Los Angeles Department of Water & Power

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May 10, 2018

Mr. Erik Ekdahl, Deputy Director
Division of Water Rights
State Water Resources Control Board
1001 I Street, 14th Floor
Sacramento, California 95814

Dear Mr. Ekdahl:

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 No. 1631 and Order Nos. 98-05 and 98-07 (Orders) 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 compact disc (CD) containing a submittal, "Compliance Reporting May 2018", which contains the following four reports required by the Orders. The reports are as follows:

- Section 2: Mono Basin Operations: Runoff Year (RY) 2017-18 and Planned Operations for RY 2018-19.
- Section 3(a): Mono Basin Fisheries Monitoring Report: Rush, Lee Vining, Parker, and Walker Creeks for RY 2017-18.
- Section 4(a): Stream Monitoring Report RY 2017-18.
- Section 5: Mono Basin Waterfowl Habitat Restoration – 2017 Compliance and Periodic Overview Report.

In addition to these reports, the submittal also includes Section 1: the RY 2017-18 Status of Restoration Compliance Report, which summarizes the status of LADWP's compliance activities in the Mono Basin to date and planned activities for the upcoming runoff year. We have also added two reports prepared by LADWP staff, as Sections 3(b) and 4(b), to the Mono Basin Fisheries Monitoring Report, and the Stream Monitoring Report, listed above, respectively, as supplemental information.

The filing of these reports, along with the restoration and monitoring performed by LADWP in the Mono Basin, fulfills LADWP's requirements for RY 2017-18, as set forth in Decision No. 1631 and the Orders.

Electronic copies of the submittal on CD will be provided to the interested parties listed on the enclosed distribution list. Hard copies of the submittal will be provided upon request.

If you have any questions, please contact Dr. Paul C. Pau, Eastern Sierra Issues Supervisor, at (213) 367-1187.

Sincerely,

Anselmo G. Collins
Director of Water Operations

PCP:jem
Enclosures
c/enc: Distribution List
Dr. Paul C. Pau

Mono Basin Distribution List
Runoff Year 2018-19

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

COMPLIANCE REPORTING

Mono Basin Operations
Fisheries Monitoring
Stream Monitoring
Waterfowl & Limnology Monitoring

May 2018

Los Angeles Department of Water and Power

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AVERY® READY INDEX® DIVIDERS

Section 1

Status of Restoration Compliance Report

Status of Restoration Compliance Report (SORC)

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

May 2018

Los Angeles Department of Water and Power

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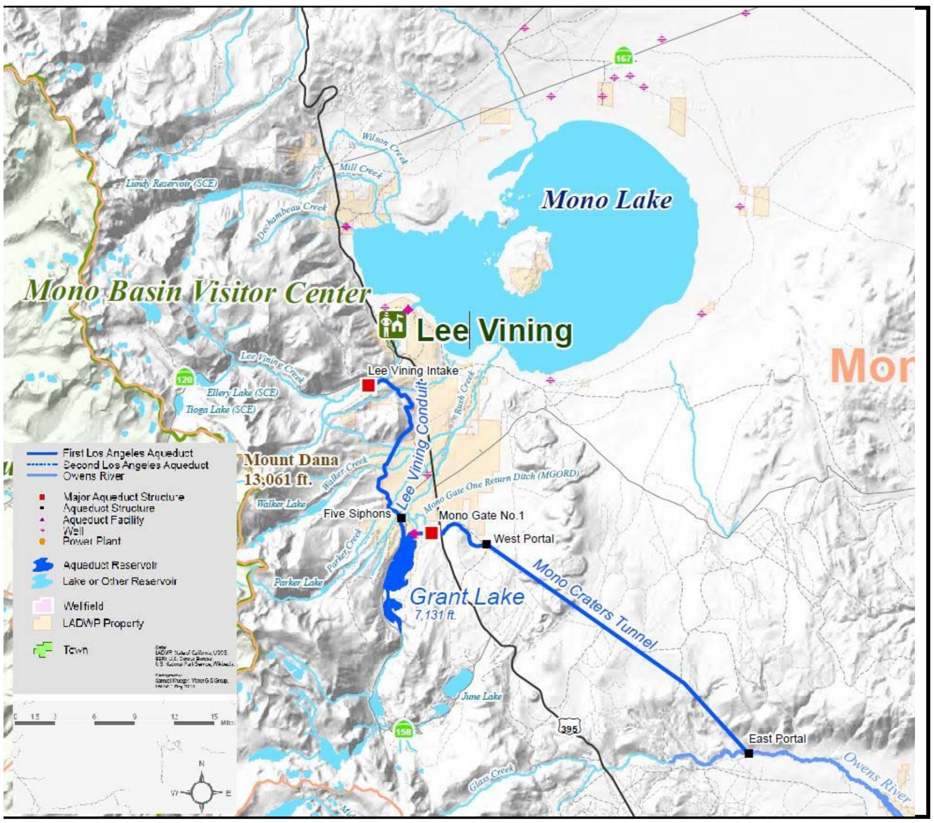
Introduction

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 stream flows, and to restore and monitor the fisheries, stream channels, and waterfowl habitat. This chapter includes the Status of Restoration Compliance Report, which summarizes the status of LADWP compliance activities in the Mono Basin to date. It is expected that the Water Board will amend LADWP's water rights license. Following SWRCB adoption of the amended license, the new requirements will be reflected in future SORC Reports.

Figure 1: Map of Mono Basin showing major Streams and LADWP facilities.



Status of Restoration Compliance Report

This document was first submitted as draft to the interested parties on April 1, 2018. It was developed to include a 21 day review period during which LADWP will review and address comments submitted by the interested parties. Following the 21 day review period, LADWP will finalize it as part of the May 2018 Status of Restoration Compliance Report as below.

Status of Restoration Compliance Report
State Water Resource Control Board Decision 1631 and Order Nos. 98-05 & 98-07

The Status of Restoration Compliance Report ("SORC Report") is organized into the following sections:

1. **Introduction** – Description of the SORC Report
2. **Definitions** – Explanations of what each category represents
3. **Updates from Previous SORC Report** – Changes over the past year
4. **Plans for the Upcoming Runoff Year** – Planned activities for the upcoming year
5. **Requirements** – Categories of the entire list of LADWP's requirements in the Mono Basin
6. **Completion Plans** – Long term plans for completing all requirements
7. **Ongoing Items Definitions** – Ongoing activities necessary for LADWP operations in the Mono Basin.

1. Introduction:

The SORC Report details the status of the Los Angeles Department of Water and Power's (LADWP) restoration requirements in the Mono Basin as outlined by the State Water Resources Control Board (SWRCB) Decision 1631 and Order Numbers 98-05 and 98-07, and any subsequent decision letters distributed by the SWRCB. This initial structure and content of the SORC report was cooperatively prepared by LADWP and the Mono Lake Committee (MLC) through an extensive series of staff discussions and a workshop held in the Mono Basin in August 2005. LADWP and MLC believe this report represents the most thorough and complete listing of Mono Basin restoration requirements and their current status available in a unified document. These requirements are categorized as ongoing, complete, in progress, incomplete or deferred as defined below in Section 2. The final section of the SORC Report details how LADWP plans to proceed with those items not listed as ongoing or completed (i.e. items in progress, incomplete, and/or deferred).

The SORC Report will be submitted by LADWP to SWRCB as part of the annual Compliance Reporting. By April 1 each year, LADWP will update and submit a draft SORC Report to the interested parties. Within 21 days of the draft submission, LADWP will accept comments on the draft SORC Report from the interested parties. Then, LADWP will finalize the SORC Report, incorporating and/or responding to comments. The final SORC Report will then be included into the final Compliance Reporting to SWRCB by May 15 of each year.

It is expected that the Water Board will amend LADWP's current water rights license following a CEQA analysis of proposed actions related to the Mono Basin settlement agreement. The new requirements are expected to take effect immediately after the Water Board issues an order, and those new requirements will be reflected in future SORC Reports. Any items no longer relevant under the new order will be moved to a new category "Eliminated" in the SORC. The new SORC will show both a new numbering system for all active items as well as the old numbering system for cross reference. Once agreement is reached on the items in the "eliminated" category, those items as well as the old numbering will no longer be shown in future SORC Reports.

2. Definitions:

Below are the definitions of the categories where each requirement has been grouped.

A. <u>Ongoing</u> Items that are current and require continuous action (e.g. Maintain road closures in floodplains of Rush and Lee Vining Creeks)
B. <u>Complete</u> Items that have been finalized (e.g. Rehabilitation of the Rush Creek Return Ditch)
C. <u>In-Progress</u> Items started and not yet finalized because of time or the timeline extends into the future (e.g. Waterfowl monitoring and reporting)
D. <u>Incomplete</u> Items not yet started or not complete because plans for completion not finalized.
E. <u>Deferred</u> Items placed on hold which need input from the Stream Scientists and/or SWRCB before plans commence (e.g. Prescribed burn program)

3. Updates from Previous SORC Report:

Since the last SORC Report of May 15, 2017, there has been no change to the report and Section 4, the Plans for Runoff Year RY2017-18, will apply to RY2018-19.

4. Plans for the Upcoming Runoff Year:

During the upcoming runoff year, RY2018-19, LADWP plans to:

1. Continue with all requirements listed under Category A – Ongoing Items, as needed based on the runoff year.
2. Continue Category C – In-Progress Items C17 "Sediment Bypass for Parker Creek". Sediment bypass will continue in the next non-Dry RY.
3. Continue Category C – In-Progress Items C18 "Sediment Bypass for Walker Creek". Sediment bypass will continue in the next non-Dry RY.

5. Requirements:

This section lists and categorizes the individual requirements based on the status of each item. The requirements are derived from SWRCB Decision 1631, and/or Order Nos. 98-05 and 98-07, and/or any subsequent decision letters distributed by SWRCB. The requirements are either described in the cited section of the order and/or are described in the cited page of the specified plan and/or document (Stream Plan, Waterfowl Plan, GLOMP, etc.) that the Order references, and/or detailed in the SWRCB letter. Plans for completing in-progress, incomplete, and deferred items are further explained in Section 6, Completion Plans. Finally, plans for those items described as ongoing are detailed in Section 7, Ongoing Items Description.

<u>Category A – Ongoing Items</u>

1. Maintain road closures in floodplains of Rush and Lee Vining Creeks – *Stream Work*
   Order 98-05 order 1; Stream Plan p. 71-75

2. Base flow releases – *Stream Management*
   Order 98-05 order 2.a.; GLOMP p. 2, table A

3. Low winter flow releases – *Stream Management*
   Order 98-05 order 2.b.

4. Annual operations plan – *Stream Management*
   Order 98-05 order 3; GLOMP p. 103, 104

5. Notification of failure to meet required flows – *Stream Management*
   Order 98-05 order 3

6. Grant operations and storage targets – *Stream Management*
   Order 98-05 order 1.a.; Decision 1631 order 1; GLOMP p. 84

7. Amount and pattern of export releases to the Upper Owens River – *Stream Management*
   Order 98-05 order 2; Decision 1631 order 7; GLOMP p. 84, 85

8. Diversion targets from streams – *Stream Management*
   Order 98-05 order 2; GLOMP p. 85

9. Export amounts dependent on Mono Lake level – *Stream Management*
   Decision 1631 order 6

10. Year type designation and guidelines – *Stream Management*
    Order 98-05 order 2; Decision 1631 order 3; GLOMP p. 87-96

11. Dry and wet cycle contingencies for stream restoration flows and base flows – *Stream Management*
    Order 98-05 order 2; GLOMP p. 97

12. Deviations from Grant Lake Operation Management Plan (GLOMP) – *Stream Management*
    Order 98-05 order 2; GLOMP p. 98, 99

13. Ramping rates – *Stream Management*
Order 98-05 order 2; Decision 1631 order 2; GLOMP p. 90-96

14. Stream restoration flows and channel maintenance flows – *Stream Management*
Order 98-05 order 1.a.

15. Salt Cedar eradication – *Waterfowl*
Order 98-05 order 4.e.; Waterfowl Plan p. 27

16. Aerial photography every five years or following an extreme wet year event – *Monitoring*
Order 98-05 order 1.b; Stream Plan p. 103

17. Make basic data available to public – *Monitoring*
Order 98-05 order 1.b as revised by Order 98-07; Order 98-07 order 1.b(2); Stream Plan p. 110

18. Operation of Lee Vining sediment bypass – Stream Facility Modifications
Order 98-05 order 2

19. Operation of the Rush Creek augmentation from the Lee Vining Conduit when necessary – *Stream Management*
Order 98-05 order 2

20. Make data from all existing Mono Basin data collection facilities available on an internet web site on a same-day basis – *Stream Management*
Order 98-05 order 2.c

Category B – Completed Items

1. Placement by helicopters of large woody debris into Rush Creek, completed fall 1999 – *Stream Work*
Order 98-05 order 1; order 1.d.; Stream Plan p. 67, 68

2. Placement by helicopters of large woody debris into Lee Vining Creek, completed fall 1999 – *Stream Work*
Order 98-05 order 1; order 1.d.; Stream Plan p. 67, 68

3. Rewater Rush Creek side channels in reach 3A, completed fall 1999 – *Stream Work*
Order 98-05 order 1; Stream Plan p. 68-71

4. Rewater Rush Creek side channel in reach 3B, completed fall 1999 with changes (see LADWP annual Compliance Reporting, May 2000) – *Stream Work*
Order 98-05 order 1; Stream Plan p. 68-71

5. Rewater Rush Creek side channel in reach 3D, completed fall 2002 with changes (see LADWP annual Compliance Reporting, May 2003) – *Stream Work*
Order 98-05 order 1; Stream Plan p. 68-71

6. Revegetate approximately 250 Jeffrey Pine trees on Lee Vining Creek, completed in 2000 – *Stream Work*
   Order 98-05 order 1; Stream Plan p. 71-75

7. Revegetate willows on Walker Creek. No planting necessary in judgment of LADWP and MLC as area revegetated rapidly without intervention – *Stream Work*
   Order 98-05 order 1; Stream Plan p. 71-75

8. Revegetate willows on Parker Creek. No planting necessary in judgment of LADWP and MLC as area revegetated rapidly without intervention – *Stream Work*
   Order 98-05 order 1; Stream Plan p. 71-75

9. Limitations on vehicular access in Rush and Lee Vining Creek floodplains, completed fall 2003 – *Stream Work*
   Order 98-05 order 1; Stream Plan p. 78-80

10. Removal of bags of spawning gravel, completed fall 2003 – *Stream Work*
    Order 98-05 order 1; Stream Plan p. 85, 86

11. Removal of limiter logs, completed 1996 – *Stream Work*
    Order 98-05 order 1; Stream Plan p. 86

12. Removal of Parker Plug, completed by California Department of Transportation 2000 – *Stream Work*
    Order 98-05 order 1; Stream Plan p. 87

13. Sediment bypass facility for Lee Vining Creek, completed winter 2005 – *Stream Facility Modifications*
    Order 98-05 order 1.f.

14. Flood flow contingency measures, completed by California Department of Transportation's Highway 395 improvements in 2002 – *Stream Management*
    Order 98-05 order 1; Stream Plan p. 76

15. Stream monitoring site selection, completed 1997 – *Monitoring*
    Order 98-05 order 2; Stream Plan p. 109

16. Waterfowl and limnology consultants, completed 2004 – *Monitoring*
    Order 98-05 order 4; Waterfowl Plan p. 27-29

17. Status report on interim restoration in Mono Basin, completed 2006 – *Other*
    Decision 1631 order 8.d (3)

18. Cultural resources investigation and treatment plan report to SWRCB, completed 1996 – *Other*
    Decision 1631 order 9, 10

19. Revegetate or assess the need to revegetate Rush Creek side channels in reach 3A five years after rewatering, assessed annually and reported in May 2006 Monitoring Report – *Stream Work*
Order 98-05 order 1; Stream Plan p. 71-75

20. Revegetate or assess the need to revegetate Rush Creek side channels in reach 3B five years after rewatering, assessed annually and reported in May 2006 Monitoring Report – *Stream Work*
Order 98-05 order 1; Stream Plan p. 71-75

21. Revegetate or assess the need to revegetate Rush Creek side channel in reach 3D and reported in May 2008 Monitoring Report – *Stream Work*
Order 98-05 order 1; Stream Plan p. 71-75

22. Rewater Rush Creek side channel 11 in reach 4C. Final review was conducted by the Stream Scientists. After presentation of the final review, LADWP followed the recommendations of the Stream Scientists not to do any action on the channel. This item is now approved by SWRCB and is therefore considered completed in 2008. – *Waterfowl*
Order 98-05 order 4.a., order 4.d.; Waterfowl Plan p. 22

23. Rewater Rush Creek side channel 14 in reach 4C. Final review was conducted by the Stream Scientists. After presentation of the final review, LADWP followed the recommendations of the Stream Scientists not to do any action on the channel. This item is now approved by SWRCB and is therefore considered complete in 2008. – *Stream Work*
Order 98-05 order 1; Stream Plan p. 68-71

24. Revegetate or assess the need to revegetate Rush Creek side channel 11 in reach 4C for five years following rewatering. LADWP followed the recommendations of the Stream Scientists not to do any action on the channel. This item is now approved by SWRCB and is therefore considered completed in 2008. – *Waterfowl*
Order 98-05 order 4.a., order 4.d.; Waterfowl Plan p. 22

25. Revegetate or assess the need to revegetate Rush Creek side channel 14 in reach 4C for five years after rewatering. LADWP followed the recommendations of the Stream Scientists not to do any action on the channel. This item is now approved by SWRCB and is therefore considered completed in 2008. – *Stream Work*
Order 98-05 order 1; Stream Plan p. 68-71

26. LADWP and MLC were to cooperatively revegetate pine trees on areas of Rush Creek and Lee Vining Creek including disturbed, interfluve, and upper terrace sites targeted from reach 3B through 5A on Rush Creek. In 2005, remaining suitable areas were assessed resulting in a map showing those areas where planting pine trees may be successful and would add to habitat complexity. LADWP and MLC investigated locations suitable for planting by LADWP and MLC staff and volunteers. Acceptable Jeffrey Pine seedlings were procured by LADWP and were planted by MLC and volunteers on all available suitable sites. This item is

considered complete and is moved to Category B "Completed Items." However, MLC may continue to water these seedlings. MLC may also plant cottonwoods with volunteers as opportunities arise – Stream Work Order 98-05 order 1; Stream Plan p. 71-75

27. Rewater Rush Creek side channel 8 in reach 4B, completed March 2007 – *Waterfowl.* The further rewatering of Rush Creek side channel complex 8 in reach 4B was deferred by the Stream Scientists. Final review is being conducted by McBain and Trush. After presentation of the final review, LADWP followed the recommendations of the Stream Scientists and SWRCB has approved the plan *Order 98-05 order 4.a., order 4.d; Waterfowl Plan p. 22*

28. Rehabilitation of the Rush Creek Return Ditch, completed 2002 – *Stream Facility Modifications.* Since then, vegetation growth has slightly reduced ditch capacity. To restore maximum capacity of 380 cfs, the return ditch embankments were raised.
Order 98-05 order 1, order 1.c.; Stream Plan p. 85, appendix III

<u>Category C – In-Progress Items</u>

1. Placement by hand crews of large woody debris into Rush Creek on an opportunistic basis based on stream monitoring team recommendations – *Stream Work*
Order 98-05 order 1; order 1.d.; Stream Plan p. 67, 68

2. Placement by hand crews of large woody debris into Lee Vining Creek on an opportunistic basis based on stream monitoring team recommendations – *Stream Work*
Order 98-05 order 1; order 1.d.; Stream Plan p. 67, 68

3. Grazing moratorium for 10 years, assessed annually and status reported in May 2009 Monitoring Report. Grazing moratorium to continue until further notice. – *Stream Management*
Order 98-05 order 1; Stream Plan p. 83

4. Grant Lake Operation Management Plan (GLOMP) preparation for revisions – *Stream Management*
Order 98-05 order 2; GLOMP p. 103, 104

5. Waterfowl project funding – *Waterfowl*
Order 98-05 order 4.b.

6. Salt Cedar eradication reporting– *Waterfowl*
Order 98-05 order 4.e.; Waterfowl Plan p. 27

7. Stream monitoring team to perform duties – *Monitoring*
Order 98-05 order 1.b as revised by Order 98-07

8. Stream monitoring reporting to the SWRCB – *Monitoring*

Order 98-05 order 1.b as revised by Order 98-07; Order 98-07 order 1.b(2); Stream Plan p. 110

9. Development, approval, and finalization of stream monitoring termination criteria for Walker and Parker Creeks – *Monitoring Order 98-07*

10. Development, approval, and finalization of stream monitoring termination criteria for Lee Vining and Rush Creeks – *Monitoring*
    Order 98-07

11. Hydrology monitoring and reporting – *Monitoring*
    Order 98-05 order 4; Waterfowl Plan p. 27

12. Lake limnology and secondary producers monitoring and reporting – *Monitoring*
    Order 98-05 order 4; Waterfowl Plan p. 27, 28

13. Riparian and Lake fringing wetland vegetation monitoring and reporting – *Monitoring*
    Order 98-05 order 4; Waterfowl Plan p. 27, 28

14. Waterfowl monitoring and reporting – *Monitoring*
    Order 98-05 order 4; Waterfowl Plan p. 28; LADWP's 2004 "Mono Lake Waterfowl Population Monitoring Protocol" submitted to SWRCB on October 6, 2004

15. Testing the physical capability for Rush Creek augmentation up to 150 cfs from the Lee Vining Conduit through the 5-Siphon Bypass facility – *Stream Management*
    Order 98-05 order 2; GLOMP p. 82, 83

16. Evaluation of the effects on Lee Vining Creek of Rush Creek augmentation for diversions up to 150 cfs through the Lee Vining Conduit – *Monitoring*
    Order 98-05 order 1.b.

17. Sediment bypass for Parker Creek – *Stream Facility Modifications*
    Order 98-05 order 1.f.

18. Sediment bypass for Walker Creek – *Stream Facility Modifications*
    Order 98-05 order 1.f.

<u>Category D – Incomplete Items</u>

None

<u>Category E – Deferred Items</u>

1. Recommend an Arizona Crossing or a complete road closure at the County Road Lee Vining Creek, if and when Mono County plans to take action – *Stream Work*
   Order 98-05 order 1; Stream Plan p. 78-80

2. Fish screens on all irrigation diversions – *Stream Facility Modifications Order 98-05 order 1; Stream Plan p. 84*

3. Prescribed burn program – *Waterfowl Order 98-05 order 4.b.(3)c.; Waterfowl Plan p. 25, 26*

4. Rewatering of Rush Creek side channel 1A in reach 4A.– *Stream Work Order 98-05 order 1; Stream Plan p. 68-71*

5. Assessing the need to revegetate the areas affected by the side channel openings for Rush Creek side channel 1A in reach 4A – *Stream Work; Order 98-05 order 1; Stream Plan p. 68-71*

6. Assessing the need to revegetate the areas affected by the side channel openings for Rush Creek side channel 4Bii in reach 4B. – Stream Work Order 98-05 order 1; Stream Plan p. 68-71

7. Assessing the need to revegetate the areas affected by the side channel openings for Rush Creek side channel 8 in reach 4B.

8. Stream monitoring for 8-10 years to inform peak flow evaluation and recommendations including the need for a Grant Lake Reservoir Outlet – *Monitoring Order 98-05 order 1.b as revised by Order 98-07*

6. Completion Plans:

The following descriptions detail how LADWP plans to fulfill SWRCB requirements in the Mono Basin for each item above not categorized as complete or ongoing. This section will be reviewed annually by LADWP for revisions to reflect progress towards completion.

<u>Category C – In-Progress Items</u>

Item C1 – During walking surveys, large woody debris will be placed into Rush Creek and will continue to be done on an opportunistic basis based on recommendations made by the Monitoring Team. This item will remain “In-Progress” until the Monitoring Team indicates that no further work is required. At that time, this item will be considered complete and will be moved to Category B “Completed Items”.

Item C2 – During walking surveys, large woody debris will be placed into Lee Vining Creek and will continue to be done on an opportunistic basis based on recommendations made by the Monitoring Team. This item will remain “In-Progress” until the Monitoring Team indicates that no further work is required. At that time, this item will be considered complete and will be moved to Category B “Completed Items”.

Item C3 – The grazing moratorium in the Mono Basin was in effect until 2009. At this time LADWP does not intend to allow grazing on its lands in the Mono Basin and will continue the moratorium in 2017. This item will remain in the Category C “In Progress”.

Item C4 – The Grant Lake Operation Management Plan (GLOMP) includes instructions to “review for revisions” every five years until Mono Lake reaches 6,391 feet above mean sea level. Although no revisions have been finalized to date, the plan was continuously under review. GLOMP is expected to be revised and replaced with “Mono Basin Operations Plan” (MBOP) after the SWRCB amends LADWP Water Rights licenses. This item will remain in Category C “In-Progress Items” until the final operation/management plan is approved by SWRCB. It is expected that a final plan will be developed after the Water Board order. Once the plan is approved, this item will be considered complete and will be moved to Category B “Completed Items”.

Item C5 – LADWP is to make available a total of $275,000 for waterfowl restoration activities in the Mono Basin. This money was to be used by the USFS if they requested the funds by December 31, 2004. Afterwards, any remaining funds are to be made available to any party wishing to do waterfowl restoration in the Mono Basin after SWRCB review. USFS has requested funds for a project estimated at $100,000. MLC has requested that the remainder of the funds be applied toward the total cost of the Mill Creek Return Ditch upgrade which would provide benefits for waterfowl habitat. The Mill Creek Return Ditch rehabilitation is a component of a Federal Energy Regulatory Commission (FERC) settlement agreement. These funds will continue to be budgeted by LADWP until such a time that they have been utilized. Currently, this money has been tentatively been included in the Settlement Agreement as part of Administrative of Monitoring Accounts to be administered by a Monitoring Administration Team (MAT). Once the full $275,000 has been utilized, this item will be considered complete and will be moved to Category B “Completed Items”.

Item C6 – Progress of the salt cedar eradication efforts is reported in the annual reports following the vegetation monitoring efforts. This was reported in the May 2016 Monitoring Report. This item will continue to be in progress until notice from SWRCB is received that LADWP’s obligation for this in the Mono Basin is complete. Once this notice is received, this item will be moved to Category B “Completed Items”.

Item C7 – The stream monitoring team continues to perform their required duties in the Mono Basin. This item will continue to be in progress until notice from SWRCB is received that LADWP’s obligation for funding and managing the monitoring team in the Mono Basin is complete. Once this notice is received, this item will be moved to Category B “Completed Items”, and LADWP will implement an appropriate monitoring program for the vegetation, stream morphology waterfowl, and fisheries.

Item C8 – Progress of the restoration efforts is reported in the annual reports. This item will continue to be in progress until notice from SWRCB is received that

LADWP's obligation for this in the Mono Basin is complete. Once this notice is received, this item will be moved to Category B "Completed Items".

Item C9 – The Stream Scientists have submitted final recommendations for termination criteria on Walker and Parker Creeks in 2007 to the SWRCB. There has been no decision from SWRCB. Once the termination criteria are finalized by the Stream Scientists and approved by SWRCB, this item will be considered complete and will be moved to Category B "Completed Items".

Item C10 – The Stream Scientists have submitted final recommendations for termination criteria on Lee Vining and Rush Creeks in 2007 to the SWRCB. There has been no decision from SWRCB. Once approved by SWRCB, this item will be considered complete and will be moved to Category B "Completed Items".

Item C11 – LADWP will continue to monitor and report on the hydrology of the Mono Basin including regular Mono Lake elevation readings, stream flows, and spring surveys until SWRCB approves that all or portions of the hydrology monitoring is no longer required. Once this occurs, all or portions of this item will be considered complete and will be moved to Category B "Completed Items". Any portions of this requirement that are deemed to be ongoing by the SWRCB will be moved to Category A "Ongoing Items".

Item C12 – LADWP will continue to monitor and report on the Mono Lake limnology and secondary producers until SWRCB approves that limnological monitoring is no longer required. Once this occurs, this item will be considered complete and will be moved to Category B "Completed Items".

Item C13 – LADWP will continue to monitor and report on the vegetation status in riparian and lake fringing wetland habitats, which is done every 5 years until SWRCB approves that vegetation monitoring is no longer required. Once this occurs, this item will be considered complete and will be moved to Category B "Completed Items".

Item C14 – LADWP will continue to monitor and report on the waterfowl populations in the Mono Basin until SWRCB approves that waterfowl monitoring is no longer required. Once this occurs, this item will be considered complete and will be moved to Category B "Completed Items".

Item C15 – Testing augmentation of Rush Creek flows with water from Lee Vining Creek through the use of the Lee Vining Conduit is possible and can occur as needed as demonstrated during peak runoff in June 2005. The augmentation has been tested up to 100 cfs and the orders call for maximum augmentation to be 150 cfs. This will only be possible if adequate runoff is available in Lee Vining Creek after the peak operation is complete. Once augmentation is successfully tested through 150 cfs, this item will be moved to Category B "Completed Items".

Item C16 – Evaluation of the effects of Rush Creek augmentation on Lee Vining Creek needs to be completed to cover diversions up to 150 cfs. Once the evaluation is completed, this item will be moved to Category B “Completed Items”.

Item C17 – Sediment bypass for Parker Creek is now in trial implementation stage. Once a plan is finalized by SWRCB and becomes part of LADWP’s operation plans, this item will be moved to Category A “Ongoing Items”.

Item C18 – Sediment bypass for Walker Creek is now in trial implementation stage. Once a plan is finalized by SWRCB and becomes part of LADWP’s operation plans, this item will be moved to Category A “Ongoing Items”.

Category D – Incomplete Items

None

Category E – Deferred Items

Item E1 – Pending further action by Mono County to improve the county road crossing at Lee Vining Creek, LADWP will write a letter to Mono County recommending an Arizona crossing at that point. Once LADWP writes this letter, or the parties agree that this is unnecessary; this item will be moved to Category B “Completed Items”.

Item E2 – LADWP was to place fish screens on all of its irrigation diversions in the Mono Basin. Subsequently LADWP ended all irrigation practices and hence does not need to install fish screens. If at a later date LADWP resumes irrigation, fish screens will be installed and this item will be moved to Category A “Ongoing Items”.

Item E3 – LADWP began a prescribed burn program with limited success. LADWP requested to remove this item from the requirements and the SWRCB instead ruled that the prescribed burn program will be deferred until Mono Lake reaches 6,391 ft. Once Mono Lake reaches 6,391 ft. LADWP will reassess the prescribed burn. Based on results from the assessment, LADWP will either reinstate the program or request relief from the SWRCB from this requirement. If LADWP reinstates the program this item will be moved to Category C “In-Progress Items”, however if LADWP requests, and is granted relief from this SWRCB requirement, this item will be moved to Category B “Completed Items”.

Item E4 - Rewatering of Rush Creek side channel 1A in reach 4A. Final review was conducted by the Stream Scientists. After presentation of the final review, LADWP followed the recommendations of the Stream Scientists not to do any action on the channel and was awaiting final decision by SWRCB. This item was approved by SWRCB and was therefore considered completed in 2008. Further work on Channel 1A was to be considered in the future if deemed appropriate. In 2014, as part of the pending new license, it has been included to be done in the future. Until the SWRCB approves the Settlement Agreement and amends LADWP’s license, it will be placed in Category E – “Deferred Item”.

Item E5 - Assessing the need to revegetate the areas affected by the side channel openings for Rush Creek side channel 1A in reach 4A will occur for five years following rewatering. LADWP followed the recommendations of the Stream Scientists not to do any action on the channel and was awaiting final decision by SWRCB. This item was approved by SWRCB and was therefore considered completed in 2008. In 2014, as part of the pending new license, it has been included to be done in the future. Until the SWRCB approves the Settlement Agreement and amends LADWP's license, it will be placed in Category E – "Deferred Item".

Item E6 - Assessing the need to revegetate the areas affected by the side channel openings for Rush Creek side channel 4Bii in reach 4B five years following rewatering (2007) occurred in the summer of 2012. The results from the assessment following the fifth year after rewatering was reported in Section 4 of the 2013 report. The final assessment concluded that satisfactory revegetation has occurred through natural processes and was considered complete and was moved to Category B "Completed Items". However, in 2014, as part of the pending new license, it has been included to be done in the future. Until the SWRCB approves the Settlement Agreement and amends LADWP's license, it will be placed in Category E – "Deferred Item".

Item E7 - Assessing the need to revegetate the areas affected by the side channel openings for Rush Creek side channel 8 in reach 4B five years following rewatering (2007) occurred in the summer of 2012. The results from the assessment following the fifth year after rewatering were reported in Section 4 of the 2013 report. The final assessment concluded that satisfactory revegetation has occurred through natural processes and was considered complete and was moved to Category B "Completed Items". However, in 2014, as part of the pending new license, it has been included to be done in the future. Until the SWRCB approves the Settlement Agreement and amends LADWP's license, it will be placed in Category E – "Deferred Item".

Item E8 – The stream monitoring team is to evaluate the restoration program after "no less than 8 years and no more than 10 years" from the commencement of the restoration program. This evaluation is to cover the need for a Grant Lake outlet, Rush Creek augmentation, and the prescribed stream flow regime. According to SWRCB Order Nos. 98-05 and 98-07, evaluation of LADWP's facilities to adequately provide proper flows to Rush Creek "*shall take place after two data gathering cycles but no less than 8 years nor more than 10 years after the monitoring program begins*". The Monitoring Team submitted final recommendation, on April 30, 2010. LADWP had 120 days after receiving the recommendation from the monitoring team to determine whether to implement the recommendation of the monitoring team. On July 28, 2010, LADWP submitted a Feasibility Report evaluating the recommendations. In September 2013, LADWP entered into a Settlement Agreement with the Stakeholders and this Agreement is pending SWRCB's approval via an amended Water Rights license. Until the SWRCB approves the Settlement Agreement and amends LADWP's license, it will be placed in Category E – "Deferred Item".

7. Ongoing Items Description:

See Section 5 for references where each requirement originates.

Category A – Ongoing Items

Item A1 – *Road closures*. Periodically LADWP personnel will visit all road closures performed by LADWP in accordance with SWRCB Order No. 98-05, Order 1, in the Lower Rush and Lee Vining Creek areas to assess their effectiveness. Where evidence exists that a road closure is ineffective, LADWP will improve the road closures through means such as additional barriers.

Item A2 – *Base flow releases*. LADWP normally will control flow releases from its facilities into Lower Rush, Parker, Walker, and Lee Vining Creeks according to agreed upon flow rate requirements as set forth in the SWRCB Decision 1631, Order Nos. 98-05 and Order 98-07, the Grant Lake Operations Management Plan, and any subsequent operations plans and decisions made by the SWRCB.

Item A3 – *Low winter flow releases*. Per the California Department of Fish and Wildlife recommendations, and SWRCB Order No. 98-05, order 2.b., LADWP will maintain winter flows into Lower Rush Creek below 70 cfs in order to avoid harming the Rush Creek fishery.

Item A4 – *Annual operations plan*. Per SWRCB Order No. 98-05, order 3, LADWP will distribute an annual operations plan covering its proposed water diversions and releases in the Mono Basin. Presently the requirement is to distribute this plan to the SWRCB and all interested parties by May 15 of each year.

Item A5 – *Notification of failure to meet flow requirements*. Per SWRCB Order No. 98-05, order 3, and SWRCB Decision 1631, order 4, if at the beginning of the runoff year, for any reason, LADWP believes it cannot meet SWRCB flow requirements, LADWP will provide a written explanation to the Chief of the Division of Water Rights by May 1, along with an explanation of the flows that will be provided. If unanticipated events prevent LADWP from meeting SWRCB Order No. 98-05 Stream Restoration Flow requirements, LADWP will notify the Chief of the Division of Water Rights within 20 days and provide a written explanation of why the requirement was not met. LADWP will provide 72 hours notice and an explanation as soon as reasonably possible for violation of SWRCB Decision 1631 minimum instream flow requirements.

Item A6 – *Grant storage targets*. LADWP will operate its Mono Basin facilities to maintain a target storage elevation in Grant Lake Reservoir between 30,000 and 35,000 acre-feet at the beginning and end of the runoff year. LADWP shall seek to have 40,000 acre-feet in Grant Reservoir on April 1 each year at the beginning of wet and extreme wet years.

Item A7 – *Export release patterns to the Upper Owens River*. Per SWRCB Decision 1631, order 7, and SWRCB Order No. 98-05, order 2, LADWP will make exports from the Mono Basin to the Upper Owens River in a manner that will not have a combined flow rate below East Portal above 250 cfs. LADWP will perform ramping of exports at 20% or 10 cfs, whichever is greater, on the ascending limb, and 10% or 10 cfs, whichever is greater, on the descending limb of the hydrograph as measured at the Upper Owens River.

Item A8 – *Diversion targets from streams*. Per the 1996 GLOMP, diversion targets for exports from the Mono Basin will be divided between Rush, Lee Vining, Parker and Walker Creeks in the following manner. During all years except dry and extremely wet years, LADWP will seek to divert one-third to one-half of the export amount from Lee Vining Creek, with the remaining water coming from Rush Creek. Only during dry years when 16,000 acre-feet of export is permitted, LADWP will seek to divert from Parker and Walker Creeks. During extremely wet years, all exports will come from diversions off of Rush Creek. Parker and Walker Creeks are expected to be flow through after the SWRCB approves the Settlement Agreement and amends LADWP Water Rights licenses.

Item A9 – *Export amounts dependent on Mono Lake level*. LADWP export amounts follow those ordered by SWRCB Decision 1631, order 2.

Item A10 – *Year type designation and guidelines*. Per SWRCB Decision 1631, order 4, SWRCB Order No. 98-05, and GLOMP, LADWP will perform runoff year forecasts for the Mono Basin with preliminary forecasts being conducted on February 1, March 1, and April 1, with the forecast being finalized on or around May 1 if necessary. LADWP developed a draft May 1 forecast methodology without a need for May snow surveys. When Gem Pass snow pillow measures show an increase in water content between April 1 and May 1, the percentage change experienced by the pillow will be applied to all of the April 1st snow course survey measurements used in calculating the runoff. A slight adjustment to the calculation may be made for dry years. Additionally, the May 1st forecast will have measured April values.

Item A11 – *Dry and wet cycle contingencies for stream restoration flows and base flows*. During consecutive dry years LADWP will release channel maintenance flows (CMF) every other year. The CMF will commence in the second consecutive dry year The channel maintenance flows for Rush Creek will be 100 cfs for five days, and for Lee Vining Creek it will be 75 cfs for five days. Ramping rates will be 10 cfs per day. The occurrence of a year type other than a dry year will terminate the dry year cycle. During consecutive wet years, LADWP will increase base flows above the minimum flow rate every other year. The increased base flows will commence in the second consecutive wet year. The occurrence of a year type other than a wet year will terminate the wet year cycle.

Item A12 – *Deviations from Grant Lake Operation Management Plan (GLOMP)*. LADWP must maintain operational flexibility to adjust or react to unpredictable circumstances.

Item A13 – *Ramping rates*. LADWP will continue to operate its Mono Basin facilities in order to provide SWRCB ramping flow requirements for Lee Vining, Parker, Walker, and Rush Creeks.

Item A14 – *Stream restoration flows and channel maintenance flows*. LADWP will continue to operate its Mono Basin facilities in order to provide peak flow requirements for Lee Vining, Parker, Walker, and Rush Creeks.

Item A15 – *Salt Cedar eradication*. LADWP will continue assisting in a Mono Basin wide effort to eradicate Salt Cedar (*Tamarisk*), and will continue to report on these efforts.

Item A16 – *Aerial Photography.* LADWP will capture aerial and/or satellite imagery of the Mono Basin (Stream Plan, 1" = 6,000' scale; SWRCB Order No. 98-05, Section 6.4.6(4), 1:6,000 scale) every five years or following an extreme wet year event, which resets the five year clock.

Item A17 – *Make basic data available to public*. Per SWRCB Order 98-05, Order 1.b., as revised by SWRCB Order No. 98-07, order 1.b(2), LADWP will continue to make all basic monitoring data available to the public.

Item A18 – *Operation of Lee Vining sediment bypass*. In order to bypass sediment past the Lee Vining diversion facility, LADWP will operate the Lee Vining Conduit control gate to assist with ramping flows towards peak with the intention of having it be in the completely open position while peak flows are passing the diversion facility. After peak flows have passed the facility, the Lee Vining Conduit control gate will slowly close assisting with ramping flows back down towards base flow condition.

Item A19 – *Operation of the Rush Creek augmentation from the Lee Vining Conduit when necessary*. At times when peak flow requirements in Rush Creek exceed facility capacities, and Grant Lake Reservoir is not spilling, LADWP will operate the Lee Vining Conduit 5-Siphon Bypass to bring water from Lee Vining Creek to Rush Creek to augment flows to the required levels.

Item A20 – Data from existing Mono Basin data collection facilities is available on a same-day basis on the LADWP.com internet web site. The data collection and reporting works, as with any other system, can experience periodic short term communication problems and/or technical difficulties, which may result in incorrect readings. LADWP will continue to monitor the data posting on a daily basis and will work to troubleshoot and correct problems as soon as possible. LADWP will continue to improve the data collection, computer, and communication systems as new technology(ies) become available.

Section 2

Mono Basin Operations

Section 2

Mono Basin Operations

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

May 2018

Los Angeles Department of Water and Power

Table of Contents — Page No.

I. 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) undertakes certain activities in the Mono Basin in compliance with the terms and conditions of its water right licenses 10191 and 10192. In addition to restoration and monitoring activities covered in this report, LADWP also reports on certain required operational activities.

II. Summary of Mono Basin RY 2017-18 Operations

A. Rush Creek

The runoff from Rush Creek was approximately 109,270 AF which amounts to the total water delivered to Grant Lake Reservoir (GLR)'s 'Damsite'. The highest flow of 721.7 cfs occurred on June 19, 2017.

Rush Creek flows below 'the Narrows', which consist of Rush Creek releases (Return Ditch, Spill, and 5-Siphons augmentation) combined with Parker and Walker Creek flows, had an approximate total of 145,392 AF. This flow terminated into Mono Lake.

RY 2017 was forecasted as an EXTREME WET year type and as such, following Guideline 'G', Rush Creek peak flow exceeded the requirements (500 cfs for 5 days followed by 400 cfs for 10 days) from June 4, 2017 to July 18, 2017, with a combination of Mono Gate One Return Ditch (MGORD) flows and GLR spills.

1. Rush Creek Augmentation

To meet high flow targets for lower Rush Creek, LADWP must at times employ facilities in addition to the Mono Gate One Return Ditch (MGORD) which has a 380 cfs capacity limit. During wetter years, LADWP utilizes one or both of its additional facilities to release higher peak flows. These facilities include the 5-Siphons bypass, which can release up to 100 cfs from Lee Vining Creek, and the GLR Spillway which can release large reservoir spills into lower Rush Creek during the wetter years.

5-Siphons Bypass

RY 2017 was forecasted as an EXTREME WET year type. In accordance with Guideline 'G', peak flows in Rush Creek require: 500 cfs for 5 days followed by 400 cfs for 10 days. The MGORD, at a maximum capacity of 380 cfs, and spills from GLR, were able to accommodate the prescribed peak flows, therefore 5-Siphons were not utilized.

Grant Reservoir Spill

Grant spilled during RY 2017 from May 31, 2017 to July 28, 2017.

B. Lee Vining Creek

RY 2017 was forecasted as an EXTREME WET year type and as such, following Guideline ‘G’, no water was diverted from Lee Vining Creek from April through September 2017, thus allowing the peak flow to pass through the diversion facility.

Lee Vining Creek had its highest flow on June 21, 2017 at 588 cfs. Total runoff for the year was approximately 87,232 AF.

C. Dry Cycle Channel Maintenance Flows

RY 2017 was forecasted as an EXTREME WET year type, therefore dry cycle channel maintenance flows (CMF) were not required in accordance with the GLOMP.

D. Parker and Walker Creeks

Parker and Walker were operated as pass through for RY 2017.

Parker Creek had its highest flow on June 20, 2017 at 105 cfs. Total runoff for the year was approximately 15,199 AF.

Walker Creek had its highest flow on June 20, 2017 at 71 cfs. Total runoff for the year was approximately 10,064 AF.

E. Grant Lake Reservoir

Grant Lake began the runoff year at approximately 30546 AF (7,113.68 ft AMSL). The reservoir did spill during the RY starting May 1, 2017 through July 28, 2017. Final storage volume by the end of the RY of March 31, 2018 was approximately 18,932 AF (7,100.09 ft AMSL).

F. Exports during RY 2017-18

During RY 2017, Mono Lake elevations were within the 6,377 ft – 6,380 ft range, allowing for up to 4,500 AF of exports per D1631. LADWP exported 4,489 AF total from the Mono Basin, which is below the allowed 4,500 AF.

G. Mono Lake Elevations during RY 2017-18

In RY 2017, Mono Lake elevations were as shown in the following table. The Lake elevation was at 6,378.3 ft AMSL at the beginning of the runoff year, and ended the runoff year at 6,381.9 ft AMSL, an increase of 3.6 ft.

RY 2017-18 Mono Lake Elevation Readings

April 1, 2017	6,378.33
May 1, 2017	6,378.57
June 1, 2017	6,379.00
July 1, 2017	6,380.21
August 1, 2017	6,381.18
September 1, 2017	6,381.58
October 1, 2017	6,381.48
November 1, 2017	6,381.40
December 1, 2017	6,381.47
January 1, 2018	6,381.52
February 1, 2018	6,381.62
March 1, 2018	6,381.62
April 1, 2018	6,381.89

III. Proposed Mono Basin Operations Plan RY 2018-19

The goal of this Mono Basin Operations Plan RY 2018-19 is to comply with regulatory requirements and to keep GLR reasonably above 11,500 AF storage. As GLR storage on April 1, 2018 is at 18,931.5 AF, which is not too far from the 11,500 AF level, water needs to be conserved.

A. Forecast for RY 2018-19

The Mono Basin's April 1st forecast for Runoff Year (RY) 2018 for April to March period is 100,700 acre-feet (AF), or 85 percent of average using the 1966-2015 long term mean of 119,103 AF (**Attachment 2**). This value puts the year type within the "NORMAL" category and operations shall be in accordance with the requirements of SWRCB D1631/Order 98-05 and Guideline 'D' of the Grant Lake Operations Management Plan (GLOMP), with modifications as shown below. See **Attachment 3**.

B. Rush Creek

1. Lower Rush Creek Base Flow

Base flows will follow Order No. 98-05 minimum requirements of 47 cubic feet per second (cfs) from April 1 to September 30, 2018. After peak flow operations, Rush Creek base flows will be 47 cfs through September, and 44 cfs for October-March.

If Grant Lake inflow is less than the dry year base flow and/or if Grant Lake storage drops below 11,500 AF, base flow requirements for a dry year under Guideline A applies.

2. Lower Rush Creek Peak Flow

Because the level of GLR is low (18,931.5 AF storage) on April 1, 2018, peak flows will follow Guideline C for a Dry-Normal II year (**Attachment 4**): 250 cfs for 5 days. Under Order 98-05, Section 1.a.(1), LADWP is allowed to reduce peak flows in dry/normal and normal years to the extent necessary to maintain the water exports allowed by Decision 1631. Also, based on RY 2003 hydrology, Mono Basin Operations Model (MBOM) analysis shows with the reduced peak flows, GLR should stay above 11,500 AF for RY 2018. Peak flow operations may be reduced or eliminated if Grant Lake storage drops below 11,500 AF in accordance with Section 1.a.(1) of Order 98-05. Ramping rate will be at 10% change ascending and descending, or 10 cfs, whichever is greater.

Should actual runoff conditions provide additional water to Lee Vining and Rush Creeks above what is predicted by this plan, LADWP may consider increasing the Lower Rush Creek peak flows to higher than 250 cfs for a short duration.

The expected magnitude and timing of the peak flows in Rush Creek at Dam Site were generated by MBOM, the results of which are shown below:

Predicted magnitude and timing of peak flows		
Creek	**Magnitude**	**Timing**
Rush	311 cfs	June 19, 2018

3. Rush Creek Augmentation

In wetter years where peak flow requirements may exceed the Mono Gate One Return Ditch (MGORD) or Grant Outlet pipe maximum design capacities, LADWP utilizes one or both of its additional facilities to release the higher peak flows. These facilities include the 5-Siphons bypass, which can release as tested 100 cfs from Lee Vining Creek, and the GLR Spillway, which can release large reservoir spills into lower Rush Creek during the wetter years.

5-Siphons Bypass

The 5-Siphons will not be utilized for augmentation.

Grant Reservoir Spill

According to the MBOM run, Grant Reservoir is not expected to spill for RY 2018.

C. Lee Vining Creek

1. Lee Vining Creek Base Flow

Base flows will follow Guideline 'D' of 54 cfs from April 1 to September 30, and 40 cfs from October 1 to March 31, 2019. Flows above 54 cfs will be diverted to Grant Lake Reservoir.

2. Lee Vining Creek Peak Flow

Based on historical patterns, LADWP believes Lee Vining Creek peak occurred on April 7, 2018 at 346 cfs. Therefore, no further "pass the peak event" is planned. However, LADWP will watch field conditions and make changes as necessary.

Channel Maintenance Flows (CMF) – In lieu of a "pass the peak event", LADWP will release CMF for a NORMAL runoff year: 160 cfs for 3 days with the usual ramping rates.

D. Dry Cycle Channel Maintenance Flows

Because RY2018 is forecasted to be a NORMAL year, dry cycle channel maintenance flows will not be required in accordance with the GLOMP.

E. Parker and Walker Creeks

Parker and Walker Creek facilities will be operated as pass through in accordance with Guideline 'D'

F. Grant Lake Reservoir

Grant Lake Reservoir (GLR) storage volume was 18,931.50 AF, corresponding to a surface elevation of 7,100.01 feet above mean sea level (AMSL) at the start of the runoff year. Using the closest available representative historical inflow data (2003 runoff year at 88 percent of normal), and above specified flows, GLR's profile is projected to be as shown in **Attachment 5**. Forecasted scenarios will be relatively close only if this year's hydrology turns out to be similar to the hydrology of the selected historical runoff year. Operations are subject to change with variations in actual hydrology during the upcoming runoff year.

G. Planned Exports for RY 2018-19

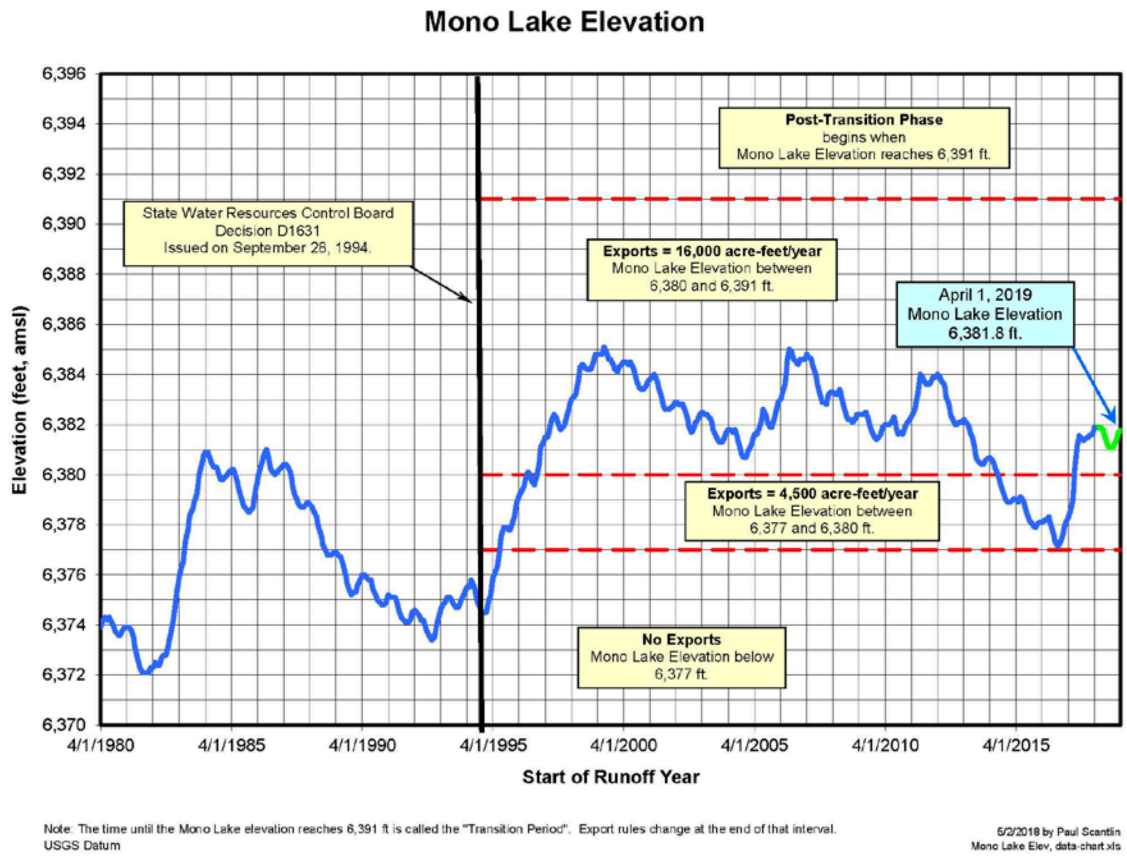
Mono Lake level reading conducted on April 1, 2018 indicated that the lake's surface water elevation was at 6,381.86 ft AMSL, well within the 6,380 ft – 6,391 ft range, thereby allowing for 16,000 AF of exports per the SWRCB Decision 1631. LADWP plans to conduct export operations at a constant of 22 cfs per day for the runoff year until the 16,000 AF amount has been reached. This may change as field conditions dictate.

H. Expected Mono Lake Elevations during RY 2018-19

Mono Lake began this runoff year at 6,381.86 ft AMSL where it is forecasted to increase and end the runoff year at approximately 6,381.8 ft AMSL (**Attachment 1**).

ATTACHMENTS

Attachment 1



Attachment 2

2018 EASTERN SIERRA
RUNOFF FORECAST
April 1, 2018

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 (1966 - 2015) (Acre-feet)
MONO BASIN:	**82,700**	**82%**	95%	70%	100,782
OWENS RIVER BASIN:	**219,000**	**73%**	87%	60%	298,151

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 (1966 - 2015) (Acre-feet)
MONO BASIN:	**100,700**	**85%**	98%	71%	119,103
OWENS RIVER BASIN:	**317,500**	**78%**	91%	66%	405,696

NOTE - Owens River Basin includes Long, Round and Owens Valleys (not incl Laws Area)

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.

2018 Forecast.xls forecast 4/4/2018 3:27 PM

Mono Basin Operations, Guideline D

Year Type:………………………………..……………………………… NORMAL
Forecasted Runoff in acre-feet...…………………………………………..100,750 – 130,670

Lower Rush Creek

Base Flows:

	April	May–Jul	Aug–Sep	Oct-Mar
Flow (cfs)	50	75	50	45

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

Peak Flows: - 380 cfs for 5 days followed by 300 cfs for 7 days*.

Ramping:
- Begin ramping on June 1st (rule of thumb). Note that peak operations will take 43 days, so timing this with peak flows in P/W Creeks, with fish movement, and cottonwood germination is beneficial.
- 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.

Augmentation: - None.

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 flows in lower Rush Creek. During this time, exports should be zero.

*Section 1. a. (1) of Order 98-05 states that LADWP may reduce SRF's in dry/normal and normal years to maintain exports allowed under D-1631; that LADWP will seek to have between 30,000 and 35,000 acre-feet (elev. 7,113' and 7,119") in Grant Lake at the beginning and end of each runoff season; and LADWP will not be required to reduce storage in Grant Lake below 11,500 acre-feet (elev. 7089.4') to provide SRFs.

Mono Basin Operations, Guideline C

Year Type:……………………………..………………………………. DRY–NORMAL II
Forecasted Runoff in acre-feet...…………………………………………..91,590 – 100,750

Lower Rush Creek

Base Flows:

	Apr–Sep	Oct-Mar
Flow (cfs)	47	44

Minimum base flows should equal the lesser of the inflow to Grant Lake or the minimum requirements listed above. 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: - 250 cfs for 5 days*.

Ramping:
- Begin ramping on May 15th (rule of thumb). Note that peak operations will take 34 days, so timing this with peak flows in P/W Creeks, with fish movement, and cottonwood germination is beneficial.
- 10 percent daily change during ascending and descending limbs, or 10-cfs, whichever is greater.

Augmentation: - None.

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

Diversions:
- Divert flows in excess of base flows until May 15th (rule of thumb).
- Diversions may resume 7 days after peak (rule of thumb); divert flows in excess of base flow requirements.

Parker and Walker Creeks

Flow-through conditions for entire year.

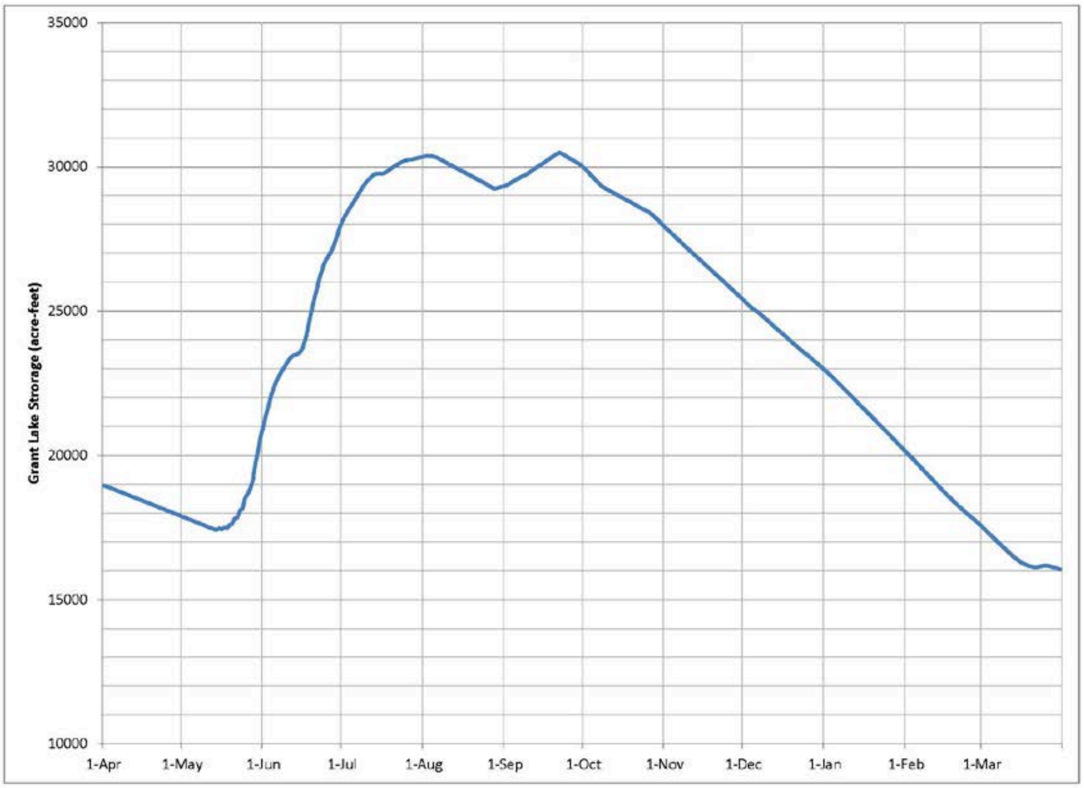
Exports

4,500 acre-feet scenario – Maintain 6 cfs export throughout the year.
16,000 acre-feet scenario – Maintain 22 cfs export throughout the year.

*Section 1. a. (1) of Order 98-05 states that LADWP may reduce SRF's in dry/normal and normal years to maintain exports allowed under D-1631; that LADWP will seek to have between 30,000 and 35,000 acre-feet (elev. 7,113' and 7,119") in Grant Lake at the beginning and end of each runoff season; and LADWP will not be required to reduce storage in Grant Lake below 11,500 acre-feet (elev. 7089.4') to provide SRFs.

Attachment 5

RY 2018/19 Grant Lake Reservoir Storage Projection Using 2003 (88% Year) Inflow



Section 3(a)

Fisheries Monitoring Report for
Rush, Lee Vining, Parker, and Walker Creeks
2017-18

Mono Basin Fisheries Monitoring Report
Rush, Lee Vining, and Walker Creeks
2017

Prepared by Ross Taylor and Associates for

Los Angeles Department of Water and Power's Annual Compliance Report to the State Water Resources Control Board

Date: April 6, 2018

Table of Contents

Executive Summary

This report presents results of the 21st year of trout population monitoring for Rush, Lee Vining, and Walker Creeks pursuant to SWRCB's Water Right Decision 1631 (D1631) and the 19th year following SWRCB Orders #98-05 and #98-07. Order #98-07 stated that the monitoring team would develop and implement a means for counting or evaluating the number, weights, lengths and ages of trout present in various reaches of Rush Creek, Lee Vining Creek, Parker Creek and Walker Creek. This report provides trout population data collected in 2017 as mandated by the Orders and the Settlement Agreement.

The 2017 runoff year (RY) was 206% of normal and classified a "Extreme Wet" runoff year (RY) type, as measured on April 1st. RY 2017 was a new record runoff for the Mono Basin and a major departure from five consecutive below "Normal" runoff years (RY 2016 was 74% of normal, RY 2015 was 25% of normal, RY 2014 was 48% of normal, RY 2013 was 66% of normal and RY 2012 was 55% of normal). Annual electrofishing mark-recapture monitoring was conducted in two sections of Rush Creek. Multiple-pass depletion electrofishing was conducted in the Lee Vining Creek main channel, the Lee Vining Creek side channel and in Walker Creek. These data were used to generate population estimates, density estimates, standing crop estimates, condition factors, relative stock densities, and growth rates and apparent survival rates from PIT tag recaptures. A single electrofishing pass was made through the MGORD section of Rush Creek to collect data to generate condition factors, relative stock densities, and growth rates and apparent survival rates from PIT tag recaptures.

Population Estimates

The Upper Rush section supported an estimated 612 age-0 Brown Trout in 2017 compared to 146 age-0 fish in 2016. This section had a total catch of 31 Brown Trout 125-199 mm in length in 2017 compared to an estimate of 55 fish in 2016 (insufficient numbers of recaptures prevented making a valid estimate in 2017). In 2017, Upper Rush supported an estimated 158 Brown Trout ≥200 mm in length compared to an estimate of 110 fish in 2016.

The Bottomlands section supported an estimated 149 age-0 Brown Trout in 2017 versus 146 age-0 fish in 2016. This section supported an estimated 59 Brown Trout 125-199 mm in length in 2017 compared to 46 fish in 2016. The Bottomlands section supported an estimated 80 Brown Trout ≥200 mm in 2017 compared to 38 trout in 2016.

Lee Vining Creek's main channel section supported an estimated 32 age-0 Brown Trout in 2017, compared to an estimated 118 age-0 fish in 2016. This section supported an estimated 13 Brown Trout 125-199 mm in length in 2017 compared to 150 fish in 2016. Lee Vining Creek's main channel supported an estimated 10 Brown Trout ≥200 mm in 2017 versus 50 fish in 2016. Between 2012 and 2017, the total Brown Trout population estimate dropped from 797 fish to 55 fish, a 93% decline.

No Rainbow Trout were captured in Lee Vining Creek's main channel in 2017. No age-0 Rainbow Trout (<125 mm) and no Rainbow Trout in the 125-199 mm size class (probable age-1 fish) were captured in Lee Vining Creek's main channel during the past two sampling years.

The 2017 age-0 Brown Trout estimate for Walker Creek was 66 fish. The 2017 population estimate for Brown Trout in the 125-199 mm size class equaled 47 trout. Brown Trout ≥200 mm in length accounted for 7% of the total catch in 2017 and the population estimate for this size class was eight Brown Trout. The largest Brown Trout captured in Walker Creek in 2017 was 249 mm in length.

In the Lee Vining Creek side channel, 23 Brown Trout were captured in two electrofishing passes during the 2017 sampling. The estimates for each size class were: <125 mm = 16 fish; 125-199 mm = three fish; and ≥200 mm= four fish. No Rainbow Trout were captured in the side channel in 2017. This was the ninth consecutive year that no age-0 Rainbow Trout were captured in the Lee Vining Creek side channel and the seventh consecutive year the no age-1 and older Rainbow Trout were captured.

Densities of Age-0 Trout

In 2017, the Upper Rush section's estimated density of age-0 Brown Trout was 1,923 fish/ha and the Bottomlands section's estimated density of age-0 Brown Trout equaled 594 fish/ha. In Walker Creek, the 2017 density estimate of age-0 Brown Trout was 1,503 fish/ha (a 77% decrease from 2016's estimate of 6,578 fish/ha).

The 2017 age-0 Brown Trout density estimate in the main channel of Lee Vining Creek was 232 fish/ha (a 73% decrease from 2016's estimate of 873 fish/ha). In 2017, the age-0 Brown Trout density estimate in the Lee Vining Creek side channel equaled 411 fish/ha.

Densities of Age-1 and older (aka Age-1+) Trout

In 2017, the Upper Rush section's estimated density of age-1+ Brown Trout was 594 fish/ha and the Bottomlands section's estimated density of age-1+ Brown Trout equaled 433 fish/ha. In Walker Creek, the 2017 density estimate of age-1+ Brown Trout was 1,253 fish/ha.

The 2017 age-1+ Brown Trout density estimate in the main channel of Lee Vining Creek was 232 fish/ha (a decrease of 84% from the 2016 estimate of 1,479 fish/ha). In 2017, the Lee Vining Creek side channel's density estimate of age-1 and older Brown Trout was 180 fish/ha.

Standing Crop Estimates

The estimated standing crop for Brown Trout in the Upper Rush section was 123 kg/ha in 2017. The estimated standing crop for Brown Trout in the Bottomlands section of Rush Creek was 50 kg/ha in 2017. The estimated standing crop for Brown Trout in Walker Creek was 85 kg/ha in 2017 (a 51% decrease from the 2016 estimate of 172 kg/ha).

The Lee Vining Creek main channel in 2017 produced a total estimated standing crop of 21 kg/ha for Brown Trout (a decrease of 81% from the 2016 estimate of 113 kg/ha). The 2017 standing crop estimate was the first time in 18 sampling seasons that it was comprised solely of Brown Trout. The Lee Vining Creek side channel produced a total Brown Trout standing crop estimate of 20 kg/ha in 2017.

Condition Factors

Condition factors of Brown Trout 150 to 250 mm in length in 2017 decreased in the MGORD section of Rush Creek from 2016's value and increased in the five other sections from 2016's values (Upper Rush, Bottomlands, Walker Creek, Lee Vining side channel, and Lee Vining main channel). In 2017, three sections (Upper Rush, Lee Vining main channel and Lee Vining side channel) had Brown Trout condition factors ≥1.00.

Relative Stock Densities (RSD)

In the Upper Rush section, the 2017 RSD-225 of 78 was the highest value for this section. This increase in the RSD-225 value was most likely influenced by the overall low numbers of fish along with poor age-0 recruitment during the previous year, leading to low numbers of age-1 trout in the 150-224 mm size class. Also, the extended spill over the Grant Lake Reservoir (GLR) dam probably spilled reservoir-origin trout into upper Rush Creek. The RSD-300 value was 15 in 2017; the highest recorded for this section and was probably influenced by the GLR spill and excellent growth rates of age-2 fish.

In the Bottomlands section of Rush Creek, the RSD-225 for 2016 was 65, the highest value recorded for this section. As in the Upper Rush section, past poor age-0 recruitment and low numbers of age-1 and older trout affected the Bottomlands RSD-225 value. The RSD-300 value was 15 in 2017, based on the capture of four Brown Trout ≥300 mm.

In the MGORD, the RSD-225 value increased from 72 in 2015 to 74 in 2016 to 88 in 2017; this was the fourth consecutive increase since the low value of 42 in 2013. In 2017, the RSD-300 value was 27, an increase from a value of 21 in 2016. The RSD-375 value in 2017 was 11, the second consecutive season with a value of 11. In 2017, a total of 28 Brown Trout ≥300 mm in length were caught, including 11 fish ≥375 mm in length.

RSD values in Lee Vining Creek were generated for the main channel combined with the side channel and for the main channel only. The RSD-225 values for the main/side combined equaled 23 and main-only equaled 26 for 2017, both increases compared to the 2016 values. In 2017, one Brown Trout greater than 300 mm in length was captured in the Lee Vining Creek main channel, which resulted in a RSD-300 of 4 for the main channel and a RSD-300 of 3 for the main/side channels combined.

Introduction

Study Area

Between October 10th and 20th 2017, Los Angeles Department of Water and Power (LADWP) staff and Ross Taylor (the SWRCB fisheries scientist) conducted the annual fisheries monitoring surveys in six reaches along Rush, Lee Vining, and Walker Creeks in the Mono Lake Basin. The six reaches were similar in length to those which have been sampled between 2009 and 2016 (Figure 1). Aerial photographs of the sampling reaches can be found in the appendices of previous reports (Taylor 2017).

Hydrology

The 2017 runoff year (RY) was 206% of normal and classified a "Extreme Wet" runoff year (RY) type, as measured on April 1st. RY 2017 was a new record runoff (245,900 acre-feet) for the Mono Basin and a departure from five consecutive below "Normal" runoff years (RY 2016 was 74% of normal, RY 2015 was 25% of normal, RY 2014 was 48% of normal, RY 2013 was 66% of normal and RY 2012 was 55% of normal). Under the existing SWRCB orders, an Extreme Wet RY prescribes a two-stage peak release of 500 cfs for five days, followed by 400 cfs for ten days in Rush Creek, followed by baseflows of 68 cfs from April 1 through September 30, and 52 cfs from October 1 through March 31. However, Rush Creek flows during the summer of 2017 exceeded these requirements because of the record volume of water. Also, extended high flows were necessary to lower Grant Lake Reservoir (GLR) so that Rush Creek flows could be lowered to accomendate the fisheries sampling in mid-October without a spill occurring. In Lee Vining Creek, the existing SWRCB orders require that the primary peak flow is passed downstream. The SRF summer baseflow to Lee Vining Creek below LADWP's point of diversion was 54 cfs or to pass all the flow if less than 54 cfs.

Streamflow discharges in Rush Creek at Dam Site (located upstream of GLR) were extremely high throughout the summer of 2017 due to the record snowpack (blue line on Figure 2). Flows released to Rush Creek downstream of GLR (Rush at MGORD) were a winter baseflow of approximately 48-50 cfs until late March, followed by a spring bench of approximately 70 cfs. On May 30th, GLR was full and started to spill and flows released to the MGORD were ramped up. MGORD releases were greater than 200 cfs for 90 days and greater than 300 cfs for 51 days (red line on Figure 2). The spill out of GLR lasted for 60 days, between May 30th and July 28th, with 45 days of the spill being >200 cfs. For three days, the peak spill equaled 445 cfs (June 21st-23rd). Flows in Rush Creek below the Narrows included the MGORD release, the GLR spill and accretions from Parker and Walker Creeks (green line on Figure 2). Accretions from Parker and Walker creeks resulted in flow fluctuations through the spring and summer, and contributed to the peak of 898 cfs in Rush Creek below the Narrows on June 21st (green line on Figure 2).

In 2017, three distinct peaks of 253 cfs, 456 cfs and 588 cfs occurred in Lee Vining Creek on May 6th, June 4th, and June 21st (Figure 3). Flows were also >300 cfs for 56 consecutive days.

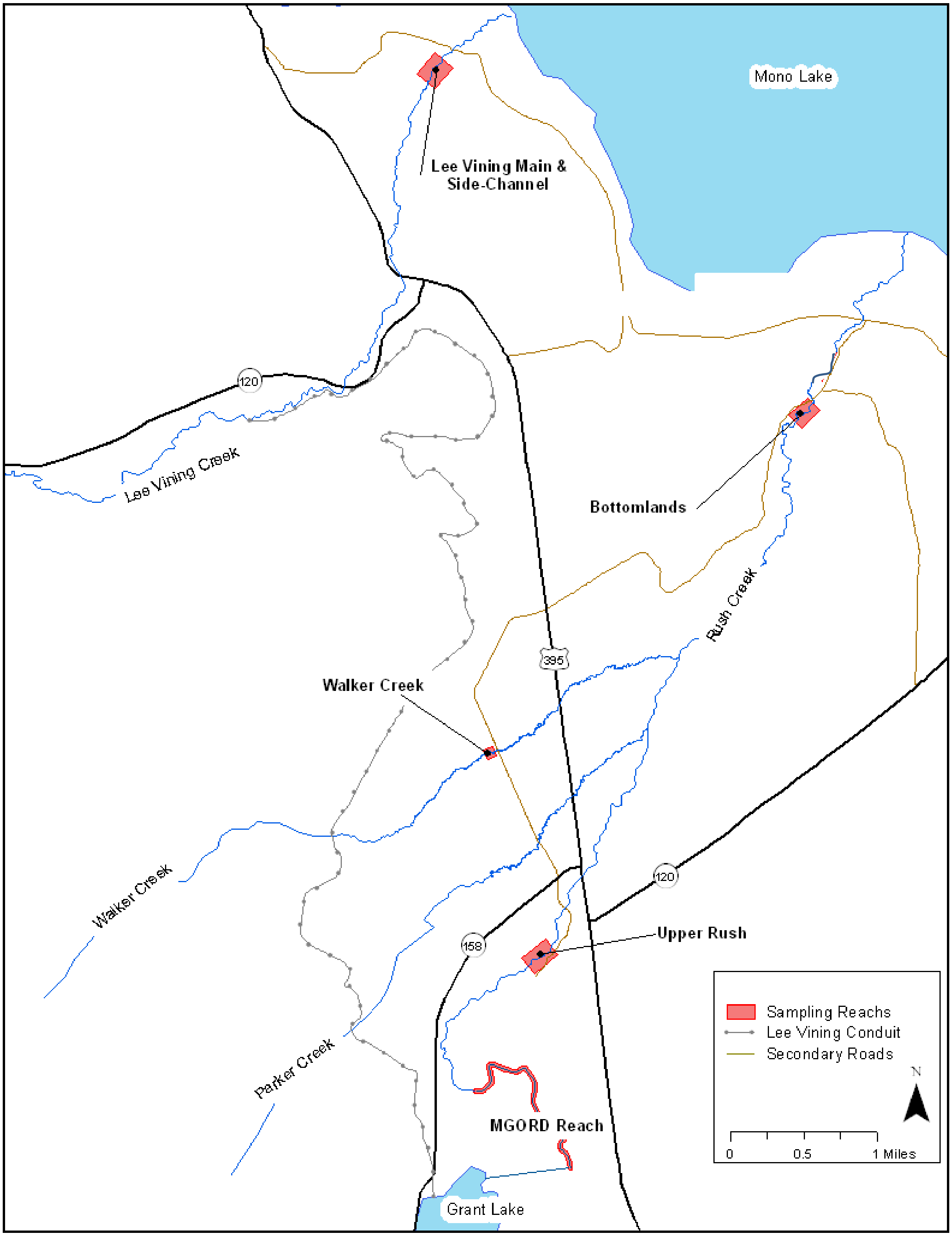


Figure 1. Annual fisheries sampling sites within Mono Basin study area, October 2017.

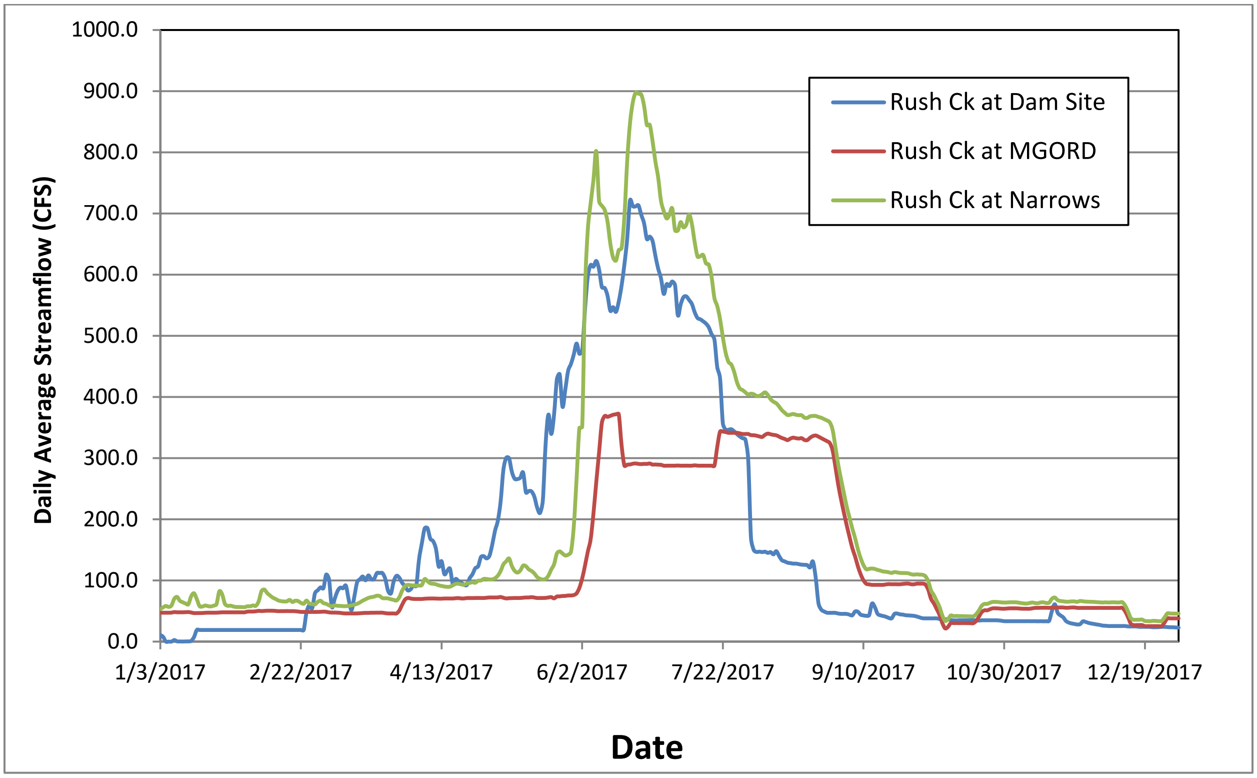


Figure 2. Rush Creek hydrographs between January 1st and December 31 of 2017.

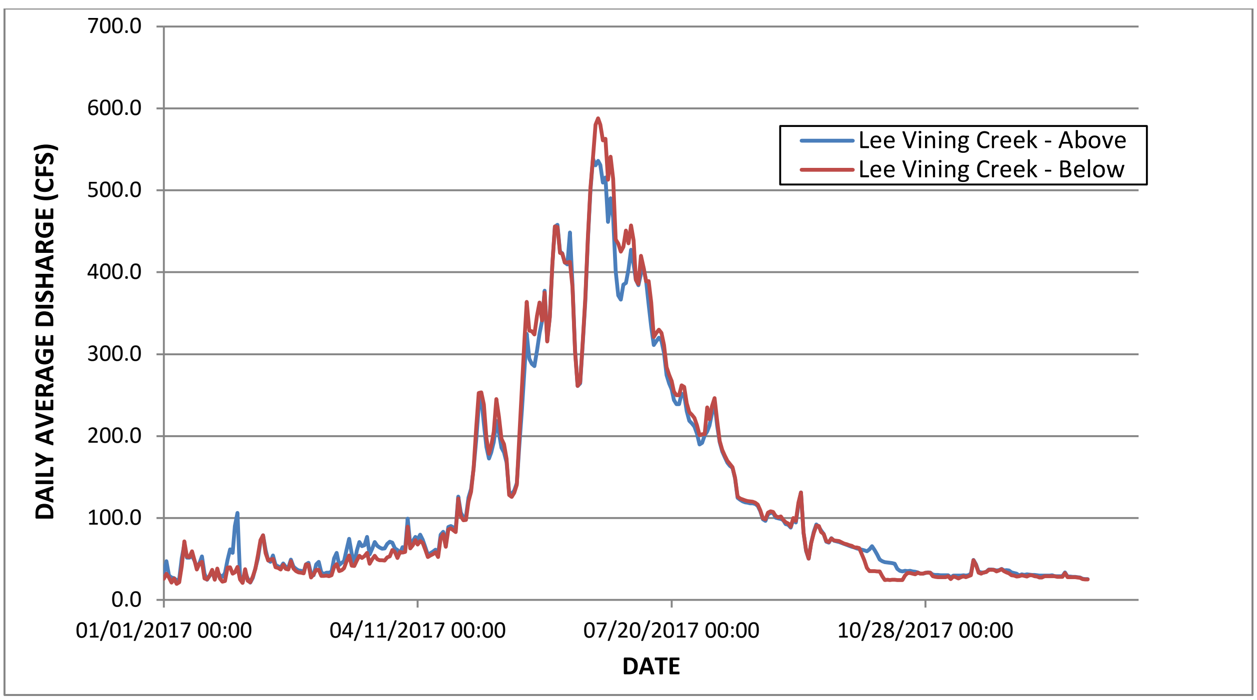


Figure 3. Lee Vining Creek hydrographs between January 1st and December 31st of 2017.

Grant Lake Reservoir

In 2017, storage elevation levels in Grant Lake Reservoir (GLR) fluctuated from a low of 7,104.2 ft to a high of 7,132.0 ft (Figure 4). In 2016, GLR spilled for 60 days, which is depicted by the blue line above the orange line on Figure 4.

Because of the record snowpack and extended runoff in 2017, GLR's elevation was well above the "*low*" GLR level as defined in the Synthesis Report by the Stream Scientists as a level where warm water temperatures should be a concern (<20,000 AF storage or approximately 7,100 ft elevation) (Figure 4). The 2017 summer water temperature monitoring documented cool water temperatures, suitable for good growth of Brown Trout, at all Rush Creek locations downstream of GLR.

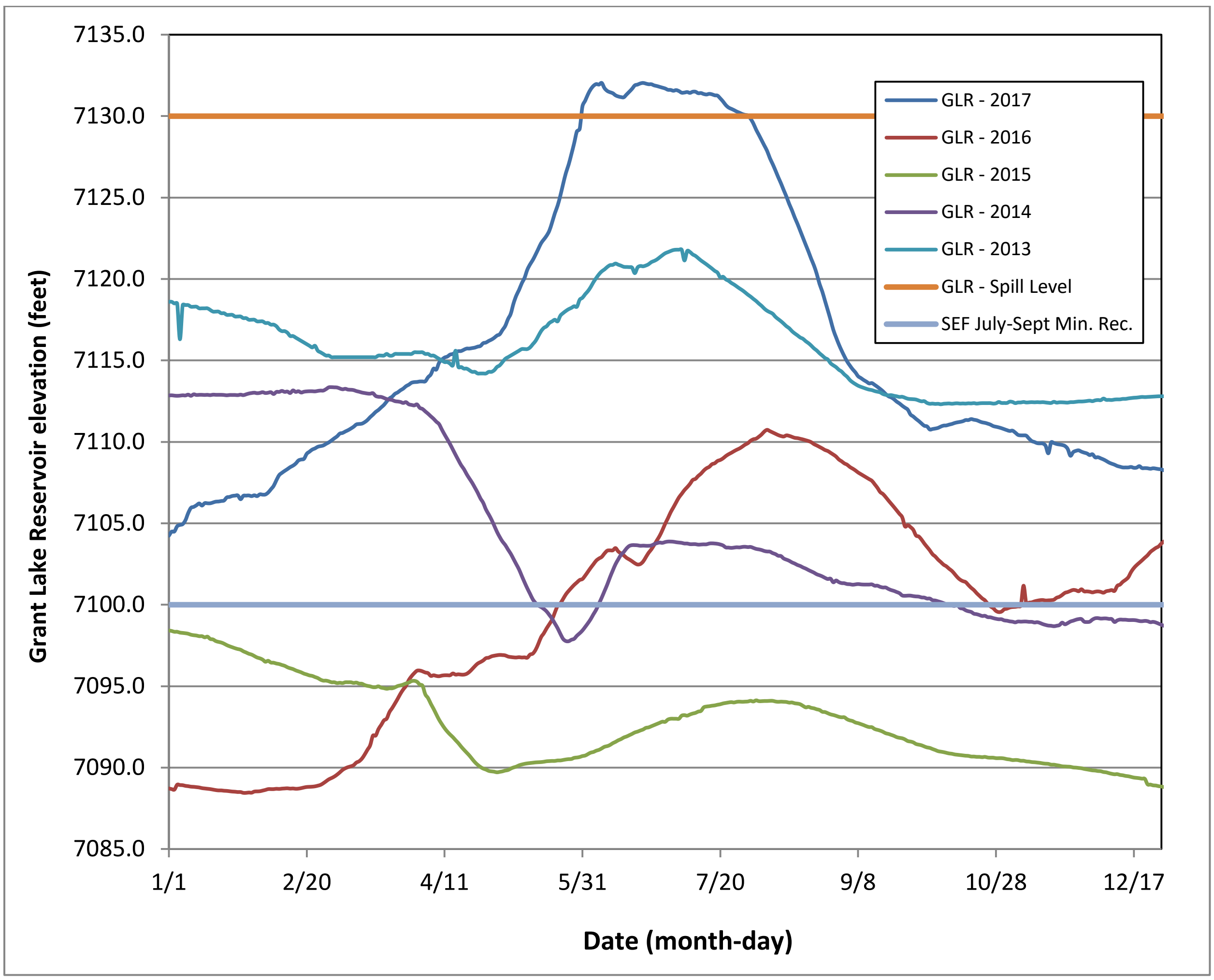


Figure 4. Grant Lake Reservoir's elevation between January 1st and December 31st 2013 - 2017.

Methods

The annual fisheries monitoring was conducted between October 10th and 20th of 2017, about a month later than usual due to the high streamflows from the record snowmelt. Closed population mark-recapture and depletion methods were utilized to estimate trout abundance. The mark-recapture method was used on the Upper and Bottomlands sections of Rush Creek. In the Lee Vining Creek main channel section where the mark-recapture method is typically used, a depletion estimate was made after three days of failing to keep the block fences up due to a heavy leaf load. The depletion method was also used on the Lee Vining Creek side channel and Walker Creek sections.

For the mark-recapture method to meet the assumption of a closed population, semi-permanent block fences were installed at the upper and lower ends of each section. The semi-permanent fences were 48 inches tall, constructed with ½ inch-mesh hardware cloth, t-posts, and rope. Hardware cloth was stretched across the entire width of the creek and t-posts were then driven at roughly five-foot intervals through the cloth on the upstream side approximately one foot from the edge. Rocks were placed on the lower edge to prevent trout from swimming underneath the fence. Rope was secured across the tops of the t-posts and anchored to both banks upstream of the fence. The hardware cloth downstream of the t-posts was raised and secured to the rope with bailing wire. Fences were raised the morning of the mark run and left in place for seven days until the recapture run was finished. To prevent failure, all fences were cleaned of leaves, twigs, and checked for mortalities at least twice daily (morning and evening). As previously stated, we were unable to maintain the Lee Vining Creek fences due to the heavy load of fallen leaves that clogged and dropped the fences within a couple of hours after a cleaning.

Depletion estimates only required a temporary blockage to prevent fish movement in and out of the study area while conducting the survey. Temporary blockage of the sections was achieved with 3/16 inch-mesh nylon seine nets installed across the channel at the upper and lower ends of the study areas. Rocks were placed on the lead line to prevent trout from swimming underneath the seine net. Sticks were used to keep the top of the seine above the water surface. Both ends of the seine net were then tied to bank vegetation to hold it in place.

Equipment used to conduct mark-recapture electrofishing on Rush Creek included a six foot plastic barge that contained the Smith-Root© 2.5 GPP electro-fishing system, an insulated cooler, and battery powered aerators. The Smith-Root© 2.5 GPP electro-fishing system included a 5.5 horsepower Honda© generator which powered the 2.5 GPP control box. Electricity from the 2.5 GPP control box was introduced into the water via two anodes. The electrical circuit was completed by the metal plate cathode attached to the bottom of the barge.

Mark-recapture runs on Rush Creek consisted of a single downstream pass starting at the upper block fence and ending at the lower block fence. In 2017, the field crew consisted of a barge operator, two anode operators, and four netters, two for each anode. The barge operator's job consisted of carefully maneuvering the barge down the creek and ensuring overall safety of the entire crew. The anode operator's job was to safely shock and hold trout until they were netted. The netters' job was to net and transport fish to the insulated cooler and monitor trout for signs of stress. Once the cooler was full, electrofishing was temporarily stopped to process the trout. The trout were then transferred from the cooler to live cars and placed back in the creek. The trout were then processed in small batches and then returned to a recovery live car in the creek. Once all the trout were processed at a sub-stop, the crew resumed electrofishing until the cooler was once again full.

The depletion runs on the Lee Vining Creek main channel consisted of a downstream pass starting at the upper block net and ending at the upper block net. The electrofishing crew consisted of one crew member operating the barge, four netters, and one bucket carrier who transported the captured trout. The insulated cooler was not used on Lee Vining Creek to reduce the weight in the barge.

Due to the depth of the MGORD, all electrofishing and netting was done from inside a drift boat. The drift boat was held perpendicular to the flow by two crew members who walked it down the channel. The electrofishing barge was tied off to the upstream side of the drift boat and a single throw anode was used. A single netter used a long handled dipnet to net the stunned trout, which were then placed in an insulated cooler equipped with aerators. A safety officer sat at the stern of the drift boat whose job was to monitor the trout in the cooler, the electrofishing equipment, the electrofishing crew, and shut off the power should the need arise. Once the cooler was full, the trout were moved to a live car and placed back in the creek for the shore-based crew to process before continuing the electrofishing effort.

For the Walker Creek and Lee Vining Creek side channel (B-1 side channel) depletions, a single pass was considered an upstream pass from the lower seine net to the upper seine net followed by a downstream pass back to the lower seine net. One member of the electrofishing crew operated the LR-24 electrofisher; another member was the primary netter and a third member was the backup netter/bucket carrier. The other crew members processed the trout captured during the first pass while the electrofishing crew was conducting on the second pass. Processed first-pass fish were temporarily held in a live car until the second pass was completed and it was determined that only two passes were required to generate a suitable estimate, or additional passes were required. The temporarily held fish were released once all fish were processed and we determined that no additional electrofishing passes were required to generate estimates.

To process trout during the mark-run, small batches of fish from the live car were transferred to a five gallon bucket equipped with aerators. Trout were then anesthetized, identified as either Brown Trout or Rainbow Trout, measured to the nearest millimeter (total length), and weighed to the nearest gram on an electronic balance. Trout were then "marked" with a small (< 3 mm) fin clip for identification during the recapture run. Trout captured in the Rush Creek Bottom-lands received lower caudal clips and trout captured in the Upper Rush section received anal fin clips. Before placing trout into the aerated recovery bucket, each fish was examined for a missing adipose fin. Trout missing their adipose fin were then scanned for their Passive Integrated Transponder (PIT) tag number. Any trout missing their adipose fin that failed to produce a tag number when scanned were recorded as having "shed" the PIT tag; in most instances these fish were retagged. Partially regenerated adipose fins of fish with PIT tags were reclipped for ease of future identification. Once recovered, fish were then moved from the recovery bucket to a live car to be held until the day's sampling effort was completed; this was done to prevent captured fish from potentially moving downstream into the actively sampled section. At the end of the electrofishing effort, fish were released from the live cars back into the sub-sections they had been captured in. Fish were then provided a seven-day period to remix back into the section's population prior to conducting the recapture-run.

Processing trout during the recapture-run was similar to the mark-run. Trout were transferred in small batches to a five gallon bucket. They were then anesthetized, identified, and examined for the "mark" fin clip. Trout that were fin clipped were only measured to the nearest millimeter and placed in the recovery bucket. Trout that were not clipped during the "mark" run (i.e. new fish) were measured to the nearest millimeter "total length," weighed to the nearest gram, and examined for missing adipose fins. New trout missing adipose fins were then scanned for their PIT tag number then placed into recovery. Again, trout that failed to produce a tag number were recorded as having "shed" the PIT tag, and were usually re-tagged.

Between 2009 and 2012, PIT tags were implanted in most age-0 trout in Rush and Lee Vining Creeks and in all ages of trout in the MGORD. No PIT tags were deployed in 2013; however the tagging program was resumed during the 2014 - 2017 field seasons.

All data collected in the field, were written on data sheets and entered into Excel spreadsheets using a field laptop computer. Data sheets were then used to proof the Excel spreadsheets.

Calculations

To calculate the area of each sample section, channel lengths and wetted widths were measured within the sample reaches. Wetted widths were measured at approximately 10-meter intervals to 0.1 meter accuracy within each reach. Average wetted widths and reach lengths were used to generate sample sectionareas (in hectares), which were then used to calculate each section's estimates of trout biomass and density.

Mark-recapture population estimates were derived from the Chapman modification of the Petersen equation (Ricker 1975 as cited in Taylor and Knudson 2011). Depletion estimates and condition factors were derived from MicroFish 3.0 software program. Estimates were generated for three size groups of trout: <125 mm in length, 125-199 mm in length, and ≥200 mm in length (200 mm is approximately eight inches).

Mortalities

For the purpose of conducting the mark-recapture methodology, accounting for fish killed during the sampling process was important. Depending on when the fish were killed and whether or not they were sampled during the mark-run, how these fish were accounted for varied.

All fish killed during the mark-run were unavailable for sampling during the recapture-run. These fish were considered "morts" in the mark-run for the purposes of mark-recapture estimates, were removed from the mark-run data, and then were added back into the total estimate after computing the mark-recapture estimate.

During the seven-day period between the mark-run and the recapture-run, when the block fences were cleaned twice daily, fence cleaners also looked for additional morts. When "marked" morts were found on the fences, we went back into the mark-run data and assigned block fence morts on a one-to-one basis as "morts" to individual fish on the mark-run based on species and size. When this occurred, a comment was added to the individual fish, such as "assigned as fence mort". These marked morts were then removed from the mark-run data since they were unavailable for sampling during the recapture-run. Because of fin deterioration on some morts, exact lengths were not always available. Fortunately, it was not critical to match the exact length when assigning these marked fence morts to fish from the mark-run, but it was important that the fence morts were placed within the proper "length group" for which estimates were computed. As with fish killed during the mark-run, these marked fence morts were added back into the total estimate after the mark-recapture estimate was computed.

Unmarked fence morts (fish not caught and clipped during the mark-run) were measured and tallied by the three length groups for which estimates were computed. These fish were then added to the total number of morts (for each length group), which were then added back into the mark-recapture estimates to provide unbiased total estimates for each length group.

Length-Weight Relationships

Length-weight regressions (Cone 1989 as cited in Taylor and Knudson. 2011) were calculated for all Brown Trout greater than 100 mm in all sections of Rush Creek. Regressions using Log10 transformed data were used to compare length-weight relationships by year and by section.

Fulton-type condition factors were computed in MicroFish 3.0 using methods previously reported (Taylor and Knudson 2012) for Brown Trout 150 to 250 mm. A trout condition factor of 1.00 was considered average (Reimers 1963; Blackwell et al. 2000).

Relative Stock Density (RSD) Calculations

Relative stock density (RSD) is a numerical descriptor of length frequency data (Hunter et al. 2007). RSD values are the proportions (percentage x 100) of the total number of Brown Trout ≥150 mm in length that are also ≥225 mm or (RSD-225), ≥300 mm (RSD-300) and ≥375 mm or (RSD-375). These three RSD values are calculated by the following equations:

RSD-225 = [(# of Brown Trout ≥225 mm) ÷ (# of Brown Trout ≥150 mm)] x 100
RSD-300 = [(# of Brown Trout ≥300 mm) ÷ (# of Brown Trout ≥150 mm)] x 100
RSD-375 = [(# of Brown Trout ≥375 mm) ÷ (# of Brown Trout ≥150 mm)] x 100

Termination Criteria Calculations and Analyses

Information regarding the proposed termination criteria, calculations, and analyses were conducted as described in past Annual Fisheries Reports (Taylor and Knudson 2012).

Water Temperature Monitoring

Water temperatures were recorded (in degrees Fahrenheit) at various locations within Rush and Lee Vining creeks as part of the fisheries monitoring program. Data loggers were deployed in January and collected data throughout the year in one-hour time intervals. Data loggers were downloaded at the end of the year and the data were summarized in spreadsheets. Water temperature data loggers were deployed at the following locations in 2017:

1. Rush Creek at Damsite – upstream of GLR.
2. Rush Creek – top of MGORD.
3. Rush Creek – bottom of MGORD.
4. Rush Creek – at old Highway 395 Bridge.
5. Rush Creek – above Parker Creek.
6. Rush Creek – below Narrows.
7. Rush Creek – at County Road crossing.
8. Lee Vining Creek – at County Road crossing.

For the fisheries monitoring program, the year-long data sets were edited to focus on summer water temperature regimes (July – September) in Rush and Lee Vining creeks, with particular focus on Rush Creek. Analysis of summer water temperature included the following metrics:

1. Daily mean temperature.
2. Average daily minimum temperature.
3. Average daily maximum temperature.
4. Number of days with daily maximums exceeding 70^{o}F.
5. Number of hours with temperatures exceeding 66.2^{o}F.
6. Number of good/fair/poor potential growth days, based on daily average temperature.
7. Number of bad thermal days based on daily average temperature.
8. Maximum diurnal fluctuations.
9. Average maximum diurnal fluctuation for consecutive 21-day period.

Results

Channel Lengths and Widths

Differences in wetted widths between years can be due to several factors such as, magnitude of spring peak flows, stream flows at time of measurements, and locations of where the measurements were taken. Lengths, widths, and areas from 2016 are provided for comparisons (Table 1). In 2017, the Upper Rush and the Bottomlands sample sections were lengthened so the block fences could be set at favorable locations to deal with increased channel depths and velocities (Table 1). The Lee Vining Creek side channel carried more water in 2017, thus its length and width increased (Table 1). Conversely, the high flows during the 2017 runoff cut off a couple of meanders in Walker Creek, resulting in a shorter channel length (Table 1).

Table 1. Total length, average wetted width, and total surface area of sample sections in Rush, Lee Vining, and Walker Creeks sampled between October 10-20, 2017. Values from 2016 are provided for comparisons.

Sample Section	Length (m) 2016	Width (m) 2016	Area (m^2) 2016	Length (m) 2017	Width (m) 2017	Area (m^2) 2017	Area (ha) 2017
Rush – Upper	406	8.2	3,329.0	430	7.4	3,182.0	0.3182
Rush - Bottomlands	437	7.3	3,190.1	452	7.1	3,209.2	0.3209
Rush – MGORD	2,230	8.3	18,509.0	2,230	7.6	16,948.0	1.6948
Lee Vining – Main	255	5.3	1,351.5	255	5.4	1,377.0	0.1377
Lee Vining - Side	137	1.7	232.9	177	2.2	389.4	0.0389
Walker Creek	193	2.3	443.9	169	2.6	439.4	0.0439

Trout Population Abundance

In 2017, a total of 373 Brown Trout ranging in size from 80 mm to 392 mm were captured in the Upper Rush section (Figure 5). For comparison, in 2016 a total of 182 Brown Trout were captured and in 2015 a total of 759 Brown Trout were captured in this section. In 2017, age-0 Brown Trout comprised 58% of the total catch (compared to 41% in 2016 and 57% in 2015). The Upper Rush section supported an estimated 612 age-0 Brown Trout in 2017 (including morts) compared to 146 age-0 Brown Trout in 2016 (a 319% increase). The estimated standard error of the population estimate for age-0 Brown Trout in 2017 was 17% (Table 2).

In 2017, Brown Trout 125-199 mm in length comprised 8% of the total catch in the Upper Rush section (compared to 19% in 2016 and 30% in 2015). Because only one fish that was marked during the marking run was caught during the recapture run, it was not possible to make a valid population estimate. The catch value of 31 fish in the 125-199 mm size class was used for computation of density and standing crop estimates.

Brown Trout ≥200 mm in length comprised 34% of the Upper Rush total catch in 2017 (compared to 40% in 2016 and 13% in 2015). In 2017, Upper Rush supported an estimated 158 Brown Trout ≥200 mm in length compared to an estimate of 110 fish in 2016 (a 44% increase). Standard error of the estimate for this size class was 6% in 2017 versus 14% in 2016. In 2017, 20 Brown Trout ≥300 mm in length were captured in the Upper Rush section and these fish comprised 5% of the total catch (Figure 5).

A total of 47 Rainbow Trout were captured in the Upper Rush section comprising 11.2% of the section's total catch in 2017 (a total of 420 trout were caught). The 47 Rainbow Trout ranged in length from 65 mm to 450 mm and most of the fish >200 mm appeared to be of hatchery origin, which most likely originated from GLR and came over the dam during the 60-day spill (Figure 6).

Within the Bottomlands section of Rush Creek, a total of 164 Brown Trout were captured in 2017 (Table 2), which ranged in size from 93 mm to 331 mm (Figure 7). For comparison, 148 Brown Trout were captured in 2016, which ranged in length from 77 mm to 470 mm. Age-0 Brown Trout comprised 35% of the total catch in 2017 versus 54% of the total catch in 2016. The Bottomlands section supported an estimated 149 age-0 Brown Trout in 2017 versus 146 age-0 fish in 2016 (a 2% increase). Estimated standard errors for the population estimates of age-0 Brown Trout were 16% for both 2016 and 2017 (Table 2).

Brown Trout 125-199 mm in length comprised 19% of the total catch in the Bottomlands section in 2017 versus 23% of the total catch in 2016. This section supported an estimated 59 Brown Trout 125-199 mm in length in 2017 compared to 40 fish in 2016 (a 48% increase). Estimated standard error for the population estimate of this size class was 7% in 2017 versus 10% in 2016 (Table 2).

Brown Trout ≥200 mm in length comprised of 46% of the total catch in 2017 (23% in 2016) with the largest trout 331 mm in length. The Bottomlands section supported an estimated 80 Brown Trout ≥200 mm in 2017 compared to 38 trout in 2016 (a 111% increase). Standard error for the estimate of this size class was 4% in 2017 versus 8% in 2016 (Table 2). In 2017, four Brown Trout ≥300 mm were captured in the Bottomlands section; these fish were 304, 315, 319, and 331 mm in length (Figure 7).

Table 2. Rush Creek mark-recapture estimates for 2017 showing total number of trout marked (M), total number captured on the recapture run (C), total 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) were those trout that were captured during the mark run, but died prior to the recapture run. Mortalities were not included in mark-recapture estimates and were added to estimates for accurate total estimates. NP = estimate not possible. BNT = Brown Trout.

Stream / Section / Species / Date	Size Class (mm)	M	C	R	Morts	**Estimate**	S.E.
		Mark - recapture estimate					
Rush Creek							
Upper Rush-BNT							
10/11/2017 & 10/18/2017							
	0 - 124 mm	156	81	20	0	**612**	105
	125 - 199 mm	19	13	1	0	**NP***	NP
	≥200 mm	103	68	44	0	**158**	10
Bottomlands-BNT							
10/12/2017 & 10/19/2017							
	0 - 124 mm	34	29	6	0	**149**	42
	125 - 199 mm	19	17	5	0	**59**	16
	≥200 mm	62	36	22	0	**80**	7

*** only 1 recap**

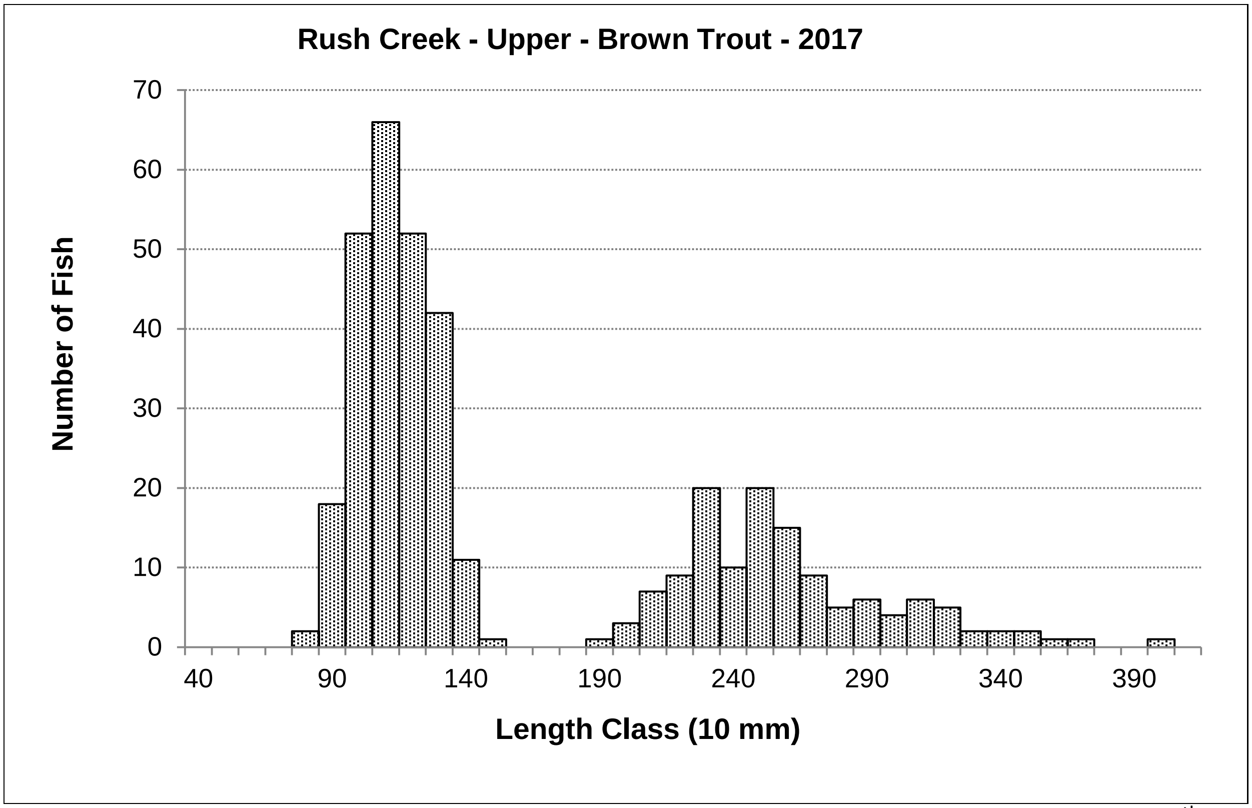


Figure 5. Length-frequency histogram of Brown Trout captured in Upper Rush, October 11th and 18th, 2017.

