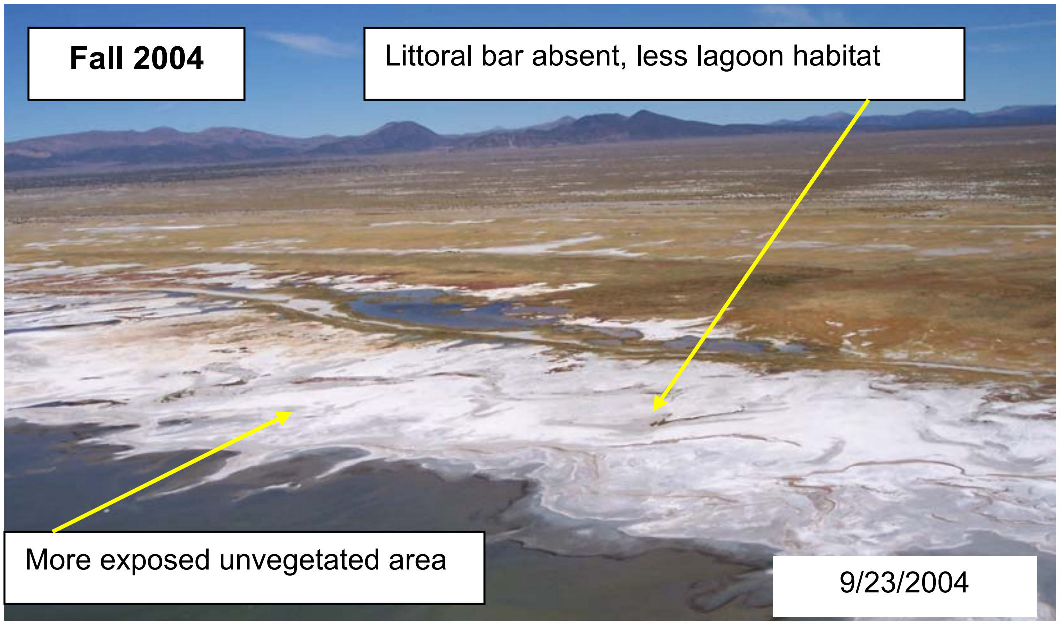


Figure 9. Changes in shoreline habitat in the South Shore Lagoon area between 2004 and 2005. This large lagoon at the west end of the South Shore Lagoon area had dried considerably by 2004. During 2005, this lagoon was full of water. This lagoon is often used by waterfowl and shorebirds.

Lagoon at South Shore Lagoons as viewed from the east

Same lagoon at South Shore Lagoons as viewed from the west

Figure 10. Changes in shoreline habitat in the Warm Springs area, Mono Lake, between 2004 and 2005. Note the reduction in exposed unvegetated areas and the development of a littoral bar that created more hypersaline lagoon habitat in this area.



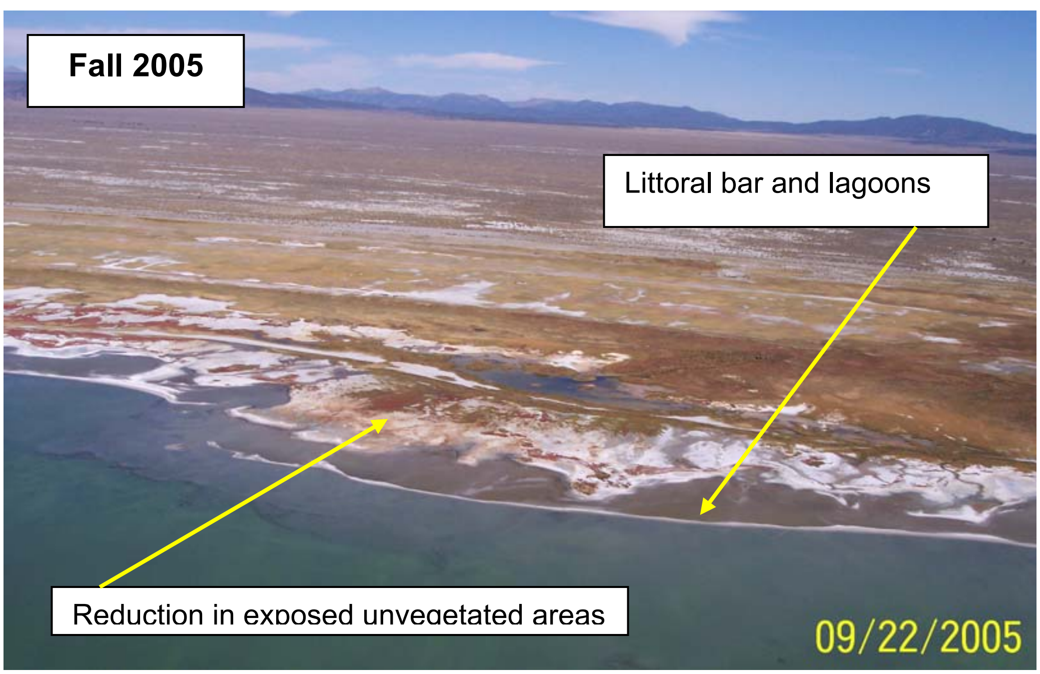


Figure 11. Bridgeport Reservoir – Comparison of conditions in fall 2004 in which the water level was very low, and 2005 in which the water level had recovered.

Figure 12. Crowley Reservoir – View of west side of McGee Bay in 2004 and 2005. The rise in reservoir level between 2004 and 2005 flooded large portions of the mudflats in this area where waterfowl typically rest and feed.

Figure 13. Brood locations 2005. The number in parentheses indicates the minimum number of broods of each species found in the indicated lakeshore segment or restoration pond complex.

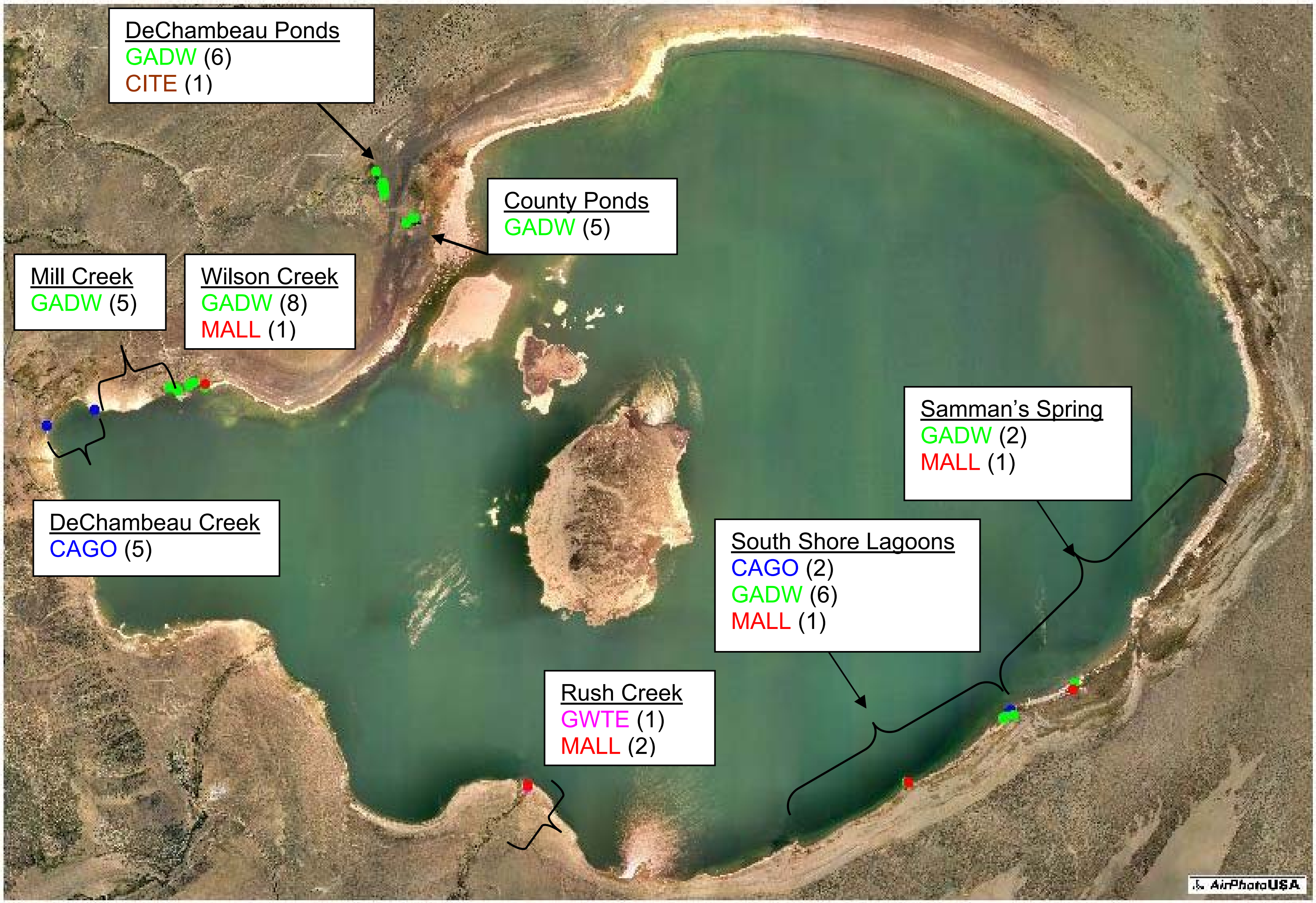


Figure 14. Habitat use by the dominant summer resident waterfowl species. The numbers in parentheses indicate the sample size. The bars represent the percent of total observations.

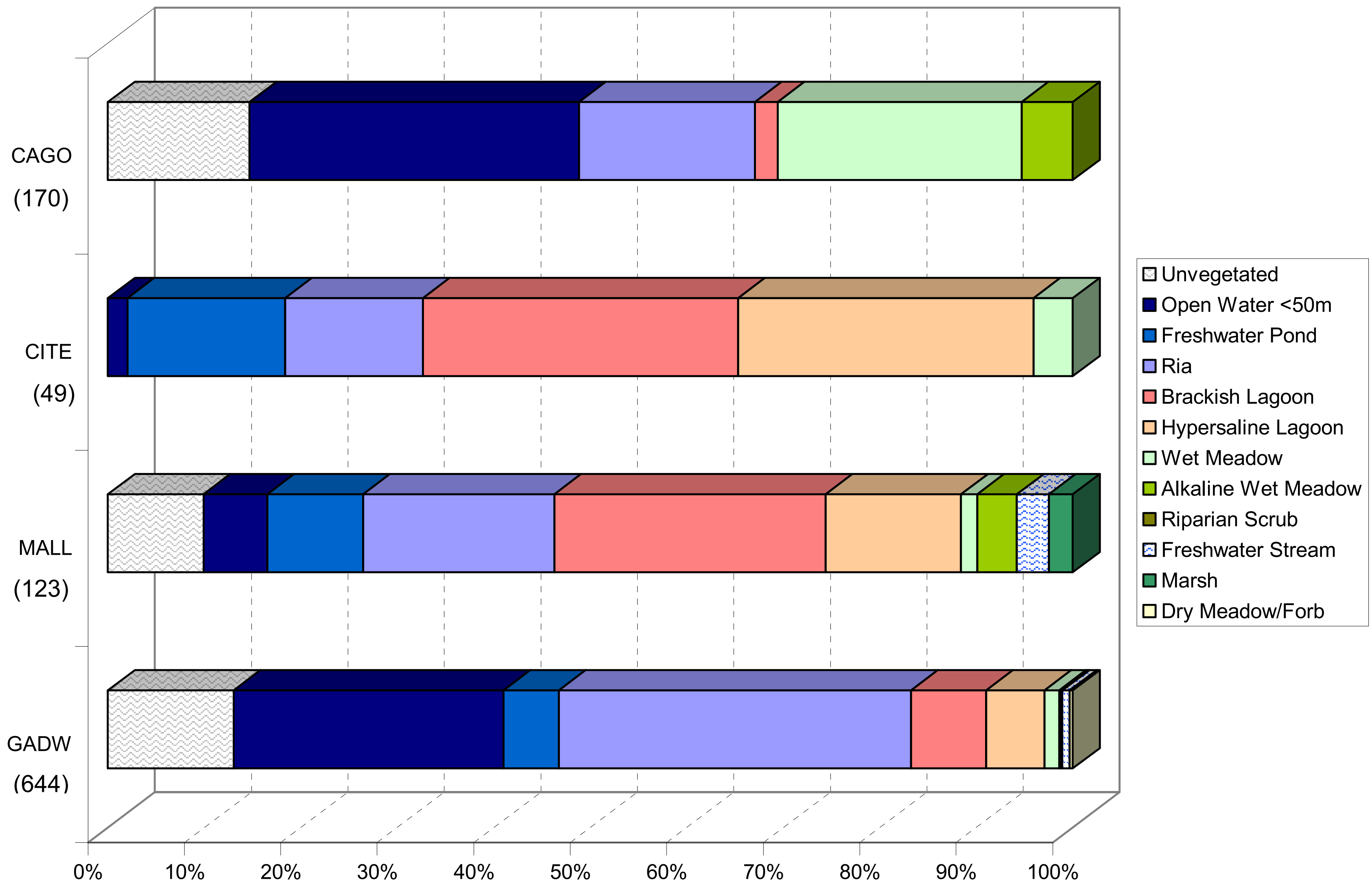


Figure 15. Foraging habitat use by the dominant shorebird species. The numbers in parentheses indicate the sample size. The bars represent the percent of total observations.