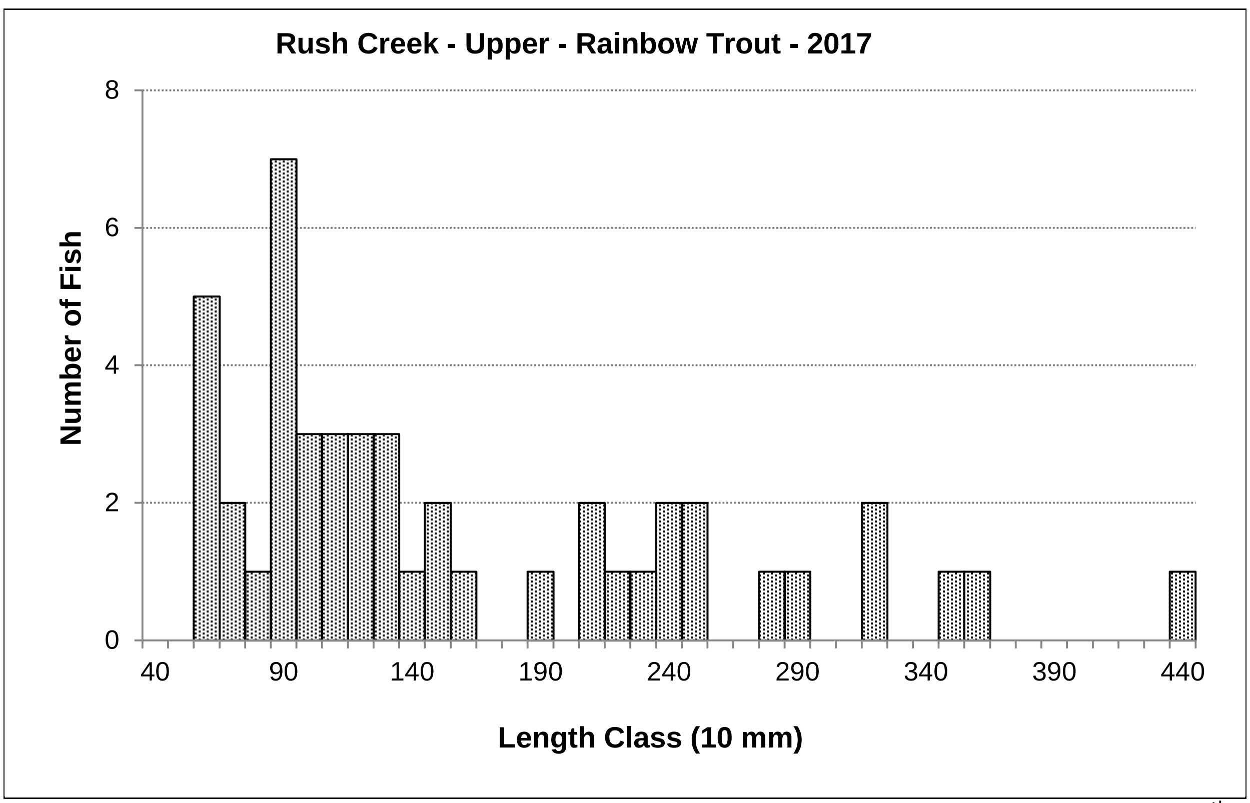


Figure 6. Length-frequency histogram of Rainbow Trout captured in Upper Rush, October 11th and 18th, 2017.

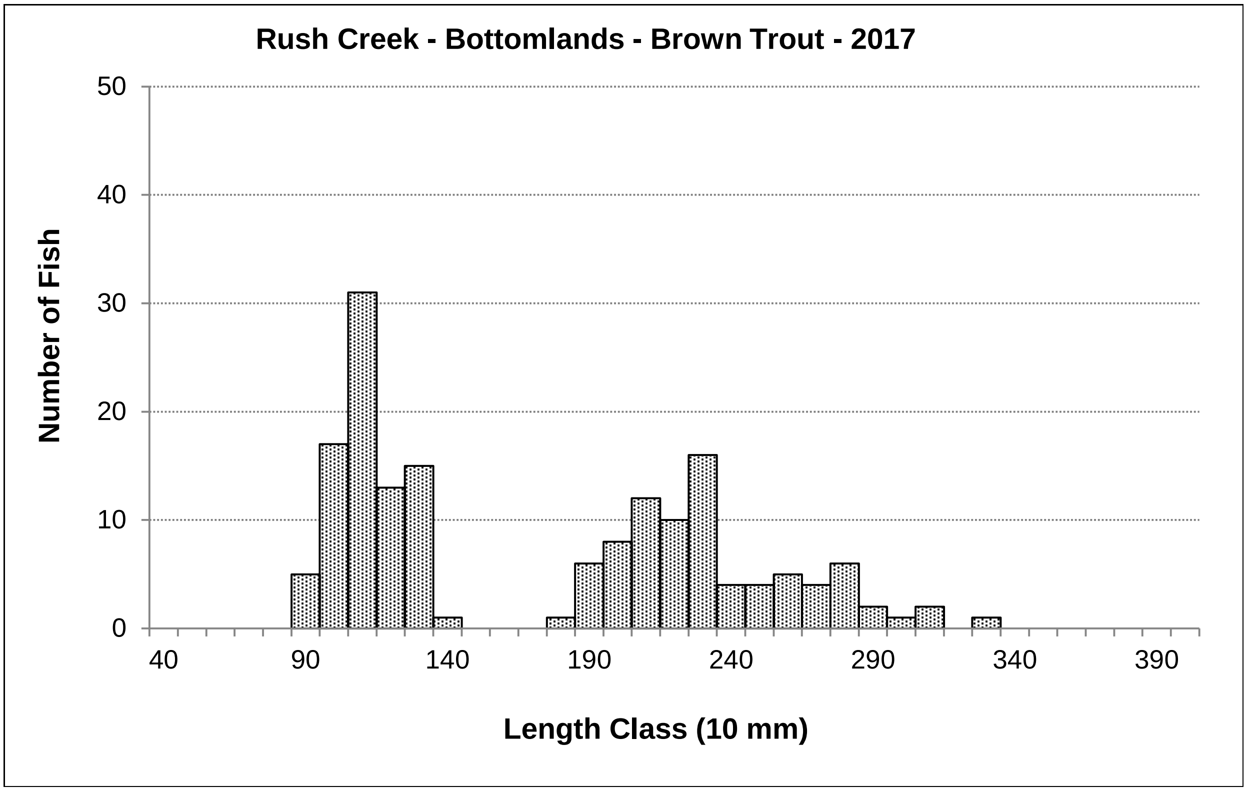


Figure 7. Length-frequency histogram of Brown Trout captured in the Bottomlands section of Rush Creek, October 12th and 19th, 2017.

Within the MGORD section of Rush Creek a total of 164 Brown Trout were captured during the single electrofishing pass made in 2017. These Brown Trout ranged in size from 93 mm to 645 mm (Figure 8). Thirty-six (presumed) age-0 Brown Trout were captured in 2017 which comprised 22% of the total catch, compared to 2% of the total catch in 2016 and 17% of the total catch in 2015.

Brown Trout 130-199 mm in length comprised 17% of the total catch in the MGORD section in 2017 versus 5% of the total catch in 2016 and 23% of the total catch in 2015. Note that the size limit of age-0 trout in the MGORD was increased to 130 mm due to faster growth previously documented in this section of Rush Creek.

Brown Trout ≥200 mm in length comprised of 61% of the total catch in the MGORD section during 2017 (93% in 2016 and 60% in 2015). In 2017, 28 Brown Trout ≥300 mm were captured in the MGORD (38 fish ≥300 mm were captured in 2016). Eleven Brown Trout ≥375 mm in length were captured in 2017 (20 fish in 2016), all 11 of these fish were >400 mm in length and six of these fish were >500 mm in length (Figure 8).

In 2017, 39 Rainbow Trout were captured in the MGORD section (Figure 9). In the previous five years, eight Rainbow Trout were captured in 2016, two in 2015, none in 2014, nine in 2013, and 40 in 2012. Many of the Rainbow Trout captured in 2017 appeared to be of hatchery origin and we suspect they spilled out of GLR during the extended 2017 runoff. In addition to hatchery origin Rainbow Trout, three Tui Chub were captured in the MGORD, and these fish are typically only captured in Rush Creek below GLR following spill events.

For the past 12 sampling years, electrofishing passes through the MGORD have produced the following total catch values (all size classes of Brown and Rainbow Trout):

- 2017 – Single pass = 203 trout.
- 2016 – Mark run = 121 trout. Recapture run = 110 trout. Two-pass average = 115.5 fish.
- 2015 – Single pass = 176 trout.
- 2014 – Mark run = 206 trout. Recapture run = 268 trout. Two-pass average = 237 fish.
- 2013 – Single pass = 451 trout.
- 2012 – Mark run = 606 trout. Recapture run = 543 trout. Two-pass average = 574.5 fish.
- 2011 – Single pass = 244 trout.
- 2010 – Mark run = 458 trout. Recapture run = 440 trout. Two-pass average = 449 fish.
- 2009 – Single pass = 649 trout.
- 2008 – Mark run = 450 trout. Recapture run = 419 trout. Two-pass average = 434.5 fish.
- 2007 – Single pass = 685 trout.
- 2006 – Mark Run = 283 trout. Recapture run = 375 trout. Two-pass average = 329 fish.

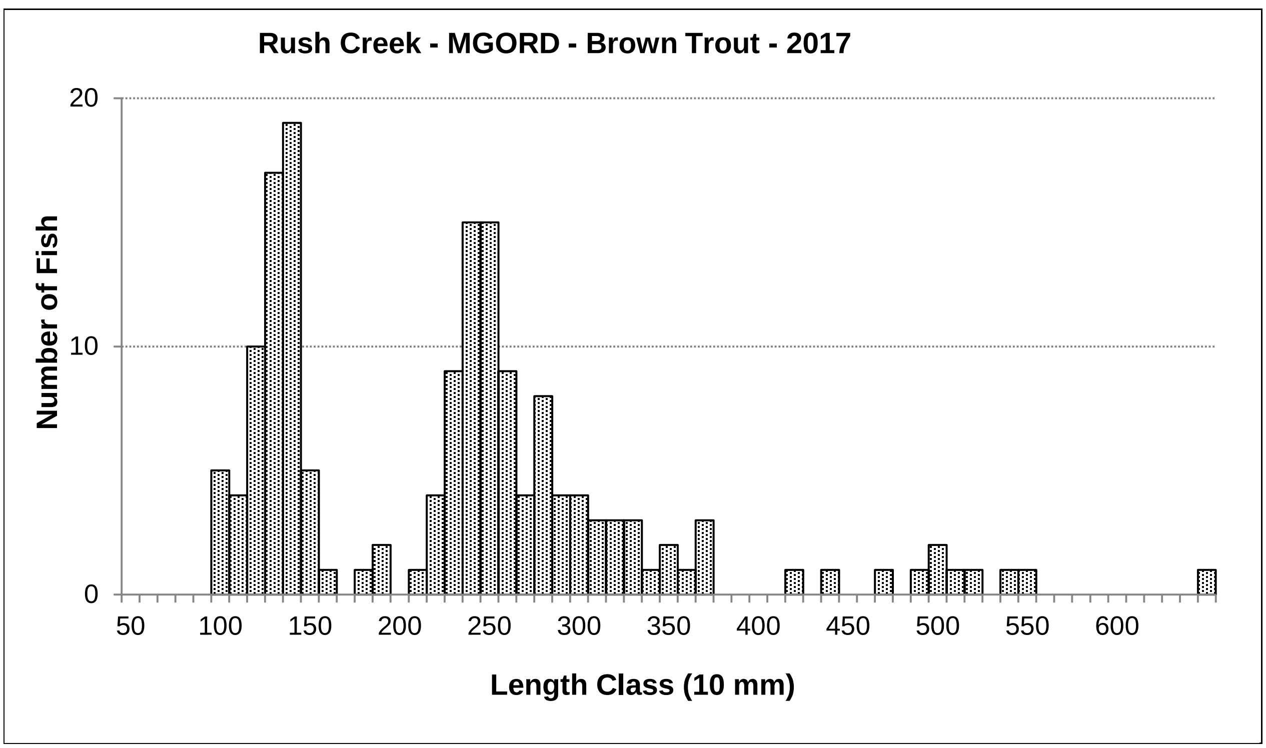


Figure 8. Length-frequency histogram of Brown Trout captured in the MGORD section of Rush Creek, October 17th, 2017.

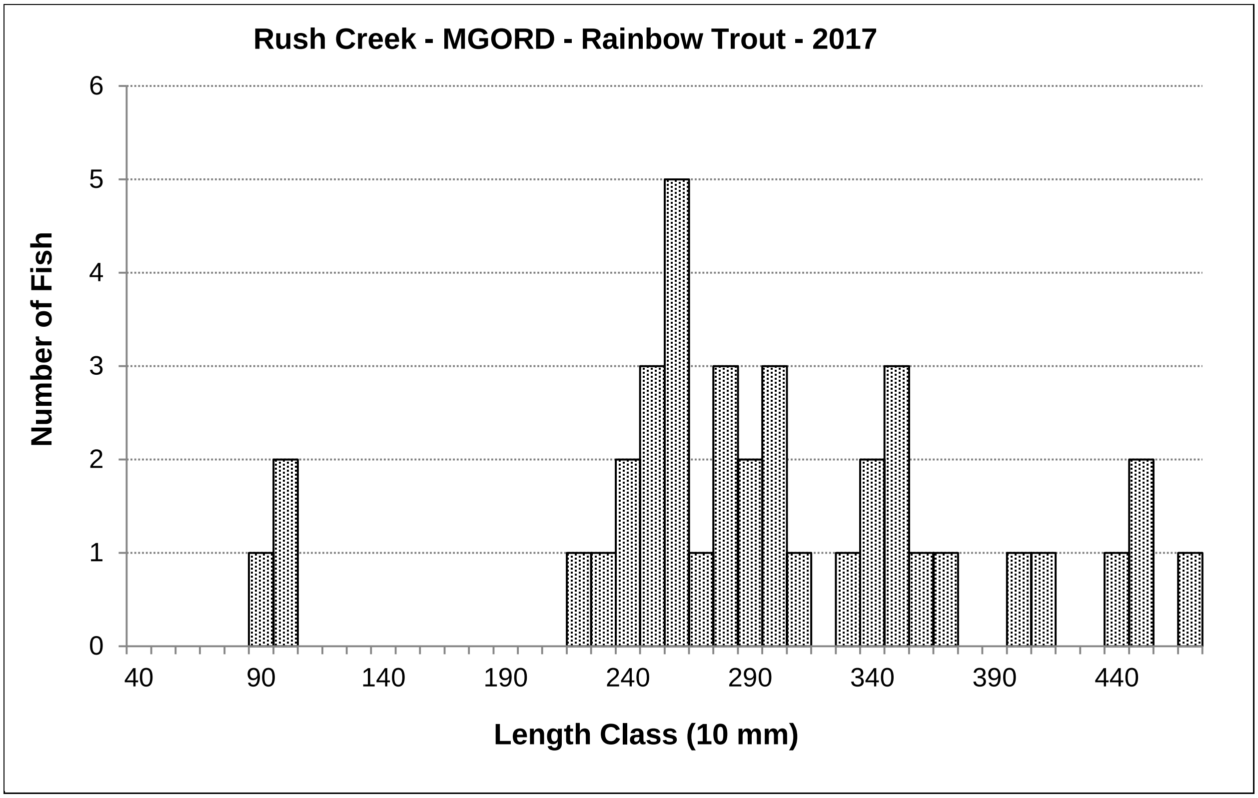


Figure 9. Length-frequency histogram of Rainbow Trout captured in the MGORD section of Rush Creek, October 17th, 2017.

Lee Vining Creek

In 2017, a total of 55 trout were captured in the Lee Vining Creek main channel section versus 246 fish in 2016, 422 fish in 2015 and 838 fish in 2012 (Table 3). All the trout captured in 2017 were Brown Trout, making 2017 the first time in 21 years that no Rainbow Trout were caught in the Lee Vining Creek main channel. In 2017, Brown Trout ranged in size from 68 mm to 305 mm (Figure 10). Age-0 fish comprised 58% of the total Brown Trout catch in 2017, compared to 28% in 2016 and 49% in 2015. Lee Vining Creek's main channel section supported an estimated 32 age-0 Brown Trout in 2017, compared to an estimated 118 age-0 Brown Trout in 2016, a 73% decrease (Table 2). Between 2012 and 2017, the age-0 Brown Trout estimates dropped from 677 fish to 32 fish (a 95% decrease).

In 2017, 13 Brown Trout 125-199 mm in length were captured and comprised 24% of the total Brown Trout catch in Lee Vining Creek's main channel section (versus 52% in 2016). This section supported an estimated 13 Brown Trout 125-199 mm in length in 2017 (Table 2) compared to 150 fish in 2016 (a 91% decrease).

In 2017, 10 Brown Trout ≥200 mm in length were captured and comprised of 20% of the total Brown Trout catch in Lee Vining Creek's main channel section (versus 20% in 2016). Lee Vining Creek's main channel supported an estimated 10 Brown Trout ≥200 mm in 2017 (versus 50 fish in 2016) (Table 2).

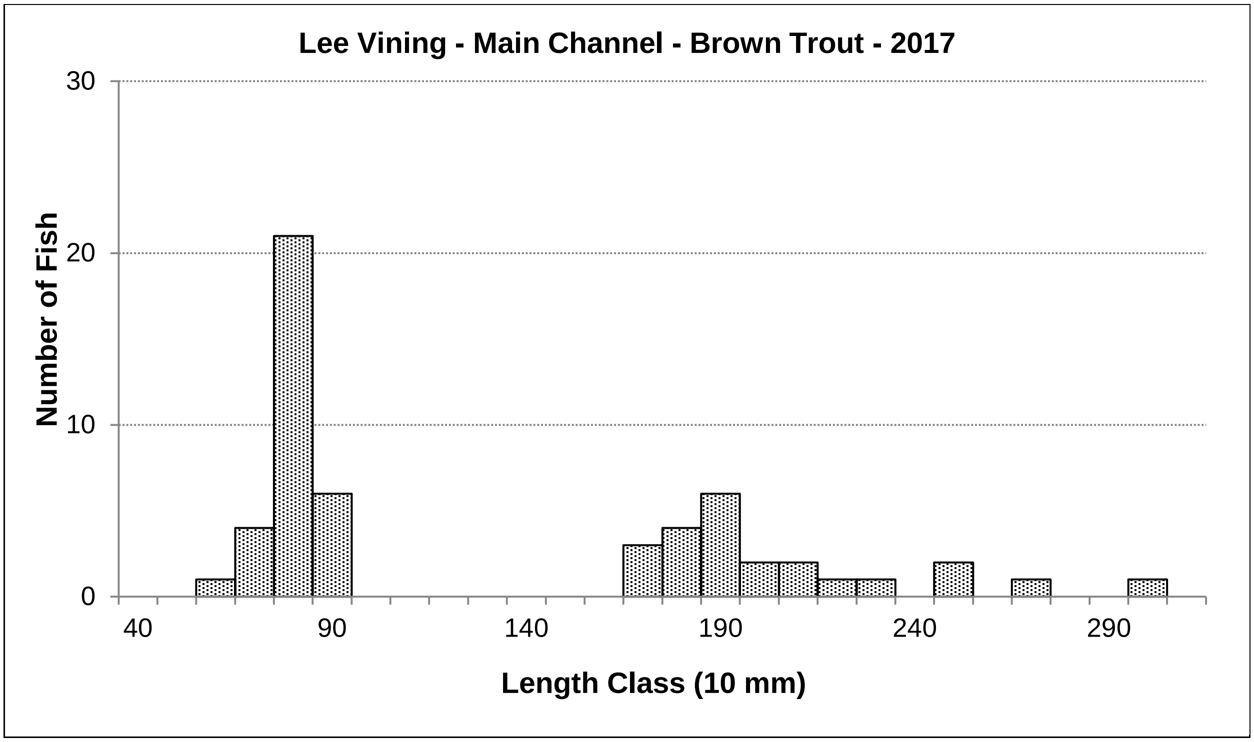


Figure 10. Length-frequency histogram of Brown Trout captured in the main channel section of Lee Vining Creek, October 13, 2017.

In the Lee Vining Creek side channel, 23 Brown Trout were captured in two electrofishing passes made during the 2017 sampling (Table 3). Sixteen age-0 fish were captured, three fish were in the 125-199 mm size class, and four fish were in the ≥200 mm size class (Figure 11). The estimates for the three size classes were equal to the catch numbers (Table 3). No Rainbow Trout were captured in the side channel in 2017. This was the ninth consecutive year that no age-0 Rainbow Trout were captured in the Lee Vining Creek side channel and the seventh consecutive year that no age-1 and older Rainbow Trout were captured.

Walker Creek

In 2017, 115 Brown Trout were captured in two electrofishing passes in the Walker Creek section (312 were captured in 2016 and 190 were captured in 2015) (Table 3). Sixty of these captured fish, or 52%, were age-0 fish ranging in size from 84 mm to 119 mm in length (Figure 12). The 2017 estimated population of age-0 Brown Trout for this Walker Creek section was 66 fish, a 77% decrease from the 2016 estimate of 292 fish. For trout <125 mm in length, the estimated probability of capture during 2017 was 69% (Table 3).

Brown Trout in the 125-199 mm size class (47 fish) accounted for 41% of the total catch in 2017 (compared to 22% in 2016). The 2017 population estimate for Brown Trout in the 125-199 mm size class was 47 trout with an estimated probability of capture of 90% (Table 3).

Brown Trout ≥200 mm in length (eight fish) accounted for 7% of the total catch in 2017 and was 5% in 2016. The 2017 population estimate for this size class was eight Brown Trout with a probability of capture of 89% (Table 3). The largest Brown Trout captured in Walker Creek in 2017 was 249 mm in length (Figure 12).

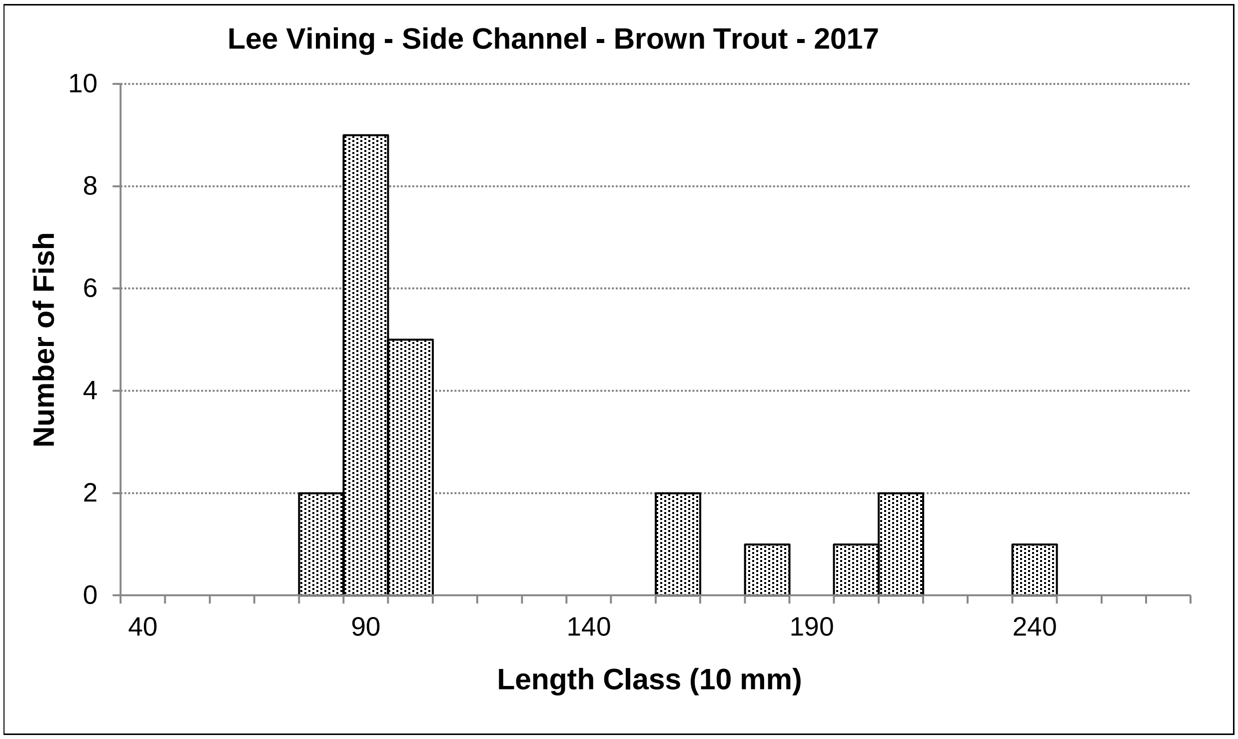


Figure 11. Length-frequency histogram of Brown Trout captured in the side channel section of Lee Vining Creek, October 14th, 2017.

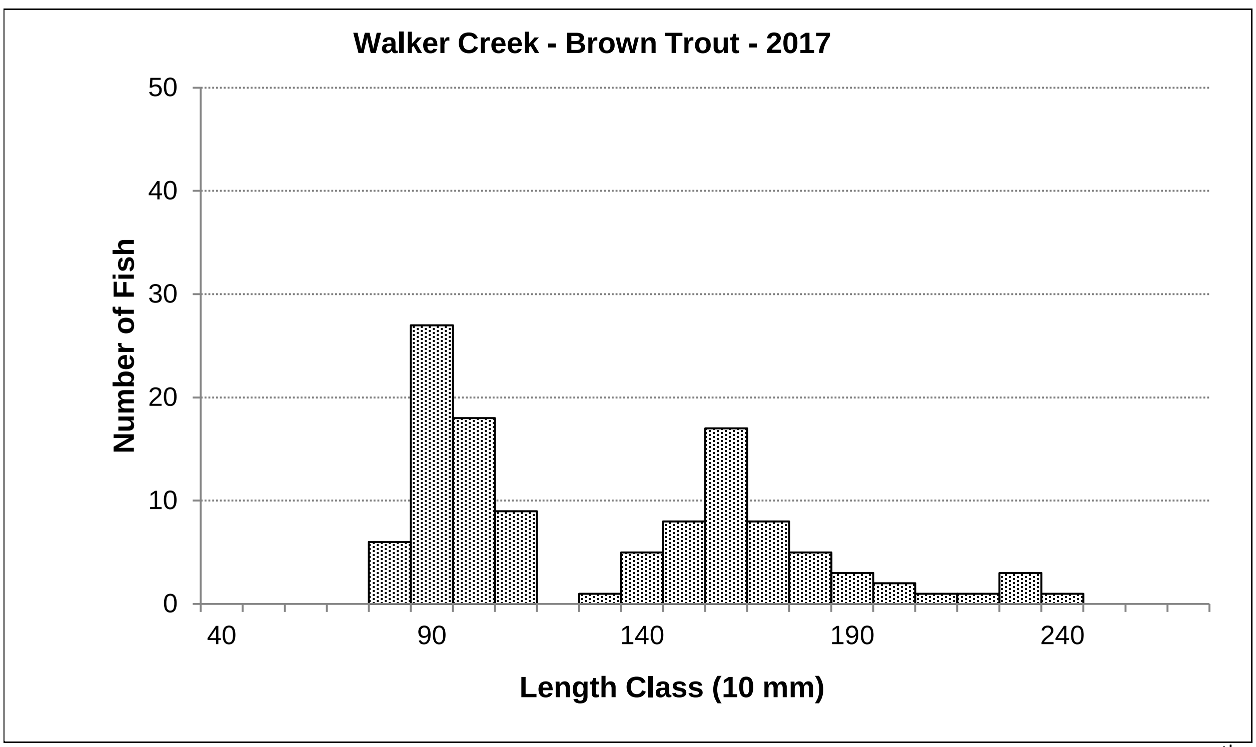


Figure 12. Length-frequency histogram of Brown Trout captured in Walker Creek, October 14th, 2017.

Table 3. Depletion estimates made in the side channel section of Lee Vining Creek and Walker Creek during October 2017 showing number of trout captured in each pass, estimated number, probability of capture (P.C.) by species and size class.

Stream - Section Date / **Species**	Size Class (mm)	Removals	Removal Pattern	**Estimate**	P.C.
Lee Vining Creek- Main Channel - 10/13/2017					
Brown Trout					
	0 - 124 mm	5	16 5 3 6 1	**32**	0.45
	125 - 199 mm	5	6 3 3 0 1	**13**	0.50
	200 + mm	5	9 0 1 0 0	**10**	0.83
Lee Vining Creek- Side Channel - 10/14/2017					
Brown Trout					
	0 - 124 mm	2	13 3	**16**	0.84
	125 - 199 mm	2	3 0	**3**	1.00
	200 + mm	2	4 0	**4**	1.00
Walker Creek - above old Hwy 395 - 10/14/2017					
Brown Trout					
	0 - 124 mm	2	45 15	**66**	0.69
	125 - 199 mm	2	42 5	**47**	0.90
	200 + mm	2	7 1	**8**	0.89

Catch of Rainbow Trout in Rush and Lee Vining Creeks

Beginning with the 2008 annual report, we have only reported catch summaries for Rainbow Trout in Rush Creek and did not attempt to estimate their populations. This decision was made because Rainbow Trout usually accounted for less than 5% of Rush Creek's total catch. In 2011, the last time GLR spilled significant amounts of water, hatchery-origin Rainbow Trout also spilled out of the reservoir. These spills resulted in Rainbow Trout accounting for 8% of the total catch in 2011, the highest we recorded in Rush Creek until 2017. For the sampling years since 2011; Rainbow Trout accounted for 5% of the total Rush Creek catch in 2012, 2% in 2013, 0.75% in 2014, 1.9% in 2015, and 2.5% in 2016. During the large snowmelt event of 2017, GLR spilled for 60 days and it appeared that fish originating from GLR came over the dam during these spills, as they likely did in 2011. For the 2017 sampling, Rainbow Trout comprised 10.9% of the total catch in Rush Creek (86 Rainbow Trout/787 total trout). Given CDFW's current policy of stocking sterile catchable Rainbow Trout, it is likely that future Rainbow Trout numbers will approach or exceed 5% of the total fish catch in Rush Creek only when major spills occur from GLR during wet RYs. We suspect that if spills at the GLR dam do not occur in the near future, Rainbow Trout numbers will again decline, following a similar pattern as observed after the 2011 season.

Between 1999 and 2012 Rainbow Trout numbers in Lee Vining Creek were variable, generally increasing during drier RY types and decreasing during wetter years. However, since 2012 the annual catch of Rainbow Trout in Lee Vining Creek has dropped steadily and dramatically. In 2012, a total of 235 Rainbow Trout were captured, including 226 age-0 fish. In 2013, 127 Rainbow Trout were captured (26 were age-0 fish), followed by 57 rainbows in 2014 (six were age-0 fish), 20 rainbows in 2015 (no age-0 fish), seven rainbows in 2016 (no age-0 fish) and no rainbows in 2017. This large drop in Rainbow Trout numbers has occurred during the time period when CDFW shifted to stocking sterile catchable Rainbow Trout. We suggest that in years prior to 2012, supplementation of the Rainbow Trout population with reproductively viable hatchery Rainbow Trout originating from CDFW stocking (upstream of LADWP's point of diversion), and their successful spawning, probably, to a large degree, supported the Lee Vining Creek Rainbow Trout population.

Sufficient numbers of age-0 Rainbow Trout were captured in the main channel of Lee Vining Creek to generate population estimates for only four of the 17 years sampled (Table 4). Adequate numbers of age-1 and older Rainbow Trout were captured in the main channel to generate population estimates for eight of the 17 years sampled (Table 5). The side channel produced enough numbers of age-0 and age-1 and older Rainbow Trout to generate population estimates for six of the 17 years sampled (Tables 6 and 7). However, no age-0 Rainbow Trout have been caught in the side channel in the past nine years and no age-1 and older Rainbow Trout have been caught in the past seven years (Tables 6 and 7).

Due to Rainbow Trout historically encompassing a large portion (10-40%) of the Lee Vining Creek trout population, an effort has been made to generate density and biomass values using the available data. In years when adequate numbers of rainbows have been captured, statistically valid density and biomass estimates have been generated. In years when less than adequate numbers of Rainbow Trout have been captured, catch numbers have been used to generate density and biomass estimates. While catch numbers are not statistically valid they were consistently lower than statistically valid estimates and allowed for comparison between all sampling years (Tables 4-7).

Table 4. Numbers of age-0 Rainbow Trout caught in Lee Vining Creek main channel section, 2000-2017.

Sample Year	Area of Sample Section (Ha)	Number of Trout on Marking Run	Number of Trout on Capture Run	Number of Recap Trout	Pop Estimate	Estimated Number of Trout per Hectare	Number of Trout Caught (Catch)	Catch per Hectare
2017	**0.1377**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2016	0.1352	0	0	0	0	0	0	0
2015	0.1224	0	0	0	0	0	0	0
2014	0.1403	4	4	2	NP	NP	6	43
2013	0.1454	19	12	5	40	275	26	179
2012	0.1279	155	138	67	318	2,494	226	1,773
2011	0.1428	1	0	0	NP	NP	1	7
2010	0.1505	0	0	0	0	0	0	0
2009	0.1505	4	4	0	NP	NP	8	53
2008	0.1377	17	31	9	57	414	39	283
2007	0.0884	42	56	22	106	1,199	76	860
2006	NS*	--	--	--	--	--	--	--
2005	0.0744	0	0	0	0	0	0	0
2004	0.0744	1	0	0	NP	NP	1	13
2003	0.0744	0	0	0	0	0	0	0
2002	0.0744	0	1	0	NP	NP	1	13
2001	0.0898	3	5	1	NP	NP	7	78
2000	0.0898	0	1	0	NP	NP	1	22

*NS stands for not sampled due to high flows

Table 5. Numbers of age-1 and older Rainbow Trout caught in Lee Vining Creek main channel section, 2000-2017.

Sample Year	Area of Sample Section (Ha)	Number of Trout on Marking Run	Number of Trout on Capture Run	Number of Recap Trout	Pop Estimate	Estimated Number of Trout per Hectare	Number of Trout Caught (Catch)	Catch per Hectare
2017	**0.1377**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2016	0.1352	7	5	5	7	52	7	52
2015	0.1224	18	14	12	21	172	20	163
2014	0.1403	36	36	21	63	449	51	364
2013	0.1454	61	45	29	120	826	77	530
2012	0.1279	7	7	5	NP	NP	9	71
2011	0.1428	5	8	5	NP	NP	8	56
2010	0.1505	12	9	7	15	100	14	93
2009	0.1505	39	32	12	98	651	59	392
2008	0.1377	71	64	37	129	936	98	712
2007	0.0884	3	5	1	NP	NP	7	79
2006	NS*	--	--	--	--	--	--	--
2005	0.0744	3	3	0	NP	NP	6	81

Table 5 (continued). Numbers of age-1 and older Rainbow Trout caught in Lee Vining Creek main channel section, 2000-2017.

Sample Year	Area of Sample Section (Ha)	Number of Trout on Marking Run	Number of Trout on Capture Run	Number of Recap Trout	Pop Estimate	Estimated Number of Trout per Hectare	Number of Trout Caught (Catch)	Catch per Hectare
2004	0.0744	2	2	2	NP	NP	2	27
2003	0.0744	5	6	5	NP	NP	6	81
2002	0.0744	10	10	7	14	188	13	175
2001	0.0898	9	8	4	NP	NP	13	145
2000	0.0898	1	3	0	NP	NP	4	45

Table 6. Numbers of age-0 Rainbow Trout caught in Lee Vining Creek side channel section, 2000-2017.

Sample Year	Area of Sample Section (Ha)	Number of Trout Caught on Pass #1	Number of Trout Caught on Pass #2	Number of Trout Caught on Pass #3	Pop Estimate	Estimated Number of Trout per Hectare	Number of Trout Caught (Catch)	Catch per Hectare
2017	**0.0389**	**0**	**0**	**--**	**0**	**0**	**0**	**0**
2016	0.0233	0	0	--	0	0	0	0
2015	0.0328	0	0	--	0	0	0	0
2014	0.0191	0	0	--	0	0	0	0
2013	0.0195	0	0	--	0	0	0	0
2012	0.0365	0	0	--	0	0	0	0
2011	0.0507	0	0	--	0	0	0	0
2010	0.0507	0	0	--	0	0	0	0
2009	0.0488	0	0	--	0	0	0	0
2008	0.0488	5	2	--	7	143	7	143
2007	0.0488	4	0	--	NP	NP	4	82
2006	0.0761	46	26	--	100	1,314	72	946
2005	0.0936	0	0	--	0	0	0	0
2004	0.0936	82	30	--	127	1,357	112	1,197
2003	0.0936	0	0	--	0	0	0	0
2002	0.0936	28	17	--	64	684	45	481
2001	0.1310	69	23	--	102	779	92	702
2000	0.0945	32	15	--	57	603	47	497

Table 7. Numbers of age-1 and older Rainbow Trout caught in Lee Vining Creek side channel section, 2000-2017.

Sample Year	Area of Sample Section (Ha)	Number of Trout Caught on Pass #1	Number of Trout Caught on Pass #2	Number of Trout Caught on Pass #3	Pop Estimate	Estimated Number of Trout per Hectare	Number of Trout Caught (Catch)	Catch per Hectare
2017	**0.0389**	**0**	**0**	**--**	**0**	**0**	**0**	**0**
2016	0.0233	0	0	--	0	0	0	0
2015	0.0328	0	0	--	0	0	0	0
2014	0.0191	0	0	--	0	0	0	0
2013	0.0195	0	0	--	0	0	0	0
2012	0.0365	0	0	--	0	0	0	0
2011	0.0507	0	0	--	0	0	0	0
2010	0.0507	1	0	--	1	20	1	20
2009	0.0488	15	0	--	15	307	15	307
2008	0.0488	3	1	--	4	82	4	82
2007	0.0488	6	0	--	NP	NP	6	123
2006	0.0761	5	0	--	NP	NP	5	66
2005	0.0936	7	2	--	9	96	9	96
2004	0.0936	5	0	--	NP	NP	5	53
2003	0.0936	13	0	--	NP	NP	13	139
2002	0.0936	29	4	--	33	353	33	353
2001	0.1310	38	3	--	41	313	41	313
2000	0.0945	9	0	--	NP	NP	9	95

Relative Condition of Brown Trout

Linear regressions of log-length to log-weight for captured Brown Trout ≥ 100 mm indicated strong correlations between length and weight (r^2 values 0.98 or greater; Table 8). Slopes of these relationships were near 3.0 (range: 2.7 to 3.1; Table 8) indicating isometric growth, which was assumed to compute fish condition factors, was reasonable.

Table 8. 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 2017 regression equations are in ***bold*** type.

Section	Year	N	Equation	r^2	P
Bottomlands	***2017***	***160***	***$Log_{10}(WT) = 3.0398*Log_{10}(L) – 5.0998$***	***0.99***	***<0.01***
	2016	132	$Log_{10}(WT) = 3.0831*Log_{10}(L) – 5.2137$	0.99	<0.01
	2015	301	$Log_{10}(WT) = 3.0748*Log_{10}(L) – 5.1916$	0.99	<0.01
	2014	238	$Log_{10}(WT) = 3.0072*Log_{10}(L) – 5.0334$	0.98	<0.01
	2013	247	$Log_{10}(WT) = 2.7997*Log_{10}(L) – 4.591$	0.98	<0.01
	2012	495	$Log_{10}(WT) = 2.8149*Log_{10}(L) – 4.6206$	0.98	<0.01
	2011	361	$Log_{10}(WT) = 2.926*Log_{10}(L) – 4.858$	0.99	<0.01

Table 8 (continued).

Section	Year	N	Equation	R^2	P
Bottomlands	2010	425	$Log_{10}(WT) = 2.999*Log_{10}(L) – 5.005$	0.99	<0.01
	2009	511	$Log_{10}(WT) = 2.920*Log_{10}(L) – 4.821$	0.99	<0.01
	2008	611	$Log_{10}(WT) = 2.773*Log_{10}(L) – 4.524$	0.99	<0.01
Upper Rush	***2017***	***309***	***$Log_{10}(WT) = 3.0592*Log_{10}(L) – 5.1198$***	***0.99***	***<0.01***
	2016	176	$Log_{10}(WT) = 3.0702*Log_{10}(L) – 5.1608$	0.99	<0.01
	2015	643	$Log_{10}(WT) = 2.9444*Log_{10}(L) – 4.8844$	0.99	<0.01
	2014	613	$Log_{10}(WT) = 2.9399*Log_{10}(L) – 4.8705$	0.99	<0.01
	2013	522	$Log_{10}(WT) = 2.9114*Log_{10}(L) – 4.816$	0.99	<0.01
	2012	554	$Log_{10}(WT) = 2.8693*Log_{10}(L) – 4.721$	0.99	<0.01
	2011	547	$Log_{10}(WT) = 3.006*Log_{10}(L) – 5.014$	0.99	<0.01
	2010	420	$Log_{10}(WT) = 2.995*Log_{10}(L) – 4.994$	0.99	<0.01
	2009	612	$Log_{10}(WT) = 2.941*Log_{10}(L) – 4.855$	0.99	<0.01
	2008	594	$Log_{10}(WT) = 2.967*Log_{10}(L) – 4.937$	0.99	<0.01
	2007	436	$Log_{10}(WT) = 2.867*Log_{10}(L) – 4.715$	0.99	<0.01
	2006	485	$Log_{10}(WT) = 2.99*Log_{10}(L) – 4.98$	0.99	<0.01
	2005	261	$Log_{10}(WT) = 3.02*Log_{10}(L) – 5.02$	0.99	<0.01
	2004	400	$Log_{10}(WT) = 2.97*Log_{10}(L) – 4.94$	0.99	<0.01
	2003	569	$Log_{10}(WT) = 2.96*Log_{10}(L) – 4.89$	0.99	<0.01
	2002	373	$Log_{10}(WT) = 2.94*Log_{10}(L) – 4.86$	0.99	< 0.01
	2001	335	$Log_{10}(WT) = 2.99*Log_{10}(L) – 4.96$	0.99	< 0.01
	2000	309	$Log_{10}(WT) = 3.00*Log_{10}(L) – 4.96$	0.98	< 0.01
	1999	317	$Log_{10}(WT) = 2.93*Log_{10}(L) – 4.84$	0.98	< 0.01
MGORD	***2017***	***159***	**$Log_{10}(WT) = 3.0052*Log_{10}(L) – 5.0205$**	**0.99**	**<0.01**
	2016	183	$Log_{10}(WT) = 3.0031*Log_{10}(L) – 5.3093$	0.99	<0.01
	2015	172	$Log_{10}(WT) = 3.131*Log_{10}(L) – 5.0115$	0.99	<0.01
	2014	399	$Log_{10}(WT) = 2.9805*Log_{10}(L) – 4.9827$	0.98	<0.01
	2013	431	$Log_{10}(WT) = 2.8567*Log_{10}(L) – 4.692$	0.98	<0.01
	2012	795	$Log_{10}(WT) = 2.9048*Log_{10}(L) – 4.808$	0.99	<0.01
	2011	218	$Log_{10}(WT) = 2.917*Log_{10}(L) – 4.823$	0.98	<0.01
	2010	694	$Log_{10}(WT) = 2.892*Log_{10}(L) – 4.756$	0.98	<0.01
	2009	689	$Log_{10}(WT) = 2.974*Log_{10}(L) – 4.933$	0.99	<0.01
	2008	862	$Log_{10}(WT) = 2.827*Log_{10}(L) – 4.602$	0.98	<0.01
	2007	643	$Log_{10}(WT) = 2.914*Log_{10}(L) – 4.825$	0.98	<0.01

Table 8 (continued).

Section	Year	N	Equation	R^2	P
	2006	593	$Log_{10}(WT) = 2.956*Log_{10}(L) – 4.872$	0.98	<0.01
	2004	449	$Log_{10}(WT) = 2.984*Log_{10}(L) – 4.973$	0.99	<0.01
	2001	769	$Log_{10}(WT) = 2.873*Log_{10}(L) – 4.719$	0.99	<0.01
	2000	82	$Log_{10}(WT) = 2.909*Log_{10}(L) – 4.733$	0.98	<0.01

Condition factors of Brown Trout 150 to 250 mm in length in 2017 increased from 2016's values in all sections, except for the MGORD which decreased slightly (Figures 13 and 14). In 2017, three sections (Upper Rush, Lee Vining main channel and Lee Vining side channel) had Brown Trout condition factors ≥1.00 (Figures 13 and 14).

The Upper Rush section had a condition factor of 1.04 in 2017, an increase from 1.00 in 2016 (Figure 13). The last time Upper Rush Brown Trout had a condition factor of 1.04 was in 2005.

The Bottomlands section of Rush Creek had a condition factor of 0.99 in 2017, an increase from the value of 0.95 in 2016 (Figure 13). The 2017 value of 0.99 matches the highest value for this section, first set in 2009. In ten years of sampling, the Bottomlands section has failed to generate a Brown Trout condition factor ≥1.00 (Figure 13).

The MGORD's 2017 condition factor was 0.97, a slight decrease from the 2016 value of 1.00. For six of the previous seven years, the condition factor of Brown Trout 150 to 250 mm in length have been less than average (Figure 13). In 2017, condition factors for larger Brown Trout in the MGORD were also computed: fish ≥300 mm had a condition factor of 0.99 (1.03 in 2016) and fish ≥375 mm had a condition factor of 1.02 (1.09 in 2016).

After four consecutive years of below average condition factors, Brown Trout in Lee Vining Creek's main channel had a condition factor 1.10 in 2017 (Figure 14). The 2017 value is the highest estimated condition factor for Brown Trout in this sample section since 2005 (Figure 14). In 2017, Brown Trout in Lee Vining Creek's side channel had a condition factor 1.12, a relatively large increase from 2016's value of 1.02 and 2015's value of 0.90 (Figure 14). For the seventh year in a row, no Rainbow Trout were captured in the Lee Vining Creek side channel.

In Walker Creek, Brown Trout had a condition factor of 0.97 in 2017, a slight increase from 0.95 in 2016 (Figure 13). Brown Trout condition factors in Walker Creek have been ≥1.00 in 11 of the 19 sampling years (Figure 13).

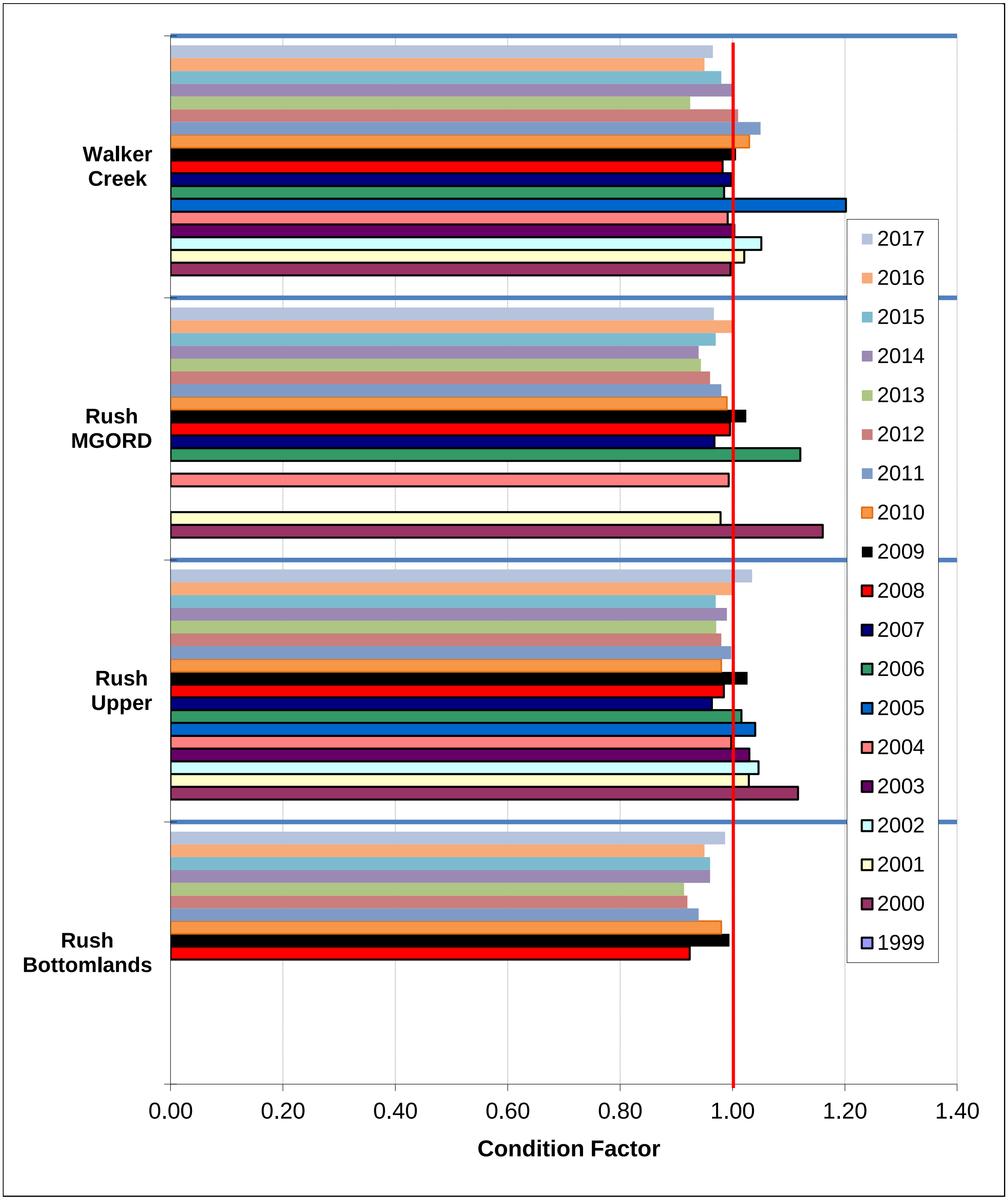


Figure 13. Condition factors for Brown Trout 150 mm to 250 mm in length from sample sections of Rush Creek and Walker Creeks from 1999 to 2017.

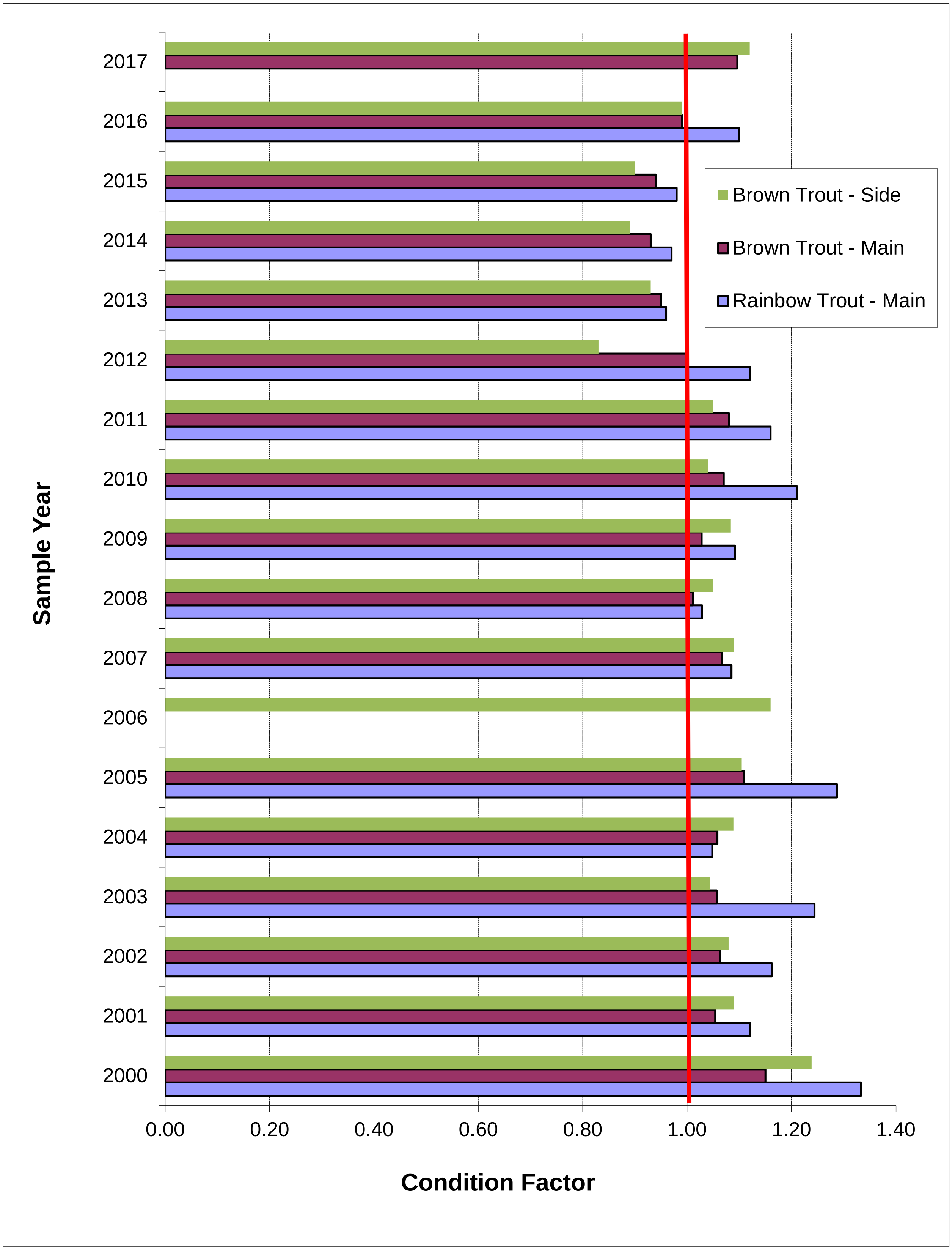


Figure 14. Comparison of condition factors for Rainbow Trout and Brown Trout 150 to 250 mm in length from the main channel and side channel sections of Lee Vining Creek from 2000 to 2017. Main channel was not sampled in 2006 due to high flows. No Rainbow Trout were captured in 2017.

Estimated Trout Densities Expressed in Numbers per Hectare

Age-0 Brown Trout

The Upper Rush section had an estimated density of 1,923 age-0 Brown Trout/ha in 2017, an increase of 338% from 2016's estimate of 439 age-0 trout/ha (Figure 15). Between 2012 and 2016 (the five consecutive dry/below average RYs) age-0 Brown Trout density estimates dropped from 8,624 fish to 439 fish (a 95% decrease). The 2017 density value in the Upper Rush section was the second lowest value ever recorded for this section and was 66% lower than the 18-year average of 5,723 age-0 Brown Trout/ha.

The Bottomlands section of Rush Creek had a density estimate of 464 age-0 Brown Trout/ha in 2017, similar to 2016's estimate of 458 age-0 trout/ha (Figure 15). Between 2012 and 2016 (the five consecutive dry/below average RYs) the age-0 Brown Trout density estimates dropped from 2,616 fish to 458 fish (an 82% decrease). When compared to the 10-year average of 1,758 age-0 Brown Trout/ha, the 2017 estimate was 74% lower.

In Walker Creek, the 2017 density estimate of 1,503 age-0 Brown Trout/ha was a 77% decrease from the 2016 estimate of 6,578 age-0 trout/ha (Figure 15). The 2017 density estimate was 58% lower than the 19-year average of 3,595 age-0 trout/ha (Figure 15).

In 2017, the estimated density of age-0 Brown Trout in the main channel section of Lee Vining Creek was 232 age-0 trout/ha, which was a 73% decrease from the 2016 density estimate of 873 age-0 trout/ha (Figure 16). Between 2012 and 2017 (the five consecutive dry/below average years followed by an extremely wet year) the age-0 Brown Trout density estimates dropped from 5,293 fish to 232 fish (a 96% decrease). The 2017 estimate was 86% lower than the 19-year average of 1,625 age-0 Brown Trout/ha.

In 2017, the age-0 Brown Trout density estimate in the side channel section of Lee Vining Creek was 411 age-0 trout/ha, which was a 378% increase from the 2016 density estimate of 86 age-0 trout/ha (Figure 16).The 2017 estimate was 17% greater than the 19-year average of 350 age-0 Brown Trout/ha.

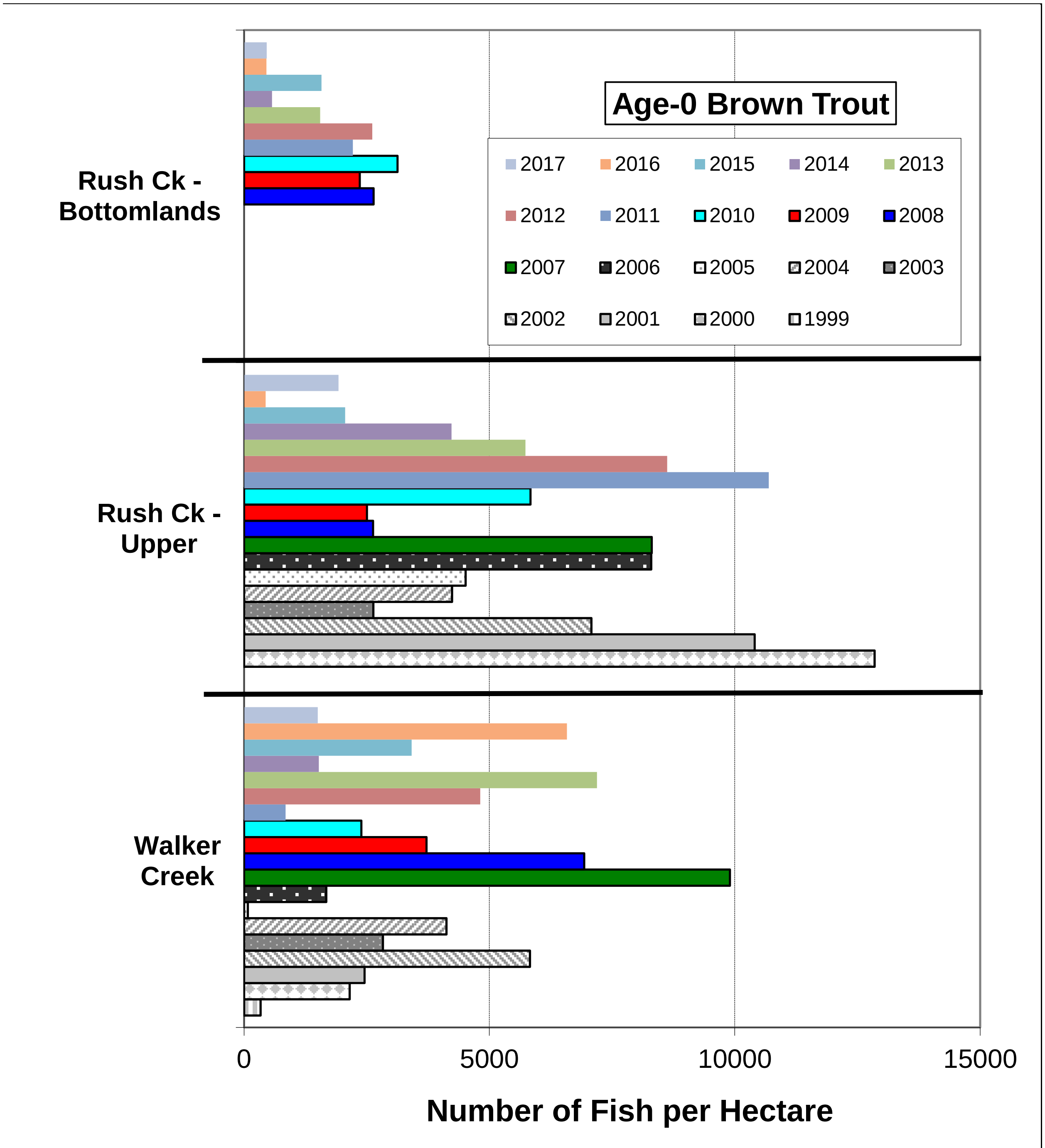


Figure 15. Estimated number of age-0 Brown Trout per hectare in Rush Creek and Walker Creek from 1999 to 2017.

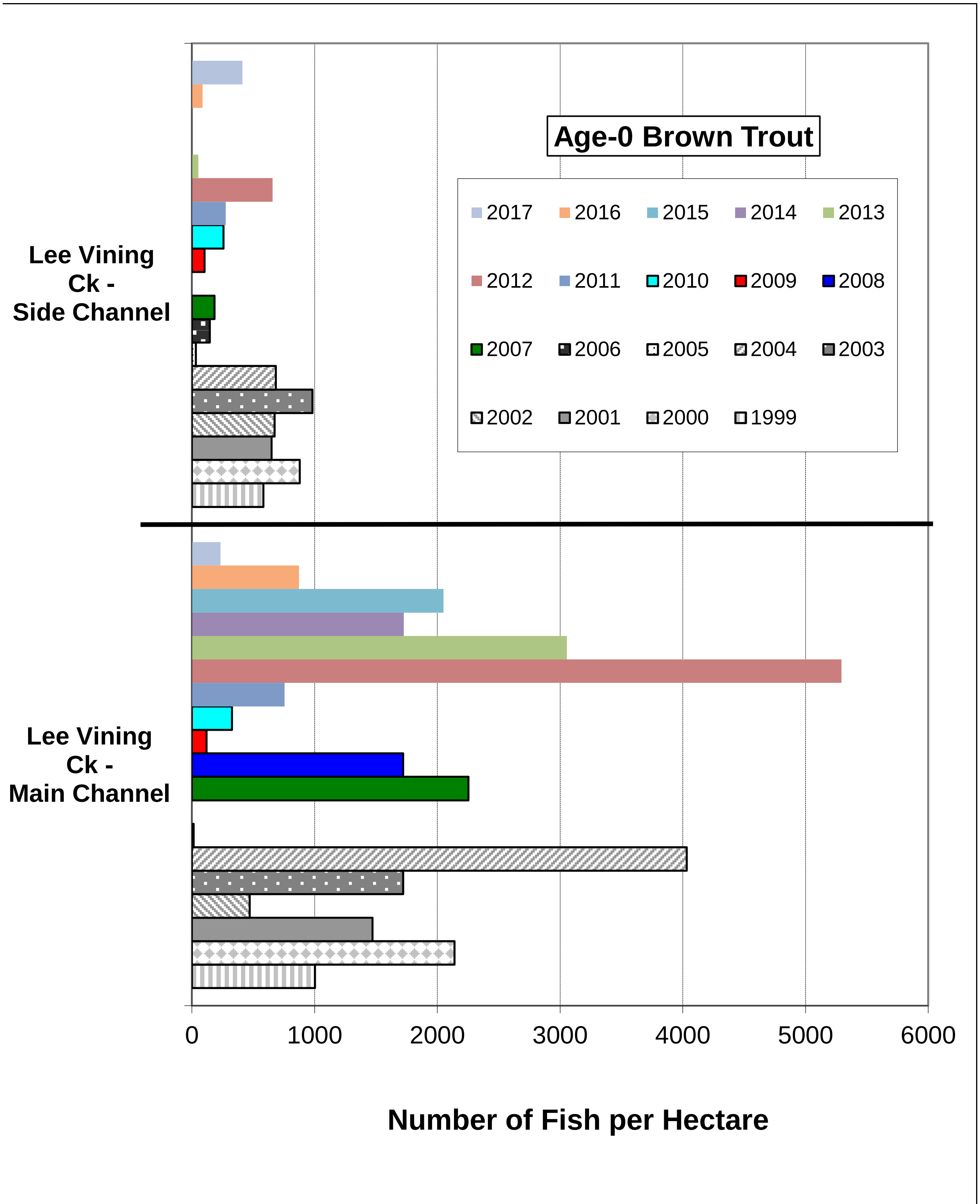


Figure 16. Estimated number of age-0 Brown Trout per hectare in Lee Vining Creek from 1999 to 2017.

Age-1 and older (aka Age-1+) Brown Trout

The Upper Rush section had an estimated density of 594 age-1+ Brown Trout/ha in 2017, an increase of 20% from the 2016 estimate of 496 trout/ha (Figure 17). Between 2012 and 2016 (the five consecutive dry/below average years), the age-1+ Brown Trout density estimates dropped from 1,993 fish to 496 fish (a 75% decrease). The 2017 estimate was the second lowest recorded for this section and was 57% lower than the 19-year average of 1,367 age-1+ Brown Trout/ha.

The Bottomlands section of Rush Creek produced a density estimate of 433 age-1+ Brown Trout/ha in 2017, a 77% increase from the 2016 estimate of 245 age-1+trout/ha (Figure 17). The 2017 density estimate of age-1+ Brown Trout/ha was the second lowest since the start of sampling the Bottomlands section in 2008 and was 60% lower than the 10-year average of 1,076 age-1+ Brown Trout/ha.

The 2017 density estimate for age-1+ Brown Trout for the Walker Creek section was 1,253 age-1+trout/ha which was a 36% decrease from the 2016 estimate of 1,960 age-1+ trout/ha (Figure 17). The 2017 density estimate of age-1+ Brown Trout was 28% lower than the 19-year average of 1,747 age-1+ Brown Trout/ha.

The 2017 density estimate for age-1+ Brown Trout in the Lee Vining main channel section was 167 trout/ha, an 89% decrease from the 1,479 age-1+ trout/ha in 2016 (Figure 18). The 2017 estimate was the fourth consecutive decrease in the density estimate of age-1+ Brown Trout for this section since 2013's estimate of 2,449 age-1+ Brown Trout/ha (Figure 18). The 2017 density estimate of age-1+ Brown Trout was 85% lower than the 18-year average of 1,117 age-1+ Brown Trout/ha.

In 2017, the side channel of Lee Vining Creek supported an estimated density of 180 age-1+ Brown Trout/ha, a decrease of 58% from the 2016 estimate of 430 age-1+ Brown Trout/ha (Figure 18). As discussed in last year's annual report, the side channel's large variations in wetted area has been a major factor driving density and standing crop estimates for this section, such that the lowest catch of fish (seven in 2015) resulted in the largest density estimate (Table 9). In October of 2017, more flow was entering the top of the side channel, which increased the wetted area within the sampling section by 67% from September of 2016 (Table 9).

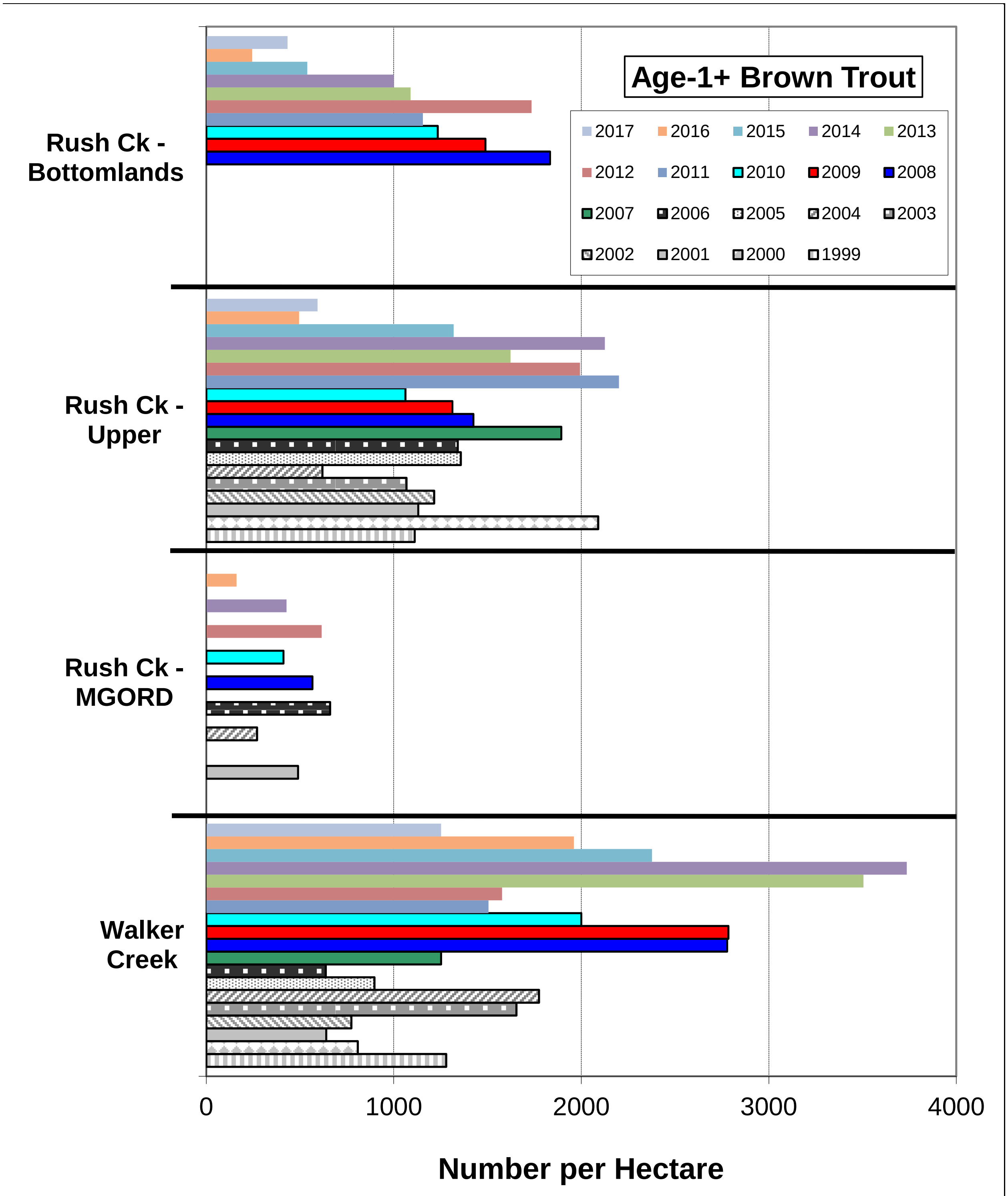


Figure 17. Estimated number of age-1 and older Brown Trout per hectare in sections of Rush and Walker Creeks from 1999 to 2017.

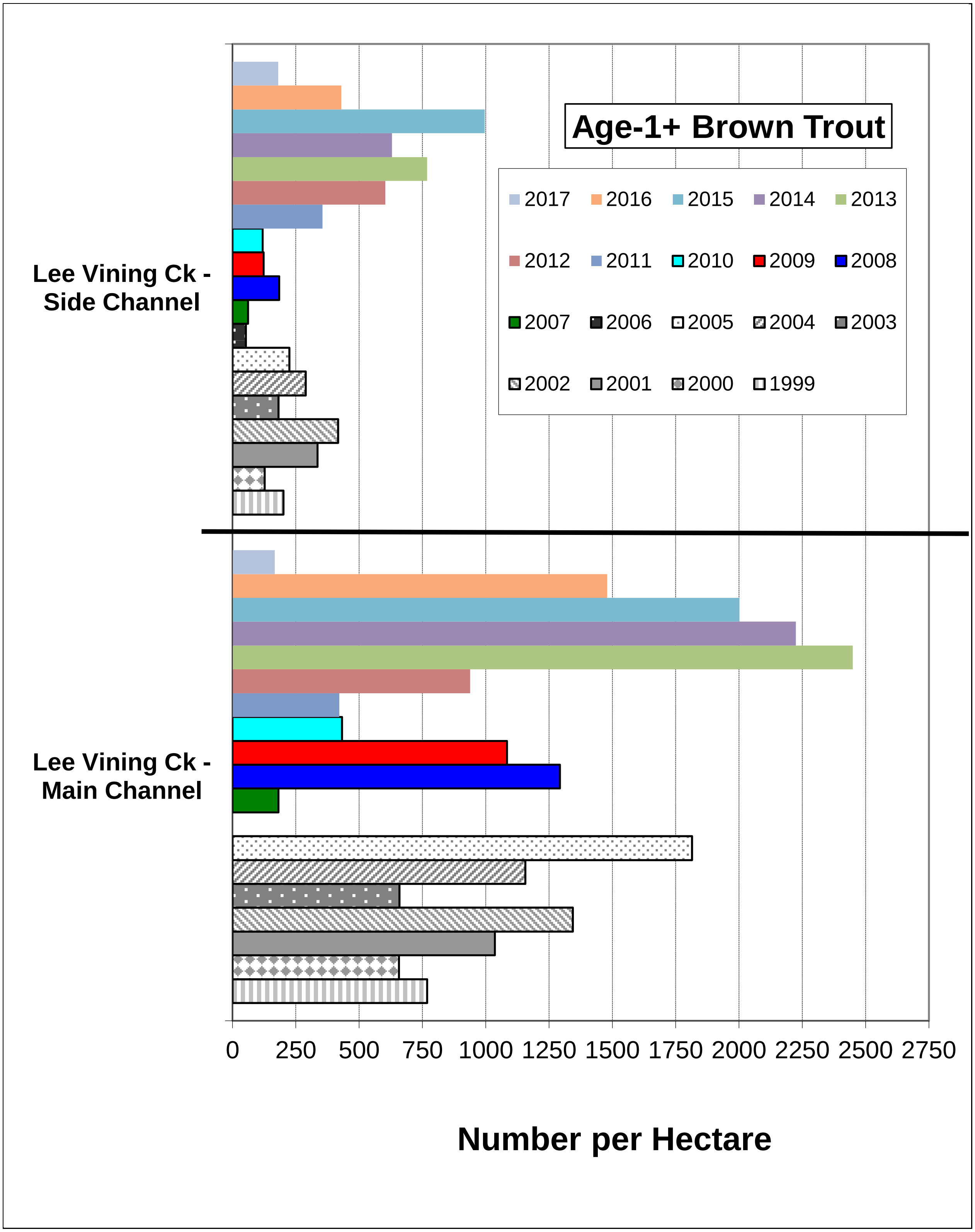


Figure 18. Estimated number of age-1 and older Brown Trout per hectare in sections of Lee Vining Creek from 1999 to 2017.

Table 9. Wetted surface area and total numbers of trout captured in the Lee Vining Creek side channel, from 2007 to 2017.

Sample Year	Wetted Channel Area (m^2)	Total Number of Trout Captured
2007	487.5	22
2008	487.5	20
2009	487.5	26
2010	507.0	20
2011	507.0	30
2012	365.0	45
2013	328.0	16
2014	190.5	12
2015	70.3	7
2016	232.9	12
2017	**389.4**	**23**

Age-0 Rainbow Trout

In 2017, for the ninth consecutive year no age-0 Rainbow Trout were captured in the Lee Vining Creek side channel. In the Lee Vining Creek main channel, for a third consecutive year, no age-0 Rainbow Trout were captured during the 2017 sampling.

Age-1 and older (aka Age-1+) Rainbow Trout

In 2017, for the seventh consecutive year no age-1 and older Rainbow Trout were captured in the Lee Vining Creek side channel.

In 2017, for the first time in 19 sampling years, no age-1 and older Rainbow Trout were captured in the Lee Vining Creek main channel. This decline from 235 Rainbow Trout caught in 2012 to no fish sampled in 2017 coincides with five years of CDFW stocking sterile Rainbow Trout into Eastern Sierra water bodies.

Estimated Numbers of Trout per Kilometer

The Upper Rush section contained an estimated 1,863 Brown Trout/km (all size classes combined) in 2017, which was a 143% increase from the 2016 estimate of 766 Brown Trout/km (Table 10). Prior to 2017, the estimated numbers of Brown Trout/km had fallen for five straight years in the Upper Rush section (Table 10). The estimated density of age-1+ Brown Trout in 2017 was 440 fish/km, an 8% increase from the 2016 estimate of 406 fish/km (Table 10).

The Bottomlands section contained an estimated of 637 Brown Trout/km (all size classes combined) in 2017, which was a 22% increase from the 2016 estimate of 523 fish/km (Table 10). Prior to 2017, the estimated numbers of Brown Trout/km had fallen for five straight years in the Bottomlands section of Rush Creek. In 2017, the estimate of 308 age-1+ Brown Trout/km represented a 75% increase from the 2016 estimate of 176 age-1+ Brown Trout/km (Table 10).

The Lee Vining Creek main channel contained an estimated 216 Brown Trout/km (all size classes combined) in 2017 (no Rainbow Trout caught in 2017) (Table 11). The 2016 total estimate was 89% less than the 2016 estimate of 1,973 Rainbow Trout and Brown Trout/km (Table 11). After the peak estimate of 4,361 fish/km in 2012 (the first of five consecutive dry/below normal years), the estimate has decreased for six consecutive years, and 2017's estimate was 95% less than 2012's estimate. For age-1+ Rainbow Trout and Brown Trout combined, the estimated density was 90 fish/km in 2017, which was a 91% decrease from the 2016 estimate of 989 age-1+ fish/km (Table 11).

The Lee Vining side channel contained an estimated 130 Brown Trout/km in (all size classes combined) 2017, a 34% increase from the 2016 estimate of 97 fish/km (Table 11). For age-1+ Brown Trout, the 2017 density estimate was 40 Brown Trout/km which was a 59% decrease from the 2016 density estimate 97 fish/km (Table 11).

The Lee Vining Creek main channel and the side channel estimates of total numbers of trout per kilometer were added in order to compare to the proposed termination criteria as discussed in the 2011 Annual Fisheries Report (Taylor and Knudson 2012). When combined, the two channels contained an estimated 180 Brown Trout/km in 2017 (no Rainbow Trout caught in 2017), a decrease of 79% from the 2016 estimate of 860 Rainbow Trout and Brown Trout/km (Table 11). Age-1+ trout in these two channels contained an estimate of 69 fish/km in 2017, an 88% decrease from 554 fish/km in 2016 (Table 11).

Table 10. Estimated total numbers of Brown Trout per kilometer of stream channel for Rush Creek sample sections from 2006 to 2017. The value within (#) denotes the number of age-1 and older trout per kilometer.

Collection Location	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Rush Creek, Upper Rush	7,905 (1,100)	8,698 (1,621)	3,607 (1,267)	3,444 (1,186)	5,726 (881)	10,821 (1,833)	8,288 (1,556)	6,105 (1,347)	4,574 (1,530)	2,468 (963)	766 (406)	**1,863 (440)**
Rush Creek, Bottom-lands	N/A	N/A	3,579 (1,467)	2,961 (1,146)	3,405 (963)	2,725 (929)	3,208 (1,279)	1,980 (817)	1,098 (700)	1,422 (362)	523 (179)	**637 (308)**

Table 11. Estimated total numbers of brown and Rainbow Trout per kilometer of stream channel for Lee Vining Creek sample sections from 2006 to 2017. The value within (#) denotes the number of age-1 and older trout per kilometer.

Collection Location	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Lee Vining, Main Channel	No Sample high flow	2,103 (148)	2,357 (1,204)	1,192 (1,023)	518 (326)	727 (258)	4,361 (506)	3,765 (1,867)	2,444 (1,471)	2,027 (1,043)	1,973 (989)	**216 (90**)
Lee Vining, Side Channel	618 (48)	129 (62)	103 (67)	133 (108)	103 (36)	159 (87)	257 (123)	131 (123)	95 (95)	100 (100)	97 (97)	**130 (40)**
LV Main + LV Side Additive Approach	N/A	1,116 (105)	1,230 (636)	663 (566)	311 (181)	443 (173)	2,668 (348)	2,588 (1,302)	1,662 (1,013)	1,591 (819)	860 (554)	**180 (69)**

Estimated Trout Standing Crops (kg/ha)

The estimated standing crop for Brown Trout in the Upper Rush section was 123 kg/ha in 2017, a 98% increase from the 2016 estimate of 62 kg/ha, which was the lowest estimate for the 19 sampling years (Table 12 and Figure 19). Since the record high estimate of 224 kg/ha in 2011, the standing crop of Brown Trout in the Upper Rush section declined by 72% over the subsequent five consecutive dry/below average water years (Figure 20). When compared to the 19-year average of 144 kg/ha, the 2017 standing crop estimate was approximately 15% lower (Figure 19).

The estimated standing crop for Brown Trout in the Bottomlands section of Rush Creek was 50 kg/ha in 2017, a 47% increase from 34 kg/ha in 2016, which was the lowest estimate for the 10 years of sampling (Table 12 and Figure 19). When compared to the 10-year average of 79 kg/ha, the 2017 standing crop estimate was approximately 37% lower (Figure 19).

Although there is not a standing crop termination criterion for Walker Creek, an estimate was still generated for this annually-sampled section. The estimated standing crop for Brown Trout in Walker Creek was 85 kg/ha in 2017, a 51% decrease from the 2016 estimate of 172 kg/ha (Table 12 and Figure 19). The 2017 standing crop estimate was the fifth lowest value recorded in Walker Creek over the 19-year sampling period and the long-term average for this period is 131 kg/ha.

The estimated total standing crop for Brown Trout in the Lee Vining Creek main channel in 2017 was 21 kg/ha, and no Rainbow Trout were caught (Table 13 and Figure 20). The 2017 estimate represented an 81% decrease from the 2016 estimate of 113 kg/ha (Table 13). The 2017 estimated standing crop of 21 kg/ha was the lowest estimate ever recorded for this section and was 79% lower than the 18-year average of 101 kg/ha.

The estimated standing crop of Brown Trout in the Lee Vining Creek side channel was 20 kg/ha in 2017, which represented a 35% decrease from 2016's estimate of 31 kg/ha (Table 13 and Figure 20). No Rainbow Trout were captured in the Lee Vining Creek side channel in 2017 and none have been sampled in the side channel section for seven consecutive years (2011-2017). When estimates of standing crops were combined for the side and main channel section of Lee Vining Creek, the total was 21 kg/ha for 2017, an 80% decrease from the 2016 estimate of 101 kg/ha (Table 13).

Table 12. Comparison of Brown Trout standing crop (kg/ha) estimates between 2012 and 2017 for Rush Creek sections. These six years cover the five drier years of 2012-2016, followed the extremely wet RY 2017.

Collection Location	2012 Total Standing Crop (kg/ha)	2013 Total Standing Crop (kg/ha)	2014 Total Standing Crop (kg/ha)	2015 Total Standing Crop (kg/ha)	2016 Total Standing Crop (kg/ha)	2017 Total Standing Crop (kg/ha)	Percent Change Between 2016 and 2017
Rush Creek – Upper	178	140	167	123	62	123	+98%
Rush Creek - Bottomlands	103	55	52	59	34	50	+47%
Walker Creek	156	194	189	183	172	85	-51%

Table 13. Comparison of total (Brown and Rainbow Trout) standing crop (kg/ha) estimates between 2012 and 2017 for the Lee Vining Creek sections. These six years cover the five drier years of 2012-2016, followed the extremely wet RY 2017.

Collection Location	2012 Total Standing Crop (kg/ha)	2013 Total Standing Crop (kg/ha)	2014 Total Standing Crop (kg/ha)	2015 Total Standing Crop (kg/ha)	2016 Total Standing Crop (kg/ha)	2017 Total Standing Crop (kg/ha)	Percent Change Between 2016 and 2017
Lee Vining Creek - Main Channel	173	184	140	150	113	21	-81%
Lee Vining Creek – Side Channel	39	26	30	45	31	20	-35%
Lee Vining Main/Side Channels Combined	143	165	126	145	101	20	-80%

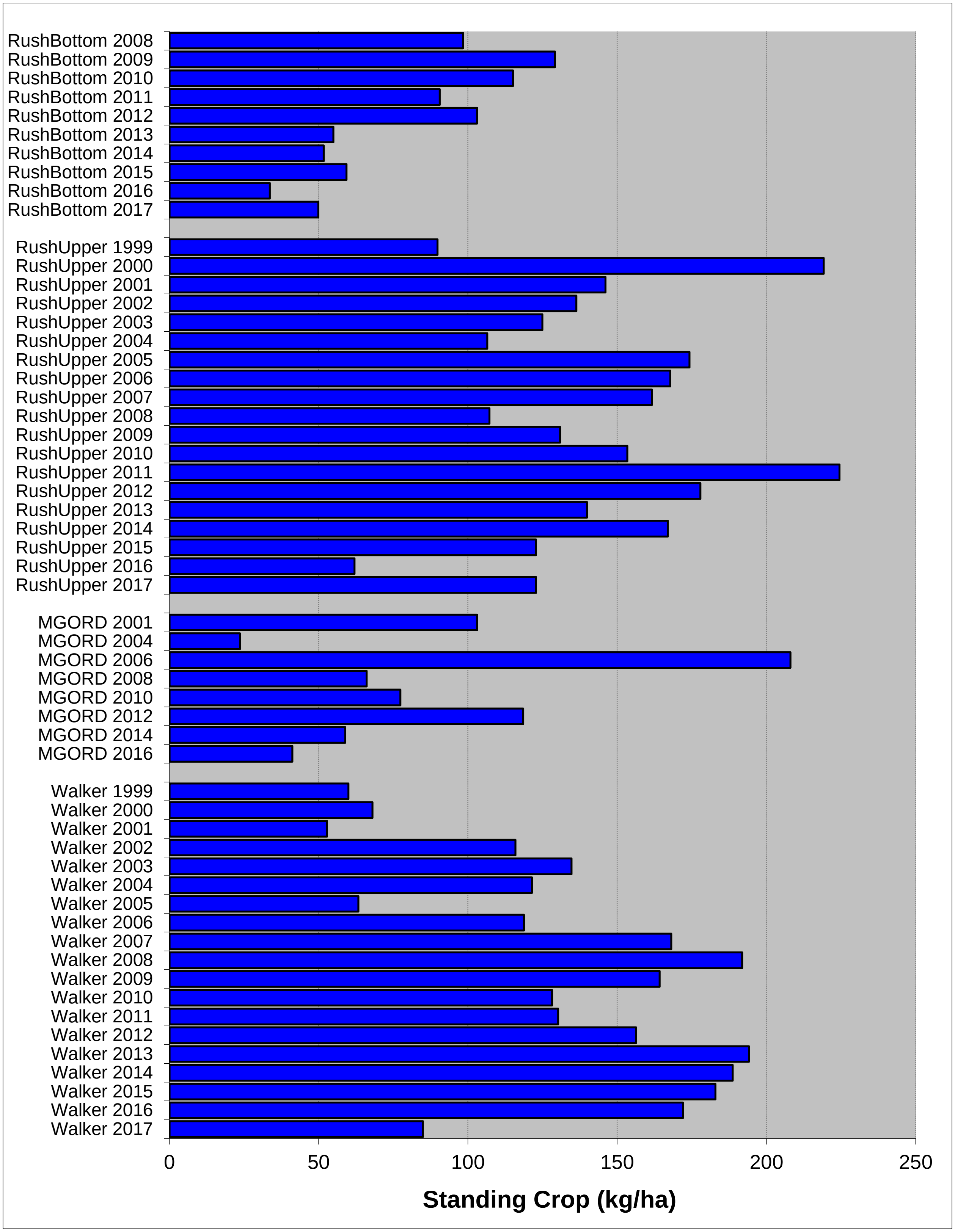


Figure 19. Estimated total standing crop (kilograms per hectare) of Brown Trout in Rush Creek sample sections from 1999 to 2017. NOTE: After 2001, MGORD estimates only made during even years.

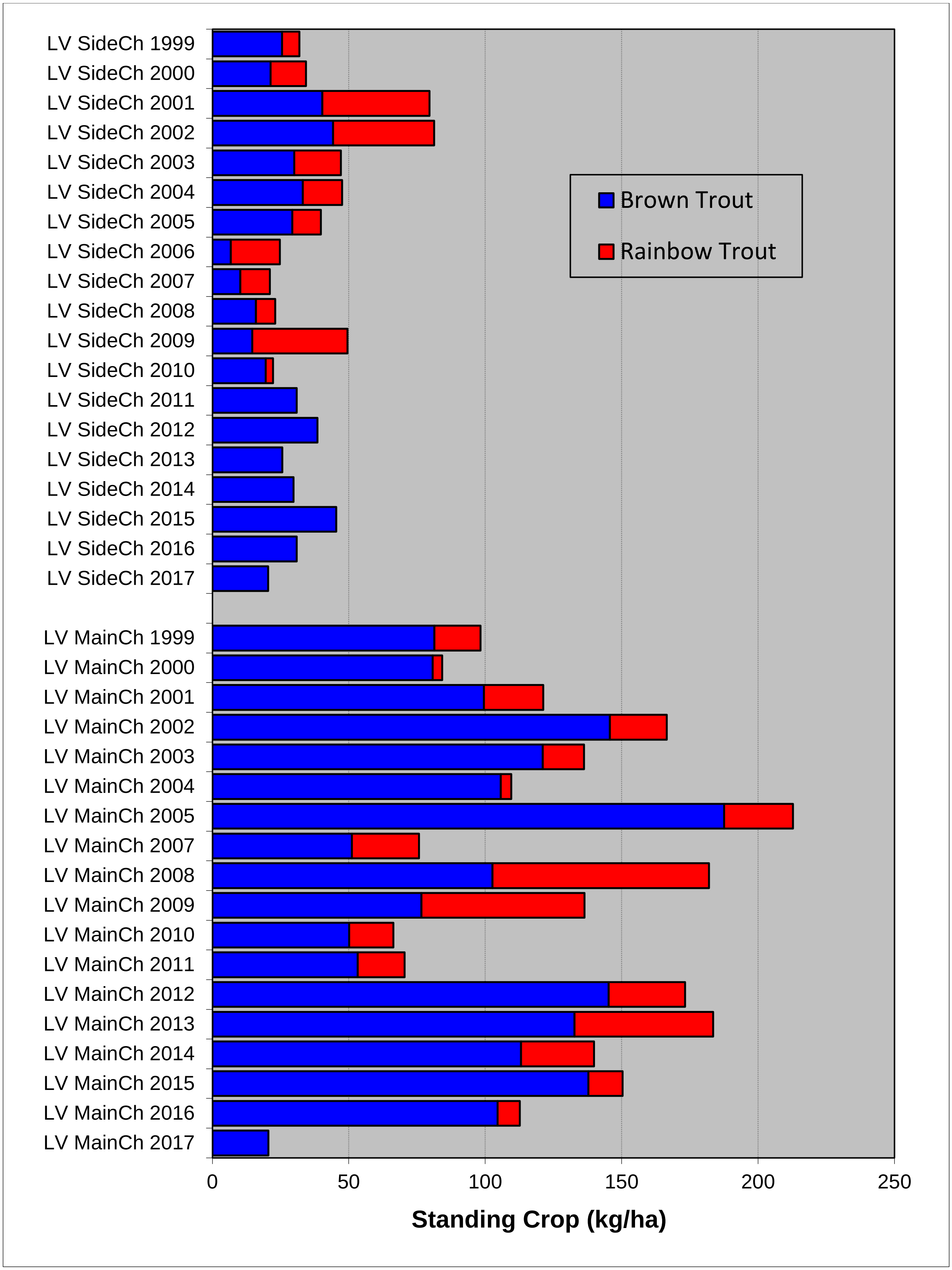


Figure 20. Estimated total standing crop (kilograms per hectare) of Brown Trout and Rainbow Trout (red) in Lee Vining Creek sample sections from 1999 to 2017.

Relative Stock Density (RSD) for Rush and Lee Vining Creeks

In the Upper Rush section, the RSD-225 of 78 for 2017 was the highest value for this section in the 18-year sampling period (Table 14). This large RSD-225 value was most likely influenced by the overall low numbers of fish, especially the low numbers of fish smaller than 225 mm. The RSD-300 value was 15 in 2017, the highest value for this section in the 18-year sampling period (Table 14). This high RSD-300 value was also most likely heavily influenced by the low numbers of fish 225 mm and smaller, although we captured 20 Brown Trout >300 mm in 2017 (Table 14). Intially, we suspected that the higher number of Brown Trout >300 mm captured in the Upper Rush section were because large fish were either displaced out of the MGORD during the large runoff or were fish swept over the GLR dam during the extended spill. However, PIT tag recapture data from 2017 documented that age-2 Brown Trout in the Upper Rush section had reached lengths >300 mm by October 2017. Over 18 sampling years, a total of 112 Brown Trout ≥300 mm were captured in the Upper Rush Creek section, an average of 6.2 fish ≥300 mm per year (Table 14).

In the Bottomlands section of Rush Creek, the RSD-225 for 2017 was 65, the highest value for this section in the 10-year sampling period (Table 14). As in the Upper Rush section, this large RSD-225 value was most likely influenced by the overall low numbers of fish along with extremely poor age-0 recruitment during the previous year, leading to low numbers of fish <225 mm. Also, 53 Brown Trout ≥225 mm in length were captured in 2017, the highest number of larger fish sampled from this section in eight years (Table 14). The RSD-300 value was 5 in 2017, based on the capture of four Brown Trout ≥300 mm (Table 14). Over the 10 sampling years a total of 16 Brown Trout ≥300 mm were captured in the Bottomlands section, an average of 1.6 fish ≥300 mm per year (Table 14).

In the MGORD, the RSD-225 value increased from 74 in 2016 to 88 in 2017; this was the fourth consecutive increase since a low value of 42 in 2013 (Table 14). The increasing RSD-225 values were most likely indicative of the continued poor recruitment of age-0 fish in the previous drought years, resulting in relatively few fish <225 mm available for capture. In 2017, the RSD-300 value was 27, an increase from a value of 21 in 2016, and was the highest RSD-300 value since the start of the five-year drought period (Table 14). The RSD-375 value in 2017 was 11, the second highest value for the 14 years of sampling data (Table 14). The total catch of Brown Trout in the MGORD during the 2017 season was 164 fish, which included: 29 fish ≥300 mm in length and 11 fish ≥375 mm in length (Table 14). For sampling conducted between 2001 and 2012, the annual average catch of Brown Trout ≥300 mm equaled 180 fish/year; then for the past six sampling years the annual average catch of Brown Trout ≥300 mm equaled 36 fish/year (Table 14). This 80% decline in larger Brown Trout coincided with the five years of drier water-years and poor summer thermal regimes within the MGORD in 2012-2016.

RSD values in Lee Vining Creek were generated for the main channel combined with the side channel and for the main channel only (Table 15). The RSD-225 value for the main/side combined equaled 23 and main channel equaled 26 for 2017, these values represent increases when compared to the 2015 and 2016 values (Table 15). In 2017, one Brown Trout greater than

300 mm in length was captured in Lee Vining Creek main channel, which generated RSD-300 values of 3 for the main/side combined and 4 for the main channel only (Table 15).

Table 14. RSD values for Brown Trout in Rush Creek sections from 2000 to 2017.

Sampling Location Rush Creek	Sample Year	Number of Trout ≥150 mm	Number of Trout ≥150-224 mm	Number of Trout 225-299 mm	Number of Trout 300-374 mm	Number of Trout ≥375 mm	RSD-225	RSD-300	RSD-375
Upper Rush	**2017**	**130**	**28**	**82**	**19**	**1**	**78**	**15**	**1**
Upper Rush	2016	103	74	26	1	2	28	3	2
Upper Rush	2015	289	246	41	0	2	15	1	1
Upper Rush	2014	366	331	31	4	0	10	1	
Upper Rush	2013	336	288	45	3	0	14	1	
Upper Rush	2012	354	284	66	3	1	20	1	
Upper Rush	2011	498	381	110	6	1	23	1	
Upper Rush	2010	308	202	97	7	2	34	3	1
Upper Rush	2009	372	322	43	5	2	13	2	1
Upper Rush	2008	227	189	31	6	1	17	3	
Upper Rush	2007	282	210	61	9	2	26	4	1
Upper Rush	2006	233	154	69	10	0	34	4	
Upper Rush	2005	202	139	56	5	2	31	3	
Upper Rush	2004	179	112	64	2	1	37	2	
Upper Rush	2003	264	216	45	2	1	18	1	
Upper Rush	2002	220	181	35	1	2	18	2	1
Upper Rush	2001	223	190	27	6	0	15	3	
Upper Rush	2000	182	158	22	2	0	13	1	
Bottomlands	**2017**	**82**	**29**	**49**	**4**	**0**	**65**	**5**	**0**
Bottomlands	2016	66	52	11	1	2	21	5	3
Bottomlands	2015	115	88	26	0	1	23	1	1
Bottomlands	2014	154	152	1	0	1	1	1	1
Bottomlands	2013	128	123	5	0	0	4	0	
Bottomlands	2012	325	290	34	1	0	11	0	
Bottomlands	2011	267	218	46	3	0	18	1	
Bottomlands	2010	307	225	81	1	0	27	0	
Bottomlands	2009	379	321	56	1	1	15	1	
Bottomlands	2008	160	141	19	0	0	12	0	
MGORD	**2017**	**104**	**12**	**64**	**17**	**11**	**88**	**27**	**11**
MGORD	2016	179	46	95	18	20	74	21	11
MGORD	2015	116	33	54	20	9	72	25	8
MGORD	2014	388	184	175	19	10	53	7	3
MGORD	2013	411	237	118	41	15	42	14	4
MGORD	2012	694	176	319	173	26	75	29	4
MGORD	2011	216	36	117	55	8	83	29	4

Table 14 (continued).

Sampling Location Rush Creek	Sample Year	Number of Trout ≥150 mm	Number of Trout ≥150-224 mm	Number of Trout 225-299 mm	Number of Trout 300-374 mm	Number of Trout ≥375 mm	RSD-225	RSD-300	RSD-375
MGORD	2010	694	252	292	115	35	64	22	5
MGORD	2009	643	156	338	123	26	76	23	4
MGORD	2008	856	415	301	118	22	52	16	3
MGORD	2007	621	144	191	259	27	77	46	4
MGORD	2006	567	60	200	280	27	89	54	5
MGORD	2004	424	130	197	64	33	69	23	8
MGORD	2001	774	330	217	119	108	57	29	14

Table 15. RSD values for Brown Trout in the Lee Vining Creek main channel + side channel sections from 2008-17. RSD values for Brown Trout in the main channel section from 2000-17.

Sampling Location Rush Creek	Sample Year	Number of Trout ≥150 mm	Number of Trout ≥150-224 mm	Number of Trout 225-299 mm	Number of Trout 300-374 mm	Number of Trout ≥375 mm	RSD-225	RSD-300
Main & Side	**2017**	**30**	**23**	**6**	**1**	**0**	**23**	**3**
Main & Side	2016	179	154	24	0	0	14	0
Main & Side	2015	227	206	21	0	0	9	0
Main & Side	2014	212	184	28	0	0	13	0
Main & Side	2013	327	309	17	1	0	6	0
Main & Side	2012	128	87	39	2	0	32	2
Main & Side	2011	78	46	26	5	1	41	1
Main & Side	2010	68	31	35	2	0	54	3
Main & Side	2009	192	159	32	1	0	17	1
Main & Side	2008	252	242	19	0	0	8	0
Main Channel	**2017**	**23**	**17**	**5**	**1**	**0**	**26**	**4**
Main Channel	2016	169	145	24	0	0	14	0
Main Channel	2015	210	192	18	0	0	9	0
Main Channel	2014	200	173	27	0	0	14	0
Main Channel	2013	325	308	16	1	0	5	0
Main Channel	2012	111	72	37	2	0	35	2
Main Channel	2011	60	31	23	5	1	48	10
Main Channel	2010	62	28	32	2	0	55	3
Main Channel	2009	137	106	30	1	0	23	1
Main Channel	2008	149	138	11	0	0	7	0
Main Channel	2007	29	24	5	0	0	17	0
Main Channel	2006	Not sampled in 2006 due to unsafe high flows					-	-
Main Channel	2005	60	37	20	2	1	38	5
Main Channel	2004	70	60	8	2	0	14	3
Main Channel	2003	52	27	23	2	0	48	4

Table 15 (continued).

Sampling Location Rush Creek	Sample Year	Number of Trout ≥150 mm	Number of Trout ≥150-224 mm	Number of Trout 225-299 mm	Number of Trout 300-374 mm	Number of Trout ≥375 mm	RSD-225	RSD-300
Main Channel	2002	100	74	23	3	0	26	3
Main Channel	2001	90	71	16	3	0	21	3
Main Channel	2000	51	32	18	1	0	37	2

Termination Criteria Results based on 2013 – 2017 Data Sets

The Rush Creek sampling sections for years 2013 through 2017, failed to meet four of the five termination criteria for any of the three, three-year running averages. For the 2015-2017 three-year average, the Upper Rush section met three of the five termination criteria: condition factor, RSD-225 and RSD-300 (Table 16).

Table 16. Termination criteria analyses for the Upper Rush section of Rush Creek. Bold values indicate that an estimated value met a termination criterion.

Termination Criteria	2015 – 2017 Average	2014 – 2016 Average	2013 – 2015 Average
Biomass (≥175 kg/ha)	103	117	143
Density (≥3,000 trout/km)	1,699	2,603	**4,382**
Condition Factor (≥1.00)	**1.00**	0.99	0.98
RSD-225 (≥35)	**40**	18	13
RSD-300 (≥5)	**6**	2	1
Conclusion	**Met three of five TC**	**Met none of five TC**	**Met one of five TC**

For the 2015-2017 three-year average, the Bottomlands section met one of the five termination criteria: RSD-225 (Table 17).

Table 17. Termination criteria analyses for the Bottomlands of Rush Creek. Bold values indicate that an estimated value met a termination criterion.

Termination Criteria	2015 – 2017 Average	2014 – 2016 Average	2013 – 2015 Average
Biomass (≥175 kg/ha)	48	48	55
Density (≥3,000 trout/km)	861	1,014	1,500
Condition Factor (≥1.00)	0.97	0.96	0.94

Table 17 (continued).

Termination Criteria	2015 – 2017 Average	2014 – 2016 Average	2013 – 2015 Average
RSD-225 (≥35)	**36**	15	9
RSD-300 (≥5)	3	2	1
Conclusion	**Met one of five TC**	**Met none of five TC**	**Met none of five TC**

For the 2015-2017 three-year average, the MGORD met both the RSD-225 and RSD-375 termination criterion (Table 18).

Table 18. Termination criteria analyses for the MGORD section of Rush Creek. Bold values indicate that an estimated value met a termination criterion.

Termination Criteria	2015 – 2017 Average	2014 – 2016 Average	2013 – 2015 Average
RSD-225 (≥60)	**78**	**66**	55
RSD-300 (≥30)	24	18	15
RSD-375 (≥5)	**10**	**7**	**5**
Conclusion	**Met TC two of three RSD values**	**Met TC two of three RSD values**	**Met TC one of three RSD values**

For the 2015-2017 three-year average, the main and side channel sections of Lee Vining Creek together met one of the four termination criteria (Table 19).

Table 19. Termination criteria analyses for the Lee Vining Creek sample sections. Bold values indicate that an estimated value met a termination criterion.

Termination Criteria	2015 - 2017 Average	2014 - 2016 Average	2013 - 2015 Average
Biomass (≥150 kg/ha)	21	101	145
Density (≥1,400 trout/km)	877	1,371	**1,947**
Condition Factor (≥1.00)	**1.01**	0.97	0.94
RSD-225 (≥30)	16	12	9
Conclusion	**Met one of four TC**	**Met none of four TC**	**Met one of four TC**

PIT Tag Recaptures

PIT Tags Implanted between 2009 and 2017

Between 2009 and 2017, a total of 7,153 PIT tags were implanted in Brown Trout and Rainbow Trout within the annually sampled sections of Rush, Lee Vining and Walker Creeks (Appendix A). All PIT tagged fish received adipose fin clips. The numbers of PIT tags implanted each year varied according to fish availability and inventory of PIT tags. The numbers implanted each year were:

In 2009, a total of 1,596 trout were tagged in Rush, Lee Vining, and Walker Creeks - 711 age-0 Brown Trout, 861 age-1+ Brown Trout, 19 age-0 Rainbow Trout, and five age-1 and older Rainbow Trout.

In 2010, a total of 1,274 trout were tagged in Rush, Lee Vining, and Walker Creeks - 855 age-0 Brown Trout, 402 age-1 and older Brown Trout, four age-0 Rainbow Trout, and 13 age-1 and older Rainbow Trout.

In 2011, a total of 1,065 trout were tagged in Rush, Lee Vining, and Walker Creeks - 851 age-0 Brown Trout, 161 age-1 and older Brown Trout, 50 age-0 Rainbow Trout and three age-1 and older Rainbow Trout.

In 2012, a total of 496 trout were tagged in Rush, Lee Vining, and Walker Creeks - 412 age-0 Brown Trout, four age-1 and older Brown Trout, and 80 age-0 Rainbow Trout. No trout in the MGORD in 2012 were tagged or retagged due to a limited number of PIT tags available for deployment.

In 2013, no PIT tags were implanted in any fish. Only length and weight data from recaptures of previously tagged fish were collected during the September 2013 sampling.

In 2014, a total of 964 trout were tagged in Rush, Lee Vining, and Walker Creeks - 459 age-0 Brown Trout, 477 age-1 and older Brown Trout, six age-0 Rainbow Trout and 22 age-1 and older Rainbow Trout. Because no PIT tags were deployed in 2013, suspected age-1 trout were tagged in 2014 and these fish were between 125 mm and 170 mm in length.

In 2015, a total of 871 trout were tagged in Rush, Lee Vining, and Walker Creeks - 738 age-0 Brown Trout, 126 age-1 and older Brown Trout, and seven age-0 Rainbow Trout.

In 2016, a total of 569 trout were tagged in Rush, Lee Vining, and Walker Creeks - 394 age-0 Brown Trout, 166 were age-1 and older Brown Trout, two age-0 Rainbow Trout, and seven age-1 and older Rainbow Trout.

In 2017, a total of 316 trout received PIT tags and adipose fin clips in Rush and Lee Vining Creeks (Table 20). In addition, two recaptured adipose fin-clipped fish had shed their original tags and were re-tagged, thus a total of 318 PIT tags were implanted during the 2017 fisheries sampling (Table 20). Of the 318 trout tagged, 300 were age-0 Brown Trout and two were age-1 and older Brown Trout (Table 26). For Rainbow Trout, 16 age-0 fish were tagged (Table 20).

Table 20. Total numbers of trout implanted with PIT tags during the 2017 sampling season, by stream, sample section, age-class and species.

Stream	Sample Section	Number of Age-0 Brown Trout (<125 mm)	Number of Age-1 and older Brown Trout	Number of Age-0 Rainbow Trout (<125 mm)	Number of Age-1 and older Rainbow Trout	Section Totals
Rush Creek	Upper Rush	192	2*	14	0	**208 Trout**
	Bottomlands	34	0	0	0	**34 Trout**
	MGORD	38	0	2	0	**40 Trout**
Lee Vining Creek	Main Channel	31	0	0	0	**31 Trout**
	Side Channel	5	0	0	0	**5 Trout**
Walker Creek	Above old 395	0	0	0	0	**0 Trout**
Age Class Sub-totals:		**300**	**2**	**16**	**0**	**Total Trout: 318**

*shed tag/new tag implanted

In October of 2017, a total of 60 previously tagged trout (that retained their tags) were recaptured in Rush Creek (Appendix B). Seventeen of the recaptures occurred in Walker Creek, followed by 17 recaptures in the MGORD (16 Brown Trout and one Rainbow Trout), 14 recaptures in the Upper Rush section (13 Brown Trout and one Rainbow Trout), and 12 recaptures in the Bottomlands section (Appendix B). Most fish were recaptured in the sections where they were initially captured and PIT-tagged, except for one Brown Trout initially tagged in Upper Rush section that was recaptured in the MGORD (Appendix B).

In October of 2017, a total of four previously tagged Brown Trout (that retained their tags) were recaptured in the Lee Vining Creek main channel section (Appendix B). No previously tagged trout were recaptured in the Lee Vining Creek side channel section.

In the following text, growth between 2016 and 2017 will be referred to as 2017 growth rates. A 2017 trout refers to a fish recaptured in October of 2017. An age of a PIT tagged trout reflects the age during the sampling year. For instance, an age-1 trout in 2017 indicates that a trout had been tagged in September 2016 as age-0 and its length and weight were measured in October 2017 when it was recaptured. However, it should be noted that fish tagged in 2016 and recaptured in 2017 were at large for 3.5 weeks longer than fish tagged and recaptured during the previous years (September to September), which likely contributed to higher growth rates of fish in sections of Rush Creek. This extra 3.5 weeks for potential growth between 2016 and 2017 is further addressed in the Discussion section of this report.

Growth of Age-1 Brown Trout between 2016 and 2017

In 2017, a total of 34 known age-1 Brown Trout were recaptured that were tagged as age-0 fish in 2016, for an overall recapture rate of 8.7% (34/390 age-0 fish tagged in 2016). Of the 34 age-1 recaptures; 22 of these fish were from Rush Creek sections, 11 fish were from Walker Creek and one fish was from the Lee Vining Creek main channel section. Thus, by creek, the age-1 recapture rates were 2.2% in Lee Vining Creek (32% in 2016), 4.8% in Walker Creek, (29% in 2016) and 19.1% in Rush Creek (5% in 2016). These recapture rates suggest relatively high survival between age-0 and age-1 in Rush Creek, but poor survival between age-0 and age-1 in Lee Vining Creek and Walker Creek. Notice that in 2016 (final year of the drought) the survival rates were opposite, with better survival rates in Walker and Lee Vining Creeks, and poor survival in Rush Creek sections.

In the Bottomlands section of Rush Creek, 12 age-1 Brown Trout were recaptured in 2017 and the average growth rates of these trout were 118 mm and 96 g (Table 21). Compared to 2016 rates, the growth rates of the 12 age-1 Brown Trout were greater by 24 mm and 34 g (Table 21). Growth rates of age-1 Brown Trout in the Bottomlands section had generally declined annually from 2010 to 2014, but the 2015-2017 growth rates increased each year, with the 2017 growth rates the largest recorded for this section (Table 21).

In the Upper section of Rush Creek, nine age-1 Brown Trout were recaptured in 2017 and the average growth rates of these trout were 132 mm and 129 g (Table 21). Compared to 2016 rates, the average growth rates of the nine age-1 Brown Trout were greater by 27 mm and 52 g (Table 21). Growth rates of age-1 Brown Trout in the Upper Rush section had generally declined annually from 2010 to 2014, but the 2015-2017 growth rates increased each year, with the 2017 growth rates the largest recorded for this section (Table 21).

In Walker Creek, 11 age-1 Brown Trout were recaptured in 2017 and the average growth rates of these trout were 66 mm and 33 g (Table 21). Compared to 2016 rates, the average growth rates of the 11 age-1 Brown Trout in 2017 were lower by 6 mm and 3 g (Table 21).

In Lee Vining Creek, only one age-1 Brown Trout was recaptured in 2017 (62 age-1 fish were recaptured in 2016) and the growth rates of this trout were 110 mm and 92 g (Table 21). Compared to 2016 rates, the average growth rates of the one age-1 Brown Trout recaptured in 2017 were greater by 36 mm and 52 g (Table 21). Growth rates of age-1 Brown Trout in Lee Vining Creek for the seven years of available data have averaged 81 mm in length and 46 g in weight (Table 21).

Growth of Age-2 Brown Trout between 2016 and 2017

In 2017, a total of 10 known age-2 Brown Trout were recaptured that were tagged as age-0 fish in 2015, for a recapture rate of 1.4% (10/709 age-0 fish tagged in 2015). Of these 10 fish, nine were recaptured in Rush Creek sections and one was recaptured in Lee Vining Creek.

In the Bottomlands section of Rush Creek, no age-2 fish were recaptured in 2017 that had been tagged as age-0 fish in 2015; this was the second consecutive year where no age-2 PIT tagged fish were recaptured in this section (Table 21).

Within the Upper section of Rush Creek, four age-2 fish were recaptured in 2017 that had been tagged as age-0 fish in 2015 (Table 21). Between age-1 and age-2, the average growth rates of these four Brown Trout were 108 mm and 239 g (Table 21). For the seven years of available data, these were, by far, the largest growth rates documented for age-2 Brown Trout in Rush Creek (Table 21).

The Lee Vining Creek main channel had a single age-2 PIT tagged Brown Trout was recaptured in 2017 that had been tagged at age-0 in 2015 (Table 21). Between age-1 and age-2, this fish experienced growth rates of 77 mm and 128 g (Table 21). When compared to the 2016 growth rates of age-2 fish, the 2017 growth rates for length were greater by 30 mm and 79 g (Table 21). Growth rates of age-2 Brown Trout in the Lee Vining Creek main channel section have averaged 55 mm in length and 69 g in weight for the seven years of available data (Table 21).

In Walker Creek five age-2 PIT tagged Brown Trout recaptured in 2017 that had been tagged as age-0 fish in 2015 and the average growth rates of these trout were 37 mm and 37 g (Table 21). Growth rates of age-2 Brown Trout in Walker Creek have averaged 40 mm in length and 36 g in weight for the seven years of available data (Table 21).

Growth of Age-3 Brown Trout between 2016 and 2017

In 2017, a total of three known age-3 Brown Trout were recaptured that were tagged as age-0 fish in 2014, for a recapture rate of 1.8% (3/169 age-1 fish tagged in 2014). One of the three fish was recaptured in Walker Creek and the other two were recaptured in the Lee Vining Creek main channel section. However, only the age-3 Brown Trout from Walker Creek had been captured in 2016 at age-2 to allow a calculation of its age-3 growth (Table 21). This fish grew by 42 mm in length and by 59 g in weight (Table 21).

In the Lee Vining Creek main channel, the two PIT tagged age-3 Brown Trout recaptured in 2017 had eluded previous recaptures since being tagged as age-0 fish in 2014. These two Brown Trout grew 207 mm and 342 g, and 178 mm and 219 g, respectively. One of these fish was >300 mm in length at age-3 (305 mm). PIT tagged age-3 Brown Trout have been recaptured in Lee Vining Creek for five consecutive years.

Table 21. Average growth (length and weight) of all Brown Trout recaptured from 2009 through 2017 by age. Note: *denotes only one PIT tagged fish recaptured. **denotes one fish that moved from Upper Rush to the MGORD.

Stream and Reach	Cohort	Average Annual Growth in Length and Weight (mm/g)								
		2008 - 2009	2009 - 2010	2010 - 2011	2011 - 2012	2012 - 2013	2013 - 2014	2014 - 2015	2015 - 2016	2016 - 2017
Upper Rush Creek	Age 1	89/51	81/50	83/48	72/33	67/35		90/55	105/77	132/129
	Age 2		58/70	54/73	43/42	41/42		64/69	99/176**	108/239
	Age 3				14/29		24/41			
	Age 4					12/-22				
	Age-5									
Rush Creek Bottom-lands	Age 1	84/43	77/40	71/35	58/25	56/24		84/41	94/62	118/96
	Age 2		50/54	35/32	30/28	27/22	32/29*	62/62		
	Age 3			13/14	17/16	11/9	35/31			
	Age 4				4/-11		18/20			
	Age-5									
LV Main Channel Brown Trout	Age 1		80/42*	72/37	99/52	61/27		73/33	74/40	110/92*
	Age 2		66/95		77/110	33/34	35/29	47/40	47/49	77/128*
	Age 3			34/92		23/48*	16/20*	27/32	42/75	
	Age 4				21/41*				25/47*	
	Age-5									
LV Main Channel Rainbow Trout	Age 1					78/47		80/35		
	Age 2						40/48*	52/50	62/74*	
	Age 3								38/82*	
	Age 4									
	Age-5									
Walker Creek Above Old 395	Age 1	68/27	51/20	71/34	68/36	59/23		58/24	72/36	66/33
	Age 2		31/26	60/56	40/33	27/21	39/35		47/44	37/37
	Age 3			28/44	18/12	9/2	20/36	27/29		42/59*
	Age 4				7/2	2/-16*		28/45*		
	Age-5						0/-10*			

Growth of MGORD Brown Trout by size class between 2016 and 2017

Because the actual age at-time-of-tagging was unknown for most trout PIT tagged in the MGORD, determination of actual ages of recaptured trout was not possible. Thus, growth rate comparisons within the MGORD were based on size classes (Table 22). Due to the majority of the Brown Trout in the MGORD being larger sized, size classes were based on the RSD values for the MGORD. When evaluating growth rates by size classes, the size classes in Table 22 designate each fish's size class in 2016, not its size class at the time of recapture in 2017.

In 2017, a total of 14 PIT tagged Brown Trout were recaptured in the MGORD that were originally PIT tagged in the MGORD. Of these 14 recaptures, 12 fish had also been captured in 2016, thus one-year growth rates between 2016 and 2017 were calculated for these 12 fish (Table 22).

No Brown Trout PIT tagged in the MGORD during the 2016 sampling within the <125 mm size class were recaptured within the MGORD in 2017. However, an age-0 Brown Trout tagged in the Upper Rush section in 2016 was recaptured in the MGORD in 2017. This trout's growth rates were 157 mm in length and 185 g in weight. In 2017, an age-1 Rainbow Trout was recaptured in the MGORD that was tagged at age-0 within the MGORD in 2016. This Rainbow Trout grew by 153 mm and 211 g between 2016 and 2017.

Two Brown Trout tagged in the MGORD during the 2016 season within the 125-225 mm size class were recaptured in 2017. These two trout had average growth rates of 90 mm and 175 g (Table 22).

There were seven Brown Trout PIT tagged in the MGORD during the 2016 sampling within the 226-300 mm size class that were recaptured in 2017. These seven trout had average growth rates of 69 mm and 172 g between 2016 and 2017 (Table 22). The weight gains of these seven fish were 123, 124, 131, 158, 220, 221, and 224 g.

There was one PIT tagged Brown Trout captured in the MGORD during the 2016 sampling within the 301-375 mm size class (346 mm) that was recaptured in 2017. This trout grew 55 mm in length and gained 238 g in weight (Table 22).

There were two PIT tagged Brown Trout captured in the MGORD during the 2016 sampling within the >375 mm size class (453 and 496 mm) that were recaptured in 2017. These two trout had average growth rates of 24 mm and 94 g between 2016 and 2017 (Table 22). The trout that was 453 mm in 2016 grew 43 mm in length and gained 336 g in weight and the trout that was 496 mm in 2016 grew 5 mm in length and lost 148 g in weight.

Table 22. Average growth rates, length (mm) and weight (g), of all PIT tagged MGORD Brown Trout recaptured from 2009 through 2017 by size class. Note: *denotes only one fish recaptured.

Size Class (mm)	Average Annual Growth Length (mm)							
	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
0-124	121							
125-225	55	59	63			70*		90
226-300	32	39	22	7		61	80	69
301-375	20	17	9	12	30*	84*	74*	55*
>375	13	18	-1	10	17	69	34	24
Size Class (mm)	**Average Annual Growth Weight (g)**							
	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017
0-124	91							
125-225	85	90	78			155*		175
226-300	53	81	34	2		203	184	172
301-375	23	54	-5	49	178*	421*	365*	238*
>375	-10	134	-47	-2	283	718	208	94

Growth of MGORD Brown Trout from non-consecutive years

Three of the 16 PIT tagged Brown Trout captured in the MGORD during the October 2017 sampling were last recaptured, measured and weighed in years prior to 2016; thus annual growth calculations were not possible. Brown Trout (#4580613) was tagged in 2015 and recaptured in 2017 and during this two-year period grew by 106 mm and gained 620 g (Table 23).

Brown Trout (#1867358) was tagged in 2011, was initially recaptured in 2012 and five years later was recaptured for a second time in October of 2017. During the five between recaptures, this fish gained an average of 310 g per year (Table 23). This Brown Trout was probably an age-3 fish when tagged in 2011, thus in 2017 it was most likely nine years old.

The other non-consecutive recapture was a Brown Trout initially tagged in 2009 (#0917818) that was recaptured in 2010, 2013, 2014 and 2017. During the eight year period between tagging and its fourth recapture in 2017, this trout's growth has averaged 31 mm and 248 g (Table 29). This Brown Trout was either an age-3 or age-4 fish when tagged in 2009, thus in 2017 it was most likely 11 or 12 years old. This Brown Trout's condition factor has varied over the eight years since being tagged: 2009 = 0.82; 2010 = 0.87; 2013 = 0.99; 2014 = 0.94; and 2017 = 0.93.

Table 23. PIT tagged Brown Trout caught in the MGORD section, for recaptures in non-consecutive years.

Last 7 Digits of PIT Tag #	Year of Capture	Total Length (mm)	Weight (g)	Difference in Length (mm)	Difference in Weight (g)
#0917818	2009	395	507		
	2010	450	790	+55	+283
	2013	523	1,412	+73	+622
	2014	570	1,739	+47	+327
	2017	645	2,494	+75	+755
#1867358	2011	348	410		
	2012	351	480	+3	+70
	2017	550	2,030	+199	+1,550
#4580613	2015	384	526		
	2017	490	1,146	+106	+620

Movement of PIT Tagged Trout between Sections

From 2009 to 2017 a total of 7,153 PIT tags were surgically implanted in Brown Trout and Rainbow Trout in the following stream reaches: Upper Rush, County Road, Bottomlands, MGORD, and Walker Creek. Between 2010 and 2017, 36 Brown Trout were recaptured in stream reaches other than where they were initially tagged. The majority of movement between sections has occurred from the Upper Rush section upstream into the MGORD, and from the MGORD downstream into the Upper Rush section. We have also documented some limited movement between the Bottomlands and County Road sections. Up to 2013, no movement between other sections had been recorded. However in 2014, a large Brown Trout initially tagged in the MGORD was recaptured in the Bottomlands section.

The 2012 Annual Fisheries Report presented the summarized data for 23 Brown Trout that had moved from one section to another. In all cases, fish which moved experienced higher growth rates than other members of their cohorts which stayed in the section where they had been tagged (LADWP 2013). These growth differences were most markedly different for Brown Trout PIT tagged as age-0 fish in the Upper Rush section that were eventually recaptured in the MGORD as age-1 or age-2 fish. Since the 2012 report, this phenomenon of superior growth rates by fish that moved relatively large distances has continued. For example, three Brown Trout tagged as age-0 fish in Upper Rush in 2014 where recaptured in 2015 in different sampling sections; two were recaptured in the MGORD and one was recaptured in the Bottomlands. These three fish experienced average growth rates of 100 mm in length and 79 g in weight; compared to average growth rates of 88 mm and 53 g for the age-1 fish that remained in the Upper Rush section.

In 2017, one Brown Trout originally tagged in the Upper Rush section in 2016 at age-0 was recaptured in the MGORD. This fish grew 157 mm in length and 185 g in weight.

PIT Tag Shed Rate of Trout Recaptured in 2017

In 2017, a total of 66 trout with adipose fin clips were recaptured and six of these fish failed to produce a PIT tag number when scanned with the tag reader. Assuming that all these fish were previously PIT tagged, the 2017 calculated shed rate was 9.1% (6 shed tags/66 clipped fish recaptured). This rate was higher than previous years' rates and higher than shed rates reported by other PIT tagging studies for juvenile trout: 3% for juvenile Brown Trout (Ombredane et al. 1998) and 3% for juvenile steelhead (Bateman and Gresswell 2006). Retention rates tend to be higher in juvenile fish because adult salmonids are known to shed tags during spawning (Bateman et al. 2009). Also, tag retention rates have also been linked tagger's experience and crew turnover rates, with less experienced taggers resulting in higher shed rates (Dare 2003).

Comparison of Length-at Age amongst Sample Sections

During 2017, three age-classes of PIT tagged Brown Trout were recaptured within four fisheries monitoring sections in Rush, Walker and Lee Vining creeks (Tables 24 and 25). Along with providing age-specific length information for each section, these data also allowed comparisons of length-at-age between sample sections and also between the years 2013-2017 (Tables 24 and 25). Again, the extra 3.5 weeks of growth between the September 2016 and October 2017 sampling events may have slightly influenced growth as measured in length.

In Upper Rush, the average length-at-age-1 in 2017 was 35 mm greater than the average length-at-age-1 in 2016 and 56 mm than the length-at-age-1 in 2015 (Table 24). Similar to 2015 and 2016, in 2017, age-1 Brown Trout in Upper Rush were larger than age-1 fish in the Bottomlands section (Table 24). However, in the Bottomlands section, the average length-at-age-1 in 2017 was 221 mm, the highest recorded for this section (Table 24).

In Upper Rush, four PIT tagged age-2 Brown Trout were caught in 2017. The average length-at-age-2 of these four Brown Trout was 313 mm, 96 mm greater than the average length-at-age-2 in 2015 (Table 24). Three of these four fish were >300 mm at age-2. In the Bottomlands section, no age-2 Brown Trout were recaptured in 2017 (Table 24).

In 2015 - 2017, no PIT tagged age-3 or age-4 Brown Trout were captured in the Bottomlands or Upper Rush sampling sections (Table 24). In 2017, no age-5 fish with PIT tags were captured in the Upper and Bottomlands sections of Rush Creek.

For Walker Creek in 2017, the average length-at-age-1 was 1 mm less than in 2016 (Table 24). In 2017, age-2 Brown Trout in Walker Creek were, on average, 1 mm longer than age-2 fish in 2016 (Table 24). In 2017, one age-3 Brown Trout was recaptured in Walker Creek and this fish was 238 mm in length (Table 24).

In the Lee Vining Creek main channel the one length-at-age-1 Brown Trout caught in 2017 was the largest PIT tagged age-1 fish documented in Lee Vining Creek (Table 25). In addition, the one age-2 Brown Trout caught in 2017 was the largest PIT tagged age-2 fish documented in Lee Vining Creek (Table 25). In 2017, the two age-3 Brown Trout in Lee Vining Creek were on average, the largest length-at-age-3 fish documented in Lee Vining Creek (Table 25).

These findings of average lengths by age-class appear to support the previous conclusions by the Stream Scientist that very few Brown Trout reach age-4 or older on Rush Creek or Lee Vining Creek. However, the growth rates that Brown Trout exhibited in 2017 allowed some age-2 and age-3 fish to exceed lengths of 300 mm, the size class approaching the metrics of the pre-1941 fishery. These large growth rates appear to be a function of extremely low fish densities and more favorable summer water temperature conditions in 2017.

Table 24. Size range of PIT tagged fish recaptured in 2013-2017 by age class for Brown Trout at three electrofishing sections on Rush and Walker Creeks. NOTE: years omitted if no fish were caught.

Section	Cohort	Size Range (mm)	Average Length (mm)
Upper Rush	Age-1	**2017** = 224-264 **2016** = 192-237 **2015** = 169-203	**2017** = 243 **2016** = 208 **2015** = 187
	Age-2	**2017** = 284-337 **2016** = 289* **2015** = 205-242	**2017** = 313 **2016** = 289* **2015** = 217
	Age-3	**2014** = 226-236 **2013** = 227-263	**2014** = 231 **2013** = 245
	Age-4	**2014** = 288 **2013** = 252-255	**2014** = 288 **2013** = 254
	Age-5	**2014** = 298	**2014** = 298
Bottomlands	Age-1	**2017** = 189-246 **2016** = 172-217 **2015** = 150-181	**2017** = 221 **2016** = 197 **2015** = 169
	Age-2	**2015** = 197-239 **2014** = 192 **2013** = 156-196	**2015** = 219 **2014** = 192 **2013** = 178
	Age-3	**2014** = 194 **2013** = 194-227	**2014** = 194 **2013** = 204
	Age-4	**2014** = 215-219	**2014** = 216
	Age-5	**2016** = 318	**2016** = 318
Walker Creek	Age-1	**2017** = 151-179 **2016** = 145-187 **2015** = 133-177	**2017** = 166 **2016** = 167 **2015** = 154
	Age-2	**2017** = 180-224 **2016** = 180-226 **2014** = 168-200 **2013** = 181-208	**2017** = 202 **2016** = 201 **2014** = 186 **2013** = 197
	Age-3	**2017** = 238 **2015** = 211-231 **2014** = 207-222 **2013** = 219-221	**2017** = 238 **2015** = 219 **2014** = 217 **2013** = 220
	Age-4	**2015** = 249 **2014** = 211 **2013** = 219	**2015** = 249 **2014** = 211 **2013** = 219
	Age-5	**2014** = 220	**2014** = 220

*Fish was tagged in Upper Rush, but moved to MGORD between age-1 and age-2.

Table 25. Size range of PIT tagged fish recaptured in 2013-2017 by age class for Brown Trout and Rainbow Trout on Lee Vining Creek. NOTE: years omitted if no fish were caught.

Section	Cohort	Size Range (mm)	Average Length (mm)
Brown Trout in Lee Vining Main Channel	Age-1	**2017** = 210 **2016** = 147-186 **2015** = 149-190	**2017** = 210 **2016** = 171 **2015** = 166
	Age-2	**2017** = 247 **2016** = 205-217 **2015** = 176-214 **2014** = 174-195 **2013** = 206-225	**2017** = 247 **2016** = 211 **2015** = 197 **2014** = 188 **2013** = 215
	Age-3	**2017** = 280-305 **2016** = 210-256 **2015** = 188-228 **2014** = 234-241 **2013** = 238-271	**2017** = 293 **2016** = 240 **2015** = 215 **2014** = 238 **2013** = 253
	Age-4	**2016** = 237	**2016** = 237
	Age-5	None captured in past four years	
Rainbow Trout in Lee Vining Main Channel	Age-1	**2016** = N/A **2015** = 140-177	**2015** = 157
	Age-2	**2016** = 232 **2015** = 195-216 **2014** = 201-229	**2016** = 232 **2015** = 204 **2014** = 215
	Age-3	**2016** = 242	**2016** = 242
	Age-4	None captured in past four years	
	Age-5	None captured in past four years	

Summer Water Temperature

During 2017, the Mono Lake Committee (MLC) also deployed water temperature data loggers, which assisted in collecting data from sites not monitored by LADWP and also served as back-ups to data loggers placed by LADWP. The MLC deployed Onset HOBO Pro v2 data loggers set to record water temperature in hourly intervals in degrees Fahrenheit so their data were compatible with LADWP's data. The MLC data utilized in this report were collected at the Above Parker Creek location on Rush Creek. Water temperature data from the remaining locations were collected by LADWP. Although water temperatures were recorded year-round during 2017, summer water temperatures in July-September were more closely examined due to influences of warmer temperatures on trout growth and condition factor (Table 26). Due to the extremely large streamflows during the RY2017, several data loggers were lost and no data were available at the County Road locations on both Rush and Lee Vining Creeks (Table 26).

Compared to the drought years of 2013-2016, the 2017 summer water temperatures in all sections of Rush Creek were a reprieve from four previous summers of stressful thermal conditions (Tables 26-29). In 2017, no Rush Creek monitoring locations had peak temperatures above 70^{o}F and maximum diurnal fluctuations were considerably lower (Table 26).

Similar to the 2013 - 2016 annual reports, a closer examination of the 2017 Rush Creek summer water temperature data was done by classifying daily average temperatures as either: 1) good potential growth days, 2) fair potential growth days, 3) poor potential growth days (daily averages within one degree or less of a "bad thermal day"), or 4) bad thermal days (Table 27).

Development of the daily average temperature ranges from results of the Rush Creek temperature modeling which defined these “thermal days” was fully described in previous annual reports (Taylor 2013 and 2014). Using these daily average metrics, good potential growth days in 2017 varied from 65 to 88 days in Rush Creek out of the 92-day period from July 1 to September 30 (Table 27). For all Rush Creek monitoring location, the remaining days were classified as “fair” potential growth days; no days in 2017 were classified as poor growth or bad thermal days (Table 27).

As was done with the 2013 - 2016 data, the diurnal temperature fluctuations for July–September 2017 were characterized by the one-day maximum fluctuation that occurred each month and by monthly averages (Table 28). Also, for each temperature monitoring location, the highest average diurnal fluctuations over consecutive 21-day durations were determined (Table 28). As would be expected with the melting of the record snowpack and extended high flows, diurnal fluctuations throughout the summer of 2017 were very low at all Rush Creek temperature monitoring locations when compared to the diurnal fluctuations during the previous drought years (Table 28). The locations that had experienced large, potentially stressful, diurnal fluctuations during the extended drought (Old 395, Below Narrows and County Road) were within acceptable ranges for good trout growth during the summer of 2017 (Table 28).

The thermal window bounded by 66.2-71.6^{o}F where Brown Trout may be physiologically stressed and living at the edge of their survival tolerance as defined by Bell (2006) was quantified for each Rush Creek temperature monitoring location in 2013 through 2017. The hourly temperature data for the 92-day (or 2,208-hour) summer period were sorted from low to high and the number of hours where temperatures exceeded 66.2^{o}F were summed by month and entire summer period (Table 29). The values from 2013 - 2016 were also included to better illustrate the variability that occurred at all the temperature monitoring locations (Table 29). The 2017 data show that all the temperature monitoring locations downstream of GLR experienced extremely large decreases in number of hours bounded by the 66.2-71.6^{o}F thermal window (Table 29). In 2017, the Rush Creek location Above Parker Creek had the most hours (14 hours) within the thernmal window window bounded by 66.2-71.6^{o}F, but still experienced a huge decrease from the 574 hours documented during the summer of 2016 (Table 29).

Table 26. Summary of water temperature data during the summer of RY 2017 (July to September). Averages were calculated for daily mean, daily minimum, and daily maximum temperatures between July 1st and September 30th. All temperature data are presented in °F. When available, values for 2013-2016 are provided for comparison.

Temperature Monitoring Location	Daily Mean (°F)	Ave Daily Minimum (°F)	Ave Daily Maximum (°F)	No. Days > 70°F	Max Diurnal Fluctuation (°F)	Date of Max. Fluct.
Rush Ck. – At Damsite	2016 = 58.9 **2017 = 58.1**	2016 = 58.3 **2017 = 57.5**	2016 = 59.5 **2017 = 58.7**	2016 = 0 **2017 = 0**	2016 = 3.2 **2017 = 2.1**	8/11/16 **9/07/17**
Rush Ck. – Top of MGORD	2013 = 63.1 2014 = 64.8 2015 = 64.4 2016 = 63.8 **2017 = 57.0**	2013 = 62.7 2014 = 64.6 2015 = 64.1 2016 = 63.0 **2017 = 56.5**	2013 = 63.7 2014 = 65.0 2015 = 64.8 2016 = 64.7 **2017 = 58.1**	2013 = 0 2014 = 0 2015 = 0 2016 = 0 **2017 = 0**	2013 = 3.4 2014 = 3.9 2015 = 2.1 2016 = 6.5 **2017 = 5.4**	7/09/13 8/13/14 7/03/15 7/07/16 **9/07/17**
Rush Ck. – Bottom MGORD	2013 = 63.2 2014 = 64.8 2015 = 64.4 2016 = 63.8 **2017 = 57.1**	2013 = 60.9 2014 = 62.9 2015 = 62.3 2016 = 61.8 **2017 = 56.5**	2013 = 67.1 2014 = 68.5 2015 = 68.0 2016 = 66.9 **2017 = 58.5**	2013 = 1 2014 = 20 2015 = 20 2016 = 1 **2017 = 0**	2013 = 9.0 2014 = 8.3 2015 = 8.4 2016 = 8.0 **2017 = 6.4**	7/09/13 7/13/14 7/06/15 7/04/16 **9/07/17**
Rush Ck. – Old Highway 395 Bridge	2013 = 62.6 2014 = 64.0 2015 = N/A 2016 = 63.5 **2017 = 59.0**	2013 = 58.8 2014 = 60.5 2015 = N/A 2016 = 60.1 **2017 = 57.5**	2013 = 68.7 2014 = 69.8 2015 = N/A 2016 = 68.8 **2017 = 61.0**	2013 = 40 2014 = 51 2015 = N/A 2016 = 47 **2017 = 0**	2013 = 13.5 2014 = 13.3 2015 = N/A 2016 = 12.5 **2017 = 7.6**	7/09/13 7/13/14 N/A 7/11/16 **9/07/17**
Rush Ck. – Above Parker	2016 = 63.2 **2017 = 59.0**	2016 = 58.8 **2017 = 57.2**	2016 = 69.4 **2017 = 61.9**	2016 = 55 **2017 = 0**	2016 = 13.7 **2017 = 8.6**	7/11/16 **9/08/17**
Rush Ck. – below Narrows	2013 = 61.2 2014 = 63.2 2015 = 62.3 2016 = 61.7 **2017 = 58.4**	2013 = 56.2 2014 = 57.1 2015 = 58.8 2016 = 56.9 **2017 = 56.3**	2013 = 67.6 2014 = 69.4 2015 = 66.1 2016 = 68.3 **2017 = 61.3**	2013 = 24 2014 = 46 2015 = 0 2016 = 34 **2017 = 0**	2013 = 16.3 2014 = 17.3 2015 = 11.5 2016 = 14.3 **2017 = 8.2**	7/19/13 7/26/14 9/23/15 7/13/16 **9/07/17**
Rush Ck. – County Road	2013 = 61.4 2014 = 62.0 2015 = 62.1 2016 = 61.6 **2017 = N/A**	2013 = 56.5 2014 = 56.7 2015 = 59.1 2016 = 56.0 **2017 = N/A**	2013 = 66.6 2014 = 67.8 2015 = 65.5 2016 = 68.3 **2017 = N/A**	2013 = 7 2014 = 24 2015 = 2 2016 = 32 **2017 = N/A**	2013 = 14.7 2014 = 17.6 2015 = 9.2 2016 = 16.1 **2017 = N/A**	8/02/13 7/26/14 7/28/15 7/11/16 **N/A**
Lee Vining – at County Road	2014 = 54.9 2015 = 55.5 **2016 = 54.6** **2017 = N/A**	2014 = 50.5 2015 = 51.4 **2016 = 50.7** **2017 = N/A**	2014 = 59.4 2015 = 59.7 **2016 = 58.6** **2017 = N/A**	2014 = 0 2015 = 0 **2016 = 0** **2017 = N/A**	2014 = 11.6 2015 = 11.2 **2016 = 10.9** **2017 = N/A**	7/01/14 7/29/15 **7/20/16** **N/A**

Table 27. Classification of 2013-2017 summer water temperature data into good growth days, fair growth days, poor growth days and bad thermal days based on daily average temperatures (92-day period from July 1 to September 30). The percent (%) designates each thermal day-type's occurrence for the 92-day summer period.

Temperature Monitoring Location	No. of Days for Good Growth Potential – Daily Ave. ≤60.5°F	No. of Days for Fair Growth Potential – Daily Ave. 60.6° – 63.9°F	No. of Days of Poor Growth Potential – Daily Ave. 64.0° - 64.9°F	No. of Bad Thermal Days - Daily Ave. ≥65°F
Rush Ck. – At Damsite	2016 = 69 (75%) **2017 = 88 (96%)**	2016 = 23 (25%) **2016 = 4 (4%)**	2016 = 0 **2016 = 0**	2016 = 0 **2016 = 0**
Rush Ck. – Top of MGORD	2013 = 14 (15%) 2014 = 5 (6%) 2015 = 7 (8%) 2016 = 10 (11%) **2017 = 66 (71%)**	2013 = 43 (47%) 2014 = 14 (15%) 2015 = 20 (22%) 2016 = 32 (35%) **2017 = 26 (29%)**	2013 = 17 (18%) 2014 = 25 (27%) 2015 = 5 (5%) 2016 = 17 (18%) **2017 = 0**	2013 = 18 (20%) 2014 = 48 (52%) 2015 = 60 (65%) 2016 = 33 (36%) **2017 = 0**
Rush Ck. – Bottom MGORD	2013 = 11 (12%) 2014 = 6 (6%) 2015 = 8 (9%) 2016 = 9 (10%) **2017 = 67 (73%)**	2013 = 38 (41%) 2014 = 11 (12%) 2015 = 20 (22%) 2016 = 31 (34%) **2017 = 25 (27%)**	2013 = 20 (22%) 2014 = 21 (23%) 2015 = 5 (6%) 2016 = 16 (17%) **2017 = 0**	2013 = 23 (25%) 2014 = 54 (59%) 2015 = 59 (64%) 2016 = 36 (39%) **2017 = 0**
Rush Ck. – Old Highway 395 Bridge	2013 = 14 (15%) 2014 = 7 (8%) 2015 = N/A 2016 = 16 (17%) **2017 = 75 (82%)**	2013 = 41 (45%) 2014 = 25 (27%) 2015 = N/A 2016 = 24 (26%) **2017 = 17 (18%)**	2013 = 33 (36%) 2014 = 27 (29%) 2015 = N/A 2016 = 19 (21%) **2017 = 0**	2013 = 4 (4%) 2014 = 33 (36%) 2015 = N/A 2016 = 33 (36%) **2017 = 0**
Rush Ck. – Above Parker Ck.	2016 = 17 (18%) **2017 = 65 (71%)**	2016 = 26 (28%) **2017 = 27 (29%)**	2016 = 24 (26%) **2017 = 0**	2016 = 25 (27%) **2017 = 0**
Rush Ck. – Below Narrows	2013 = 17 (18%) 2014 = 13 (14%) 2015 = 24 (26%) 2016 = 22 (24%) **2017 = 75 (82%)**	2013 = 69 (75%) 2014 = 58 (63%) 2015 = 44 (48%) 2016 = 52 (57%) **2017 = 17 (18%)**	2013 = 6 (7%) 2014 = 18 (20%) 2015 = 22 (24%) 2016 = 16 (17%) **2017 = 0**	2013 = 0 2014 = 3 (3%) 2015 =2 (2%) 2016 = 2 (2%) **2017 = 0**
Rush Ck. – County Road	2013 = 17 (18%) 2014 = 17 (18%) 2015 = 25 (27%) 2016 = 24 (26%) **2017 = N/A**	2013 = 64 (70%) 2014 = 59 (65%) 2015 = 39 (42%) 2016 = 50 (54%) **2017 = N/A**	2013 = 8 (9%) 2014 = 14 (15%) 2015 =23 (25%) 2016 = 13 (14%) **2017 = N/A**	2013 = 3 (3%) 2014 = 2 (2%) 2015 = 5 (6%) 2016 = 5 (6%) **2017 = N/A**

Table 28. Diurnal temperature fluctuations in Rush Creek for 2017: maximum daily for month, daily average for month, and highest average for consecutive 21-day duration (92-day period from July 1 to September 30). NOTE: 2016 values in ( ) for comparison.

Temperature Monitoring Location	Maximum and Average Daily Diurnal Fluctuation for July	Maximum and Average Daily Diurnal Fluctuation for August	Maximum and Average Daily Diurnal Fluctuation for September	Highest Average Diurnal Fluctuation for a Consecutive 21-Day Duration
Rush Ck. – At Damsite	Max = 2.0°F (2.1) Ave = 1.5°F (1.3)	Max = 1.8°F (3.2) Ave = 1.1°F (1.6)	Max = 2.5°F (1.3) Ave = 1.0°F (0.9)	1.5 °F (2.4) July 2-22
Rush Ck. – Top of MGORD	Max = 2.7°F (6.5) Ave = 0.9°F (3.1)	Max = 4.5°F (4.8) Ave = 2.4°F (1.3)	Max = 5.4°F (1.2) Ave = 1.8°F (0.7)	2.1°F (3.4) Aug 18 – Sept 7
Rush Ck. – Bottom MGORD	Max = 3.3°F (8.0) Ave = 2.4°F (5.4)	Max = 5.0°F (7.0) Ave = 2.6°F (4.8)	Max = 6.4°F (6.4) Ave = 2.7°F (5.1)	3.0°F (5.7) Aug 26 – Sept 15
Rush Ck. – Old Highway 395 Bridge	Max = 3.9°F (12.5) Ave = 3.0°F (9.9)	Max = 5.3°F (10.1) Ave = 3.4°F (8.4)	Max = 7.6°F (9.4) Ave = 4.2°F (7.9)	4.4°F (10.4) Sept 5 - 25
Rush Ck. – Above Parker Ck.	Max = 5.1°F (13.7) Ave = 4.1°F (11.3)	Max = 5.6°F (12.4) Ave = 4.3°F (10.6)	Max = 8.6°F (12.2) Ave = 6.0°F (9.9)	6.4°F (11.8) Sept 8 - 28
Rush Ck. – below Narrows	Max = 5.2°F (14.3) Ave = 4.6°F (11.9)	Max = 5.9°F (13.2) Ave = 4.4°F (11.4)	Max = 8.2°F (13.9) Ave = 6.1°F (11.7)	6.4°F (12.3) Sept 7 - 27
Rush Ck. – County Road	Max = N/A (16.1) Ave = N/A (13.3)	Max = N/A (14.0) Ave = N/A (12.0)	Max = N/A (14.6) Ave = N/A (11.7)	N/A (14.0) N/A

Table 29. Number of hours that temperature exceeded 66.2°F in Rush Creek: by month and for 92-day period from July 1 to September 30, 2013 - 2017. Percent (%) designates amount of month or summer where hourly temperatures exceeded 66.2°F.

Temperature Monitoring Location	Number of Hours Temperature exceeded 66.2°F in July (744 hours)	Number of Hours Temperature exceeded 66.2°F in August (744 hours)	Number of Hours Temperature exceeded 66.2°F in Sept. (720 hours)	Number of Hours Temperature exceeded 66.2°F in 92-day period
Rush Ck. – At Damsite	2016 = 0 hrs **2017 = 0 hrs**	2016 = 0 hrs **2017 = 0 hrs**	2016 = 0 hrs **2017 = 0 hrs**	2016 = 0 hrs **2017 = 0 hrs**
Rush Ck. – Top of MGORD	2013 = 4 hrs (0.5%) 2014 = 315 hrs (42%) 2015 = 140 hrs (19%) 2016 = 42 hrs (6%) **2017 = 0 hrs**	2013 = 4 hrs (0.5%) 2014 = 96 hrs (13%) 2015 = 205 hrs (28%) 2016 = 127 hrs (17%) **2017 = 0 hrs**	2013 = 0 hrs 2014 = 0 hrs 2015 = 0 hrs 2016 = 0 hrs **2017 = 0 hrs**	2013 = 8 hrs (0.4%) 2014 = 411 hrs (19%) 2015 = 345 hrs (16%) 2016 = 169 hrs (8%) **2017 = 0 hrs**
Rush Ck. – Bottom MGORD	2013 = 121 hrs (16%) 2014 = 282 hrs (38%) 2015 = 305 hrs (41%) 2016 = 142 hrs (19%) **2017 = 0 hrs**	2013 = 229 hrs (31%) 2014 = 248 hrs (33%) 2015 =282 hrs (38%) 2016 = 268 hrs (36%) **2017 = 0 hrs**	2013 = 61 hrs (9%) 2014 = 115 hrs (16%) 2015 = 17 hrs (2%) 2016 = 38 hrs (5%) **2017 = 2 hrs (0.3%)**	2013 = 411 hrs (19%) 2014 = 645 hrs (29%) 2015 = 604 hrs (27%) 2016 = 448 hrs (20%) **2017 = 2 hrs (0.09%)**
Rush Ck. – Old 395 Bridge	2013 = 181 hrs (24%) 2014 = 287 hrs (39%) 2016 = 216 hrs (29%) **2017 = 0 hrs**	2013 = 228 hrs (31%) 2014 = 248 hrs (33%) 2016 = 263 hrs (35%) **2017 = 0 hrs**	2013 = 73 hrs (10%) 2014 = 117 hrs (16%) 2016 = 53 hrs (7%) **2017 = 3 hrs (0.4%)**	2013 = 482 hrs (22%) 2014 = 639 hrs (29%) 2016 = 532 hrs (24%) **2017 = 3 hrs = (0.1)**
Rush Ck. – Above Parker Creek	2016 = 240 hrs (32%) **2017 = 0 hrs**	2016 = 269 hrs (36%) **2017 = 0 hrs**	2016 = 65 hrs (9%) **2017 = 14 hrs (2%)**	2016 = 574 hrs (26%) **2017 = 14 hrs (0.6%)**
Rush Ck. – below Narrows	2013 = 158 hrs (21%) 2014 = 244 hrs (33%) 2015 = 129 hrs (17%) 2016 = 167 hrs (22%) **2017 = 0 hrs**	2013 = 192 hrs (26%) 2014 = 193 hrs (26%) 2015 = 189 hrs (25%) 2016 = 222 hrs (30%) **2017 = 0 hrs**	2013 = 55 hrs (7%) 2014 = 105 hrs (15%) 2015 = 0 hrs (0%) 2016 = 49 hrs (7%) **2017 = 0 hrs**	2013 = 405 hrs (18%) 2014 = 542 hrs (25%) 2015 = 318 hrs (14%) 2016 = 438 hrs (20%) **2017 = 0 hrs**
Rush Ck. – County Road	2013 = 197 hrs (27%) 2014 = 222 hrs (30%) 2015 = 174 hrs (23%) 2016 = 212 hrs (28%) **2017 = N/A**	2013 = 172 hrs (23%) 2014 = 195 hrs (26%) 2015 = 119 hrs (16%) 2016 = 233 hrs (31%) **2017 = N/A**	2013 = 42 hrs (6%) 2014 = 79 hrs (11%) 2015 = 0 hrs (0%) 2016 = 42 hrs (6%) **2017 = 0 hrs**	2013 = 411 hrs (19%) 2014 = 496 hrs (23%) 2015 = 293 hrs (13%) 2016 = 487 hrs (22%) **2017 = 0 hrs**

Discussion

The 2017 sampling year was highlighted by the end of the extended drought conditions that persisted in the Mono Basin and throughout most of California between 2012 and 2016. Within the Mono Basin the 2017 runoff year was 206% of normal and classified as an Extreme-Wet RY. The extremely large runoff resulted in an extended spill of water over the GLR dam for 60 days and high flows in lower Rush Creek. These extremely high flows delayed the annual fish sampling by 3.5 weeks from mid September to mid-October. The extended snowmelt and high flows also resulted in a summer of cool water temperatures with relatively small diurnal fluctuations. These cool summer water temperatures in combination with extremely low densities of fish resulted in the largest growth rates recorded since the PIT tagging program was started in 2009. Thus, this report's Discussion is focused on the trout populations' response to the Extreme Wet RY and favorable summer water temperatures. Also, the low densities of trout in both Rush and Lee Vining Creeks was a lingering effect of the extended drought, thus the 2017 age-0 recruitment and age class structure are topics of discussion.

2017 Summer Water Temperature and Trout Growth Rates

Before discussing the 2017 growth rates, the issue of the 3.5 weeks of extra time between the September 2016 and October 2017 sampling must be addressed. Several researchers have documented that Brown Trout growth is greatest during the spring and fall months and lower in summer and winter months (Brown 1945; Swift 1961; Jensen and Berg 1995). In another study of Brown Trout residing in seven Spanish streams, growth varied during the year, peaking between March and September and then gradually decreasing during the fall to a winter minimum (Nicol and Almodovar 2004). Weight gains of age-2 Brown Trout in water temperatures between 52^{o}F and 59^{o}F that were fed to satiation had average growth rates of 2.8% per week during the fall months (Brown 1945). In regards to growth measured in length, age-1 Brown Trout grew 2.2-2.5% per week during the fall months (Swift 1961). Nicol and Almodovar (2004) recorded decreasing growth rates (in weight) during September and October, even though water temperatures were cooler and similar to temperatures documented during high growth periods during spring months, suggesting that decreasing photo-period influenced fall growth rates. Thus, the extra 3.5 weeks that previously PIT tagged fish were at large in Rush Creek between September 2016 and October 2017 may have resulted in about 10% extra growth by weight and about 8% extra growth by length.

The 2017 Brown Trout growth in Rush Creek appeared to reflect these good thermal conditions with the largest gains in lengths and weights in both the Upper and Bottomlands sampling sections since the start of the PIT tagging program. In the Upper Rush section, PIT tagged fish recaptured at age-1 and age-2 had the highest growth rates in 2017 (Table 30). Age-1 recaptures in the Upper Rush section gained an average of 129 g between 2016 and 2017; a growth rate 130% greater than the average growth rate (56 g) for the nine years of available tag return data (Table 30). The Upper Rush section's age-2 recaptures gained an average of 239 g between 2016 and 2017; a growth rate 134% greater than the average growth rate (102 g) for the seven years of available tag return data (Table 30). Three of the four Upper Rush age-2 recaptures were >300 mm in length, a size previously not approached until age-4 or age-5 (Table 24). During the 2017 sampling, a total of 17 Brown Trout between 300-350 mm were caught in the Upper Rush section, the largest number of fish in this size class ever caught in this section during 18 seasons. Based on the 2017 PIT tag data, it's possible that most of these fish were age-2. Similarly, record-high growth rates also occurred in the Bottomlands section. For example, age-1 recaptures in the Bottomlands gained an average of 96 g between 2016 and 2017; a growth rate 109% greater than the average growth rate (46 g) for the eight years of available tag returns (Table 30). Because the extra 3.5 weeks that tagged fish were at large may have accounted for 10% extra growth by weight, the large growth rates documented in 2017 suggest that a combination of low densities and favorable summer water temperatures were important factors.

As discussed in last year's report, the summer of 2016 had very low fish densities and the summer thermal regime was poor (Taylor 2017). At these very low densities, Brown Trout in Rush Creek experienced high growth rates during the summer of 2016, even though warm water and stressful diurnal fluctuations occurred (Table 30). The summer of 2017 was the first year in two decades of the Mono Basin fisheries monitoring where in Rush Creek there were extremely low densities of fish in combination with summer water temperatures consistent with good growth potential. Studies have determined that trout growth in streams is a complex interaction of population density, water temperature and food availability (Baerum et al. 2013). Conditions in Rush Creek during 2017 may have been favorable for growth with respect to multiple variables. In the Synthesis Report, two of the key flow recommendations (lower winter baseflows to increase low-velocity holding habitat and higher GLR storage levels to create cooler summer thermal regimes) were developed specifically to shift the population structure of Brown Trout in Rush Creek from one dominated by high densities of younger, smaller trout to a population with lower densities comprised of older, and larger, trout (McB&T and RTA 2010). At the time of Synthesis Report development, the Stream Scientists were vexed by what would be the method or environmental trigger to knock back the persistently high densities of younger trout. Little did we know that three years after completion of the Synthesis Report, five consecutive years of drought would provide the mechanism to "reset" the densities in Rush Creek and then be followed by a wet year to provide the thermal conditions required for good growth potential.

Density-dependent growth in stream-dwelling salmonids is well researched and there's broad support for the hypothesis that density-dependent growth occurs at low population densities, probably due to exploitive completion (Grant and Imre 2005). One study used controlled reaches of a small stream and determined that population density affected growth in trout parr (yearlings and older) and that competition and population regulation was not just limited to early life-stages, as suggested by other researchers (Bohlin et al. 2002). Another analysis used data collected from 19 trout populations (six species and 16 different studies) and determined that 15 of the 19 populations showed evidence of decreased growth rates with increasing densities (Grant and Imre 2005). This analysis was focused primarily on age-0 trout (Grant and Imre 2005). For Upper Rush, 12 years (2006-2017) of age-0 Brown Trout and total Brown Trout population estimates were plotted versus the average weights of age-0 Brown Trout from those sample years (Figure 25). Trend lines through each of the population estimates strongly suggest that density-dependent growth of age-0 fish does occur in the Upper Rush section (Figure 21).

Unlike in 2016, the improved growth rates documented in 2017 translated into better condition factors of trout that were 150-250 mm in length, in most sections of Rush Creek. The condtion factor in Upper Rush was 1.04 in 2017, the highest value recorded in the past 13 years for this section.

Table 30. Annual growth rate (g) for PIT tagged or fin-clipped age-0 to age-1, age-1 to age-2, and age-2 to age-3 brown trout in two sections of Rush Creek by year. N/A = not available

Age Class	**Growth Years**	**Upper Rush Growth (g)**	**Bottomlands Growth (g)**	**Fin clip or PIT Tag**
Age-0 to Age-1	2006-2007	32	N/A	Ad Clip
	2008-2009	51	43	Ad Clip
	2009-2010	48	40	PIT Tag
	2010-2011	48	36	PIT Tag
	2011-2012	33	25	PIT Tag
	2012-2013	35	25	PIT Tag
	2013-2014	N/A	N/A	N/A
	2014-2015	55	41	PIT Tag
	2015-2016	77	62	PIT Tag
	2016-2017	**129**	**96**	PIT Tag
Age-1 to Age-2	2008-2009	N/A	N/A	Ad Clip
	2009-2010	70	54	PIT Tag
	2010-2011	73	32	PIT Tag
	2011-2012	42	28	PIT Tag
	2012-2013	42	22	PIT Tag
	2013-2014	N/A	29	PIT Tag
	2014-2015	69	62	PIT Tag
	2015-2016	176	N/A	PIT Tag
	2016-2017	**239**	**N/A**	PIT Tag

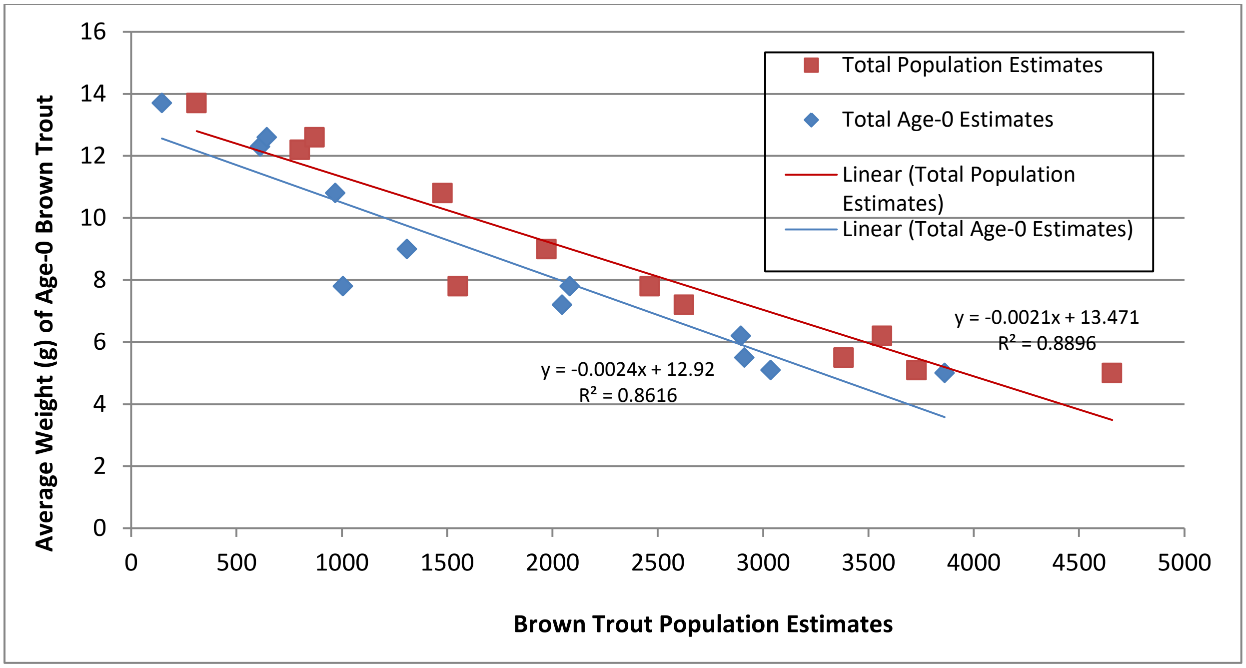


Figure 21. Relationship between average weights of age-0 brown trout and population estimates (age-0 and all trout) in the Upper Rush sampling section, 2006-2017.

Apparent Survival Rates

Apparent survival rates of age-1 Brown Trout were calculated with the following equation: [# age-1 recaps in 2017/capture probability of age-1 fish] ÷ [# age-0 tagged in 2016 - # shed tags]. For mark-recapture sections, capture probabilities were derived from the recapture run data: # of recaptures/# of captures. The 2017 apparent survival rates were higher in Rush Creek; 100% in the Upper section and 72.3% in the Bottomlands section (Table 31). In contrast, Lee Vining Creek's age-1 Brown Trout had an apparent survival rate of 4.8% and Walker Creek's equaled 7.0% (Table 31). Since the number of age-1 fish (125 – 199 mm size group) recaptured during the mark-recapture estimates were extremely low in the Rush Creek sections during 2017 (Table 2), it is highly likely that estimated capture probabilities for both sections of Rush Creek were inaccurate and much lower than true capture probabilities, which most likely led to over-estimates of apparent survival, especially in Upper Rush (Table 31).

The 2016 apparent survival rates were provided to show that rates flipped for all sections between the 2016 Dry RY and the 2017 Extreme Wet RY. During 2016 when flows were low and warm in Rush Creek, survival was low; and when flows were low and cool in Walker and Lee Vining creeks, survival was high. In sharp contrast, during 2017 when flows in all creeks were at or near record highs and cool, survival rates were high in Rush Creek and low in Walker and Lee Vining creeks. We speculate that the low apparent survival rates documented in Walker and Lee Vining creeks may be a function of channel morphology where limited side channels or off channel areas were available for fish to seek refuge during the extended peak flow events. Also, it is possible that previously tagged fish were displaced from the sample sections during the extended high flows and were unavailable for recapture.

Table 31. Apparent survival rates of age-1 Brown Trout in Rush, Walker and Lee Vining creeks in 2017. The 2016 values are in parentheses for comparisions.

Creek and Section	Capture Probability	No. Age-1 Recaps in 2017	No. Age-0 Tagged in 2016	No. Shed Tags	Apparent Survival Rate
Rush – Upper	.25	9	36	2	106% (22.7%)
Rush - Bottomlands	.21	12	79	0	72.3% (9.7%)
Walker Creek	.69	11	228	1	7.0% (37.8%)
Lee Vining Creek	.45	1	46	0	4.8% (46.3%)

Age-0 Recruitment and Age-Class Structure in Rush and Lee Vining Creeks

The availability and location of spawning habitat in Rush Creek was a concern during the development of Decision 1631 and subsequent SWRCB Orders #98-05 and #98-07. The Mono Basin EIR noted that 55 redds were found between 1985 and 1989, primarily in the uppermost 0.85 miles of Rush Creek below GLR dam (page 3D-19). Section 5.4.2 of Decision 1631 (titled Flows for Providing Fishery Habitat) stated, “There is general agreement that adult habitat and spawning habitat in Rush Creek are limited.” Much of the early instream flow recommendations centered on the stability of introduced spawning substrate. In contrast, our experience since 1999 after the fisheries sampling methods were established, was that annual recruitment of age-0 Brown Trout in the Rush Creek sections was variable, yet sufficient enough to translate into ample numbers of age-1 and older fish in subsequent years. Previous annual fisheries monitoring reports have shown that wide ranges in the numbers of age-0 Brown Trout produced in 2000-2004 eventually translated into similar numbers of age -1 and older fish (Hunter et al. 2004 - 2007). We also stated in the Synthesis Report that “In Rush Creek, ample recruitment of age-0 Brown Trout has occurred the past ten years” (McB&T and RTA 2010).

During the five below-normal RY types, the numbers of age-0 Brown Trout declined in both annually sampled sections of Rush Creek. In the Upper Rush section, the population estimate of age-0 Brown Trout declined by 95% between 2012 and 2016. Age-0 Brown Trout in the Bottomlands section experienced an 83% decline in population estimates between 2012 and 2016. Between 2012 and 2015, the decreased fish numbers in Rush Creek were fairly steady and progressive. However, the paucity of age-0 Brown Trout in 2016 (only 46 were captured) suggested that the trout population had crashed after five years of drought, probably due to extremely low numbers of adult spawners and possible reduced egg viability due to warm water induced stress.

When compared to the 2016 estimates, the 2017 population estimates of age-0 in the Rush Creek sections suggest different factors influenced the 2017 recruitment of age-0 fish. In the Bottomlands section, the 2017 age-0 estimate was a 2% increase from the 2016 estimate, virtually no change, and these low numbers would be consistent with the record low number of available adult fish that spawned during the fall/early winter of 2016. Conversely, in the Upper Rush section, the 2017 age-0 estimate was three times larger than the 2016 estimate. How did a record low number of available adult spawners in Upper Rush in the fall/early winter of 2016 translate into a tripling of the age-0 estimate in 2017? We speculate that one or a combination of two factors may have influenced this large increase in age-0 recruitment in 2017. First, age-0 fish produced by spawning in the lower reaches of the MGORD had better survival because the record low numbers of larger fish in the MGORD reduced predation of fry. This speculation is also supported by the relatively large number of age-0 Brown Trout caught during the single electrofishing pass through the MGORD in 2017 (46 fish ≤135 mm). The second factor was that the extended high flows in Rush Creek flushed MGORD-origin age-0 Brown Trout downstream into the Upper Rush sampling section. We know high streamflows displaced fish, based on the relatively large numbers of hatchery-origin Rainbow Trout that were flushed out of GLR and ended up in the Upper Rush section.

As previously described, the five years of drought and stressful summer water temperatures resulted in a severe drop in fish numbers in all Rush Creek sections. The record low numbers of age-0 fish in 2016 may continue to affect the ability of Rush Creek's Brown Trout population to rebound. In 2017, age-1 Brown Trout were extremely scarce, in fact so few were caught during the Upper Rush mark run that only a single clipped fish was caught during the recapture run. For the first time in 18 sampling seasons, we were unable to generate a valid estimate for Brown Trout between 125 and 199 mm in the Upper Rush section. The catch of Brown Trout in this size class was 31 fish; however the actual number of true age-1 fish in this size class was probably much lower due to growth rates of age-0 fish from time of emergence to our sampling in October of 2017. Of the 31 fish caught in the 125 to 199 mm size class, 24 fish were between 125 and 135 mm and most of these were likely age-0 fish. In the Bottomlands section we also caught 31 Brown Trout in the 125 to 199 mm size class, and of these, 18 fish were between 125 and 135 mm in length and most likely age-0 fish. Similarily, very few age-1 Brown Trout were caught in Lee Vining Creek and the apparent survival of age-1 fish was less than 5% based on PIT tag data (Table 31). Previous studies have confirmed that drought conditions affect the overwintering survival of age-0 trout due to a lack of fat/lipid reserves, resulting in diminished numbers of age-1 fish the following year (Hakala and Hartman 2004). In the Mono Basin streams, this apparently small cohort of Brown Trout will be age-2 fish in the fall of 2018 and age-3 fish in 2019, typical ages that comprise the bulk of the spawning populations in Rush and Lee Vining creeks, thus age-0 recruitment may remain low for the next couple of years. If favorable summer water temperatures in Rush Creek continued, low densities of age-0 fish may bolster the growth and survival of older fish.

Limited information was found concerning post-drought responses by stream dwelling trout populations. However, an assessment of naturally reproducing Rainbow Trout populations in Colorado on National Forest lands concluded that shortly after an extended period of drought (2000-2004), Rainbow Trout numbers were at stable, or increased, levels due to the fish's wide distribution across multiple watersheds (Adams et al. 2008). However, a continued rebound of trout populations in Mono Basin streams is dependant on this winter's snowpack and GLR level going into the 2018 RY.

As of mid February 2018, the Mono Basin had experienced a below normal winter and the snow water content in the Sierras was approximately 25% of normal. LADWP's 2018 Eastern Sierra forecast made on February 1st for the Mono Basin was 55% to 62% of normal. Luckily, several large storms hit the Mono Basin in March and raised the forecast on April 1st to close to 70% of normal. GLR's elevation on April 5th was at 7,099 feet, thirty-five feet below spill level and one foot below 7,100 feet, the level at which less than favorable summer thermal conditions occur in Rush Creek. We suspect that even if RY 2018 is close to an average RY that Rush Creek below GLR will once again experience unfavorable summer water temperature conditions, which will translate into continued low population numbers and trout in below average condition.

Methods Evaluation

In 2017, mark-recapture and depletion estimates were again used to produce population estimates on Rush, Lee Vining and Walker Creeks. As in past years, we started off cleaning the block fences twice a day, but several periods of windy conditions and falling leaves resulted in block fence failures. After the upstream fences at Upper Rush and the Lee Vining Creek main channel failed several times each we implemented a more rigorous fence cleaning schedule. Also, the later sampling date in October appeared to result in more leaf litter, especially in Lee Vining Creek. After three days of constant fence failure we decided to conduct a depletion estimate on the Lee Vining Creek main channel because the constantly failing fences violated the closed-population assumption of a valid mark-recapture estimate. When flow conditions are favorable, mid-September sampling is recommended.

As in previous years, small variations in wetted channel widths were measured, which resulted in changes to sample section areas. Also, we moved the location of several block fences due to changes in channel depths and increased velocities. As previously mentioned, the Walker Creek sampling reach was shorter in 2017 due to meander cutoffs caused by the high runoff flows. Thus, it is recommended that channel lengths and widths are re-measured annually.

The PIT tagging program was continued during the October 2017 sampling and tags were implanted primarily in age-0 fish. The PIT tagging program allowed us to document the record growth rates of trout between 2016 and 2017, including the ability of age-2 fish to exceed lengths of 300 mm the in Upper Rush section. Continuation of the PIT tagging program is important as the fisheries monitoring program moves towards its post-settlement phase.

Trout size classes (0-124, 125-199, and ≥200 mm) developed and discussed during the 2008 annual report should continue to be used (Hunter et al. 2008). Using these size classes provides for long-term consistency as well as year to year consistency with the annual fisheries data sets.

To ensure that electrofishing sampling can be conducted safely and efficiently, flows in Rush and Lee Vining creeks should not exceed 40 cfs. (± 5 cfs.) during the annual sampling period. Allowances for flow variances to allow for safe wading conditions and effective sampling were included in the new Terms of Settlement.

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Appendices for the 2017 Mono Basin Annual Fisheries Report

Appendix A: Tables of Numbers of Brown Trout and Rainbow Trout Implanted with PIT Tags (by sampling section) between 2009 and 2016

Table B-1. Total numbers of trout implanted with PIT tags during the 2009 sampling season, by stream, sample section, age-class and species.

Stream	Sample Section	Number of Age-0 Brown Trout	Number of Age-1 Brown Trout	Number of Age-0 Rainbow Trout	Number of Age-1 Rainbow Trout	Reach Totals
Rush Creek	Upper Rush	256	26	15	1	**298 Trout**
	Bottomlands	164	68	0	0	**232 Trout**
	County Road	108	29	0	0	**137 Trout**
	MGORD	54	642*	0	0	**696 Trout**
Lee Vining Creek	Main Channel	10	45	4	3	**62 Trout**
	Side Channel	5	0	0	1	**6 Trout**
Walker Creek	Above old 395	114	51	0	0	**165 Trout**
Totals:		**711**	**861**	**19**	**5**	**Total Trout: 1,596**

*Many of these MGORD trout were >age-1.

Table B-2. Total numbers of trout implanted with PIT tags during the 2010 sampling season, by stream, sample section, age-class and species.

Stream	Sample Section	Number of Age-0 Brown Trout (<125 mm)	Number of Age-1 and older Brown Trout	Number of Age-0 Rainbow Trout (<125 mm)	Number of Age-1 and older Rainbow Trout	Reach Totals
Rush Creek	Upper Rush	242	11	4	0	**257 Trout**
	Bottomlands	284	3	0	0	**287 Trout**
	County Road	210	7	0	0	**217 Trout**
	MGORD	1	359*	0	12	**372 Trout**
Lee Vining Creek	Main Channel	24	8	0	1	**33 Trout**
	Side Channel	13	0	0	0	**13 Trout**
Walker Creek	Above old 395	81	14	0	0	**95 Trout**
Totals:		**855**	**402**	**4**	**13**	**Total Trout: 1,274**

*Many of these MGORD trout were >age-1.

Table B-3. Total numbers of trout implanted with PIT tags during the 2011 sampling season, by stream, sample section, age-class and species.

Stream	Sample Section	Number of Age-0 Brown Trout (<125 mm)	Number of Age-1 and older Brown Trout	Number of Age-0 Rainbow Trout (<125 mm)	Number of Age-1 and older Rainbow Trout	Reach Totals
Rush Creek	Upper Rush	393	3	30	0	**426 Trout**
	Bottomlands	178	1	11	0	**190 Trout**
	County Road	196	1	6	0	**203 Trout**
	MGORD	8	142*	3	3	**156 Trout**
Lee Vining Creek	Main Channel	24	0	0	0	**24 Trout**
	Side Channel	11	14	0	0	**25 Trout**
Walker Creek	Above old 395	41	0	0	0	**41 Trout**
Totals:		**851**	**161**	**50**	**3**	**Total Trout: 1,065**

*Many of these MGORD trout were >age-1.

Table B-4. Total numbers of trout implanted with PIT tags during the 2012 sampling season, by stream, sample section, age-class and species.

Stream	Sample Section	Number of Age-0 Brown Trout (<125 mm)	Number of Age-1 and older Brown Trout	Number of Age-0 Rainbow Trout (<125 mm)	Number of Age-1 and older Rainbow Trout	Reach Totals
Rush Creek	Upper Rush	117	1	2	0	**120 Trout**
	Bottomlands	110	1	6	0	**117 Trout**
	County Road	0	2	0	0	**2 Trout**
	MGORD	0	0	0	0	**0 Trout**
Lee Vining Creek	Main Channel	125	0	72	0	**197 Trout**
	Side Channel	0	0	0	0	**0 Trout**
Walker Creek	Above old 395	60	0	0	0	**60 Trout**
Age Class Sub-totals:		**412**	**4**	**80**	**0**	**Total Trout: 496**

Table B-5 Total numbers of trout implanted with PIT tags during the 2014 sampling season, by stream, sample section, age-class and species.

Stream	Sample Section	Number of Age-0 Brown Trout (<125 mm)	Number of Age-1 Brown Trout (125-170 mm)	Number of Age-0 Rainbow Trout (<125 mm)	Number of Age-1 Rainbow Trout (125-170 mm)	Section Totals
Rush Creek	Upper Rush	243	86	1	0	**330 Trout**
	Bottomlands	34	43	0	0	**77 Trout**
	MGORD	13	125-199 mm = 60 Brown Trout ≥200 mm = 185 Brown Trout			**258 Trout**
Lee Vining Creek	Main Channel	127	103	5	22	**257 Trout**
	Side Channel	0	0	0	0	**0 Trout**
Walker Creek	Above old 395	42	0	0	0	**42 Trout**
Age Class Sub-totals:		**459**	**232***	**6**	**22**	**Total Trout: 964**

*this sub-total excludes age-1 and older MGORD fish

Table B-6. Total numbers of trout implanted with PIT tags during the 2015 sampling season, by stream, sample section, age-class and species.

Stream	Sample Section	Number of Age-0 Brown Trout (<125 mm)	Number of Age-1 and older Brown Trout	Number of Age-0 Rainbow Trout (<125 mm)	Number of Age-1 and older Rainbow Trout	Section Totals
Rush Creek	Upper Rush	234	2*	7	0	**243 Trout**
	Bottomlands	167	3*	0	0	**170 Trout**
	MGORD	29	125-199 mm = 37 Brown Trout ≥200 mm = 83 Brown Trout (2 shed/new)			**149 Trout**
Lee Vining Creek	Main Channel	195	1*	0	0	**196 Trout**
	Side Channel	0	0	0	0	**0 Trout**
Walker Creek	Above old 395	113	0	0	0	**113 Trout**
Age Class Sub-totals:		**738**	**6****	**7**	**0**	**Total Trout: 871**

*shed tag/new tag implanted **this sub-total excludes age-1 and older MGORD fish

Table B-7. Total numbers of trout implanted with PIT tags during the 2016 sampling season, by stream, sample section, age-class and species.

Stream	Sample Section	Number of Age-0 Brown Trout (<125 mm)	Number of Age-1 and older Brown Trout	Number of Age-0 Rainbow Trout (<125 mm)	Number of Age-1 and older Rainbow Trout	Section Totals
Rush Creek	Upper Rush	36	0	1	0	**37 Trout**
	Bottomlands	79	1*	0	0	**80 Trout**
	MGORD	4 BNT 1 RBT	125-199 mm = 9 BNT ≥200 mm = 154** BNT and 7 RBT			**175 Trout**
Lee Vining Creek	Main Channel	46	1*	0	0	**47 Trout**
	Side Channel	1	0	0	0	**1 Trout**
Walker Creek	Above old 395	228	1*	0	0	**229 Trout**
Age Class Sub-totals:		**394**	**166**	**2**	**7**	**Total Trout: 569**

*shed tag/new tag implanted **two of these BNT = shed tag/new tag implanted

Appendix B: Table of PIT-tagged Fish Recaptured during October 2017 Sampling

Appendix C. PIT tagged trout recaptured in Rush and Lee Vining Creek sections, October 2017.

Date of Recapture	Species	Length (mm)	Weight (g)	PIT Tag Number	Location of 2016 Recapture	Location of Initial Capture and Tagging
10/12/2017	BNT	214	99	989001006111292	Bottomlands	Bottomlands
10/19/2017	BNT	203	81	989001004581358	Bottomlands	Bottomlands
10/19/2017	BNT	224	119	989001004581362	Bottomlands	Bottomlands
10/19/2017	BNT	229	129	989001006111236	Bottomlands	Bottomlands
10/19/2017	BNT	189	57	989001006111294	Bottomlands	Bottomlands
10/13/2017	BNT	305	351	989001001954368	LV Main	LV Main Channel
10/13/2017	BNT	280	228	989001001954878	LV Main	LV Main Channel
10/13/2017	BNT	247	175	989001004581375	LV Main	LV Main Channel
10/13/2017	BNT	210	103	989001006110986	LV Main	LV Main Channel
10/17/2017	BNT	645	2494	985121020917818	MGORD	MGORD
10/17/2017	BNT	550	2030	985121021867358	MGORD	MGORD
10/17/2017	BNT	496	1381	989001001356456	MGORD	MGORD
10/17/2017	BNT	490	1146	989001004580613	MGORD	MGORD
10/17/2017	BNT	301	281	989001004581126	MGORD	MGORD
10/17/2017	**RBT**	260	224	989001006110905	MGORD	MGORD
10/17/2017	BNT	304	261	989001006110908	MGORD	MGORD
10/17/2017	BNT	280	245	989001006110948	MGORD	MGORD
10/17/2017	BNT	330	333	989001006110983	MGORD	MGORD
10/17/2017	BNT	280	204	989001006111276	MGORD	**Upper Rush**
10/17/2017	BNT	352	383	989001006111290	MGORD	MGORD
10/17/2017	BNT	338	366	989001006111324	MGORD	MGORD
10/17/2017	BNT	327	324	989001006111341	MGORD	MGORD
10/17/2017	BNT	501	1454	989001006111367	MGORD	MGORD
10/17/2017	BNT	365	488	989001006111380	MGORD	MGORD
10/17/2017	BNT	283	248	989001006111384	MGORD	MGORD
10/17/2017	BNT	363	501	989001006111387	MGORD	MGORD
10/11/2017	BNT	284	203	989001004580732	Upper Rush	Upper Rush
10/11/2017	BNT	306	329	989001004581042	Upper Rush	Upper Rush
10/11/2017	BNT	325	350	989001004581051	Upper Rush	Upper Rush
10/11/2017	BNT	337	396	989001004581059	Upper Rush	Upper Rush
10/11/2017	BNT	230	125	989001006111210	Upper Rush	Upper Rush
10/11/2017	BNT	264	174	989001006111229	Upper Rush	Upper Rush
10/11/2017	BNT	251	169	989001006111232	Upper Rush	Upper Rush
10/11/2017	BNT	246	142	989001006111244	Upper Rush	Upper Rush
10/11/2017	BNT	248	168	989001006111251	Upper Rush	Upper Rush
10/11/2017	BNT	224	104	989001006111259	Upper Rush	Upper Rush
10/11/2017	**RBT**	255	173	989001006111268	Upper Rush	Upper Rush

Appendix C. PIT tagged trout recaptured in Rush and Lee Vining Creek sections, October 2017.

Date of Recapture	Species	Length (mm)	Weight (g)	PIT Tag Number	Location of 2016 Recapture	Location of Initial Capture and Tagging
10/11/2017	BNT	224	105	989001006111273	Upper Rush	Upper Rush
10/18/2017	BNT	245	141	989001006111242	Upper Rush	Upper Rush
10/18/2017	BNT	256	158	989001006111277	Upper Rush	Upper Rush
10/14/2017	BNT	238	133	989001001953504	Walker Creek	Walker Creek
10/14/2017	BNT	224	102	989001004580857	Walker Creek	Walker Creek
10/14/2017	BNT	194	75	989001004580876	Walker Creek	Walker Creek
10/14/2017	BNT	217	94	989001004580913	Walker Creek	Walker Creek
10/14/2017	BNT	197	70	989001004580930	Walker Creek	Walker Creek
10/14/2017	BNT	180	62	989001004580937	Walker Creek	Walker Creek
10/14/2017	BNT	170	48	989001006111006	Walker Creek	Walker Creek
10/14/2017	BNT	169	43	989001006111014	Walker Creek	Walker Creek
10/14/2017	BNT	161	38	989001006111055	Walker Creek	Walker Creek
10/14/2017	BNT	179	51	989001006111064	Walker Creek	Walker Creek
10/14/2017	BNT	175	48	989001006111072	Walker Creek	Walker Creek
10/14/2017	BNT	169	39	989001006111106	Walker Creek	Walker Creek
10/14/2017	BNT	158	38	989001006111123	Walker Creek	Walker Creek
10/14/2017	BNT	151	33	989001006111179	Walker Creek	Walker Creek
10/14/2017	BNT	161	36	989001006111183	Walker Creek	Walker Creek
10/14/2017	BNT	169	44	989001006111199	Walker Creek	Walker Creek
10/14/2017	BNT	167	41	989001006111264	Walker Creek	Walker Creek

Section 3(b)

Rush Creek High-Quality Pool Survey

Rush Creek
High-Quality Pool Survey

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City of Los Angeles Department of Water and Power
Watershed Resources Division

March 2018

TABLE OF CONTENTS

1.0 INTRODUCTION

Fish habitat in alluvial rivers and streams is an assemblage of fast and slow water habitat where fish populations readily move between these habitats based on their life histories and strategies. Of particular importance are pools (which are slow water habitat) as they are essential for fish survival and growth (Platts, 1974). The California State Water Resources Control Board issued Decision 1631 in 1994 and subsequent Orders 98-05 and 98-07 to the Los Angeles Department of Water and Power (LADWP) for ecosystem recovery in the Mono Basin of California. LADWP implemented a stream restoration program in Mono Basin streams to achieve specified quantitative termination criteria for stream ecosystem recovery specified in Order 98-07. Following 12 years post implementation of the stream restoration plan, the state appointed Stream Scientists reviewed data and surmised that the quantitative criteria specified in Order 98-07 had served their purpose but had limited utility in future monitoring of Mono Basin Streams. As part of their *Synthesis of Instream Flow Recommendations to the State Water Resources Control Board and the Los Angeles Department of Water and Power* (Mono Basin Synthesis Report, McBain et al., 2010), the Stream Scientists proposed alternative metrics for monitoring trout habitat in Mono Basin Streams. Based on the importance of pools as trout habitat, the Stream Scientists' presented the following hypothesis for Rush Creek:

> *"A large increase in the number of high-quality (Class 4 and 5) pools occurred in Rush Creek below the Narrows between the runoff year 2002 and runoff year 2008 surveys. Future wet runoff years will not appreciably continue this trend of increasing pool frequency. Instead, future improvements to Rush Creek pool and deep run habitats will likely be expressed as increases in residual depths and more abundant undercut bank habitat. As undercut bank habitat and accumulation of wood in the channel increase, brown trout holding and foraging habitat should also increase."*

Numerous fish habitat surveys have been conducted over the past 20 years. These surveys have classified pool habitat following high-flow events, as their associated discharges form and maintain pool habitat. Surveys were initiated in 2002 (Hunter et al., 2003) and repeated in 2008 (Knudson et al., 2009) and 2011 (Taylor and Knudson, 2012). Following the highest flows on record for Rush Creek in 2017, LADWP Watershed Resources Staff conducted a survey in early 2018. Overall, trends indicate that high-quality pool habitat is relatively constant or increasing along the length of the stream with minor declines in the upper reaches. However, caution must be exercised comparing these data to past results because of uncertainty surrounding previous methods.

2.0 STREAM FLOWS

All fish habitat surveys have coincided with the five highest flow events on record for Rush Creek at the Narrows (Appendix 1). Both the 2011 and 2018 surveys were conducted almost immediately after peak flows. Respectively, these flows were the 5th and highest flows on record. The 2008 survey was preceded by the 2006 runoff and was the 4th highest flow. Finally, the 2002 survey followed the 1998 runoff year, which was the 3rd largest flow on record. All these flows were competent to mobilize and transport sediment, as discharges over 300 cfs are thought to be capable of initiating sediment transport along the lower reaches of Rush Creek (StreamWise, 2004).

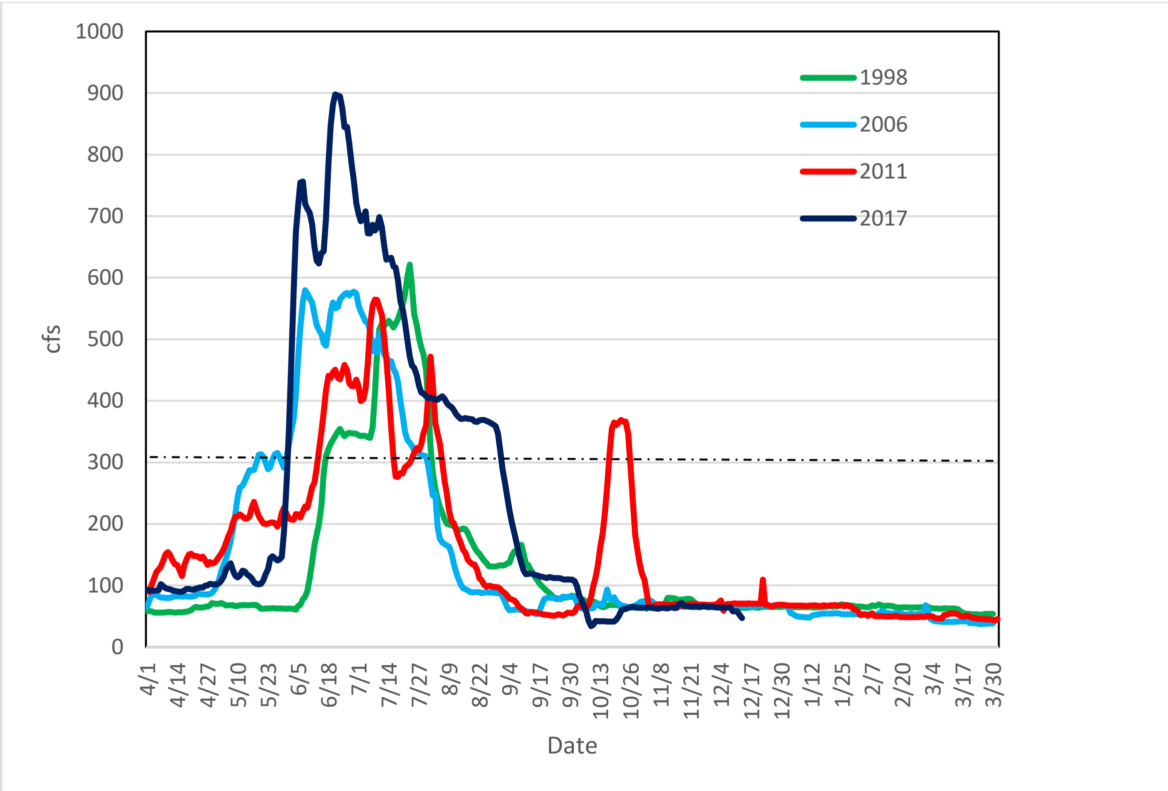

Figure 1. Daily-Mean Average Stream Flow at the Narrows, Rush Creek, Runoff Years 1998, 2006, 2011, and 2017, (Runoff Year April 1 - March 31)

The horizontal line depicts the minimum discharge (300 cfs) at which sediment transport is initiated (StreamWise, 2004).

3.0 METHODS

The 2018 pool-habitat survey was conducted from January 8-31, 2018. The survey started approximately a mile upstream of U.S. Highway 395 and continued to the Rush Creek Delta. Previous surveys were conducted over the same spatial extent yet timing varied throughout the year. However, stream reaches were re-delineated in 2018, unlike past surveys (Figure 2). These reaches are based on geomorphic, geological, and hydrological features and represent the physical variables that drive both pool formation and maintenance.

These reaches are:

> Reach 1 – Approximately one mile upstream of Highway 395 to Highway 395. This reach is defined by its high gradient (3% average slope) and straight stream course that flows over glacial outwash, which is composed of erosion-resistant large boulders and cobbles.
>
> Reach 2 – Highway 395 to the Narrows. This segment deeply incises through the coarse piedmont deposits associated with ancient "Lake Russel," which was the precursor to Mono Lake, supports a gradient of 2% and is relatively straight. Additionally, both Parker and Walker Creeks join immediately upstream of the Narrows.
>
> Reach 3 – the Narrows to "the Ford." This reach extends from the Narrows (a granite dike that Rush Creek flows across) to the road crossing of Oil Plant Road. The reach is steep with an average grade of 1.8% and supports a moderate degree of meandering. The substrate along the upper portions of the river are mainly granitic in origin, while downstream low-density volcanic rocks become more evident. This reach also contains a pronounced knickpoint (Figure 4). This feature represents the pulse of incision that followed the rapid decline in base-level that occurred with the drop in the surface elevation of Mono Lake in the late 20th century. The stream in the immediate vicinity of this feature is highly unstable as the channel and its adjacent floodplain adjust to this incision.
>
> Reach 4 – "the Ford" to the Rush Creek Delta. This reach spans from the Ford to the Rush Creek Delta and is sinuous as the stream is easily able to mobilize and transport the light volcanic material that composes both its channel and banks. The average slope of this reach is 0.9%.

Figure 2. Rush Creek Stream Reaches Surveyed in January 2018

In conducting the survey, methods detailed by Platts *et al*. (1983) were used with some modifications. Platts' methodology classifies habitat into fast water habitat (high and low gradient riffles), slow (pools), and an intermediate class (glide/run). Additionally, Platts' method numerically ranks pool-habitat based on both physical (width and depth of pools) and fish-hiding cover (water depth, substrate, bubble curtain and instream and overhanging bank vegetation). Pools are assigned a value of 2 – 5, with larger values denoting higher-quality pools. Class 1 pools were not documented as they are small and usually a part of another habitat unit (e.g. pocket pools associated with a high gradient riffle). To assist the surveyor in ranking, a dichotomous key is utilized:

Table 1. Pool Classification Key (Platts *et al*. 1983)

Table 1. — Rating of pool quality; designed for streams between 20 and 60 ft in width

	Description	Pool rating
1A	If the pool maximum diameter is within 10 percent of the average stream width of the study site	Go to 2A, 2B
1B	If the maximum pool diameter exceeds the average stream width of the study site by 10 percent or more	Go to 3A, 3B
1C	If the maximum pool diameter is less than the average stream width of the study site by 10 percent or more......	Go to 4A, 4B, 4C
2A	If the pool is less than 2 ft in depth ...	Go to 5A, 5B
2B	If the pool is more than 2 ft in depth ..	Go to 3A, 3B
3A	If the pool is over 3 ft in depth or the pool is over 2 ft depth and has abundant fish cover[1]	Rate 5
3B	If the pool is less than 2 ft in depth, or if the pool is between 2 and 3 ft and the pool lacks fish cover	Rate 4
4A	If the pool is over 2 ft with intermediate[2] or better cover	Rate 3
4B	If the pool is less than 2 ft in depth but pool cover for fish is intermediate or better	Rate 2
4C	If the pool is less than 2 ft in depth and pool cover is classified as exposed[3]	Rate 1
5A	If the pool has intermediate to abundant cover	Rate 3
5B	If the pool has exposed cover conditions	Rate 2

[1]If cover is abundant, the pool has excellent instream cover and most of the perimeter of the pool has a fish cover.
[2]If cover is intermediate, the pool has moderate instream cover and one-half of the pool perimeter has fish cover.
[3]If cover is exposed, the pool has poor instream cover and less than one-fourth of the pool perimeter has any fish cover.

Further, criteria to step 4B of Platts' *et al.* key were added to clarify situations where: the residual depth of the pool was greater than two feet deep and had less than 50% cover, then the pool was rated Class 2. Additionally, a pool's residual depth was used to make the survey independent of discharge, as varying flows would lead to changes in pool depths and thus surveys at different discharges would not comparable. Residual depth is calculated as the difference between the pool's maximum depth and its riffle-crest depth, which is the pool's downstream hydraulic control that dictates the surface-water elevation of the pool (Hilton and Lisle, 1993). Also, if a pool was classified as Class 4 or Class 5 pools, the percent and the type of instream cover was recorded. The types of cover are:

- Overhanging Vegetation
- Submerged Vegetation
- Large woody accumulations
- Small woody accumulations
- Boulders
- Root wads
- Undercut banks
- Bubble curtains
- Depth ≥ 3'

The previous surveys (2002, 2008 and 2011) used both Platts' methodology and a modified version. Hunter *et al*. (2003) used Platts' methods with residual depths. However, a modified method was introduced in 2008 (Knudson *et al*., 2009) and was used again in 2011. This method used residual depths, but also provided numeric values for determining cover for high-quality pools (Class 4 and Class 5), and thus removed the subjectivity associated with Platts' method. The modifications are as follows:

> "The pool's maximum width had to be at least 90% of the mean channel width, and its residual depth had to be at least 2.0 feet; then –
>
> (1) The pool was rated as Class-5 if (a) it had a residual depth >3.0 feet with some (>25%) hiding cover, or if (b) it had a residual depth of 2.0 to 2.9 feet with abundant (>75%) cover;
>
> (2) The pool was rated as Class-4 if (a) it had a residual depth >3.0 feet with sparse (<25%) cover, or if (b) it had a residual depth of 2.0 to 2.9 feet with intermediate (50-74%) cover."

There are numerous issues associated with these modifications. First, it is unclear if the aforementioned cover criteria is meant to either augment or replace a portion of Platts' key. Prior reports (2009 and 2012) never explicitly state where these changes fit into Platts' methods. In 2018, staff worked under the assumption that the modified cover criteria replaced steps 3A and 3B in Platts' key. The issue with this modification is that in steps 3A or 3B in Platts' key, a pool could only be classified as either a Class 4 or Class 5. However, using Knudson's modification it is ambiguous how to classify pools that possess the required width and depth for a Class 4 pool, but yet lacks their adapted cover values. Further, Knudson's methods also failed to provide a classification scheme for high-quality pools that possess cover that ranges from 26-49%. For instance, pool "P4-8" (Appendix 3) possesses the physical characteristics (both water depth and width) to be classified as a Class 4 pool, but has only 30% cover. Consequently, it is uncertain how this pool would be rated. In an attempt to examine how previous surveys (2002, 2008 and 2011) handled similar situations, raw data for all Class 4 and Class 5 pools were requested but unfortunately were not made available at the time of this report. Further, when asked to explain this deficiency, Stream Scientist, Mr. Ross Taylor had no clarification or rationale for the lapse in cover values (personal communication, 2018). Therefore, results of the past survey may not accurately reflect actual conditions.

4.0 RESULTS

4.1 HIGH-QUALITY POOLS

In 2018, of the 58 high-quality pools (Class 4 and Class 5) surveyed, all but one were found below the Narrows (Figures 3, 4, and 5). In Reach 1 the number of high quality pools has decreased from a high of three Class 5 pools and one Class 4 to only one Class 4 pool in 2018, while for Reach 2, both the 2011 and 2018 surveys did not contain any high quality pools (Figure 6). Reach 3 in 2018 had two less Class 5 pool when compared to 2008, but contained eight more pools than the 2011 survey and with respect to Class 4 pools, they remained relatively stable over the four surveys with a high of 16 in 2002 and a low of 13 in 2011 (Figure 6). In Reach 4, the number of high quality pools has steadily increased from 2002 when there was a total of 5 pool to 24 pool in 2018 and the total number of high quality pools from 2011 to 2018 only increased by one pool; but there was a shift from about an equal numbers of Class 4 and 5 pools to less Class 4 pools and more high quality Class 5 pools (Figure 6).

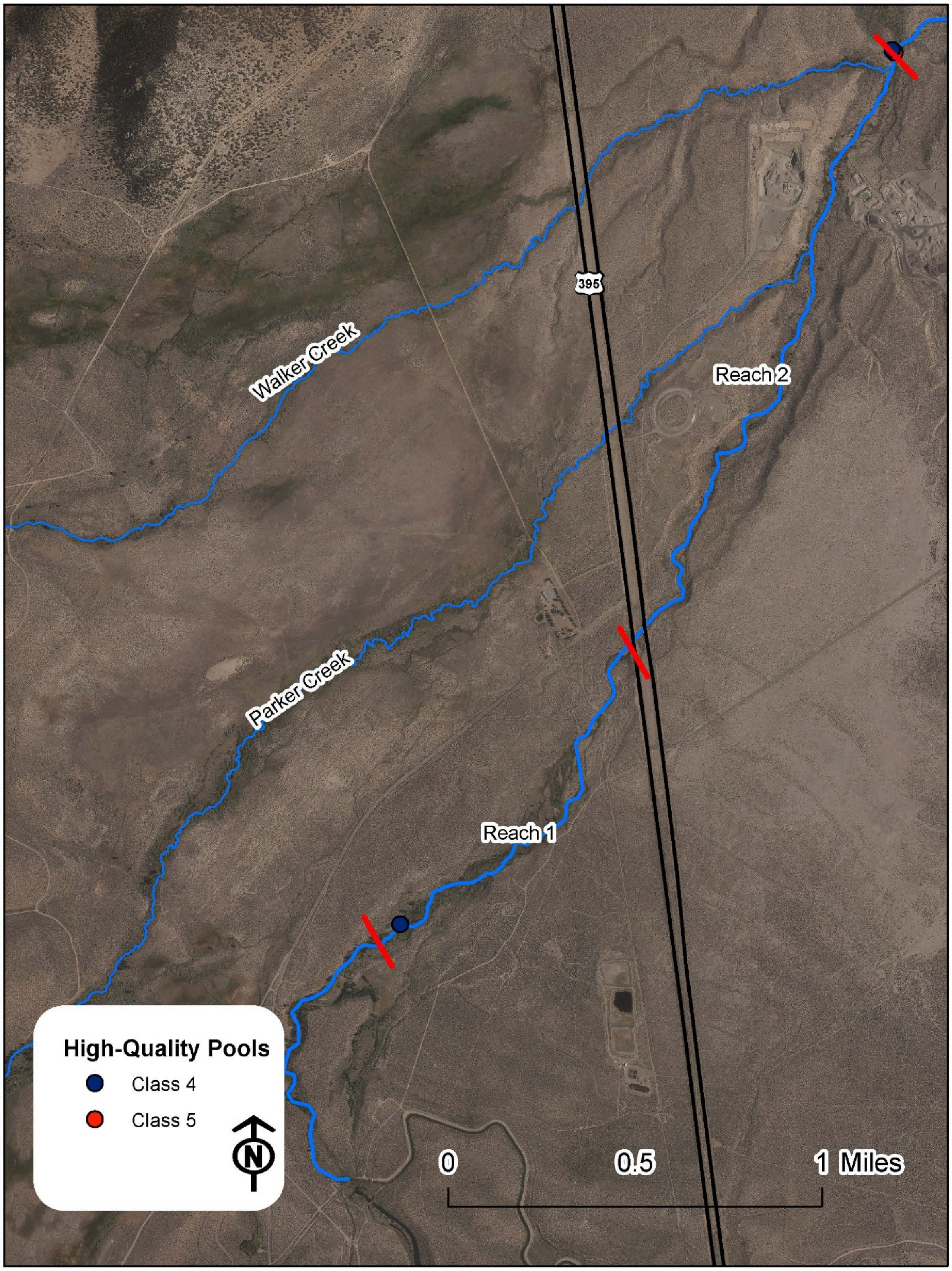

Figure 3. High-Quality Pool Habitat in Reaches 1 and 2 on Rush Creek, 2018

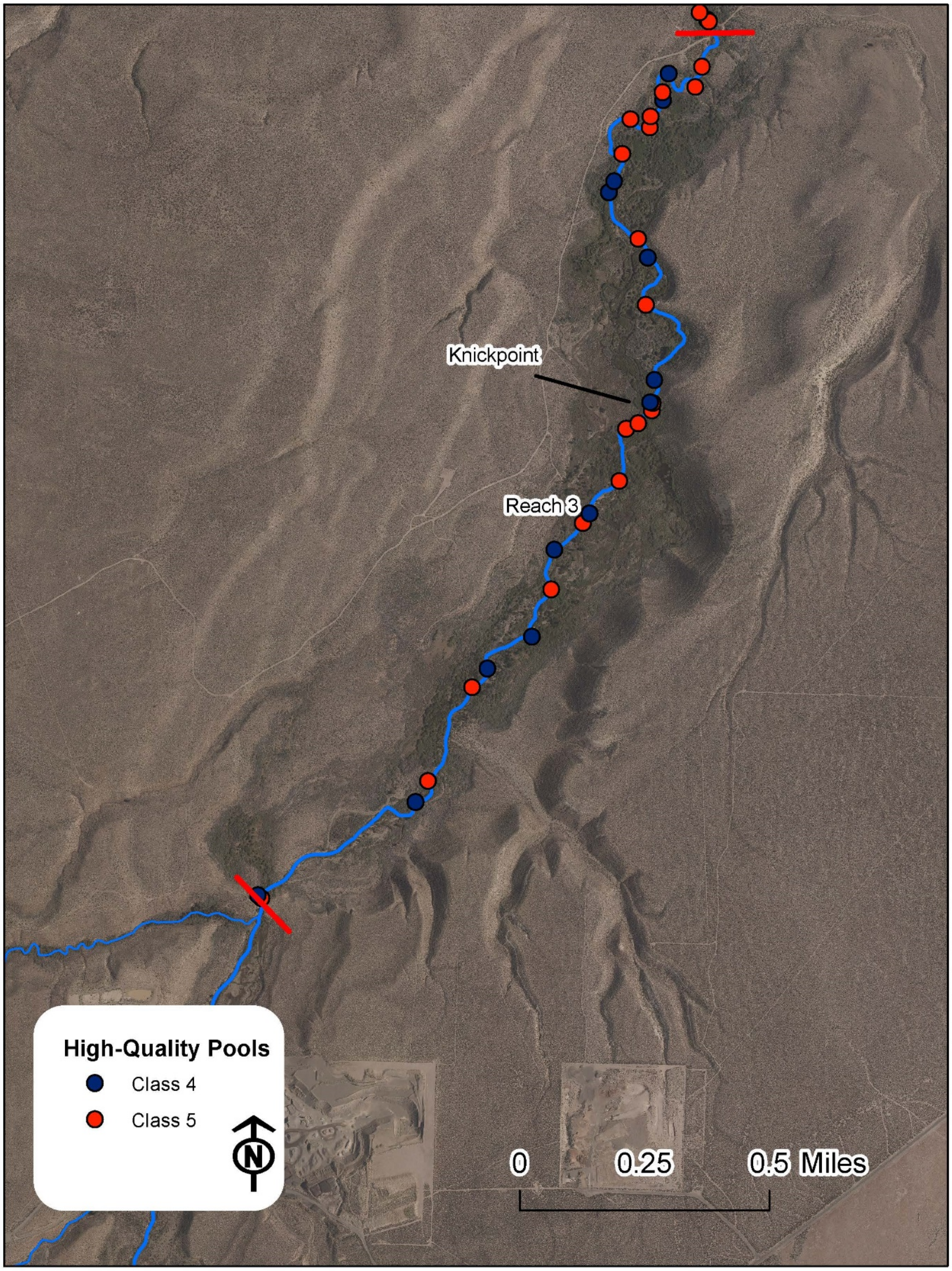

Figure 4. High-Quality Pool Habitat and Knickpoint, Reach 3 on Rush Creek, 2018

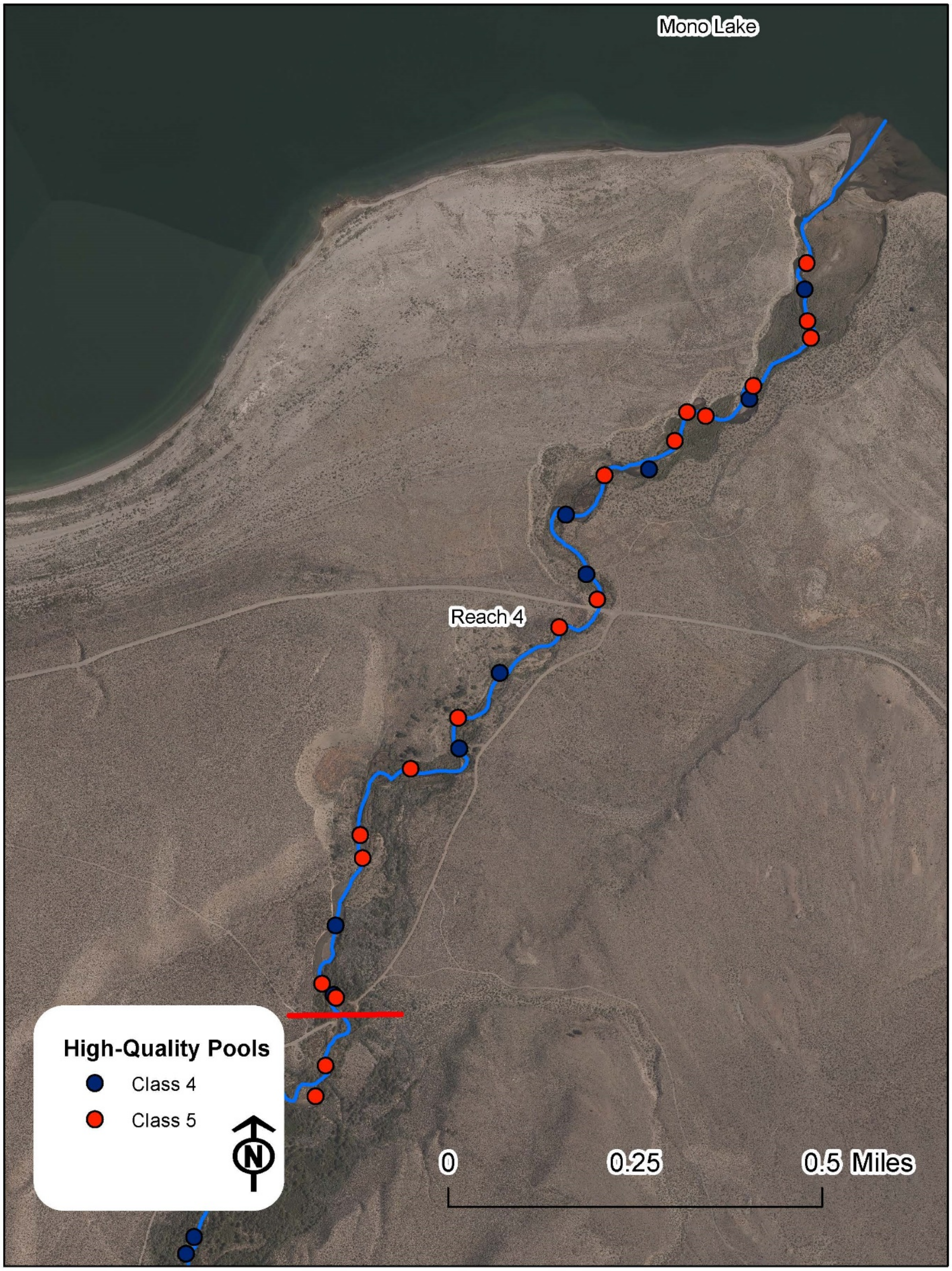

Figure 5. High-Quality Pool Habitat, Reach 4 of Rush Creek, 2018

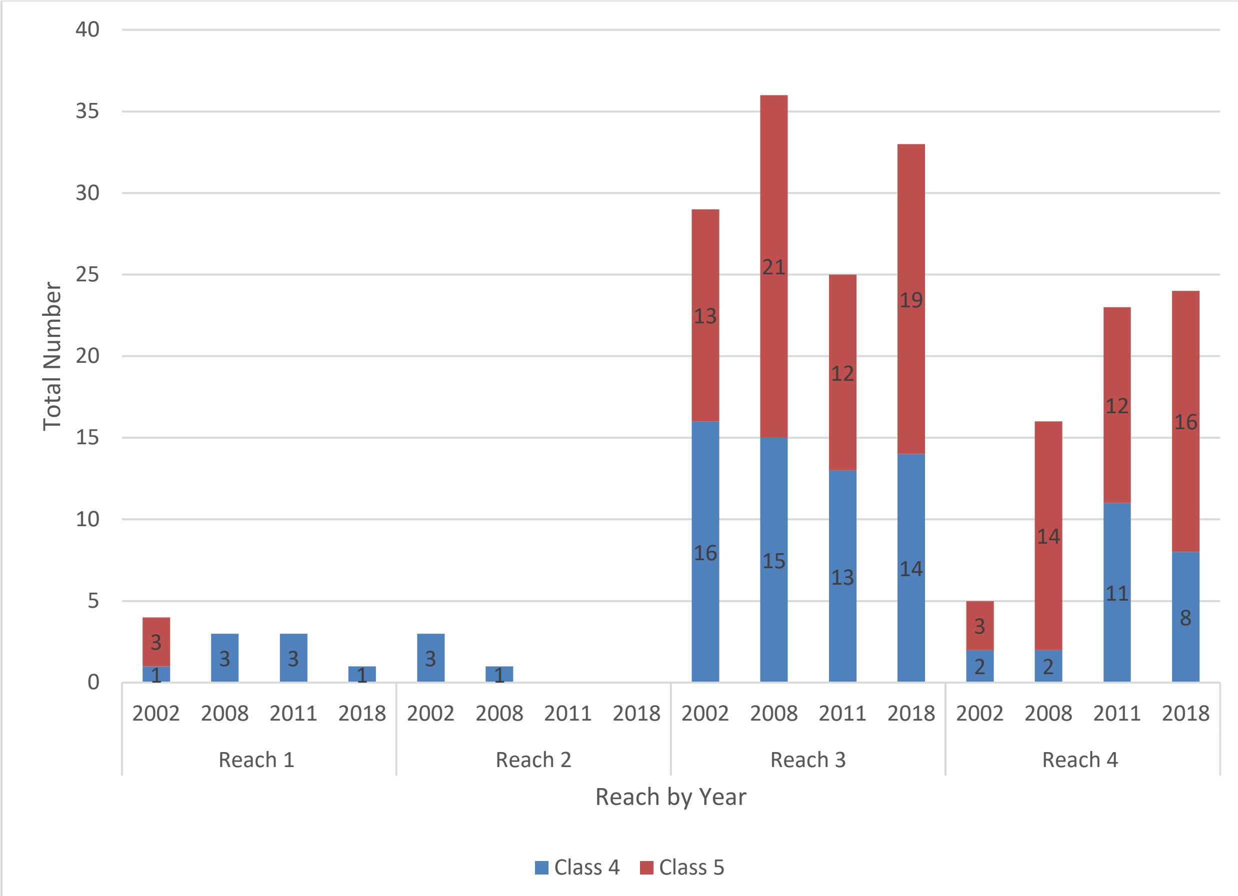

Figure 6. Total Number of High Quality (Class 4 and Class 5) Pools by Reach for Survey Years 2002, 2008, 2011 and 2018

4.2 KNICKPOINT

The 2017 flows contained enough energy to propagate a knickpoint up the "10 side-channel" and in doing so captured the entirety of the main-stem flow (Figure 7). This knickpoint traveled past the point where the "10 side-channel" diverges from the main stem and continued upstream. The total length of the headcut was approximately 3,500 feet and finally stopped approximately one-tenth of a mile below where the "8 side-channel" diverges from Rush Creek (Appendix 2). As a result of this incision, the number of high-quality pools in the "10 side-channel", has declined to one Class 5 and one Class 4 pool. In comparison, in 2008 there were three Class 5 pools and three Class 4 pools (in 2011 the "10 side-channel" was not surveyed).