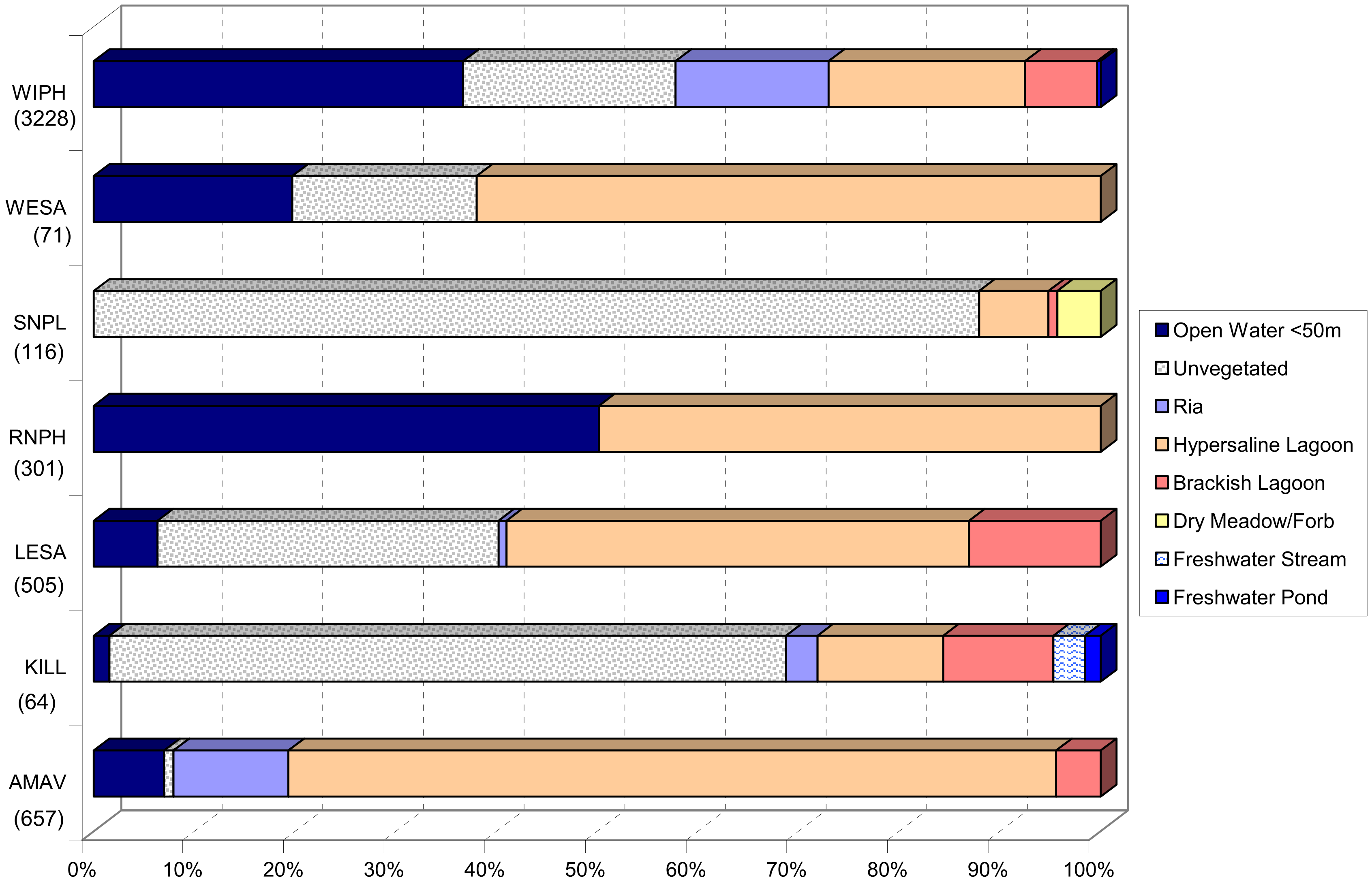


Figure 16. Total waterfowl detected at each waterbody during fall aerial surveys, 2005.

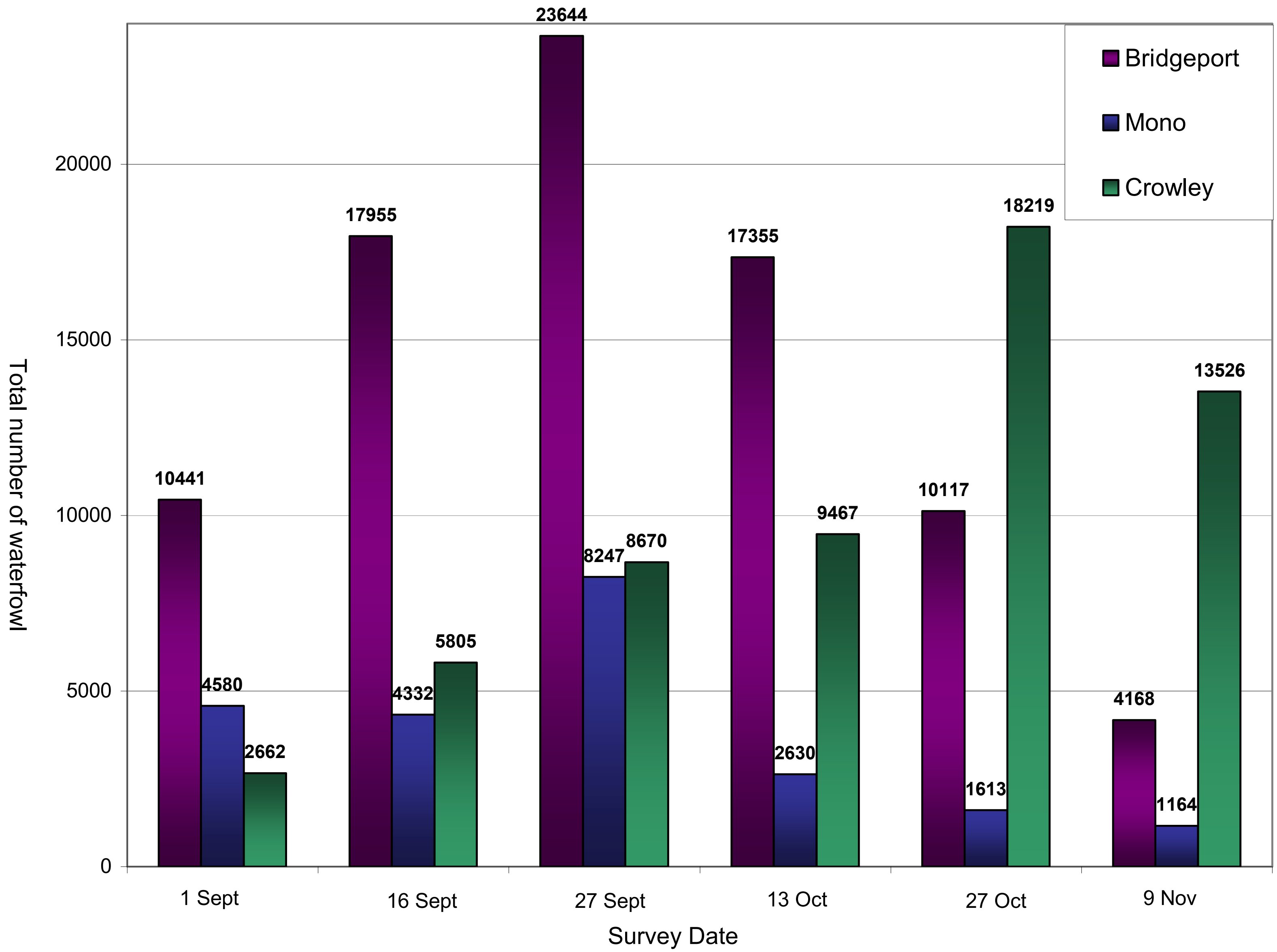


Figure 17. Total detections of dominant species at Mono Lake during fall aerial surveys, 2005

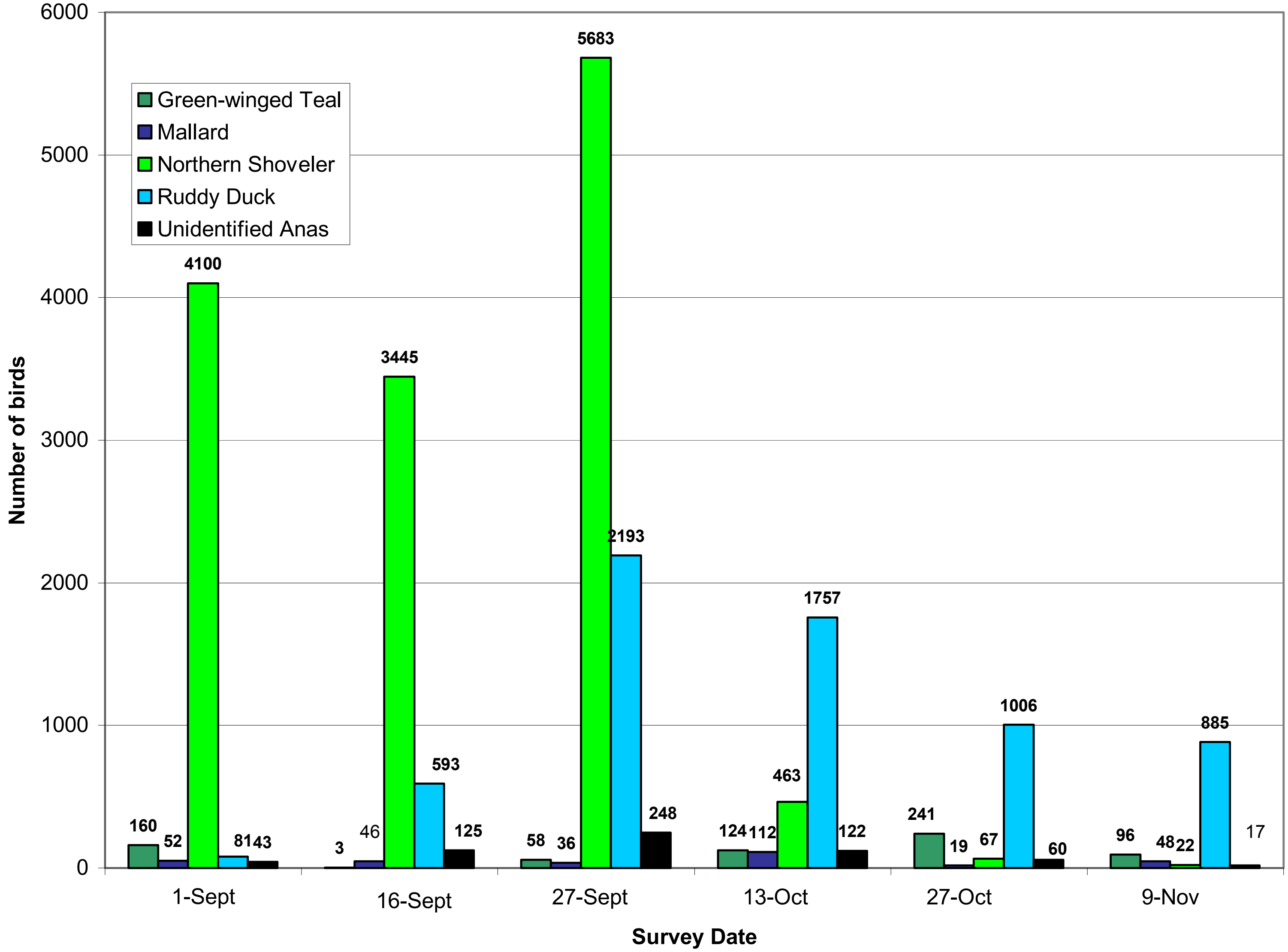


Figure 18. The proportion of waterfowl detected offshore (on crosslake transects) and in each of the lakeshore segments at Mono Lake during each fall aerial survey.

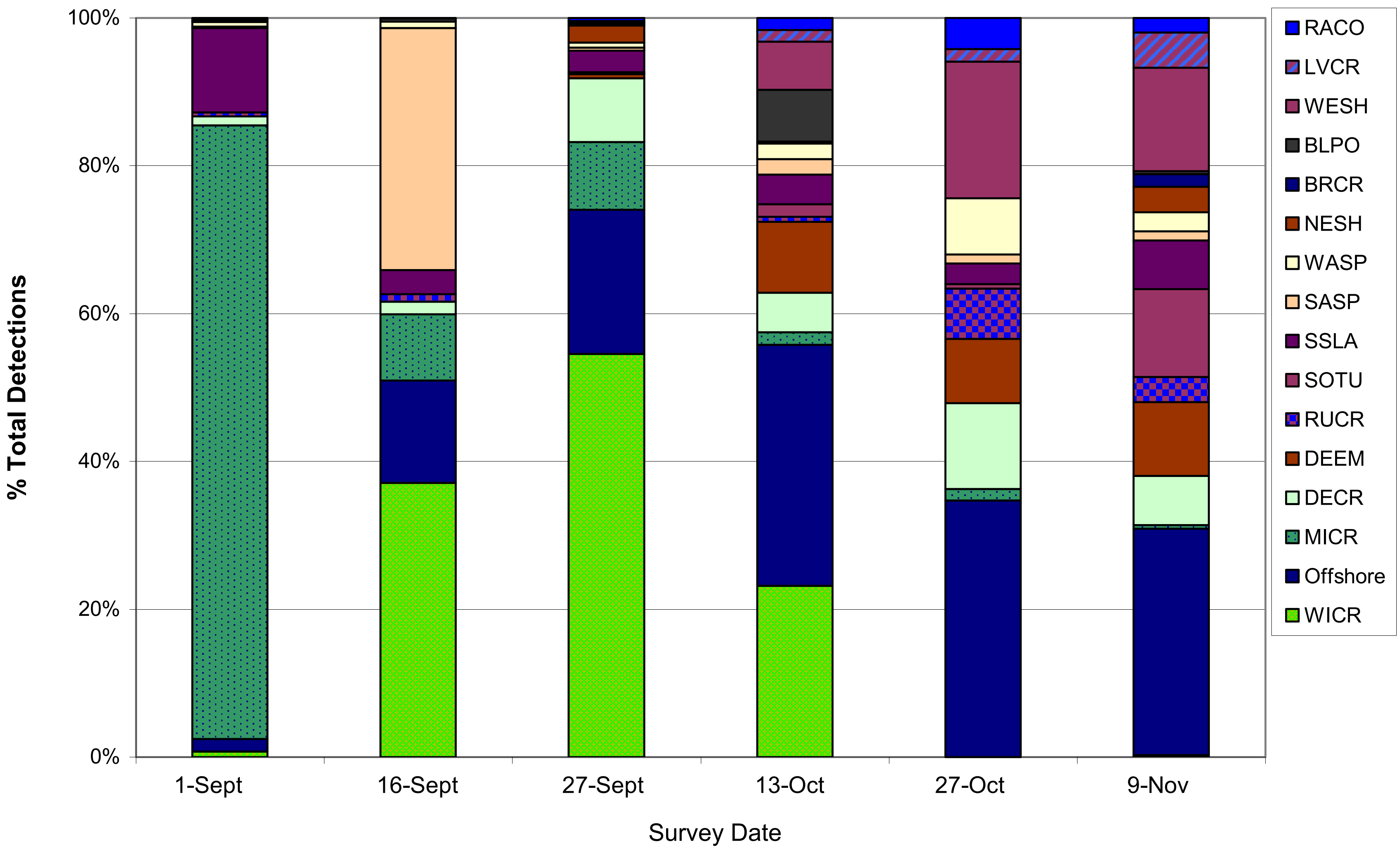


Figure 19. Proportional Distribution of Ruddy Ducks at Mono Lake during each fall survey, 2004