Figure 7. Spatial Extent of Headcut Associated with Knickpoint Migration on Rush Creek Following 2017 High Flows

5.0 DISCUSSION

Despite the vagueness and inconsistencies of prior surveys, the overall trend in high-quality pool habitat (Class 4 and Class 5) along Rush Creek shows that while pools are slightly declining in the upper reaches, they remain relatively constant in Reach 3 and there is a marked increase in Reach 4. These trends are related to the loss of instream woody debris in the upper reaches and the geomorphological variables in the lower reaches.

The decline in high-quality pools in the upper two reaches is primarily a function of the loss of the "Trihey" pools. These pools were in relation to artificially placed root wads placed in Rush Creek in the late 1990s (Mono Basin Synthesis Report, 2010). Over time these structures have deteriorated or been removed from the active channel following high flows. In the near future, it is unlikely that these upper reaches will support high-quality pool habitat given their steep grade and large substrate. Instead, high-quality pool habitat in these reaches will be a function of large woody-debris that is naturally introduced as adjacent trees senesce and fall into the creek. Such processes will take decades. In Reach 3, high-quality pools over time have remained relatively constant, despite the losses of pools associated with the upstream propagation of the knickpoint. Lastly, there has been a positive increase in pools in Reach 4. This increase is a function of the high degree of meandering of the stream and the association of pools with these features.

6.0 SUMMARY

2017 witnessed the highest flows on record for Rush Creek. Following these high flows a trout habitat survey was conducted to document changes in fish habitat along the length of the creek and analyses focused on the trend of high-quality pool habitat over time. When compared to surveys conducted in 2002, 2008 and 2011 the number of high-quality pools in the upper reaches have slightly declined because of the loss of artificial instream-structures while Reaches 3 and 4 have remained constant and increased, respectively. It is evident that high flows in Rush Creek are competent to maintain high-quality pools but also form new pools. Subsequently, these results fully support the hypothesis made in the Mono Basin Synthesis Report (2010) that the number of high-quality pools will remain constant over time.

We do note that caution must be taken with the results of previous years' surveys because of both the variations and discrepancies in methods. As recommended in the Synthesis Report, future surveys should use Platts' *et al.* (1983) methods and all data should be published (Appendix 3 and 4).

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8.0 APPENDICES

Appendix 1. Ranking of Maximum Mean Daily Stream Flow

Rank	Runoff Year (April 1 - March 31)	Maximum Daily Mean cfs
1	2017	898
2	1995	647
3	1998	636
4	2006	580
5	2011	564
6	2010	493
7	2005	422
8	1996	390
9	2004	374
10	2008	311
11	2003	283
12	1999	255
13	2000	255
14	2016	255
15	1997	230
16	2002	224
17	1993	205
18	2001	200
19	1991	193
20	1992	188
21	1994	130
22	1990	121
23	2013	115
24	2009	108
25	2015	79
26	2012	64
27	2007	62
28	2014	58

Appendix 2. Knickpoint

Top photograph - knickpoint on Rush Creek, approximately one-tenth of a mile below divergence of “8 side-channel.” Bottom photograph - extent of downcutting (approximately 1.5 feet) following the passage of the knickpoint in the “10 side-channel.”

Appendix 3. All Data, 2018 Survey

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
PO-1	0	47	4	2	2.1	19	3	50	1	4194501	314964	11	Beaver Activity
HGR-1	47	225											
P4-1	272	81	4	1	2.2	24	4	20	1	4194567	315033	11	Left Bank Side Channel Start Dry
HGR-2	353	372											
PO-2	725	50	3	1	1.8	25	2	40	1	4194605	315142	10	
HGR-3	775	182											
	957	35											Left Bank Side Channel Return
PO-3	992	174	4	2	2.1	18	2	25	1	4194717	315184	10	Beaver Activity
HGR-4	1166	85											
GL-1	1251	116											Beaver Activity
HGR-5	1367	36											
	1403	99											Right Bank Side Channel Start
	1502	28											Right Bank Side Channel Return
HGR-6	1530	93											
GL-2	1623	100											
HGR-7	1723	69											Right and Left Bank Side Channel Start
GL-3	1792	62											
HGR-8	1854	2											Left Bank Side Channel Start
	1856	39											Upper Rush Fence Start
	1895	65											Right Bank Side Channel Return
LGR-1	1960	82											
HGR-9	2042	58											
LGR-2	2100	73											
	2173	20											Left Bank Side Channel Return
PO-4	2193	36	3	1	1.6	25	3	50	1	4194852	315490	10	
	2229	12											Left Bank Side Channel Start
HGR-10	2241	72											
	2313	11											Right Bank Side Channel Start

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
PO-5	2324	46	3	1	1.9	21	2	55	1,8	4194876	315522	10	Moto's Pool
HGR-11	2370	10											
	2380	35											Right Bank Side Channel Start
	2415	11											Left Bank Side Channel Return
GL-4	2426	64											
	2490	80											Right Bank Side Channel Start
HGR-12	2570	29											
PO-6	2599	16	3	1	2.4	19	3	50	1,2	4194922	315553	10	
	2615	18											Right Bank Side Channel Return
HGR-13	2633	71											Right Bank Side Channel Return
	2704	208											Sub Stop C Boulders, Trihey Stump Missing
LGR-3	2912	87											
HGR-14	2999	23											
PO-7	3022	35	3	2	1.3	25	2	25	8,2	4194971	315671	10	Trihey Stump Left Bank
GL-5	3057	41											Left Bank Trihey Stump
HGR-15	3098	16											Upper Rush Fennce End
	3114	50											Left Bank Side Channel Start
GL-6	3164	77											
HGR-16	3241	224											
GL-7	3465	20											
	3485	8											Left Bank Staff Gauge
HGR-17	3493	328											
PO-8	3821	41	4	1	2.2	15	3	60	1	4195157	315815	11	
HGR-18	3862	110											
LGR-4	3972	153											
HGR-19	4125	183											
	4308	100											Left Bank Side Channel Start
GL-8	4408	53											

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
HGR-20	4461	56											
GL-9	4517	81											
LGR-5	4598	62											
HGR-21	4660	69											Right Bank Side Channel Start
GL-10	4729	39											
HGR-22	4768	198											
LGR-6	4966	35											
HGR-23	5001	10											Right Bank Side Channel Return
	5011	17											Start Old 395 Bridge
	5028	60											End Old 395 Bridge
LGR-7	5088	59											
HGR-24	5147	71											
LGR-8	5218	69											
HGR-25	5287	215											
LGR-9	5502	56											
HGR-26	5558	27											
LGR-10	5585	58											
HGR-27	5643	93											Left Bank Side Channel Start
GL-11	5736	102											
	5838	26											Left Bank Side Channel Return
HGR-28	5864	47											
GL-12	5911	110											
HGR-29	6021	73											
LGR-11	6094	80											
LGR-12	6174	41											South 395 Start
HGR-30	6215	6											
	6221	153											South 395 End
GL-13	6374	19											

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
HGR-31	6393	13											
	6406	63											North 395 Start
	6469	301											North 395 End
GL-14	6770	37											
HGR-32	6807	166											
	6973	109											
GL-15	7082	43											Hip Chain Reset
HGR-33	7125	14											
PO-9	7139	22	3	2	1.9	24	2	40		4195978	316249	10	
HGR-34	7161	38											
GL-16	7199	45											
HGR-35	7244	75											
LGR-13	7319	76											
HGR-36	7395	155											
LGR-14	7550	49											
HGR-37	7599	91											
LGR-15	7690	71											
HGR-38	7761	237											
LGR-16	7998	77											
HGR-39	8075	64											
PO-10	8139	32	3	2	1.3	23	2	45		4196229	316272	10	
HGR-40	8171	239											
LGR-17	8410	20											
	8430	50											Trihey Stump Left Bank
HGR-41	8480	208											
LGR-18	8688	19											
	8707	23											Right Bank Side Channel Start
HGR-42	8730	156											Right Bank Side Channel Return

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
	8886	56											
GL-17	8942	31											
HGR-43	8973	28											
LGR-19	9001	76											
HGR-44	9077	275											
PO-11	9352	62	3	1	1.8	24	2	20		4196576	316395	11	
HGR-45	9414	102											Left Bank Side Channel Start
	9516	129											Left Bank Side Channel Return
	9645	13											Left Bank Side Channel Return
LGR-20	9658	148											
HGR-46	9806	161											
	9967	506											Right Bank Side Channel Start
	10473	99											Right Bank Side Channel Return
LGR-21	10572	174											
HGR-47	10746	98											Right Bank Side Channel Start
	10844	16											Right Bank Side Channel Return
LGR-22	10860	108											
HGR-48	10968	70											
GL-18	11038	32											
HGR-49	11070	23											
	11093	93											Left Bank Split Channel Start
	11186	92											Left Bank Split Channel Return
GL-19	11278	45											
HGR-50	11323	279											
GL-20	11602	91											
HGR-51	11693	545											
PO-12	12238	150	3	1	1.6	25	2	20		4197293	316812	8	Channel Split Start
HGR-52	12388	537											Parker Creek, Channel Split Return

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
	12925	81											
	13006	422											Left Bank Side Channel Start Dry
GL-22	13428	54											
HGR-53	13482	192											
	13674	276											Left Bank Side Channel Return Dry
	13950	307											Right Bank Side Channel Start Dry
	14257	147											Right Bank Side Channel Return Dry
	14404	120											Left Bank Side Channel Return Dry
LGR-23	14524	95											Right Bank Side Channel Start Dry, Staff Gauge
HGR-54	14619	125											Left Bank Side Channel Start Dry
	14744	19											Left Bank Side Channel Return Dry
	14763	173											Right Bank Side Channel Start Dry
GL-23	14936	63											
HGR-55	14999	39											
LGR-24	15038	75											
HGR-56	15113	37											
	15150	100											Trihey Stump Right Bank
LGR-25	15250	84											
HGR-57	15334	44											Trihey Stump Right Bank
	15378	57											Trihey Stump Right Bank
	15435	171											Staff Gauge Left Bank
	15606	22											Trihey Stump Right Bank ID Tag 3080
GL-24	15628	43											
HGR-58	15671	51											
	15722	110											Right Bank Staff Gauge
HGR-59	15832	42											Walker Creek
GL-25	15874	28											Narrows
HGR-60	15902	117											

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
P5-1	16019	30	5	2	3.2	30	5	60	8,5	4198318	317160	9	
P4-2	16049	36	3	1	1.8	39	4	50	8,5	4198328	317149	10	
HGR-61	16085	27											
GL-26	16112	29											
HGR-62	16141	22											
GL-27	16163	14											Right Bank Side Channel Start
HGR-63	16177	6											
	16183	244											Right Bank Side Channel Return
LGR-26	16427	82											
HGR-64	16509	146											
LGR-27	16655	44											
HGR-65	16699	262											
	16961	124											Left Bank Side Channel Start Dry
LGR-28	17085	109											Left Bank Side Channel Return Dry
HGR-66	17194	133											
LGR-29	17327	92											
HGR-67	17419	105											
GL-28	17524	36											
HGR-68	17560	111											Right Bank Side Channel Start
GL-29	17671	32											
HGR-69	17703	57											Right Bank Side Channel Return
	17760	12											
GL-30	17772	101											Beaver Activity
HGR-70	17873	25											
PO-13	17898	42	3	1	1.6	19	2	70	1,2	4198591	317638	10	
HGR-71	17940	97											
GL-31	18037	8											
P4-3	18045	27	4	1	2.5	23	4	35	1	4198629	317656	8	

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
HGR-72	18072	98											New Channel, Left Bank Side Channel Start Old
PO-14	18170	106	3	1	1.5	21	2	50	1,2	4198648	317696	9	Left Bank Side Channel Return Old
HGR-73	18276	40											
P5-2	18316	79	5	1	4	29	5	25	1,9	4198697	317697	10	
HGR-74	18395	132											
	18527	85											Old P5-8
LGR-30	18612	58											
HGR-75	18670	109											
LGR-31	18779	104											
HGR-76	18883	156											
GL-32	19039	39											Left Bank Side Channel Start
HGR-77	19078	64											
PO-15	19142	95	3	1	1.3	24	2	50	1,2,8	4198934	317778	10	Left Bank Side Channel Return
GL-33	19237	56											
LGR-32	19293	100											
HGR-78	19393	46											
P5-3	19439	141	6+	1	5+	26	5	40	1,2	4198999	317840	8	
HGR-79	19580	133											
P5-4	19713	66	4	1	3.6	24	5	30	2,1	4199060	317889	8	
HGR-80	19779	59											
LGR-33	19838	97											
HGR-81	19935	128											
PO-16	20063	50	3	1	2.6	20	2	5	1	4199139	317915	9	Alcove Pool
HGR-82	20113	39											
PO-17	20152	34	3	1	1.6	20	2	50	2,8	4199135	317942	9	
LGR-34	20186	30											
	20216	52								4199134	317964	10	4BII Dry
HGR-83	20268	60											

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
PO-18	20328	57	3	2	1.1	20	2	50	1	4199160	317994	12	
HGR-84	20385	61											
P4-4	20446	51	3	1	2.4	26	4	70	1	4199163	318032	13	Right Bank Side Channel Start
HGR-85	20497	45											
GL-34	20542	35											
HGR-86	20577	132											Right Bank Side Channel Return
PO-19	20709	93	4	1	2.3	21	2	10	1	4199235	318040	10	
HGR-87	20802	79											
LGR-35	20881	76											
HGR-88	20957	55											
PO-20	21012	45	4	1	2.2	20	3	50	1	4199309	318090	8	Old Beaver Sign
HGR-89	21057	10											
P5-5	21067	48	6+	1	4.6+	34	5	60	2,1,9	4199315	318095	8	
HGR-90	21115	41											
LGR-36	21156	51											
HGR-91	21207	93											
GL-35	21300	47											
P4-5	21347	199	4	1	2.6	28	4	40	1,2	4199443	318105	8	
HGR-92	21546	12											
GL-36	21558	76											
	21634	44											Left Bank Side Channel Start, 8 Channel
LGR-37	21678	104											
	21782	95											Right Bank Side Channel Start
P5-6	21877	110	5	1	3.6	44	5	50	1,2	4199528	318196	8	Beaver Cut Down Big Cottonwood
HGR-93	21987	29											
P4-6	22016	37	3	1	2.1	30	4	20	2,1	4199560	318218	8	Left Bank Side Channel Start
HGR-94	22053	108											
	22161	57											Right Bank Braiding Start

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
	22218	153											Channel Braiding
GL-37	22371	42											Old Beaver Sign
LGR-38	22413	36											
GL-38	22449	56											
P5-7	22505	33	5	1	3.2	23	5	60	1,2	4199664	318314	8	
GL-39	22538	41											
HGR-95	22579	33											
PO-22	22612	21	4	1	2.1	20	3	90	8,1	4199682	318324	8	Headcut
HGR-96	22633	111											
GL-40	22744	65											
HGR-97	22809	56											
GL-41	22865	67											
	22932	40											
	22972	26											Left Bamk Beaver Pond
PO-23	22998	54	4	1	2.5	17	3	50	1,2	4199817	318327	8	Right Bank Staff Gauge
HGR-98	23052	5											
P5-8	23057	84	6	1	4.3	31	5	50	2,1,8	4199833	318336	10	
HGR-99	23141	54											
P5-9	23195	141	4	1	3.1	26	5	45		4199851	318376	10	
HGR-100	23336	68											
P5-10	23404	77	5.0+	1	4.1	26	5	55		4199891	318419	9	
HGR-101	23481	19											
P5-11	23500	23	5	1	3.2	25	5	40	1,8	4199915	318423	12	
HGR-102	23523	18											
P4-7	23541	58	4	2	2.5	>30	4	40		4199918	318414	10	Beaver Sign
GL-42	23599	151											
HGR-103	23750	20											
P4-8	23770	25	4	1	2.4	31	4	30	2	4199991	318428	10	

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
HGR-104	23795	38											Start of 10 Channel taking all flow, old main cut off
GL-43	23833	41											
HGR-105	23874	71											
PO-24	23945	81	4	1	2.3	13	2	13	1	4200037	318435	12	
HGR-106	24026	70											
LGR-39	24096	78											
HGR-107	24174	34											
PO-25	24208	50	3	1	1.6	24	3	55	1	4200094	318498	8	Fresh Beaver Sign
HGR-108	24258	113											
PO-26	24371	62	3	1	2.3	15	2	25	1	4200124	318526	8	
HGR-109	24433	64											
PO-27	24497	66	4	1	3.4	17	2	5	1,9	4200152	318495	10	Redd at pool tail
HGR-110	24563	18											
PO-28	24581	46	4	2	2.3	19	3	60	2,1	4200177	318512	10	
HGR-111	24627	27											
GL-44	24654	39											
LGR-40	24693	54											
	24747	25											Channel drop in elevation
HGR-112	24772	86											
GL-45	24858	34											
HGR-113	24892	103											
P5-12	24995	80	6+	2	4.2	30	5	75	9,1	4200233	318400	10	Beaver, Where willows were holding head cut
HGR-114	25075	35											
GL-46	25110	71											
LGR-41	25181	39											
HGR-115	25220	68											
GL-47	25288	121											
HGR-116	25409	71											

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
GL-48	25480	57											
LGR-42	25537	40											
HGR-117	25577	107											
P4-9	25684	46	4	2	1.7	28	4	35	2,3	4200386	318406	10	
HGR-118	25730	62											
LGR-43	25792	26											
HGR-119	25818	32											
PO-29	25850	69	4	2	2.2	20	3	85	1	4200411	318374	10	
	25919	8											Left Bank Old Main Channel Return
LGR-44	25927	40											
HGR-120	25967	36											
P5-13	26003	56	6	2	3.9	28	5	40	1	4200445	318376	10	
HGR-121	26059	19											
GL-49	26078	54											
HGR-122	26132	38											
GL-50	26170	115											
LGR-45	26285	45											
HGR-123	26330	101											
GL-51	26431	102											
HGR-124	26533	74											
P4-10	26607	69	3	1	2.2	25	4	20	1	4200596	318280	10	
HGR-125	26676	75											
P4-11	26751	96	4	1	2.8	24	4	10	1	4200632	318298	10	
HGR-126	26847	60											
GL-56	26907	143											
P5-14	27050	67	6+	1	5.1	28	5	60	1,9	4200719	318323	10	
HGR-127	27117	74											
GL-57	27191	75											

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
HGR-128	27266	59											
LGR-46	27325	51											
	27376	141											Bottomland Upper Fence
PO-30	27517	94	3	1	2	22	2	25	1	4200806	318286	10	
HGR-129	27611	126											
P5-15	27737	166	4	1	3	27	5	30	2,1	4200831	318350	10	
LGR-47	27903	78											
HGR-130	27981	48											
P5-16	28029	71	4	1	3.1	29	5	30	2,1	4200805	318412	10	
HGR-131	28100	36											
P5-17	28136	99	4	1	3.2	24	5	40	2,1	4200840	318415	9	
LGR-48	28235	69											
HGR-132	28304	39											
P4-12	28343	102	4	1	3.1	24	4	20	1	4200894	318455	11	
HGR-133	28445	26											
P5-18	28471	65	5	1	3.9	30	5	40	1,2	4200919	318454	10	
HGR-134	28536	36											
PO-31	28572	62	4	1	2.2	21	2	45	1	4200956	318434	10	
HGR-135	28634	37											
LGR-49	28671	74											
P4-13	28745	81	4	1	2.7	24	4	55	2,1	4200979	318473	9	
LGR-50	28826	57											
	28883	17											Bottomlands Lower fence
GL-58	28900	102											
	29002	62											Left Bank Channel Split Start
HGR-136	29064	114											
GL-59	29178	40											
P5-19	29218	45	3	1	2.4	28	5	75	2,1	4200935	318559	10	

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
HGR-137	29263	61											
PO-32	29324	7	4	1	3	21	2	30	1,8	4200965	318557	10	
	29331	33											Left Bank Channel Return
HGR-138	29364	98											
	29462	43											Right Bank Channel Split Start
P5-20	29505	8	4	1	3	29	5	35	2	4201001	318581	12	
	29513	18											Right Bank Channel Split Return
HGR-139	29531	28											
P4-14	29559	204	4	1	2.9	25	4	10	2	4201153	318598	8	
HGR-140	29763	94											Right Bank Side Channel Split Dry
HGR-141	29857	113											Ford Crossing
GL-60	29970	46											
P5-21	30016	64	5.0+	2	3.4	26	5	60	1,2,9	4201147	318603	8	Beaver
HGR-142	30080	36											
P5-22	30116	135	4	1	3.2	26	5	30	1	4201177	318573	8	
HGR-143	30251	117											Overview Photo
	30368	225								4201234	318565	8	Old Pool, Channel then use to make 90 degree turn to right
P4-15	30593	53	3	1	2.1	30	4	15	2	4201302	318602	8	
HGR-144	30646	122											New channel joins old main channel
GL-61	30768	21											
HGR-145	30789	252											
PO-33	31041	65	4	1	2.7	21	2	25	1,2	4201418	318649	8	
HGR-146	31106	25											
P5-23	31131	58	5	1	3.3	27	5	40	1,2,8	4201447	318660	9	
LGR-51	31189	28											
PO-34	31217	58	3	1	1.9	26	2	10		4201490	318663	10	
HGR-147	31275	46											
P5-24	31321	60	4	1	3.3	36	5	40	2,8	4201497	318655	10	

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
LGR-52	31381	222											
HGR-148	31603	22											
	31625	175											Upper County Road Fence
PO-35	31800	44	4	1	3.3	17	3	55	1,2,9	4201620	318709	8	
HGR-149	31844	111											
GL-62	31955	31											
HGR-150	31986	19											
	32005	8											Left Bank side channel start
P5-25	32013	49	5	1	3.4	28	5	70	1,2	4201639	318764	12	
GL-63	32062	46											
	32108	5											Left Bank side channel return
HGR-151	32113	110											
LGR-53	32223	153											
HGR-152	32376	118											Channel Split Start
P4-16	32494	22	3	2	1.8	30	4	25	1,5,8	4201683	318868	10	Channel Split Return
LGR-54	32516	57											
HGR-153	32573	162											County Road Lower fence
P5-26	32735	27	5	1	3.3	40	5	35	1,9	4201749	318865	10	
HGR-154	32762	73											
PO-36	32835	41	3	1	2	21	2	35	1	4201754	318907	10	
LGR-55	32876	38											
HGR-155	32914	105											
GL-64	33019	56											
LGR-56	33075	81											
HGR-156	33156	38											
P4-17	33194	49	4	2	2.3	28	4	25	8,1	4201846	318955	8	
HGR-157	33243	9											
PO-37	33252	33	3	1	1.5	26	2	30		4201846	318967	10	

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
GL-65	33285	23											
PO-38	33308	73	5	2	3	19	3	50	1,2	4201856	318975	11	
LGR-57	33381	57											
HGR-158	33438	64											
LGR-58	33502	98											
HGR-159	33600	18											
GL-66	33618	44											
PO-39	33662	66	4	2	1.9	20	2	60		4201911	319071	10	
HGR-160	33728	51											
P5-27	33779	74	6	1	4.1	25	5	80	9,1	4201944	319083	11	
HGR-161	33853	270											
	34123	52											Test Station Road Culvert
P5-28	34175	50	6	1	4.5	27	5	25	9	4202003	319165	9	
LGR-59	34225	50											
HGR-162	34275	18											
GL-67	34293	37											
HGR-163	34330	68											
P5-29	34398	120	4	1	3.6	30	5	30	8,1	4202057	319141	8	
HGR-164	34518	44											
LGR-60	34562	107											
GL-68	34669	152											
HGR-165	34821	12											Side Channel Pool left bank start
PO-40	34833	38	4	1	2.1	15	3	80		4202165	319075	10	
HGR-166	34871	72											
P4-18	34943	9	4	1	2.4	25	4	10	2	4202186	319097	10	
	34952	36											Side Channel Pool left bank return
HGR-167	34988	239											
LGR-61	35227	31											

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
PO-41	35258	61	3	1	1.5	27	2	35		4202248	319173	15	
HGR-168	35319	61											
P5-30	35380	72	5	1	4	32	5	45	9,1	4202271	319180	10	
HGR-169	35452	97											Right Bank Side Channel Start
GL-69	35549	48											
	35597	66											right bank side channel return
LGR-62	35663	50											
HGR-170	35713	76											
P4-19	35789	60	4	1	2.8	35	4	35	8,5	4202283	319276	10	
HGR-171	35849	40											
GL-70	35889	50											
LGR-63	35939	156											
P5-31	36095	49	5	1	3.6	30	5	40	9,1	4202344	319332	10	
GL-71	36144	114											
P5-32	36258	109	5	1	3.8	32	5	25	9,2	4202406	319358	10	
HGR-172	36367	102											
P5-33	36469	59	6	1	4.4	40	5	30	9,2	4202398	319398	8	
HGR-173	36528	55											
GL-72	36583	117											
LGR-64	36700	66											
HGR-174	36766	191											
P4-20	36957	117	4	1	2.8	25	4	15	2,1	4202434	319492	14	
HGR-175	37074	72											
P5-34	37146	68	4	1	3.4	38	5	20	2,1	4202463	319500	10	
HGR-176	37214	53											
LGR-65	37267	8											
	37275	116											channel dropped 3 ft
PO-42	37391	104	4	1	2.5	20	2	20	1,2	4202518	319558	10	

Habitat Type	Start Distance (ft)	Habitat Length (ft)	Max Depth (ft)	Riffle Crest (ft)	Residual Depth (ft)	Pool Width (ft)	Pool Class	Instream cover/ %	Instream Cover Type	Northing	Easting	GPS Accuracy +/- (ft)	Comments
HGR-177	37495	81											
LGR-66	37576	52											
P5-35	37628	107	6	2	4.2	52	5	50	2,9	4202566	319624	13	
GL-73	37735	60											
P5-36	37795	75	6	2	4.2	32	5	70	9,2	4202602	319617	9	
GL-74	37870	91											
HGR-178	37961	75											
P4-21	38036	72	4	1	2.7	24	4	10	9,2	4202670	319611	8	
LGR-67	38108	65											
HGR-179	38173	74											
P5-37	38247	50	6	2	4	30	5	10	1,2	4202727	319615	9	
	38297	714											
Mono Lake	39011												

Appendix 4. Photos of High Quality Pools (Class 4 and 5), 2018 Survey

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P4-3

P4-4

P4-5

P4-6

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P4-19

P4-17

P4-20


P4-21


P5-1


P4-22


P5-2


P4-23


P5-3


P5-4 (Right Bank)


P5-6


P5-4 (Left Bank)


P5-7


P5-5


P5-8


P5-9


P5-12


P5-10


P5-13


P5-11


P5-14


P5-15


P5-19


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Section 4(a)

Stream Monitoring Report For RY 2017-18

RY2017 Mono Basin
Stream Monitoring Report

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April 15, 2018

Introduction

This annual report summarizes findings gained from the RY2017 monitoring season in the Rush Creek Bottomlands (downstream of the Narrows). The primary goal was to continue development of a long-term monitoring methodology that will objectively evaluate ecological performance of the Synthesis Report (2009) and its instream flow recommendations. In the previous monitoring season, RY2016 (LADWP 2017) focused on (1) sampling stream channel morphology attributes that did not require fixed monitoring stations (except side-channel entrances) and (2) measuring RY2016 cottonwood and yellow willow annual branch increments under varied geomorphic settings affecting water availability. Unusually high runoff during RY2017 required modifications. Streamflows were too high to reliably measure all desired morphological stream channel features. RY2017 also marked the beginning of our investigation into three spectral imagery alternatives for measuring cottonwood and yellow willow vigor remotely, and included maiden UAV flights.

Two recently-graduated HSU Masters students, Emily Cooper and Mason London, performed the bulk of the 2017 ABI fieldwork, and contributed significantly to the analyses. Jordan Adair, a graduate student of Jim Graham, did the UAV fieldwork and the immense data processing required of the UAV's high spatial resolution. Jordan also provided text for the draft report. And Katrina Nystrom, our new HSU graduate student, assisted in data analyses and report preparation. Special thanks go to Robbie Di Paolo of the Mono Lake Committee for his much-appreciated fieldwork, lively field discussions, and project coordination.

The high streamflows of RY2017 offered a realistic test for a future, long-term monitoring plan. Several channel reaches were modified significantly. Although the basic channel morphology measurements made in RY2016 could not be repeated in RY2017, they are proposed for RY2018. The greatest change occurred in lower Rush Creek approximately mid-way between the old gage location and the Ford. One bend in an over-tightened meander was cut-off, creating an expansive point bar unlike any other in Rush Creek (Figures 1 and 2). With this bend cut-off and other pronounced channel changes, a sample strategy relying on fixed cross-sections would have been compromised. Even though several trees measured in RY2016 were scoured away, the ABI measurements in RY2017 could still be compared to the RY2016 ABI measurements.

Figure 1. UAV aerial view of newly formed point bar in Lower Rush Creek in early-August 2017. Match red and white circles on following figure (streamflow left to right).

Figure 2A. Downstream perspective of right bank channel along point bar of previous figure in early-October (looking downstream).

Figure 2B. Downstream perspective of entire point bar of previous figure in early-October (looking downstream).

RY2017 Annual Branch Increment (ABI)

Summer Fieldwork

Between September 30th and October 11th 2017, cottonwoods and yellow willows measured in RY2016 were measured again in RY2017 following the RY2016 protocol. Refer to Section 4: RY2016 Monitoring Report in LADWP (2017) for ABI measurement and analytical protocols. One change has been the re-labeling of ASI (annual stem increment), used in RY2016, to ABI annual branch increment for RY2017 (Wilms and Wilms 1998). Figure 3 locates each tree measured in Lower Rush Creek.

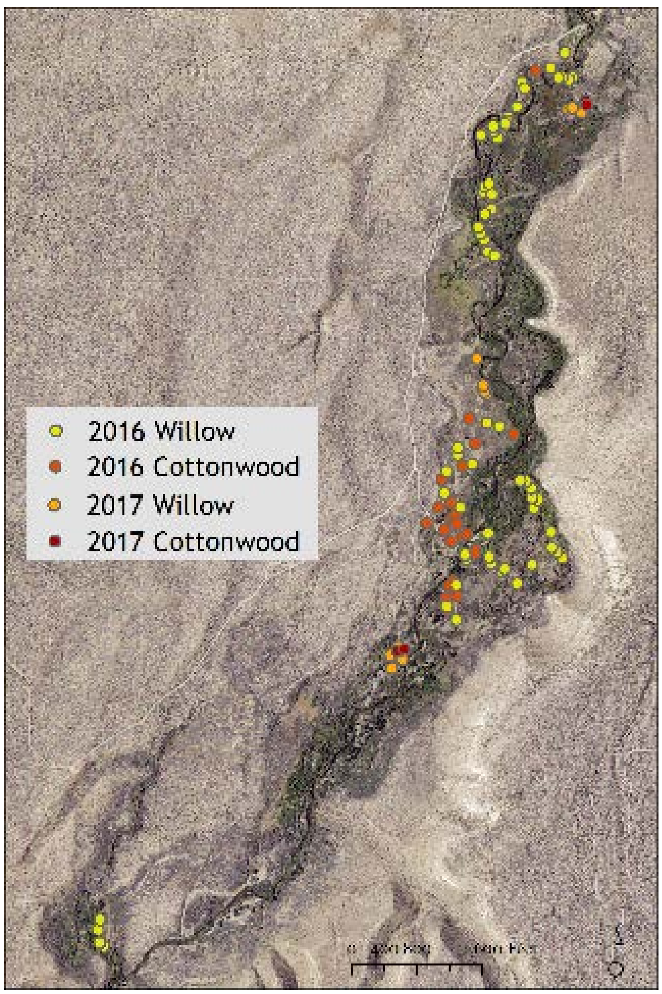

Figure 3. RY2016 and RY2017 cottonwood and yellow willow trees measured for ABI in the Rush Creek Bottomlands.

Findings

Cumulative ABI Distributions for Each Measured Tree

Each of the 41 cottonwoods and 68 yellow willows sampled in RY2017 had a unique cumulative distribution of annual branch increments (ABI). Four cottonwoods and seven yellow willows of the RY2016 'cohort' of measured trees were scoured away. These were replaced by 14 cottonwoods, 15 yellow willows, and 2 red willows in RY2017. The cumulative ABI distribution for mature yellow willow R3_01 (on RB 14-15 Floodplain opposite 'Gary Smith' photo point) was similar to many ABI distributions (Figure 4), though no two cumulative distributions were alike.

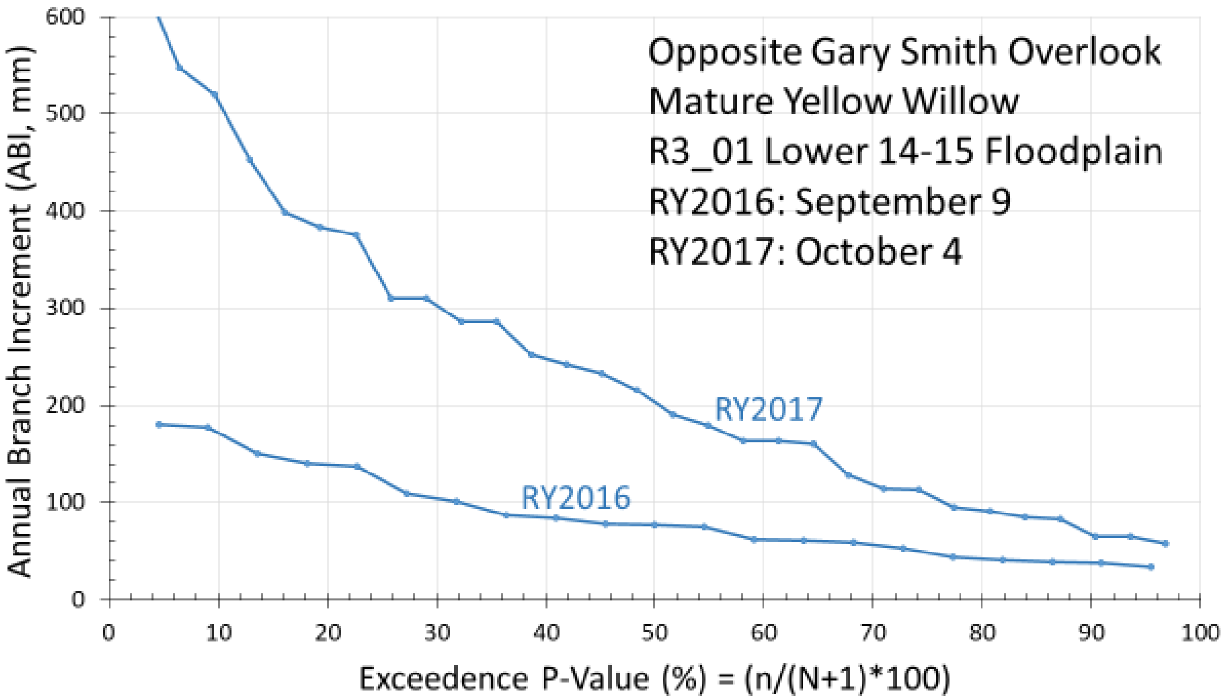

Figure 4. Distribution of ABI measurements in RY2016 and RY2017 for mature yellow willow R3_01 on RB 14-15 Floodplain opposite 'Gary Smith' photo point.

Although Figure 4 gives the appearance that growth differences were relatively greater (i.e. comparing ABI at the same exceedence values) for longer growing branches. But, the actual percentage differences in RY2016 and RY2017 ABIs were similar. For example, Cottonwood R4_13 is located on the terrace edge of the 8-Floodplain close to the solitary Jeffrey Pine. In drier RYs, water availability should be restrictive; ABI was modest in RY2016 (Figure 5). But in EXTREME WET RY2017, water was flowing down the 8 Side-Channel through the summer. Figure 5 identifies the percentage ABI increase at three exceedences: P-value = 18%, 50%, and 82%.

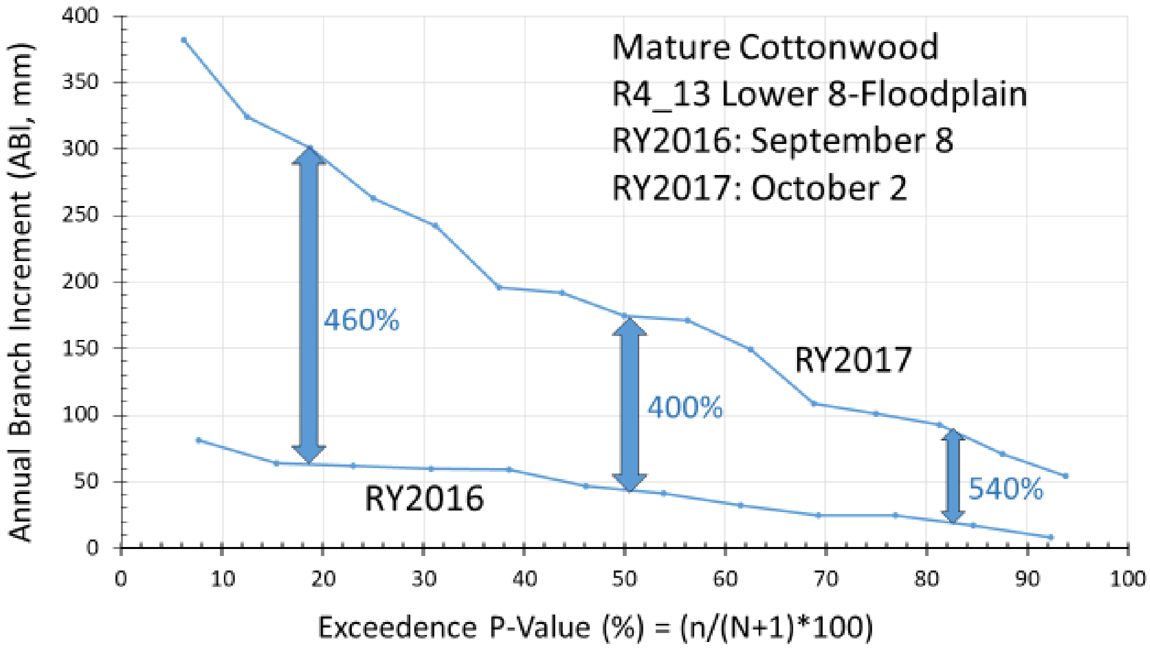

Figure 5. Percentage ABI increases for Cottonwood R4_13 Lower 8-Floodplain at P-values of 18%, 50%, and 82%.

Grouped ABI Cumulative Distributions

Generally several trees in close proximity were measured to assess a particular geomorphic setting. Lower floodplain, point bar, upper floodplain, and low terraces were expected to offer different water availabilities and therefore different cumulative ABI distributions. Many of these are given in the RY2016 monitoring report (LADWP 2017 Section 4).

Even though the 13-Floodplain surface is 5 ft to 7 ft above the low flow channel, these four mature yellow willows experienced significantly higher branch growth in RY2017 than RY2016 (Figures 6 and 7).

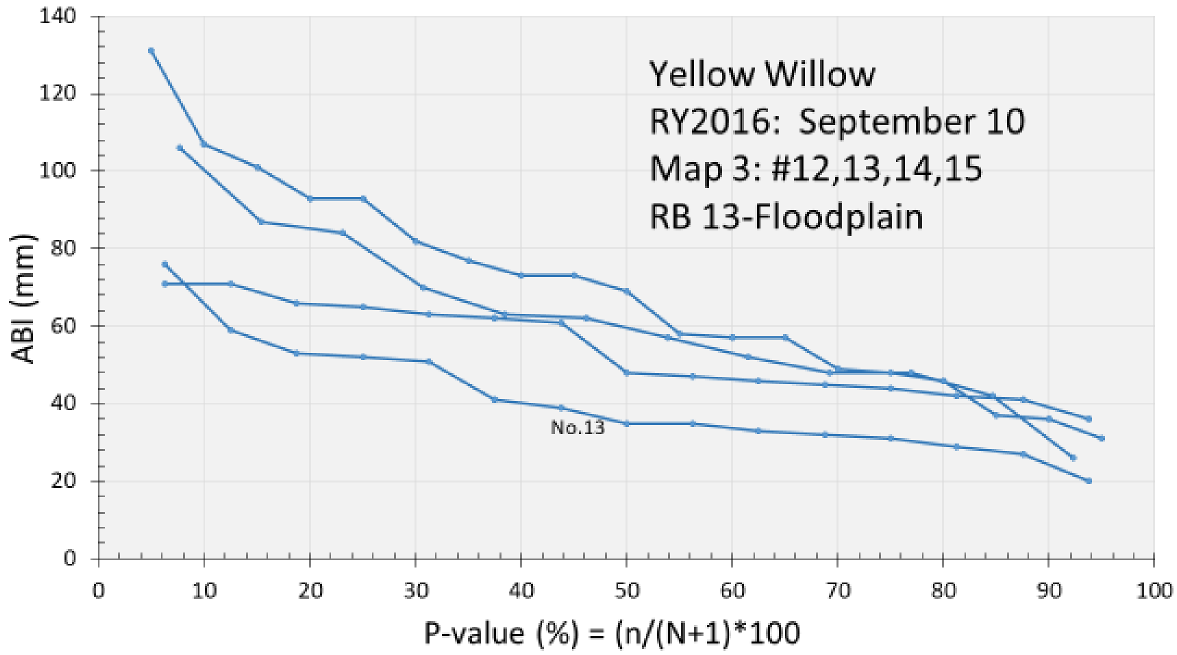

Figure 6. Cumulative ABI distributions for four yellow willows on the 13-Floodplain in Lower Rush Creek measured September 10, 2016.

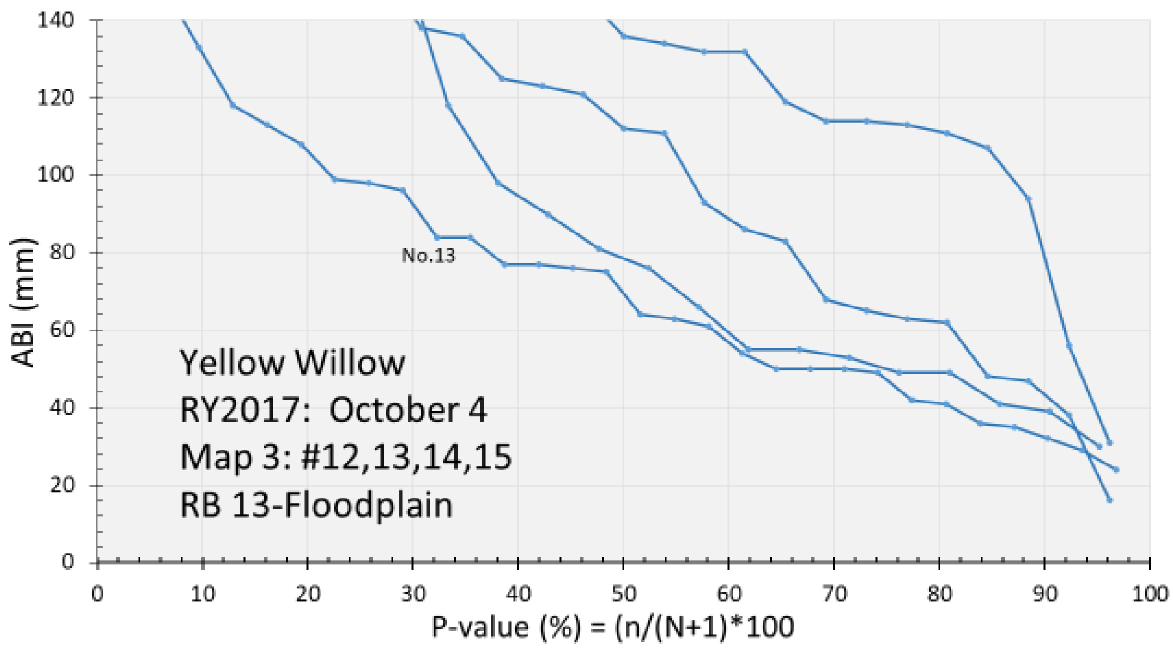

Figure 7. Cumulative ABI distributions for four yellow willows on the 13-Floodplain in Lower Rush Creek measured October 4, 2017.

Overall Cumulative ABI Distributions

With RY2017 being an EXTREME WET runoff year, floodplain-wide ABI was expected to significantly exceed overall ABI in RY2016. Figures 8 to 11 are composites of all cumulative ABI distribution curves for each cottonwood and yellow willow measured in both RYs.

In RY2016, only three yellow willows (5.2% of 58 trees measured) exceeded an ABI of 300 mm; In RY2017, thirty-one trees (45.6% of 68 trees) exceeded an ABI of 300 mm (Figures 8 and 9).ABI increased more sharply in RY2017 among yellow willows than cottonwoods. This may be a result of yellow willows occupying lower (in elevation) floodplain surfaces than cottonwoods.

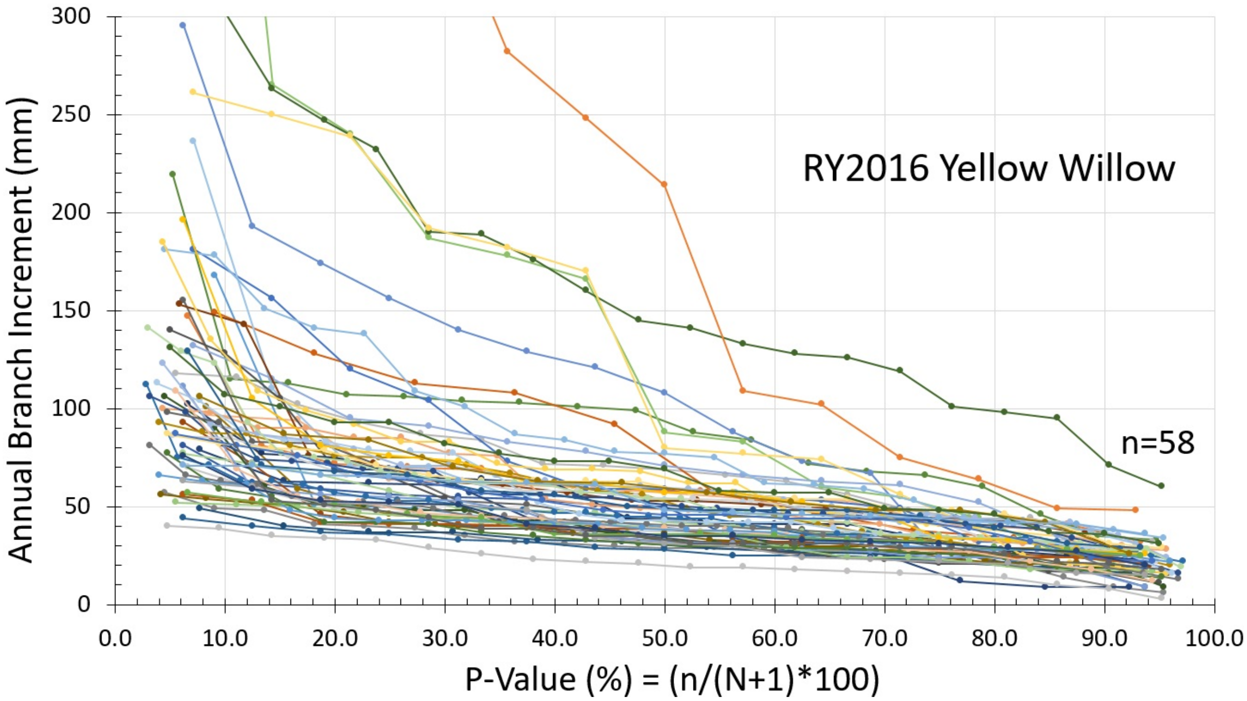

Figure 8. Individual tree ABI distributions of all yellow willows in RY2016.

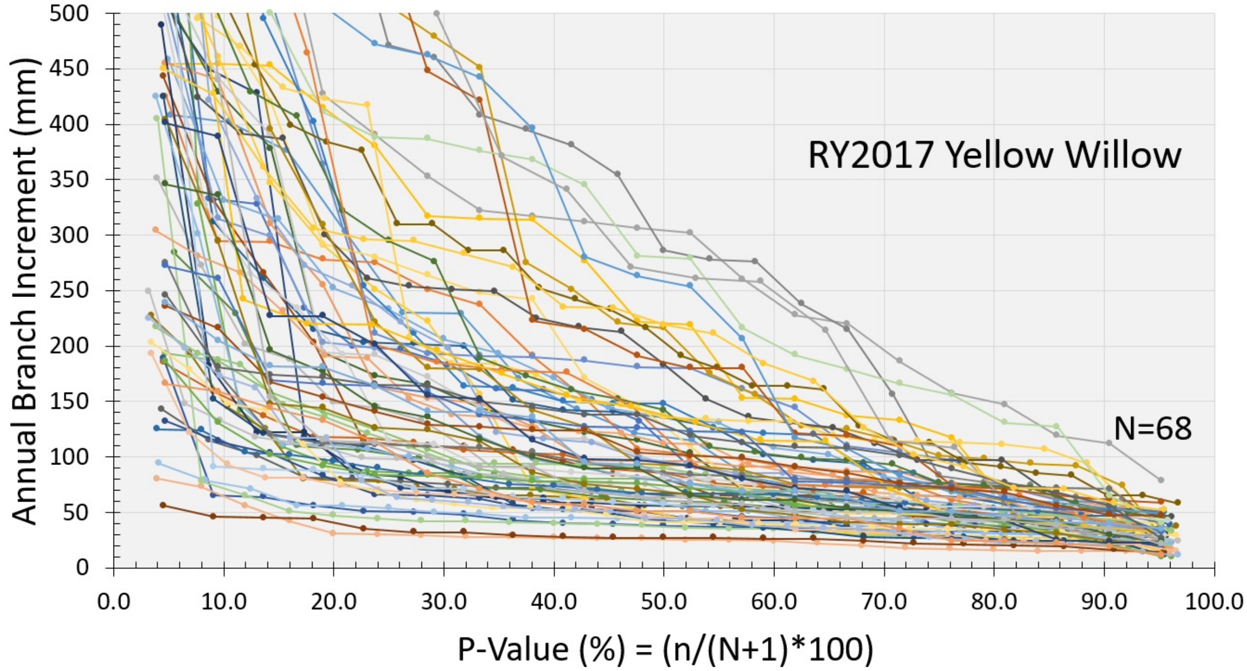

Figure 9. Individual tree ABI distributions of all yellow willows in RY2017.

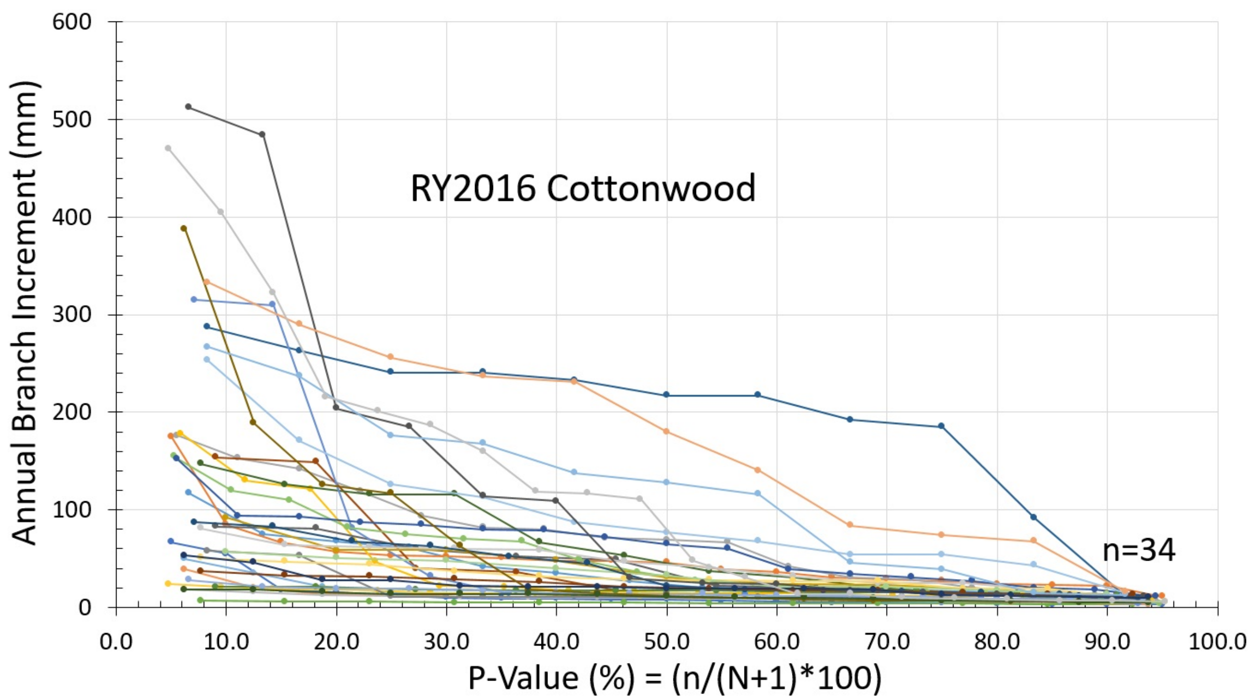

Figure 10. Individual tree ABI distributions of all cottonwoods in RY2016.

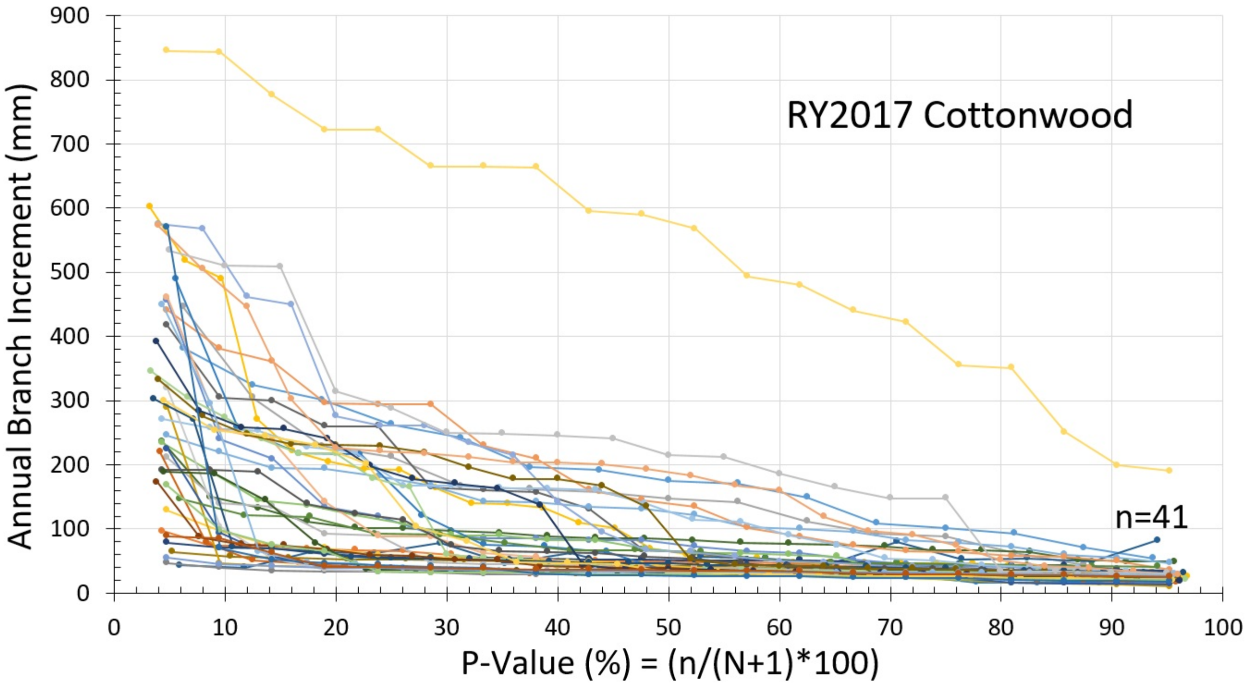

Figure 11. Individual tree ABI distributions of all cottonwoods in RY2017.

Comparative ABI Ratio: RY2016 / RY2017

Annual branch increment (ABI) is just one variable quantifying seasonal vigor in cottonwoods and willows. The most significant outcome of the RY2017 field season is summarized quantitatively by Figure 12. The dotted 1:1 line defines no difference in median ABI between RY2016 and RY2017 for individual cottonwoods and yellow willow trees. RY2017 generated significantly more branch growth than RY2016. RY2016 was a DRY NORMAL I runoff year type whereas RY2017 was an EXTREME WET runoff year type (LADWP 2017).

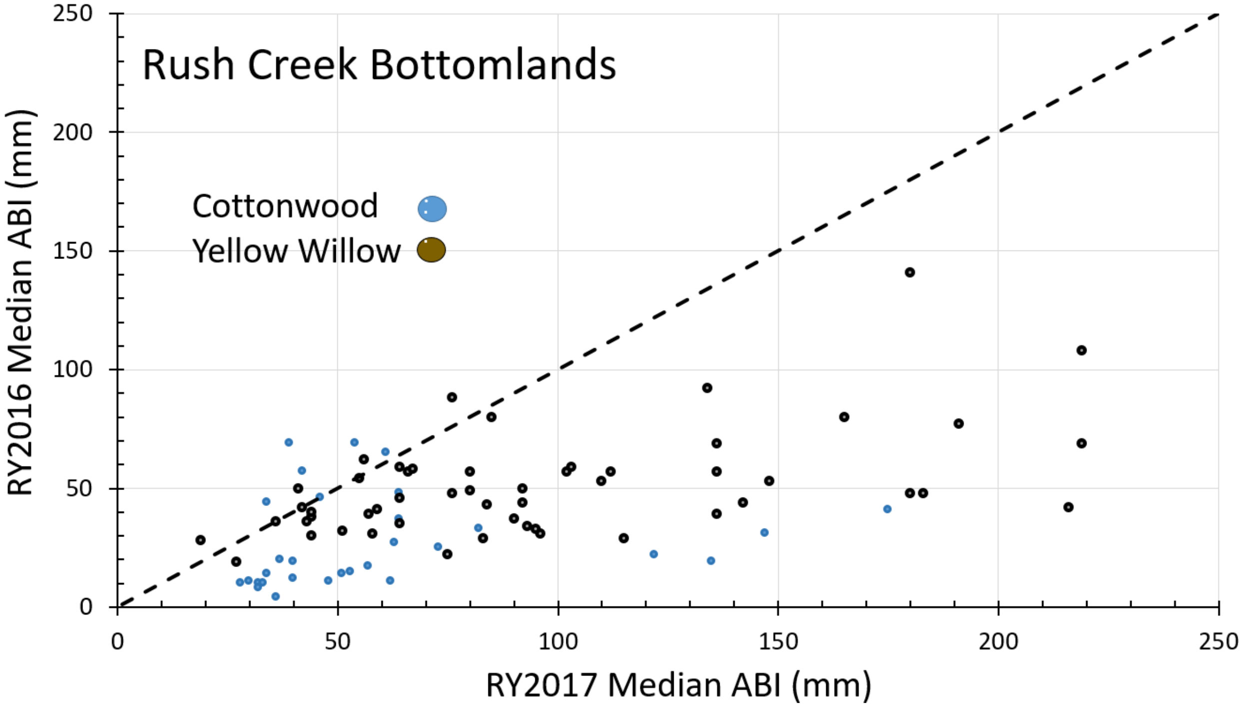

Figure 12. Comparison of median RY2016 to RY2017 ABI for cottonwood and yellow willow trees measured in Lower Rush Creek.

Yellow willows in Lower 8 Floodplain had the greatest RY2017 median ABI values (Figure XX). Throughout the RY2017 snowmelt and recession, streamflow within the 8-Side Channel network was greater and continued longer than observed since at least RY1994. Before the early-October ramp-down (for electrofishing), surface streamflow meandered across the entire 8-Floodplain, returning to Rush Creek mainstem at the bottom of the 8-Floodplain. Major channelbed aggradation at the 8 Side-Channel (Figure 13) from peak RY2017 flood diverted streamflow from the mainstem and into the 8 Side-Channel, making water highly accessible through the summer to cottonwoods and willows in Lower 8-Floodplain.

Figure 13. The 8 Side-Channel entrance on August 5, 2015 with channelbed elevation indicted for October 7, 2017 (looking downstream).

Although the percentage increase in median ABI (from RY2016 to RY2017) might appear greater for larger RY2017 branch increments, dotted lines in Figure 14 defining uniform 150% and 300% median ABI increases show growth percentages were similar over a wide range in median ABI for yellow willows.

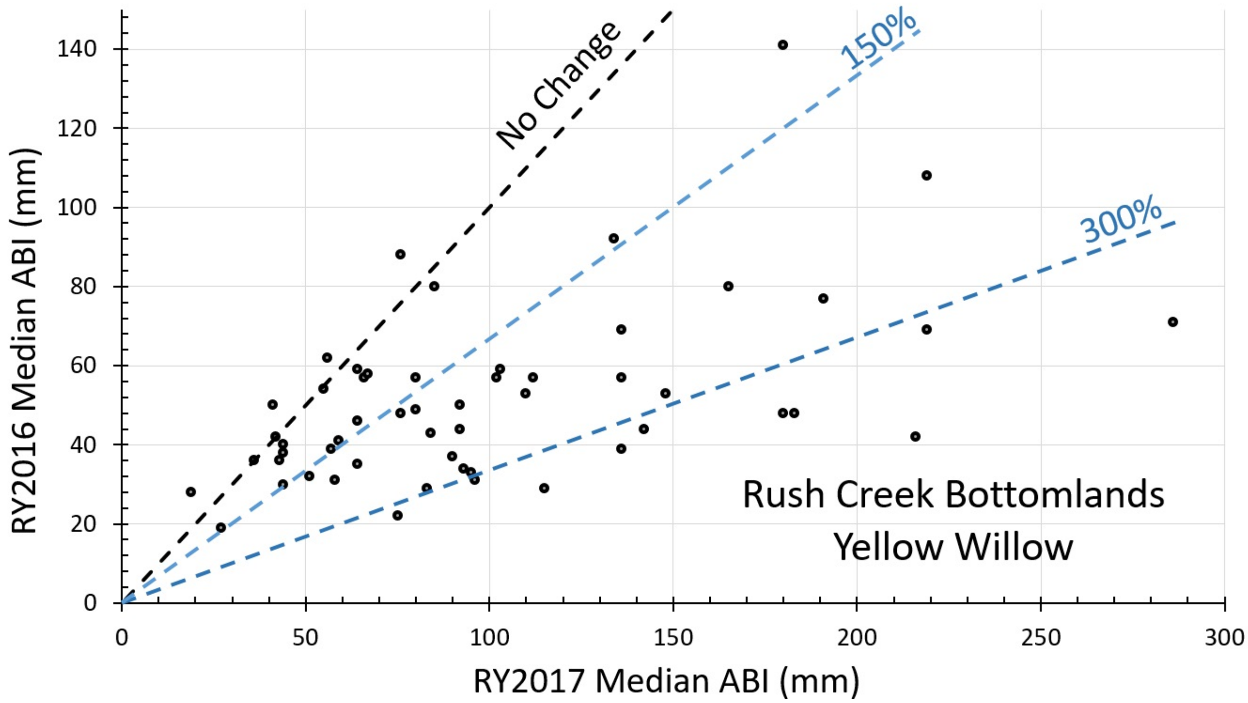

Figure 14. Percentage median ABI increases between RY2016 and RY2017 for yellow willows including dashed lines indicating 150% and 300% increases in RY2017 ABI.

Many cottonwoods exhibited median ABI increases exceeding 300% (Figure 15). However, several had increases less than 100%, and some exhibited negative increases (i.e., branch increments were greater in RY2016 (a DRY NORMAL I runoff year) than RY2017 (an EXTREME WET runoff year). These trees were located close to the mainstream channel with direct root access to baseflows even in drier runoff years. High, sustained streamflows in RY2017 could have stressed these cottonwoods.

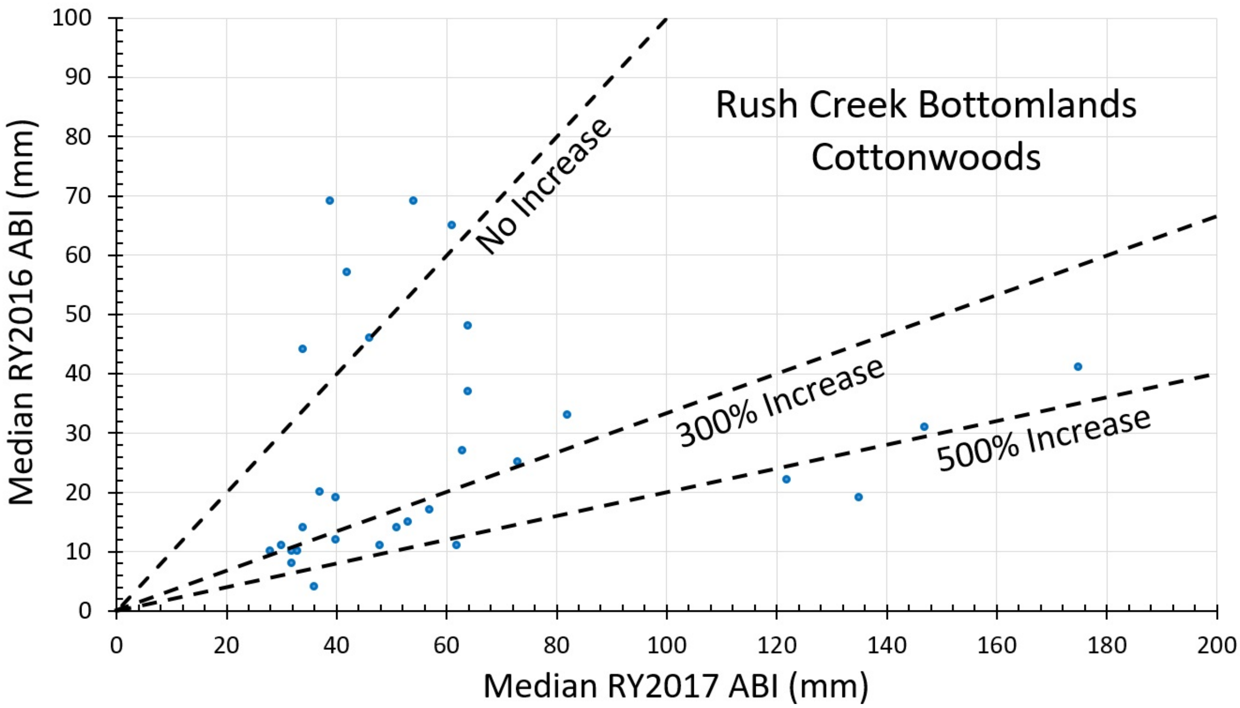

Figure 15. Percentage median ABI increases between RY2016 and RY2017 for cottonwoods including dashed lines indicating 300% and 500% increases in RY2017 ABI.

Encountering an EXTREME WET runoff year as RY2017 will help establish a baseline for highly favorable growing conditions (though careful not to call this baseline ‘optimal’ conditions) and presumably high ABI. This baseline was compared to ABI in RY2016, and will be in proposed fieldwork for RY2018.

Re-Visiting Geomorphic Findings RY2016 Report

In RY2018, channel morphology measurements will be resumed in both Rush Creek Bottomland sample reaches (Figure 1 in Section 4 of LADWP 2017). Field measurements will include ambient, active, bankfull widths taken at 100 ft intervals and at all riffle channel widths (Figures 2 through 5 in Section 4 of LADWP 2017). Residual pool/run depths exceeding 1 ft deep will be measured throughout both channel reaches. Channel widths during the RY2017 flood peak also will be measured using flood debris lines, but at an interval less than 100 ft, to define the flood corridor width. Beaver dams, mostly destroyed in the RY2017 flood hydrograph also wil be inventoried and photo-documented. And invert elevation of side-channel entrances will be re-surveyed to measure elevational shifts (relative to adjacent riffle crest thalweg elevations) attributable to the RY2017 flood hydrograph.

Median RY2016 W_{ACT} in Lower Mainstem Rush Creek was 30.5 ft; Median RY2016 W_{ACT} in Upper Mainstem Rush Creek was 27.4 ft (Figure 16). Just as seemingly minor changes in stage height of 0.10 to 0.20 ft can make a big difference triggering side-channel streamflows, a 3.1 ft difference in W_{ACT} discriminated two distinct channel types. When W_{ACT} was measured randomly every 100 ft (Figure 17) instead, both reaches appeared to have extremely similar W_{ACT} distributions. 'Random' measurements at other channel features (than riffle crests only) included points of maximum point bar curvature, mid- and lower-riffle locations, and split channels. Median RY2016 W_{ACT} in Lower Mainstem Rush Creek was 28.9 ft; Median RY2016 W_{ACT} in Upper Mainstem Rush Creek was 27.9 ft. Riffle crests were notably broader in Lower Rush Creek than Upper Rush Creek between P-values of 60% to 85% (LADWP 2017 Section 4). During the RY2017 field season while measuring cottonwood and yellow willow ABIs, the Upper Mainstem Channel did not appear to have been widened by RY2017 peak runoff.

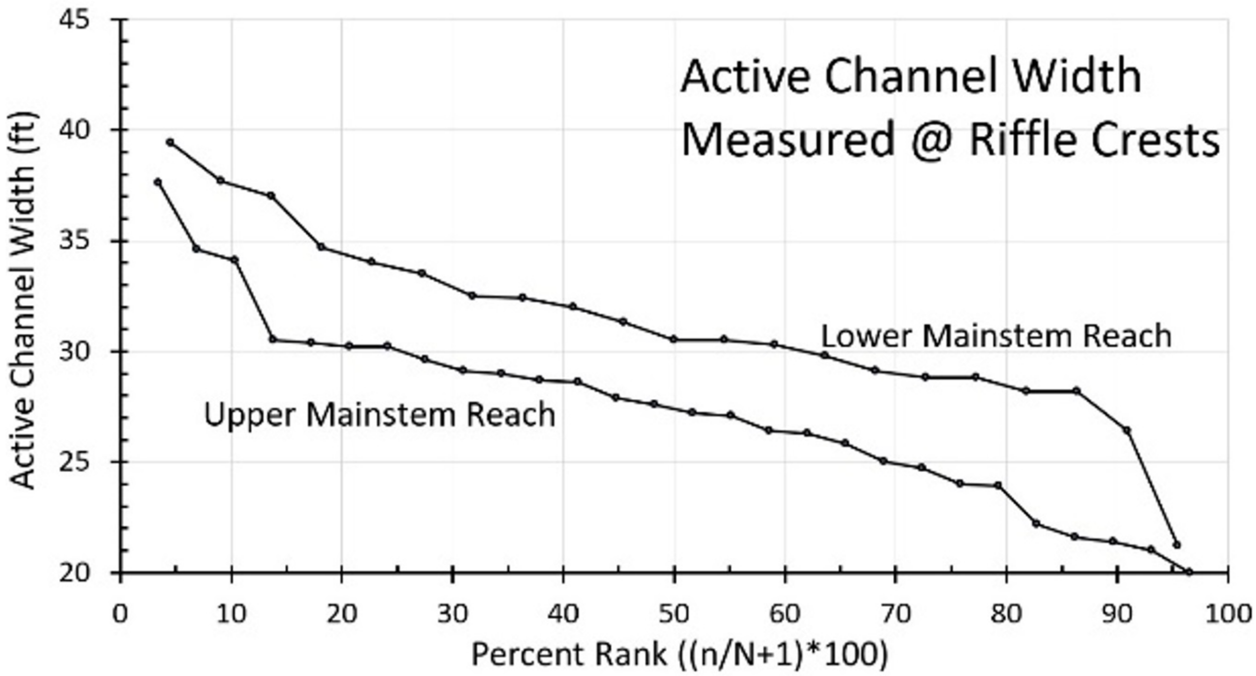

Figure 16. RY2016 active channel widths in Lower and Upper mainstem reaches measured only at riffle crests.

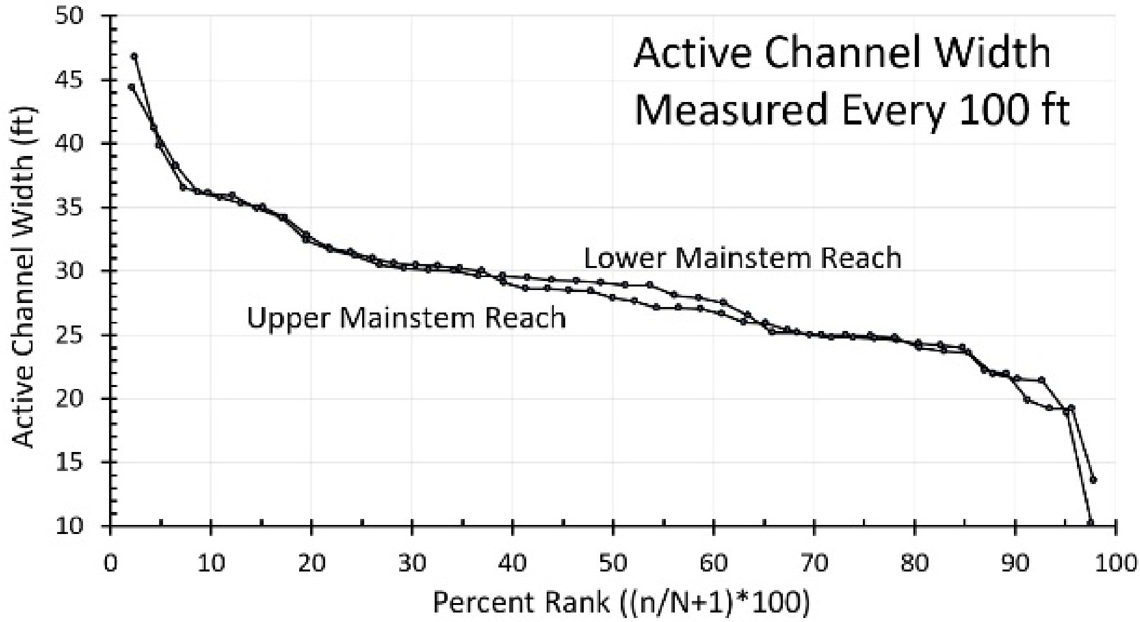

Figure 17. RY2016 active channel widths in Lower and Upper mainstem reaches measured every 100 feet.

Graduate Student Jordan Adair and DJI Inspire 1 Version 2 UAV

Spectral Imagery Assessing Cottonwood and Yellow Willow Vigor

A long-term monitoring plan would require annual fieldwork to measure cottonwood and yellow willow ABI. But with remote sensing becoming more technologically feasible and cost-effective, we are exploring compatible methodological alternatives for evaluating plant vigor remotely. NASA Landsat, USDA National Agriculture Imagery Program (NAIP), and Unmanned Aerial Vehicle (UAV) were three spectral imagery alternatives explored.

NASA Landsat and USDA NAIP are widely available, free datasets that contain the spectral bands needed to calculate Normalized Difference Vegetation Index (NDVI). Landsat images have a 30-meter spatial resolution and are available twice monthly extending back more than 30 years. NAIP images have a 1-meter spatial resolution and are available every other year during the growing season, typically July or August.

Landsat and NAIP images can be downloaded from the United States Geological Survey (USGS) Earth Explorer website.

The objective for the RY2017 summer fieldwork (and subsequent data processing) was to evaluate how well NDVI values derived from NASA Landsat, USDA NAIP, and UAV spectral imagery correlated with our ABI field measurements. Following a brief review of NDVI, the three methodologies were evaluated individually on a scale of increasing spatial resolution. An application and findings are presented for each, followed by recommendations.

Normalized Difference Vegetation Index

Normalized Difference Vegetation Index (NDVI) is a ratio of red and near-infrared light that can be used to evaluate vegetative vigor. NDVI uses red (VIS) and near-infrared (NIR) wavelengths in satellite-derived or aerial imagery pixels. Plants absorb light in the visible spectrum and reflect light in near-infrared wavelengths; more reflected light in the near-infrared wavelengths indicates dense vegetation (Equation No.1) (Tucker et al. 1991). NDVI calculations for a given pixel result in values ranging from -1 to +1, with a value close to zero indicating no vegetation; values close to +1 represent the highest density of photosynthesizing vegetation (Weier and Herring, 2000).

Equation No. 1.

$$NDVI = \frac{(NIR - VIS)}{(NIR + VIS)}$$

NDVI has been used to monitor severity of drought impacts (Peters et al. 2002), to determine rates of green-up and senescence (Reed et al. 1994; Pettorelli et al. 2005), and to monitor long-term productivity in agricultural lands (Lenney et al. 1996).

NASA Landsat Spectral Imagery

Background

NASA Landsat offered the most extensive dataset. Seventeen years of Landsat-derived NDVI images (RY1999 through RY2016) were downloaded from the USGS Earth Resources Observation and Sciences (EROS) and Science and Processing Architecture (ESPA) Interface using a Python script. Next these images were batch-processed using a Python script and Esri ArcMap to create a subset of images encompassing the Rush Creek Bottomlands.

Application

As an exploratory analysis, we tested whether Landsat NDVI values could distinguish dry months from wet months, i.e., would there be a definable relationship between NDVI and monthly runoff in the Rush Creek Bottomlands? Average, minimum, and maximum NDVI values were calculated for each image. To account for issues with snow cover and reflectance only images from April to September were analyzed. Finally, the various NDVI values were compared to average monthly discharge values from RY1999 to RY2013 for Lower Rush Creek and a simple linear model was constructed to see if stream flow data could be used to predict NDVI values at 30-meter resolution (Figure 18). Discharge values were only used until RY2013 as this was the last year of reliable data for Lower Rush Creek. Monthly Lower Rush Creek discharges (in acre-feet, af) were calculated by combining monthly discharge values from below Parker Creek, below Walker Creek, the Mono Gate One Return Ditch, and Grant Lake spill when spills occurred.

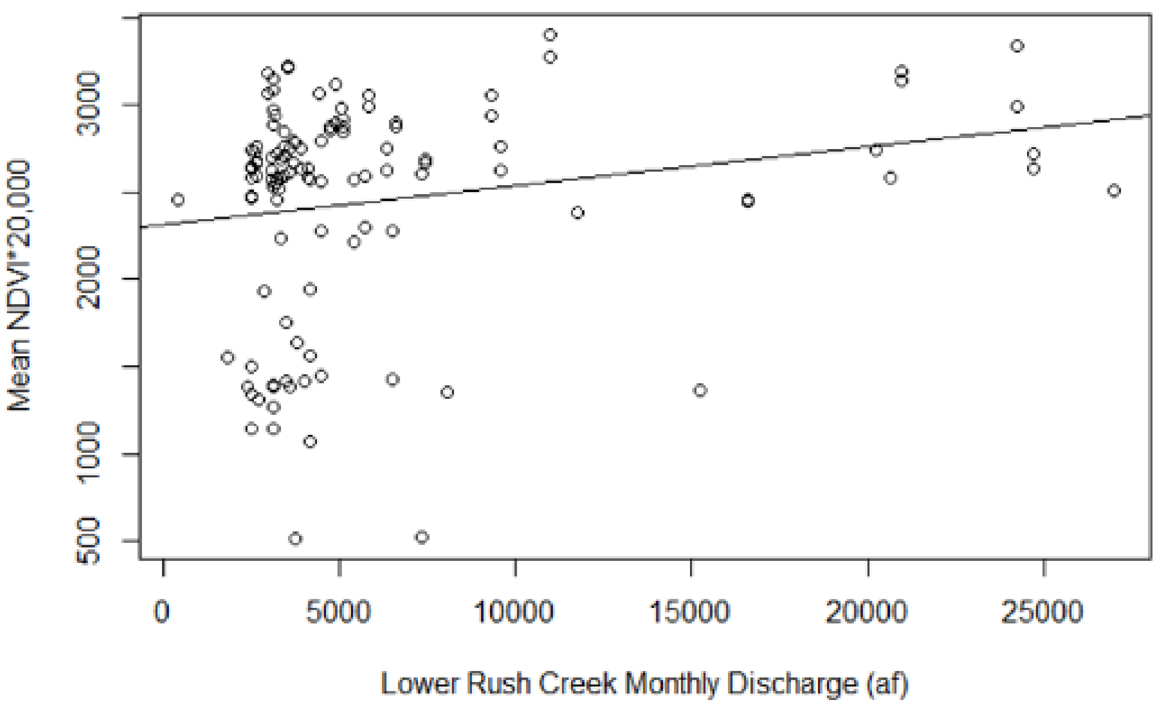

Figure 18. Mean NDVI as a function of Lower Rush Creek monthly runoff (ac-ft).

Findings

Monthly discharges (measured in ac-ft) for Lower Rush Creek were related to changes in NDVI values at the same scale based on the results of the simple linear regression model (P-value = 0.03) (Figure 18). The linear model, though marginally statistically significant, accounted for little variability having a poor correlation between Landsat-derived NDVI and monthly discharge of $R^2 = 0.04$.

USDA NAIP Spectral Imagery

Background

NAIP imagery from July 2016 was downloaded from the USGS Earth Explorer website and the NDVI tool in the ENVI image processing software was used to create 1-meter NDVI images from the NAIP imagery. Using the R programming language, simple linear models were constructed using NAIP-derived NDVI values and RY2016 ABI measurements to determine if there is a significant relationship between NDVI values and measured growth. The USDA NAIP imagery provides a significant boost in resolution. Landsat imagery (left) had a 30 meter resolution while the NAIP had a one meter resolution (Figure 19).

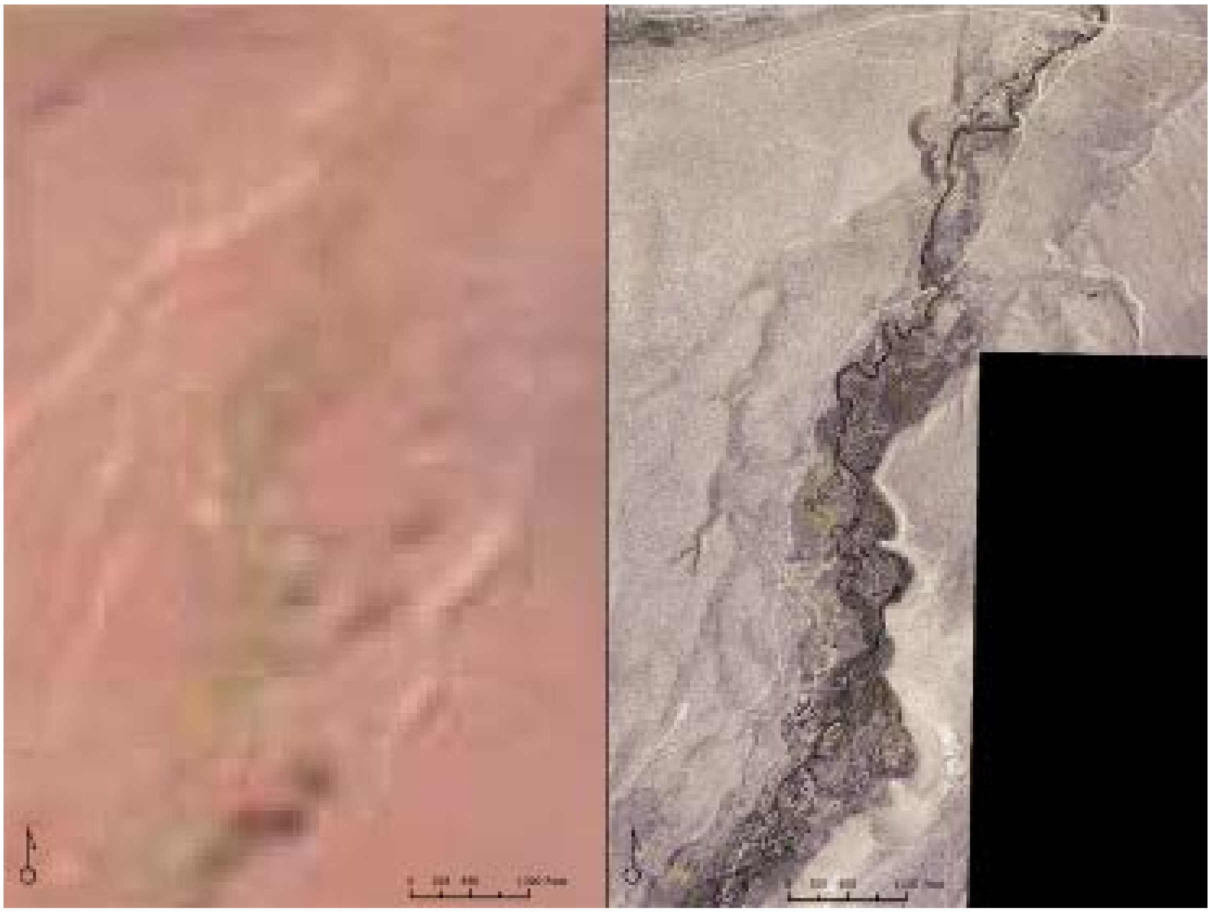

Figure 19. Landsat RY2016 imagery (left) at 30 meter resolution and 1 meter RY2016 NAIP imagery (right) at 1 meter resolution (with identical spatial scales) for Lower Rush Creek.

Application

The RY2016 ABI field data were plotted as a function of USDA NAIP derived NDVI values for RY2016 to document/evaluate relationships between plant vigor and NBVI's 1-meter resolution imagery.

Findings

NAIP derived NDVI values from 2016 and 2016 field measurements shows little relationship between NDVI values and growth measurements when looking at NDVI values for willows (Figure 20). Based on initial exploration of the data the only relationship between the 2016 field measurements and NDVI was minimum stem growth as a function of minimum NDVI. A simple linear model was constructed using minimum NDVI to predict minimum stem growth was statistically significant but explained little variability in the data ($P = 0.02$ $R^2 = 0.1$).

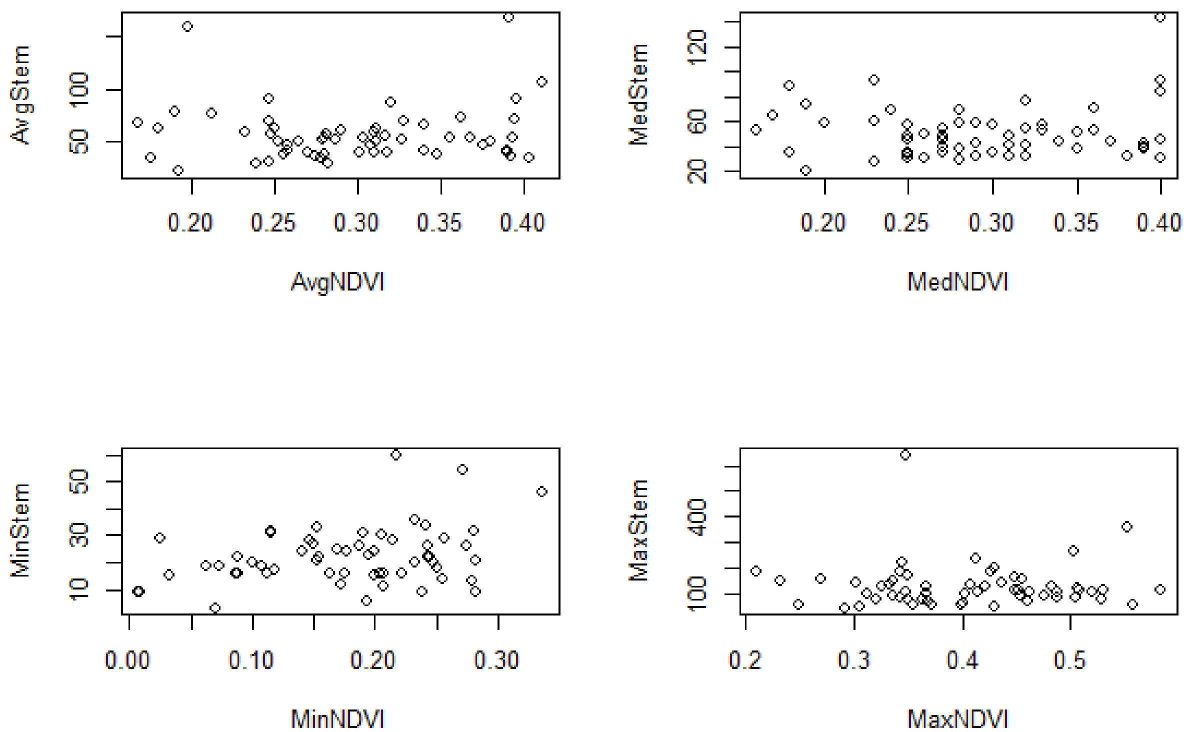

Figure 20. Minimum, maximum, average, and median RY2016 ABI (mm) for yellow willow plotted as a function of NAIP-derived NDVI.

UAV Spectral Imagery

Background

UAV data have been combined with other remote sensing data sets to create high resolution images and digital terrain models of geomorphic features (Flener et al. 2013). Multispectral imagery acquired by UAVs has been used to assess stress in orchard trees, detect deficiencies in certain crops, locate bark beetle infestation in trees, and map invasive rangeland species (Hogan et al. 2017, Primicerio et al. 2012). However few studies have used UAV acquired multispectral imagery to estimate relative vigor in riparian vegetation.

Application

In RY2017 summer, a DJI Inspire 1 version 2 UAV was flown over the Lower Rush Creek Bottomlands (Figure 21). The Inspire was equipped with a stock 12-megapixel

DJI camera as well as a MicaSense RedEdge multispectral camera that was mounted separately. The UAV missions were planned using the DJI Go and Drone Deploy mobile software applications and controlled on an Apple iPhone. UAV images were mosaicked using AgiSoft PhotoScan the day they were acquired to check quality and determine if the areas of interest along Lower Rush Creek were covered. NDVI images with 5 to 7 cm resolution were created from the RedEdge images using the NDVI tool in ENVI. Python scripts extracted pixels from the images of individual trees measured for ABI in RY2016 and again in RY2017.

Figure 21. UAV launch locations in RY2017.

All UAV flights took place August 10th through August 12th. We flew the following areas: August 10th - Narrows, Riparian 4 and 6 (Locations 1, 2, and 3); August 11th - Riparian 1,2,3,4 (Location 3, 4, 5, and 6); August 12th - Riparian 4 (Location 3).

Findings

Acquired UAV imagery provided images at approximately 5 cm resolution and multispectral images at approximately 7 cm resolution. Comparison to the coarser resolution of the NAIP spectral imagery (Figures 22 and 23) clearly showed the potential of UAV imagery. With color images at 5 cm resolution, future high resolution maps can be created of Lower Rush Creek. Multispectral imagery at 7 cm distinguished tree species and can be used to generate NDVI images for estimating relative variations in vigor among individual trees.

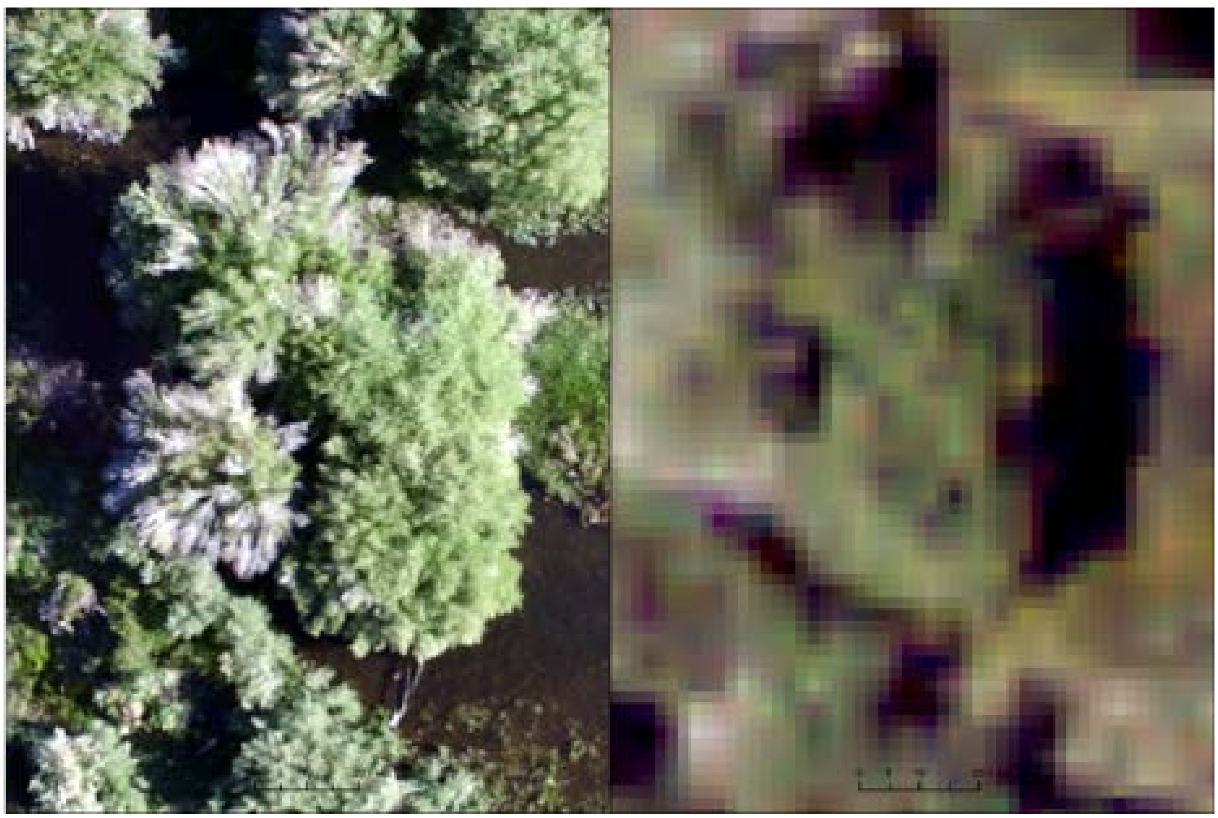

Figure 22. UAV acquired color imagery at 5 cm spatial resolution (left) compared to 1 m NAIP imagery (right) of the same yellow willow.

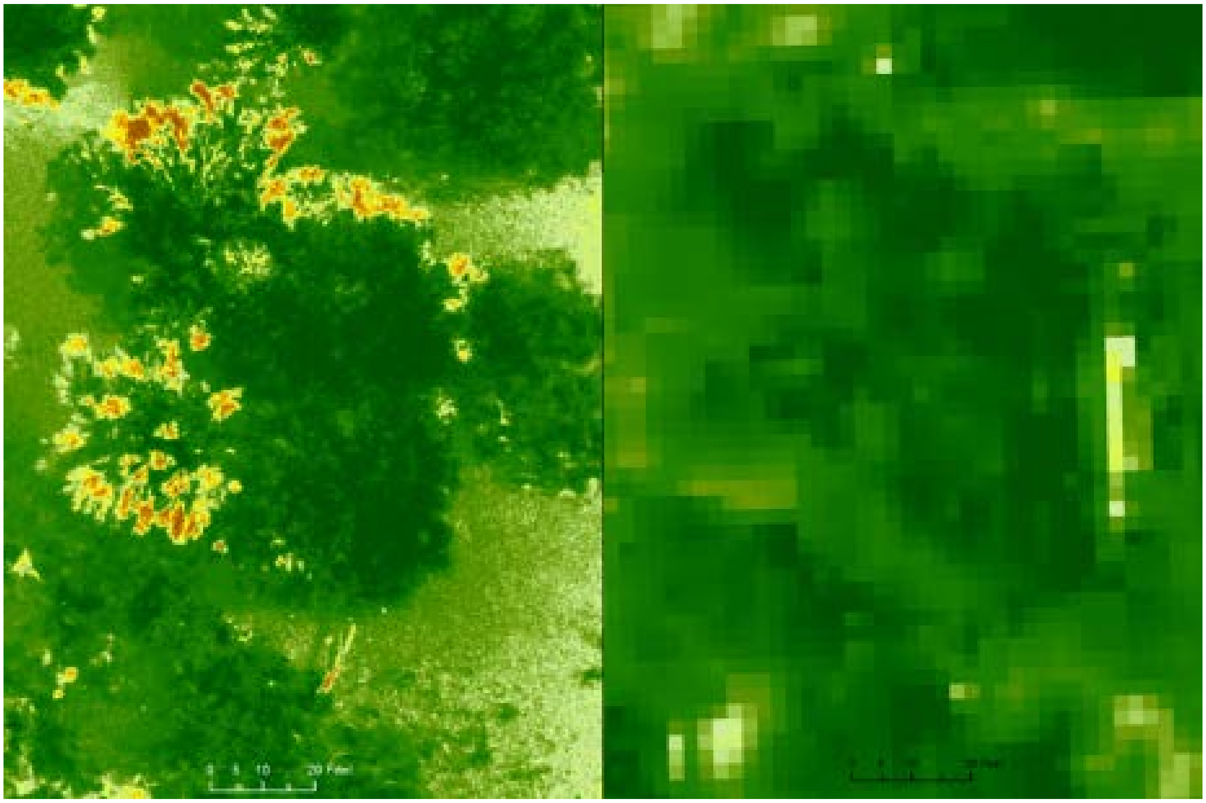

Figure 23. UAV derived NDVI imagery (left) at 7cm resolution compared to NAIP derived NDVI imagery (right) at one meter resolution of the same yellow willow.

Pixels for each tree were extracted based on a circular sampling buffer measured in ArcMap to exclude pixel values associated with surrounding bare earth or water. Python scripts and ArcMap were used to calculate average, median, minimum, and maximum NDVI values for the pixels. The entire range of pixel values, therefore, was not extracted from each tree (Figures 24 and 25). Presently, this circular buffering methodology is being refined before applying to the entire RY2017 ABI field data.

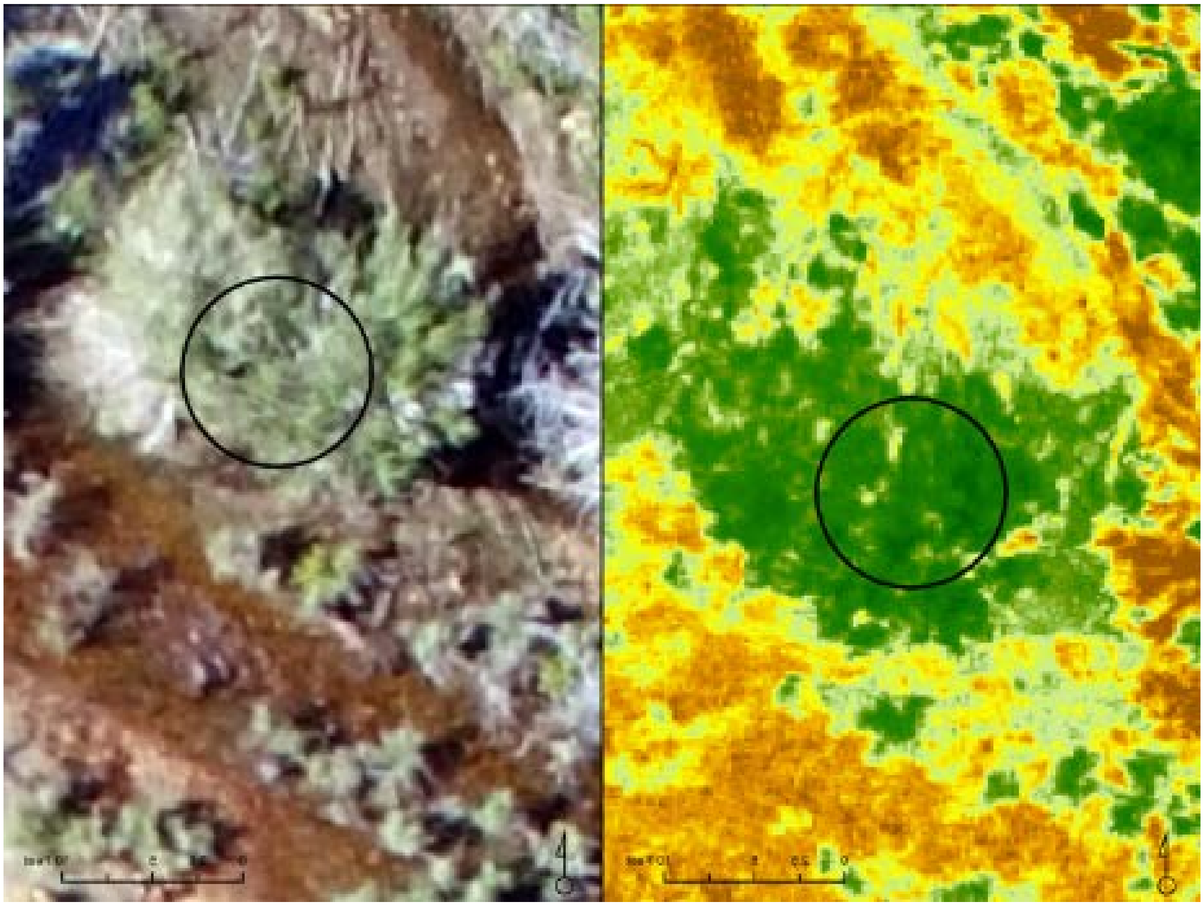

Figure 24. Circular buffer for extracting UAV-derived NDVI values in a yellow willow.