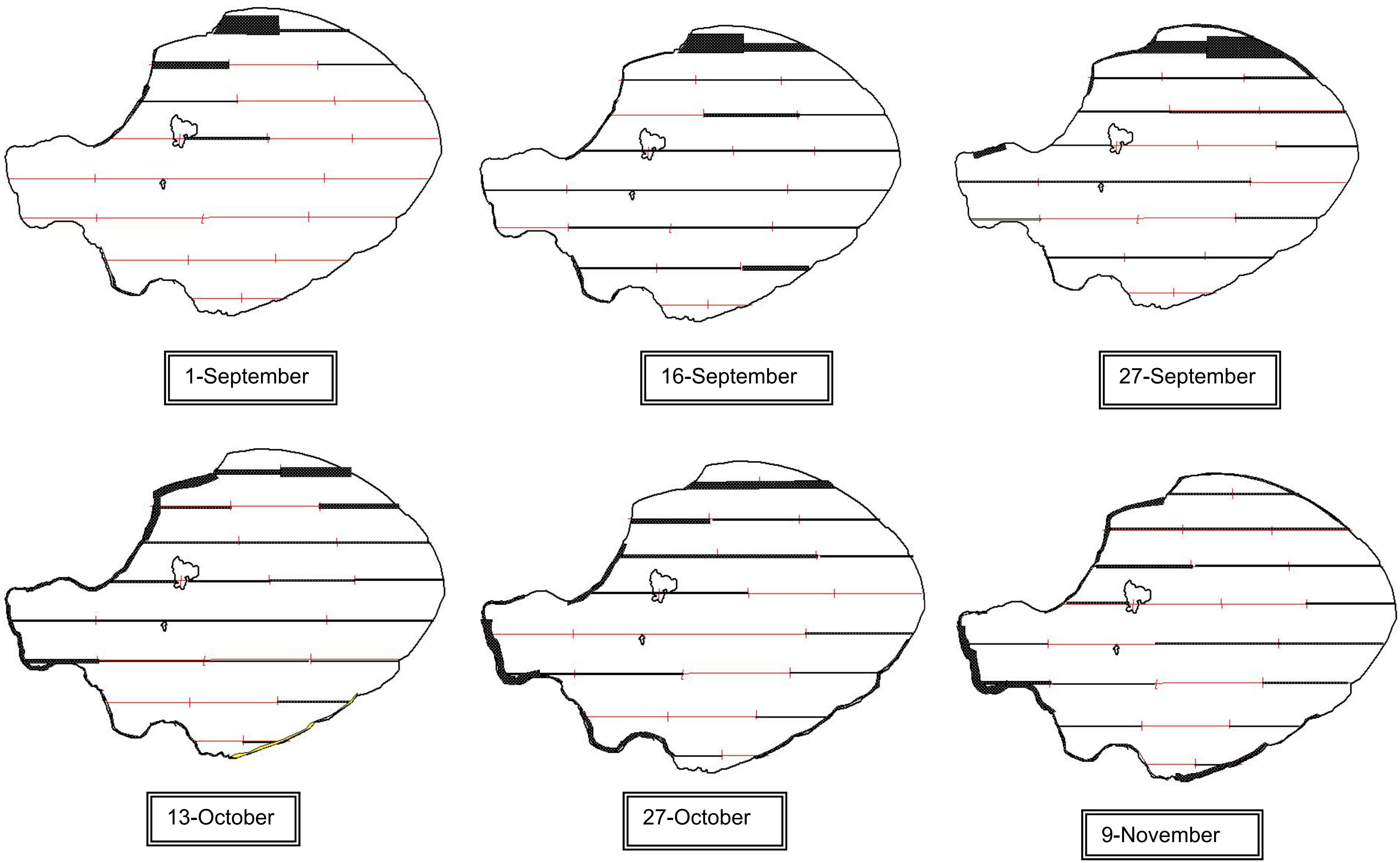


Figure 20. Total detections of dominant species at Bridgeport Reservoir during fall aerial surveys

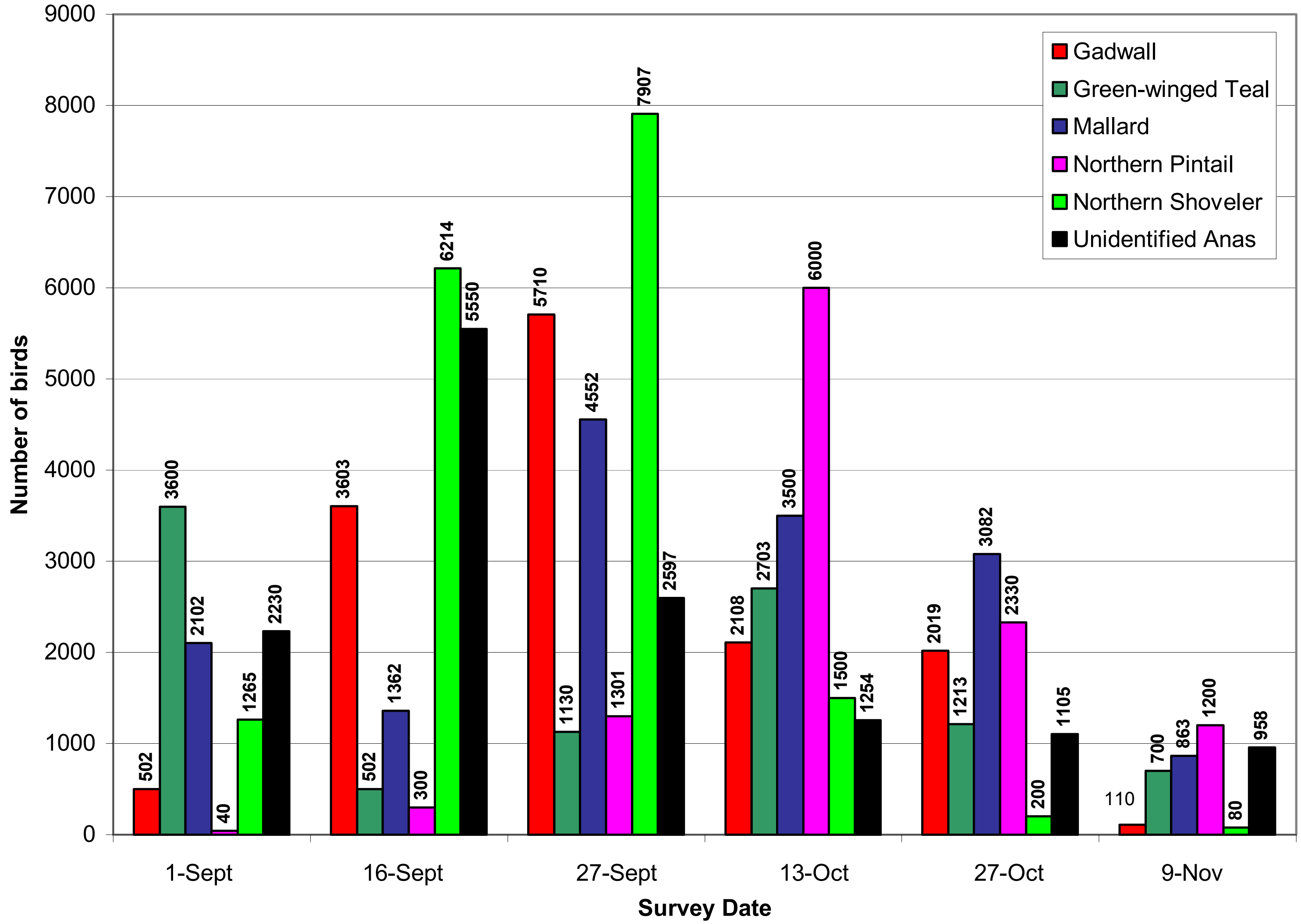


Figure 21. Total detections of dominant species at Crowley Reservoir during fall aerial surveys

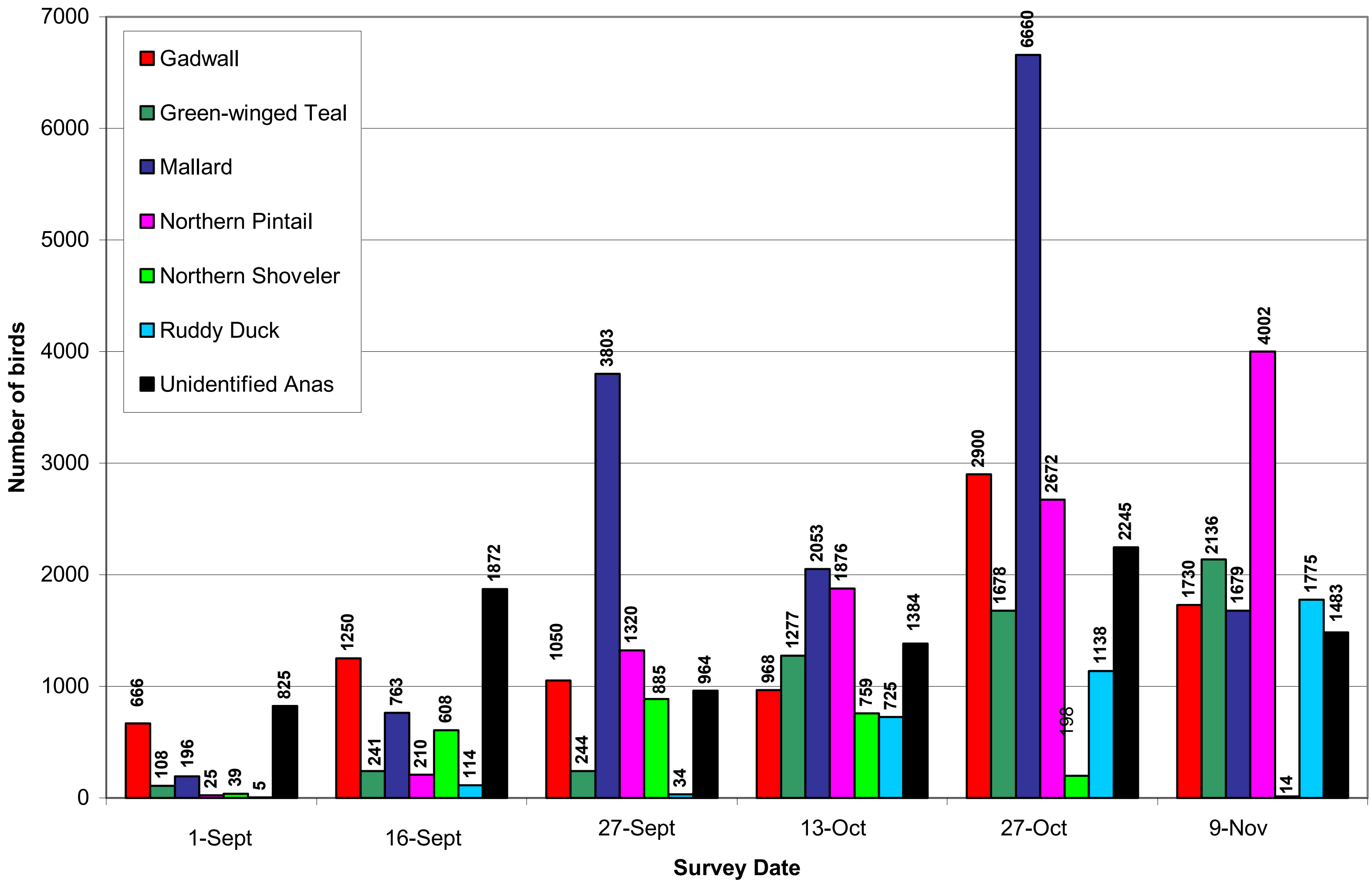


Figure 22. Total fall detections of the dominant species at all three bodies of water.

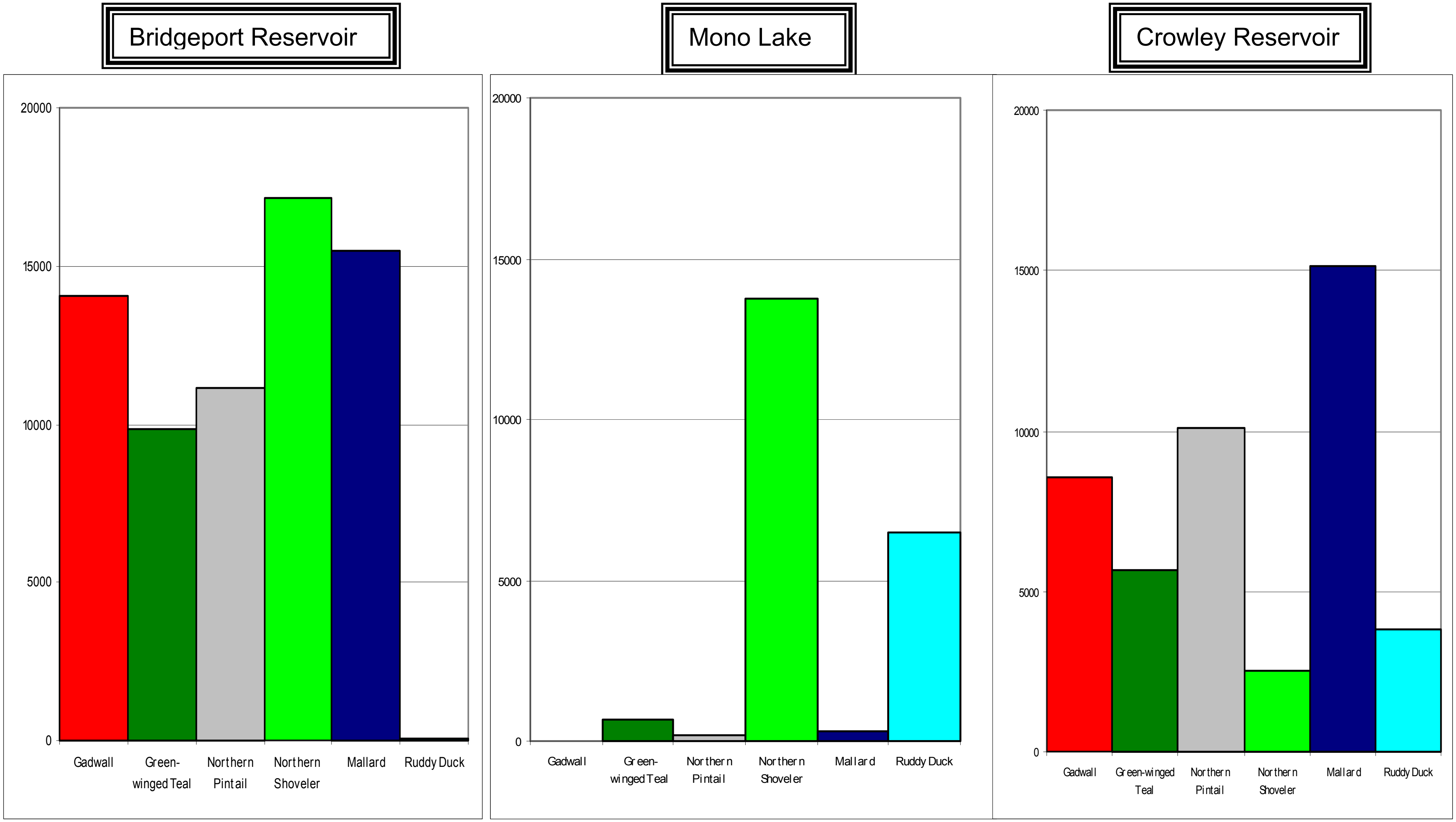
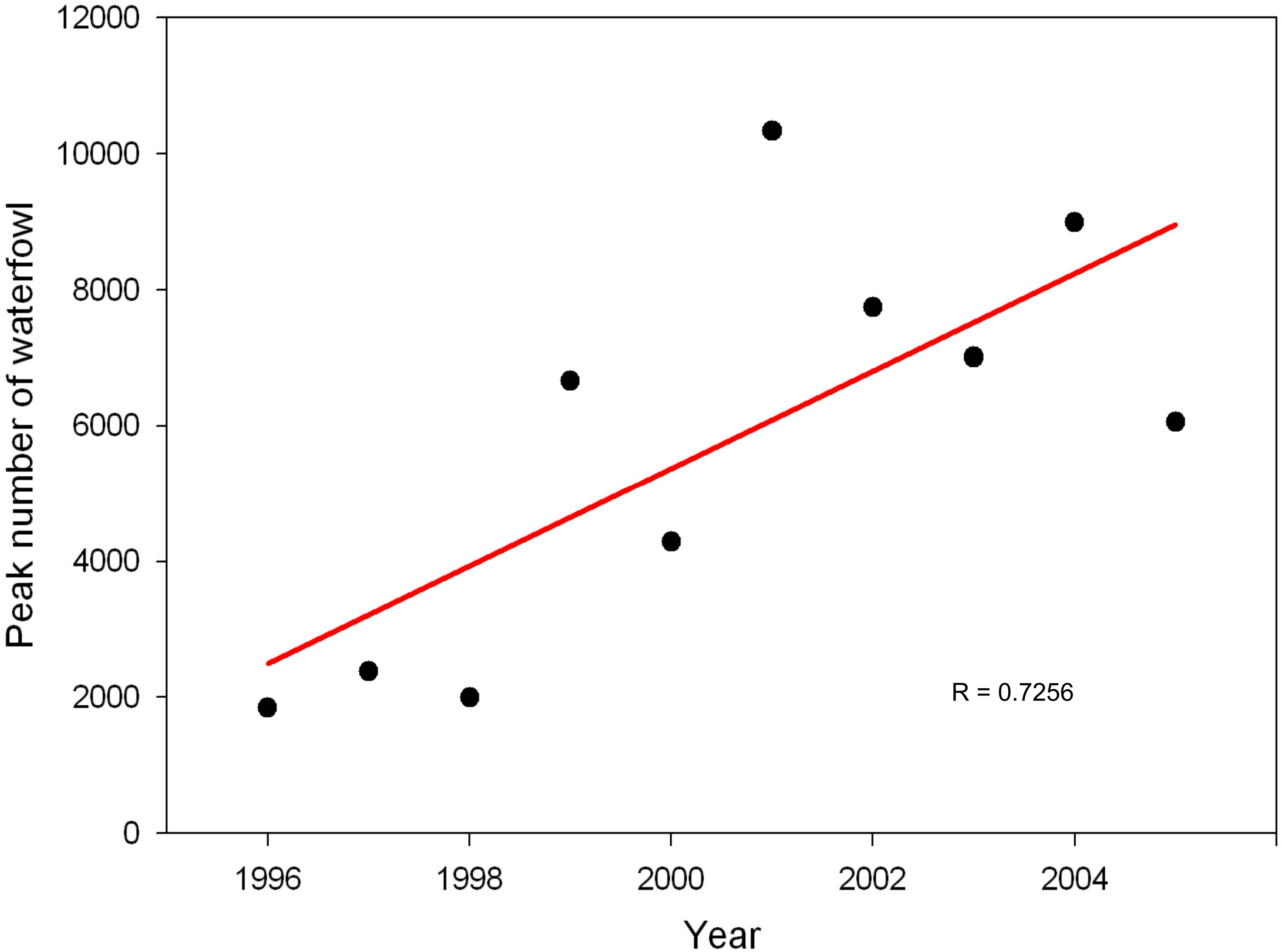


Figure 23. Trend in peak waterfowl numbers (not including Ruddy Ducks) at Mono Lake, 1996-2005



Appendix 1. 2005 Ground count surveys - Dates and times that surveys were conducted at each summer survey area.

Survey 1

Survey area	**Survey Date and Time**		
	June 6	June 7	June 8
RUCR	0550-0650 hrs		
SOTU	0736-0837 hrs		
SSLA	0838-1050 hrs		
SASP			0654-0931 hrs
WASP			0932-1057 hrs
WICR		0831-0923 hrs	
MICR		0708-0829 hrs	
DECR		0557-0706 hrs	
LVCR		1208-1250 hrs	
DEPO		1109-1150 hrs	
COPO		1048-1101 hrs	

Survey 2

Survey area	**Survey Date and Time**		
	June 27	June 28	June 29
RUCR	1130-1226 hrs		
SOTU	0550-0650 hrs		
SSLA	0650-0900 hrs		
SASP			0812-1126 hrs
WASP			0637-0807 hrs
WICR		0800-0906 hrs	
MICR		0630-0800 hrs	
DECR		0545-0630 hrs	
LVCR		1022-1105 hrs	
DEPO		1200-1235 hrs	
COPO		1250-1300 hrs	

Appendix 1. Continued

Survey 3

Survey area	Survey Date and Time		
	July 18	July 19	July 20
RUCR	0603-0715 hrs		
SOTU	0800-0854 hrs		
SSLA	0855-1150 hrs		
SASP			0625-1005 hrs
WASP			1006-1210 hrs
WICR		0800-0925 hrs	
MICR		0642-0800 hrs	
DECR		0555-0642 hrs	
LVCR		1233-1311 hrs	
DEPO		1058-1130 hrs	
COPO		1140-1200 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
Baird's Sandpiper	*Calidris bairdii*	BASA
Bufflehead	*Bucephala albeola*	BUFF
Canada Goose	*Branta canadensis*	CAGO
Canvasback	*Aythya valisineria*	CANV
Cinnamon Teal	*Anas cyanoptera*	CITE
Common Loon	*Gavia immer*	COLO
Common Merganser	*Mergus merganser*	COME
Great Blue Heron	*Ardea herodias*	GBHE
Greater Yellowlegs	*Tringa melanoleuca*	GRYE
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
Long-billed Dowitcher	Limnodromus scolopaceus	LBDO
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
Ruddy Duck	*Oxyura jamaicensis*	RUDU
Sanderling	Calidris alba	SAND
Semipalmated Plover	Charadrius semipalmatus	SEPL
Short-billed Dowitcher	*Limnodromus griseus*	SBDO
Snowy Plover	*Charadrius alexandrinus*	SNPL
Spotted Sandpiper	*Actitis macularia*	SPSA
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
Anas spp.	Unidentified *Anas* species	UNTE
Calidris spp	Unidentified *Calidris* species	CALX
Limnodromus spp.	Unidentified *Limnodromus* species	DOWX
Phalaropus spp.	Unidentified *Phalaropus* species	PHAX

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*).

<u>Marsh</u>

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*).

<u>Wet Meadow</u>

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.

<u>Alkaline Wet Meadow</u>

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.

<u>Dry meadow/forb</u>

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.

<u>Riparian and wetland scrub</u>

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.

<u>Great Basin scrub</u>

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. 2005 Fall aerial survey dates

Survey Number	1	2	3	4	5	6
Mono Lake	1 Sept	16 Sept	27 Sept	13 Oct	27 Oct	9 Nov
Bridgeport Reservoir	1 Sept	16 Sept	27 Sept	13 Oct	27 Oct	9 Nov
Crowley Reservoir	1 Sept	16 Sept	27 Sept	13 Oct	27 Oct	9 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 4

Vegetation Report

2006

Mono Lake Vegetation

Monitoring Report

Prepared by

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Mono Lake Vegetation Monitoring

The Los Angeles Department of Water and Power conducted vegetation-monitoring activities in lake fringing wetlands surrounding Mono Lake and in tributary stream deltas during the 2005 growing season. These efforts were undertaken to fulfill State Water Resources Control Board obligations as directed in Decision 1631 and Order No. 98-05. Monitoring protocol was developed working closely with the waterfowl monitoring consultants. The objective of these monitoring efforts is to determine wetland changes as lake levels rise and how those changes may relate to waterfowl activity in the region.

Wetland Monitoring

Wetland monitoring sites were established in 1999 at three locations in the Mono Lake Basin; Sammon Springs, Warm Springs, and Dechambeau Embayment (Figure 1). Vegetation monitoring was conducted along permanent transects using the point intercept method to determine species composition and cover for each site. Caution was taken to minimize disturbance to extant vegetation along the permanent transects. Horizontal coordinates of each monitoring site and permanent transects were determined with GPS. Photographs of the monitoring transects are attached as Appendix 1.

Sammon Springs

At Sammon Springs, three transects established by California State Parks biologists were utilized to determine species composition and cover (Figure 2). These transects were utilized in order to minimize the number of permanent markers visible at this popular tufa viewing site. Transects varied in length with two being 100 meters long while the third was 75 meters. Species composition and cover values are presented in Table 1.

Warm Springs

At Warm Springs, three permanent transects were established perpendicular to the Mono Lake shoreline in 1999 (Figure 3). Transects were randomly located within the marsh areas at each site. Transects extended from the current lake elevation (6382 ft) to approximately 6392 ft (≈ 550 m).

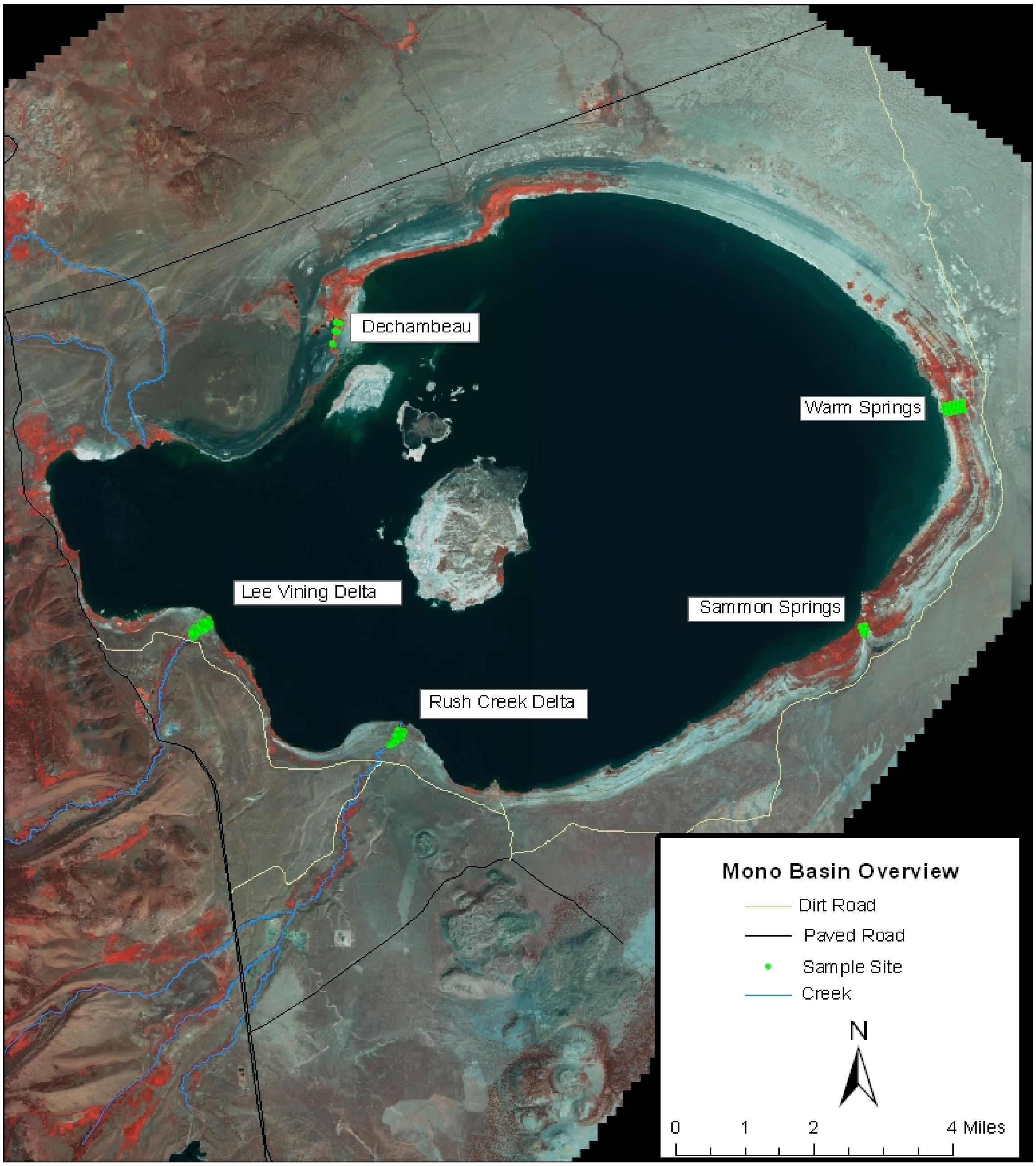


Figure 1. Overview map of the Mono Basin

At 100 m intervals along each permanent transect, 50 m long sampling transects were established (n=6) parallel to the lake shore. Sampling transects ran either north or south from the permanent transect. The direction was randomly chosen. Average cover and species composition are presented in Table 2. Values are averages of the three sampling points of approximately equal distance from the lake shore.

Dechambeau Embayment

At Dechambeau Embayment, three permanent transects were established perpendicular to the Mono Lake shoreline (Figure 4). Transects were randomly located within the marsh areas at each site. Transects extended approximately 100 m from the current lake shore. At each end, and the mid-point of each permanent transect, a 50 m long sampling transect was established (n=3). Sampling transects ran either north or south from the permanent transect. The direction of each sampling transect was randomly chosen. Average cover and species composition presented in Table 3 are averages of the sampling points of approximately equal distance from the lake shore.

Tributary Delta Monitoring

Six transects were established within the delta areas of both Lee Vining and Rush Creeks (Figures 1, 5, and 6). The first transect was located near the mouth of each delta and extended upstream at approximately 100 m intervals. Vegetation monitoring was conducted using the point intercept method to determine species composition and cover for each site. These data are presented in Tables 4 and 5. Horizontal coordinates of each sampling transect were determined with GPS. GPS readings were also taken at approximately 10 m intervals along each sampling transect. With all sampling, caution was taken to disturb existing monitoring areas as little as possible.