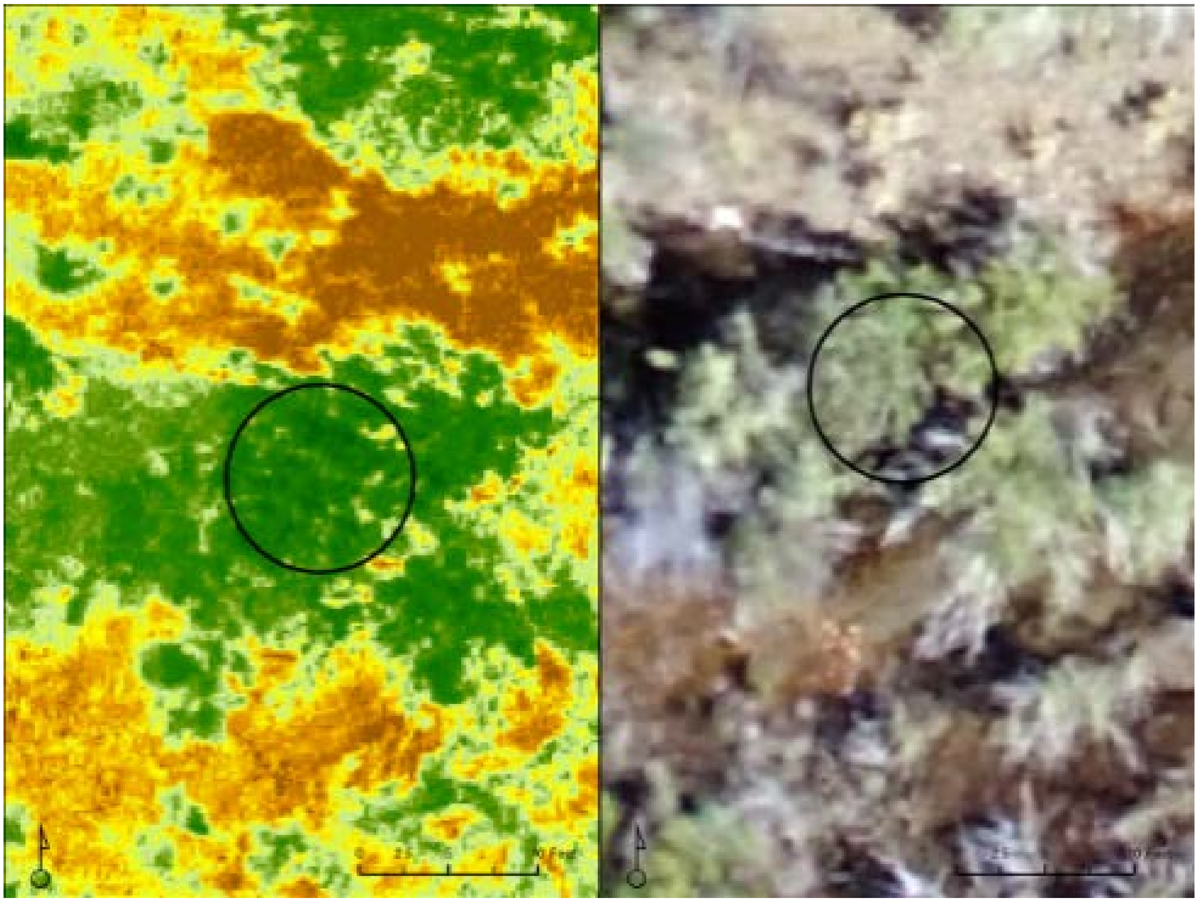

Figure 25. Example of circular buffer used to extract UAV-derived NDVI values in a yellow willow.

Processing large NDVI data sets generated from the UAV spectral imagery has been a learning experience, particularly on manually applying this circular buffer. An available software to more easily identify individual trees is Tribmle eCognition. The following paper uses eCognition to classify forest type using one-meter satellite imagery:

Shiba, M., & Itaya, A. (2006, March). Using eCognition for improved forest management and monitoring systems in precision forestry. In *Precision Forestry in plantations, semi-natural and natural forests. Proceedings International Precision Forestry Symposium, Stellenbosch University, South Africa*.

Preliminary results, until all sampled trees have been processed, have been encouraging. A total of 19 yellow willows have been processed for assessing ABI as a function of NVDI (Figure 26).

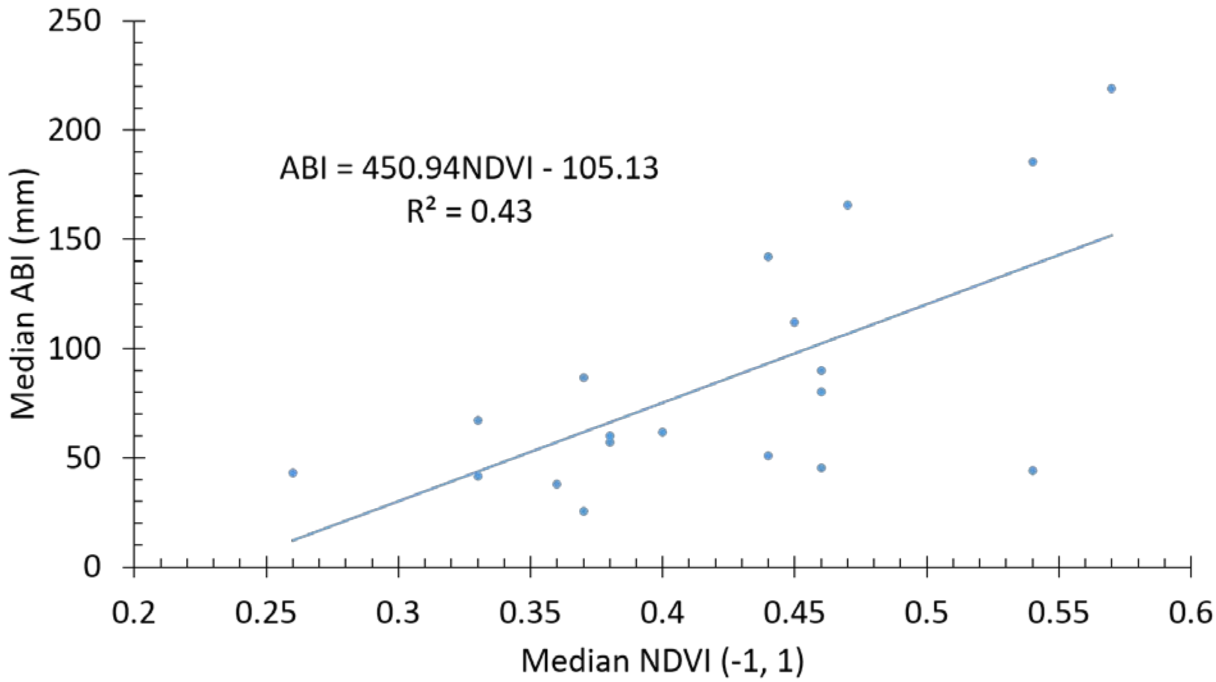

Figure 26. Median RY2017 ABI as a function of median NDVI for 19 yellow willows.

Two outliers have been removed. NDVI explained considerably more variance in ABI (from 6% to 42.5%) without outliers R4_10 and R4_11 removed. Both yellow willows were younger and received low NDVI values, but had relatively high ASI values. NDVI may not capture tree responses among young trees because of their less dense branching. As more trees are processed, there will be considerably more learned.

The RY2016 and RY2017 ABI data showed that one measure of vigor is quantifiable. Given the large number of values generated per tree by UAVs, summarizing NDVI value distributions relying only the mean, median, max, and/or min, seems to be greatly under-utilizing a large data set collected at high resolution. Many mature yellow willows have significant portions of their canopy as dead branches while having other portions bright green. Unique shapes of the cumulative NDVI distribution curves for single trees could provide considerably more insight. With the high spatial resolution of the UAV NDVI data, dead branches can be distinguished from those alive.

Due to its high spatial resolution, the UAV-derived NDVI measurements provide anywhere from 3,000 to 12,000 pixel values per individual tree. Figure 27 provides cumulative RY2017 NDVI distributions for three yellow willows where: (1) R5_16 was in the Backwater of 4-Floodplain (total NDVI values = 3,588), (2) R5_26 was in the Central 4-Floodplain (total NDVI values = 7,706) and (3) R3_01 was in the Lower RB 14-15 Terrace opposite in the Lower RB 14-1 (total NDVI values = 3,089). Note R3_01 has a wider range of NDVI values than backwater tree R5_16, but smaller range of values than Central 4-Floodplain tree R5_26.

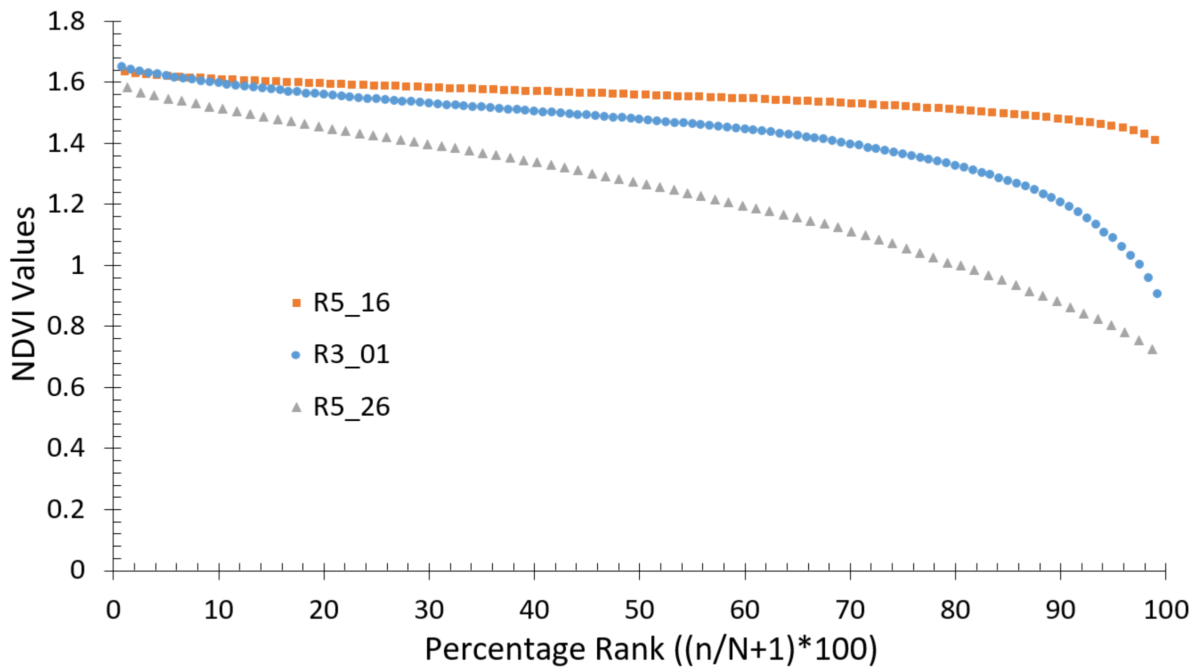

Figure 27. Cumulative RY2017 NDVI distributions for three yellow willows (NDVI scale of 0 to 2 represents the NDVI ratios (Equation 1) ranging from -1 to +1).

Although these trees have similar maximum NDVI values (where P-values are low), tree R5_16 located in 4-Floodplain Backwater had greater median and minimum NDVI values compared to the median and minimum NDVI values of R5_26 in the Central 4-Floodplain and R3_01 in the LB 14-15 Floodplain. A smaller range of NDVI values means less variability and should therefore reflect a uniformly healthy willow tree without patches of dying branches. This relationship was supported by field notes from 2017 monitoring, describing tree R5_16 as appearing healthy with dense branching. Similarly, larger ranges of values, such as in the central 4-Floodplain tree R5_26 and LB terrace tree R3_01, should reflect willow trees with patches of healthy and unhealthy branches. As the variability in branch health within an individual tree increases, the range (i.e., variability) in NDVI should increase. The range of NDVI values will likely be more important for assessing tree vigor than means or medians. NDVI measurements should be a useful remote-sensing tool for evaluating tree health in a log-term monitoring plan. However, to evaluate tree response to runoff year with NDVI measurements, measurements will be needed year-to-year. What will be the magnitudes and shapes of the cumulative NDVI distributions for these three trees if RY2018 is a dry runoff year?

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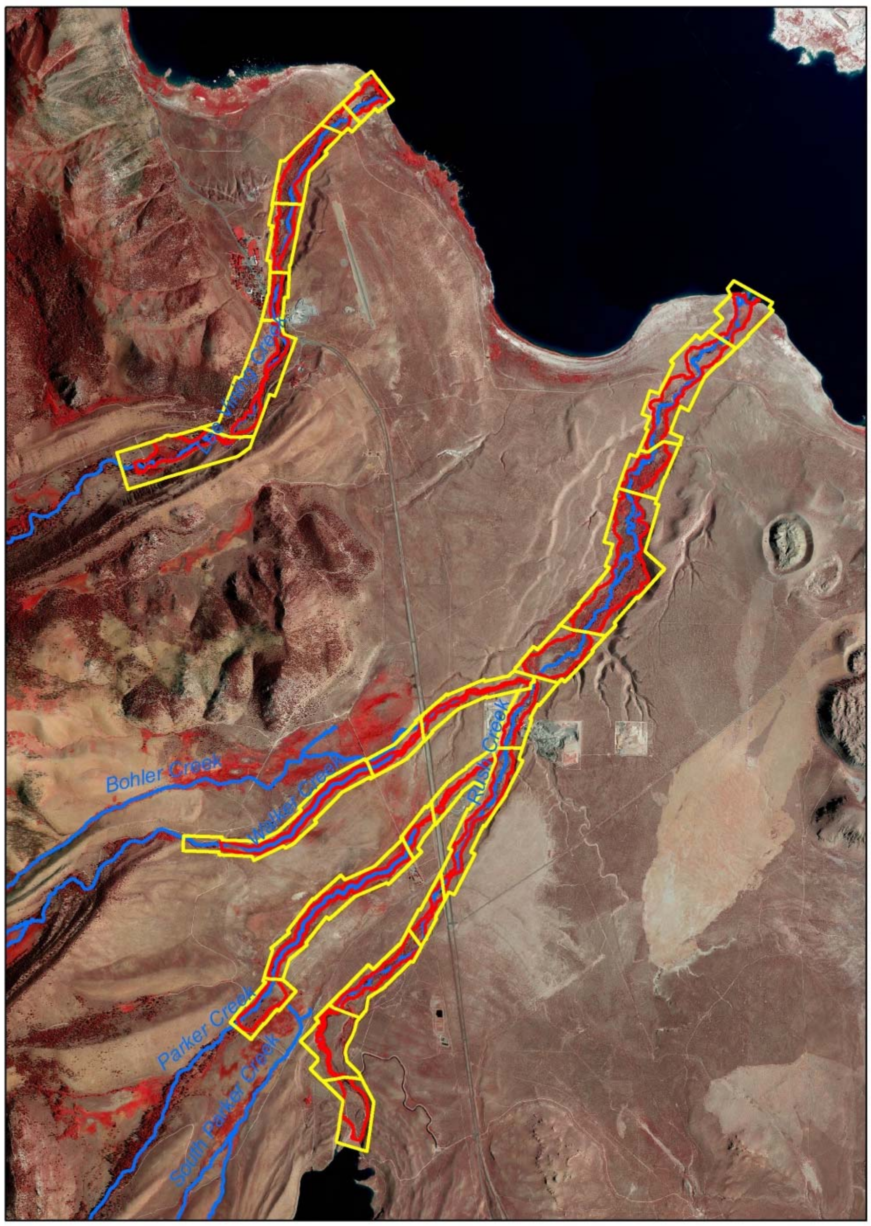
Section 4(b)

Mono Lake Tributaries
Riparian Inventory
1929-2017

Mono Lake Tributaries
Riparian Inventory
1929-2017
Sherman Jensen/LADWP



April 2018

1.0 INTRODUCTION

The purpose was to compile and evaluate vegetation inventories for select tributaries of Mono Lake (Rush, Lee Vining, Parker, and Walker Creeks). Mapping of 1929, 1999, 2004, and 2009 conditions is from an *Atlas of Riparian Vegetation Mapping* (McBain and Trush 2005) and mapping of 2014 and 2017 conditions was conducted by Sherman Jensen/LADWP. Mapping is intended as a basis for evaluating restoration goals and specific woody riparian termination criteria suggested by the SWRCB for mitigation of water rights impacts to Rush and Lee Vining Creeks.

SWRCB Order WR 98-07 specifies the stream restoration program may be terminated upon approval of …. (in part):

> Whether the stream restoration and recovery process has resulted in a functional and self-sustaining stream system with healthy riparian ecosystem components for which no extensive physical manipulation is required on an ongoing basis.

The same order further includes termination criteria for monitoring to include:

> Acreage of riparian vegetation, including mature trees of sufficient diameter, height, and location to provide woody debris in the streams; quantified criteria for Rush and Lee Vining Creeks are as stated in R-DWP-68B (see Table 1-1).

The values that serve as termination criteria (Table 1-1) were summarized from Ridenhour et al. (1995) Draft Work Plan, Mono Basin Stream Restoration, October 4, 1995[1]. McBain and Trush (2003) state:

> Original termination criteria for riparian acreage presented in Ridenhour et al. (1995) are based on the mapping results presented by Jones and Stokes in the Mono Basin EIR (Jones and Stokes 1993).

But areas of pre-diversion (1929) woody riparian vegetation reported in APPENDIX P of the EIR is compiled for different reaches that sum to different values than those in R-DWP-68B. Although the intent of termination criteria is to be the area of riparian vegetation present before LADWP diverted water from creeks, as more-or-less evident on 1929 imagery, the tangible basis for riparian vegetation acreage termination criteria is a mystery.

The intent was that woody riparian termination criteria describe pre-project conditions. Where contemporary states preclude the restoration of pre-project conditions, a corresponding functionally equivalent criterion will be established. Changes in termination criteria may also be recommended based on improved understanding of restoring these streams (SWRCB Order WR 98-07).

[1] I have been unsuccessful in locating this important document.

Jones and Stokes (1993) mapped the pre-diversion riparian vegetation from 1929 black-and-white stereo aerial imagery at 1:24,000 scale. Their original map was hand drawn and planimetered (McBain and Trush 2003) and included meadow as part of pre-diversion riparian vegetation. Given the small-scale and coarse-resolution of the 1929 imagery, mapping of riparian vegetation likely included open water (stream), streambars, and scrub/meadow vegetation on floodplain and terrace landforms. Map error likely far exceeds the precision of riparian vegetation termination criteria (0.1 acre; Table 1-1)

Table 1-1. Woody riparian vegetation termination criteria (R-DWP-68B).

Rush Creek		Lee Vining Creek	
Reach	(acres)	Reach	(acres)
1	na[2]	1	20.0
2	5.0	2	30.0
3A	21.5	3A	22.2
3B	2.9	3B	32.9
3C	11.2	3C	4.0
3D	10.0	**TOTAL**	**109.1**
4A	26.3		
4B	80.2		
4C	38.7		
5A	37.8		
TOTAL	**233.6**		

The goal of the stream restoration program proposed by Los Angeles is to:

> *…restore the stream systems and their riparian habitats by providing proper flow management in a pattern that allows natural stream processes to develop functional, dynamic, and self-sustaining stream systems* (SWRCB Order 98-05).

Riparian vegetation mapping for 1929 through 2017 conditions is evaluated relative to both the precise riparian vegetation termination criteria and the more general goal of the stream restoration program.

[2] Rush Creek Reach 1 is exempt from woody riparian vegetation restoration (SWRCB Order WR 98-07).

2.0 APPROACH

McBain and Trush (2005) identified a ***riparian corridor*** for Rush, Parker, Walker, and Lee Vining Creeks as noted by the red lines on Figure 2-1. They mapped vegetation types "heads-up" for a somewhat wider ***map extent*** (as denoted by yellow lines on Figure 2-1) for 1929, 1999, 2004 and 2009 conditions[3]. Maps included in the Riparian Vegetation Atlas (*ibid*.) display 6 general types:

Riparian woody vegetation: Includes 18 vegetation types dominated by trees and shrubs. Prominent types are mixed willow, narrowleaf willow, yellow willow, rose, Pacific willow, quaking aspen, and black cottonwood.

Riparian herbaceous: Includes 2 prominent vegetation types (wet meadow and Great Basin grassland) dominated by herbaceous vegetation. Meadows mapped for 1929 conditions included irrigated pastures contiguous to floodplains. Meadows mapped for 1999, 2004, and 2009 conditions include some (but not all) alkali scrub/meadow on floodplain and low terrace influenced by high water table.

Open: Includes streambars and deltas of Rush and Lee Vining Creeks immediately above Mono Lake. Small streambars were probably not perceivable from the relatively small-scale, black-and-white 1929 imagery and were likely included with adjacent vegetation.

Water: Portions of streams not obscured by vegetation. The stream was not evident from the 1929 images so Rush and Lee Vining Creeks were each mapped as a continuous 10 feet wide buffer.

Desert: Includes 10 vegetation associations dominated by upland scrub species. Prominent types are sagebrush, sagebrush/grassland, and sagebrush/bitterbrush. Includes some, but not all, alkali scrub/meadow on floodplain and low terrace influenced by high water table.

Human disturbed: Includes roads, gravel pits, urban, and power facilities.

McBain and Trush used Autocad to produce maps of riparian vegetation included in the Riparian Vegetation Atlas. Unfortunately, most of the Autocad files used to make these maps were compiled in a manner resulting that only the polygons could be retrieved and imported to ArcMap GIS – the attributes (i.e. vegetation series and association) were lost. In recourse, polygons imported to ArcMap were assigned to the six general types based on maps in the Riparian Vegetation Atlas for 1929, 1999, and 2004 conditions. ArcMap shapefiles with attributes were provided for 2009 mapping.

[3] Lee Vining Creek above Highway 395 was mapped <u>only</u> in 2004; the lowest reaches of Rush and Lee Vining Creeks were embayed by Mono Lake in 1929 and were not mapped; Parker and Walker Creeks were not mapped in 2009.

McBain and Trush mapping was clipped to two extents to facilitate consistent comparison between years (Figure 2-1). The *riparian corridor* was defined by McBain and Trush (2003) as:

> *The riparian corridor boundary defined in our 1999 mapping served as the riparian corridor boundary in 1929 (presumably the corridor width as M&T defined it has not changed in the last 100 years).*

McBain and Trush used the same riparian corridor boundary for clipping 2004 and 2009 mapping that was then compared to termination criteria in R-DWP-68B (Table 1-1)[4]. Yet there are many areas where riparian vegetation identified by McBain and Trush overlapped the riparian corridor (Figure 2-2), suggesting some riparian vegetation was not considered relative to achieving termination criteria. In recourse, mapping was also compiled for *map extents* (Figure 2-1) defined as the area mapped for 1929, 1999, 2004 and 2009 conditions[5] and corresponding with reaches defined for stream segments. Map extents provide a more rational basis for comparison of changes over time and termination criteria. While riparian corridors are marked on inventory maps and tabular data for riparian corridors are included in appendices, subsequent discussions focus primarily on the map extents associated with reaches.

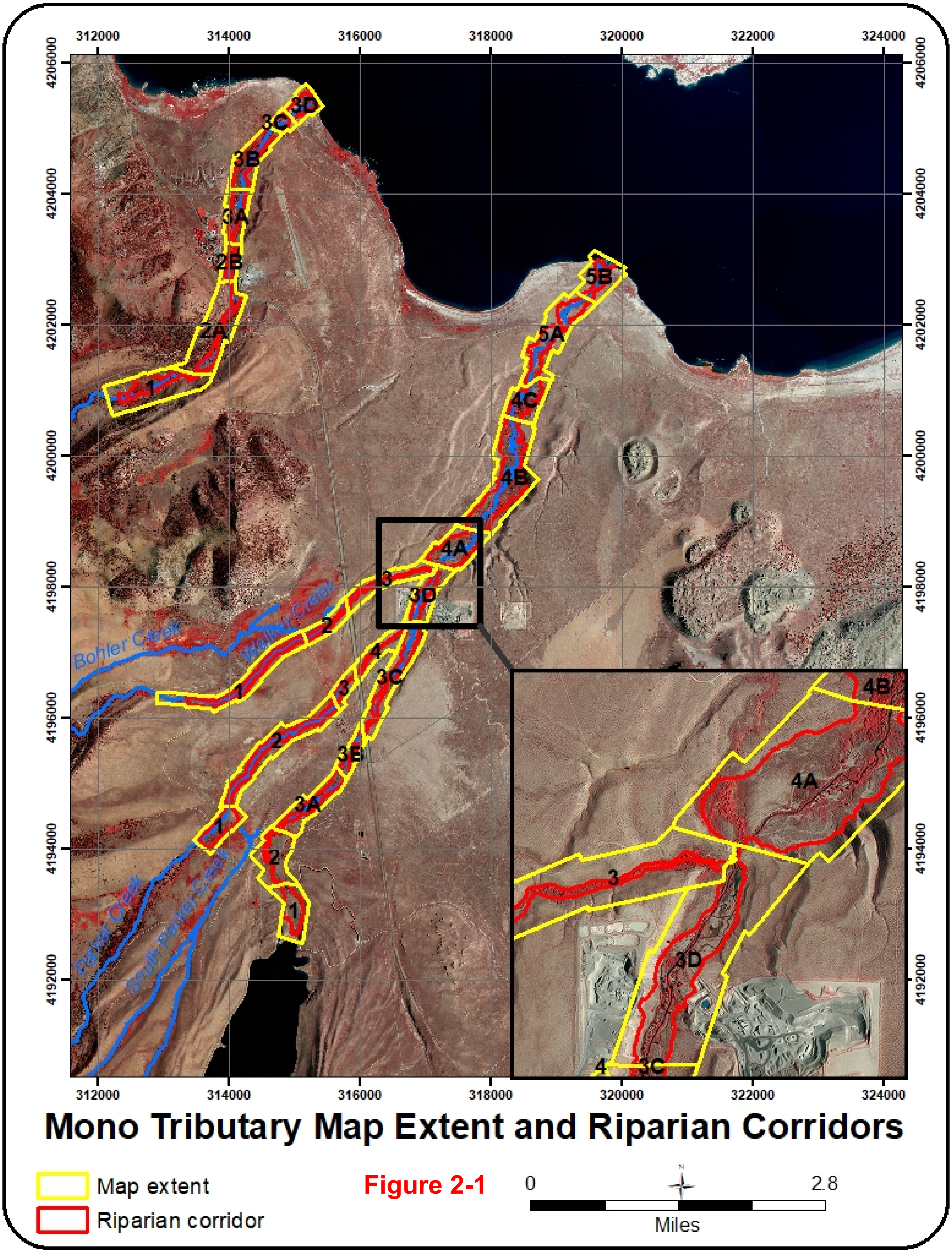
Sherman Jensen/LADWP updated riparian vegetation mapping for 2014 and 2017 conditions using both spectral analyses and heads-up mapping from high-resolution (1 foot pixels), 4 band imagery. Spectral analysis allowed more precise delineation of small features (e.g. water in the stream channel) than drawing boundaries on hard-copy maps or heads-up mapping employed by McBain and Trush. Sherm identified 11 map units that were correlated with the six types identified by McBain and Trush (2005) (Table 2-1). The simplified correlation symbol and name (i.e. riparian, meadow, streambar, water, scrub, and miscellaneous feature) are used consistently for all mapping and analysis. *Not mapped* is also used for areas that were not inventoried for a period. Also, *Mono Lake* is applied to the lowest reaches of Lee Vining and Rush Creeks for 1929 when they were flooded by Mono Lake.

Table 2-1. Correlation of McBain and Trush (2005) and Jensen map units.

M&T (2005)	Jensen	Correlation	
		Symbol	Name
Riparian woody	Riparian woodland	R	Riparian
	Riparian shrub		
	Jeffery pine		
Riparian herbaceous	Meadow	M	Meadow
	Scrub/meadow		
Open	Streambar	SB	Streambar
Water	Water	W	Water
	Marsh		
Desert	Scrub	S	Scrub
Human disturbed	Developed	X	Misc feature
	Road		

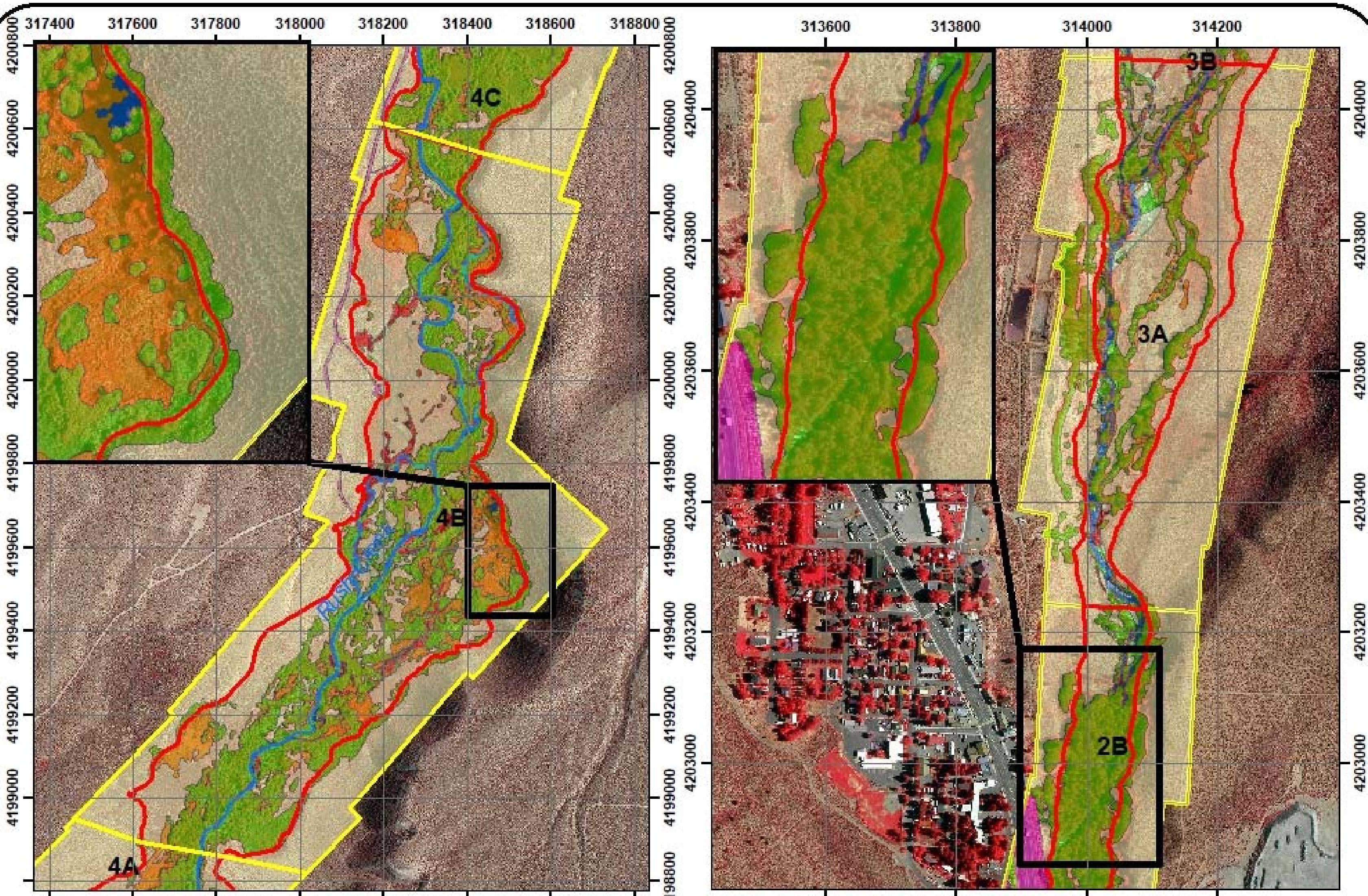
[4] The areas of woody riparian vegetation listed in Table 6 of the Riparian Vegetation Atlas (McBain and Trush 2005), exclusive of termination criteria and Jones and Stokes mapping, appear to be for the riparian corridor and exclude woody riparian vegetation that was mapped, but occurs outside the corridor.

[5] Mapping was extended using appropriate imagery for a few areas to provide more consistent map extent between years.



Mono Tributary Map Extent and Riparian Corridors

Figure 2-1



A. Rush Creek Reach 4B.

B. Lee Vining Reach 2B and 3A.

Examples of 2009 McBain and Trush Mapping that Overlaps Riparian Corridor

Figure 2-2

3.0 RESULTS

Large scale maps of vegetation types by reach for 1929 (APPENDIX A), 1999 (APPENDIX B), 2004 (APPENDIX C), 2009 (APPENDIX D), 2014 (APPENDIX E), and 2017 (APPENDIX F) are provided. A tabular summary of the area of vegetation types in the *riparian corridor* is buried in APPENDIX G. Results for the map extents follow.

The area of vegetation types for the total map extent (Figure 2-1) for each of the six periods is displayed in Figure 3-1 and listed in Table 3-1. From this broad perspective, the area of woody riparian vegetation exceeded the termination criteria (342.7 acres) for all years except 2009. This overall result is skewed because all years except 2009 include Walker and Parker Creeks, which were not included in the termination criteria. Regardless, the total area of hydric types (riparian, meadow, water, and streambar) for 2014 and 2017 exceed those of 1999 and 2004 and, considering map errors, are comparable with 1929.

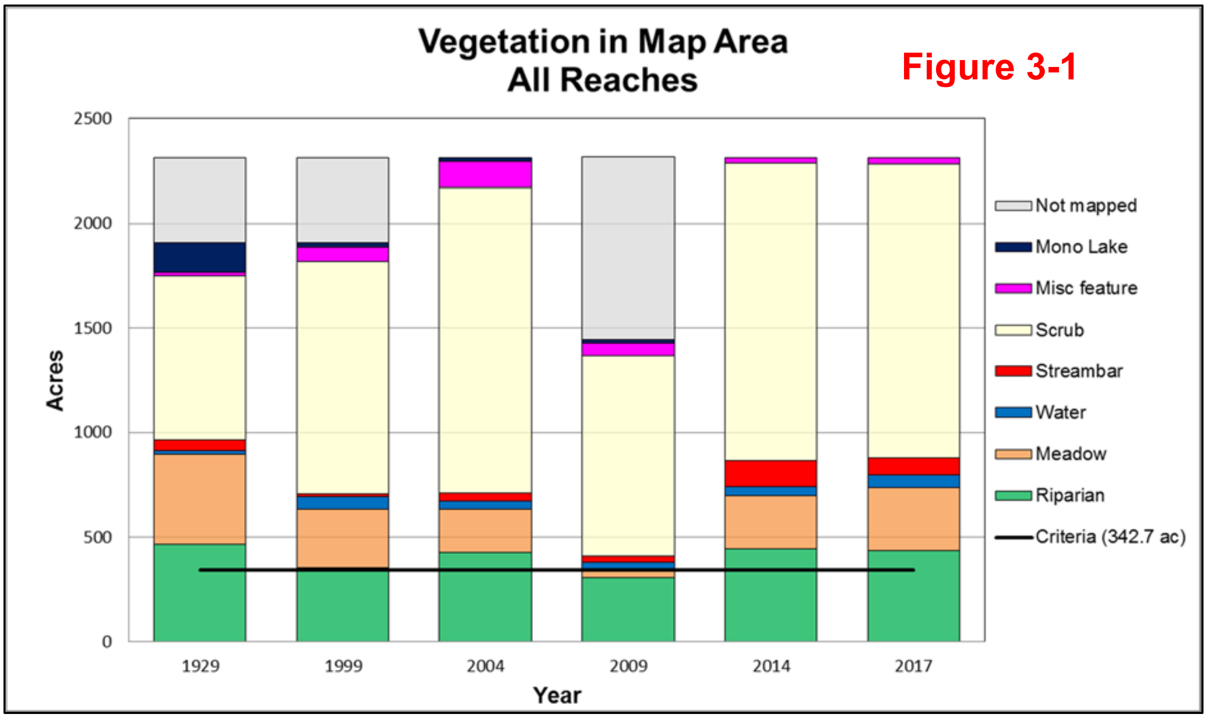


Table 3-1. Area of vegetation types in all map areas.												
Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	465	20	354	15	425	18	307	13	442	19	437	19
Meadow	429	19	279	12	207	9	38	2	258	11	300	13
Water	19	1	59	3	42	2	36	2	40	2	59	3
Streambar	49	2	16	1	37	2	28	1	127	5	80	3
subtotal	*962*	*42*	*708*	*31*	*711*	*31*	*410*	*18*	*867*	*37*	*876*	*38*
Scrub	787	34	1113	48	1462	63	959	41	1418	61	1407	61
Misc feature	17	1	69	3	122	5	58	3	30	1	32	1
Mono Lake	141	6	19	1	20	1	18	1	0	0	0	0
Not mapped	407	18	406	18	0	0	870	38	0	0	0	0
TOTAL	**2315**	**100**	**2315**	**100**	**2315**	**100**	**2315**	**100**	**2315**	**100**	**2315**	**100**

3.1 Lee Vining Creek

Lee Vining Creek consists of 7 reaches, one of which (3D) was inundated by Mono Lake in 1929 (Figure 3-2). Reach 1 and most of Reach 2A were not mapped in 1929, 1999, and 2009, but were included with the total termination criteria. The total area of riparian, including 10-15 acres in Reach 3D, exceeded the total termination criteria (109.1 acres) in 2004, 2014, and 2017 (Figure 3-3). The total area of hydric resources (riparian, meadow, water, and streambar) has mostly increased since 1999 (Table 3-2). The overall trend of Lee Vining Creek is improving. Specific reaches of Lee Vining Creek are subsequently discussed.

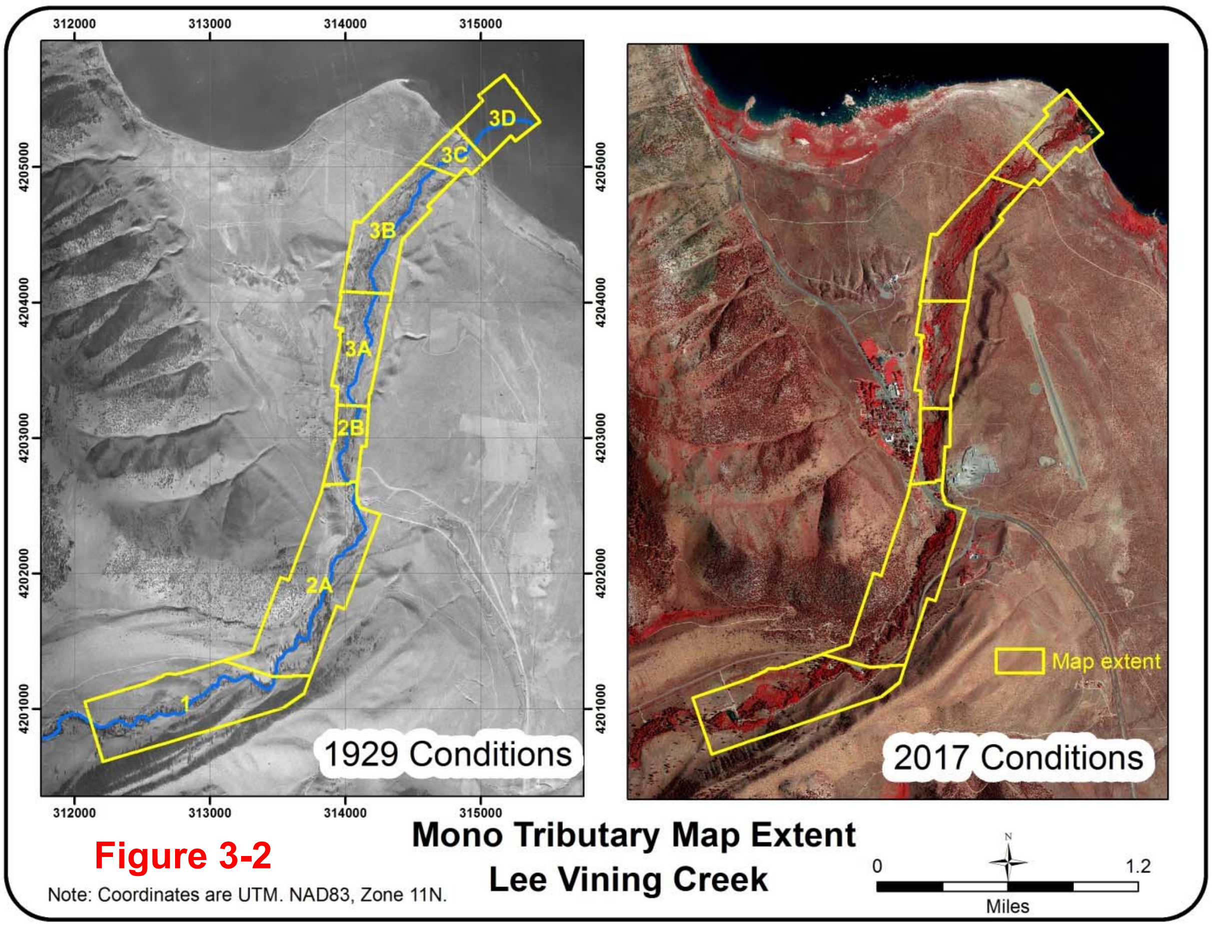


Figure 3-2

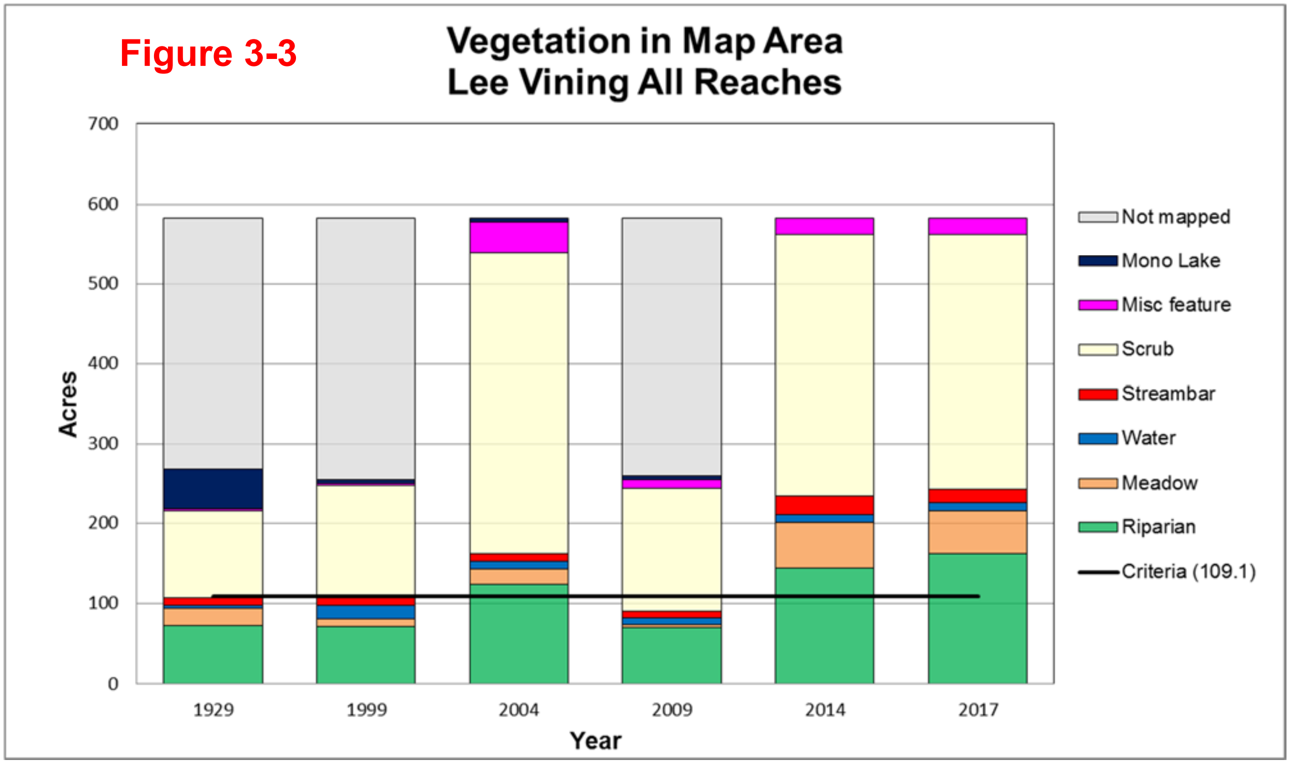


Table 3-2. Area of vegetation types in Lee Vining all reaches map areas.												
Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	73	12	72	12	125	21	70	12	145	25	163	28
Meadow	22	4	9	2	18	3	4	1	56	10	53	9
Water	3	1	18	3	10	2	8	1	9	2	11	2
Streambar	10	2	9	2	10	2	8	1	23	4	17	3
subtotal	***108***	***18***	***107***	***18***	***163***	***28***	***90***	***15***	***234***	***40***	***244***	***42***
Scrub	108	19	140	24	377	65	154	26	328	56	319	55
Misc feature	2	0	3	0	38	6	11	2	21	4	20	4
Mono Lake	50	9	5	1	6	1	6	1	0	0	0	0
Not mapped	315	54	328	56	0	0	322	55	0	0	0	0
TOTAL	**583**	**100**	**583**	**100**	**583**	**100**	**583**	**100**	**583**	**100**	**583**	**100**

Lee Vining Reach 1

This reach is upstream of Highway 120 crossing and includes the LADWP diversion structure on Lee Vining Creek (Figure 3-4). The reach is the lower end of a broad, relatively flat bottomed glacial canyon. Stream grade is less than 2 percent. This 160 acre map extent was not mapped in 1929, 1999, or 2009. The extent of riparian exceeded the termination criteria (20 acres) for all other periods (Figure 3-5). The area of hydric resources (riparian, meadow, water, and streambar) has remained relatively consistent since 2004 (Table 3-3). The trend of this reach is stable. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation. Termination criteria have been achieved.

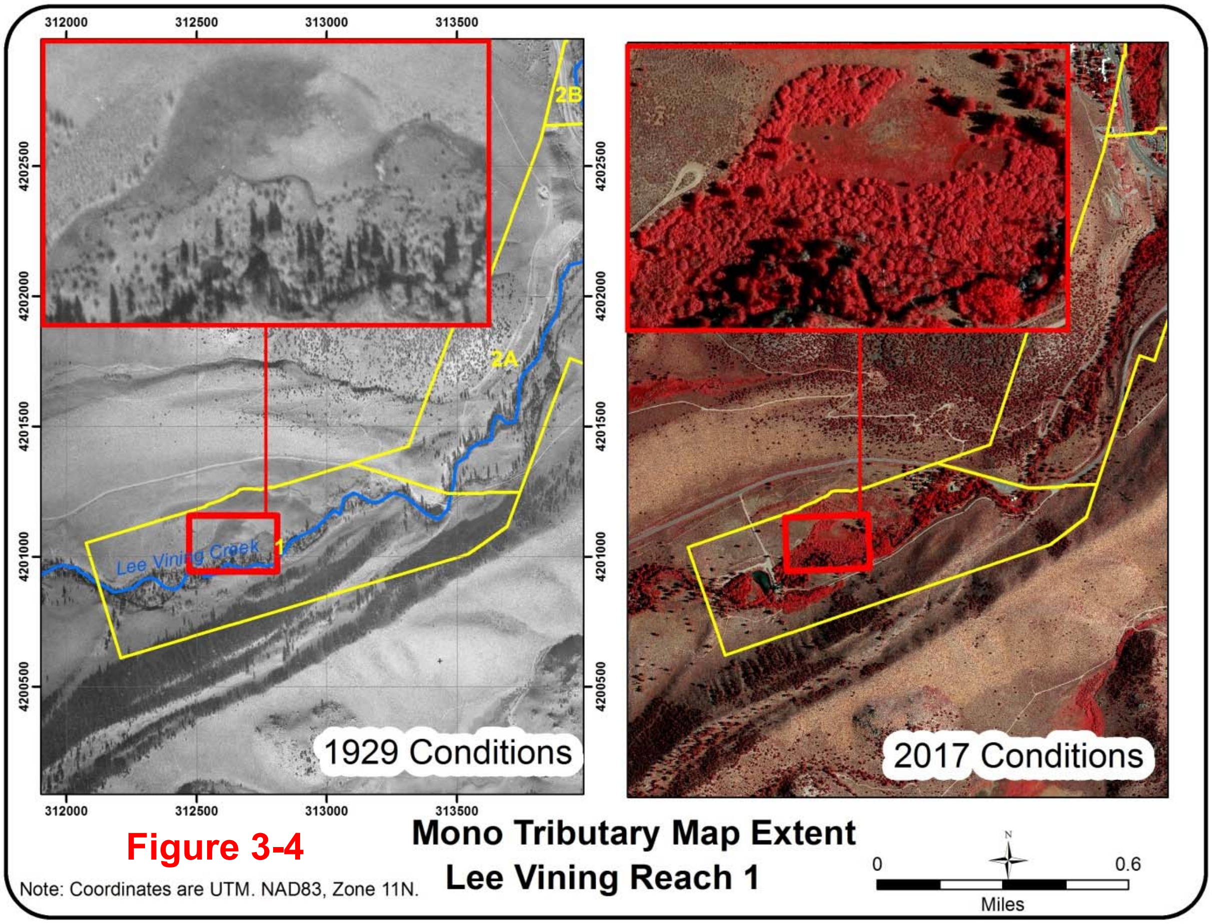


Figure 3-4

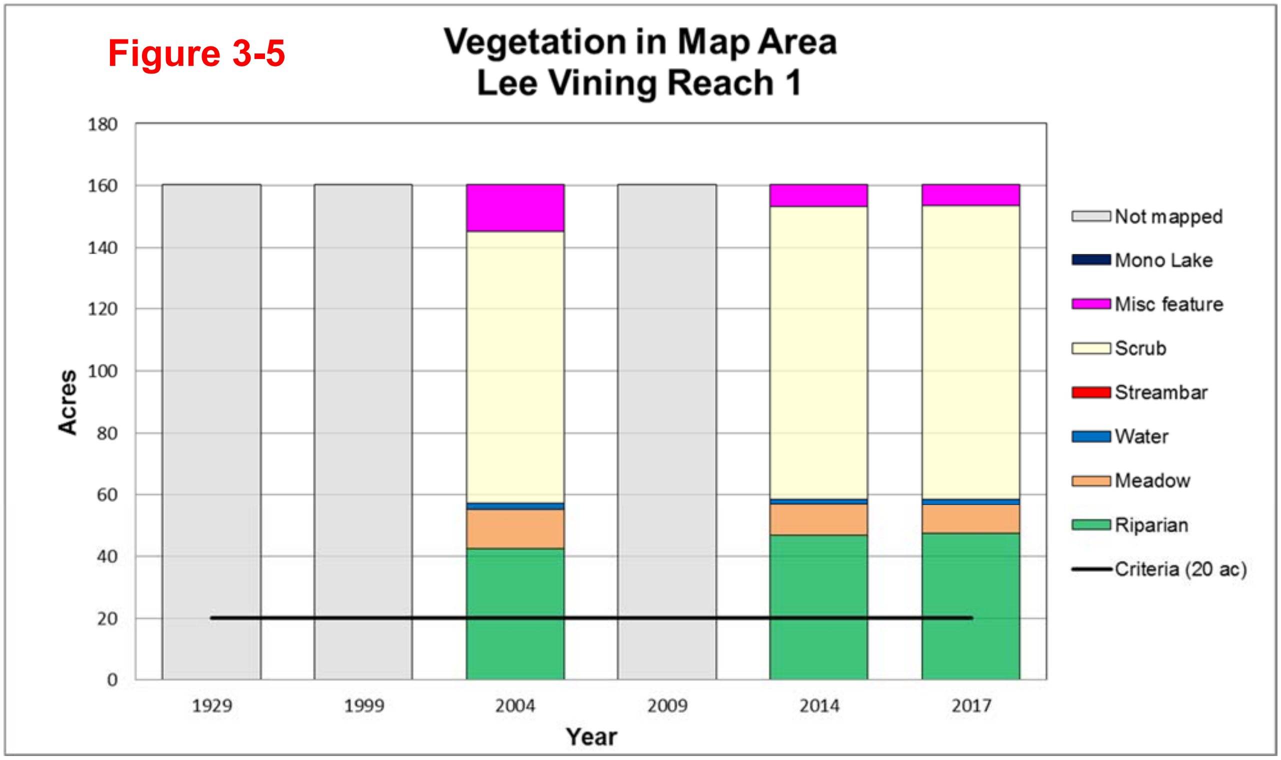


Table 3-3. Area of vegetation types in Lee Vining Reach 1 map area.

Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	0	0	0	0	42	26	0	0	47	29	47	30
Meadow	0	0	0	0	13	8	0	0	10	6	9	6
Water	0	0	0	0	2	1	0	0	1	1	2	1
Streambar	0	0	0	0	0	0	0	0	0	0	0	0
subtotal	***0***	***0***	***0***	***0***	***57***	***36***	***0***	***0***	***59***	***36***	***58***	***36***
Scrub	0	0	0	0	88	55	0	0	95	59	95	59
Misc feature	0	0	0	0	15	9	0	0	7	5	7	4
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	160	100	160	100	0	0	160	100	0	0	0	0
TOTAL	**160**	**100**	**160**	**100**	**160**	**100**	**160**	**100**	**160**	**100**	**160**	**100**

Lee Vining Reaches 2A and 2B

Reach 2A extends from the crossing of Highway 120 to the crossing of Highway 395 (Figure 3-6). Reach 2B extends about 2,000 feet below Highway 395. The termination criteria for Reach 2A and 2B (Figure 3-7) were combined (McBain and Trush 2005) for a total of 30 acres. The stream flows in a steep, narrow canyon confined by lateral moraine. Stream grade is about 6 percent. Reach 2A was not mapped in 1929, 1999, and 2009. The area of riparian (Table 3-4) exceeds the termination criteria (30 acres) for 2004, 2014, and 2017 and has increased steadily since 2009. Contemporary woody riparian vegetation appears both more extensive and with high canopy cover compared with 1927. The trend of the reach is improving. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation. Termination criteria have been achieved since 2014.

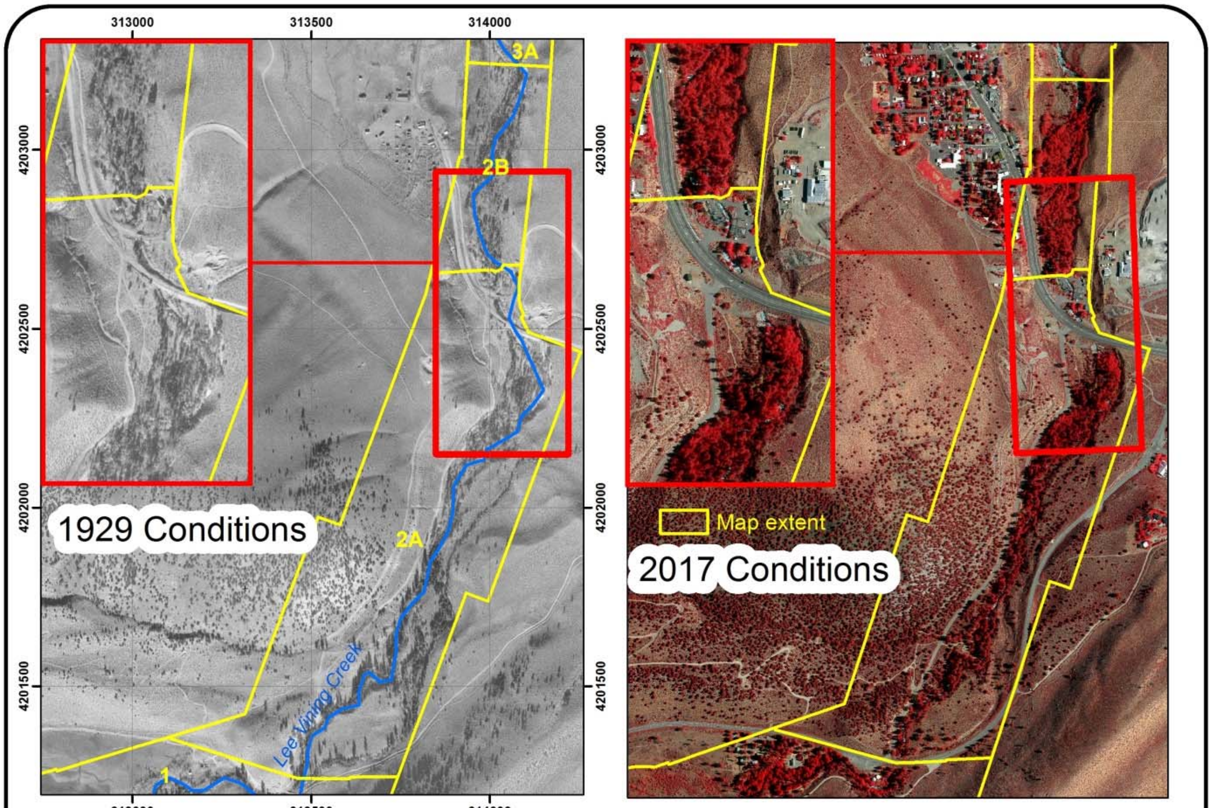


Figure 3-6

Mono Tributary Map Extent
Lee Vining Reaches 2A and 2B

Note: Coordinates are UTM. NAD83, Zone 11N.

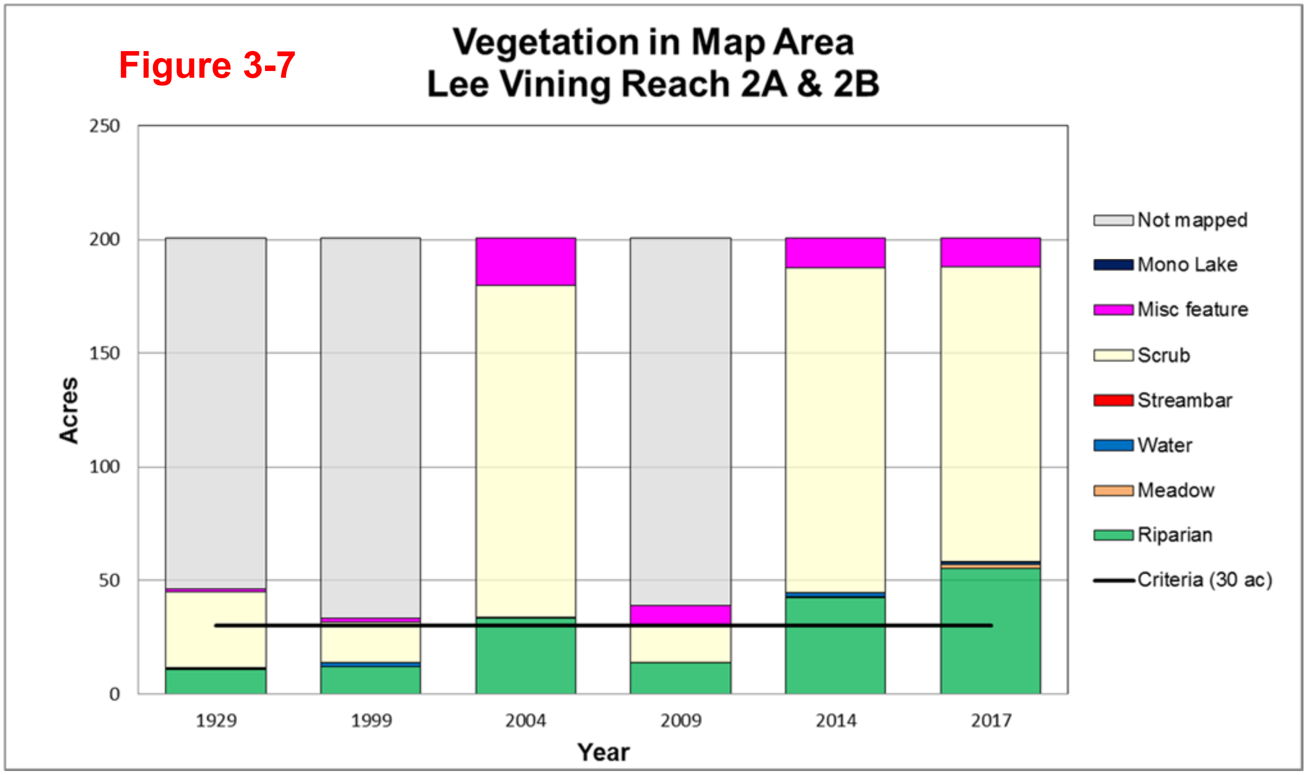


Table 3-4. Area of vegetation types in Lee Vining Reach 2A&B map areas.

Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	11	5	12	6	33	17	14	7	42	21	55	27
Meadow	0	0	0	0	0	0	0	0	1	0	2	1
Water	1	0	2	1	0	0	0	0	2	1	1	0
Streambar	0	0	0	0	0	0	0	0	0	0	0	0
SUBTOTAL	***12***	***6***	***14***	***7***	***34***	***17***	***14***	***7***	***45***	***22***	***58***	***29***
Scrub	33	16	17	9	146	73	16	8	143	71	130	65
Misc feature	2	1	2	1	21	10	9	5	13	7	13	6
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	154	77	167	83	0	0	162	81	0	0	0	0
TOTAL	**201**	**100**	**201**	**100**	**201**	**100**	**201**	**100**	**201**	**100**	**201**	**100**

Lee Vining Reach 3A

Reach 3A is about 3,100 feet in length (Figure 3-8). Alluvial floodplain and terrace are confined by high benches built of glacial outwash. Stream gradient is 3.6 percent. While the woody riparian termination criterion (20.5 acres) has not been achieved (Figure 3-9), the extent of hydric resources (riparian, meadow, water, and streambar) have increased since 1929 (Table 3-5). McBain and Trush (2005) report this reach is unlikely to achieve the woody riparian termination criterion. The contemporary stream channel is probably more incised and meadow has replaced woody riparian on stream terrace compared to 1929 conditions. The trend for the reach is improving. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

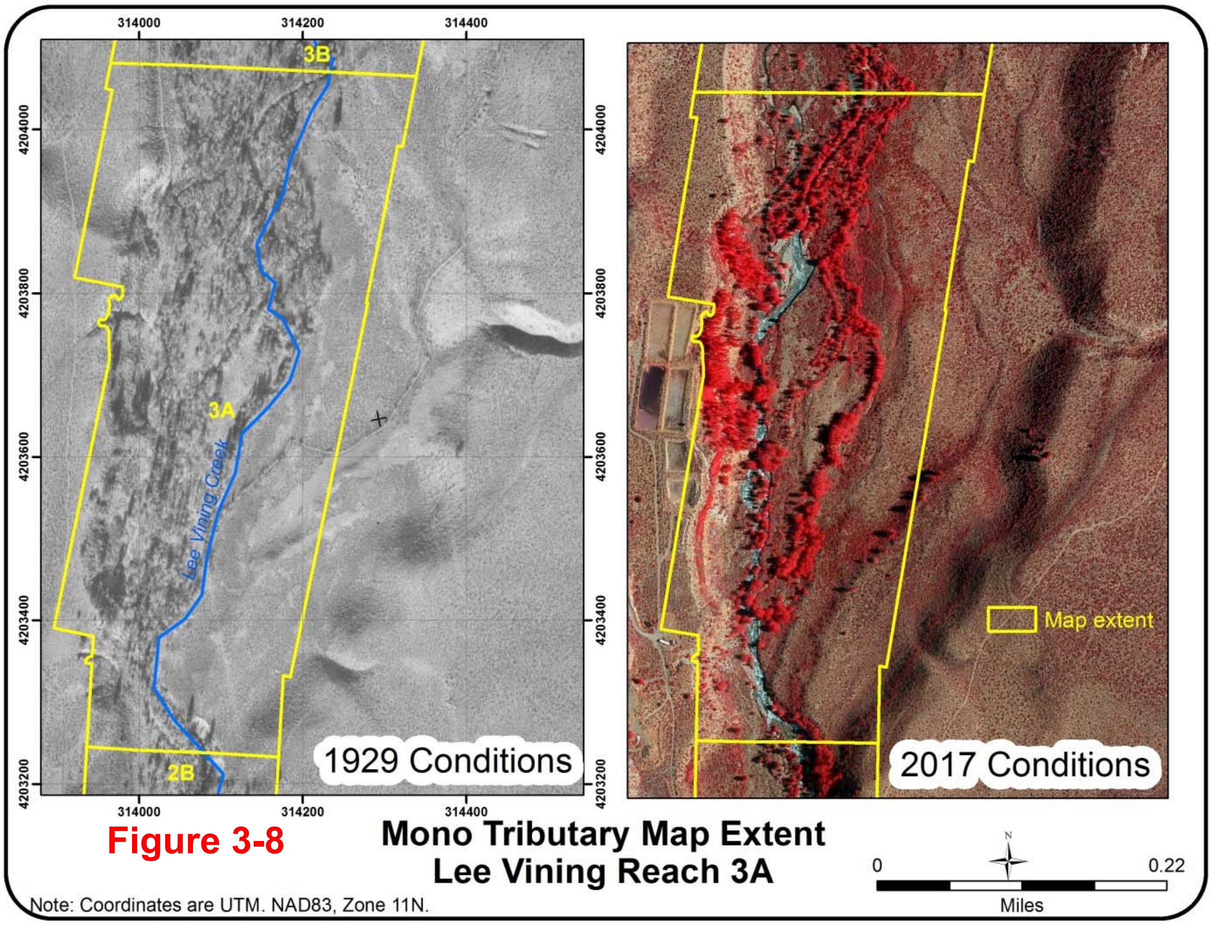


Figure 3-8

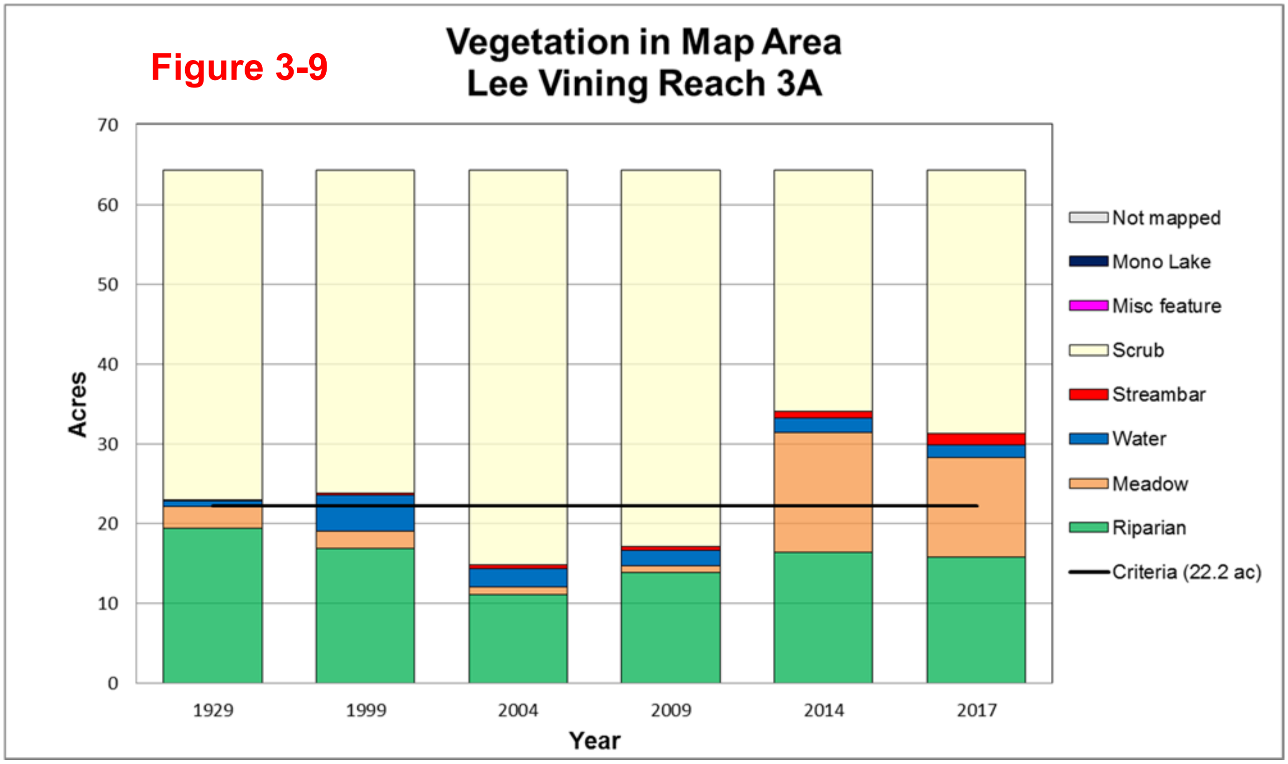


Table 3-5. Area of vegetation types in Lee Vining Reach 3A map area.												
Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	19	30	17	26	11	17	14	22	16	26	16	24
Meadow	3	4	2	3	1	1	1	1	15	23	13	19
Water	1	1	5	7	2	4	2	3	2	3	2	2
Streambar	0	0	0	0	1	1	1	1	1	1	1	2
subtotal	***23***	***36***	***24***	***37***	***15***	***23***	***17***	***27***	***34***	***53***	***31***	***49***
Scrub	41	64	40	63	49	77	47	73	30	47	33	51
Misc feature	0	0	0	0	0	0	0	0	0	0	0	0
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**64**	**100**	**64**	**100**	**64**	**100**	**64**	**100**	**64**	**100**	**64**	**100**

Lee Vining Reach 3B

Reach 3B extends about 3,750 feet above the county road crossing (Figure 3-10). Alluvial floodplain and terrace are confined by high benches built of glacial outwash. Stream gradient is 2.8 percent. The woody riparian termination criteria (32.9 acres) has not been achieved (Figure 3-11), but the extent of hydric resources (riparian, meadow, water, and streambar) are similar to that identified for 1929 conditions (Table 3-6). McBain and Trush (2005) report this reach is unlikely to achieve the woody riparian termination criterion. The contemporary stream channel is probably more incised and meadow has replaced woody riparian on stream terrace compared to 1929 conditions. The trend of the reach is improving. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

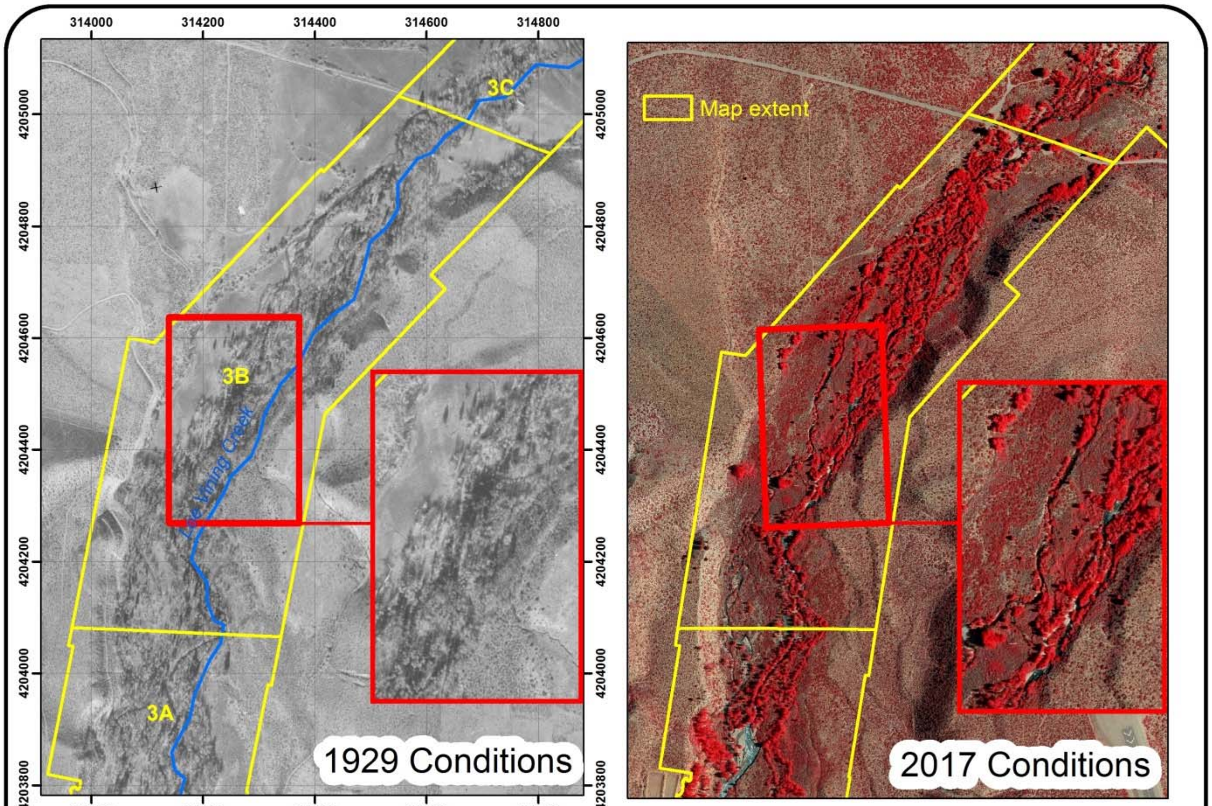


Figure 3-10 **Mono Tributary Map Extent Lee Vining Reach 3B**

Note: Coordinates are UTM. NAD83, Zone 11N.

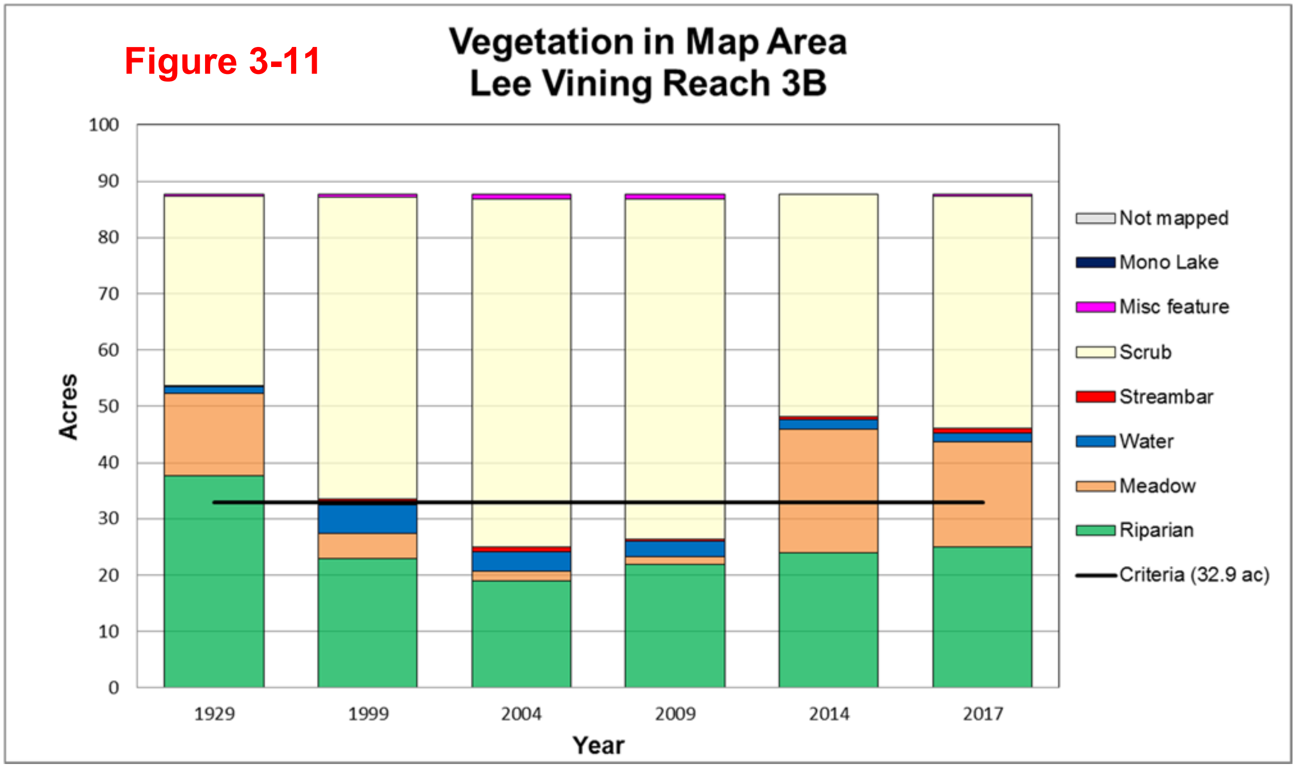


Table 3-6. Area of vegetation types in Lee Vining Reach 3B map area.												
Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	38	43	23	26	19	22	22	25	24	27	25	28
Meadow	14	17	5	5	2	2	1	2	22	25	19	21
Water	1	1	5	6	3	4	3	3	2	2	2	2
Streambar	0	0	1	1	1	1	0	0	1	1	1	1
subtotal	***54***	***61***	***34***	***38***	***25***	***28***	***26***	***30***	***48***	***55***	***46***	***53***
Scrub	34	38	54	61	62	71	61	69	40	45	41	47
Misc feature	0	0	1	1	1	1	1	1	0	0	0	0
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**88**	**100**	**88**	**100**	**88**	**100**	**88**	**100**	**88**	**100**	**88**	**100**

Lee Vining Reach 3C

Reach 3C extends about 1,250 feet below the county road crossing (Figure 3-12). The area is transitional to the delta of Lee Vining Creek. Stream gradient is 2.4 percent. The woody riparian termination criterion (4 acres) has been achieved (Figure 3-13). The extent of hydric resources (riparian, meadow, water, and streambar) has increased since 1999 conditions (Table 3-7). The contemporary stream channel is probably more incised and streambars higher-and-drier compared to 1929 conditions. The trend for the reach is improving. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation. Termination criteria have been exceeded since at least 1999.

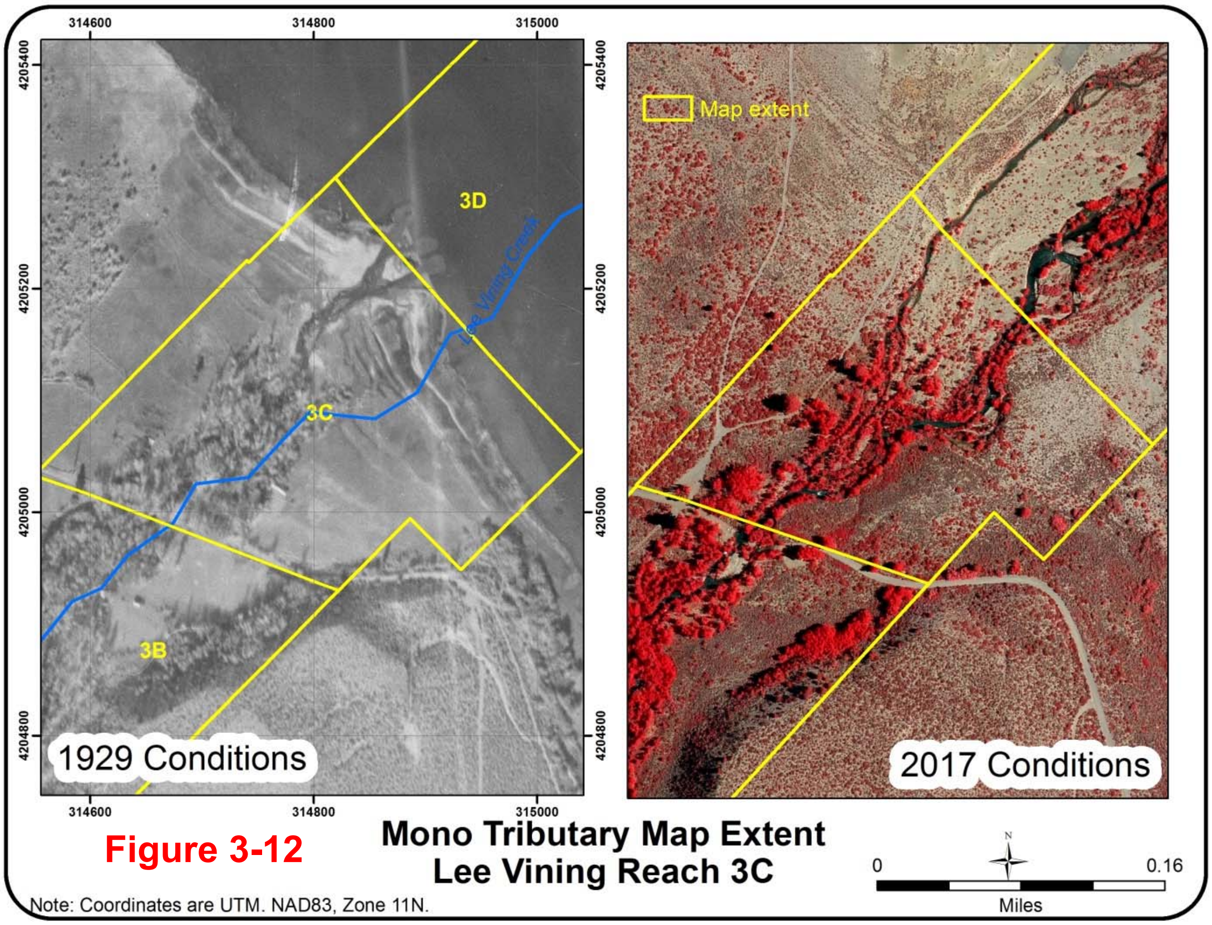


Figure 3-12 **Mono Tributary Map Extent Lee Vining Reach 3C**

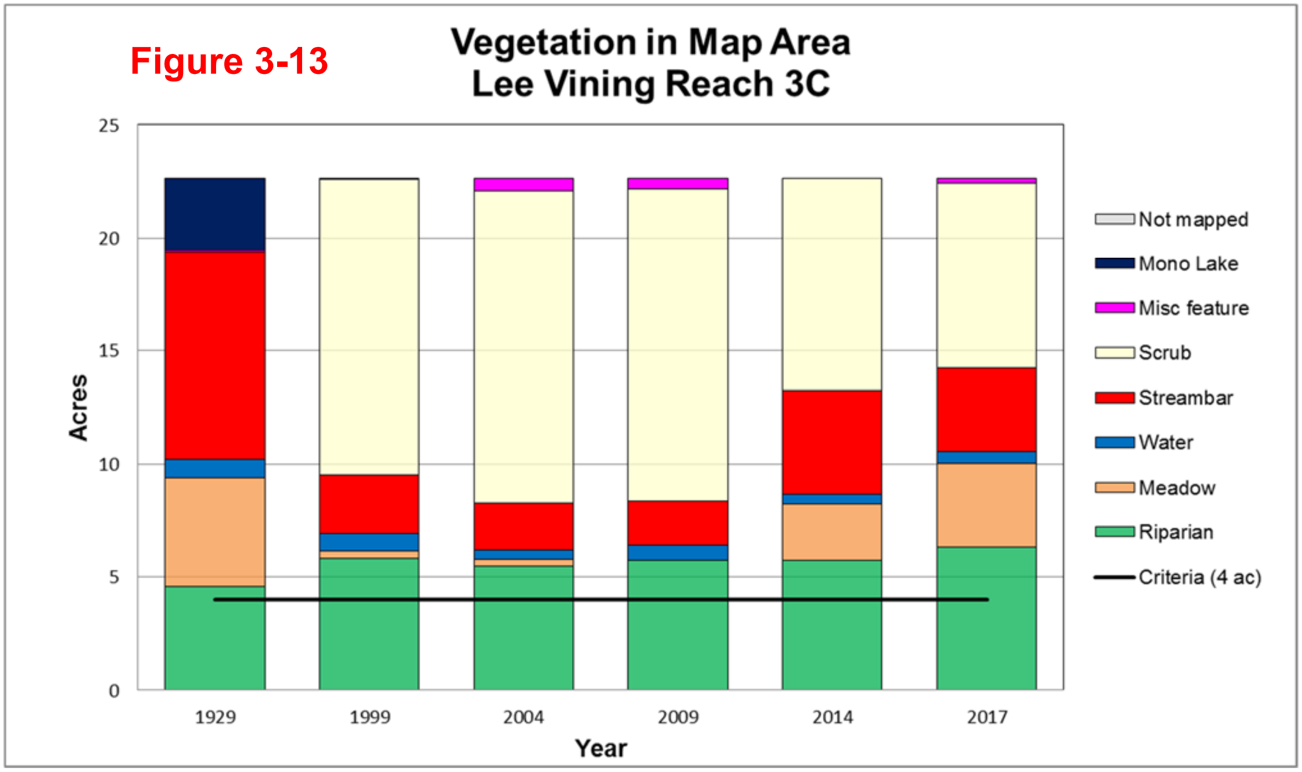


Table 3-7. Area of vegetation types in Lee Vining Reach 3C map area.

Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	5	20	6	26	5	24	6	25	6	25	6	28
Meadow	5	21	0	1	0	1	0	0	2	11	4	16
Water	1	4	1	3	0	2	1	3	0	2	0	2
Streambar	9	41	3	12	2	9	2	9	5	20	4	16
subtotal	***19***	***86***	***10***	***42***	***8***	***36***	***8***	***37***	***13***	***58***	***14***	***63***
Scrub	0	0	13	58	14	61	14	61	9	42	8	36
Misc feature	0	0	0	0	1	3	0	2	0	0	0	1
Mono Lake	3	14	0	0	0	0	0	0	0	0	0	0
Not mapped	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**23**	**100**	**23**	**100**	**23**	**100**	**23**	**100**	**23**	**100**	**23**	**100**

Lee Vining Reach 3D

Reach 3D is the contemporary delta of Lee Vining Creek and was inundated in 1929 (Figure 3-14). Stream gradient is about 0.1 percent. A woody riparian termination criterion was not established. The area of hydric resources (riparian, meadow, water, and streambar) has increased since 1999 conditions (Figure 3-15). This reach is influenced by annual fluctuations in Mono Lake elevation. The trend of the reach is improving. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

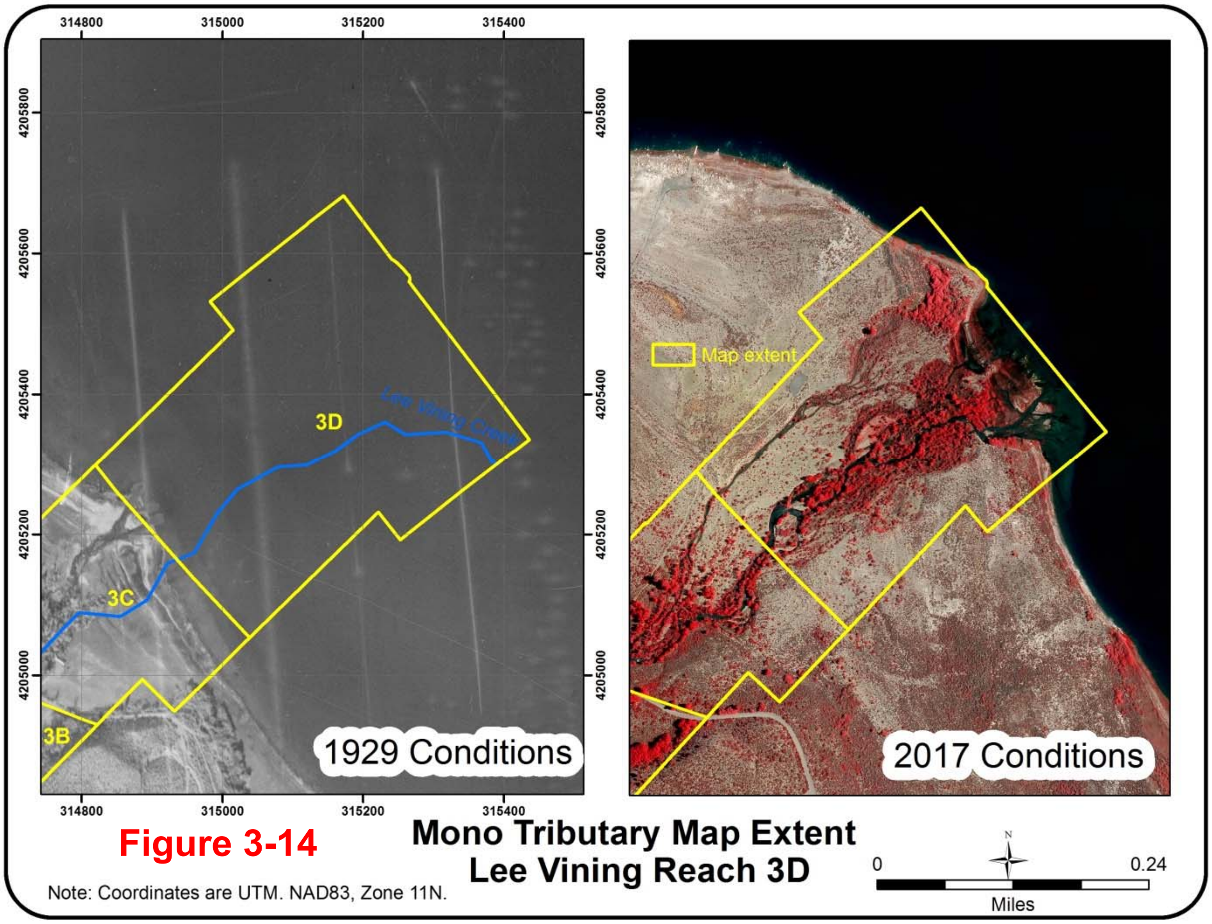


Figure 3-14 **Mono Tributary Map Extent Lee Vining Reach 3D**

Note: Coordinates are UTM. NAD83, Zone 11N.

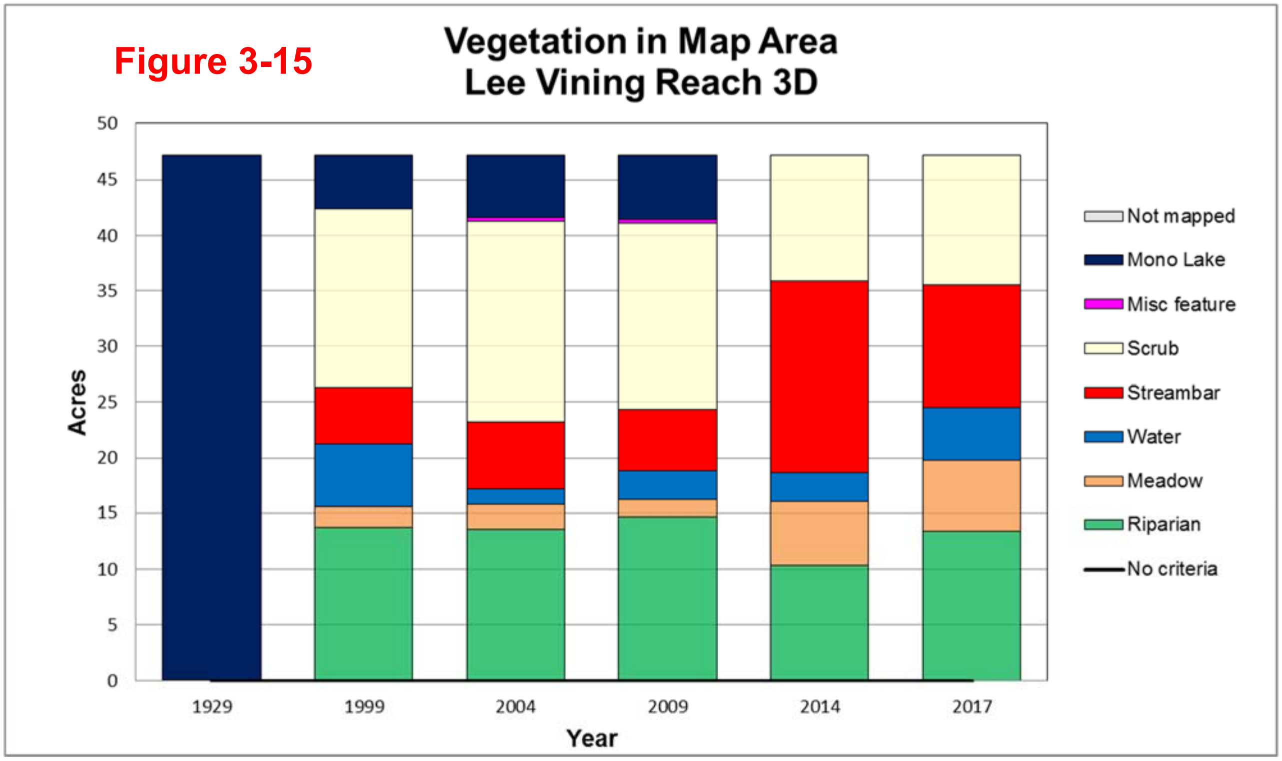


Table 3-8. Area of vegetation types in Lee Vining Reach 3D map area.												
Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	0	0	14	29	14	29	15	31	10	22	13	28
Meadow	0	0	2	4	2	5	2	4	6	12	6	14
Water	0	0	6	12	1	3	3	5	3	5	5	10
Streambar	0	0	5	11	6	13	6	12	17	37	11	23
subtotal	***0***	***0***	***26***	***56***	***23***	***49***	***24***	***52***	***36***	***76***	***35***	***75***
Scrub	0	0	16	34	18	38	17	35	11	24	12	25
Misc feature	0	0	0	0	0	1	0	1	0	0	0	0
Mono Lake	47	100	5	10	6	12	6	12	0	0	0	0
Not mapped	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**47**	**100**	**47**	**100**	**47**	**100**	**47**	**100**	**47**	**100**	**47**	**100**

3.2 Rush Creek

Rush Creek consists of 11 reaches, one of which (5B) was inundated by Mono Lake in 1929 (Figure 3-16). The total woody riparian termination criteria (234 acres) was approached in all years since 1999 (Figure 3-17). The area of contemporary hydric resources (riparian, meadow, water and streambar) is comparable to that identified for 1929 and have increased somewhat since 1999 (Table 3-9). The overall trend of Rush Creek is improving. Specific reaches of Rush Creek are subsequently discussed.

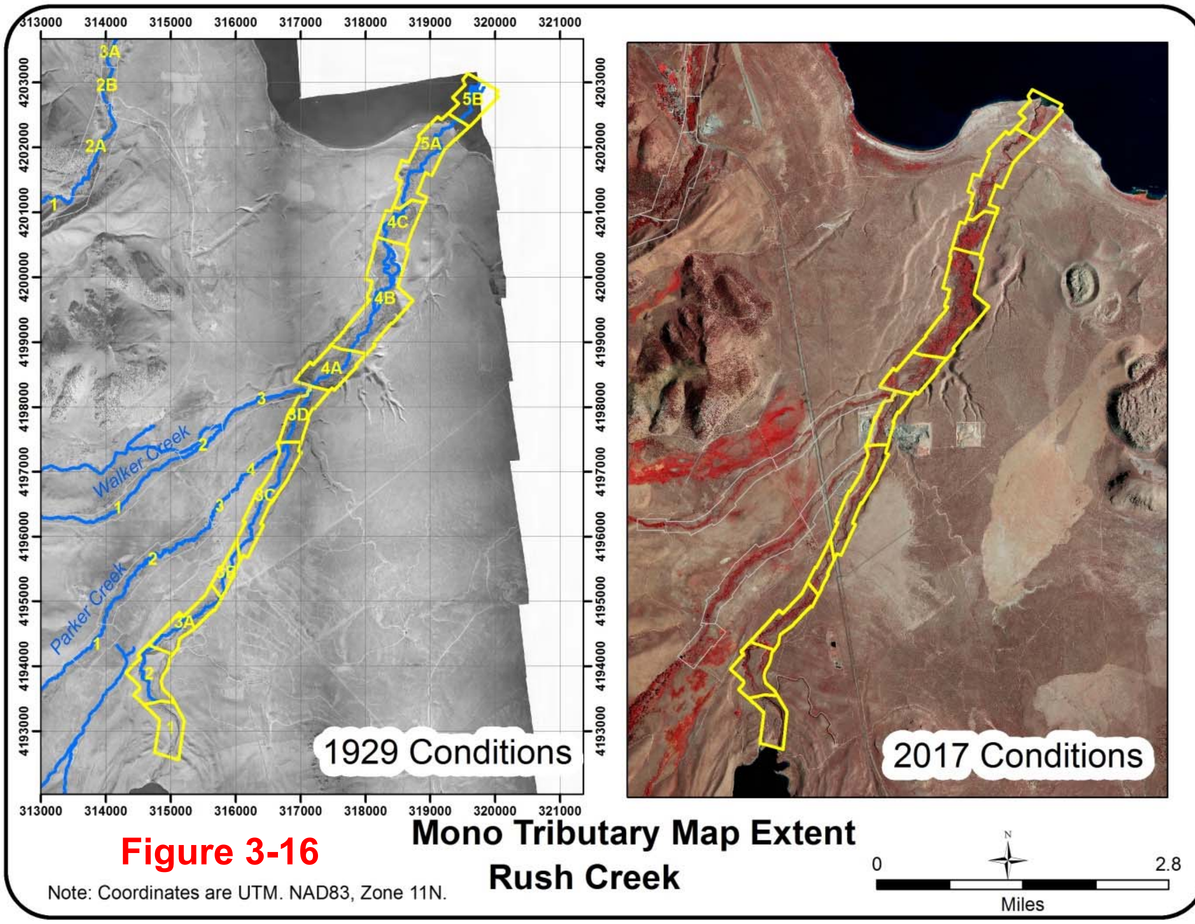


Figure 3-16 **Mono Tributary Map Extent Rush Creek**

Note: Coordinates are UTM. NAD83, Zone 11N.

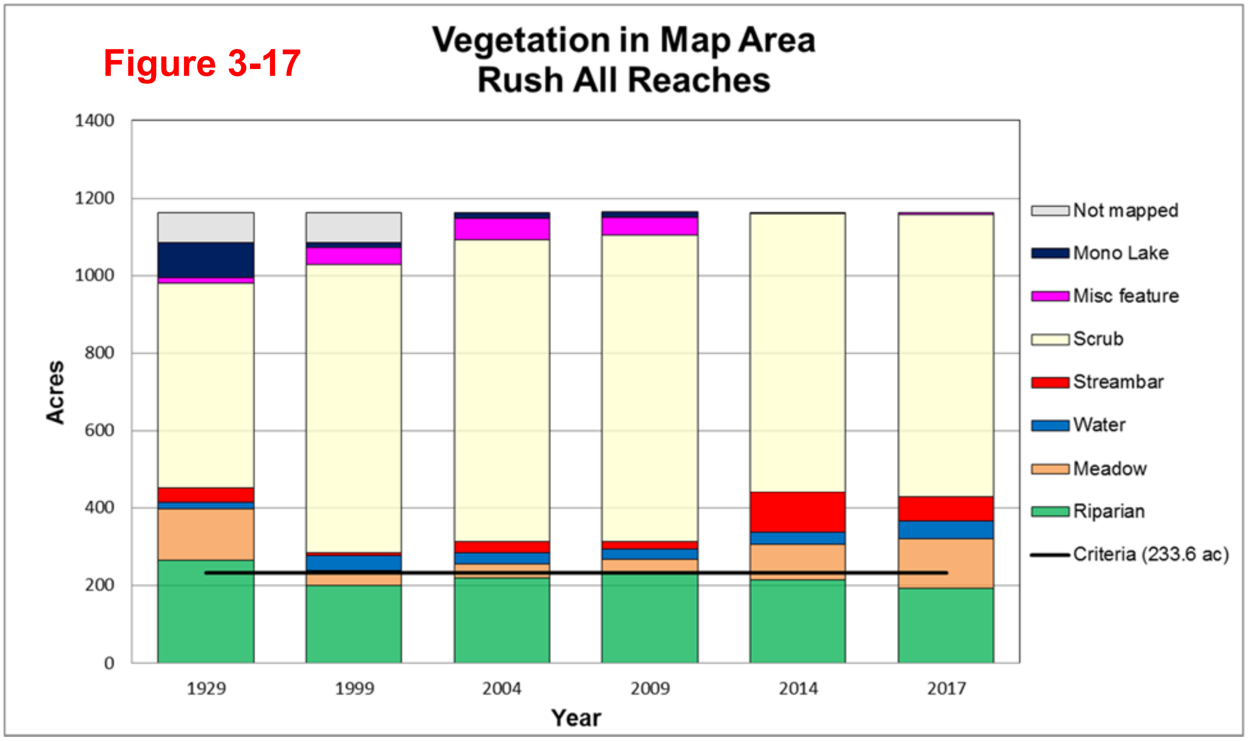


Table 3-9. Area of vegetation types in Rush all reaches map areas.												
Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	265	23	201	17	219	19	232	20	216	19	193	17
Meadow	133	11	38	3	38	3	35	3	91	8	127	11
Water	15	1	38	3	28	2	28	2	30	3	47	4
Streambar	40	3	7	1	27	2	20	2	104	9	62	5
subtotal	*454*	*39*	*284*	*24*	*313*	*27*	*315*	*27*	*441*	*38*	*429*	*37*
Scrub	526	45	743	64	782	67	790	68	719	62	729	63
Misc feature	14	1	44	4	55	5	47	4	4	0	6	1
Mono Lake	91	8	15	1	15	1	12	1	0	0	0	0
Not mapped	79	7	78	7	0	0	0	0	0	0	0	0
TOTAL	**1164**	**100**	**1164**	**100**	**1164**	**100**	**1164**	**100**	**1164**	**100**	**1164**	**100**

Rush Reach 1

Reach 1 is about is about 2,700 feet long between Grant Lake Dam and Rush Creek Return Ditch (Figure 3-18) and crosses the terminal moraine. While a woody riparian termination criterion (6.2 acres) was established, impacts of construction and management of Grant Lake Reservoir preclude achievement (Table 3-10). Reach 1 is exempt from woody riparian vegetation restoration (SWRCB Order WR 98-07).