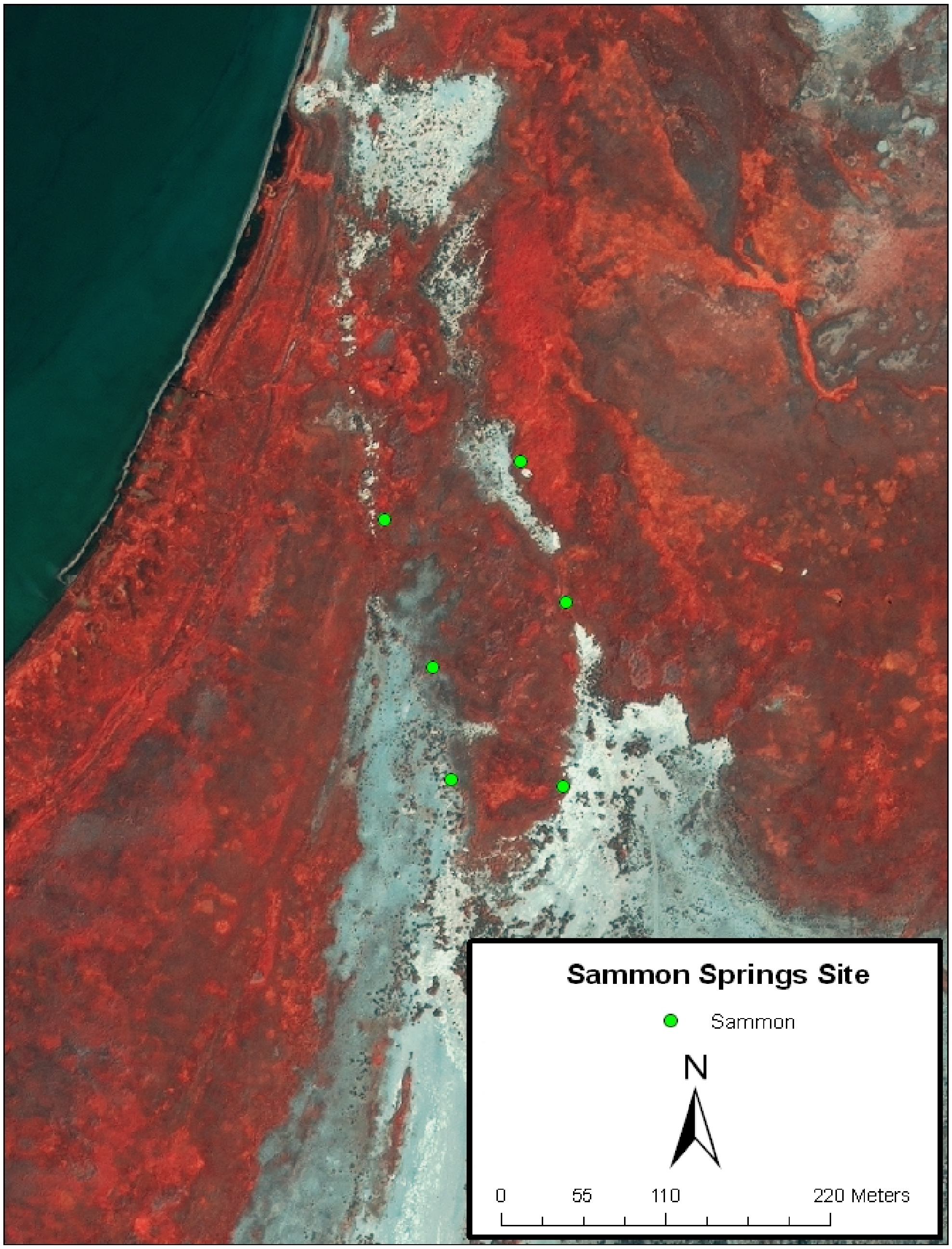


Figure 2. Sammon Springs sampling locations.

Table 1. Species list and average cover (%) of each for the three sampling transects at the Sammon Springs Wetland Vegetation monitoring area.

	Transect 1		Transect 2		Transect 3	
	1999	**2005**	**1999**	**2005**	**1999**	**2005**
Bare	6.33	**1.3**	2	**1**	12	**13**
Litter	6.33	**1.3**	2	**10**	7	**5**
Water	--	**--**	2	**--**	--	**--**
AAFF	--	**1.3**	--	**--**	--	**--**
Casteleja spp.	--	**--**	2	**--**	--	**--**
Chrysothamnus nauseosus	--	**2.7**	--	**1**	6	**7**
Carex spp	--	**32**	--	**1**	--	**2**
Disticilis spicata	10.67 (4)	**6.7**	3	**--**	7	**4**
Epilobium spp.	2.67	**--**	--	**--**	--	**--**
Eleocharis macrostachya	28.00 (1)	**--**	6	**--**	5	**--**
Hordeum jubatum	--	**--**	--	**--**	2	**--**
Mimulus glabrata	--	**--**	2	**--**	--	**--**
Juncus balticus	13.33 (3)	**42.7 (1)**	34	**49**	17	**40**
Muhlenbergia asperifolia	--	**--**	2	**1**	2	**--**
Poa pratensis	--	**--**	--	**--**	2	**--**
Scirpus acutis	--	**--**	27	**21**	1	**--**
Scirpus americanus	28.00 (1)	**9.3 (3)**	8	**1**	10	**3**
Scirpus nevadensis	5.33	**2.7**	--	**3**	23	**17**
Solidago spectablis	--	**--**	3	**--**	4	**8**
Typha latifolia	--	**--**	7	**12**	2	**1**

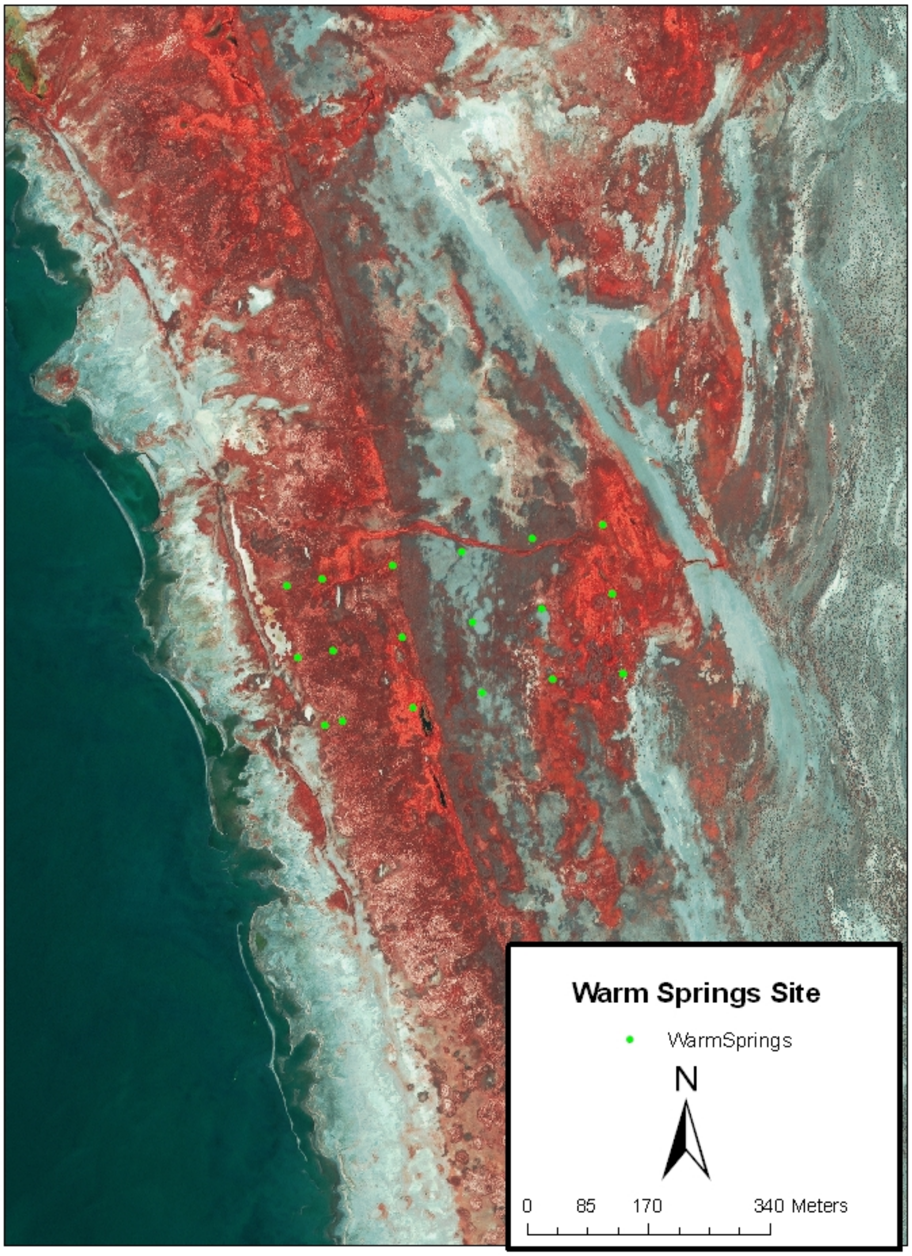


Figure 3. Warm Springs sampling locations.

Table 2. Species list and average cover (%) of each of the sampling transects for the Warm Springs Wetland Vegetation monitoring area. Values are averages of sampling points of approximately equal distance from the lake shore. Transect 1 is closest to the lake while transect 6 is furthest from the lake.

	Transect 1		**Transect 2**		**Transect 3**		**Transect 4**		**Transect 5**		**Transect 6**	
	99	**05**	**99**	**05**	**99**	**05**	**99**	**05**	**99**	**05**	**99**	**05**
Bare	10.67	--	3.33	--	6.67	--	20.67	16.7	1.33	--	2.00	1.1
Litter	10.67	27	16.00	18	11.33	12.7	15.33	18.7	7.33	4	--	3.3
Water	3.33	--	0.67	--	10.67	4.7	--	--	--	--	--	--
Disticilis spicata	--	--	--	--	--	--	15.33	15.3	2.00	1.3	--	--
Juncus balticus	--	--	--	--	1.33	1.3	--	--	3.33	--	3.33	5.3
Scirpus acutis	--	--	--	--	16.67	5.3	--	--	--	--	2.66	--
Scirpus americanus	--	--	18.00	16	5.33	55.3	--	--	13.33	14.0	74.00	78
Scirpus nevadensis	64.67	73	58.67	66	37.33	20.7	46.00	49.3	62.66	75.4	16.00	11
Unknown annual forb	--	--	--	--	--	--	--	--	0.66	2.7	--	--
Unknown mustard	10.67	0.67	3.33	--	10.67	--	2.67	--	2.66	2.6	2.00	1.3

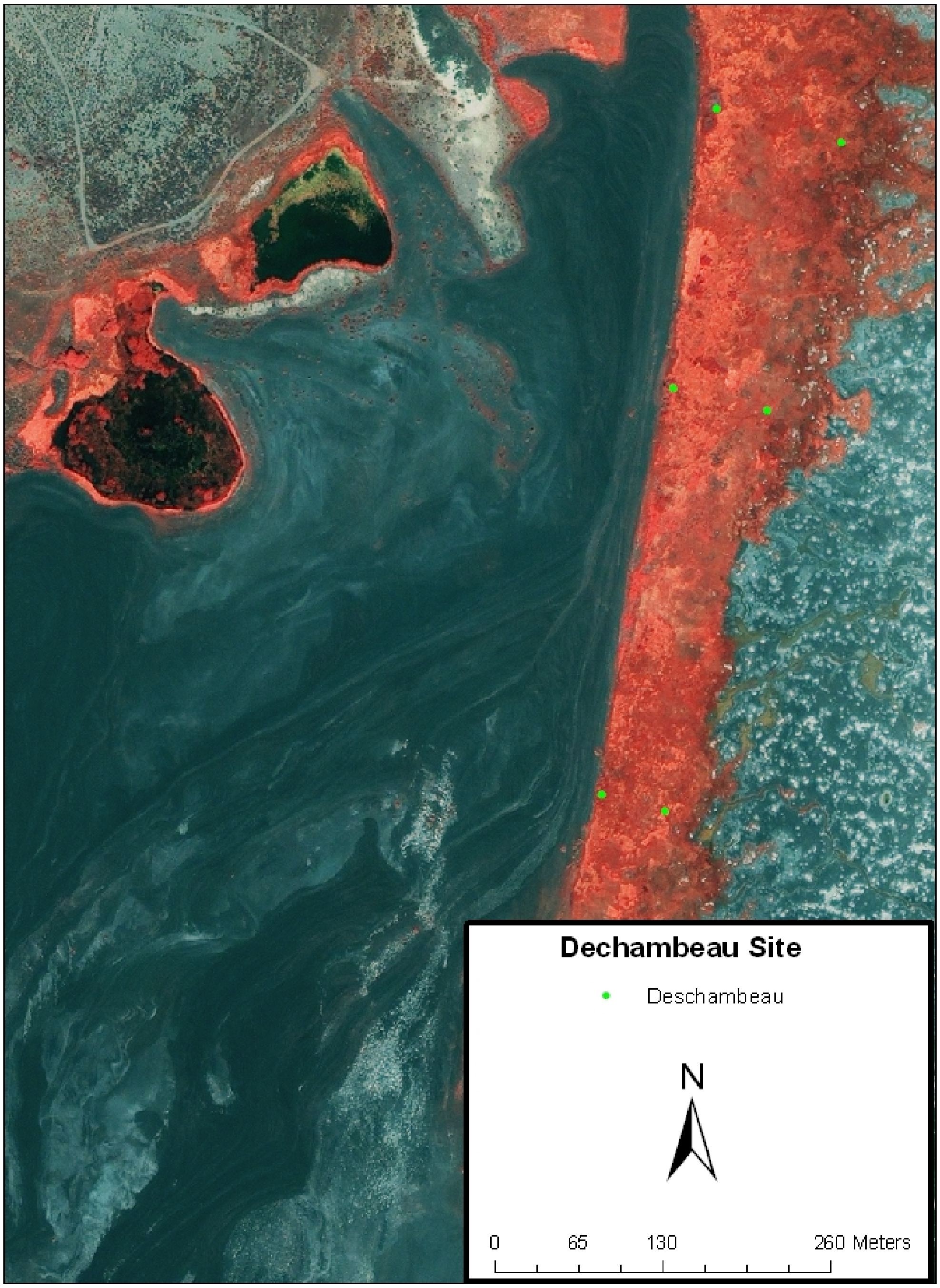


Figure 4. Dechambeau embayment sampling locations.

Table 3. Species list and average cover (%) of each of the transects for the Dechambeau Embayment Wetland Vegetation monitoring area. Values are averages of sampling points of approximately equal distance from the lake shore. Transect 1 is closest to the lake while transect 3 is furthest from the lake.

	Transect 1		**Transect 2**		**Transect 3**	
	99	**05**	99	**05**	99	**05**
Litter	8	**2**	--	**4**	1.3	**--**
Water	20.7	**--**	--	**--**	--	**--**
Allenrolfea occidentalis	0.7	**--**	--	**--**		**--**
Bassia hyssopifolia	0.7	**--**	6	**--**	1.3	**1.3**
Carex rostrata	0.7	**--**	--	**--**	--	**--**
Descurainia pinnata	1.3	**--**	3.3	--	18	**2.7**
Disticilis spicata	22	**--**	14.7	**3.3**	6	**--**
Epilobium	--	**--**	--	**0.7**	--	**4.7**
Horeum jubatum	1.3	**--**	44	**14.7**	17.3	**0.7**
Juncus balticus	1.3	**--**	--	**3.3**	0.7	**0.7**
Muhlenbergia	2	**16**	--	**--**	--	**--**
Poa secunda	4	**--**	14	**8.7**	--	**--**
Polypogon	--	**--**	1.3	**--**	4.7	**5.3**
Salix exigugua	--	**--**	--	**--**	0.7	**--**
Salsola tragus	--	**--**	--	**--**	2.7	**--**
Sarcobatus vermiculatus	--	**--**	--	**--**	0.7	**--**
Scirpus acutis						
Scirpus pungens	31.2	**82**	16	**61.3**	27.3	**75.3**
Scirpus nevadensis	--	**--**	--	**4**	--	**--**
Triglogin concinna	4.7	**--**	--	**--**	--	**--**
Typha latifolia	--	**--**	--	**--**	2.7	**9.3**
Veronica perigrina	--	**--**	--	**--**	1.3	**--**
Unk Chenepod	--	**--**	--	**--**	8	**--**
Unknown Mustard	--	**--**	--	**--**	6	**--**

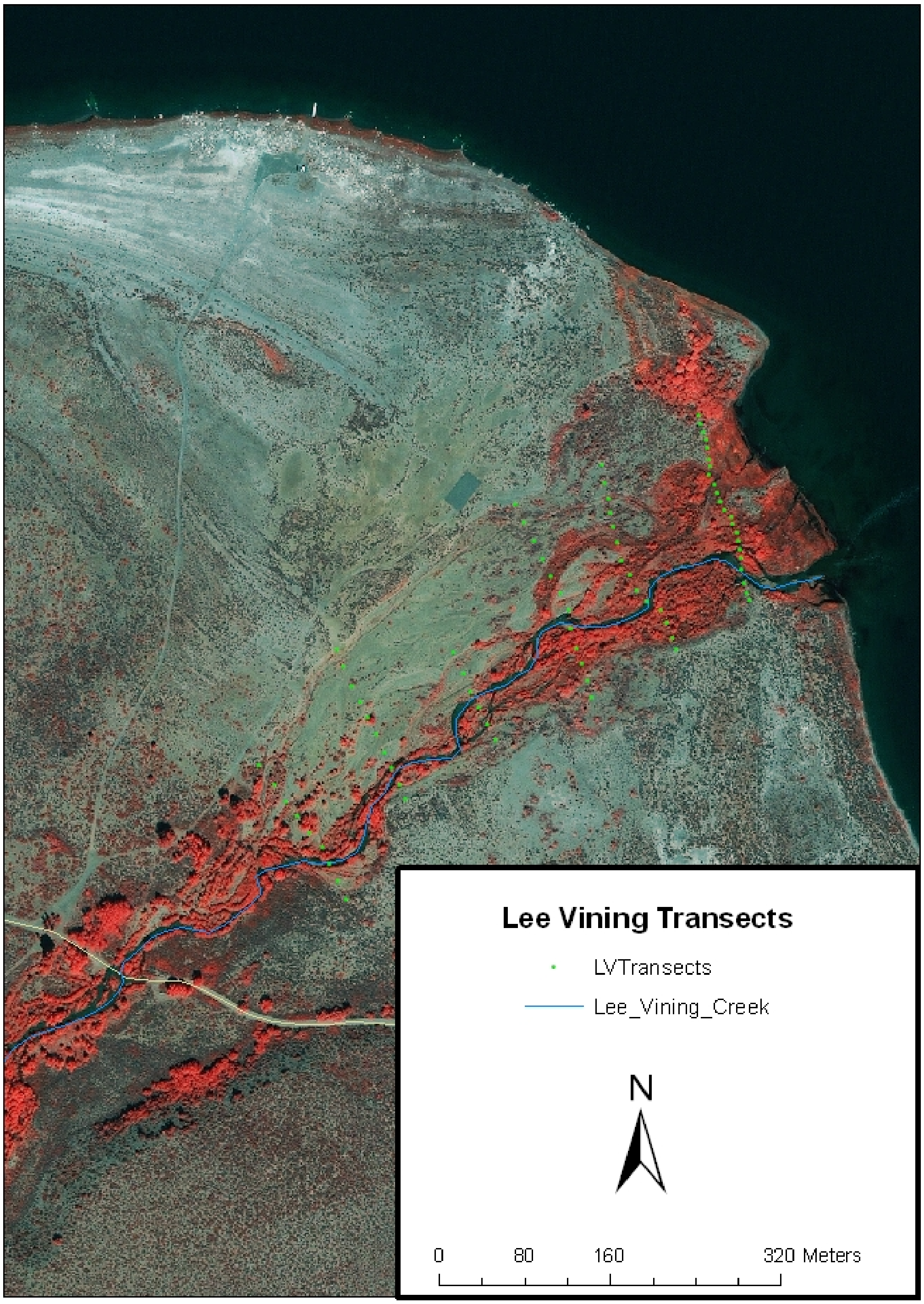


Figure 5. Lee Vining Creek transect locations.

Table 4. Species list and average cover (%) of each for the Lee Vining Delta vegetation monitoring transects.

	T1		T2		T3		T4		T5		T6	
	99	**05**	99	**05**	99	**05**	99	**05**	99	**05**	99	**05**
Annual Forb	--	**0.4**	--	**0.3**	--	**--**	--	**--**	--	**0.4**	--	**0.4**
Achillia millifolium	--	**0.8**	--	**--**	--	**2.0**	--	**0.7**	--	**--**	--	**--**
Agrostis stolonifera	4.4	**--**	--	**0.3**	--	**--**	--	**--**	--	**--**	--	**--**
Arnica longifolia	--	**0.8**		**--**	--	**--**	--	**--**	--	**--**	--	**--**
Artemesia ludoviciana	--	**2.3**	2.9	**--**	3.9	**2.7**	3.6	**0.7**	1.7	**0.4**	1.9	**1.7**
Artemesia tridentata	4.3	**0.4**	0.96	**--**	--	**--**	0.7	**0.7**	2.3	**1.7**	0.6	**2.1**
Bare	17.4	**15.5**	9.6	**26.3**	29.1	**29.3**	51.8	**61.1**	57.6	**70.6**	42.9	**47.1**
Calamagrostis niglecta	--	**--**	--	**1.0**	--	2.4	--	**2.2**	--	**--**	--	**--**
Carex spp	--	**1.9**	--	**5.5**	--	**2.4**	--	**--**	--	**--**	--	**0.8**
Chrysothamnus nauseosus	--	**1.5**	--	**0.3**	--	**--**	--	**--**	0.56	**0.4**	--	**0.8**
Cirsium vulgare	--	**0.4**	--	**--**	--	**--**	--	**--**	--	**--**	--	**--**
Deschampsia cespitosa	--	**--**	0.96	**--**	0.97	**--**	--	**--**	--	**--**	--	**--**
Distichiclis spicata	--	**--**	0.96	**--**	--	**--**	--	**--**	4.5	**--**	1.8	**--**
Epilobium spp	--	**0.8**	--	**--**	--	**1.7**	--	**--**	--	**--**	--	**--**
Juncus balticus	--	**4.5**	--	**1.4**	--	**1.3**	--	**--**	--	**--**	0.6	**2.5**
Juncus nevadensis	--	**3.5**	6.7	**4.8**	--	**4.4**	2.9	**0.7**	--	**--**	--	**--**
Juncus orthophyllis	--	**0.7**	--	**--**	--	**--**	--	**--**	--		--	**--**
Lupinus spp.	4.3	**3.4**	3.8	**2.8**	5.8	**6.4**	2.2	**--**	1.1	**0.9**	3.7	**10.1**
Melalotis alba	8.7	**--**	4.8	**--**	0.97	**--**	--	**--**	--	**--**	1.8	**--**
Meticago lupulina	--	**4.2**	--	**1.7**	--	**1.0**	0.7	**--**	--	**--**	--	**--**
Mulch	8.7	**9.1**	9.6	**11.8**	12.6	**18.9**	5	**10.1**	8.5	**6.9**	14.7	**15.5**
Muhlenbergia spp.	4.3	**3.8**	--	**1.0**	--	**0.3**	2.2	**--**	--	**0.4**	2.5	**--**
Oenothera	--	**0.4**	--	**--**	--	**--**	--	**--**	--	**--**	--	**--**
Penstemon spp	--	**--**	--	**--**	--	**1.3**	--	**--**	--	**--**	--	**--**
Phlox	--	**--**	--	**--**	--	**0.3**	--	**--**	--	**--**	--	**--**
Poa pratensis	--	**--**	--	**6.2**	1.9	**0.3**	1.4	**--**	0.6	**--**	0.6	**0.4**
Poa secunda	--	**--**	--	**--**	--	**--**	--	**--**	1.7	**0.7**	--	**--**
Populus trichocarpa	--	**0.8**	0.96	**0.3**	--	**0.7**	--	**4.3**	4.5	**2.2**	12.3	**2.1**
Pursia tridentata	--	**--**	--	**--**	--	**0.3**	--	**0.7**	2.3	**2.6**	--	**4.6**
Rosa woodsii	--	**0.4**	--	**0.3**	0.97	**--**	--	**--**	3.95	**--**	3.1	**--**
Rumex crispus	--	**--**	--	**--**	0.97	**--**	--	**--**	--	**--**	--	**--**
Salix spp.	4.4	**--**	--	**--**	--	**2.4**	--	**2.9**	--	**--**	--	**--**
Salix exigua	13	**8.3**	45.2	**9.3**	23.3	**5.7**	5	**0.7**	2.3	**2.2**	2.5	**--**
Salix exigua (dead)	17.4	**0.4**	--	**0.3**	2	**0.7**	--	**--**	--	**--**	--	**--**
Salix lutea	--	**3.4**	4.8	**4.8**	6.8	**1.3**	--	**0.7**	--	**--**	4.9	**0.4**
Saponaria officianalis	--	**0.8**	--	**2.8**	--	**1.0**	--	**--**	--	**--**	--	**--**
Scripus americanus	--	**3.4**	--	**--**	--	**--**	--	**--**	--	**--**	--	**--**
Solidago spectablis	--	**6.8**	1.9	**5.5**	--	**1.7**	--	**--**	--	**--**	--	**--**
Trifolium longipes	--	**0.4**	--	**0.3**	--	**0.3**	--	**--**	--	**--**	--	**--**
Verbascum thapsus	--	**--**	--	**--**	--	**--**	--	**--**	--	**--**	--	**0.4**
Valeriana californica	--	**--**	--	**--**	2.9	**--**	2.9	**--**	1.1	**--**	--	**--**
Water	13	**21.1**	6.7	**11.4**	6.8	**10.2**	21.6	**8.6**	7.3	**9.1**	6.1	**10.1**

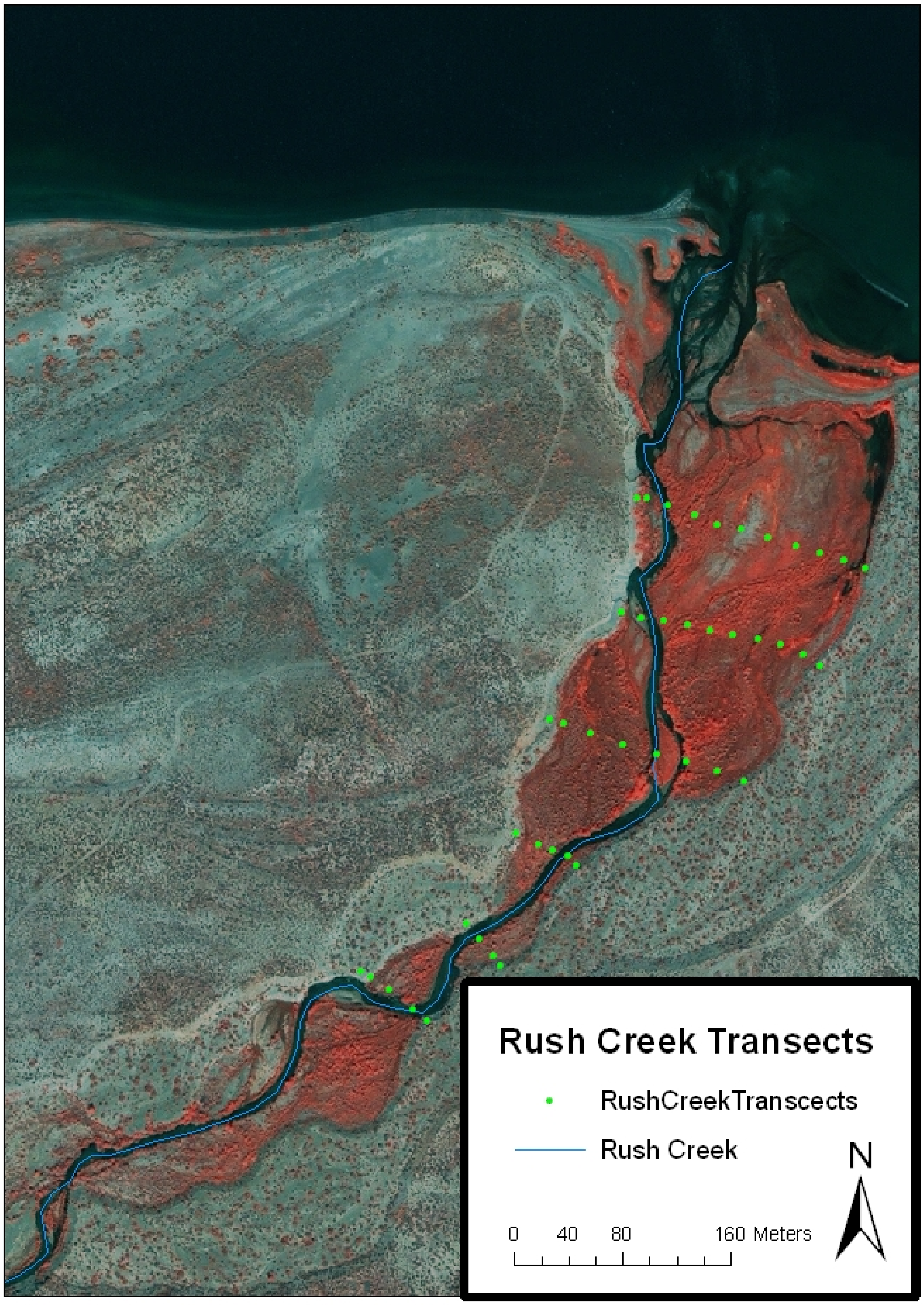


Figure 6. Rush Creek sampling locations.

Table 5. Species list and average cover (%) of each for the Rush Creek Delta vegetation monitoring transects.