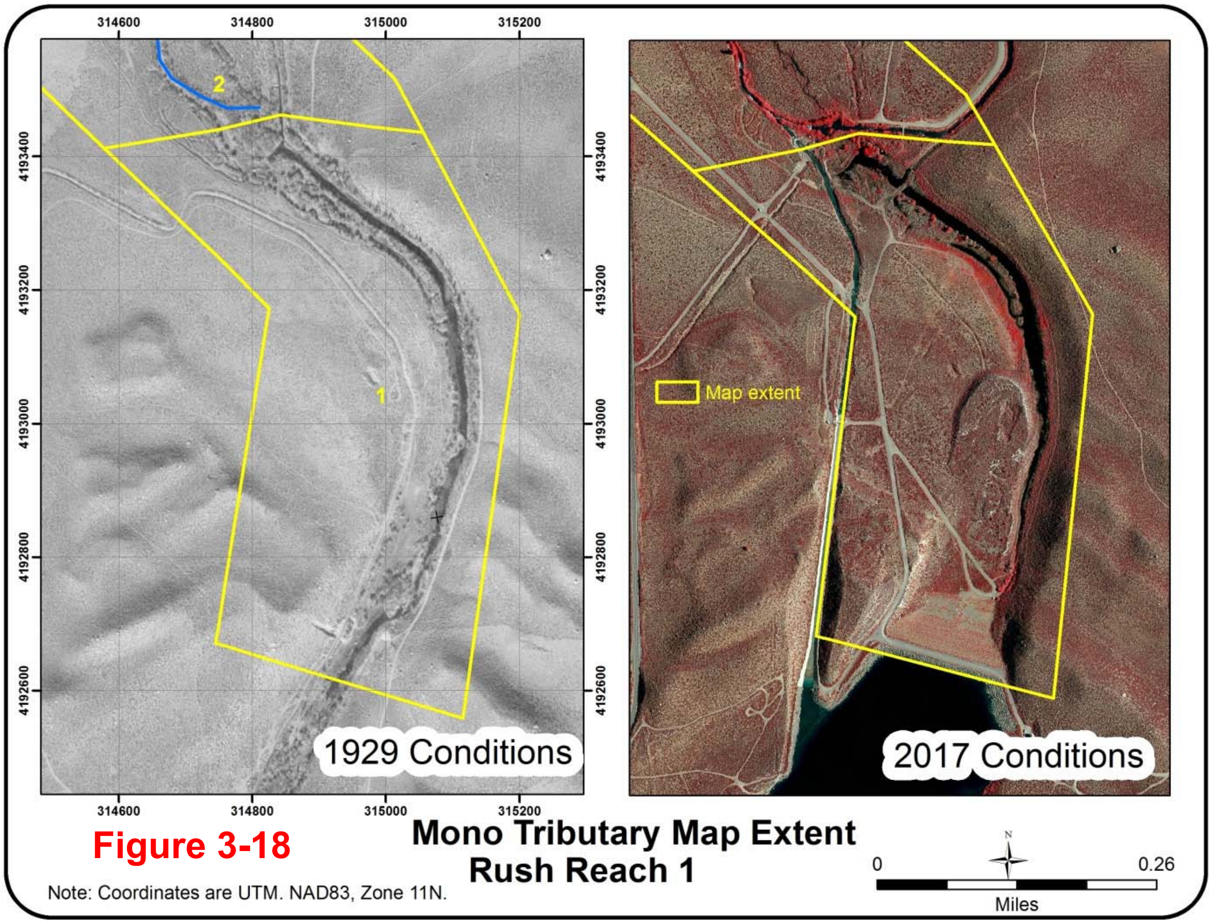


Figure 3-18

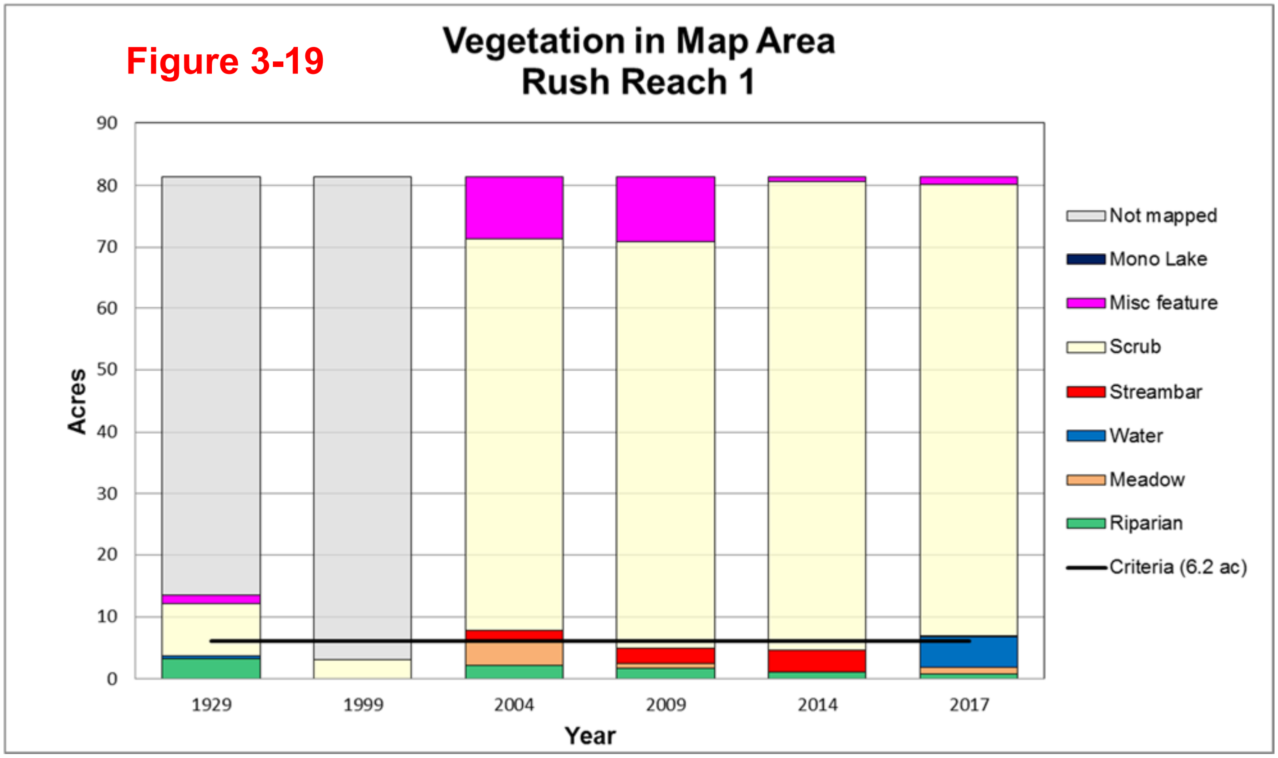


Table 3-10. Area of vegetation types in Rush Reach 1 map area.												
Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	3	4	0	0	2	3	2	2	1	1	1	1
Meadow	0	0	0	0	4	5	1	1	0	0	1	1
Water	0	1	0	0	0	0	0	0	0	0	5	6
Streambar	0	0	0	0	2	2	3	3	4	4	0	0
subtotal	***4***	***5***	***0***	***0***	***8***	***9***	***5***	***6***	***5***	***6***	***7***	***9***
Scrub	8	10	3	4	64	78	66	81	76	93	73	90
Misc feature	1	2	0	0	10	12	10	13	1	1	1	2
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	68	83	78	96	0	0	0	0	0	0	0	0
TOTAL	**81**	**100**	**81**	**100**	**81**	**100**	**81**	**100**	**81**	**100**	**81**	**100**

Rush Reach 2

Reach 2 extends about 3,800 feet below the Rush Creek Return Ditch and includes two forks (Figure 3-20). It is a canyon with the floodplain confined by lateral moraine. Stream gradient is 2.3 percent. The woody riparian termination criterion (5 acres) has been achieved (Figure 3-21). The extent of hydric resource (riparian, meadow, water, and streambar) has remained relatively consistent since 1929 (Table 3-11); minor differences are attributed to mapping error. The trend of this reach is stable. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

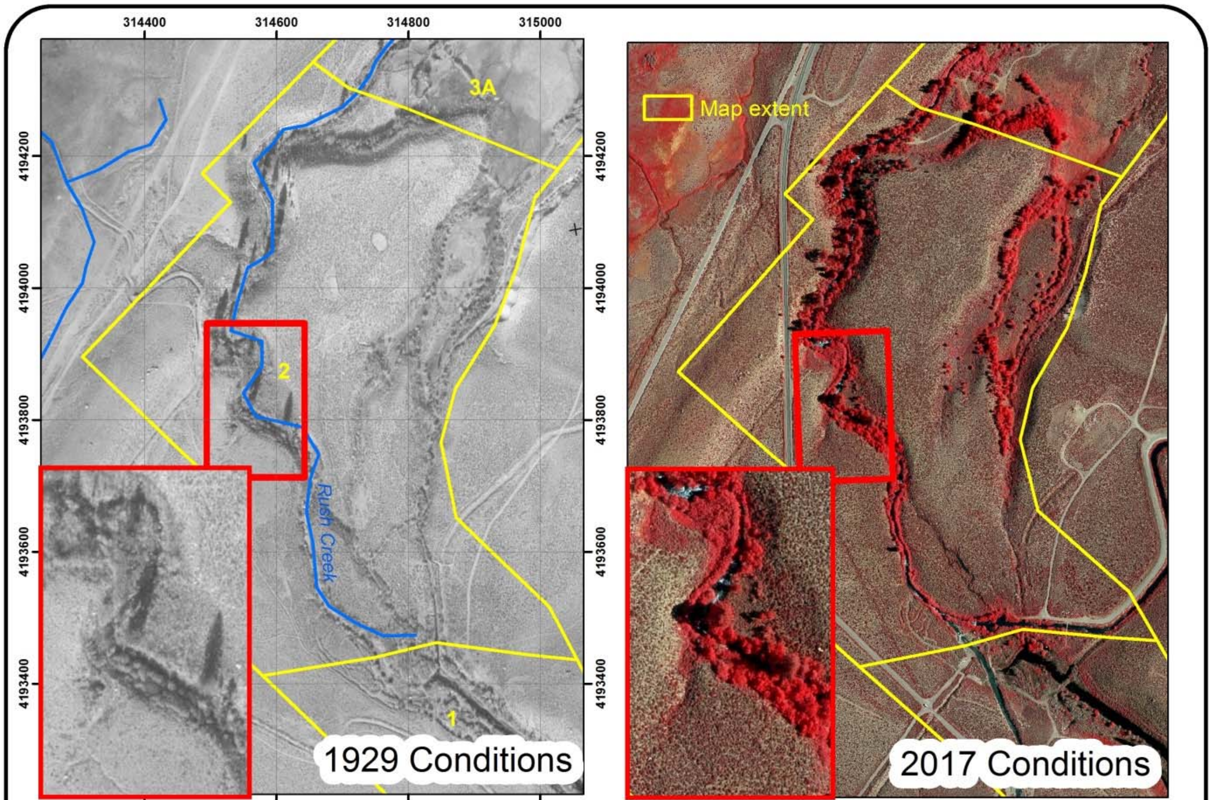


Figure 3-20 Mono Tributary Map Extent
Rush Reach 2

Note: Coordinates are UTM. NAD83, Zone 11N.

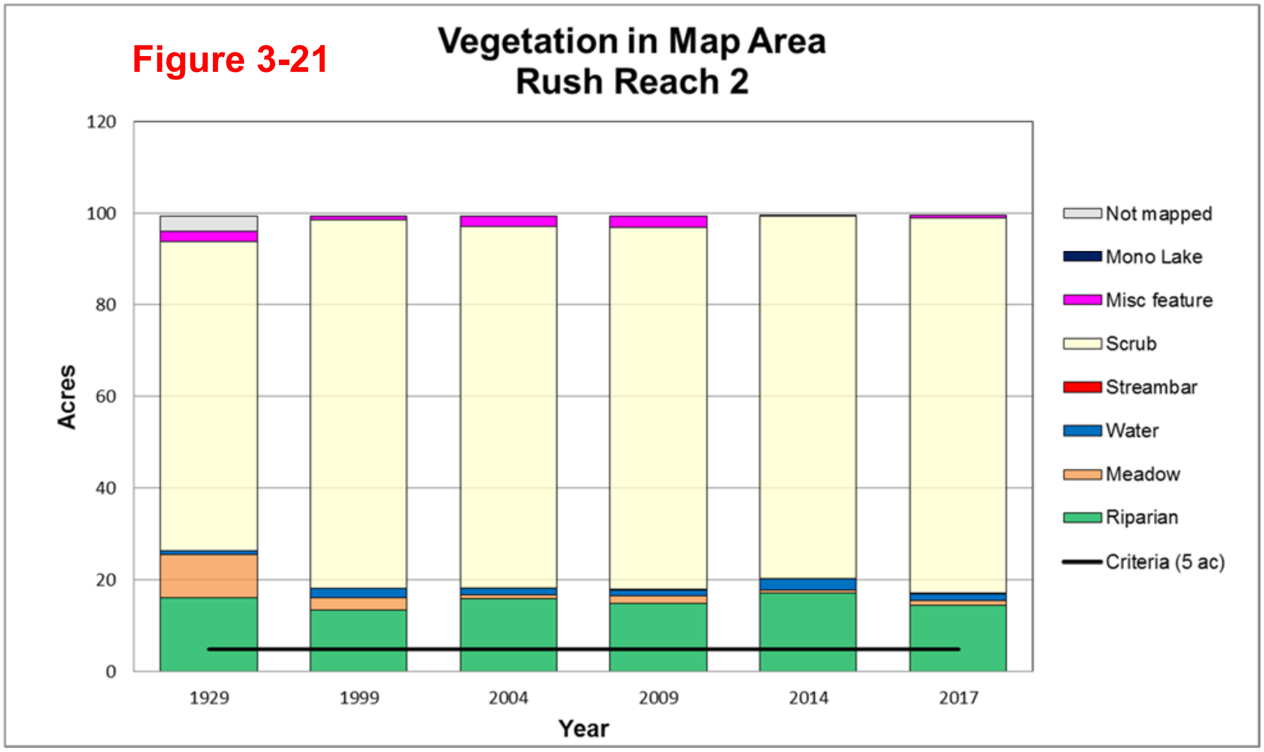


Table 3-11. Area of vegetation types in Rush Reach 2 map area.

Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	16	16	13	14	16	16	15	15	17	17	14	15
Meadow	9	9	3	3	1	1	2	2	1	1	1	1
Water	1	1	2	2	1	1	1	1	2	2	2	2
Streambar	0	0	0	0	0	0	0	0	0	0	0	0
subtotal	***26***	***26***	***18***	***18***	***18***	***18***	***18***	***18***	***20***	***20***	***17***	***17***
Scrub	68	68	80	81	79	79	79	80	79	79	82	82
Misc feature	2	2	1	1	2	2	2	2	0	0	0	0
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	3	3	0	0	0	0	0	0	0	0	0	0
TOTAL	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Rush Reach 3A

Reach 3A is about 4,700 feet long (Figure 3-22). It is relatively unconfined and crosses a broad bench of glacial outwash. Stream gradient is 2.3 percent. The woody riparian termination criteria (21.5 acres) was achieved in 2014 (Figure 3-23). The extent of hydric resources (riparian, meadow, water, and streambar) has increased since 1999 (Table 3-12). The trend for the reach is improving. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

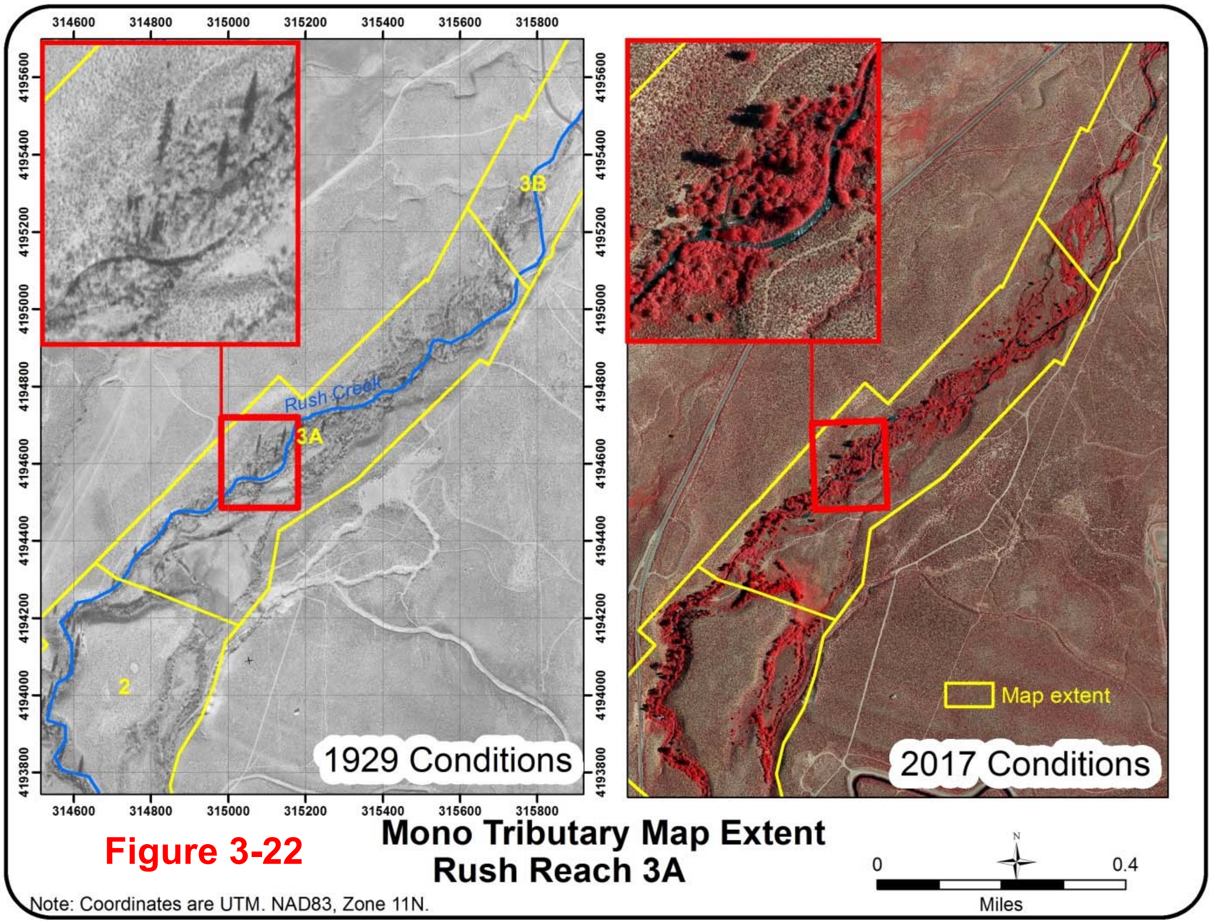


Figure 3-22 Mono Tributary Map Extent Rush Reach 3A

Figure 3-23

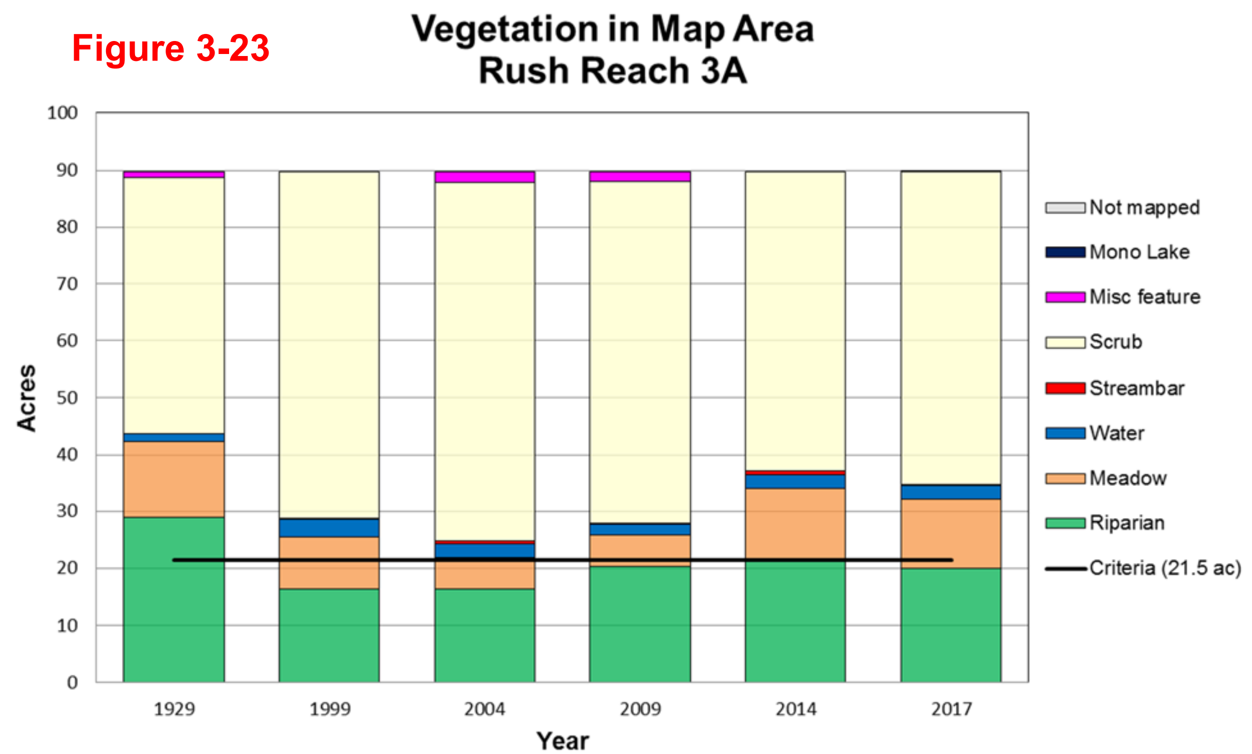


Table 3-12. Area of vegetation types in Rush Reach 3A map area.												
Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	29	32	16	18	16	18	20	23	22	24	20	22
Meadow	14	15	9	10	6	6	5	6	13	14	12	14
Water	1	2	3	3	2	3	2	2	2	3	2	3
Streambar	0	0	0	0	1	1	0	0	1	1	0	0
subtotal	***44***	***49***	***29***	***32***	***25***	***28***	***28***	***31***	***37***	***41***	***35***	***39***
Scrub	45	50	61	68	63	70	60	67	53	59	55	61
Misc feature	1	1	0	0	2	2	2	2	0	0	0	0
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**90**	**100**	**90**	**100**	**90**	**100**	**90**	**100**	**90**	**100**	**90**	**100**

Rush Reach 3B

Reach 3B extends about 2,800 feet long above Highway 395 (Figure 3-24). It is relatively unconfined and crosses a broad bench comprised of glacial outwash. Stream gradient is 1.4 percent. The woody riparian termination criteria (2.9 acres) was exceeded every year since 2004 (Figure 3-25). The extent of hydric resource (riparian, meadow, water, and streambar) has generally increased over the same period (Table 3-13). The trend for the reach is improving. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

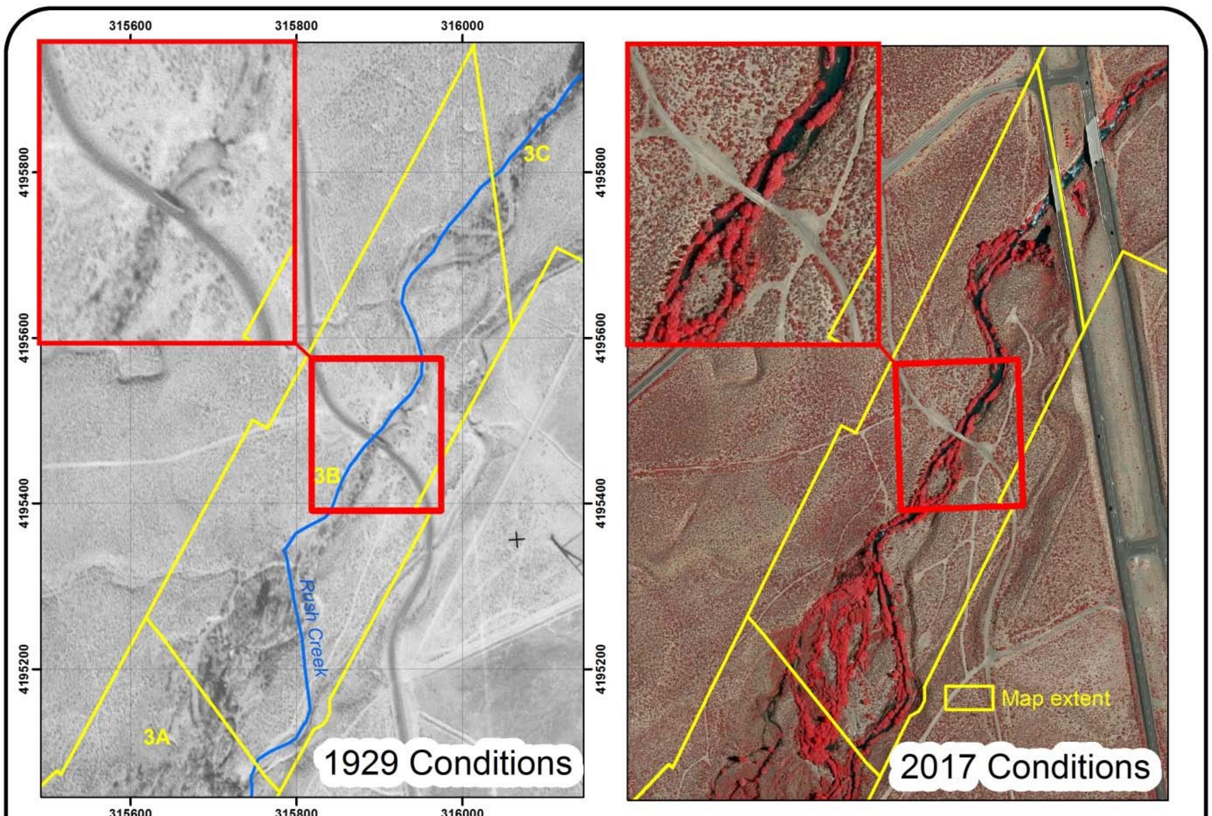


Figure 3-24 **Mono Tributary Map Extent**
Rush Reach 3B

Note: Coordinates are UTM. NAD83, Zone 11N.

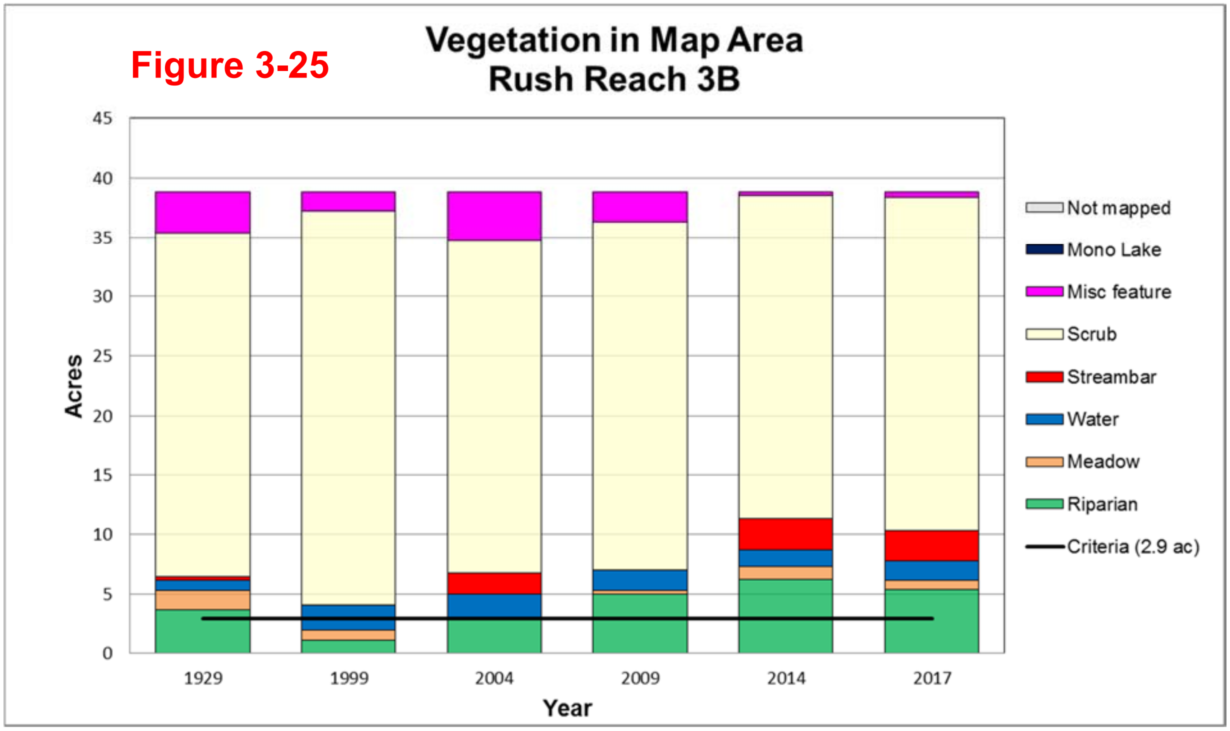


Table 3-13. Area of vegetation types in Rush Reach 3B map area.												
Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	4	10	1	3	3	7	5	13	6	16	5	14
Meadow	2	4	1	2	0	0	0	1	1	3	1	2
Water	1	2	2	5	2	5	2	4	1	4	2	4
Streambar	0	1	0	0	2	5	0	0	3	7	2	6
subtotal	***6***	***17***	***4***	***10***	***7***	***17***	***7***	***18***	***11***	***29***	***10***	***26***
Scrub	29	74	33	85	28	72	29	75	27	70	28	72
Misc feature	4	9	2	4	4	11	3	7	0	1	0	1
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**39**	**100**	**39**	**100**	**39**	**100**	**39**	**100**	**39**	**100**	**39**	**100**

Rush Reach 3C

Reach 3B extends from Highway 395 crossing to the confluence of Parker Creek and is about 6,900 feet long (Figure 3-26). The moderately wide floodplain is confined by broad benches comprised of glacial outwash. Stream gradient is 2.3 percent. The woody riparian termination criterion (2.9 acres) was achieved in 2009, 2014, and 2017 (Figure 3-27).   While the total extent of hydric resources (riparian, meadow, water, and streambar) has remained relatively constant (Table 3-14) over time, contemporary riparian vegetation appears more vigorous. The trend for this reach is stable. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

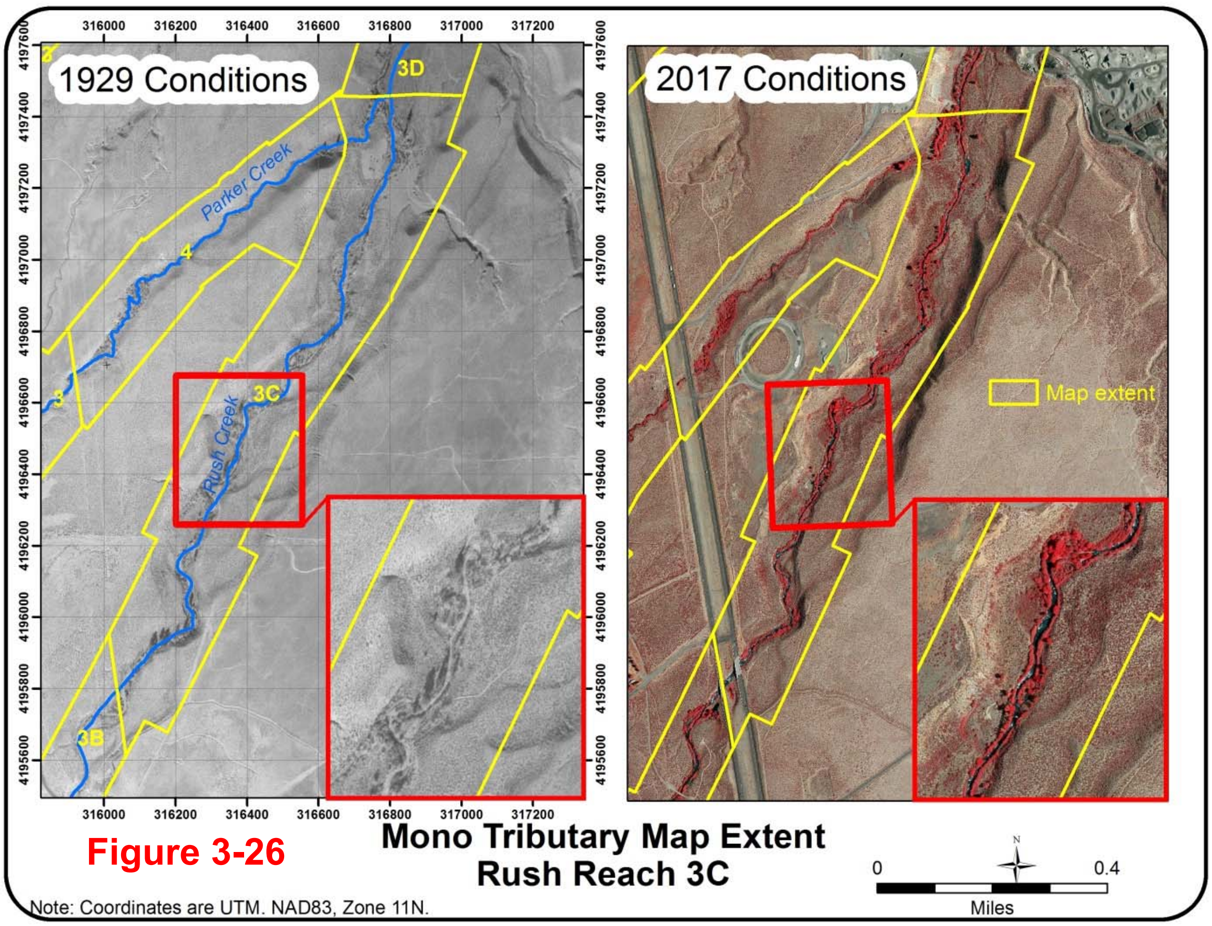


Figure 3-26

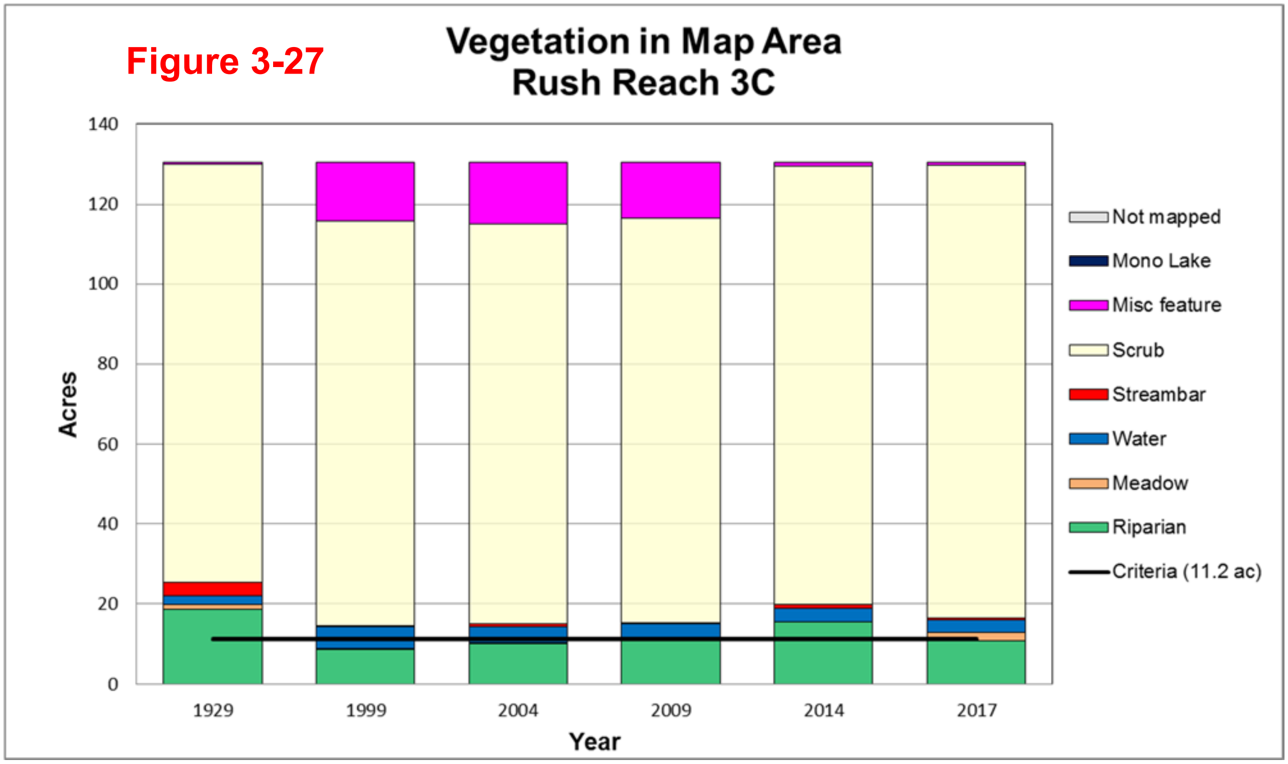


Table 3-14. Area of vegetation types in Rush Reach 3C map area.

Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	19	14	9	7	10	8	11	9	15	12	11	8
Meadow	1	1	0	0	0	0	0	0	0	0	2	1
Water	2	1	5	4	4	3	4	3	4	3	3	2
Streambar	3	3	0	0	1	1	0	0	1	1	0	0
subtotal	***25***	***19***	***14***	***11***	***15***	***12***	***15***	***12***	***20***	***15***	***17***	***13***
Scrub	105	80	101	78	100	77	101	78	110	84	113	87
Misc feature	0	0	15	11	15	12	14	11	1	1	1	1
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**130**	**100**	**130**	**100**	**130**	**100**	**130**	**100**	**130**	**100**	**130**	**100**

Rush Reach 3D

Reach 3B extends from the confluence of Parker Creek to the Narrows and is about 3,200 feet long (Figure 3-28). The moderately wide floodplain is confined by broad benches comprised of glacial outwash. Borrow pits flank both sides of the stream bottom. A restoration area that borders the east side of the stream in the lower half of the reach (see inset on Figure 3-28) was high-and-dry through 2014, but was partially flooded in 2017, enhancing likelihood of new riparian habitat. Stream gradient is 2.0 percent. The woody riparian termination criteria (10 acres) has not been achieved (Figure 3-29), although the total area of water and riparian exceeded termination criterion in 2009 and 2017. The total extent of hydric resource (riparian, meadow, water, and streambar) has remained relatively constant over time (Table 3-15). The trend for this reach is stable. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

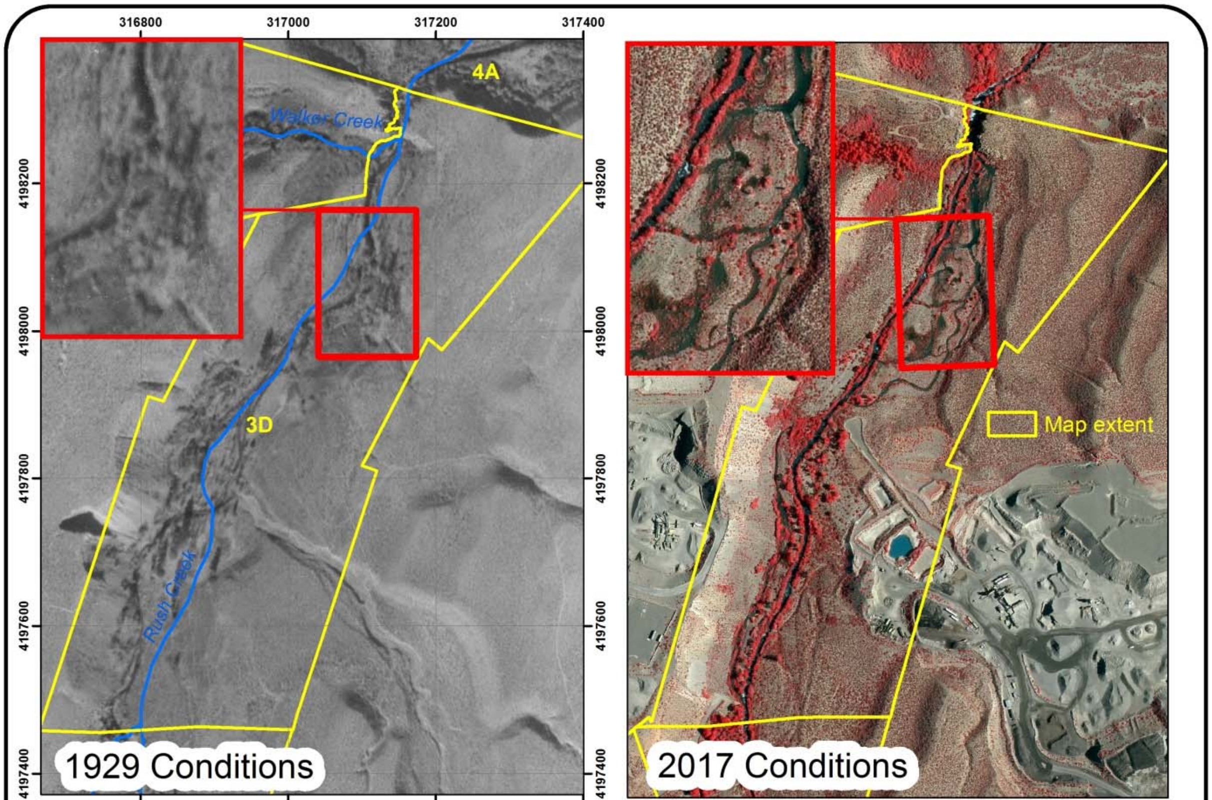


Figure 3-28 **Mono Tributary Map Extent Rush Reach 3D**

Note: Coordinates are UTM. NAD83, Zone 11N.

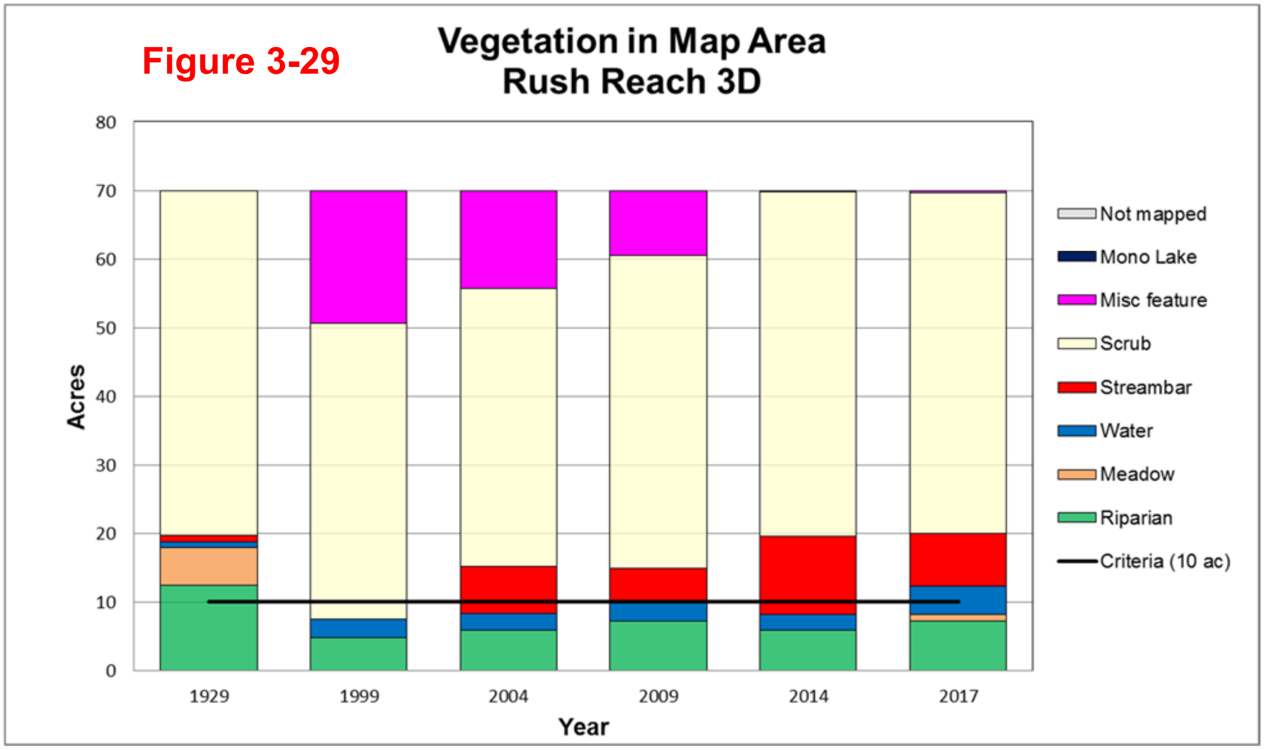


Table 3-15. Area of vegetation types in Rush Reach 3D map area.												
Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	12	18	5	7	6	8	7	10	6	8	7	10
Meadow	6	8	0	0	0	0	0	0	0	0	1	2
Water	1	1	3	4	2	3	3	4	2	3	4	6
Streambar	1	1	0	0	7	10	5	7	12	16	8	11
subtotal	***20***	***28***	***7***	***11***	***15***	***22***	***15***	***21***	***20***	***28***	***20***	***28***
Scrub	50	72	43	62	41	58	46	65	50	72	50	71
Misc feature	0	0	19	28	14	20	9	13	0	0	0	0
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**70**	**100**	**70**	**100**	**70**	**100**	**70**	**100**	**70**	**100**	**70**	**100**

Rush Reach 4A

Reach 4A is the upper reach of the "bottomlands" and extends about 3,050 feet below the Narrows (Figure 3-30). The wide floodplain is relatively unconfined. The east flank of the bottomlands was irrigated meadow in 1929. The reach appears to be somewhat incised and stream gradient is 1.9 percent. The woody riparian termination criterion (26.3 acres) was achieved in 2004 and 2009 (Figure 3-31). In 2014 and 2017 riparian canopy was delineated more precisely with spectral analysis and areas previously mapped as riparian were mapped as meadow. The total extent of hydric resources (riparian, meadow, water, and streambar) has remained relatively constant over time (Table 3-16). The trend of this reach is stable. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

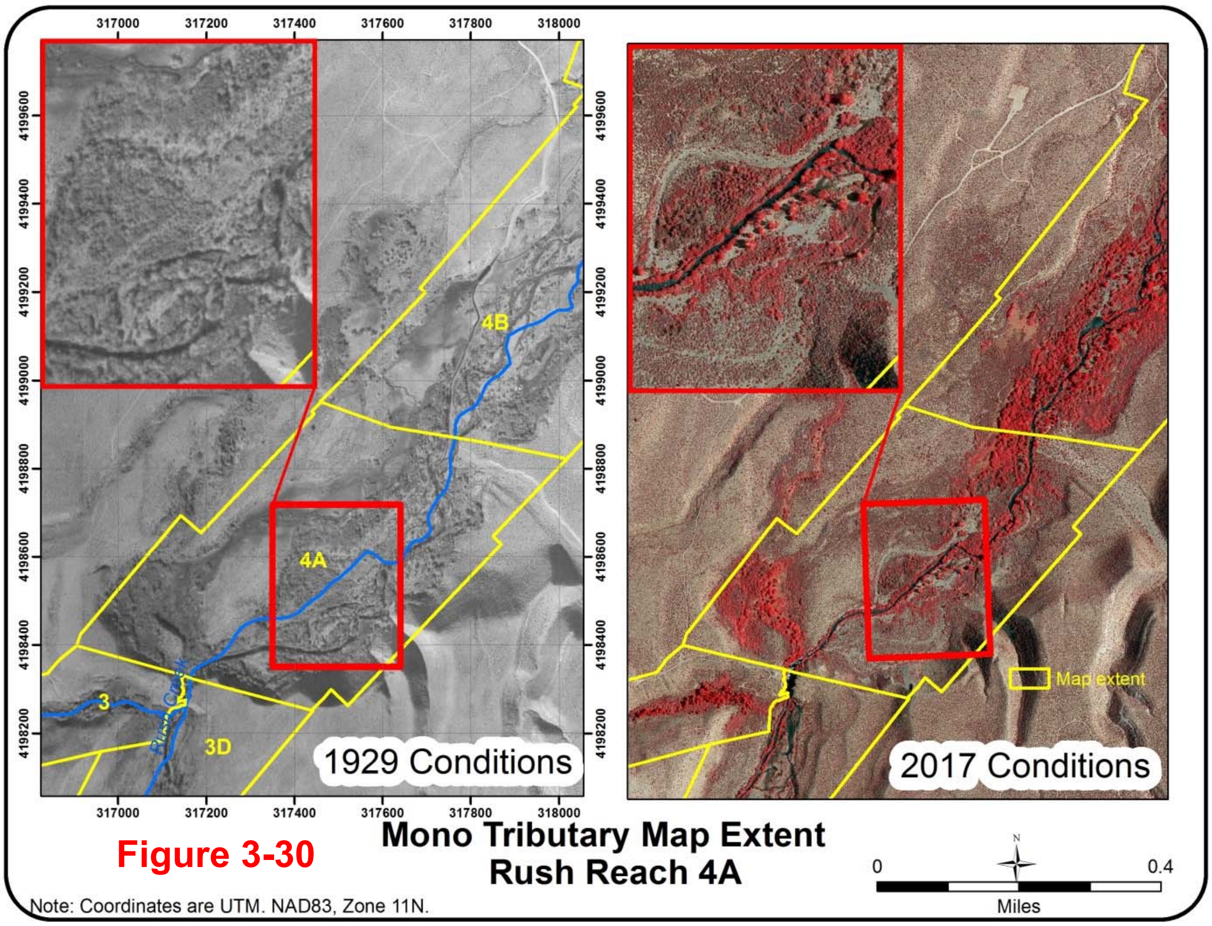


Figure 3-30 Mono Tributary Map Extent Rush Reach 4A

Note: Coordinates are UTM. NAD83, Zone 11N.

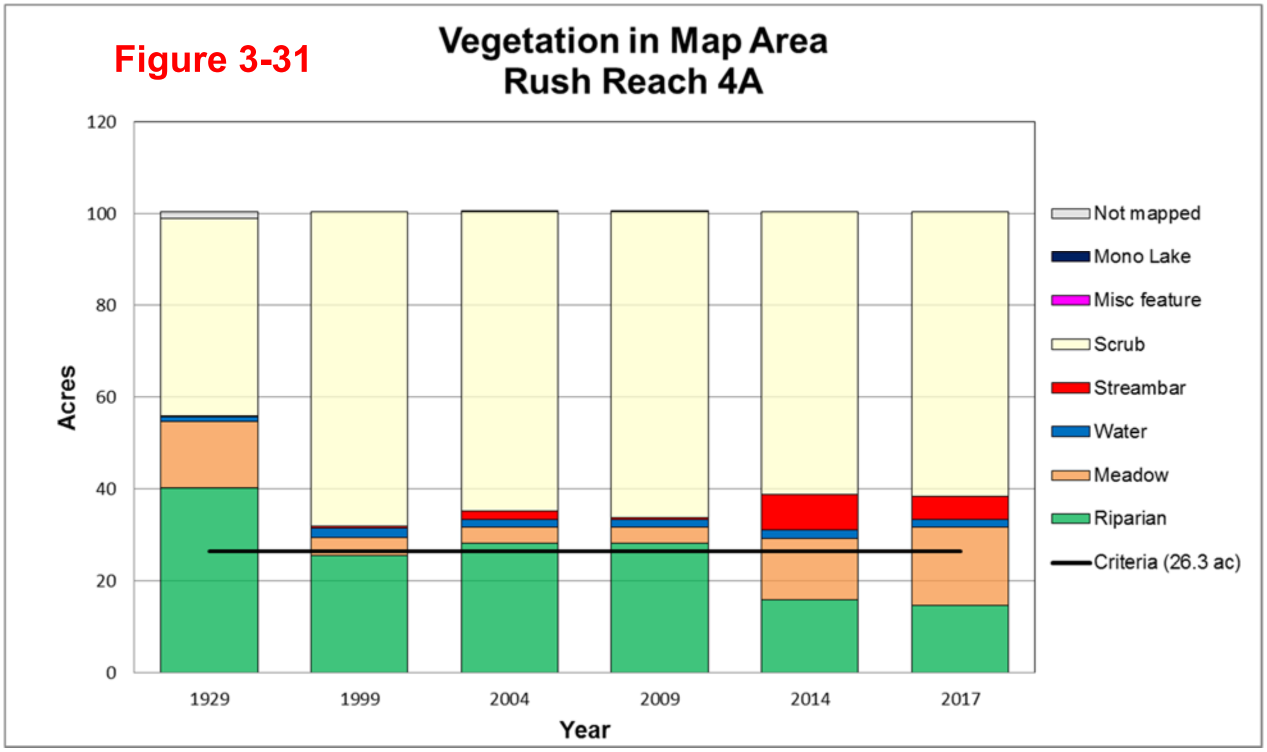


Table 3-16. Area of vegetation types in Rush Reach 4A map area.

Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	40	40	26	25	28	28	28	28	16	16	15	15
Meadow	14	14	4	4	4	3	4	4	13	13	17	17
Water	1	1	2	2	2	2	2	2	2	2	2	2
Streambar	0	0	0	0	2	2	0	0	8	8	5	5
subtotal	***56***	***56***	***32***	***32***	***35***	***35***	***34***	***33***	***39***	***39***	***38***	***38***
Scrub	43	43	69	68	65	65	67	67	62	61	62	62
Misc feature	0	0	0	0	0	0	0	0	0	0	0	0
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	1	1	0	0	0	0	0	0	0	0	0	0
TOTAL	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Rush Reach 4B

Reach 4B is part of the "bottomlands" and is about 7,550 feet long (Figure 3-32). The wide floodplain is relatively unconfined. Part of the east flank of the bottomlands was irrigated meadow in 1929. Stream gradient is 1.1 percent. The woody riparian termination criterion (80 acres) was approached in 2009 and 2014 (Figure 3-33). The total extent of hydric resource (riparian, meadow, water, and streambar) has increased since 1999 (Table 3-17). Contemporary hydric resources would likely exceed those of 1929 if not for irrigation. The trend of this reach is improving. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

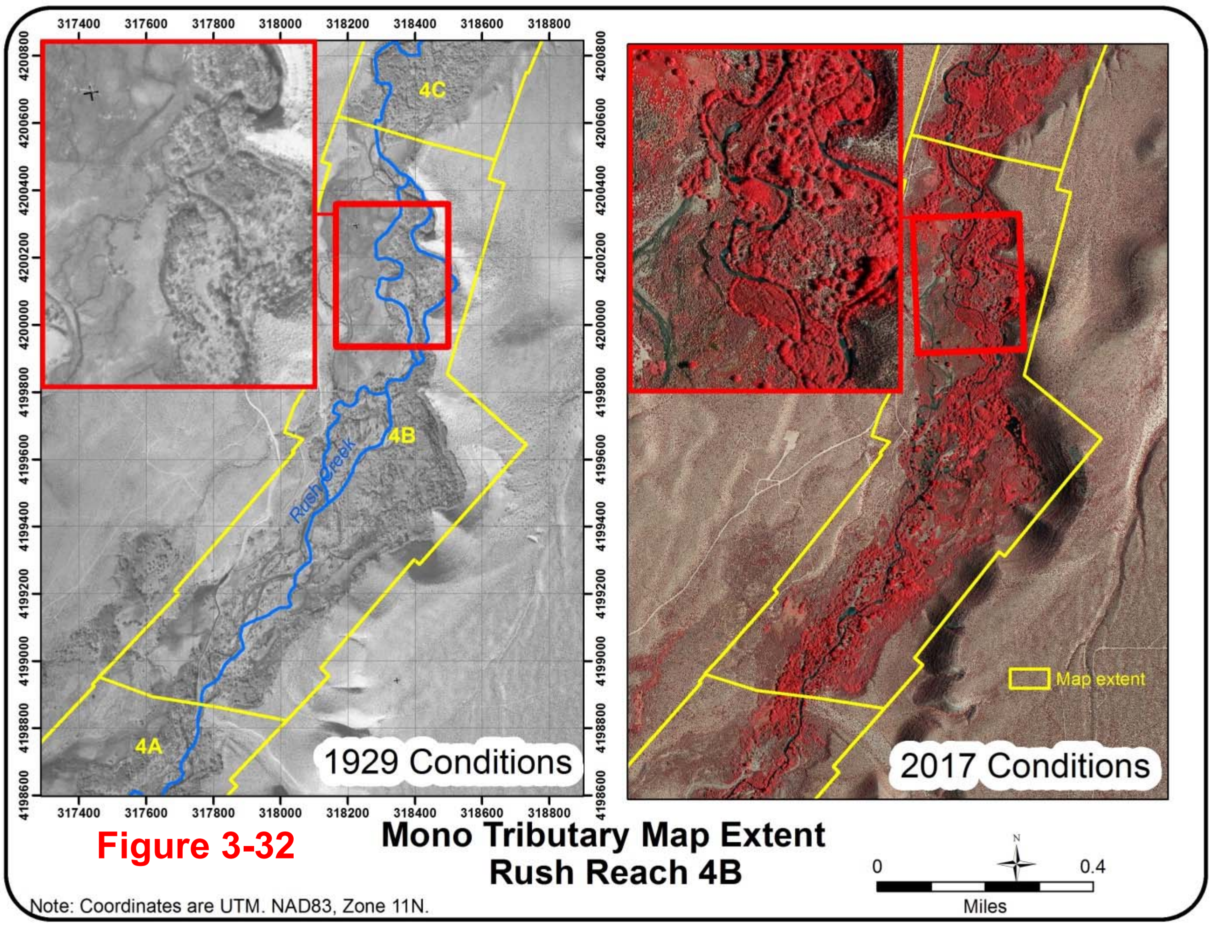


Figure 3-32

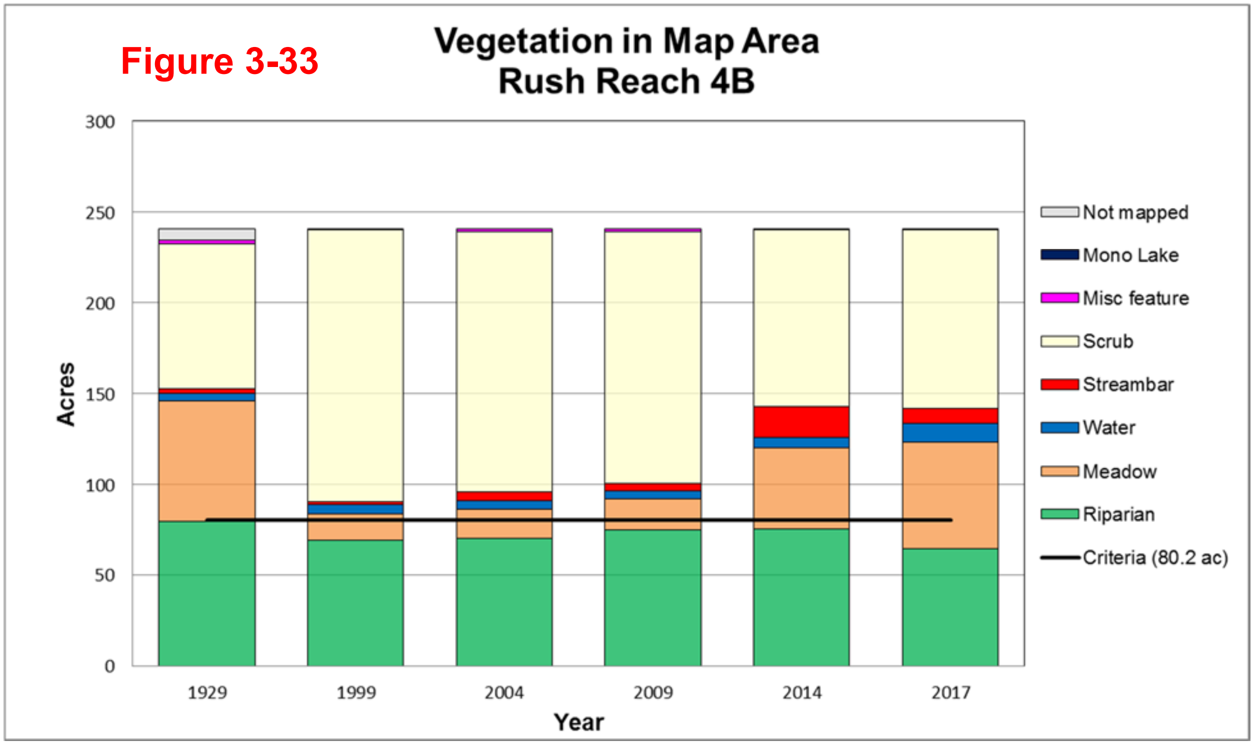


Table 3-17. Area of vegetation types in Rush Reach 4B map area.

Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	79	33	69	29	70	29	75	31	76	31	65	27
Meadow	67	28	15	6	16	7	17	7	45	18	59	24
Water	4	2	5	2	5	2	5	2	6	2	10	4
Streambar	3	1	2	1	5	2	4	2	17	7	9	4
subtotal	***153***	***63***	***90***	***38***	***96***	***40***	***101***	***42***	***143***	***59***	***142***	***59***
Scrub	80	33	150	62	143	59	139	57	97	40	98	41
Misc feature	2	1	0	0	2	1	2	1	0	0	1	0
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	6	2	0	0	0	0	0	0	0	0	0	0
TOTAL	**241**	**100**	**241**	**100**	**241**	**100**	**241**	**100**	**241**	**100**	**241**	**100**

s

Rush Reach 4C

Reach 4C is part of the “bottomlands” and extends about 3,350 feet upstream of the ford (Figure 3-34). The wide floodplain is relatively unconfined. Part of the east flank of the bottomlands was irrigated meadow in 1929. Stream gradient is 0.7 percent. Although contemporary riparian vegetation appears both more extensive and more robust than 1929 conditions, the woody riparian termination criterion (39 acres) has not been achieved. It appears the criterion was set at least 10 acres too high (Figure 3-35). The total extent of hydric resource (riparian, meadow, water, and streambar) has increased since 1929 (Table 3-18). The trend for this reach is improving. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

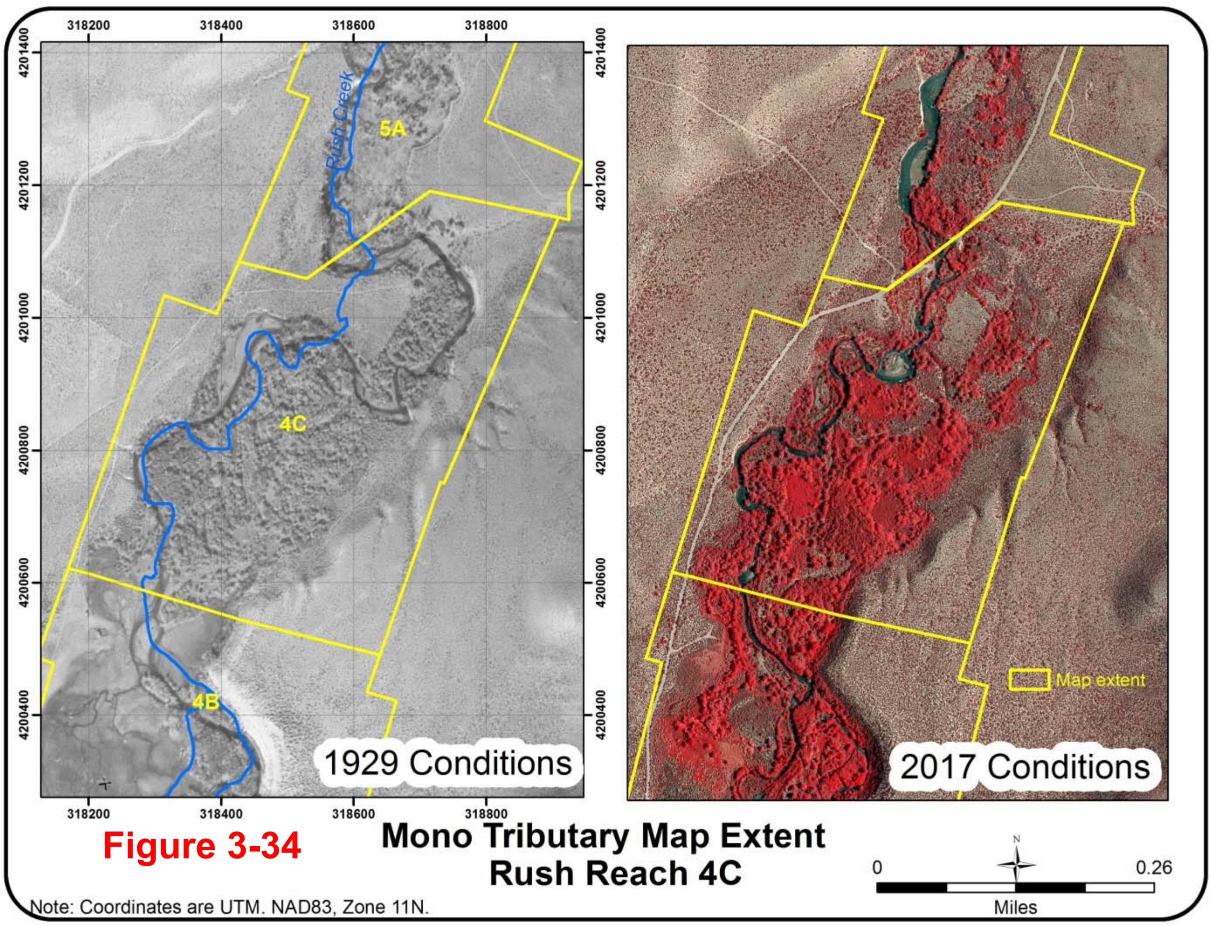


Figure 3-34

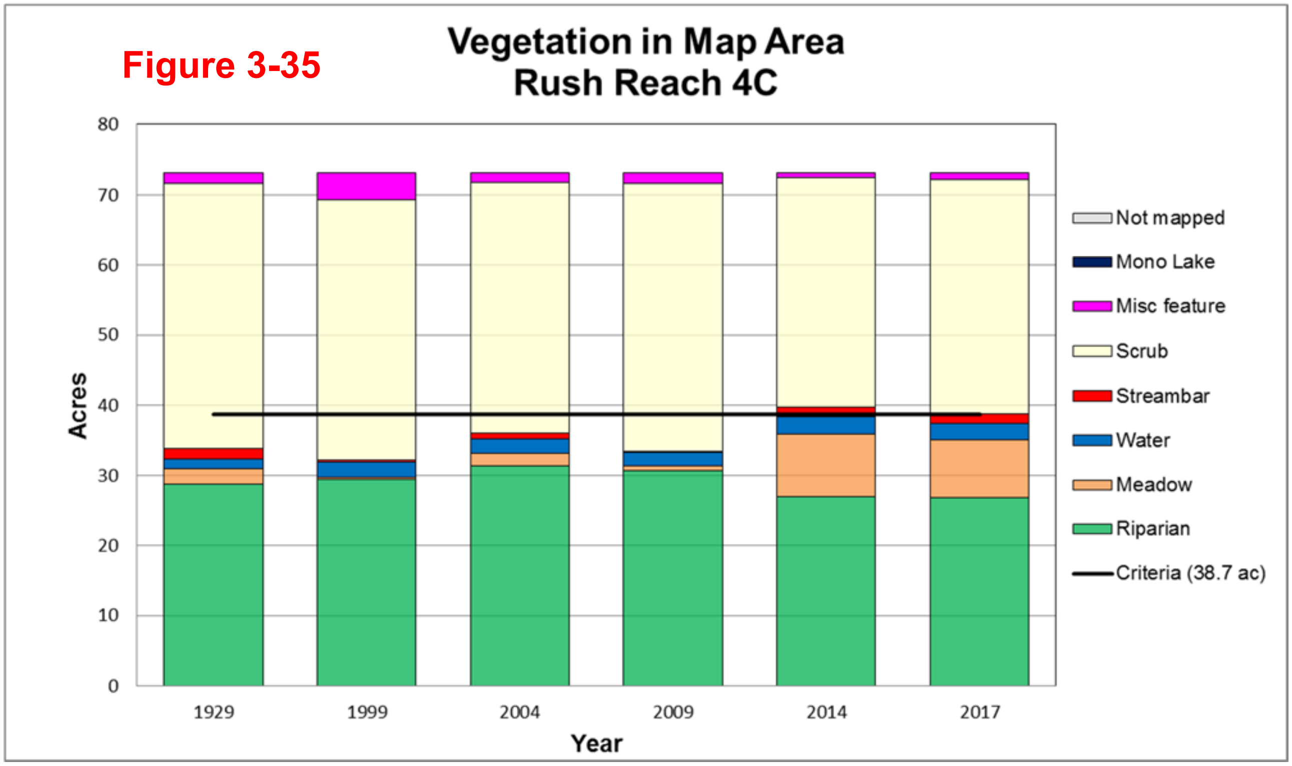


Table 3-18. Area of vegetation types in Rush Reach 4C map area.

Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	29	39	29	40	31	43	31	42	27	37	27	37
Meadow	2	3	0	0	2	2	1	1	9	12	8	11
Water	1	2	2	3	2	3	2	3	2	3	2	3
Streambar	2	2	0	0	1	1	0	0	1	2	1	2
subtotal	***34***	***46***	***32***	***44***	***36***	***49***	***34***	***46***	***40***	***54***	***39***	***53***
Scrub	38	52	37	51	36	49	38	52	33	45	33	46
Misc feature	1	2	4	5	1	2	2	2	1	1	1	1
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**73**	**100**	**73**	**100**	**73**	**100**	**73**	**100**	**73**	**100**	**73**	**100**

Rush Reach 5A

Reach 5A is about 6,900 feet long; the lower half of the reach is transitional to the Rush Creek delta (Figure 3-36). The wide floodplain is relatively unconfined. Part of the east flank of the bottomlands was irrigated meadow in 1929. Stream gradient is 0.8 percent. The woody riparian termination criterion (38 acres) has not been achieved (Figure 3-37). This reach is unlikely to achieve termination criteria because of channel down-cutting (McBain and Trush 2005) in response to lowering of Mono Lake. Streambars identified in 2014 and 2017 are high-and-dry with low potential for establishment of riparian vegetation[6]. Other hydric resource (riparian, meadow, and water) have colonized the incised channel bottom and have remained relatively consistent since 1999 (Table 3-19). The incision lowered alluvial groundwater and limited the extent of riparian to the incised channel bottom. Parts of the channel bottom were further down-cut by runoff in 2017. The trend for this reach is deteriorating. This reach is <u>not</u> functional and may get worse before it gets better. Future aggradation may occur if Mono Lake continues to rise.

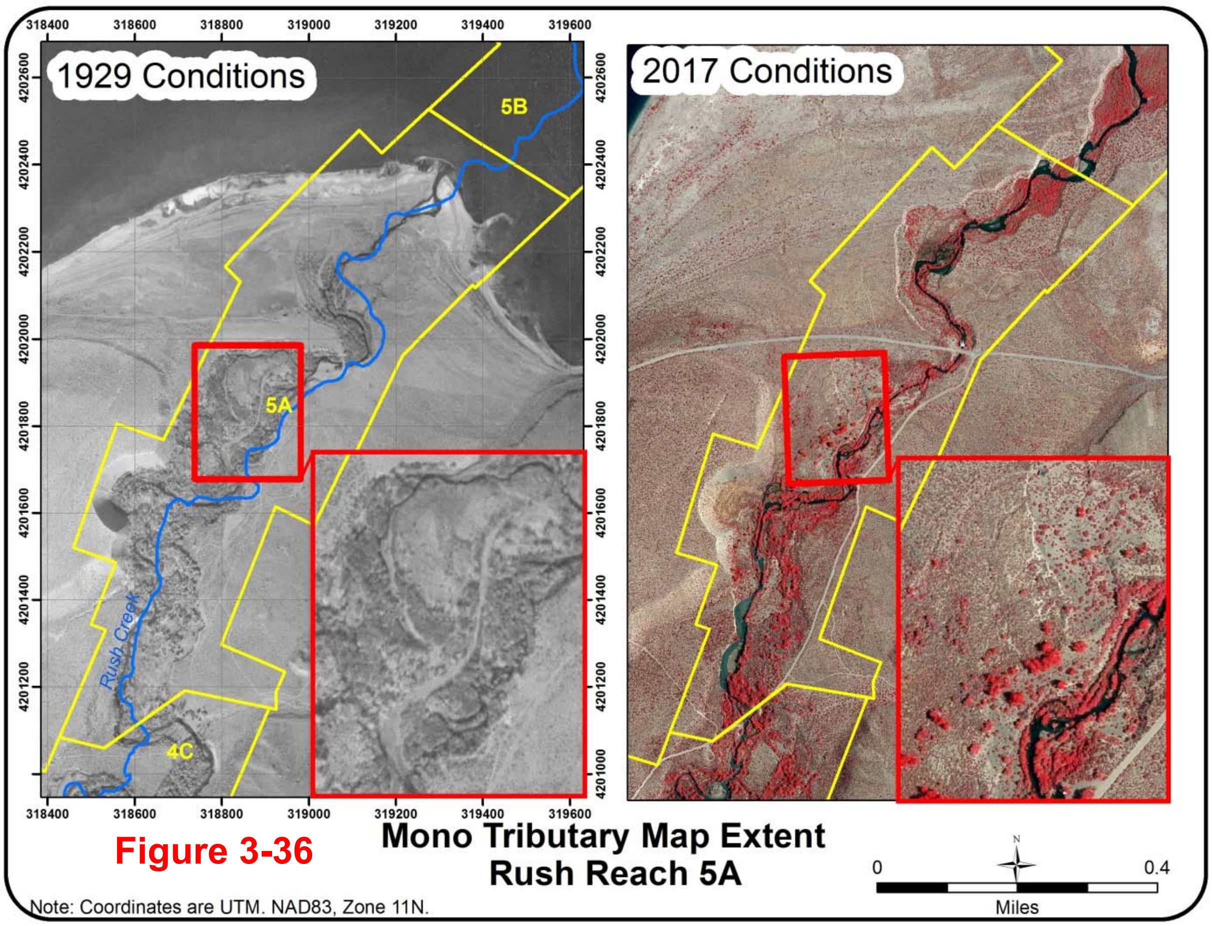


Figure 3-36

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[6] Large areas of streambar delineated in 2014 and 2017 were mapped as Scrub in 1999, 2004, and 2009.

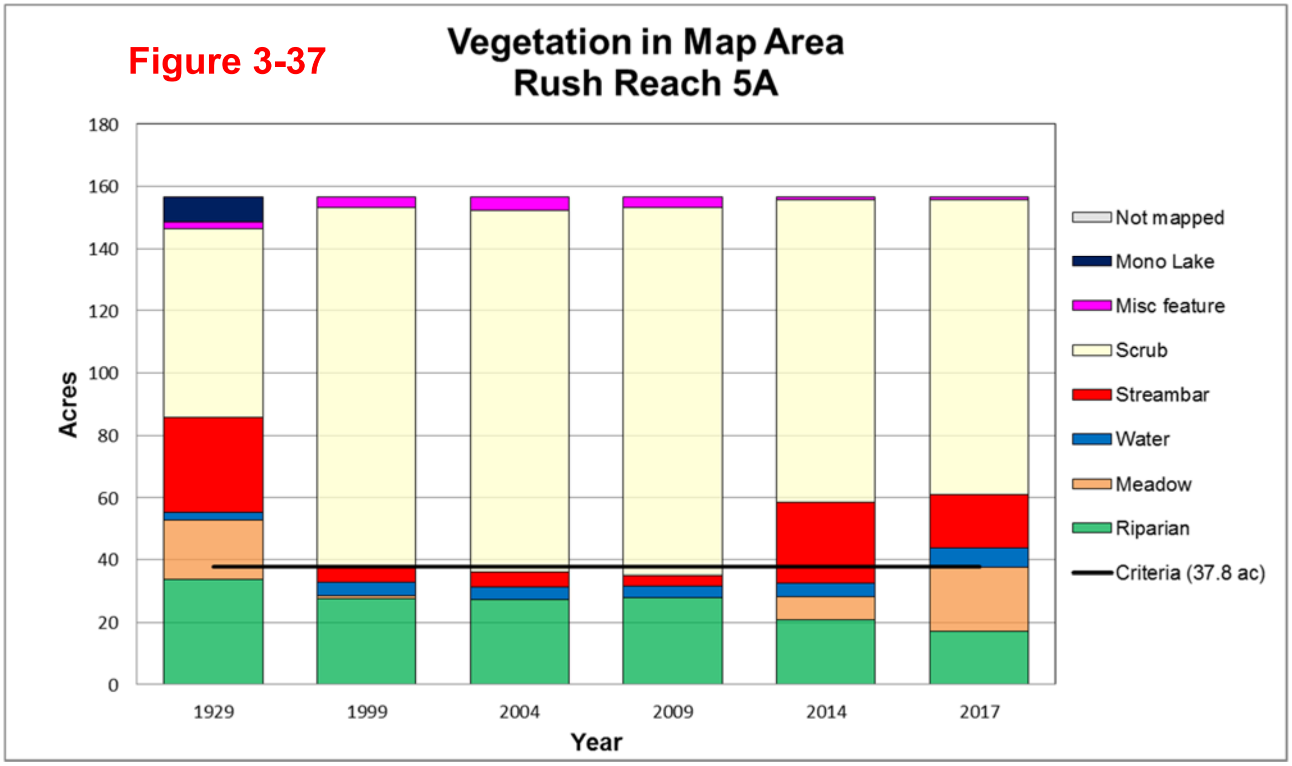


Table 3-19. Area of vegetation types in Rush Reach 5A map area.												
Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	34	22	28	18	27	17	28	18	21	13	17	11
Meadow	19	12	1	1	0	0	0	0	7	5	20	13
Water	3	2	4	3	4	3	4	2	4	3	6	4
Streambar	30	19	4	3	5	3	3	2	26	17	17	11
subtotal	***86***	***55***	***37***	***24***	***36***	***23***	***35***	***22***	***59***	***37***	***61***	***39***
Scrub	61	39	116	74	116	74	118	75	97	62	95	60
Misc feature	2	1	3	2	4	3	4	2	1	1	1	1
Mono Lake	8	5	0	0	0	0	0	0	0	0	0	0
Not mapped	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**157**	**100**	**157**	**100**	**157**	**100**	**157**	**100**	**157**	**100**	**157**	**100**

Rush Reach 5B

Reach 5B is the contemporary delta of Rush Creek and was inundated in 1929 (Figure 3-38). Stream gradient is about 0.7 percent. Woody riparian termination criterion was not established. Streambar identified in 2014 and 2017 (Figure 3-39) are high-and-dry with low potential for establishment of riparian vegetation. The area of other hydric resource (riparian, meadow and water) has generally increased since 1999 conditions(Table 3-20). This reach is influenced by annual fluctuations in Mono Lake elevation. The trend for the reach is improving. This reach is functional and self-sustaining (delta) with healthy riparian ecosystem that requires no physical manipulation.

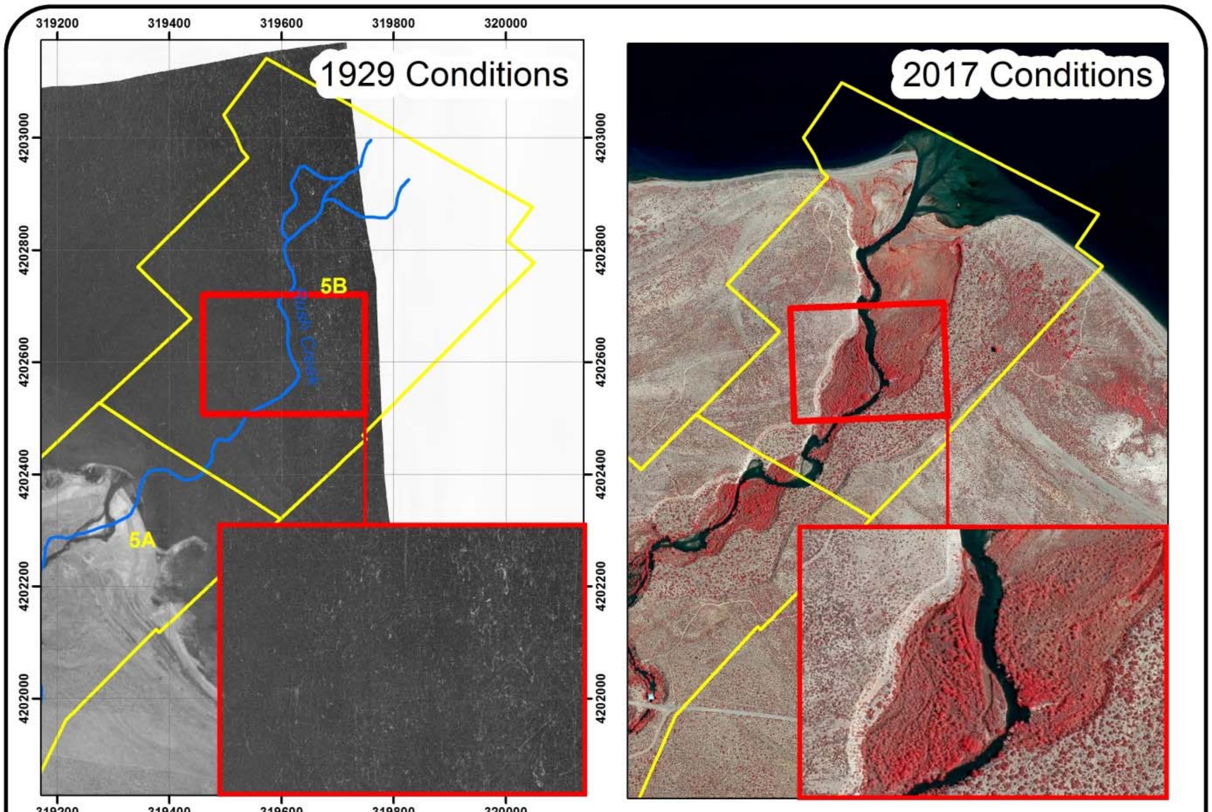


Figure 3-38 Mono Tributary Map Extent
Rush Reach 5B

Note: Coordinates are UTM. NAD83, Zone 11N.

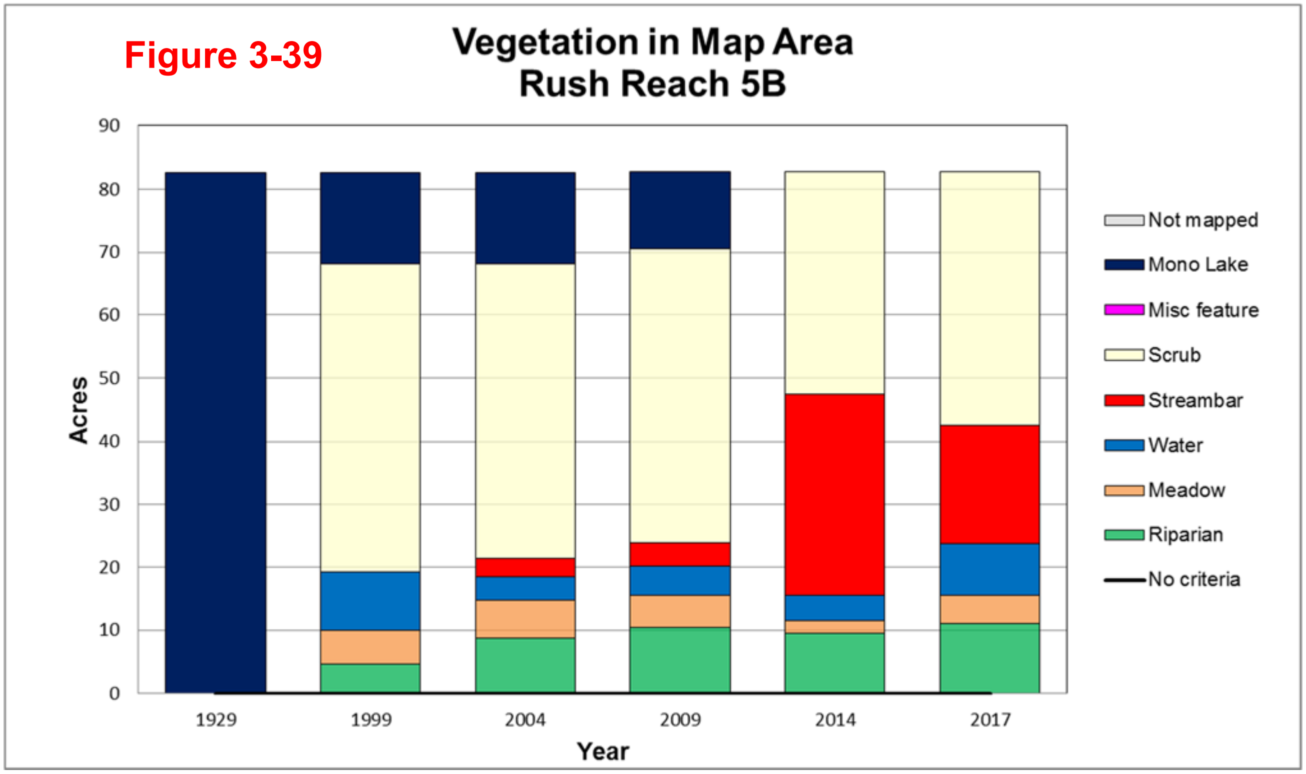


Table 3-20. Area of vegetation types in Rush Reach 5B map area.

Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	0	0	5	6	9	11	10	13	9	11	11	13
Meadow	0	0	5	6	6	7	5	6	2	3	4	5
Water	0	0	9	11	4	5	5	6	4	5	8	10
Streambar	0	0	0	0	3	4	4	4	32	39	19	23
subtotal	***0***	***0***	***19***	***23***	***21***	***26***	***24***	***29***	***47***	***57***	***43***	***51***
Scrub	0	0	49	59	47	57	47	56	35	43	40	49
Misc feature	0	0	0	0	0	0	0	0	0	0	0	0
Mono Lake	83	100	15	18	15	18	12	15	0	0	0	0
Not mapped	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**83**	**100**	**83**	**100**	**83**	**100**	**83**	**100**	**83**	**100**	**83**	**100**

3.3 Parker Creek

Parker Creek consists of 4 reaches (Figure 3-40). Parker Creek was not mapped in 2009. There is no woody riparian termination criterion for Parker Creek. The area of riparian has remained constant since 1999 (Figure 3-41). Irrigation of meadows along Parker Creek was curtailed in 2000, resulting in less meadow and more scrub. Meadow has remained constant since 2004. The overall trend for Parker Creek appears stable (Table 3-21). Specific reaches of Parker Creek are subsequently discussed.

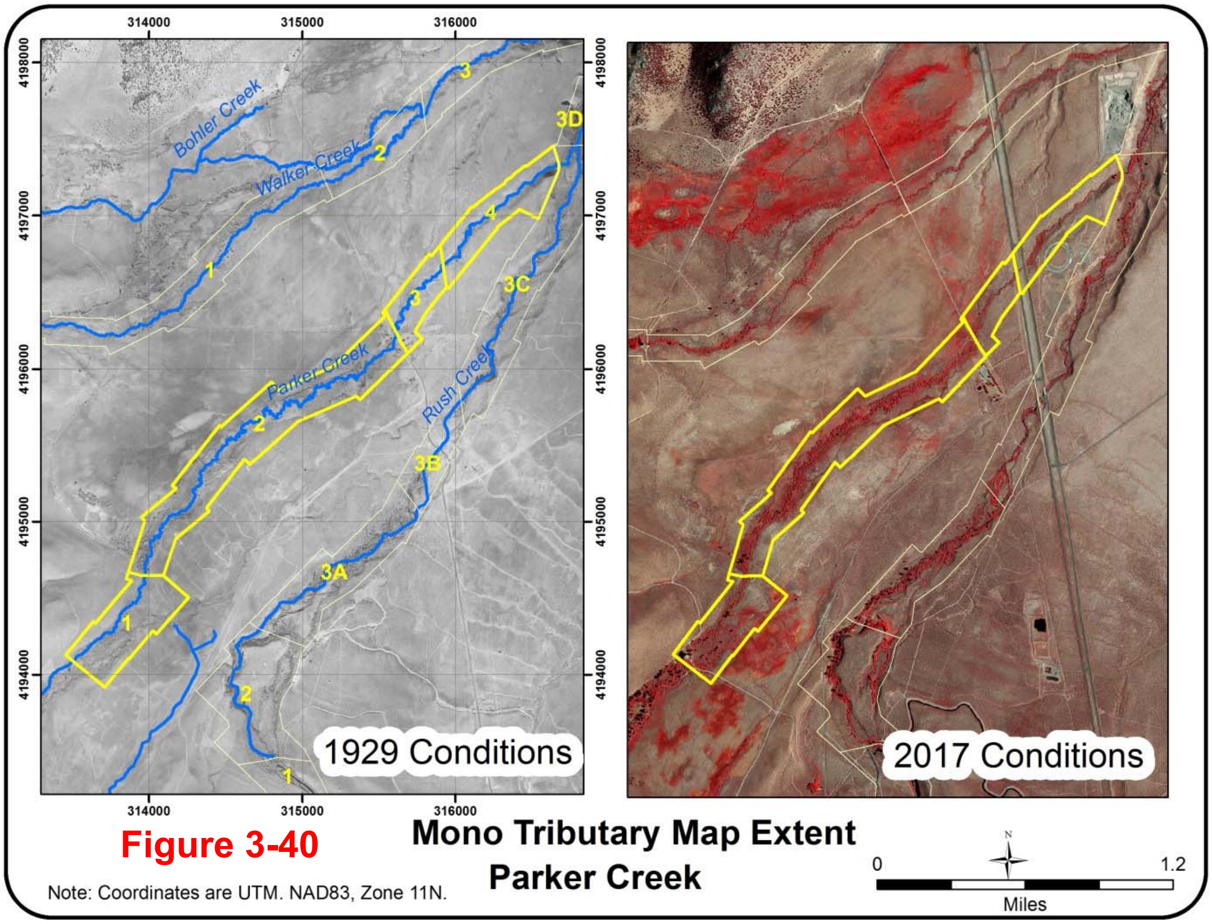


Figure 3-40

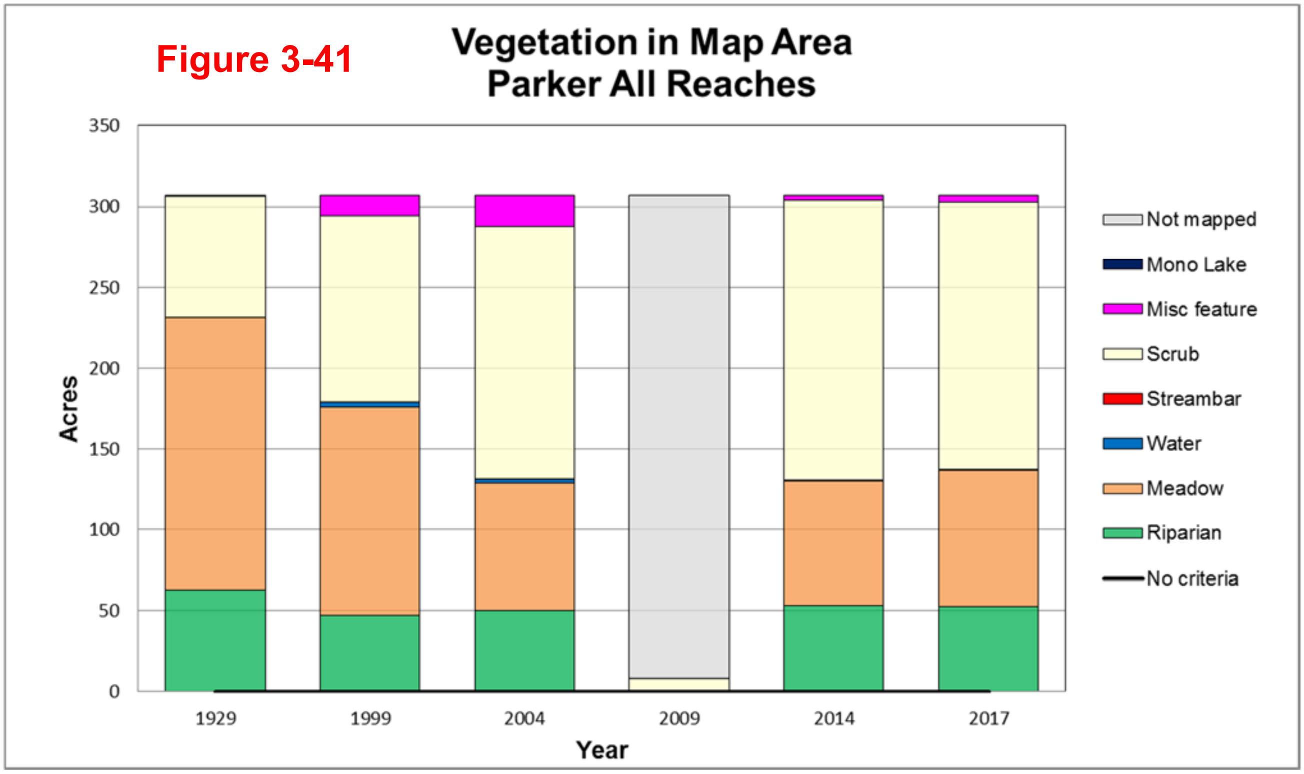


Table 3-21. Area of vegetation types in Parker all reaches map areas.

Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	63	20	47	15	50	16	0	0	53	17	53	17
Meadow	168	55	129	42	79	26	0	0	77	25	84	27
Water	0	0	2	1	2	1	0	0	0	0	1	0
Streambar	0	0	0	0	0	0	0	0	0	0	0	0
subtotal	***231***	***75***	***179***	***58***	***131***	***43***	***0***	***0***	***130***	***43***	***137***	***45***
Scrub	75	24	116	38	156	51	8	3	173	57	166	54
Misc feature	0	0	12	4	19	6	0	0	3	1	4	1
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	0	0	0	0	0	0	299	97	0	0	0	0
TOTAL	**307**	**100**	**307**	**100**	**307**	**100**	**307**	**100**	**307**	**100**	**307**	**100**

Parker Reach 1

Reach 1 is a unconfined reach about 2,750 feet long (Figure 3-42). Parts of the map area were irrigated meadow in 1929. Stream gradient is 1.9 percent. Riparian vegetation has increased since 1929 (Figure 3-43). Meadow has increased slightly since 1999 (Table 3-22). The trend for this reach is stable. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

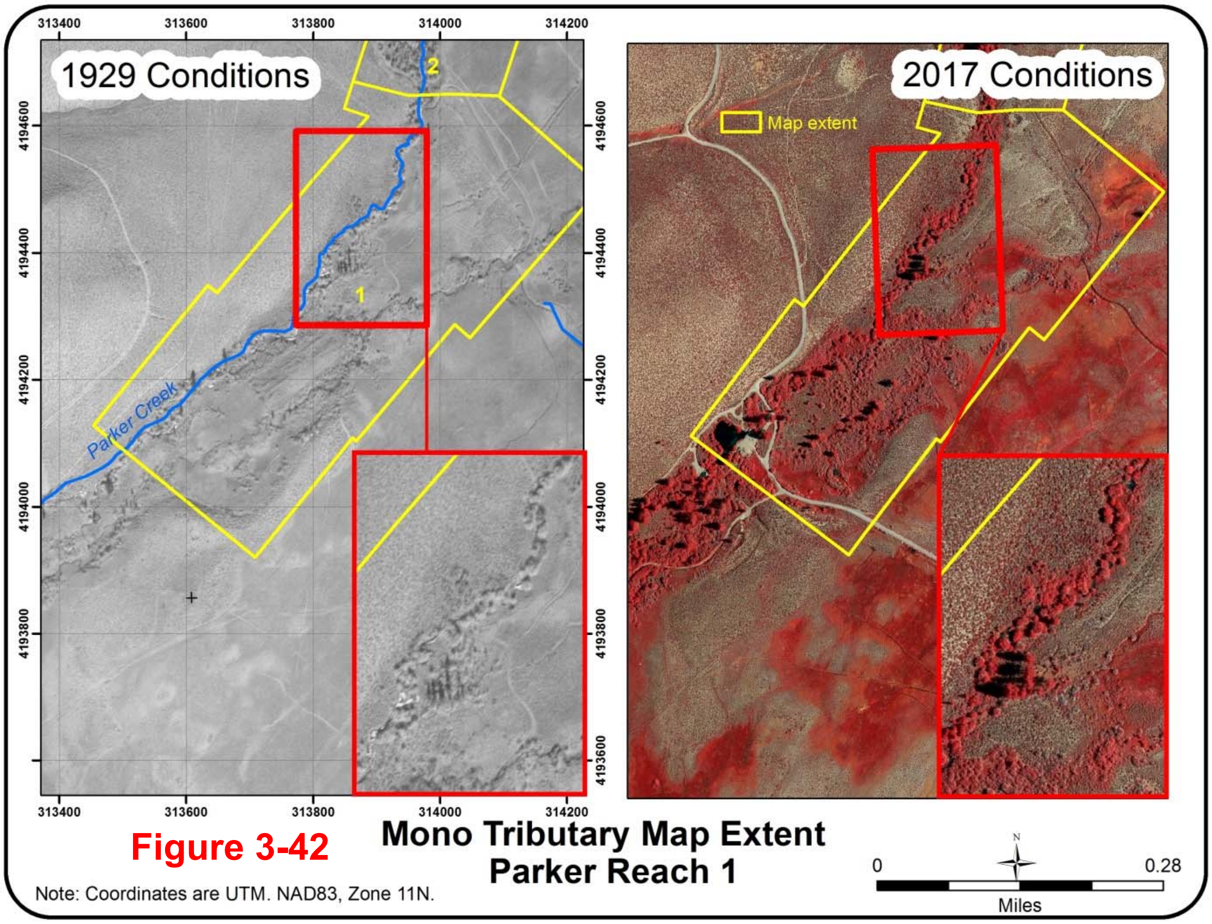


Figure 3-42

Mono Tributary Map Extent
Parker Reach 1

Note: Coordinates are UTM. NAD83, Zone 11N.

Figure 3-43

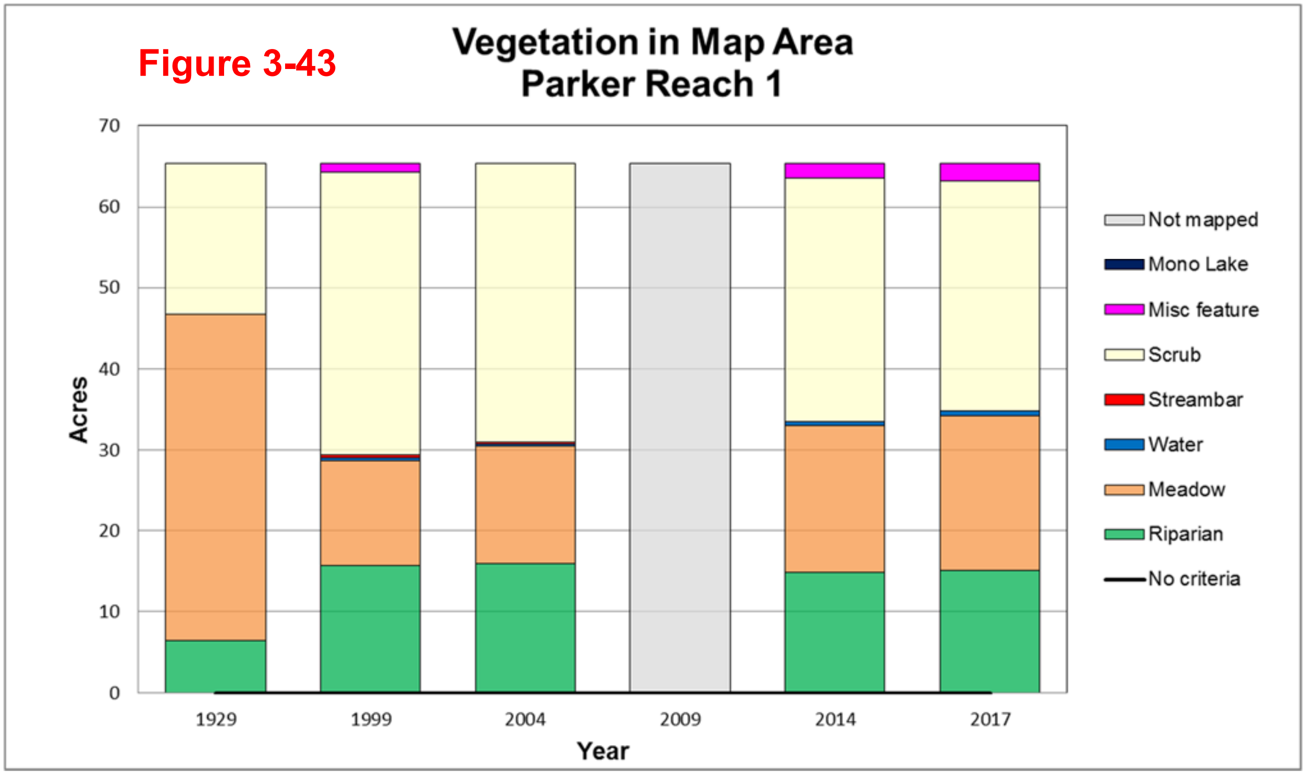


Table 3-22. Area of vegetation types in Parker Reach 1 map area.

Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	6	10	16	24	16	24	0	0	15	23	15	23
Meadow	40	62	13	20	15	22	0	0	18	28	19	29
Water	0	0	0	1	0	0	0	0	0	1	1	1
Streambar	0	0	0	0	0	0	0	0	0	0	0	0
subtotal	***47***	***71***	***29***	***45***	***31***	***47***	***0***	***0***	***33***	***51***	***35***	***53***
Scrub	19	29	35	53	34	53	0	0	30	46	28	43
Misc feature	0	0	1	2	0	0	0	0	2	3	2	3
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	0	0	0	0	0	0	65	100	0	0	0	0
TOTAL	**65**	**100**	**65**	**100**	**65**	**100**	**65**	**100**	**65**	**100**	**65**	**100**

Parker Reach 2

Reach 2 is unconfined and runs about 10,900 feet above Old Highway 395 crossing (Figure 3-44). Parts of the map area were irrigated meadow in 1929. Stream gradient is 1.7 percent. While McBain and Trush (2005) mapping for 1929 indicates a reduction in riparian vegetation relative to contemporary conditions (Figure 3-45), comparison of imagery (Figure 3-44) tells a different story. Irrigation of meadows along Parker Creek was curtailed in 2000, resulting in less meadow and more scrub. The trend for the reach is stable to improving (Table 3-23). This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

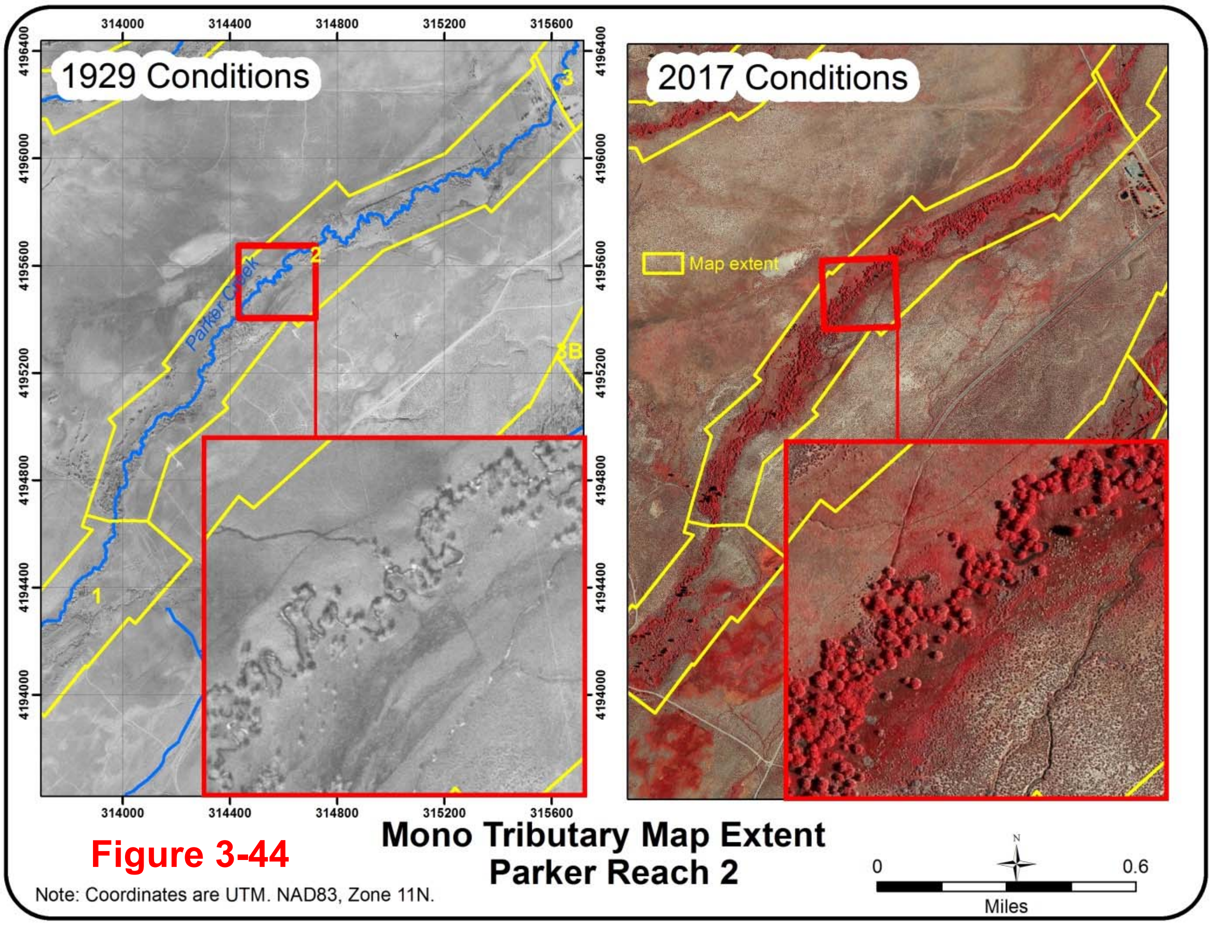


Figure 3-44

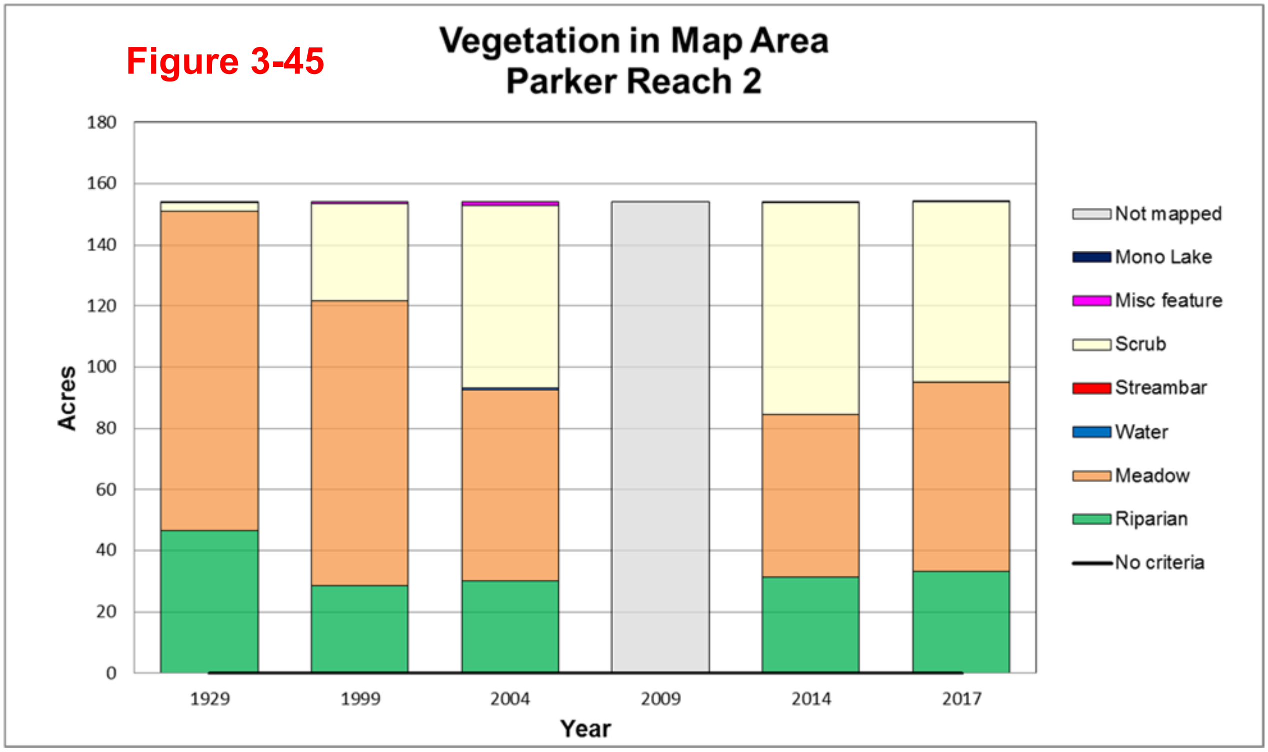


Table 3-23. Area of vegetation types in Parker Reach 2 map area.												
Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	47	30	29	19	30	19	0	0	31	20	33	22
Meadow	104	68	93	60	63	41	0	0	53	35	62	40
Water	0	0	0	0	1	0	0	0	0	0	0	0
Streambar	0	0	0	0	0	0	0	0	0	0	0	0
subtotal	***151***	***98***	***122***	***79***	***93***	***61***	***0***	***0***	***85***	***55***	***95***	***62***
Scrub	3	2	32	21	60	39	0	0	69	45	59	38
Misc feature	0	0	1	0	1	1	0	0	0	0	0	0
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	0	0	0	0	0	0	154	100	0	0	0	0
TOTAL	**154**	**100**	**154**	**100**	**154**	**100**	**154**	**100**	**154**	**100**	**154**	**100**

Parker Reach 3

Reach 3 is moderately confined and extends about 2,350 feet from the Old Highway 395 crossing to the new Highway 395 crossing (Figure 3-46). Upper parts of the map area were irrigated meadow in 1929. Stream gradient is 1.1 percent. While the extent of riparian has varied since 1929 (Figure 3-47), comparison of imagery at large-scale (see inset of Figure 3-46) indicates contemporary riparian is at least as extensive as 1929 with higher canopy cover. Variation between years is attributed to mapping error (Table 3-24). This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

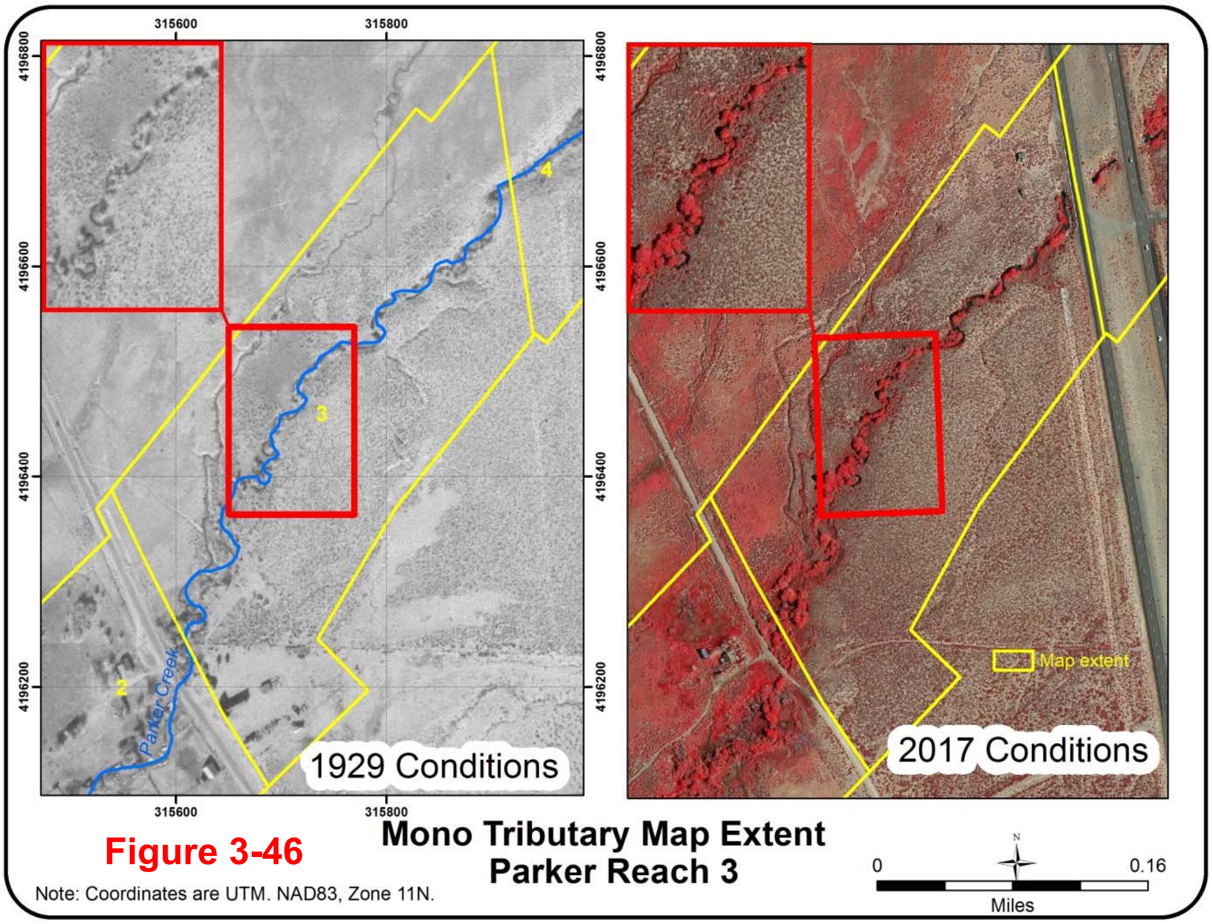


Figure 3-46

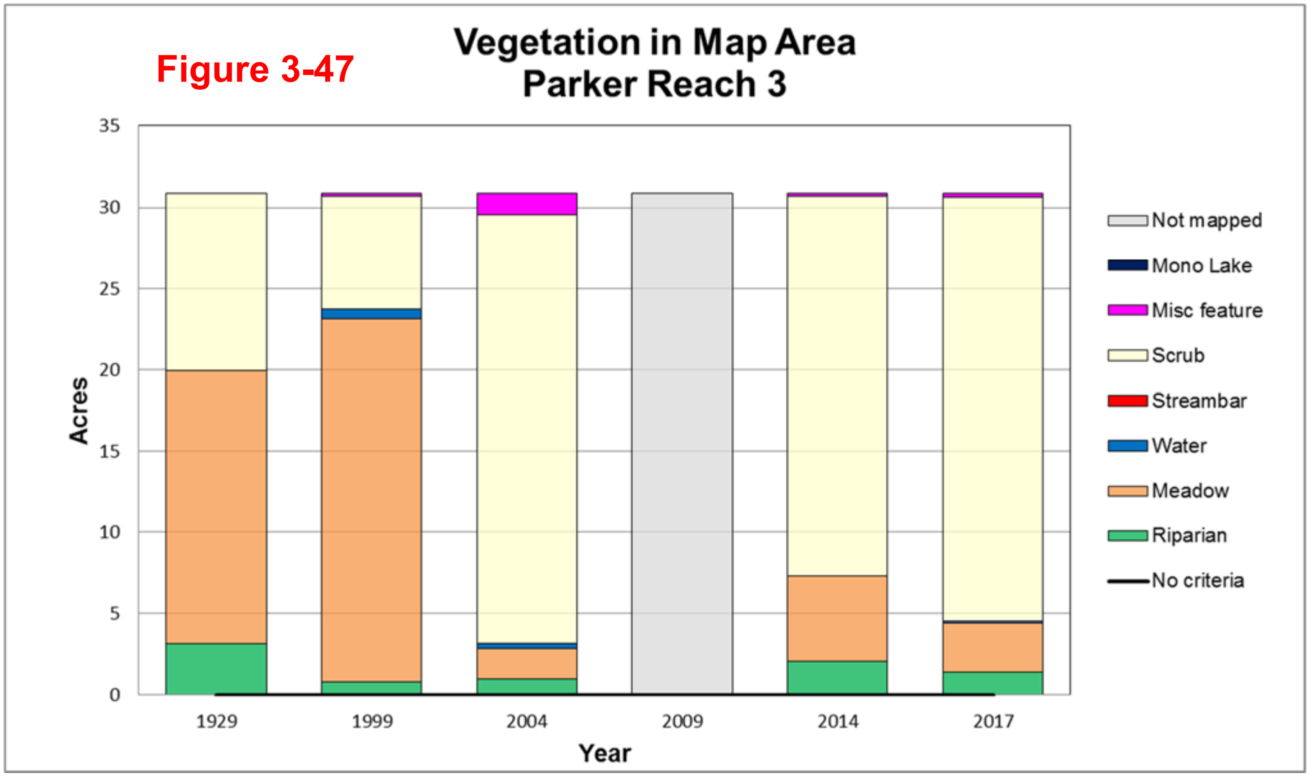


Table 3-24. Area of vegetation types in Parker Reach 3 map area.

Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	3	10	1	3	1	3	0	0	2	7	1	5
Meadow	17	54	22	72	2	6	0	0	5	17	3	10
Water	0	0	1	2	0	1	0	0	0	0	0	0
Streambar	0	0	0	0	0	0	0	0	0	0	0	0
subtotal	***20***	***65***	***24***	***77***	***3***	***10***	***0***	***0***	***7***	***24***	***5***	***15***
Scrub	11	35	7	23	26	86	0	0	23	76	26	85
Misc feature	0	0	0	1	1	4	0	0	0	1	0	1
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	0	0	0	0	0	0	31	100	0	0	0	0
TOTAL	**31**	**100**	**31**	**100**	**31**	**100**	**31**	**100**	**31**	**100**	**31**	**100**

Parker Reach 4

Reach 4 is confined and extends about 4,650 feet between Highway 395 crossing and the confluence of Rush Creek (Figure 3-48). Stream gradient is 3.7 percent. While the extent of riparian has varied since 1929 (Figure 3-49), comparison of imagery at large-scale (see inset of Figure 3-48) indicates the extent of contemporary riparian is similar to the extent of riparian in 1929 with higher canopy cover. Variation between years is attributed to mapping error (Table 3-25). This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

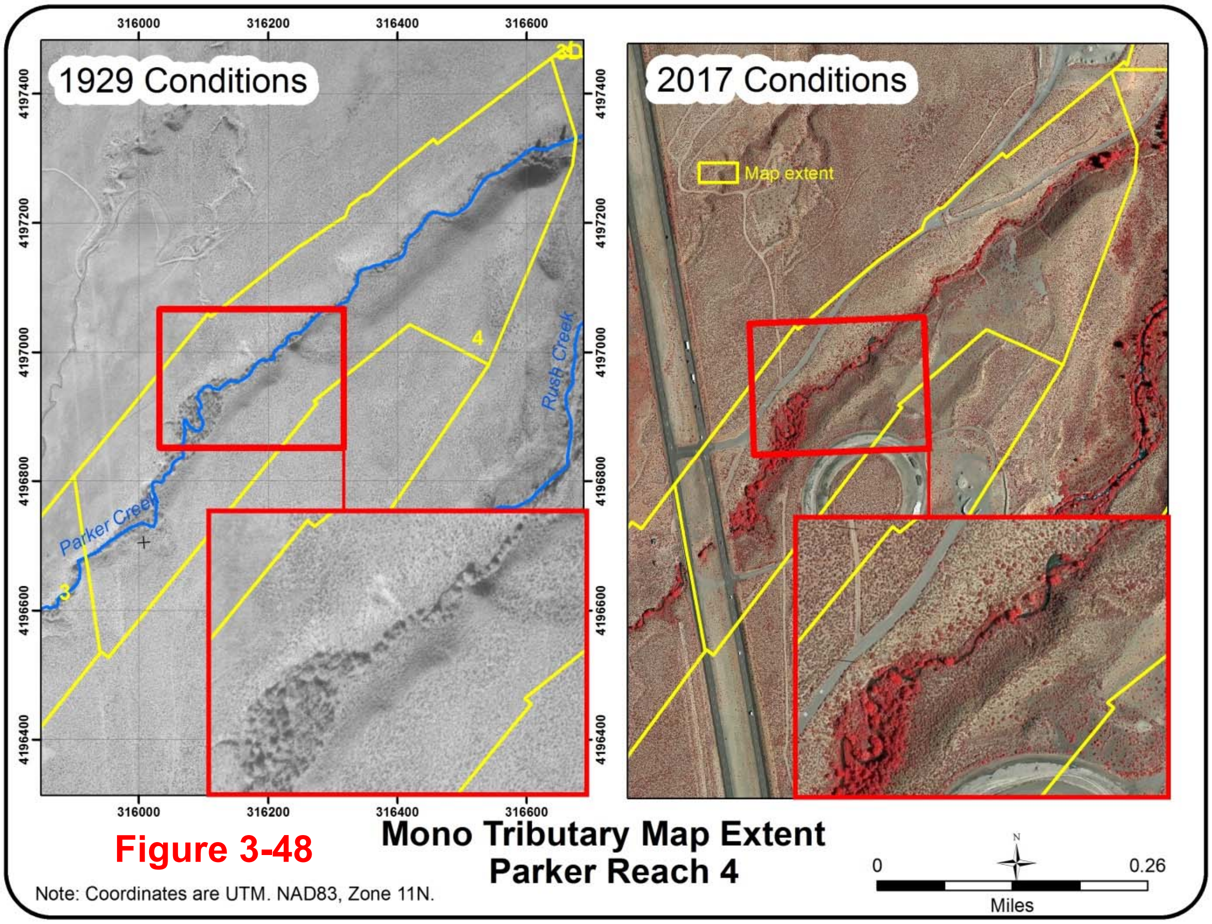


Figure 3-48

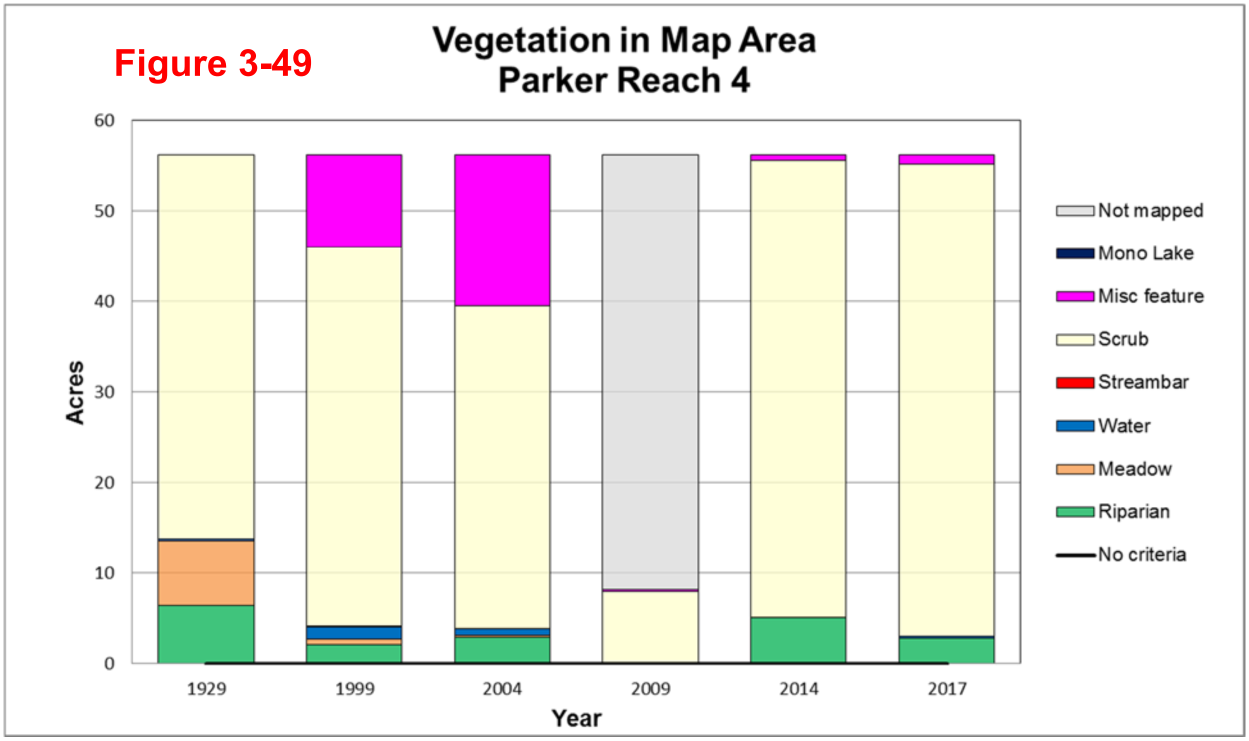


Table 3-25. Area of vegetation types in Parker Reach 4 map area.

Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	6	11	2	4	3	5	0	0	5	9	3	5
Meadow	7	13	1	1	0	0	0	0	0	0	0	0
Water	0	0	1	2	1	1	0	0	0	0	0	0
Streambar	0	0	0	0	0	0	0	0	0	0	0	0
subtotal	***14***	***24***	***4***	***7***	***4***	***7***	***0***	***0***	***5***	***9***	***3***	***5***
Scrub	42	76	42	74	36	64	8	14	51	90	52	93
Misc feature	0	0	10	18	17	30	0	0	1	1	1	2
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	0	0	0	0	0	0	48	86	0	0	0	0
TOTAL	**56**	**100**	**56**	**100**	**56**	**100**	**56**	**100**	**56**	**100**	**56**	**100**

3.4 Walker Creek

Walker Creek consists of 4 reaches (Figure 3-50). Walker Creek was not mapped in 2009. There is no woody riparian termination criterion for Walker Creek. The area of riparian has remained relatively consistent since 1999. Irrigation of meadows along Warker Creek was curtailed in 2000, resulting in less meadow and more scrub (Figure 3-51). The overall trend for Walker Creek appears stable (Table 3-26). Specific reaches of Parker Creek are subsequently discussed.

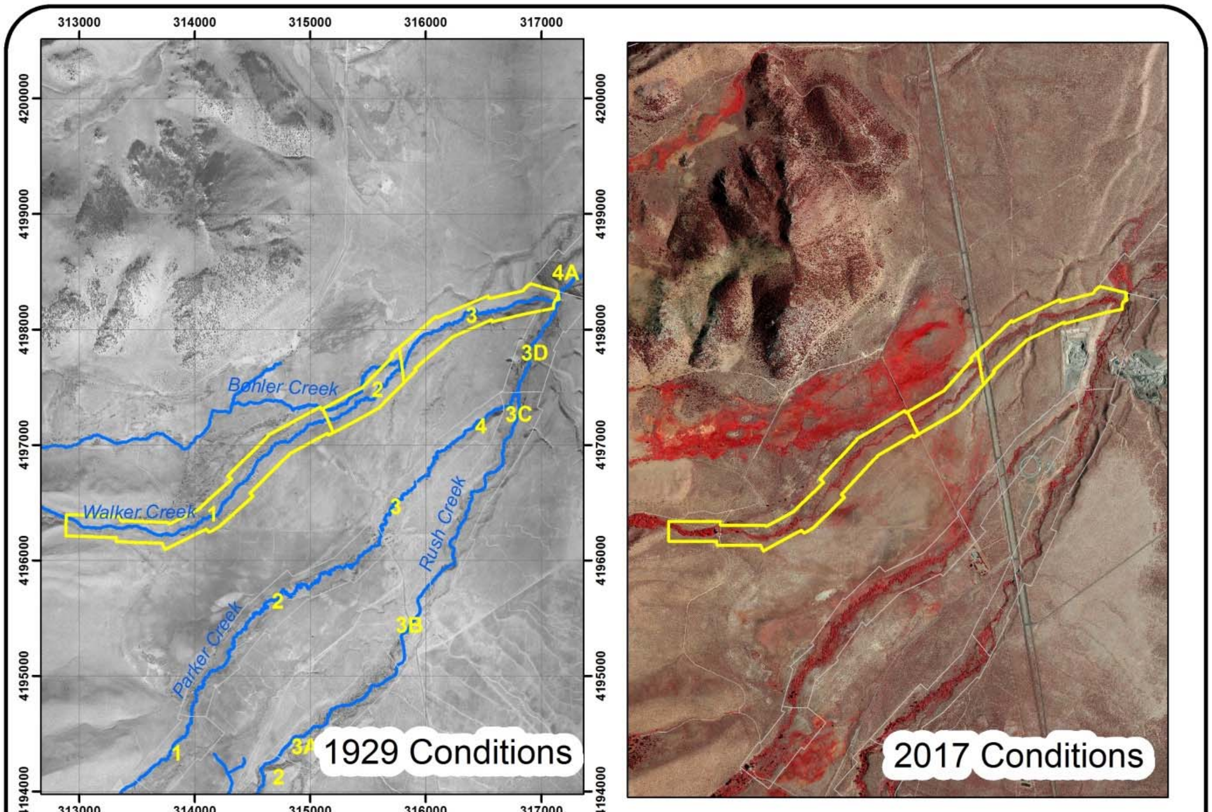


Figure 3-50 Mono Tributary Map Extent Walker Creek

Note: Coordinates are UTM. NAD83, Zone 11N.

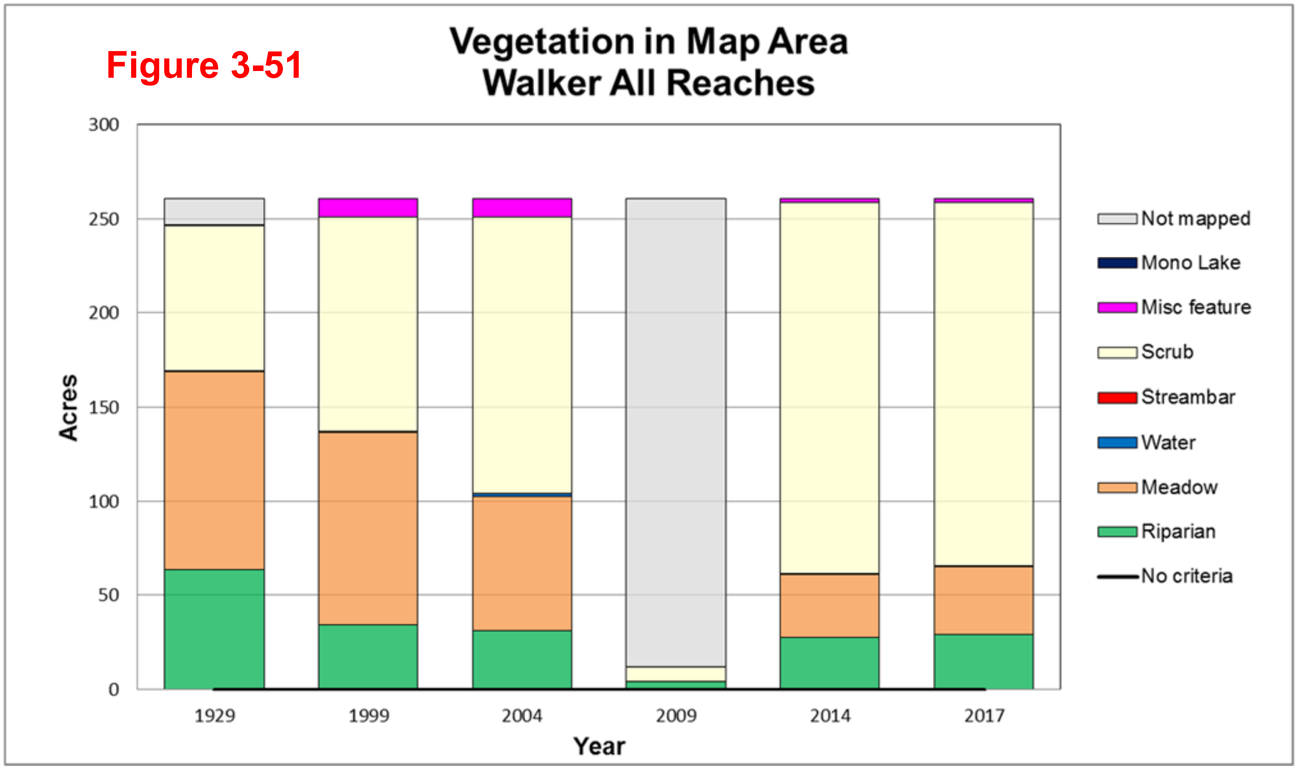


Table 3-26. Area of vegetation types in Walker all reaches map areas.												
Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	64	24	34	13	31	12	5	2	27	10	29	11
Meadow	105	40	103	39	72	27	0	0	34	13	36	14
Water	0	0	0	0	2	1	0	0	0	0	1	0
Streambar	0	0	0	0	0	0	0	0	0	0	0	0
subtotal	***169***	***65***	***137***	***53***	***105***	***40***	***5***	***2***	***61***	***24***	***66***	***25***
Scrub	78	30	114	44	147	56	7	3	198	76	193	74
Misc feature	1	0	10	4	10	4	0	0	2	1	2	1
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	14	5	0	0	0	0	249	95	0	0	0	0
TOTAL	**261**	**100**	**261**	**100**	**261**	**100**	**261**	**100**	**261**	**100**	**261**	**100**

Walker Reach 1

Reach 1 extends about 9,500 feet above Old Highway 395 crossing (Figure 3-52). The upper half is somewhat confined and the lower half is unconfined. Stream gradient is 4.4 percent. There are no termination criteria for Walker Creek. The extent of riparian has decreased slightly since 1929 (Figure 3-53); the extent of meadow has decreased substantially, probably in response to elimination of irrigation (Table 3-27). Not considering loss of irrigated meadow, the trend for this reach appears stable. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

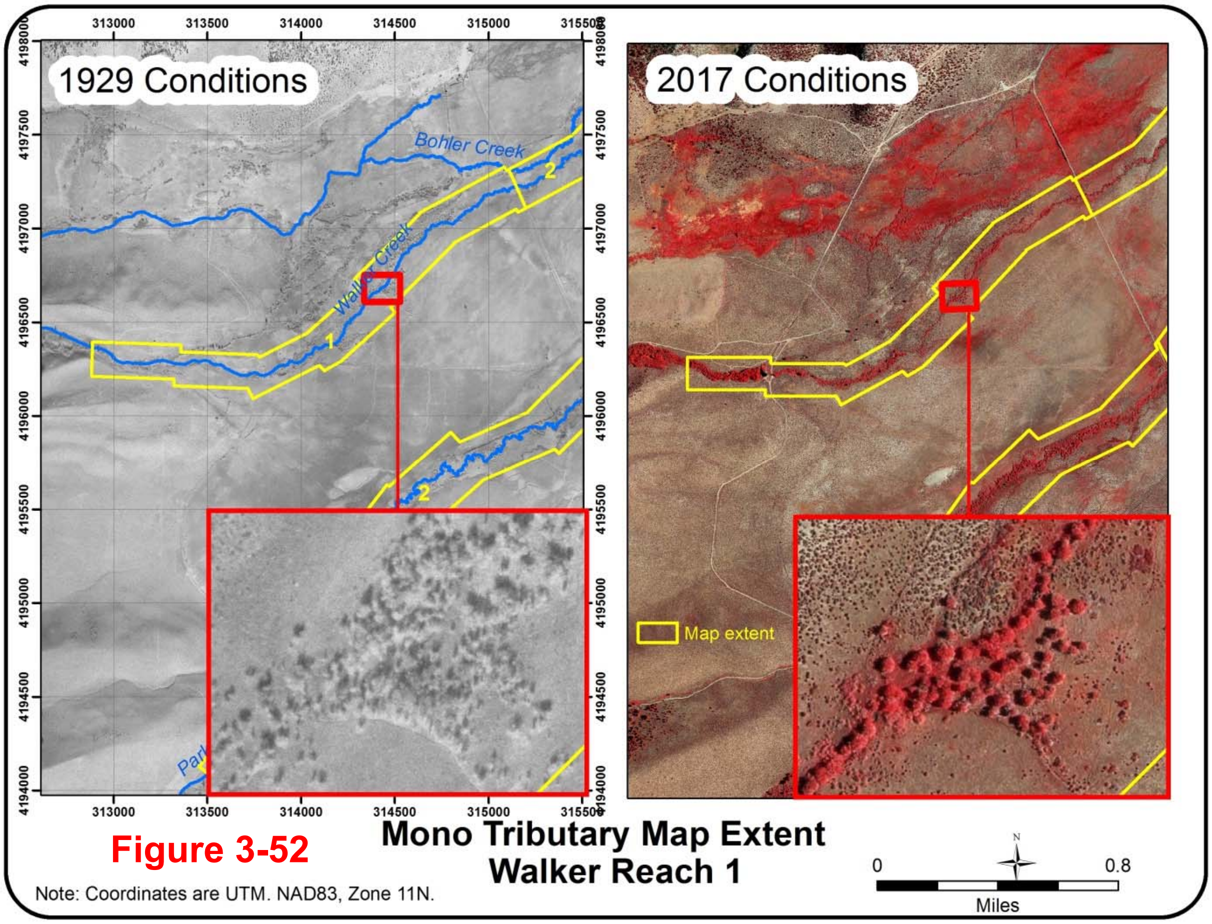


Figure 3-52
Mono Tributary Map Extent
Walker Reach 1

Note: Coordinates are UTM. NAD83, Zone 11N.

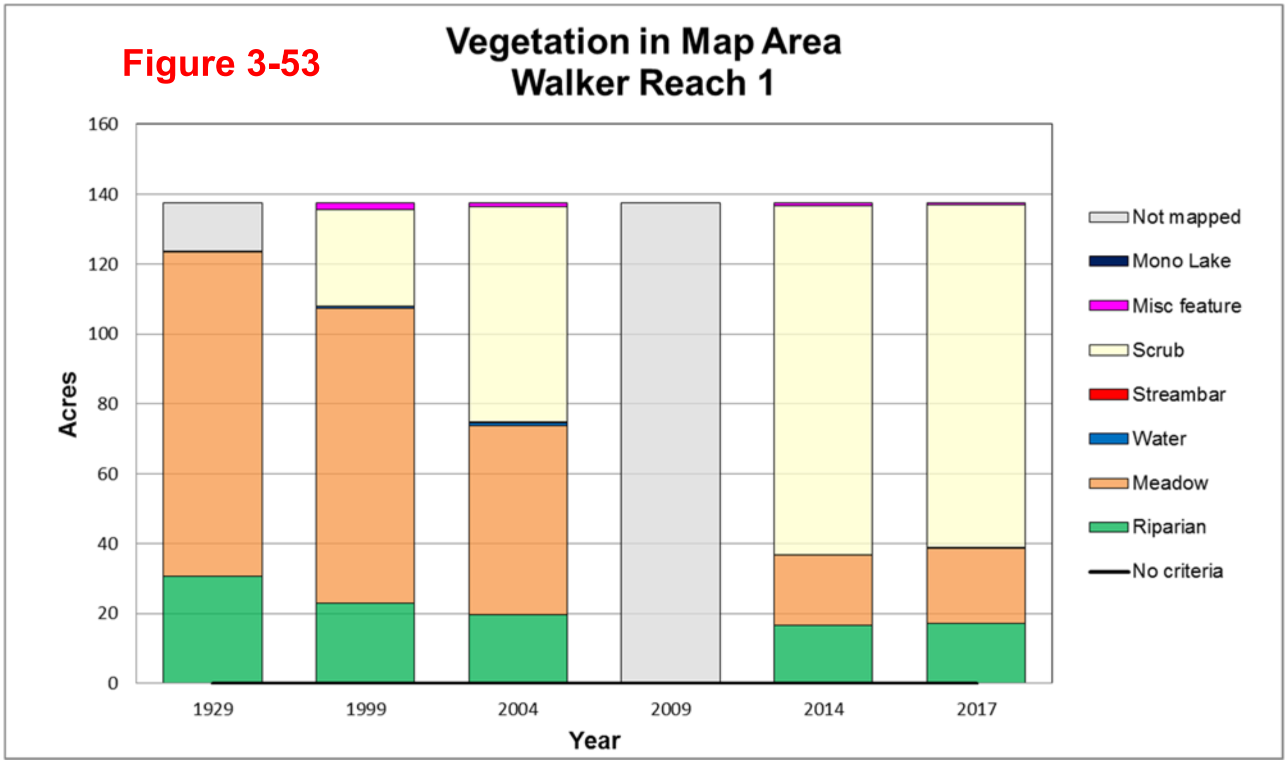


Table 3-27. Area of vegetation types in Walker Reach 1 map area.												
Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	31	22	23	17	20	14	0	0	17	12	17	12
Meadow	93	67	85	61	54	39	0	0	20	15	22	16
Water	0	0	0	0	1	1	0	0	0	0	0	0
Streambar	0	0	0	0	0	0	0	0	0	0	0	0
subtotal	***124***	***90***	***108***	***78***	***75***	***54***	***0***	***0***	***37***	***27***	***39***	***28***
Scrub	0	0	28	20	62	45	0	0	100	73	98	71
Misc feature	0	0	2	1	1	1	0	0	1	1	1	0
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	14	10	0	0	0	0	138	100	0	0	0	0
TOTAL	**138**	**100**	**138**	**100**	**138**	**100**	**138**	**100**	**138**	**100**	**138**	**100**

Walker Reach 2

Reach 2 extends about 3,350 feet between Old Highway 395 and new Highway 395 crossings (Figure 3-54). The upper third is unconfined and the lower two thirds is confined. Stream gradient is 1.6 percent. Irrigated meadow was present in 1929. There are no termination criteria for Walker Creek. The 1929 mapping of riparian (Figure 3-55) is too high; it includes areas with a few riparian trees/shrubs surrounded by more extensive meadow (see 1929 maps in APPENDIX A). The extent of contemporary riparian appears similar to 1929, but canopy cover is higher. The extent of meadow has decreased since 1929 (Table 3-28). The trend for this reach appears stable. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

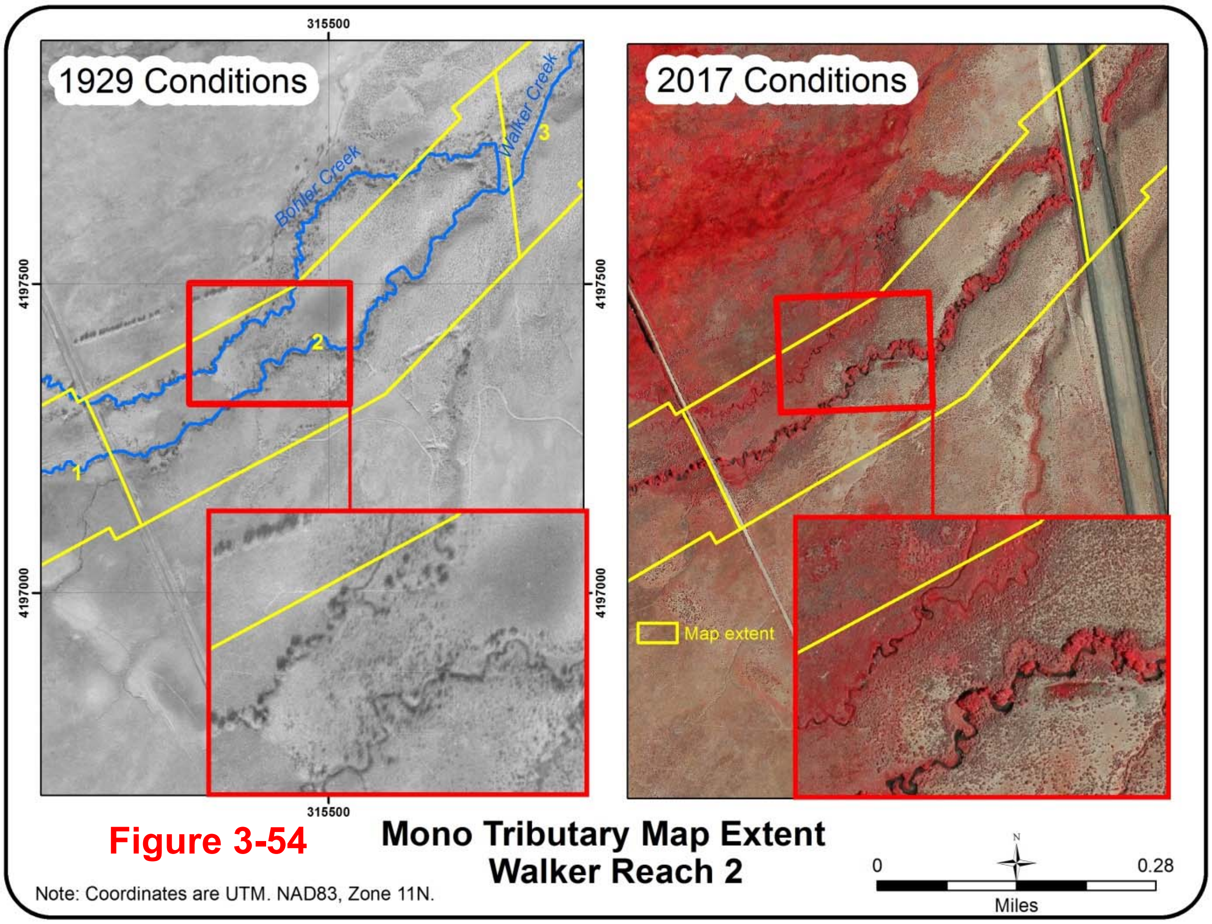


Figure 3-54

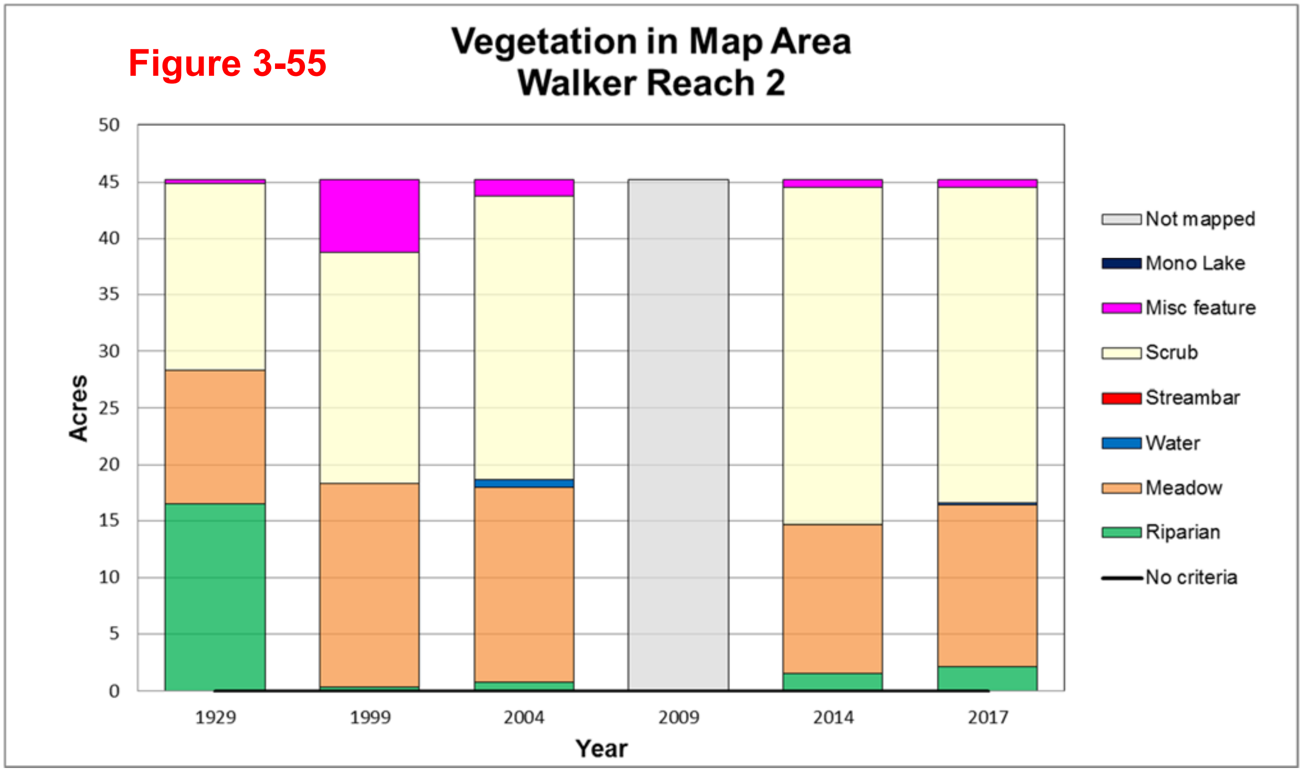


Table 3-28. Area of vegetation types in Walker Reach 2 map area.

Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	17	37	--	1	1	2	--	--	2	3	2	5
Meadow	12	26	18	40	17	38	--	--	13	29	14	32
Water	--	--	--	--	1	1	--	--	--	--	--	--
Streambar	--	--	--	--	--	--	--	--	--	--	--	--
subtotal	***28***	***63***	***18***	***41***	***19***	***41***	***--***	***--***	***15***	***32***	***17***	***37***
Scrub	17	37	20	45	25	55	--	--	30	66	28	62
Misc feature	0	1	6	14	1	3	0	0	1	1	1	1
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	0	0	0	0	0	0	45	100	0	0	0	0
TOTAL	**45**	**100**	**45**	**100**	**45**	**100**	**45**	**100**	**45**	**100**	**45**	**100**

Walker Reach 3

Reach 3 extends about 8,050 feet from Highway 395 crossings to the confluence with Rush Creek (Figure 3-56). The floodplain is confined and the stream gradient is 2.2 percent. There is no termination criterion for Walker Creek. The extent of contemporary riparian appears similar to 1929 (Figure 3-57), but canopy cover is higher. Minor differences (Table 3-29) are attributed to mapping error. The trend for this reach is stable. This reach is functional and self-sustaining with healthy riparian ecosystem that requires no physical manipulation.

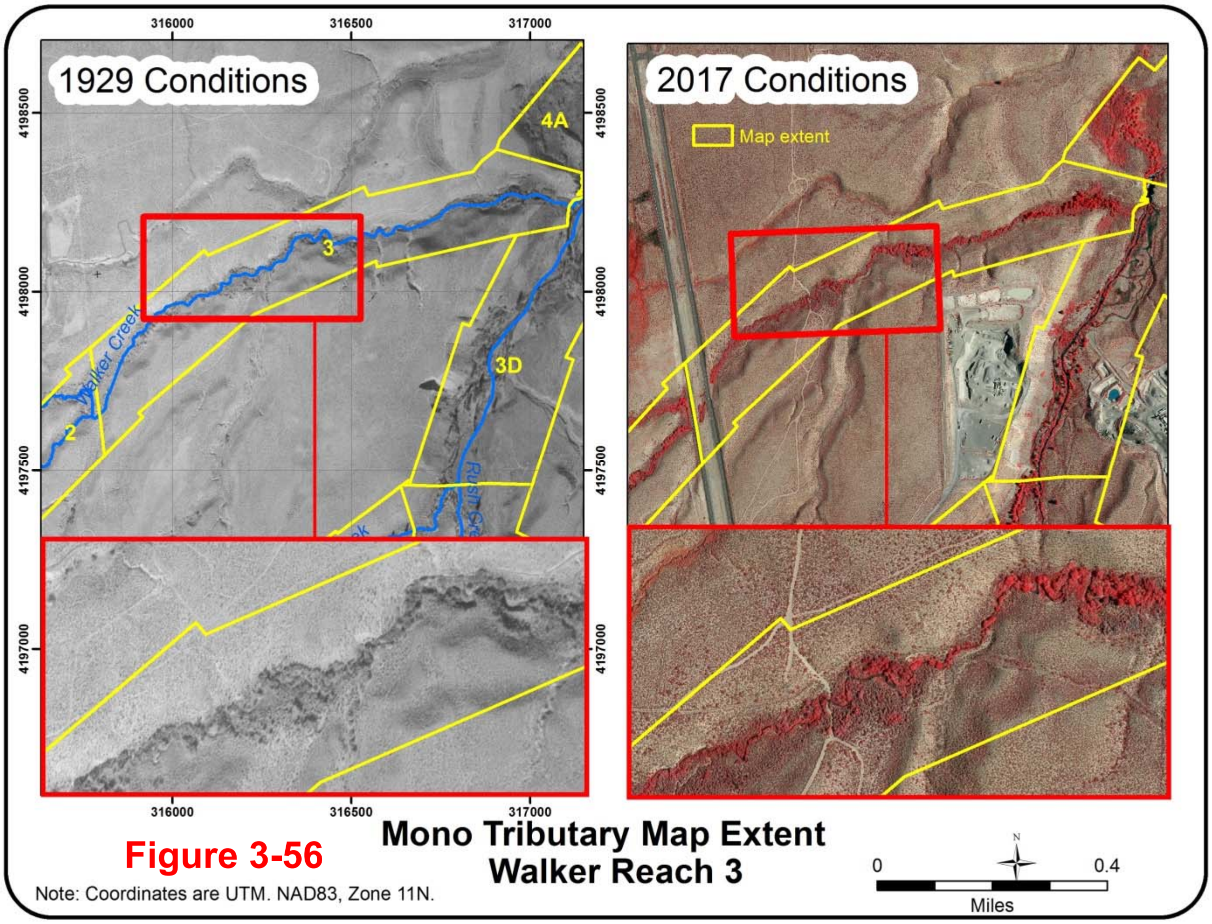


Figure 3-56

Figure 3-57

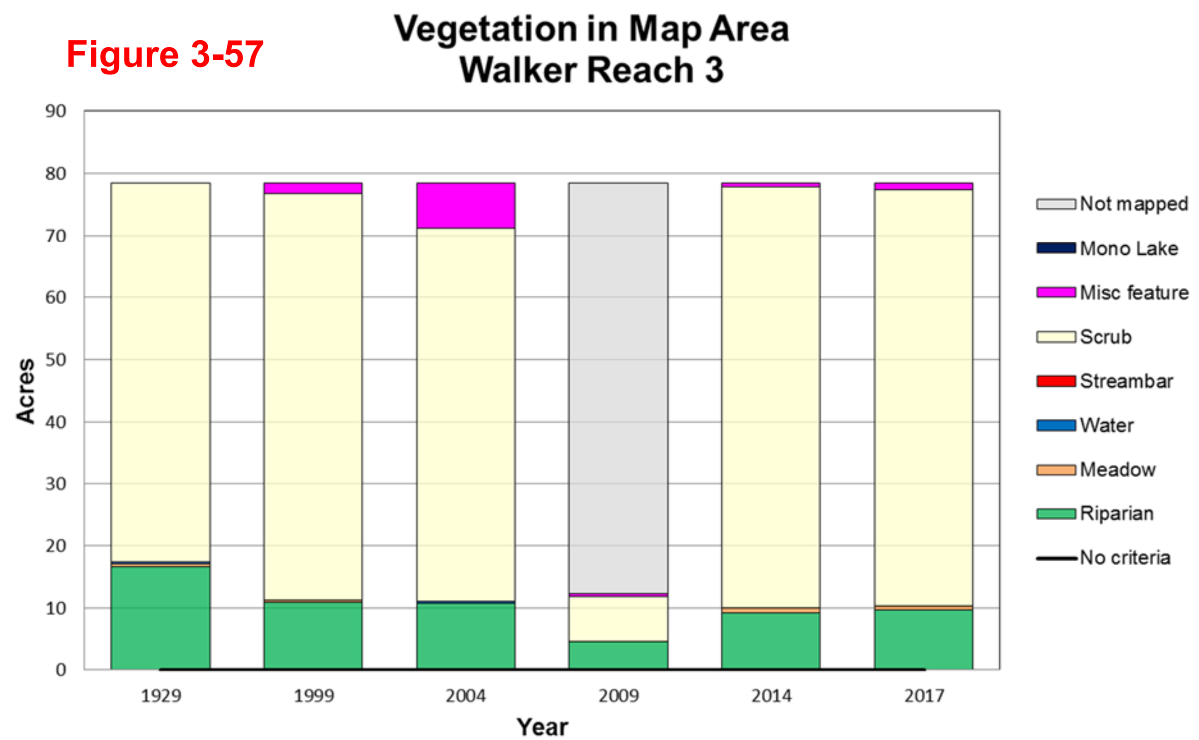


Table 3-29. Area of vegetation types in Walker Reach 3 map area.												
Veg Type	1929		1999		2004		2009		2014		2017	
	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)	(ac)	(%)
Riparian	17	21	11	14	11	14	5	6	9	12	10	12
Meadow	1	1	0	1	0	0	0	0	1	1	1	1
Water	0	0	0	0	0	0	0	0	0	0	0	0
Streambar	0	0	0	0	0	0	0	0	0	0	0	0
subtotal	***17***	***22***	***11***	***14***	***11***	***14***	***5***	***6***	***10***	***13***	***10***	***13***
Scrub	61	78	65	84	60	77	7	9	68	87	67	86
Misc feature	0	0	2	2	7	9	0	0	0	1	1	1
Mono Lake	0	0	0	0	0	0	0	0	0	0	0	0
Not mapped	0	0	0	0	0	0	66	84	0	0	0	0
TOTAL	**78**	**100**	**78**	**100**	**78**	**100**	**78**	**100**	**78**	**100**	**78**	**100**

4.0 SUMMARY

Assessment of stream reaches is summarized in Table 4-1. One reach (Rush 5a) was not in proper functioning condition. It incised in response to lowered lake level; parts of the reach were further scoured by high flow in 2017. The prominent ash tuff substrate with low density in this reach may make it more prone to erosion/transport. Vigorous woody riparian vegetation is limited to the incised channel bottom. This incised reach may aggrade as woody debris accumulates in the channel and lake level rises. All other reaches are functional and self-sustaining with a healthy riparian ecosystem that requires no physical manipulation.

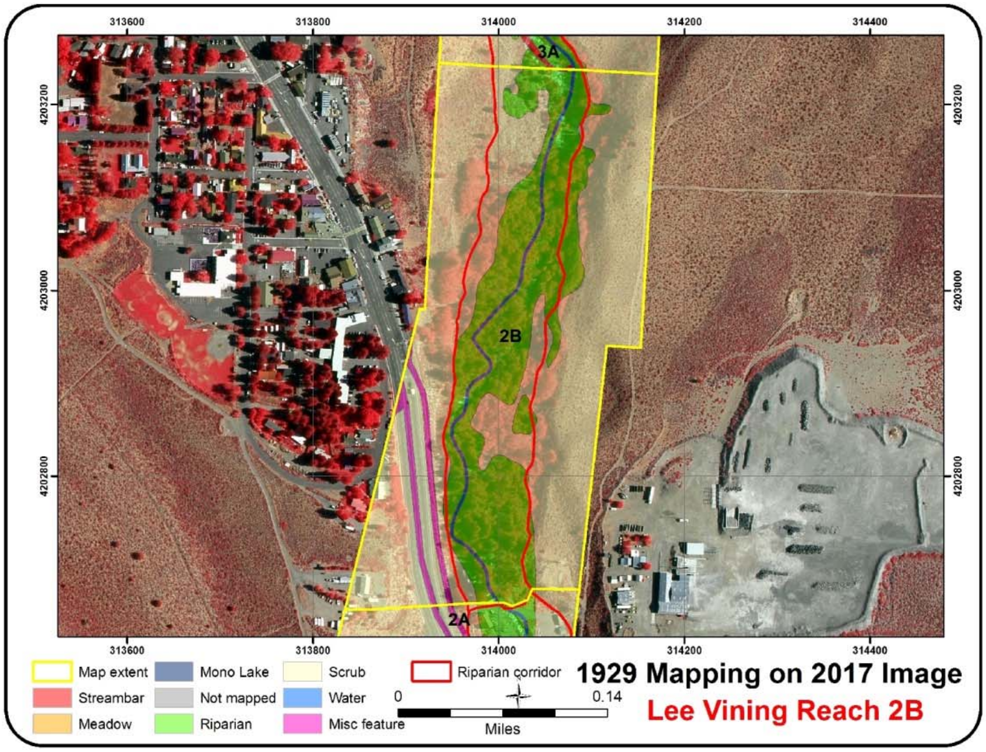
The woody riparian termination criteria (WRTC) has been achieved for 9 of the 14 reaches assigned criteria. Three reaches with substantial meadow vegetation and shallow groundwater are approaching the WRTC. The area of riparian mapped by McBain and Trush (2005) for Rush Reach 4c in 1929 is about 10 acres less than the WRTC, suggesting the criterion is too high. Contemporary estimates of riparian for Rush 4c are similar to 1929 conditions and the trend is improving. The extent of riparian has declined relative to WRTC for the non-functional reach (Rush 5a). From a stream perspective, the total WRTC have been achieved for both Rush and Lee Vining Creeks.

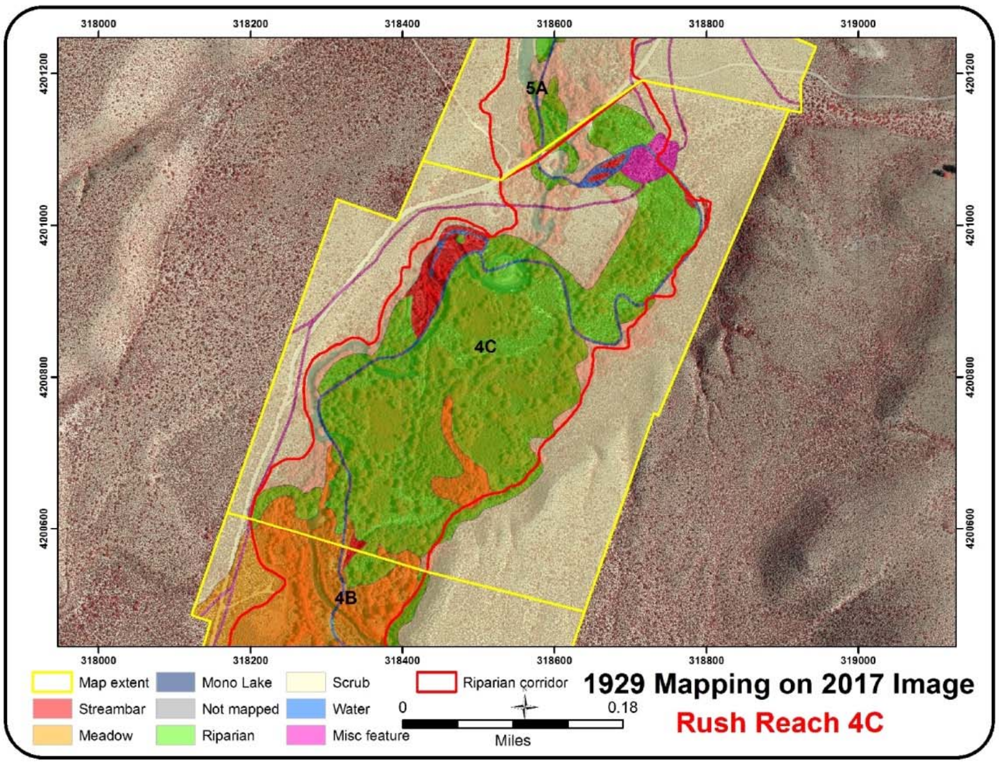
Trend was evaluated based on changes in the extents of hydric resources (riparian, meadow, streambar, and water) over time and on interpretation of imagery viewed at very large scale, sometimes with overlays of mapping for earlier periods. Eleven (11) of the 23 reaches are improving, 11 are stable, and 1 is deteriorating.

Changes are apparent from the 1929 mapping plotted on the 2017 image. Two example reaches (Figure 4-1) show extensive areas mapped as scrub in 1929 that are now riparian, areas mapped as meadow that are now riparian, and areas mapped as riparian that are now other hydric vegetation types. Maps of 1929 vegetation on the 2017 image for all reaches are included in APPENDIXH. These maps illustrate substantial change in the extents of hydric resources over the last 88 years.

The overall assessment for all reaches is that streams are functional and self-sustaining with a healthy riparian ecosystem that requires no physical manipulation. The total WRTC has been achieved and the trend is improving. Overall, riparian habitat is approaching its potential.

Table 4-1. Stream reach summary.					
Stream	Reach	Functional	WRTC	Trend	Comment
Rush	1	NA	--	--	Grant Lake dam and spillway
	2	Yes	Yes	Stable	At or near potential
	3a	Yes	Yes	Improve	--
	3b	Yes	Yes	Improve	--
	3c	Yes	Yes	Stable	--
	3d	Yes	No	Stable	Approaching WRTC
	4a	Yes	Yes	Stable	--
	4b	Yes	Yes	Improve	Recent channel realignment will enhance woody riparian
	4c	Yes	No	Improve	WRTC 10 acres too high
	5a	No	No	Deteriorating	Lower half of reach is incised in response to lower lake level
	5b	Yes	--	Improve	Rush Creek delta
	ALL	**Yes**	**Yes**	**Improve**	**Approaching potential**
Lee Vining	1	Yes	Yes	Stable	At or near potential
	2a 2b	Yes	Yes	Improve	Approaching potential
	3a	Yes	No	Improve	Approaching WRTC
	3b	Yes	No	Improve	Approaching WRTC
	3c	Yes	Yes	Improve	1929 delta
	3d	Yes	--	Improve	Lee Vining delta
	ALL	**Yes**	**Yes**	**Improve**	**Approaching potential**
Parker	1	Yes	--	Stable	Approaching potential
	2	Yes	--	Stable	Approaching potential
	3	Yes	--	Improve	Approaching potential
	4	Yes	--	Stable	Approaching potential
	ALL	**Yes**	**--**	**Stable**	**Approaching potential**
Walker	1	Yes	--	Stable	Approaching potential
	2	Yes	--	Stable	Approaching potential
	3	Yes	--	Stable	Approaching potential
	ALL	**Yes**	**--**	**Stable**	**Approaching potential**
ALL	**ALL**	**Yes**	**Yes**	**Improve**	**Approaching potential**





Examples of 1929 Mapping on the 2017 Image

Figure 4-1

5.0 LITERATURE CITED

McBain and Trush. 2003. Monitoring results and analyses for runoff season 2002-03. Mono Basin Tributaries: Lee Vining, Rush, Walker, and Parker Creeks. Report to LADWP. 105 pp.

McBain and Trush. 2005. Atlas of riparian vegetation mapping conducted by McBain and Trush, including pre-diversion conditions, and mapping conducted in 1999 and 2004. Mono Basin tributaries: Rush, Parker, Walker, and Lee Vining Creeks. 60 pp (mostly maps).

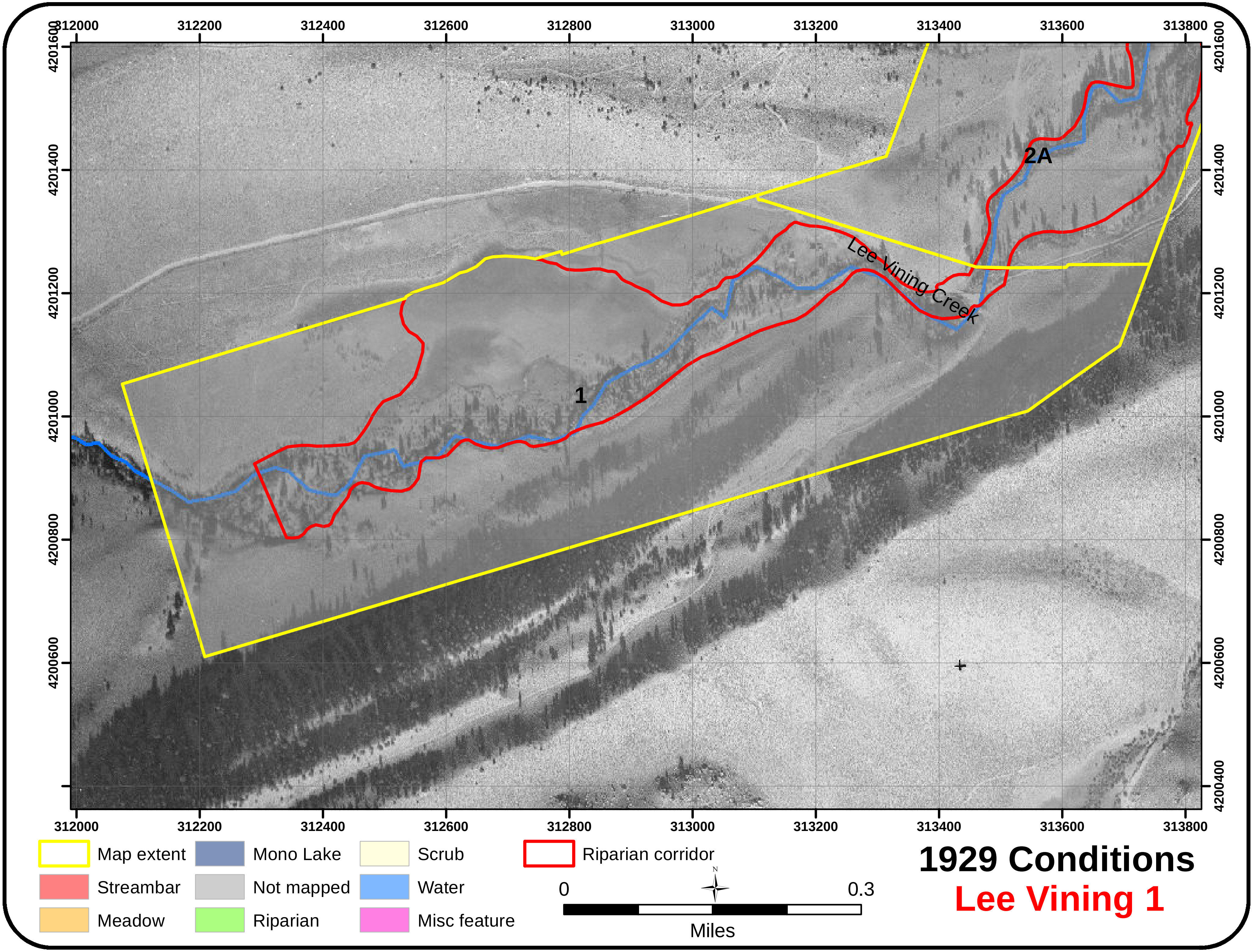
R-DWP-68B. 1997. Termination criteria for Rush Creek and Lee Vining Creek (summarized from Ridenhour et al (1995) Draft Work Plan, Mono Basin stream restoration). 3pp.

Ridenhour, Hunter, and Trush. 1995. Work Plan: Mono Basin Stream Restoration (Rush Creek, Lee Vining Creek, Walker Creek, and Parker Creek). Prepared for LADWP. 228 pp.

SWRCB Order WR 98-05. 1998. State of California, State Water Resources Control Board Order WR 98-05. Order requiring stream and waterfowl habitat restoration measures. 80 pp.

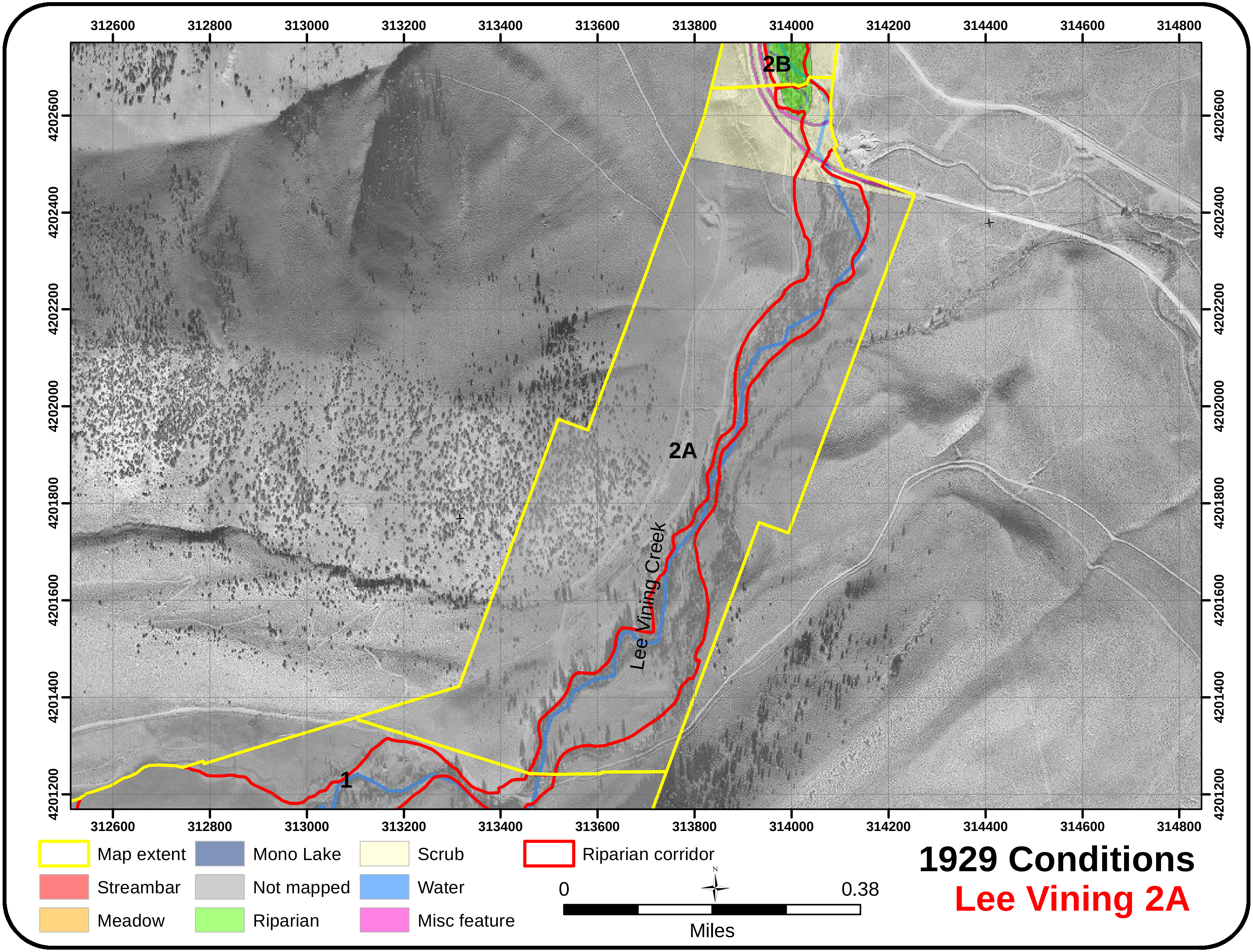
SWRCB Order WR 98-07. 1998. State of California, State Water Resources Control Board Order WR 98-07. Order amending provisions of Order 98-05 applicable to stream restoration measures and dismissing petitions for reconsideration. 10 pp.

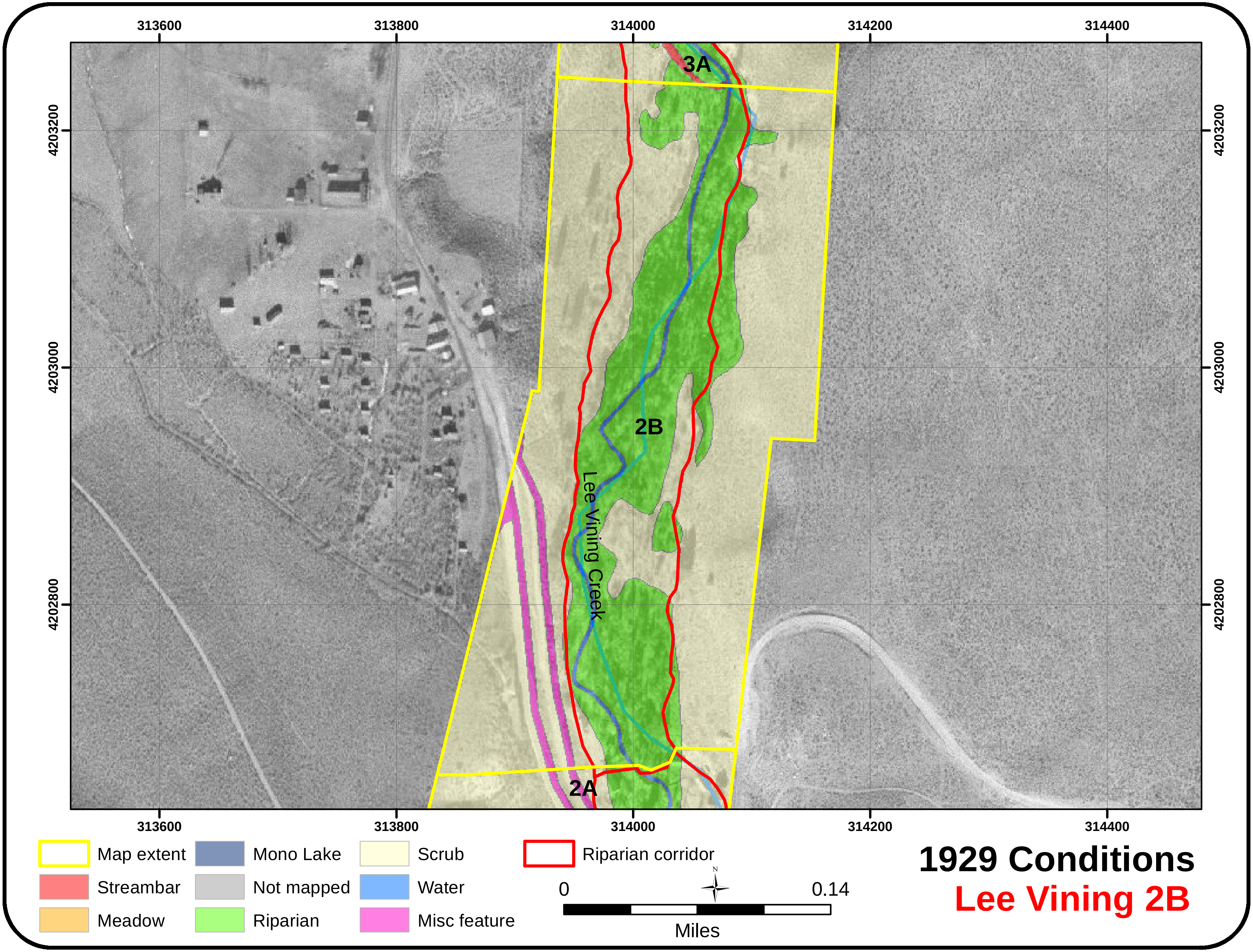
APPENDIX A
RIPARIAN MAPPING
1929 CONDITIONS

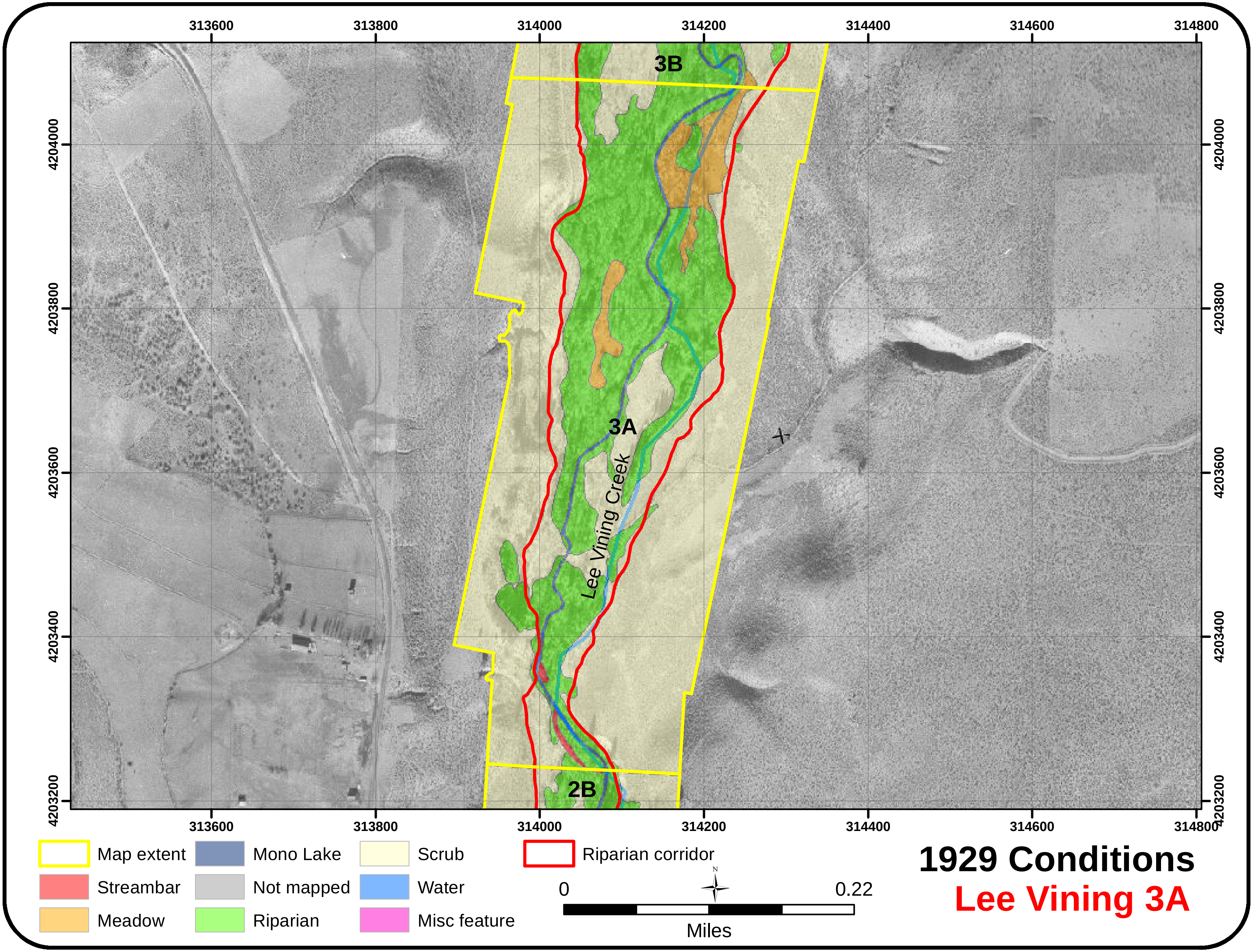


1929 Conditions

Lee Vining 1


2B
2A
1
Lee Vining Creek
312600
312800
313000
313200
313400
313600
313800
314000
314200
314400
314600
314800
4202600
4202400
4202200
4202000
4201800
4201600
4201400
4201200
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.38
Miles
N
1929 Conditions
Lee Vining 2A


313600
313800
314000
314200
314400
4203200
4203000
4202800
3A
2B
2A
Lee Vining Creek
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
N
0
0.14
Miles
1929 Conditions
Lee Vining 2B



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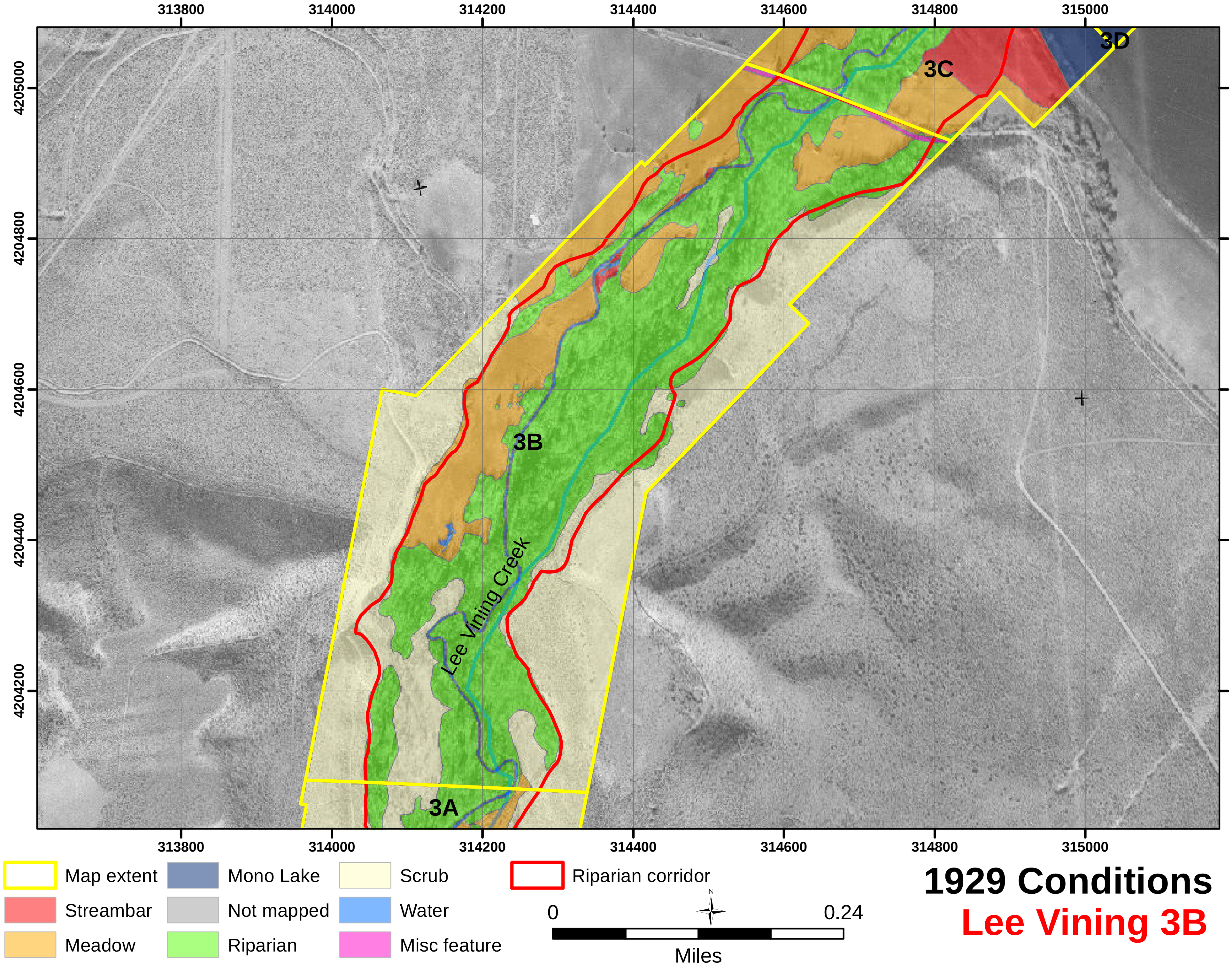
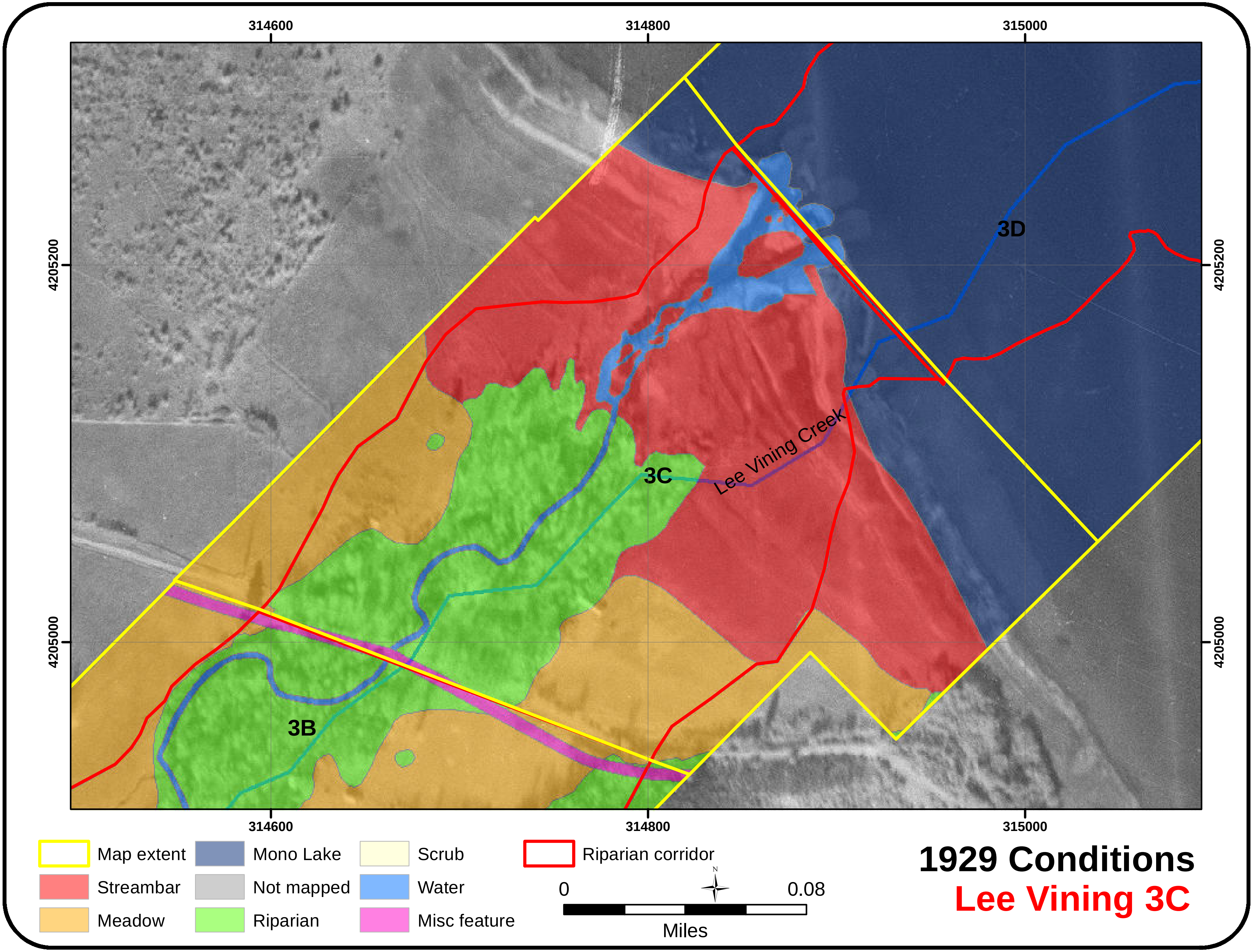
313800
314000
314200
314400
314600
314800
4204000
4203800
4203600
4203400
4203200
3B
3A
2B
Lee Vining Creek
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.22
Miles
N
1929 Conditions
Lee Vining 3A

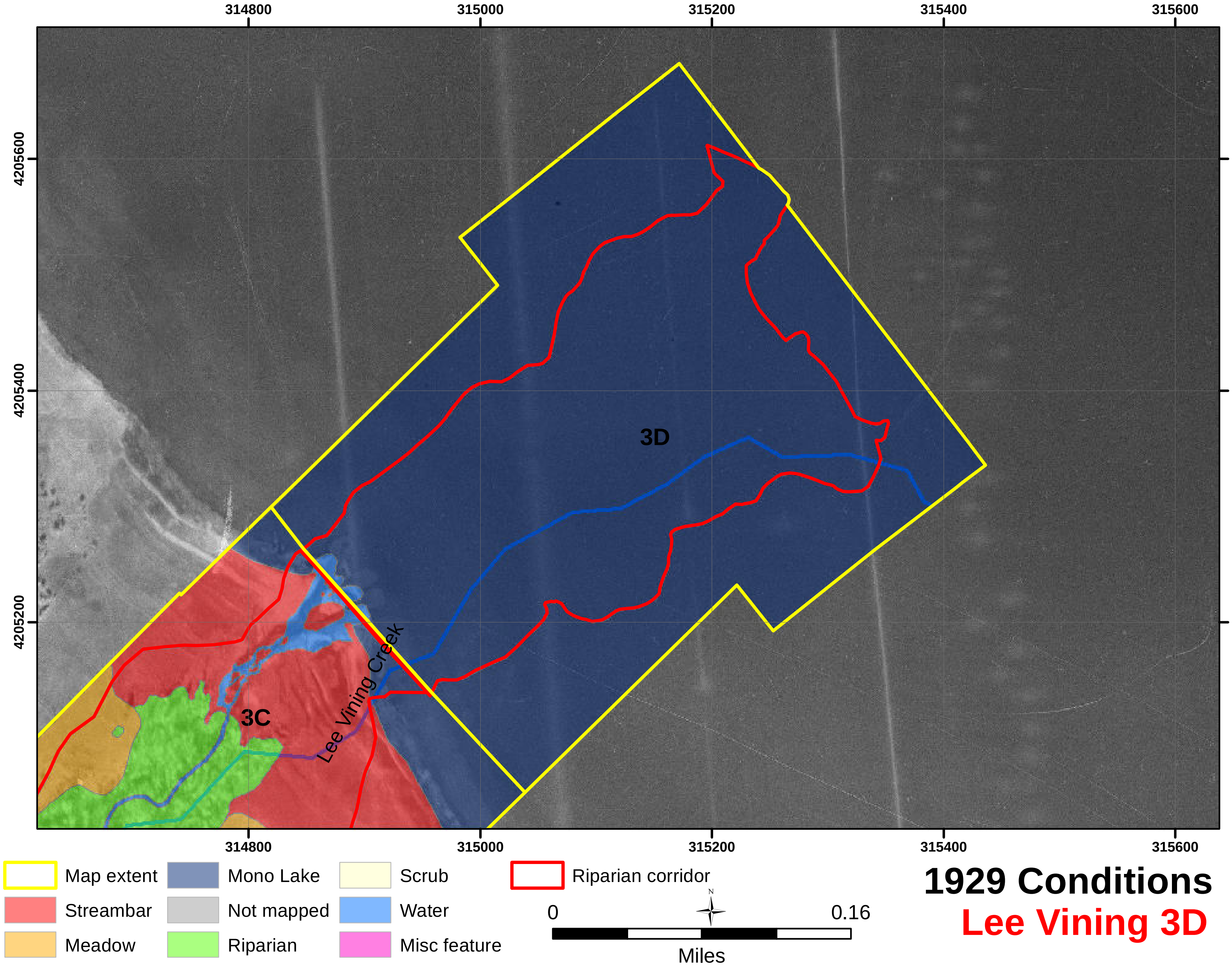


1929 Conditions

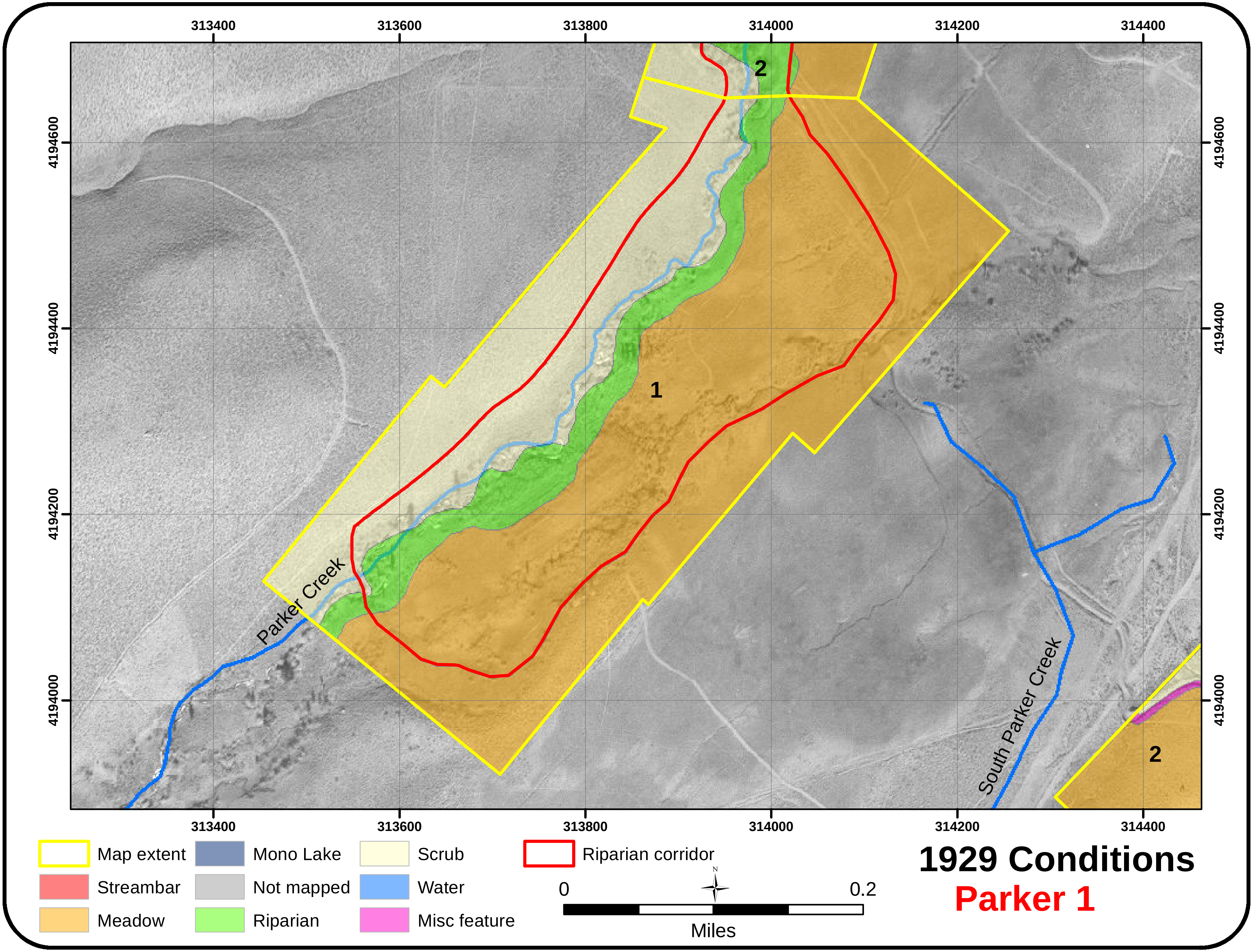
Lee Vining 3B



314600
314800
315000
4205200
4205000
3D
3C
3B
Lee Vining Creek
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.08
Miles
N
1929 Conditions
Lee Vining 3C



1929 Conditions
Lee Vining 3D



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313600
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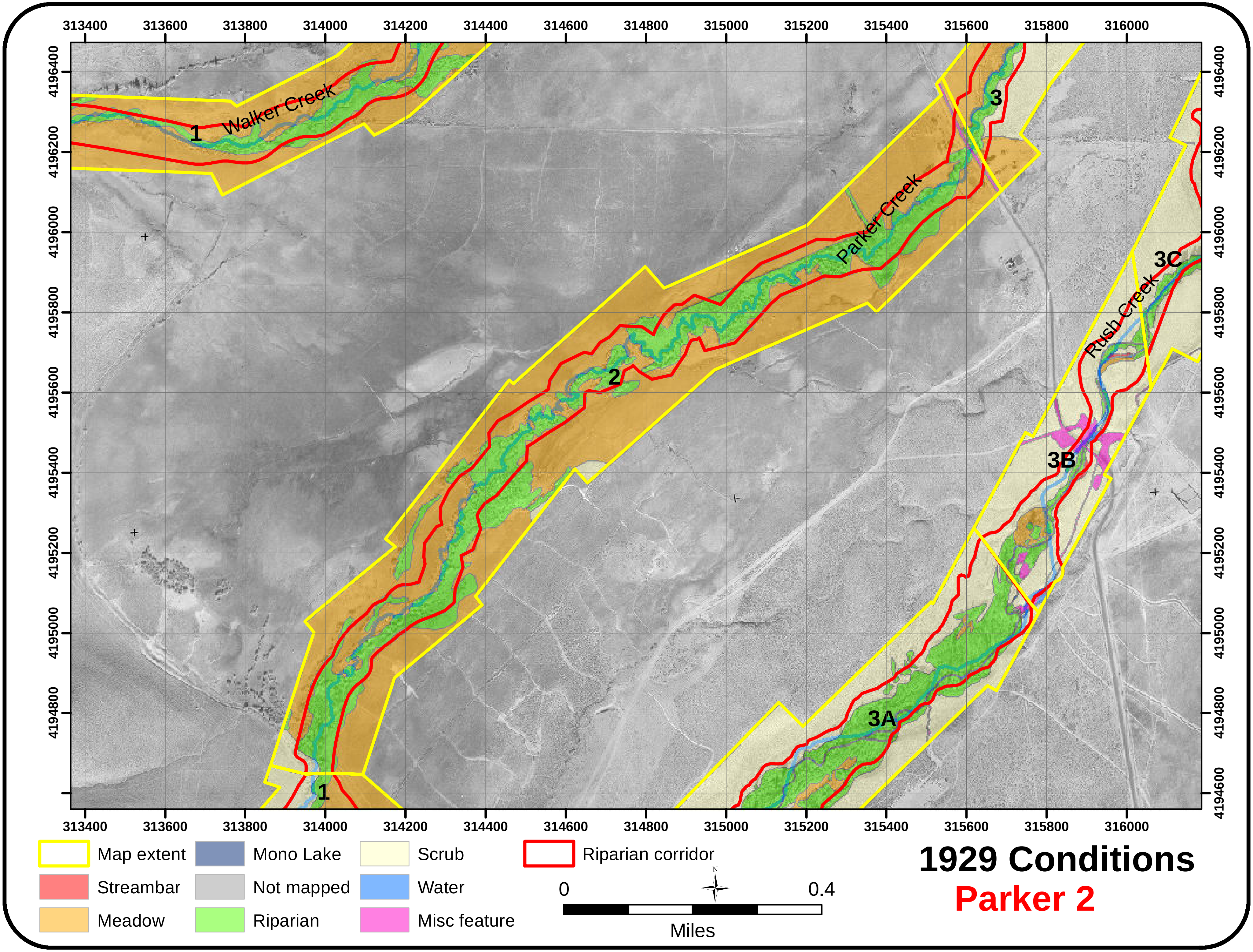
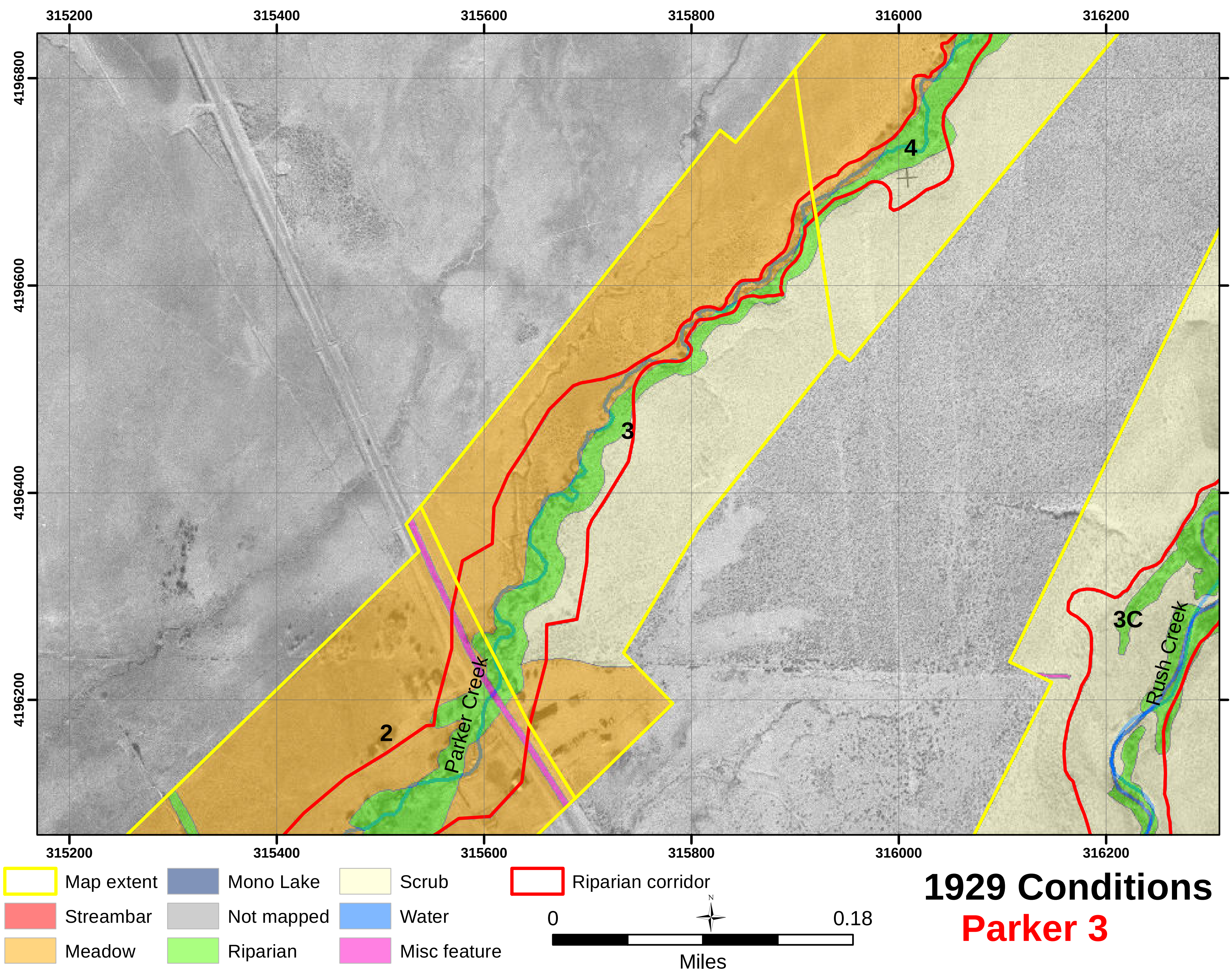
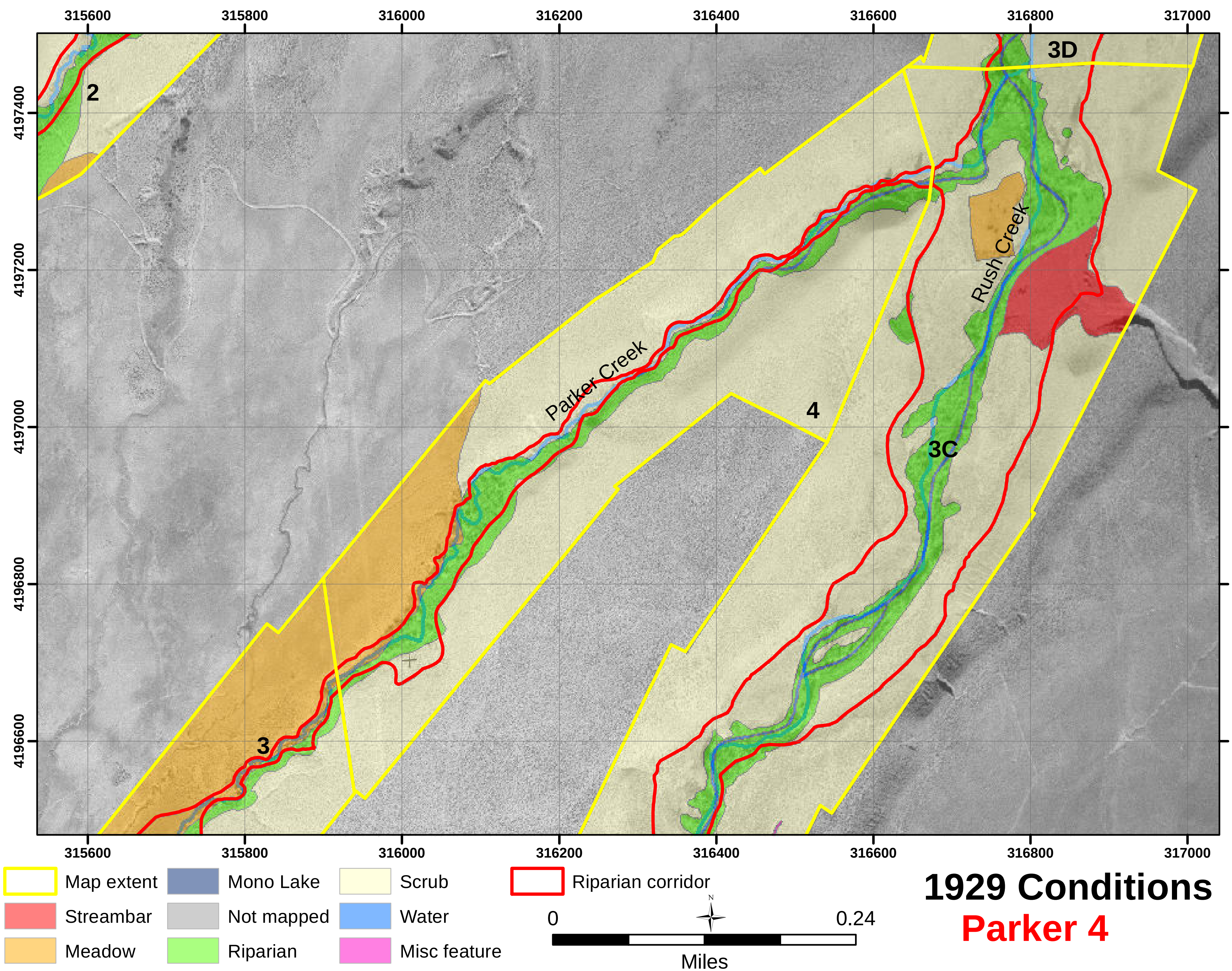
314200
314400
4194600
4194400
4194200
4194000
Parker Creek
South Parker Creek
1
2
2
Map extent
Mono Lake
Scrub
Riparian corridor
Streambar
Not mapped
Water
Meadow
Riparian
Misc feature
0
0.2
Miles
N
1929 Conditions
Parker 1



Walker Creek
Parker Creek
Rush Creek
1
2
3
3A
3B
3C
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.4
Miles
1929 Conditions
Parker 2