	T1		T2		T3		T4		T5		T6	
	99	**05**	99	**05**	99	**05**	99	**05**	99	**05**	99	**05**
Artemesia ludovisciana	--	**--**	--	**--**	--	**--**	--	**--**	--	**---**	1.42	**2.4**
Bare	17	**11**	13.8	**12.6**	16.9	**5.2**	9.5	**8.8**	17.6	**19.1**	21.7	**25**
Carex aquatilis	--	**--**	1.1	**--**	--	**--**	--	**--**	--	**--**	--	**--**
Carex nebrascensis	0.5	**2.9**	--	**5.9**	--	**4.8**	--	**--**	3.9	**--**	2.4	**3.6**
Carex praegracilis	0.5	**--**	--	**--**	0.6	**--**	--	**--**	5.9	**--**	--	**--**
Carex spp	--	**--**	--	**--**	--	**7.4**	--	**5**	--	**--**	--	**--**
Casteleja spp	--	**--**	--	**--**	--	**0.4**	--	**--**	--	**--**	--	**--**
Chrysothamnus nauseosus	--	**--**	--	**--**	1.1	**--**	1.6	**2.5**	2	**3.2**	--	**1.2**
Deschampsia cespitosa	2	**--**	--	**0.4**	--	**--**	--	**--**	--	**--**	--	**--**
Distichiclis spicata	--	**0.4**	--	**--**	--	**--**	--	**2.5**	--	**--**	2.4	**1.2**
Eleocaris spp	--	**1.8**	--	**--**	--	**1.3**	--	**--**	--	**--**	--	**--**
Epilobium ciliatum	--	**0.4**	--	**--**	--	**0.5**	--	**--**	--	**--**	--	**--**
Equsetum avense	--	**0.4**	--	**--**	--	**--**	--	**--**	--	**1.6**	--	**1.2**
Juncus balticus	11	**19.8**	23.8	**27.7**	14.7	**17.4**	12.7	**16.3**	13.7	**15.9**	8.4	**2.4**
Juncus bufonis	1.5	**--**	--	**--**	--	**--**	--	**--**	--	**--**	--	**--**
Juncus longistylus	3.5	**--**	3.3	**--**	2.8	**--**	1.6	**--**	--	**--**	--	**--**
Juncus nevadensis	--	**8.8**	--	**10.9**	--	**13.9**	--	**--**	--	**--**	--	**--**
Lupinus spp.	--	**8.4**	0.6	**---**	1.1	**0.4**	17.5	**11.3**	--	**--**	--	**--**
Mimulus guttatus	--	**1.1**	--	**--**	--	**--**	--	**--**	--	**--**	--	**--**
Mulch	3	**7.3**	2.7	**5**	3.4	**3.9**	--	**7.5**	--	**12.7**	3.6	**4.8**
Muhlenbergia asperina	--	**--**	--	**1.3**	0.6	**3.5**	--	**6.3**	--	**11.1**	--	**--**
Muhlenbergia spp.	3	**2.2**	1.1	**---**	1.2	**--**	--	**--**	--	**--**	--	**--**
Poa patensis	--	--	--	**--**	--	**--**	--	**--**	--	**--**	--	**--**
Poa secunda	--	--	--	**--**	2.3	**--**	--	**--**	--	**--**	--	**--**
Potentilla biennis	0.5	--	--	**--**	--	**--**	--	**--**	--	**--**	--	**--**
Pursia tridentata	--	--	--	**2.1**	0.6	**2.6**	--	**2**	--	**--**	--	**--**
Rosa woodsii	--	--	--	**--**	--	**--**	--	**1.3**	--	**3.2**	--	**--**
Rumex crispus	--	--	--	**0.4**	--	**--**	--	**--**	--	**--**	--	**--**
Salix exigua	32.5	**7.7**	27.8	**13.4**	39.5	**8.7**	39.7	**1.3**	19.6	**1.6**	28.9	**3.6**
Salix exigua (dead)	6	**0.4**	--	**0.4**	--	**3.9**	--	**1.3**	--	**--**	--	**--**
Salix lutea	--	**14.3**	2.8	**8.4**	6.2	**16.1**	--	**8.8**	3.9	**1.6**	--	**3.6**
Salix lutea (dead)	--	**--**	--	**0.4**	----	**0.9**	--	**--**	--	**--**	--	**--**
Scirpus acutus	--	**--**	--	**--**	--	**--**	--	**--**	--	**--**	--	**--**
Salidago spectablis	--	**--**	--	**0.4**	--	**0.9**	--	**5**	--	**--**	--	**--**
Scirpus americanus	--	**4.8**	--	**0.4**	--	**--**	--	**--**	--	**--**	--	**--**
Scirpus microcarpus	--	**--**	--	**--**	--	**--**	--	**--**	--	**--**	--	**--**
Scirpus nevadensis	--	**1**	--	**--**	--	**0.9**	--	**--**	--	**--**	--	**--**
Sheperdia argentea	--	**--**	--	**--**	--	**--**	--	**--**	--	**--**	--	**1**
Tamarix rammosisima	0.5	**--**	--	**--**	--	**--**	--	**--**	3.9	**--**	--	**--**
Triglochin maritimus	0.5	**0.7**	0.6	**--**	--	**--**	--	**--**	--	**--**	--	**--**
Un-Identified Annual Forb	0.5	**1.1**	--	**1.1**	--	**2.1**	--	**--**	--	**3**	--	**--**
Verbascum thapsus	--	**--**	--	**--**	--		--	**1.3**	--	**--**	--	**--**
Water	17.5	**5.5**	22.2	**9.2**	8.5	**5.2**	15.9	**18.8**	29.4	**27**	31.3	**50**

Analysis

For each site, average cover by species was calculated for both 1999 and 2005 utilizing data from all transects samples at a site during that particular year. These values were then used to calculate indices of community similarity. These indices allow us to compare how similar or dissimilar the communities are between the sampling periods. Two different indices were selected, the Proportional Similarity Index (PS) and Morisita's Index. The Proportional Similarity Index yields a percent score indicating how similar the two communities are. Morisita's index indicates that probability that two randomly selected individuals from a community at two different times will be the same species. Scores range for 0.0 to 1.0, with a score of 0.0 indicating the two periods are vastly different and a score of 1.0 indicating they are identical. Results are presented in Table 6.

Table 6. Indices of community similarity for the Mono Basin lake fringing wetlands and tributary deltas.

Site	Proportional Similarity	Morisita's Index
Rush Creek	0.70	0.58
Lee Vining Creek	0.95	0.80
Dechambeau	0.31	0.29
Sammon Springs	0.64	0.15
Warm Springs	0.91	1.0

Discussion

Succession is a natural process describing the sequential changes in plant and animal communities. Succession may be affected by external processes, such as a change in water levels, or internal processes in which each new community creates an environment favorable for colonization by other plant and animal species. During succession, the diversity of plant species generally increases, the height and size of the dominant plant species generally increases, and the size of the plant seeds generally increases. Wetlands are dynamic with species and community composition reflecting changing water levels. Part of the diversity of wetlands is dependent upon this dynamic change.

Comparisons for each of the Mono Basin sites indicate that changes are occurring at some sites while very little change is occurring on others. There have been very minimal changes in the vegetation community for both Warm Springs and the Lee Vining Creek delta. There have been a few changes at Dechambeau and the Rush Creek delta areas. There have substantial changes at Sammon Springs.

Changes observed at the Sammon Springs location are not surprising. Prior to the initial sampling conducted in 1999, the area had been burned two consecutive years as part of the State Parks controlled burning program in the basin. Vegetation changes are a result of the sampling area recovering from those burns.

The changes observed at Dechambeau are not surprising either. During the initial sampling, the was an abundance of *Hordeum jubatum* sampled along both the second and third transects. This species is considered early successional. By 2005, *Scirpus americanus* a later successional species dominated in these transects areas which are closer to the lake edge.

The Rush Creek changes are most likely due to changes resulting that have occurred in the Delta area between the two sampling periods. The changes are evident on Figure 8 and Figure 9. There may also be some differences due to sampling technique. Permanent transects markers were not established because the area is a popular recreation area. Therefore, when sampling was conducted, a GPS unit recorded the sampling route. Utilizing this same method in 2005 likely resulted in some "straying" from the original course which could have resulted in differences. This may also be the cause of differences observed in Lee Vining Creek, although the changes were smaller than those observed for Rush Creek.

Analysis of the Warm Springs data indicated almost no change between the two sampling periods. This is not surprising since there has been little in the way of disturbance at the site. The site is dominated by few species, and they are later successional species.

Lake Fringing Wetland Mapping

The aerial photography and examination of vegetation mapping of Mono Basin waterfowl habitat was comprised of three separate steps. Methods of each step were fully described in the 1999 Mono Basin Vegetation and Habitat Mapping Report (LADWP 1999). The satellite imagery for the project was obtained between July 10 and August 20 2005. Space Imaging acquired satellite imagery from their IKONOS platform at a resolution of 0.8 meters in true color as a single 4-band (red, green, blue, near infra-red). These four bands were collected simultaneously with identical look angles, and were precisely registered. The scale of the photography was 1:24000 or 1" = 2000'.

In 1999, a GIS database was developed from the 1999 imagery using ESRI ArcView software. ESRI's new ARCMAP software was used to compare vegetation and waterfowl habitat conditions between 1999 (Fig. 7) and 2005 (Fig. 8). The two years of aerial photography were layered 2005 over 1999. When the images are layered in this fashion, the view can be toggled back and forth between the two. The vegetation cover class polygons developed from the 1999 imagery were then layered on the 2006 imagery. The edges of the polygons were examined to determine if there was a match between the image and the polygon. If there were any questionable edges, the polygon was viewed over the 1999 imagery to determine if the differences were due to differences in the imagery or vegetation change (Figures 8 and 9). In some cases, the edge of a polygon did not appear to line up with a visible vegetation boundary. However, when the 1999 image was viewed, the boundary became more obvious and understandable when viewed over the 2005 image. A number of large discrepancies were apparent between 1999 and 2006. These were almost entirely in the lake fringing areas and are not surprising considering the changes that have occurred in lake elevation between the two sampling periods. New vegetation polygons have been developed for these areas. Ground truthing these polygons will be conducted during the 2006 growing season and the results of the mapping will be reported in the 2006 annual monitoring report, May 2007.

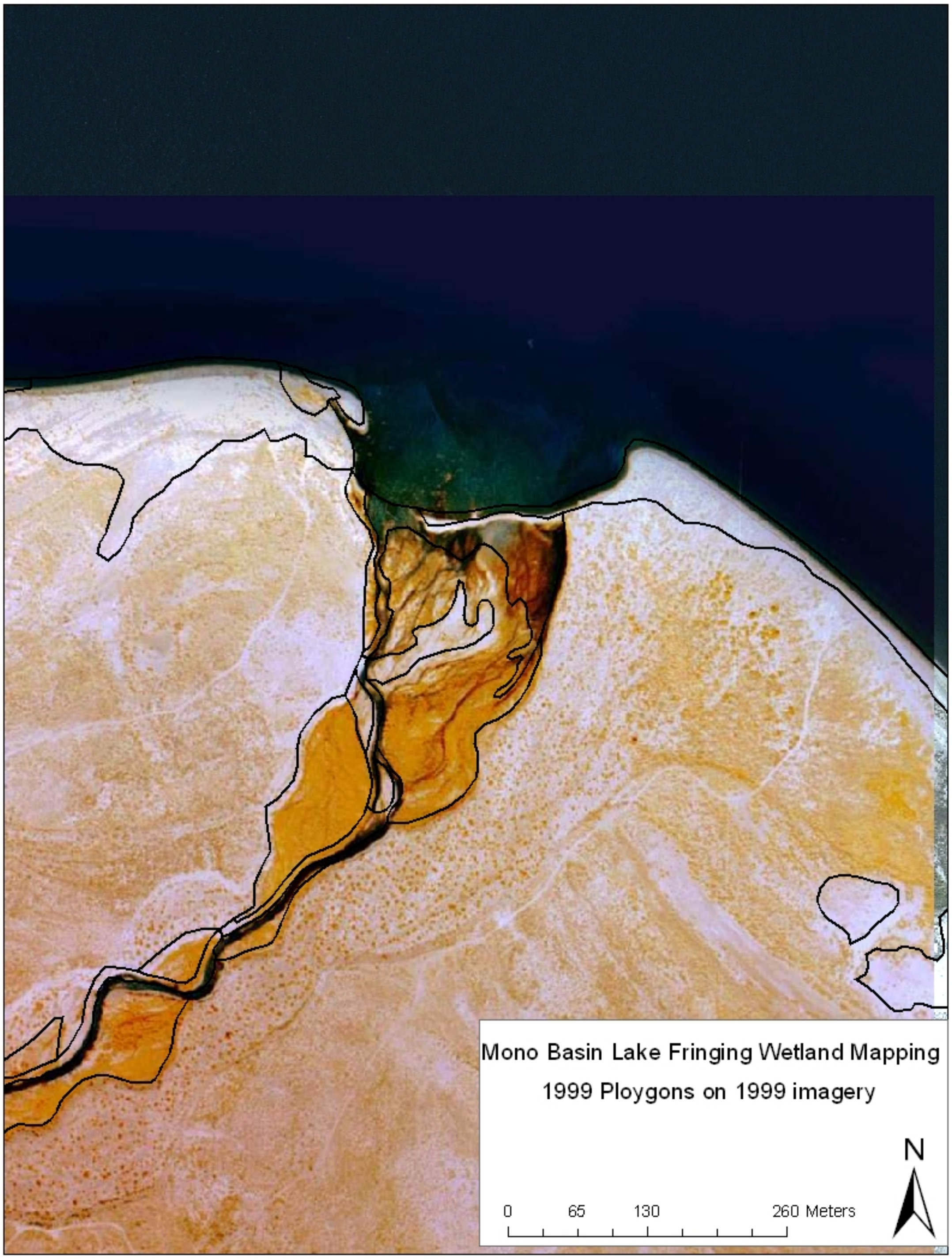


Figure 8. Vegetation polygons for the Rush Creek delta area as seen on the 1999 aerial imagery.

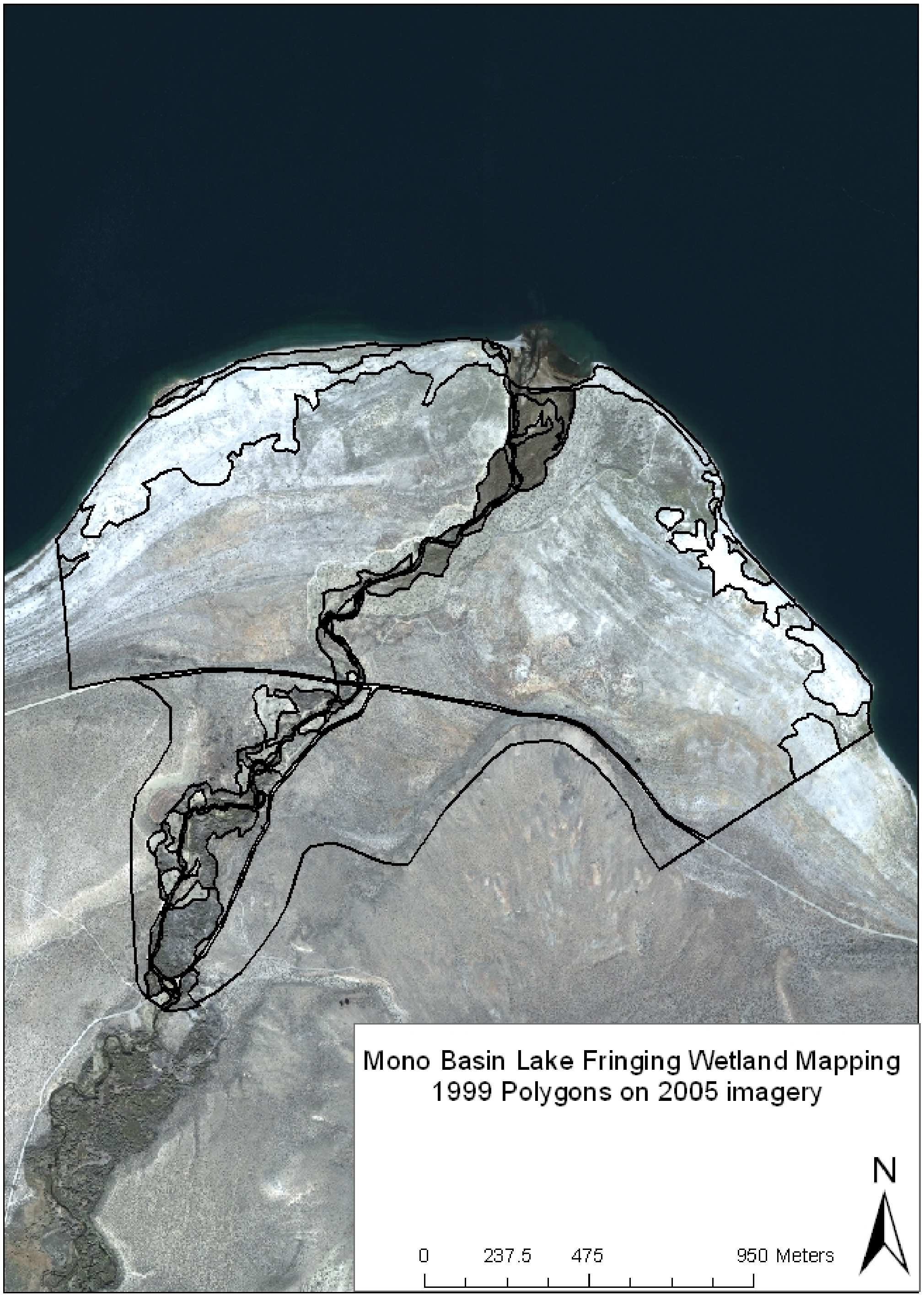


Figure 9. Vegetation polygons from 1999 for the Rush Creek delta area as seen on the 2005 aerial imagery.

Salt Cedar Control

Annual surveys for salt cedar have continued in the lake fringing wetlands and the riparian areas along all of the tributaries to Mono Lake. Two large trees have been stump cut and treated during the last two years, one on Lee Vining Creek above County Road and one in the County Park area. No other trees have been located. The Forest Service also removed salt cedar from a number of locations throughout the Mono Basin (Reis pers. comm..).

Additional Vegetation Monitoring

In 1999, two overflow channels in reach 3A of Rush Creek that were blocked by artificial berms were re-opened. A single side channel in reach 3B was also opened. Surveys of these openings has been conducted annually. Monitoring results indicate that natural re-establishment of riparian vegetation is occurring. No plantings of willow or cottonwoods are necessary at either site. Although not necessary, some cottonwood plantings in reaches 3A and 3B would accelerate the process. John Bair of McBain and Trush has determined suitable planting locations for Jeffery Pine seedlings in the vicinity of the opening in reach 3B. The map has been included in McBain and Trush's annual report.

The Stream Restoration Plan also indicated that a riparian planting program may be necessary for Parker and Walker Creeks between old and new highway 395. Annual surveys of both creeks indicate that natural recruitment and establishment is ongoing. No additional revegetation efforts are necessary for these streams.

Appendix 1

Mono Basin Delta Photos (2005)—Lee Vining Creek

Lee Vining T1-N

Lee Vining T2-S

Lee Vining T1-S

Lee Vining T2-N

Mono Basin Delta Photos (2005)—Lee Vining Creek

Lee Vining T3-N

Lee Vining T4-S

Lee Vining T3-S

Lee Vining T4-N

Mono Basin Delta Photos (2005)—Lee Vining Creek

Lee Vining T5-N

Lee Vining T6-S

Lee Vining T5-S

Lee Vining T6-N

Mono Basin Delta Photos (2005)—Rush Creek

Rush Creek T1-W

Rush Creek T2-E

Rush Creek T1-E

Rush Creek T2-W

Mono Basin Delta Photos (2005)—Rush Creek

Rush Creek T3-W

Rush Creek T4-E

Rush Creek T3-E

Rush Creek T4-W

Mono Basin Delta Photos (2005)—Rush Creek

Rush Creek T5-W

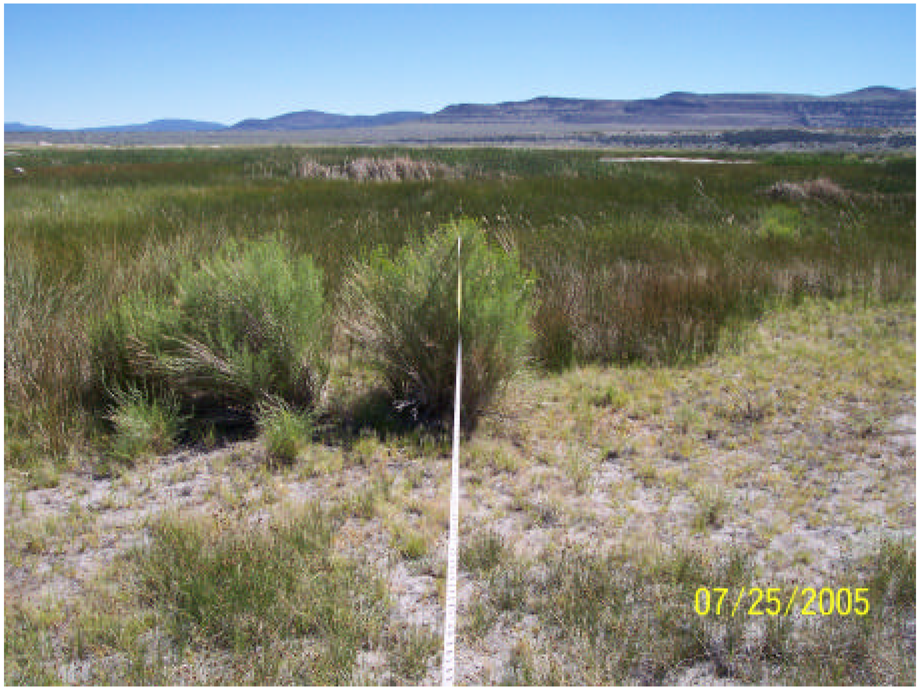
Rush Creek T6-E

Rush Creek T5-E

Rush Creek T6-W

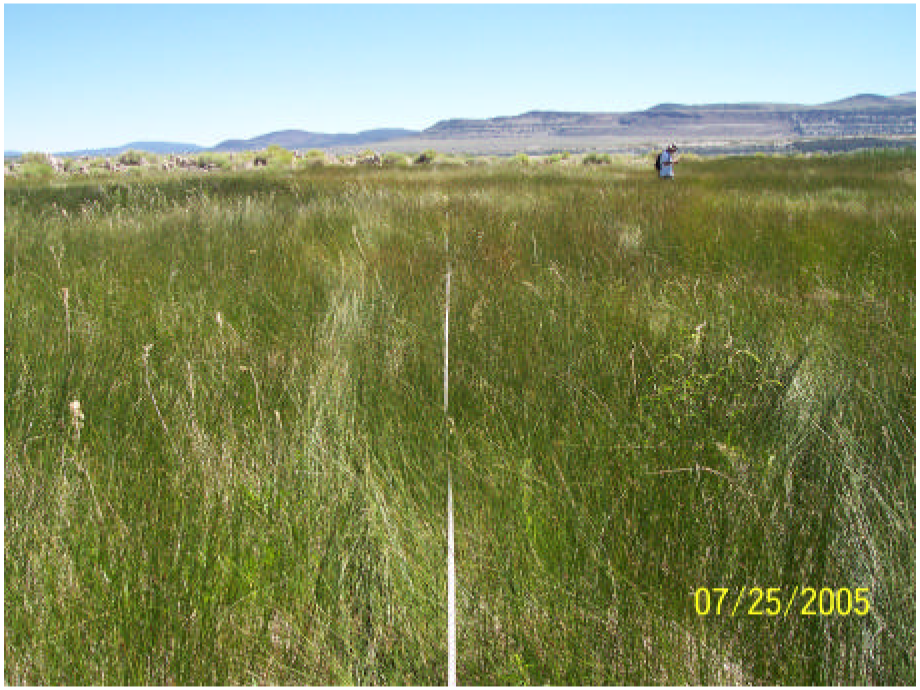
Mono Basin Wetland Photos (2005)—Sammon Springs

Sammon S-E



Sammon M-W

Sammon S-W



Sammon N-W

Mono Basin Wetland Photos (2005)—DeChambeau

N0_S50

N50_S50

N100_N50

M0_S50

M37.5_S50

M75_S50

S0_S50

S25_N50

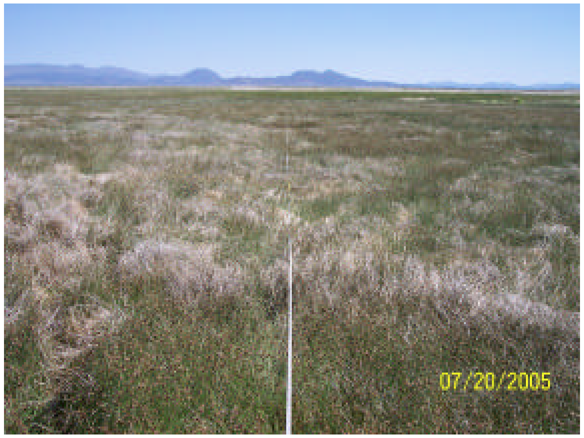
S50_N50

Mono Basin Wetland Photos (2005)—Warm Springs

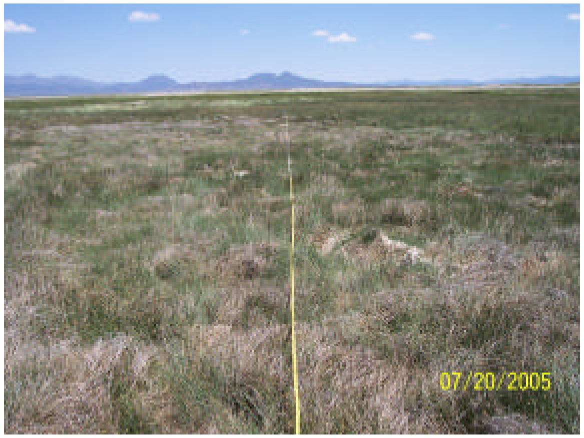
N250N

N200S

N100S

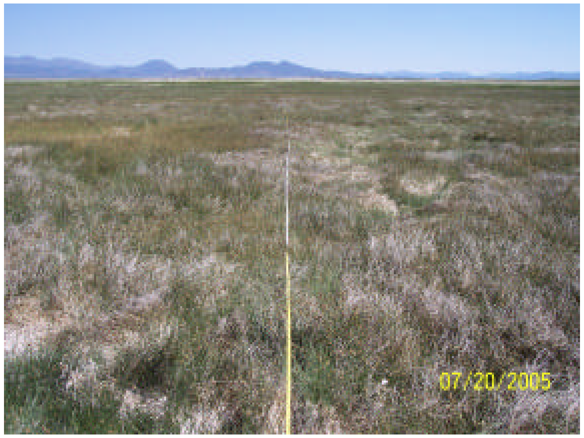


M250N

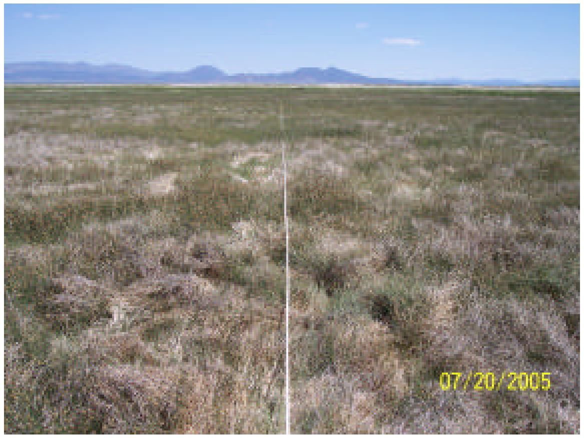


M200N

M100S



S225N

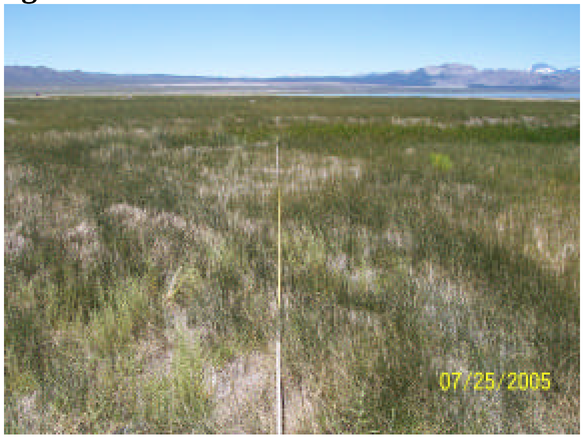


S200N

S100S

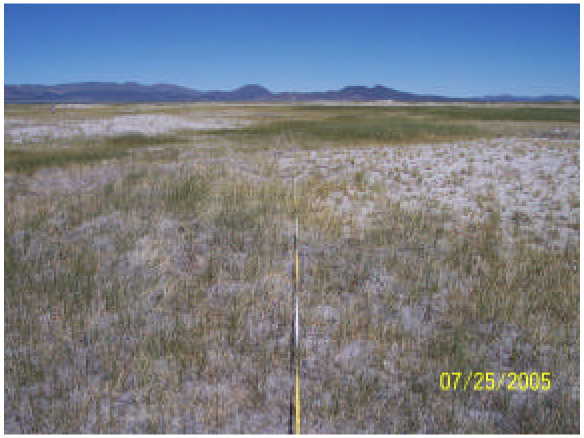
Mono Basin Wetland Photos (2005)—Warm Springs

N0S

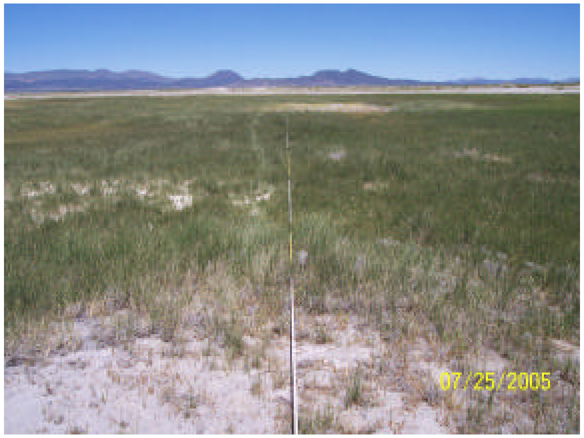


N100+S

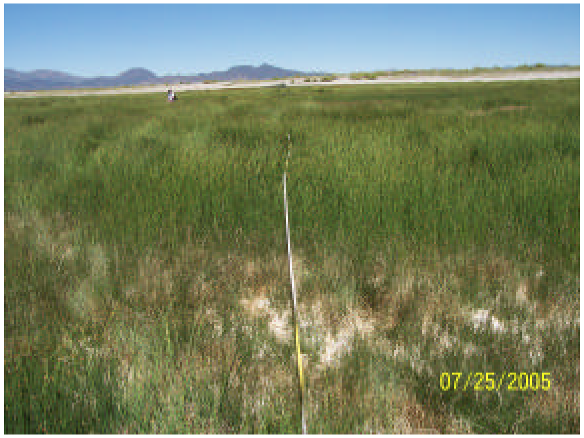
N200+S



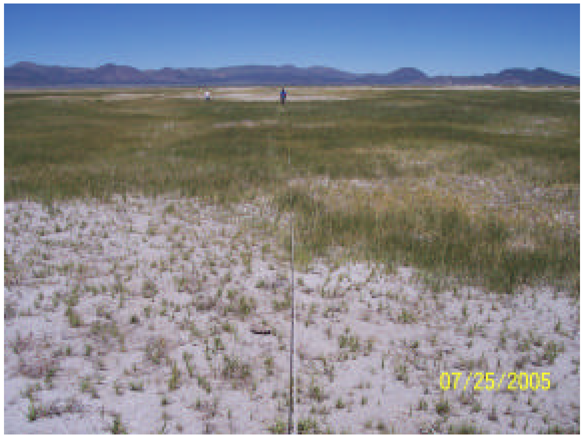
M0N



M100+N



M200+N



S0N

S100+S

S200+S