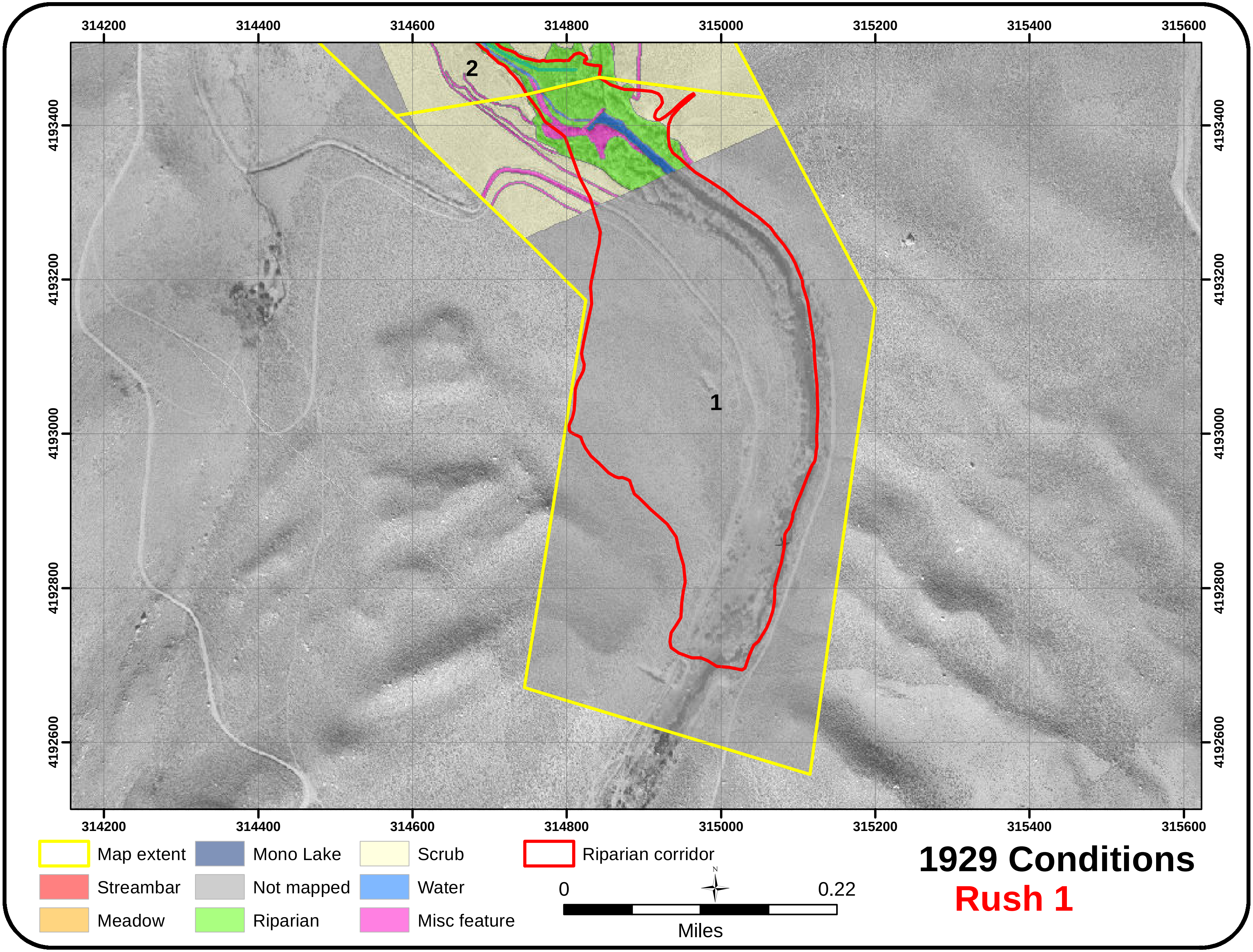


1929 Conditions
Parker 3



1929 Conditions

Parker 4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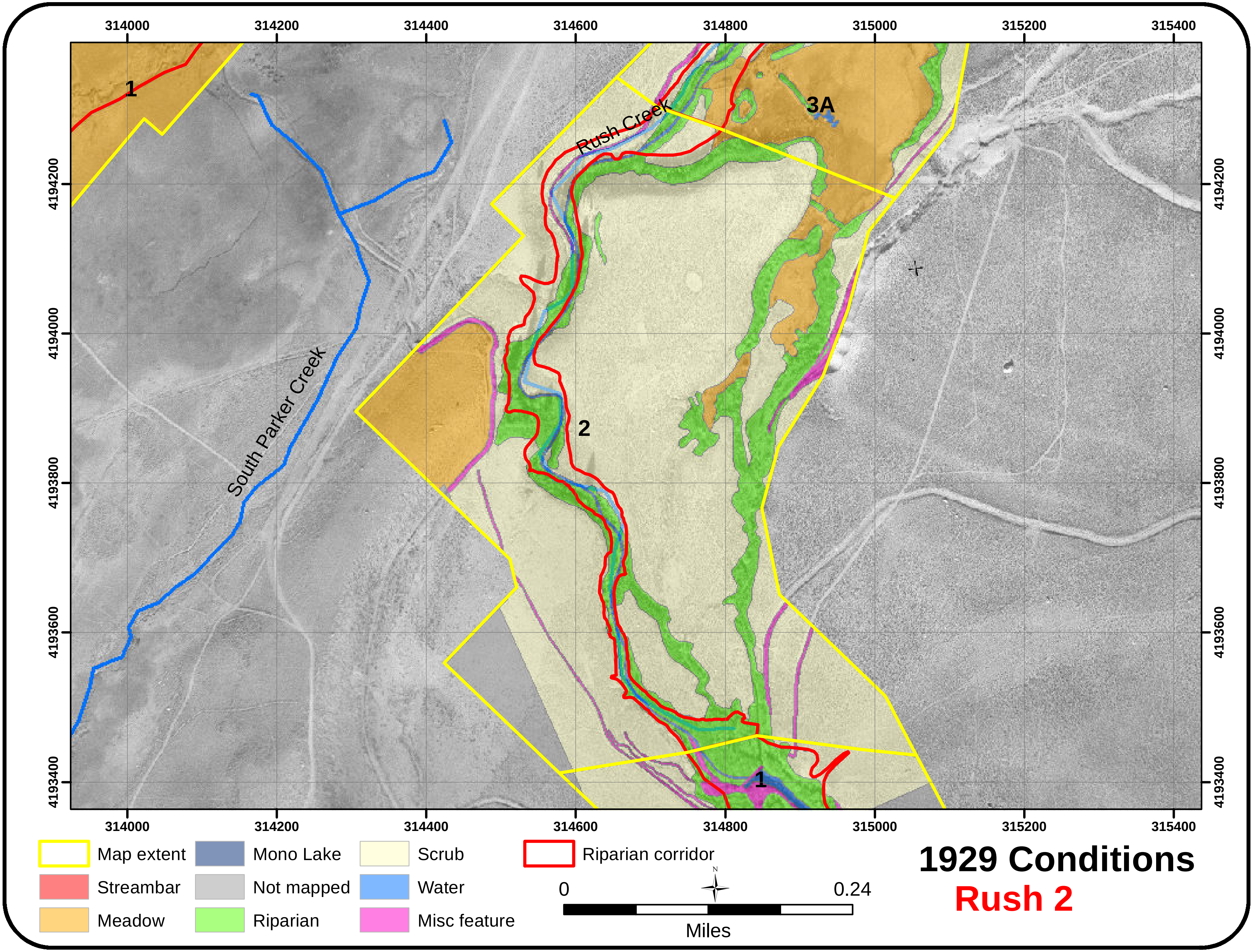
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.22
Miles
N
1929 Conditions
Rush 1



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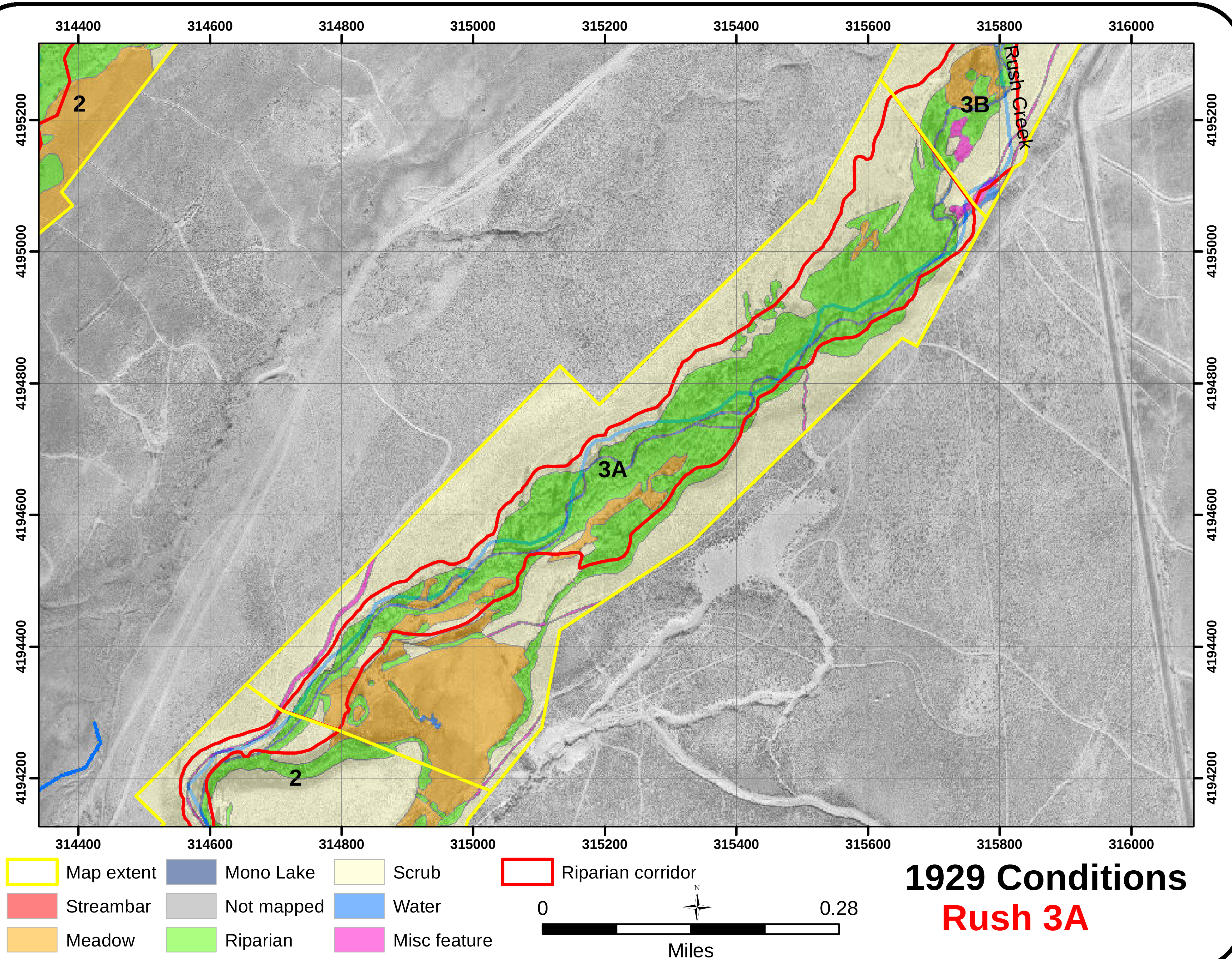
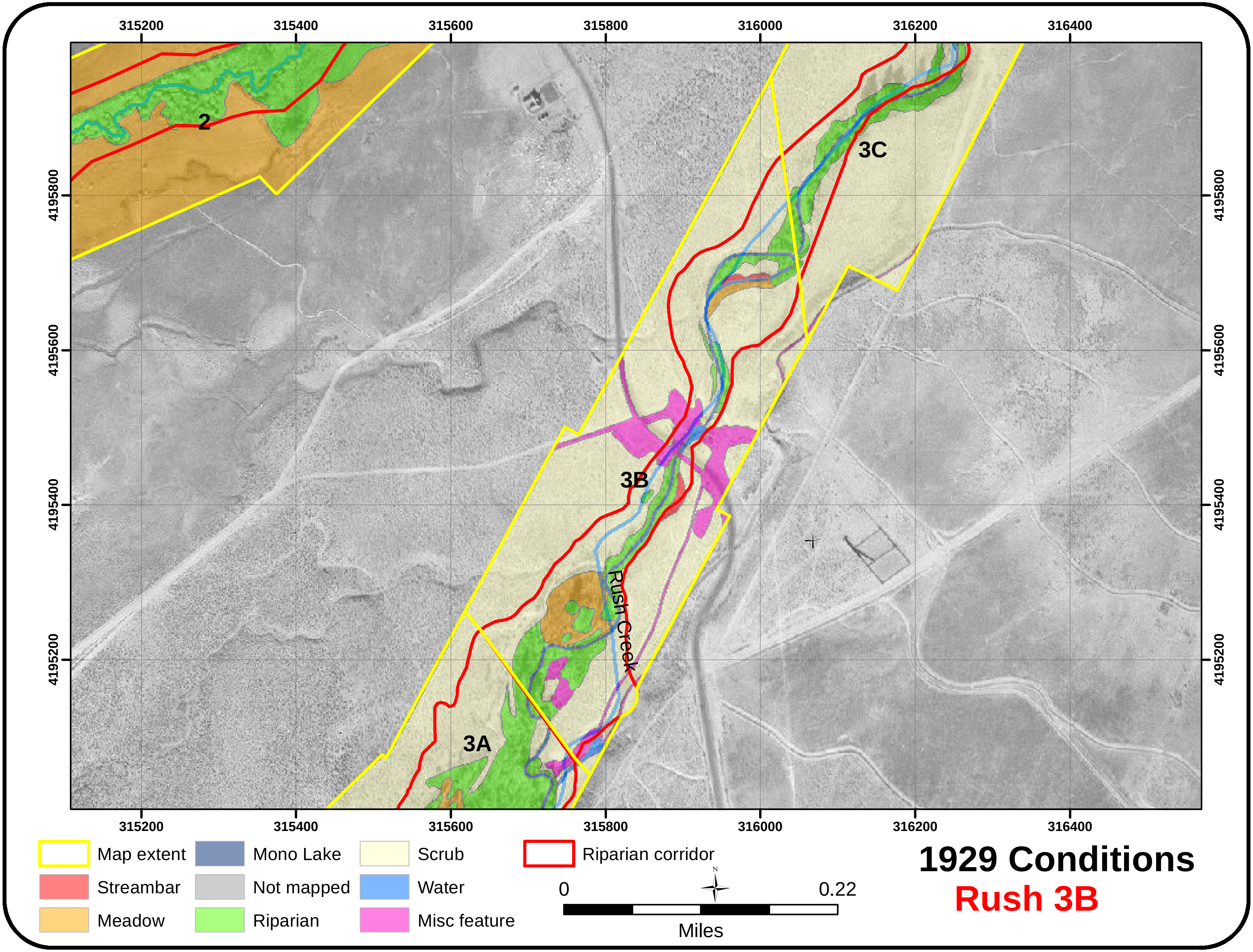
1
3A
Rush Creek
South Parker Creek
2
1
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.24
Miles
N
1929 Conditions
Rush 2



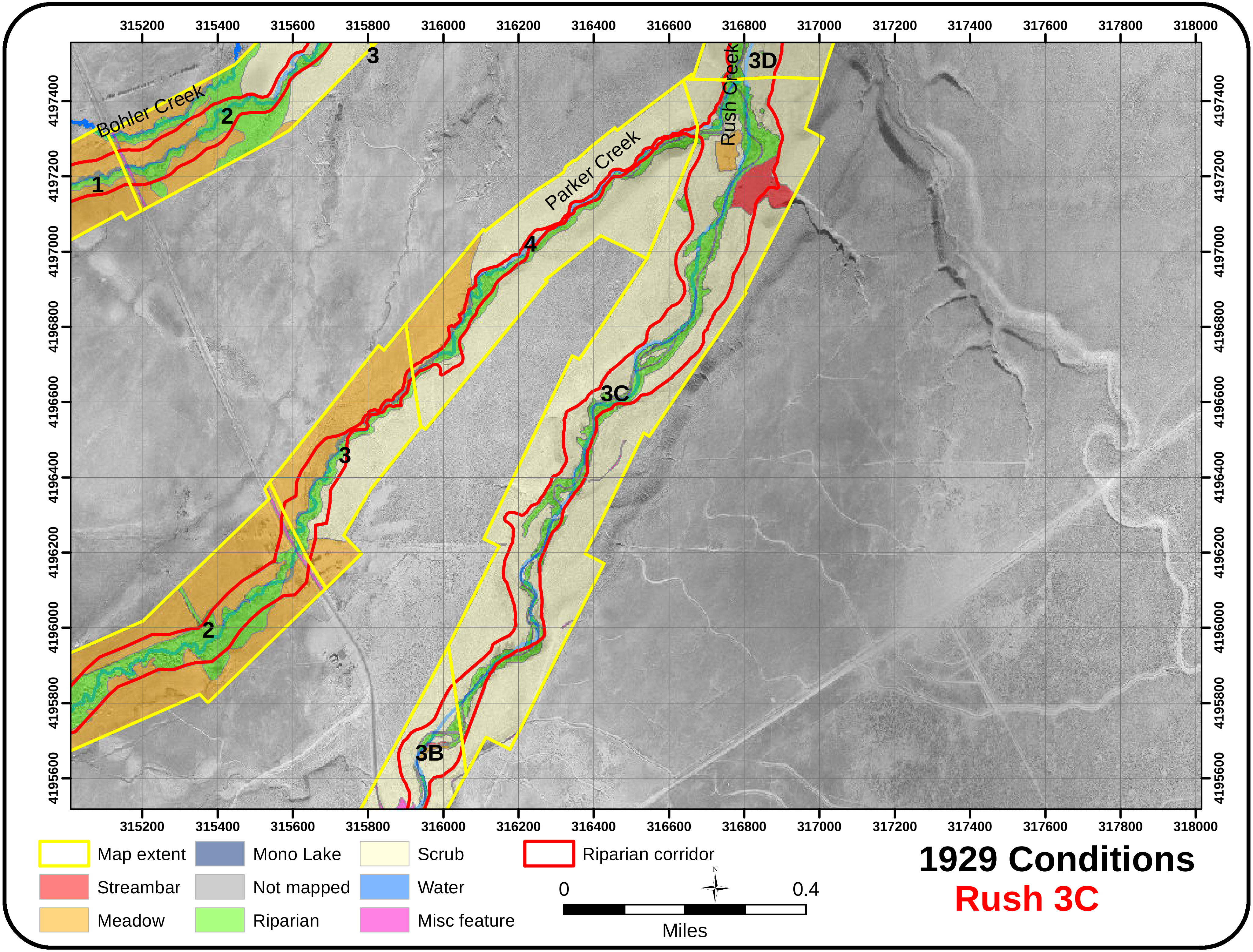
1929 Conditions

Rush 3A



1929 Conditions

Rush 3B



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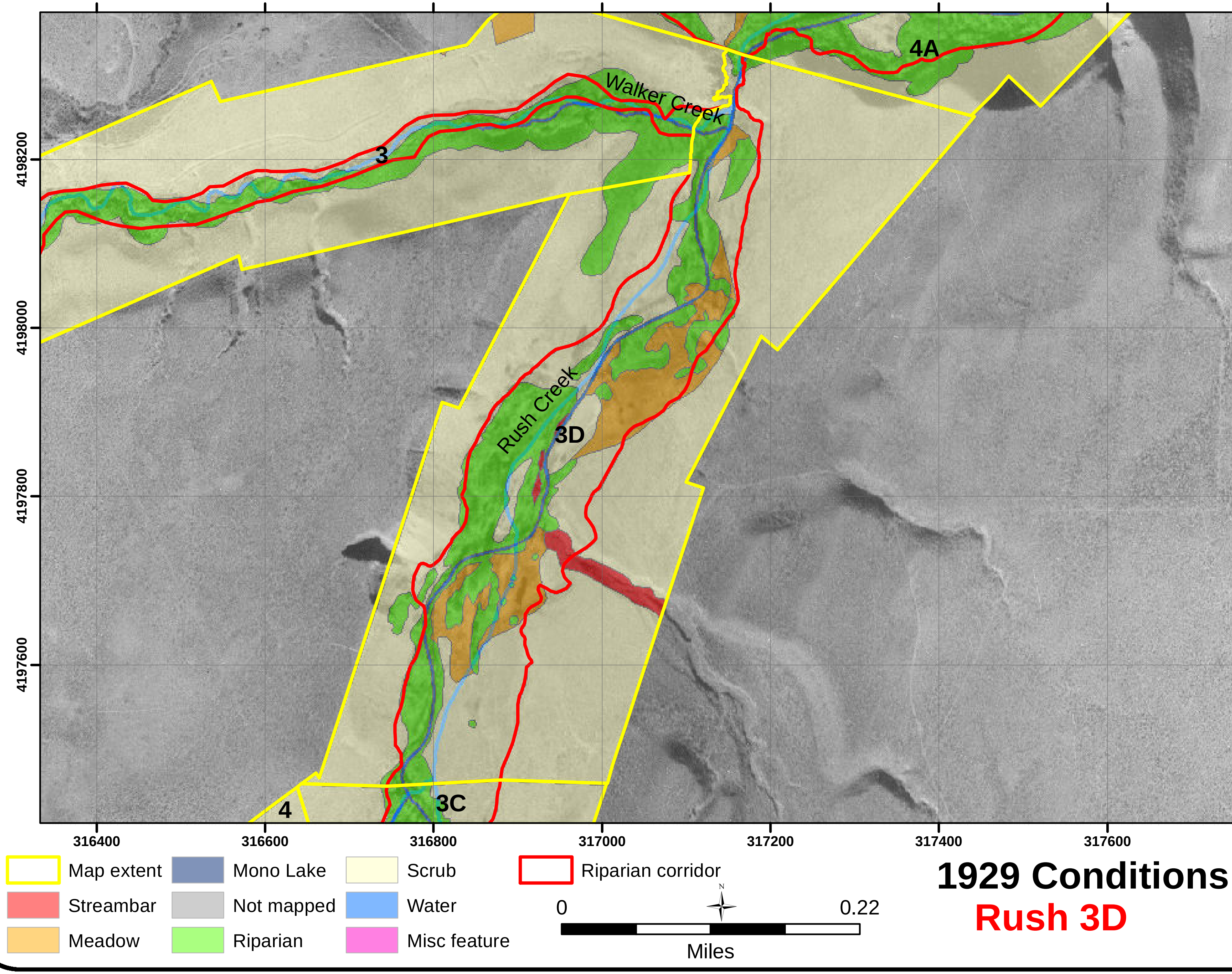
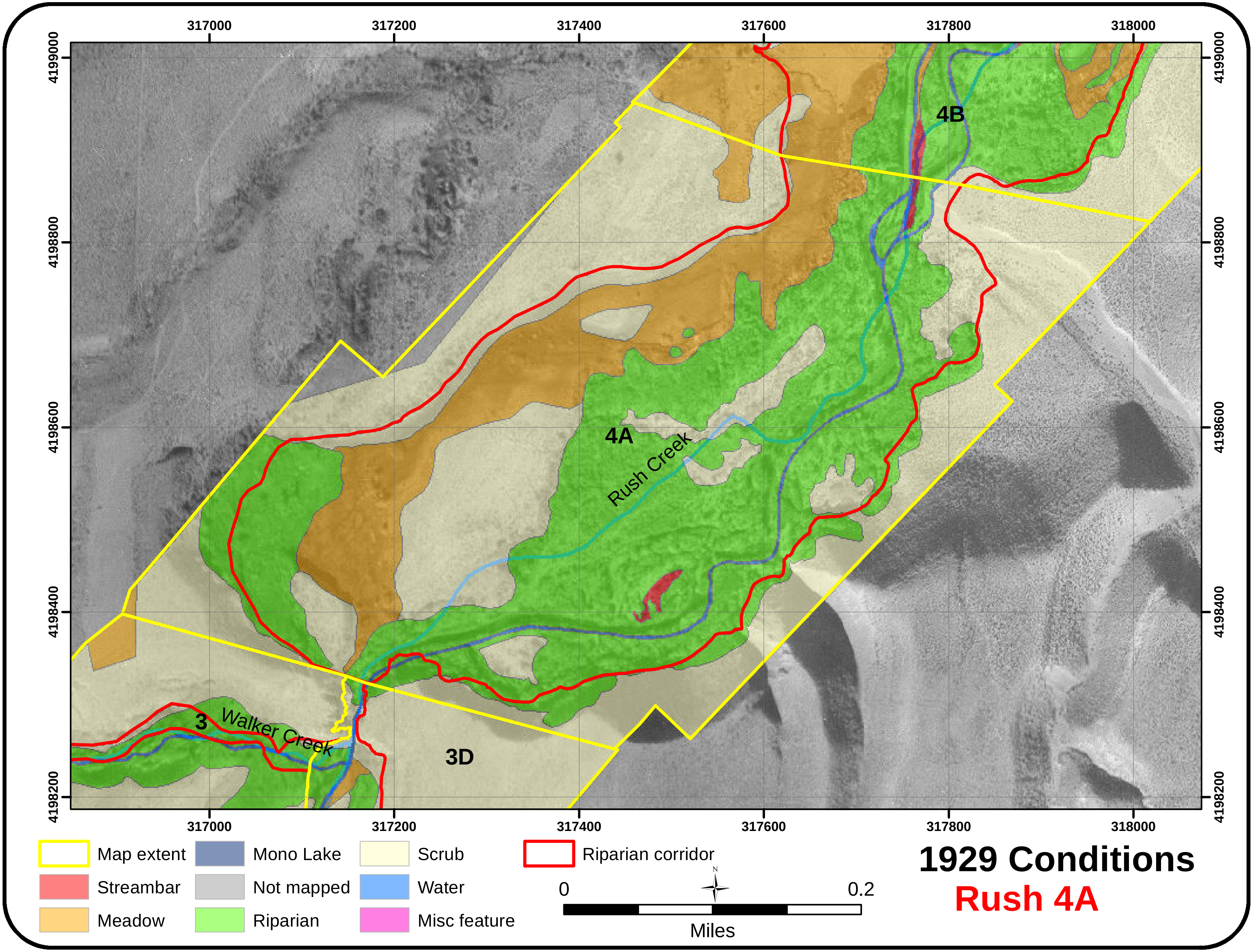
4197200
4197000
4196800
4196600
4196400
4196200
4196000
4195800
4195600
Bohler Creek
Parker Creek
Rush Creek
1
2
3
4
3B
3C
3D
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.4
Miles
N
1929 Conditions
Rush 3C



1929 Conditions

Rush 3D



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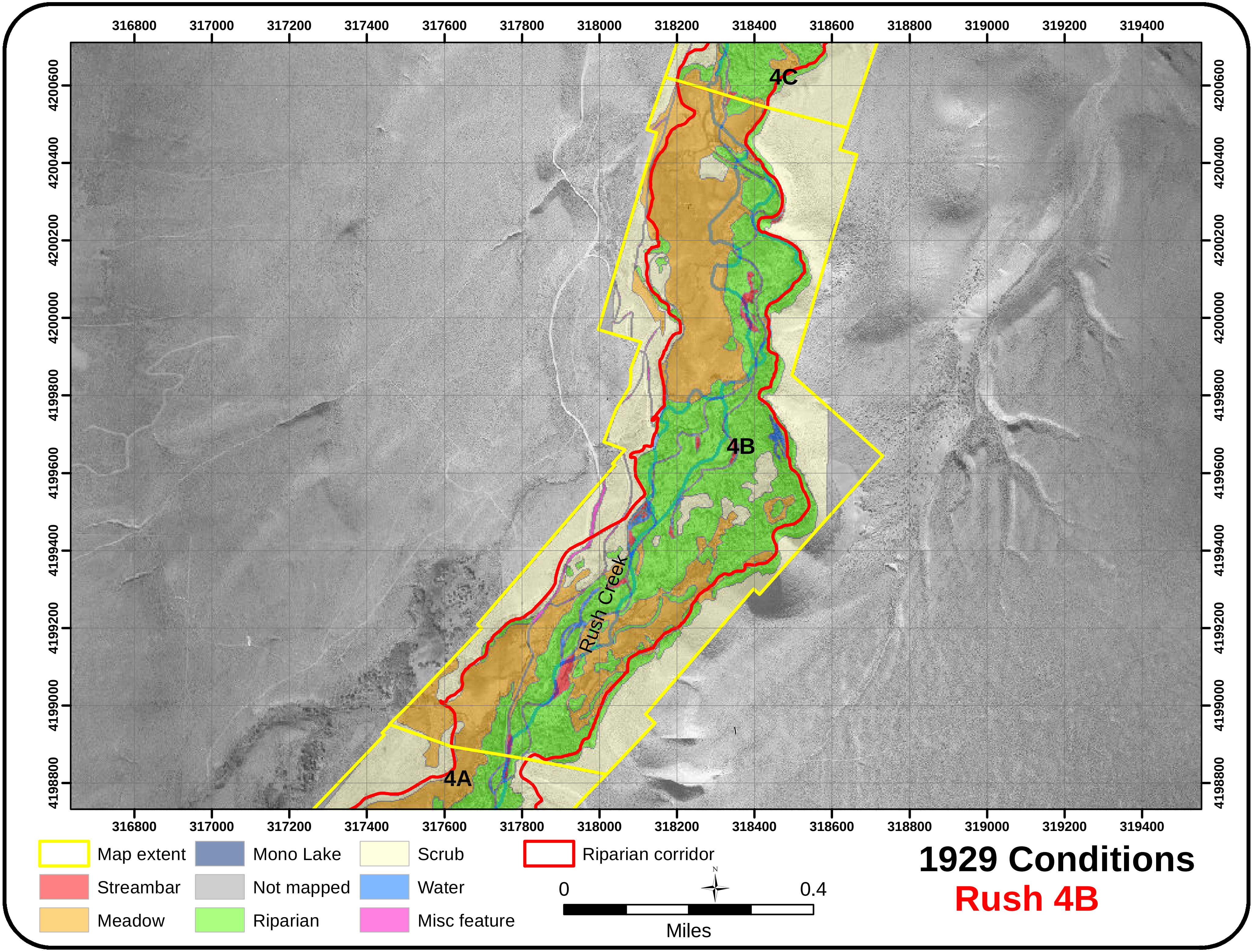
4B
4A
Rush Creek
3
Walker Creek
3D
Map extent
Mono Lake
Scrub
Riparian corridor
Streambar
Not mapped
Water
Meadow
Riparian
Misc feature
N
0
0.2
Miles
1929 Conditions
Rush 4A



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4B
4A
Rush Creek
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319200
319400
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4200400
4200200
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4199600
4199400
4199200
4199000
4198800
Map extent
Streambar
Meadow
Mono Lake
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Riparian
Scrub
Water
Misc feature
Riparian corridor
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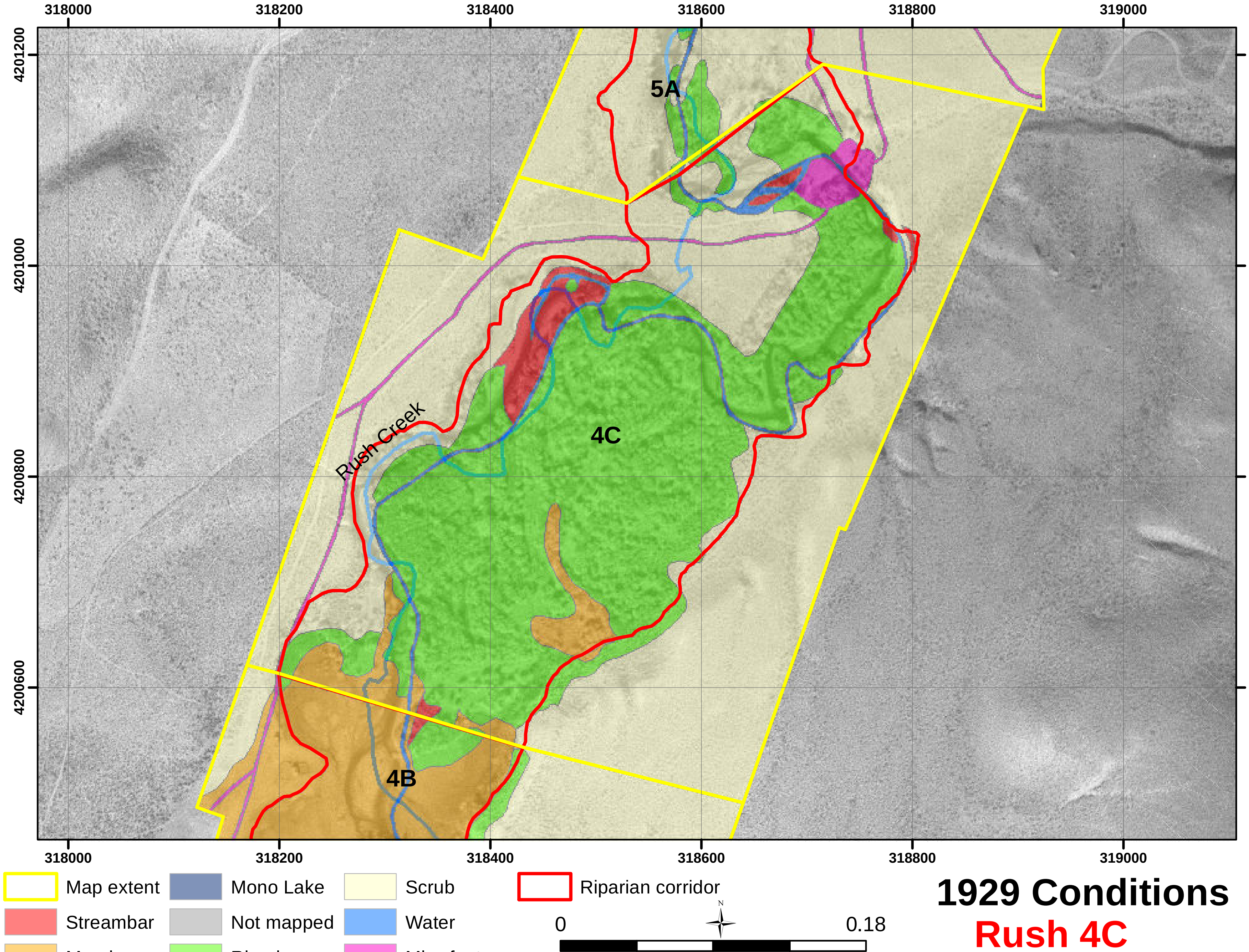
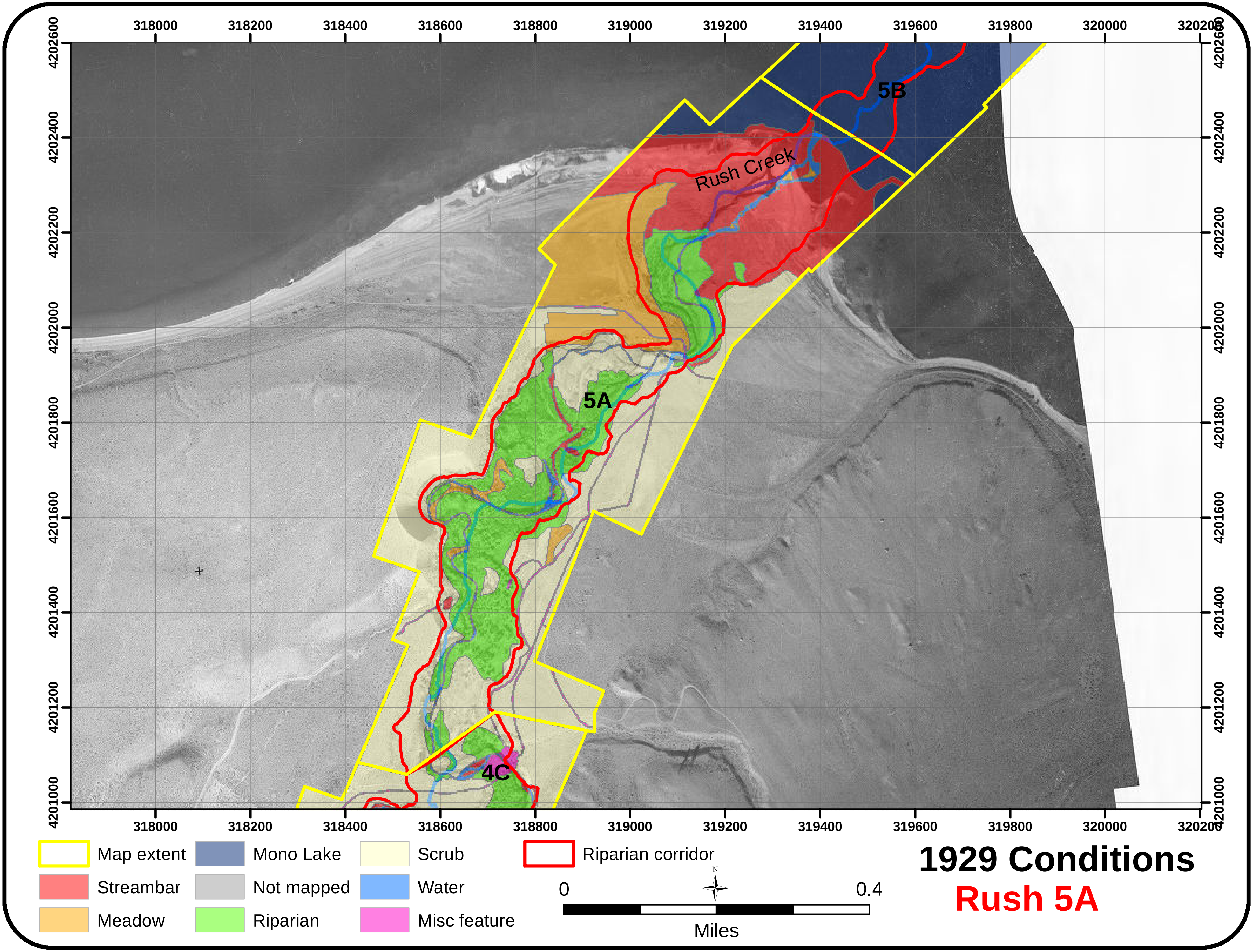
0.4
N
Miles
1929 Conditions
Rush 4B

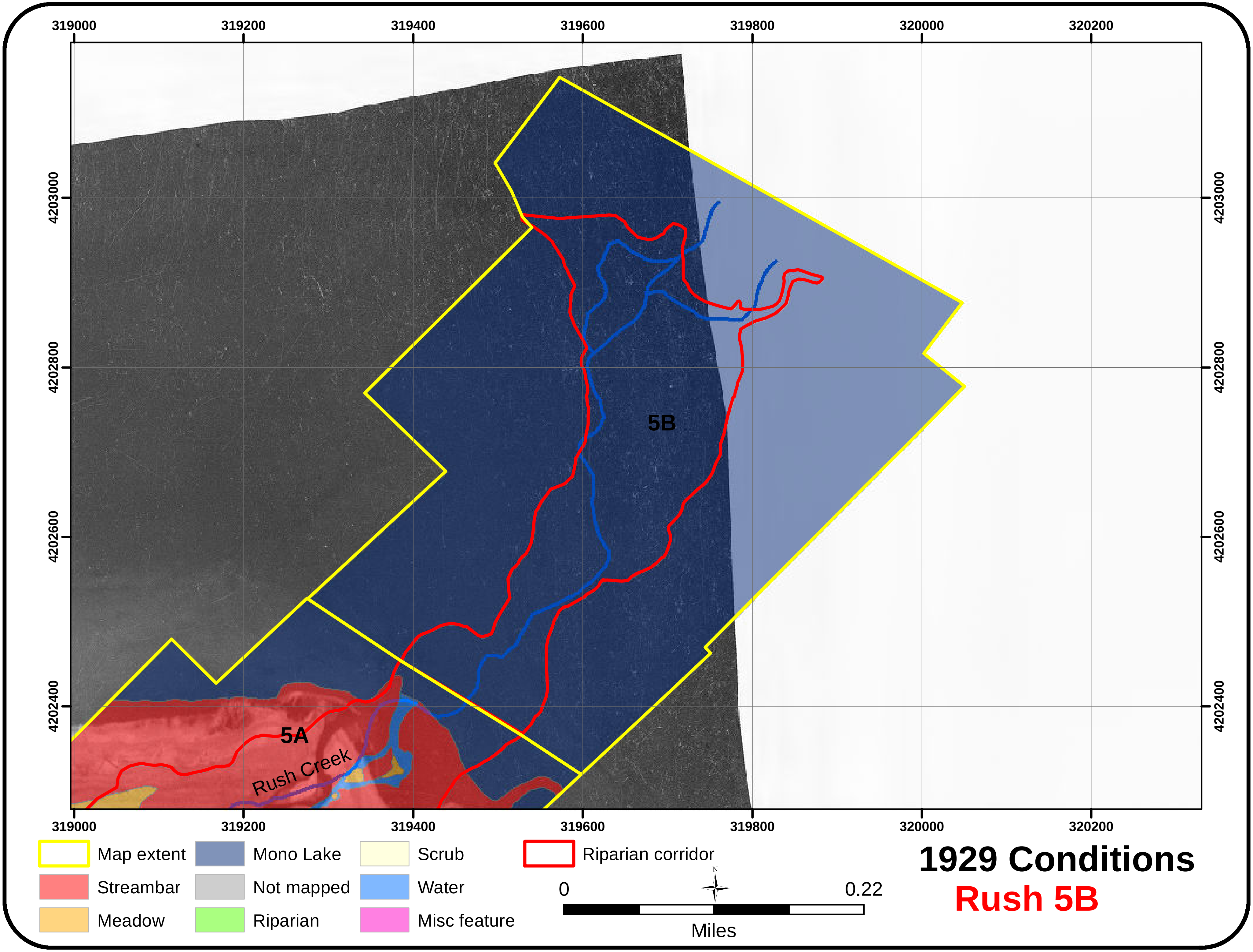


1929 Conditions

Rush 4C



5B
Rush Creek
5A
4C
Map extent
Mono Lake
Scrub
Riparian corridor
Streambar
Not mapped
Water
Meadow
Riparian
Misc feature
0
0.4
Miles
1929 Conditions
Rush 5A



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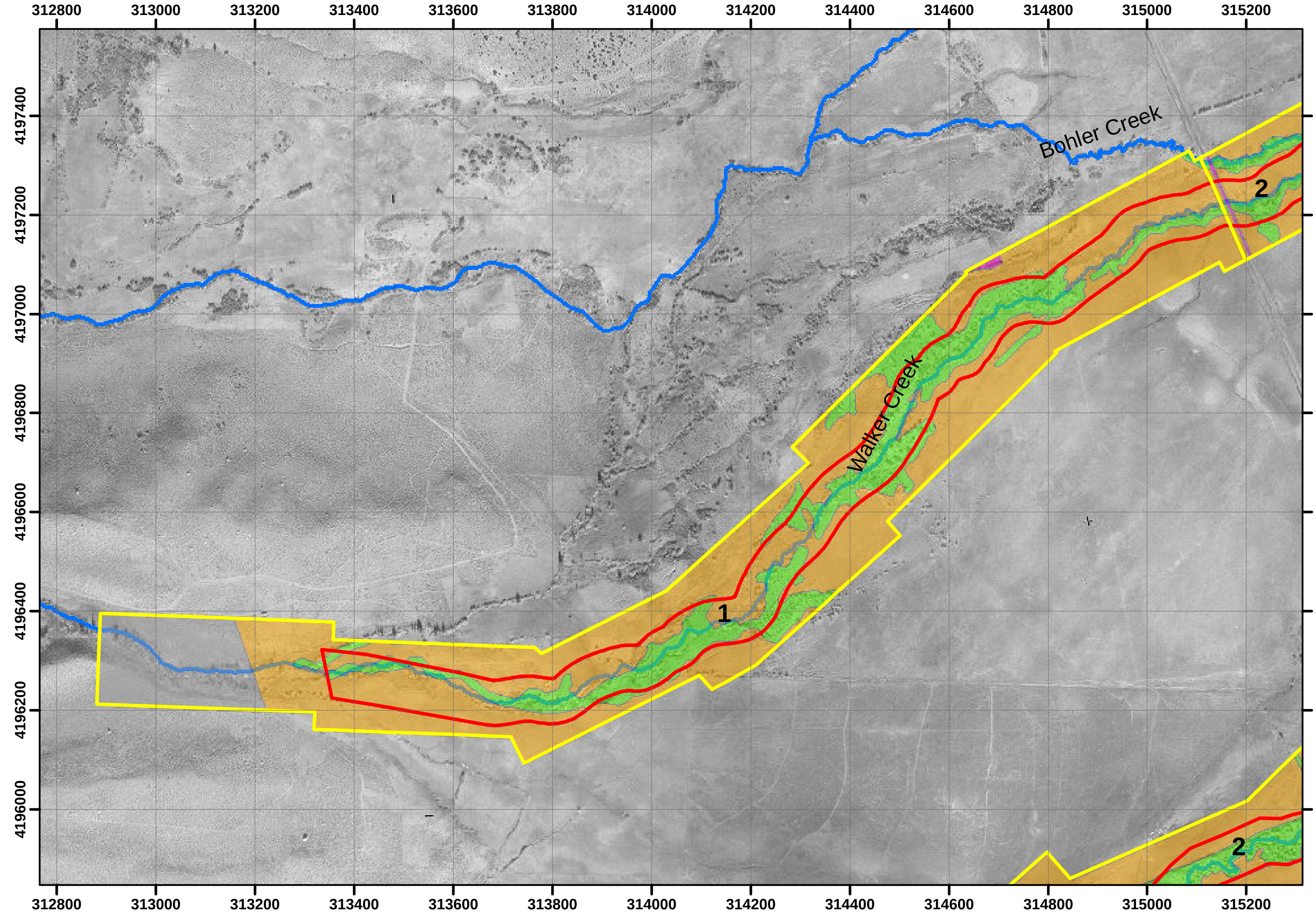
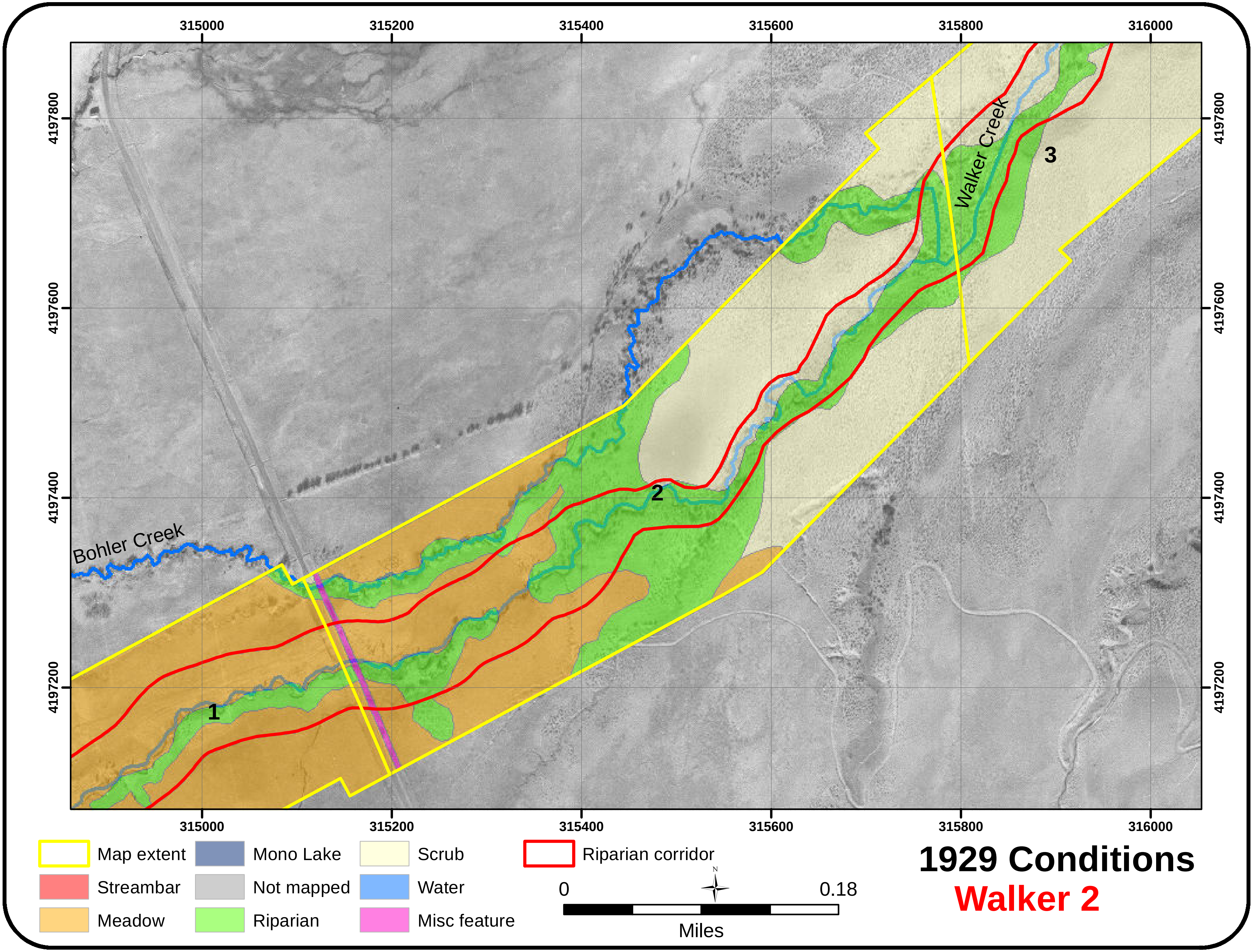
4202400
5B
5A
Rush Creek
Map extent
Mono Lake
Scrub
Riparian corridor
Streambar
Not mapped
Water
Meadow
Riparian
Misc feature
0
0.22
Miles
N
1929 Conditions
Rush 5B



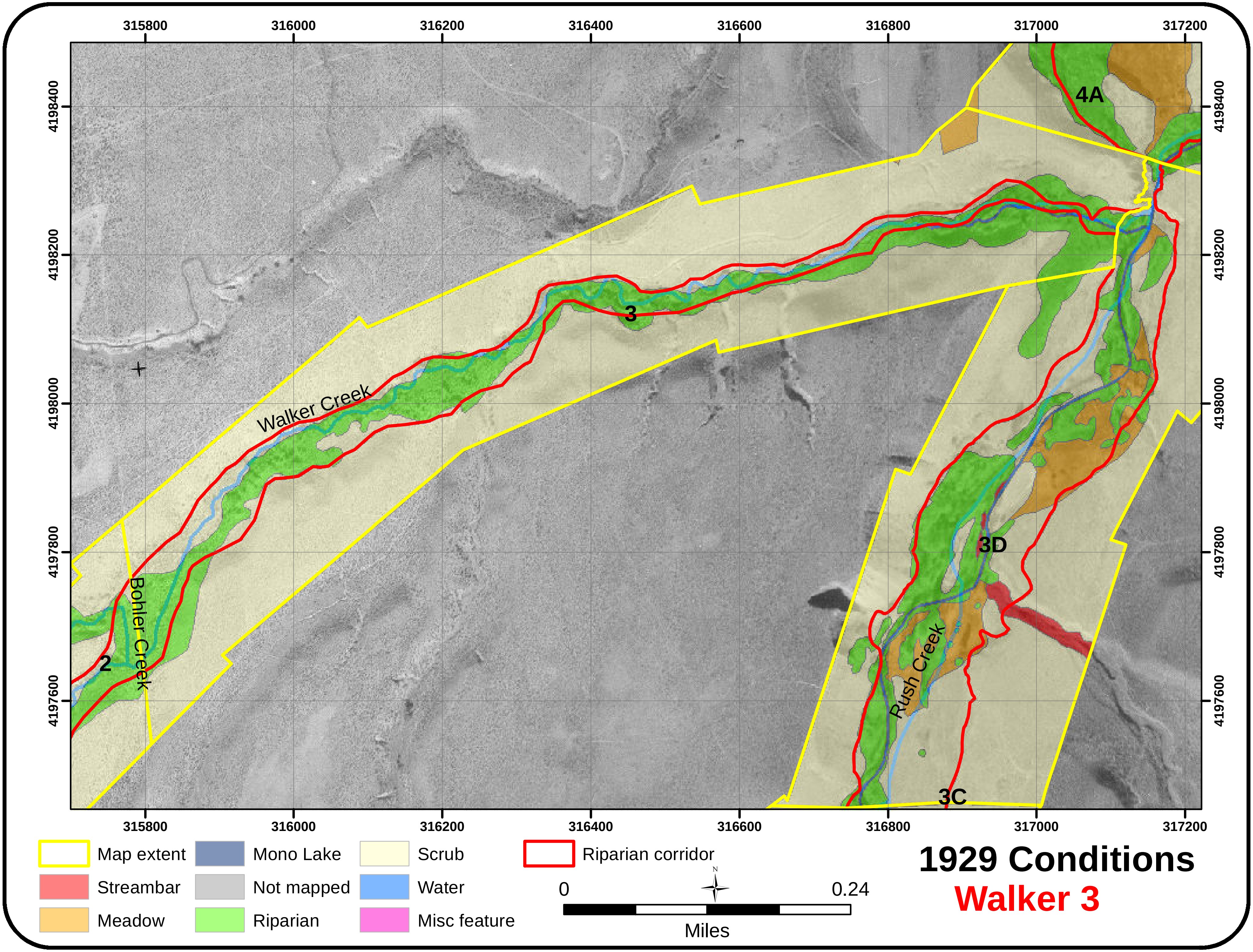
1929 Conditions

Walker 1



1929 Conditions

Walker 2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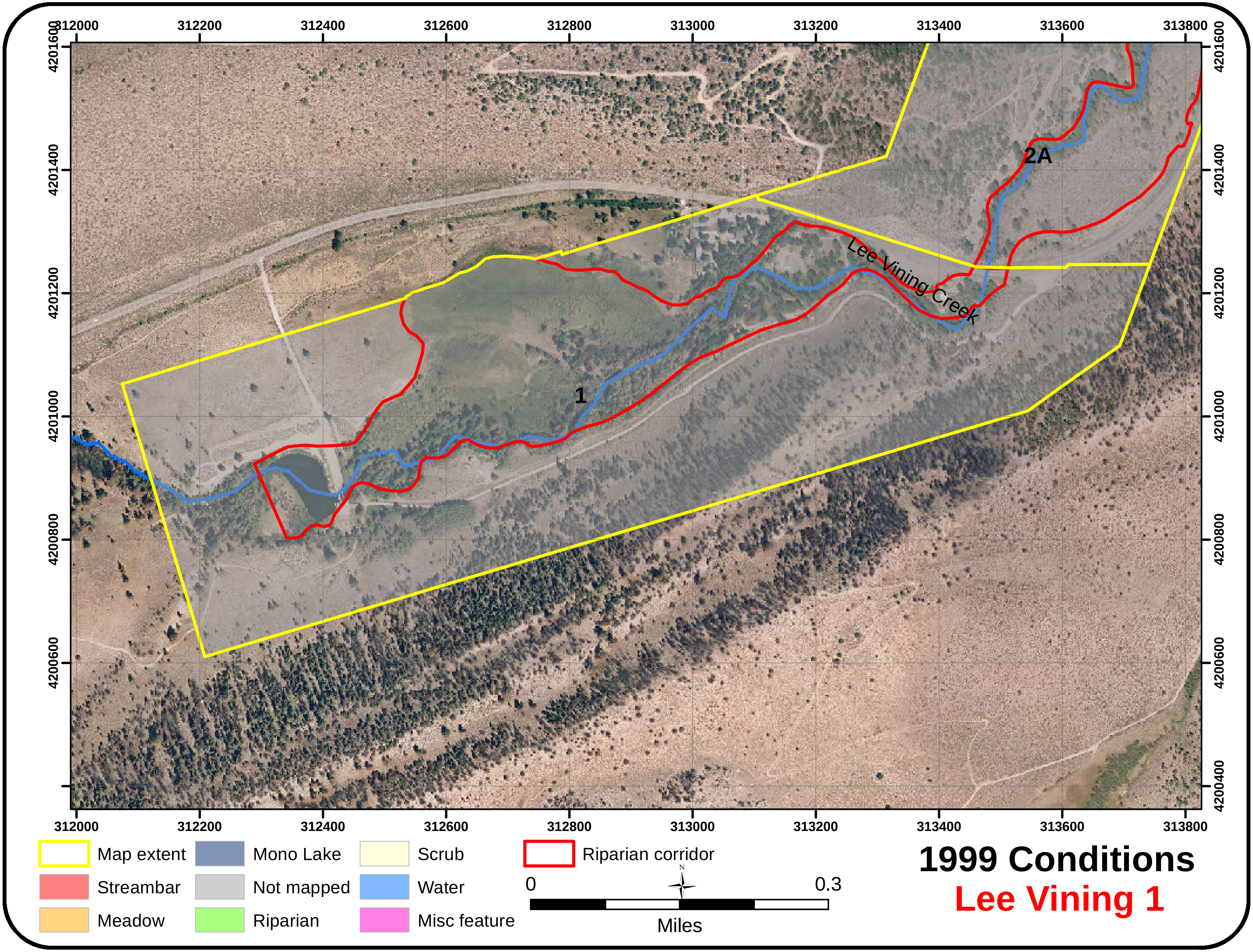
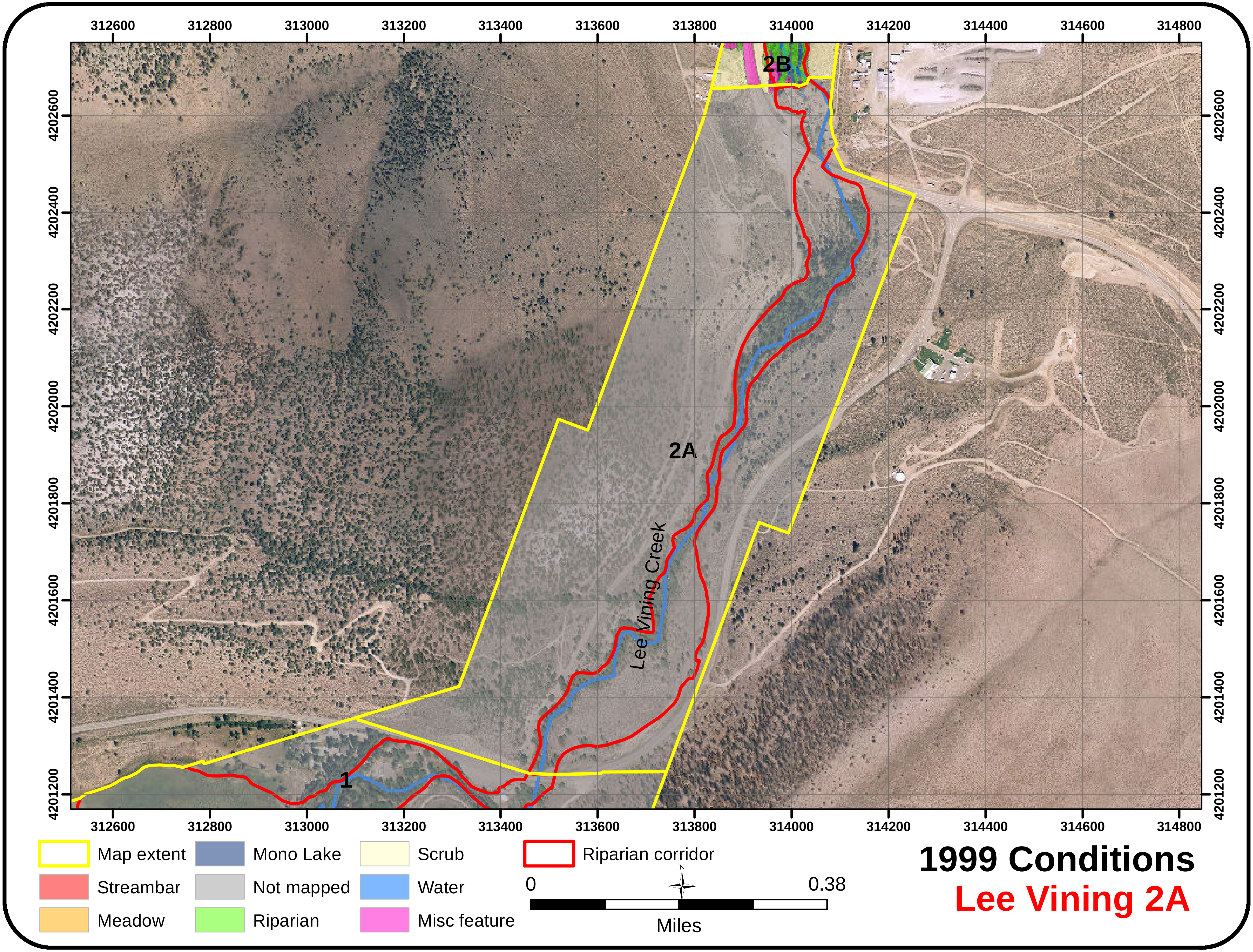
316000
316200
316400
316600
316800
317000
317200
4198400
4198200
4198000
4197800
4197600
Walker Creek
Bohler Creek
Rush Creek
2
3
3C
3D
4A
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.24
Miles
N
1929 Conditions
Walker 3

APPENDIX B
RIPARIAN MAPPING
1999 CONDITIONS



2A
1
Lee Vining Creek
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.3
Miles
N
1999 Conditions
Lee Vining 1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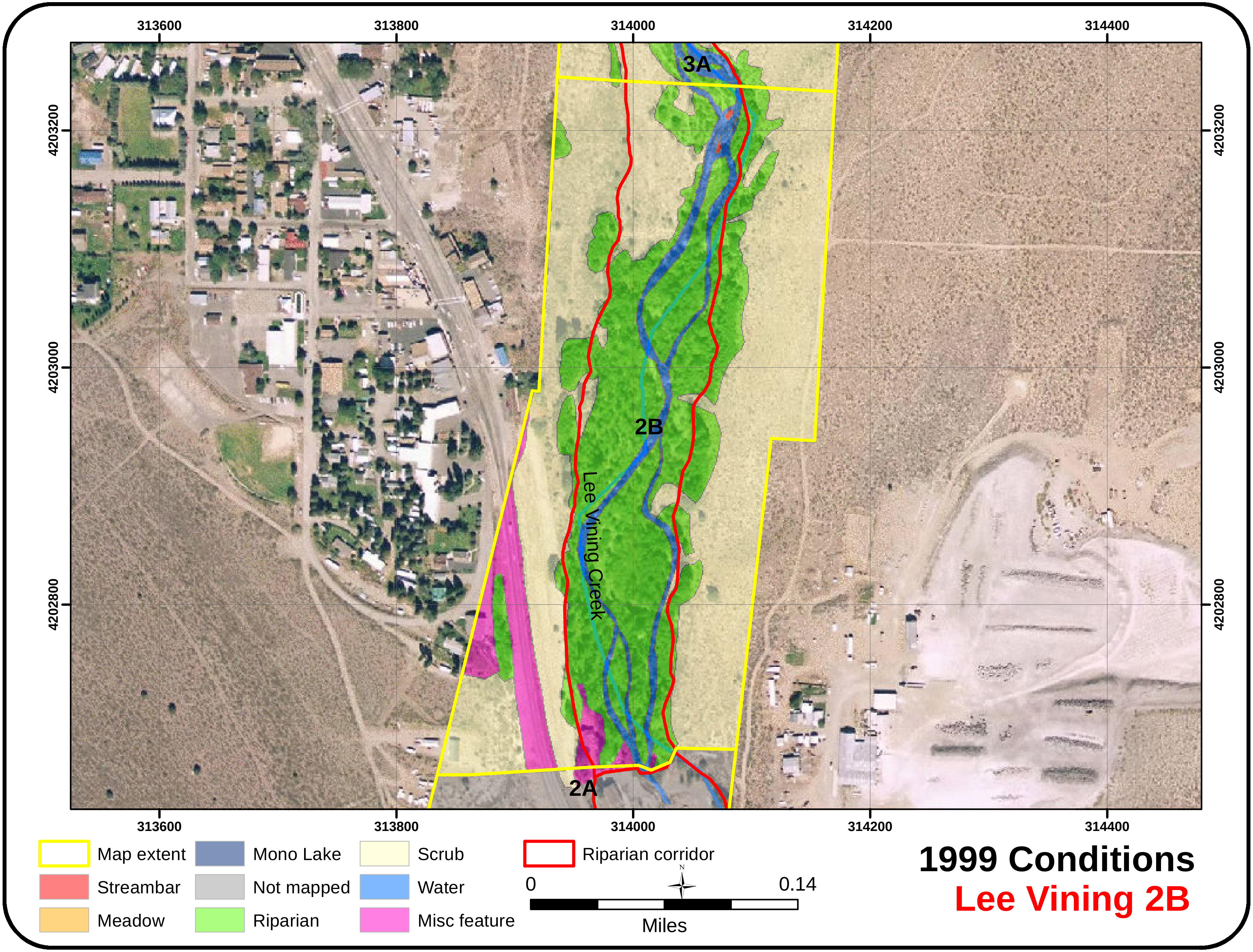
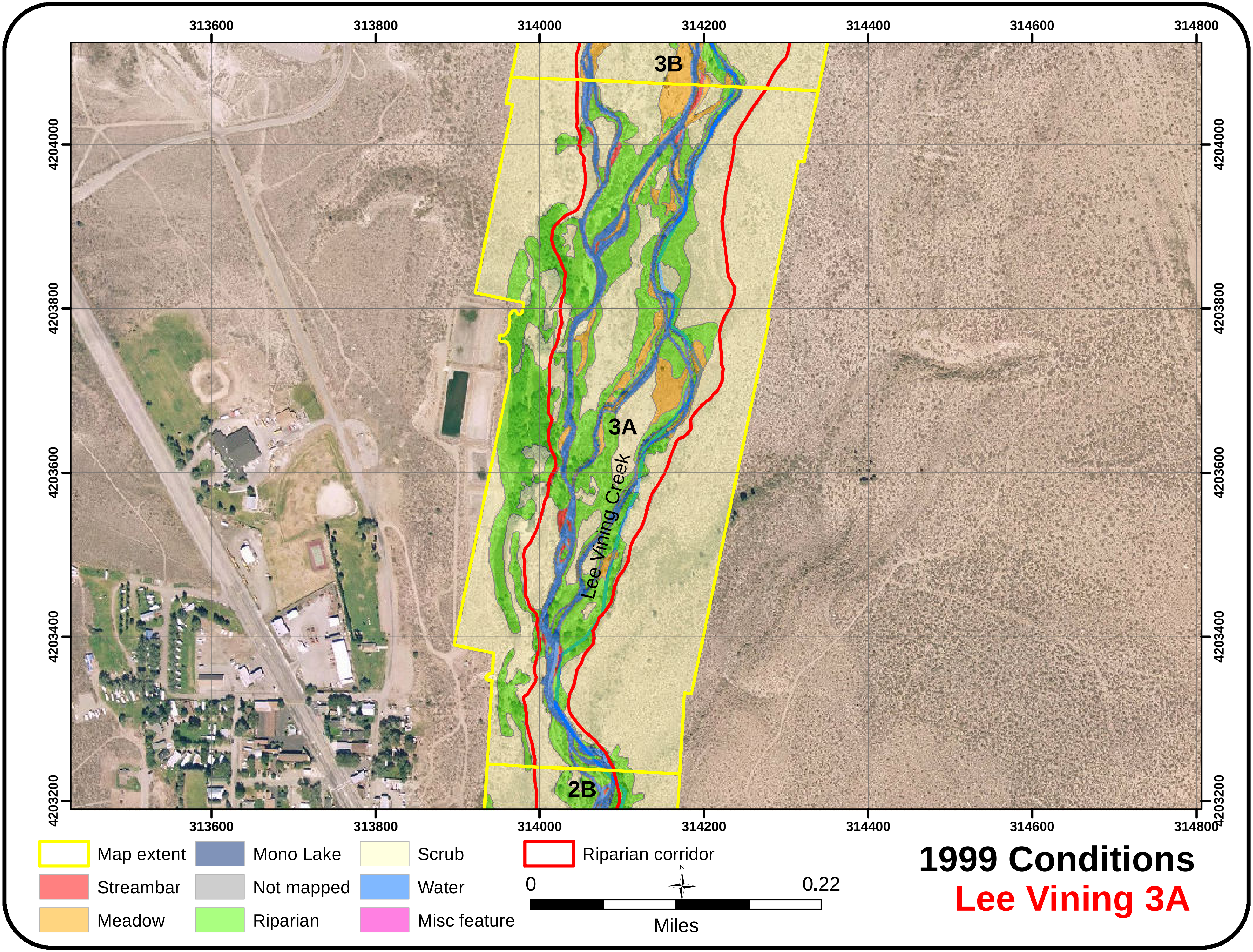
312800
313000
313200
313400
313600
313800
314000
314200
314400
314600
314800
4202600
4202400
4202200
4202000
4201800
4201600
4201400
4201200
2B
2A
1
Lee Vining Creek
Map extent
Mono Lake
Scrub
Riparian corridor
Streambar
Not mapped
Water
Meadow
Riparian
Misc feature
0
0.38
Miles
N
1999 Conditions
Lee Vining 2A



1999 Conditions

Lee Vining 2B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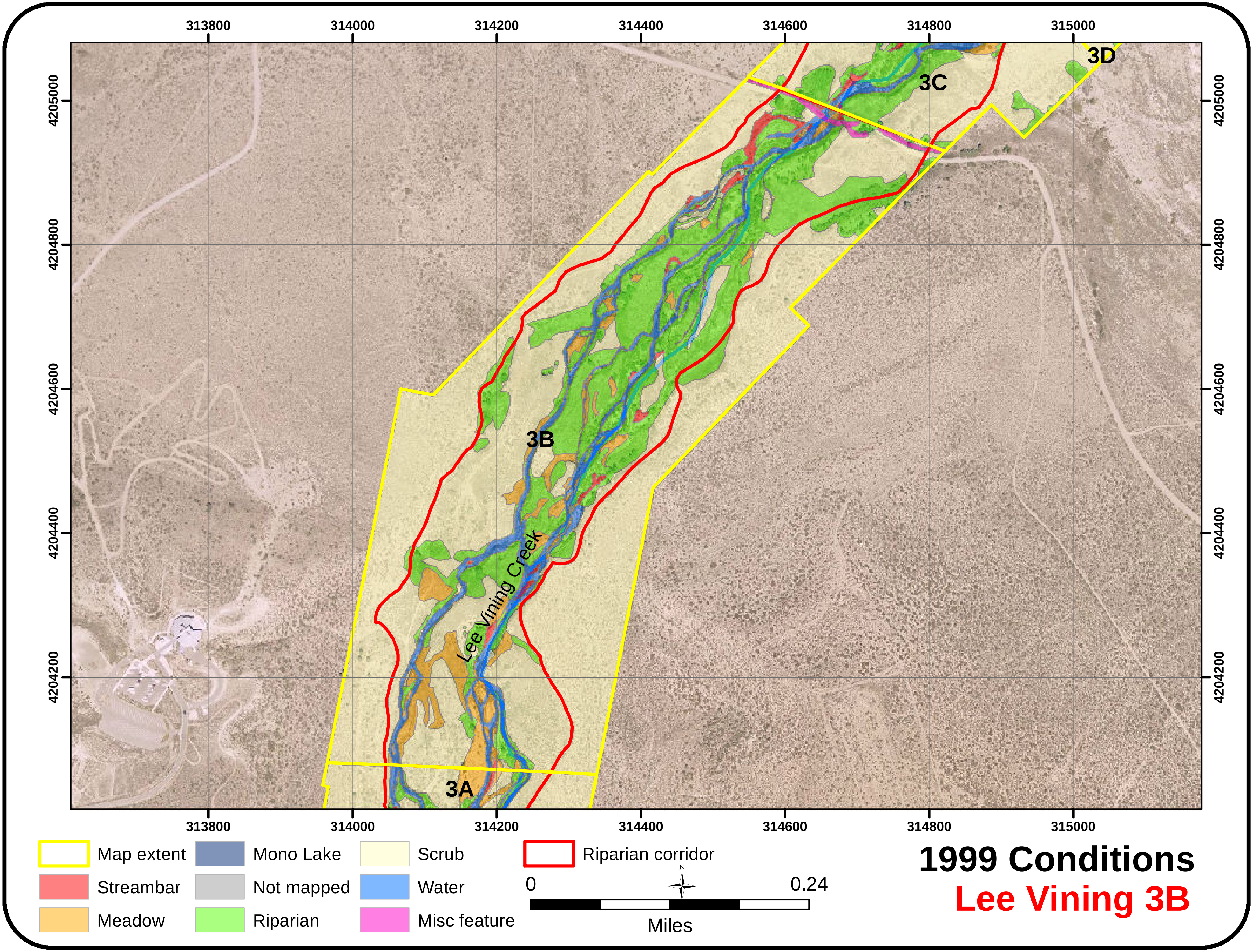
313800
314000
314200
314400
314600
314800
4204000
4203800
4203600
4203400
4203200
3B
3A
2B
Lee Vining Creek
Map extent
Mono Lake
Scrub
Riparian corridor
Streambar
Not mapped
Water
Meadow
Riparian
Misc feature
0
0.22
Miles
1999 Conditions
Lee Vining 3A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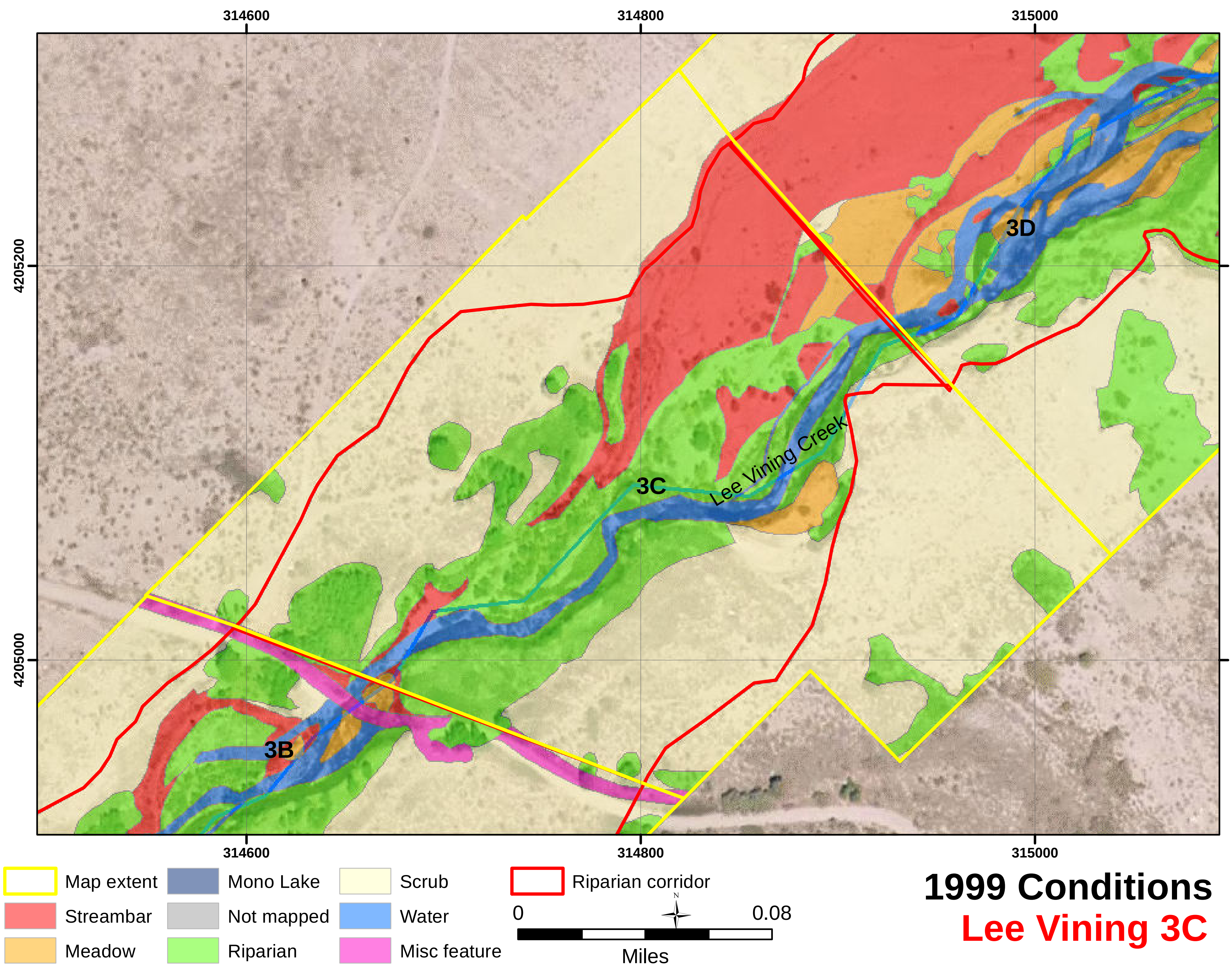
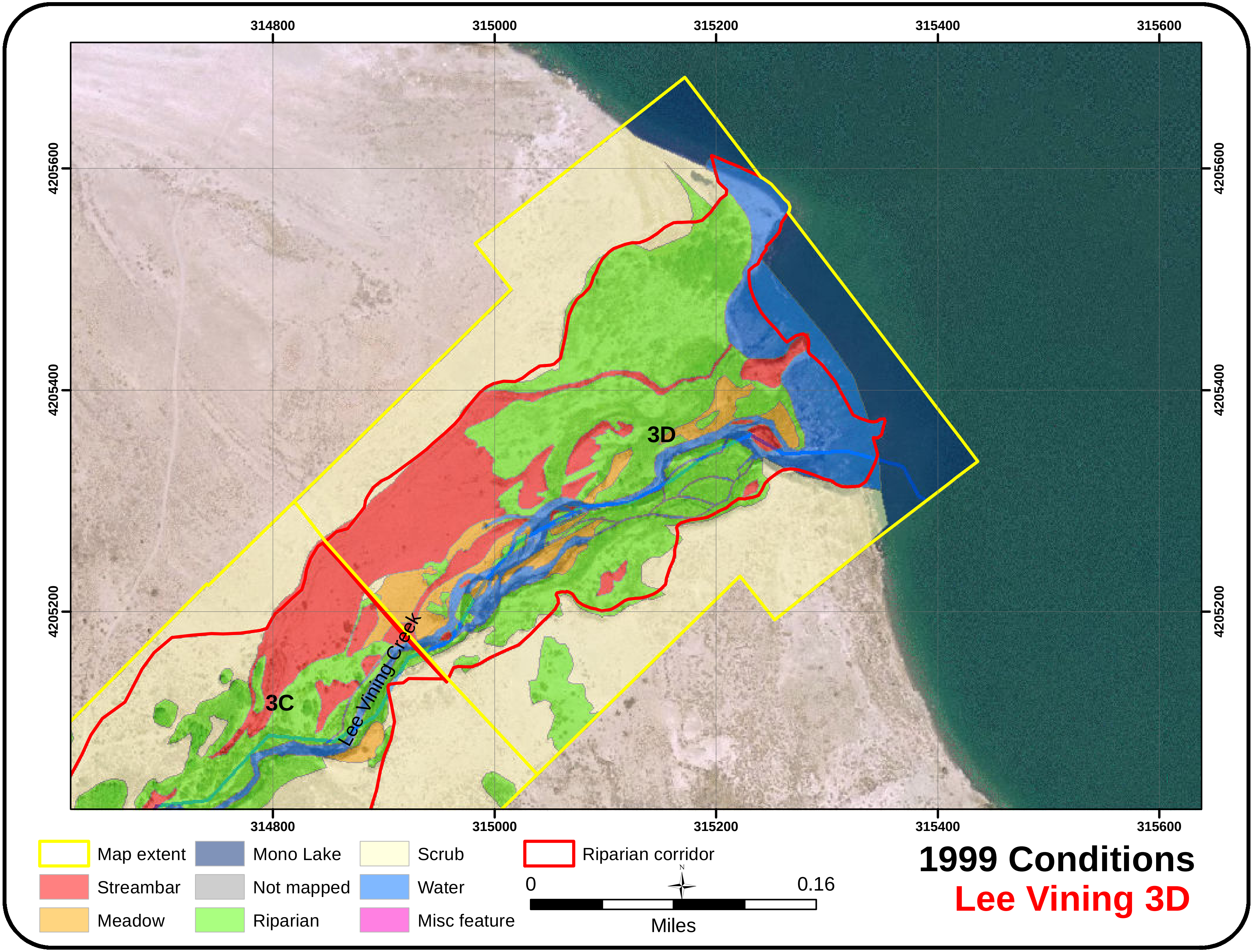
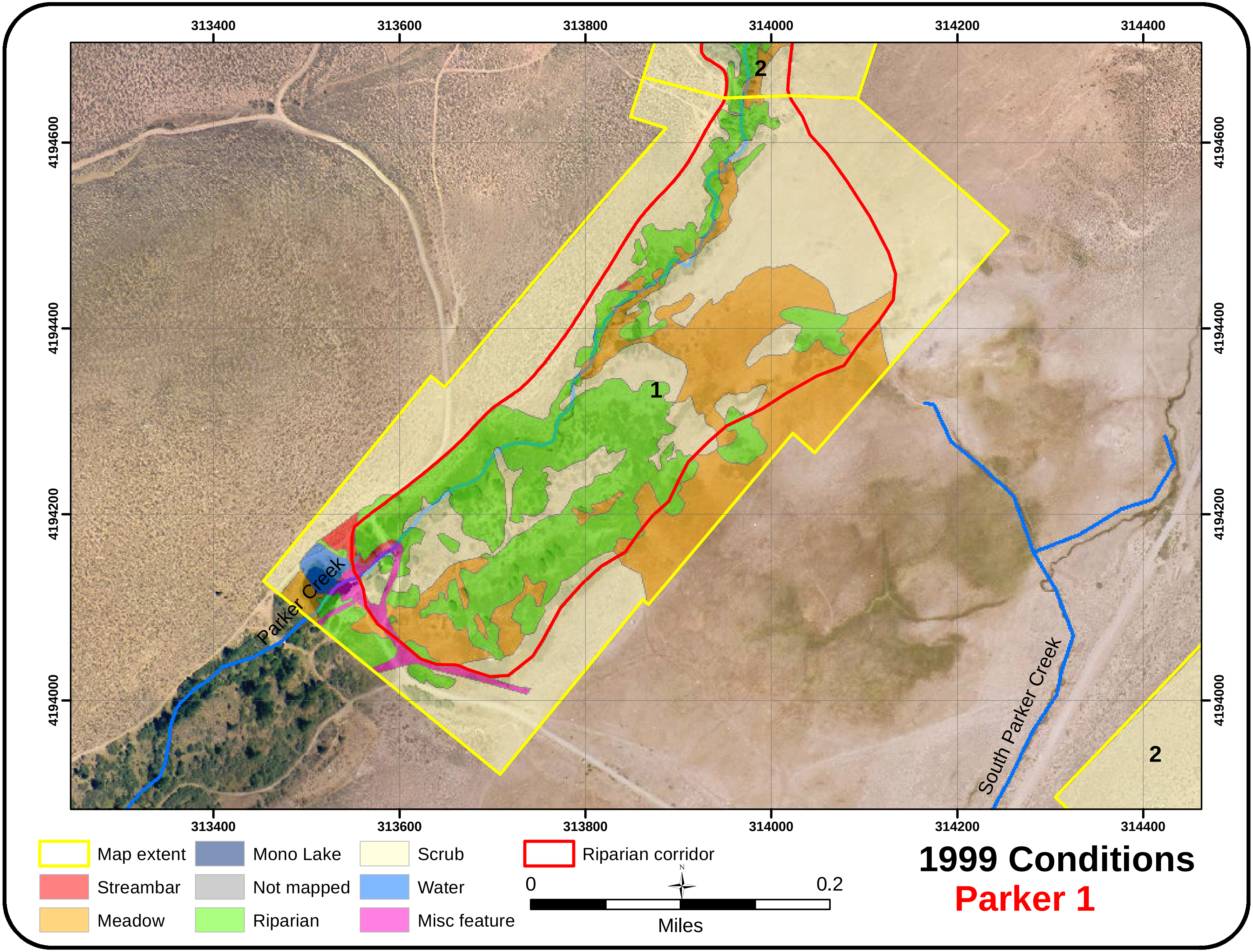
314400
314600
314800
315000
4205000
4204800
4204600
4204400
4204200
3A
3B
3C
3D
Lee Vining Creek
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.24
Miles
N
1999 Conditions
Lee Vining 3B



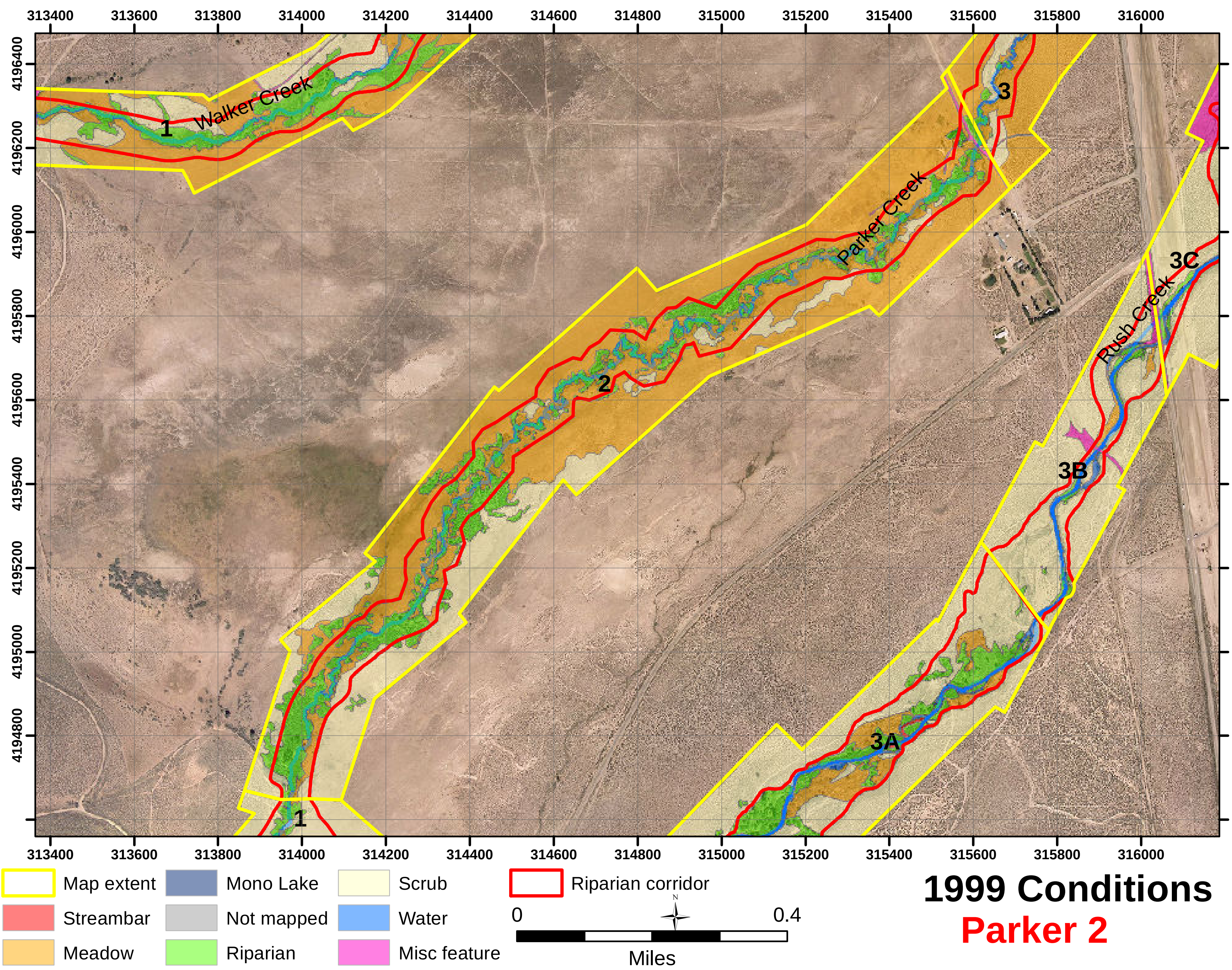
1999 Conditions
Lee Vining 3C



314800
315000
315200
315400
315600
4205600
4205400
4205200
3D
3C
Lee Vining Creek
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.16
Miles
N
1999 Conditions
Lee Vining 3D

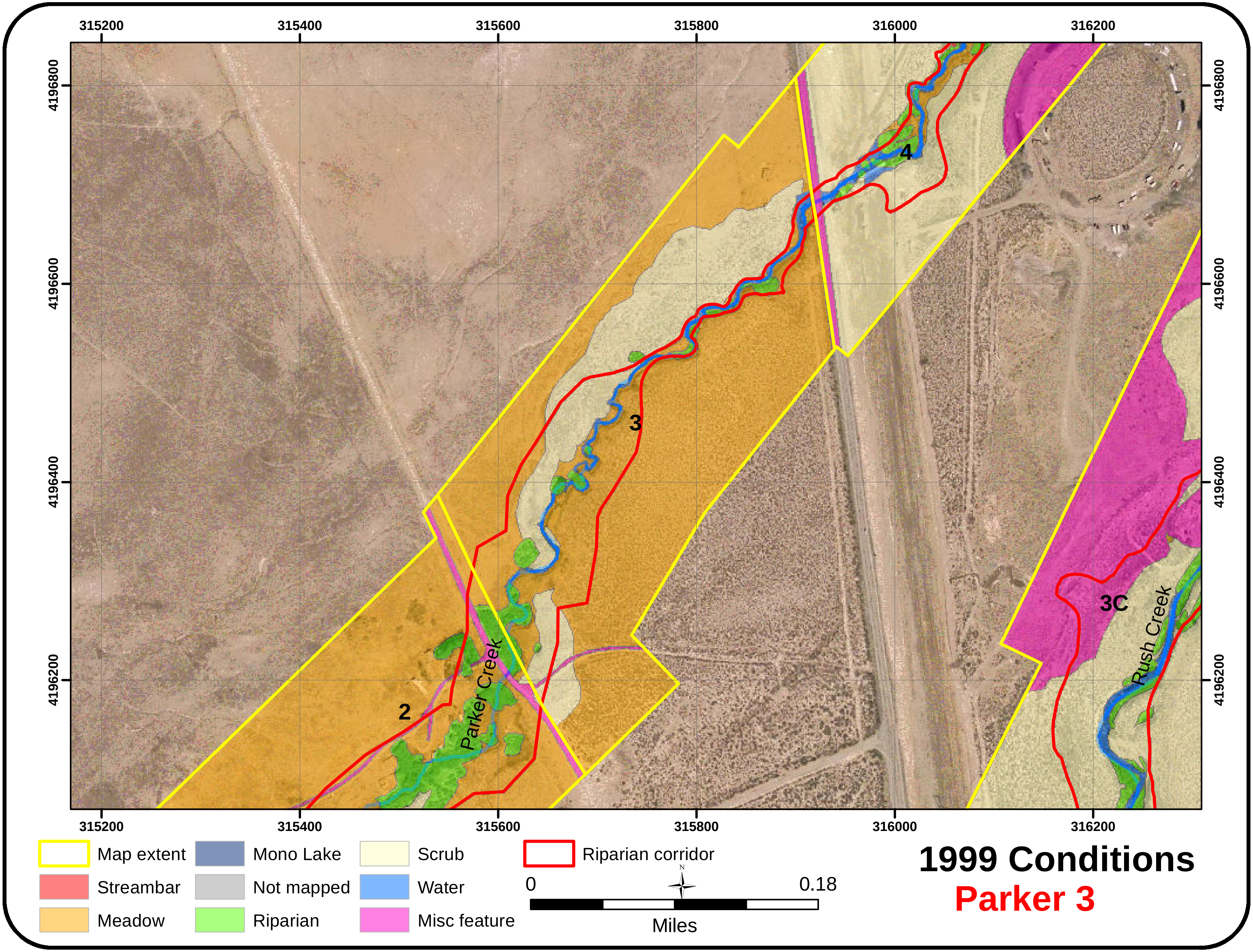


313400
313600
313800
314000
314200
314400
4194600
4194400
4194200
4194000
1
2
2
Parker Creek
South Parker Creek
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.2
Miles
N
1999 Conditions
Parker 1



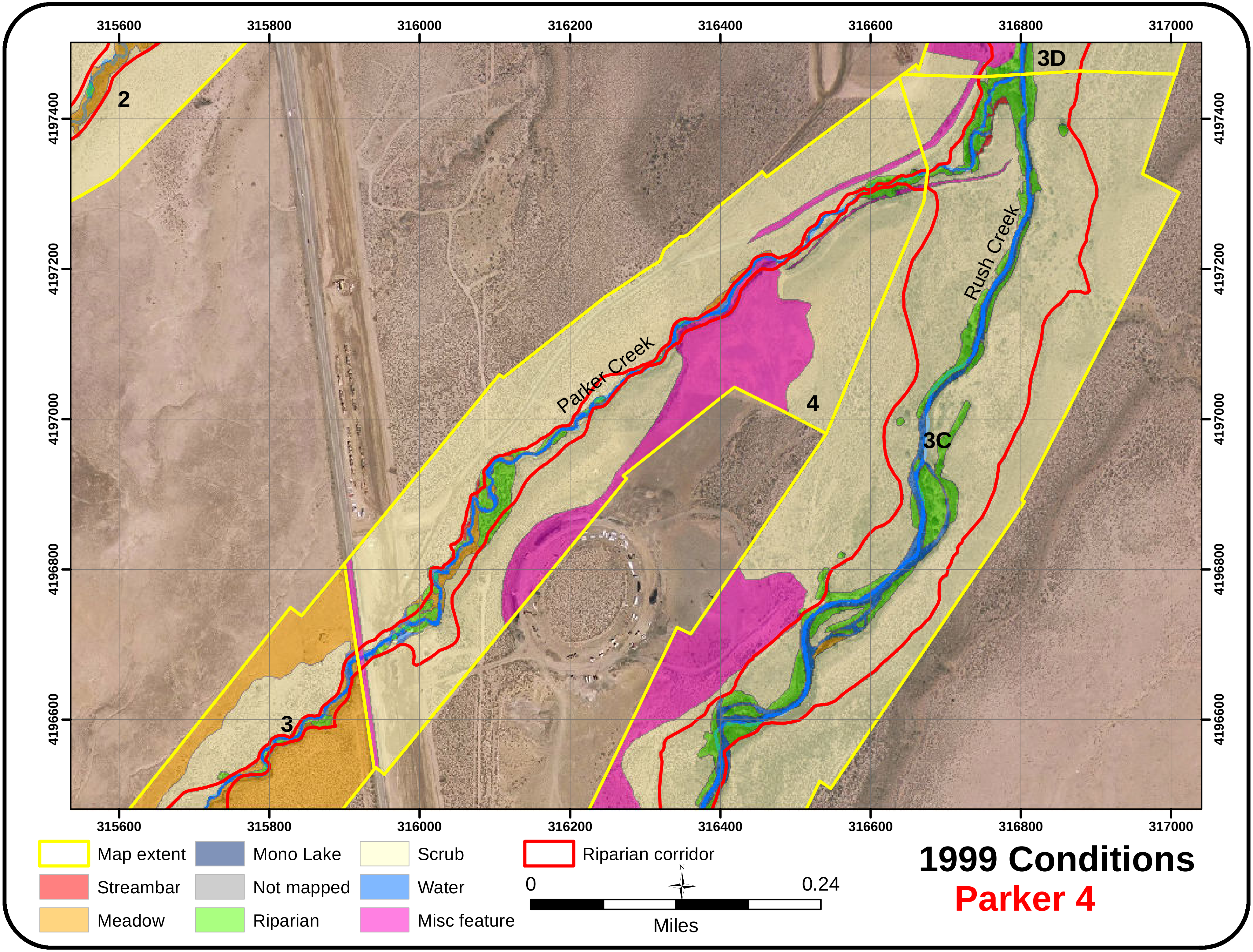
1999 Conditions

Parker 2

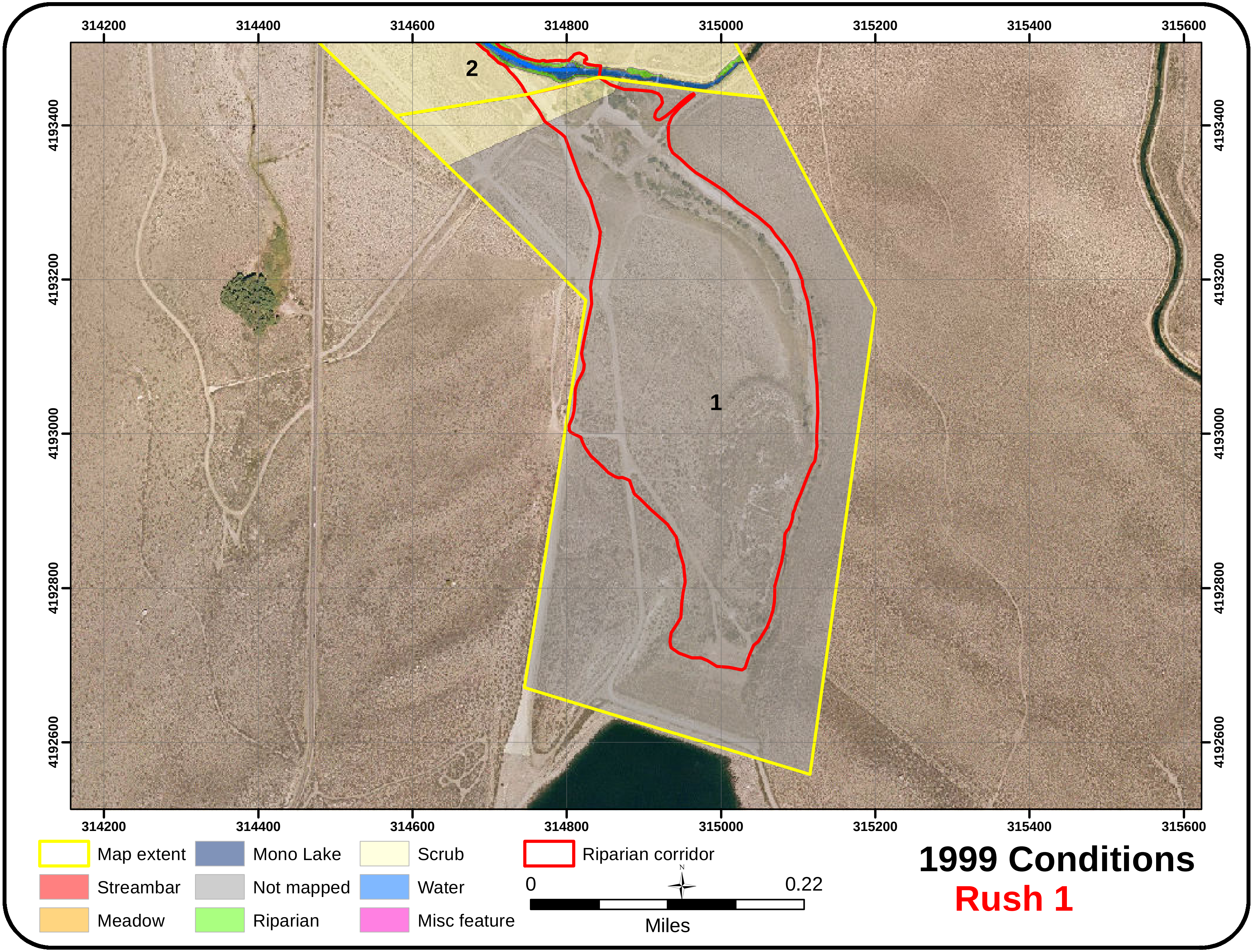


1999 Conditions

Parker 3

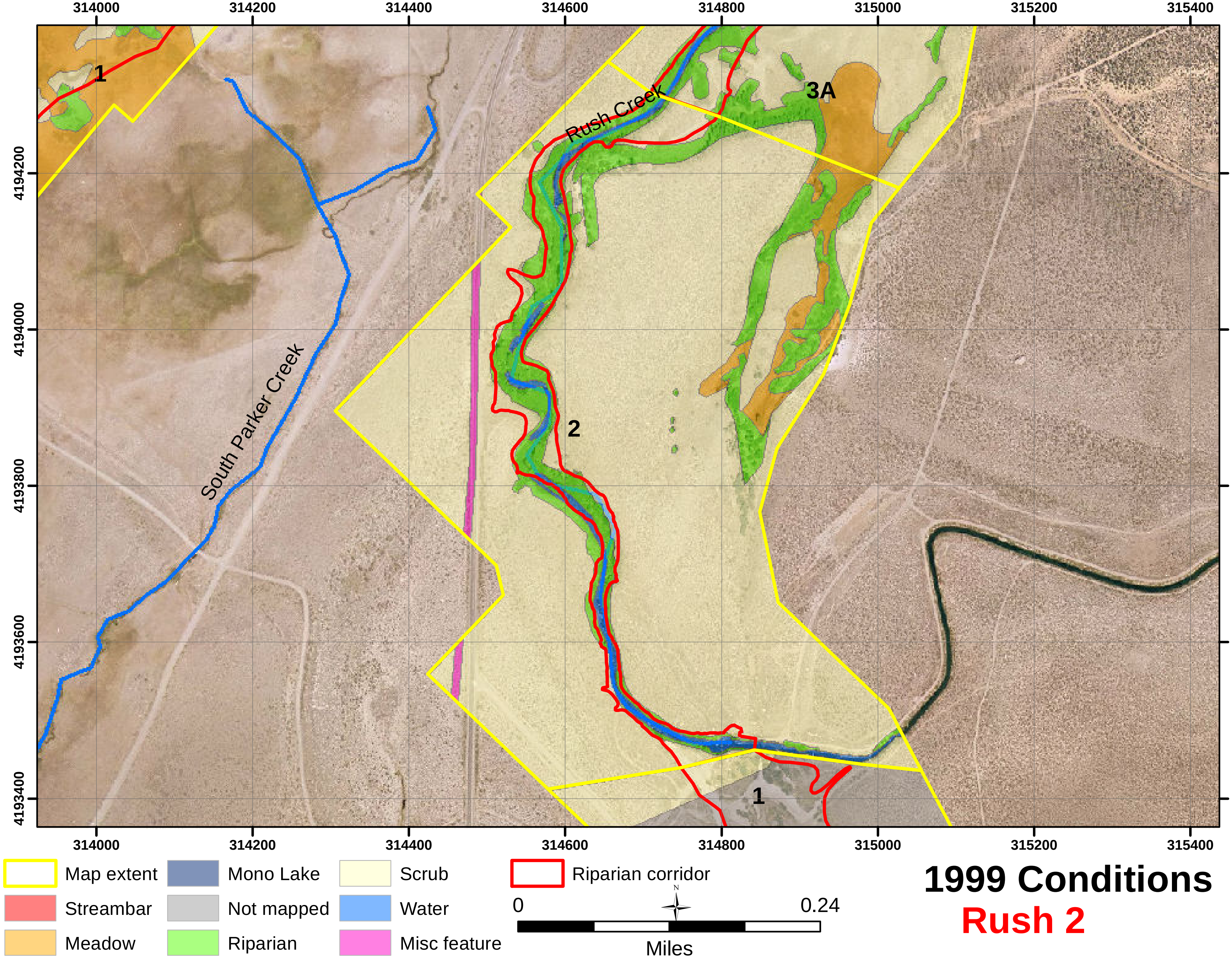


315600
315800
316000
316200
316400
316600
316800
317000
4197400
4197200
4197000
4196800
4196600
2
3
4
3C
3D
Parker Creek
Rush Creek
Map extent
Mono Lake
Scrub
Riparian corridor
Streambar
Not mapped
Water
Meadow
Riparian
Misc feature
0
0.24
Miles
N
1999 Conditions
Parker 4



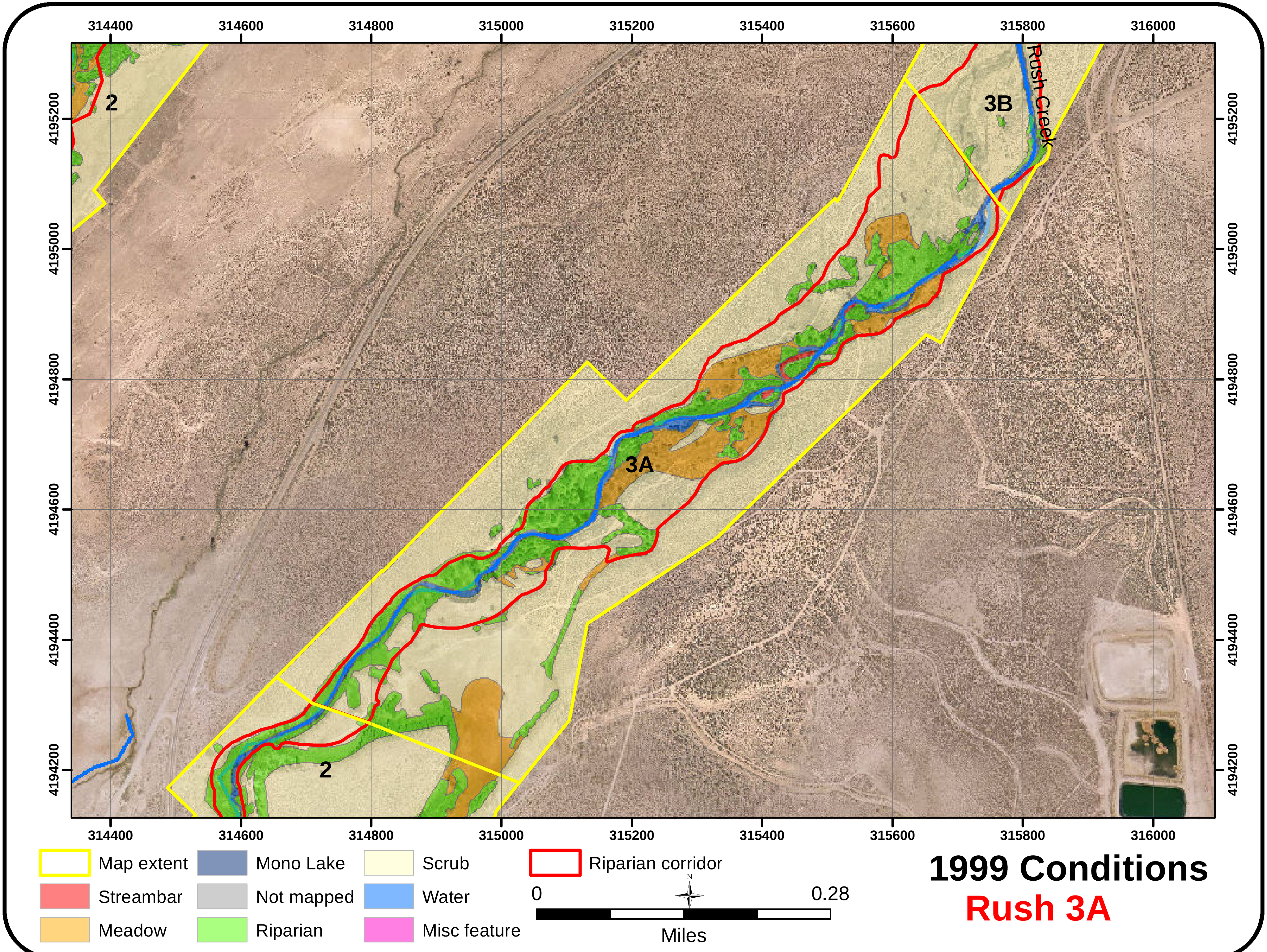
1999 Conditions

Rush 1

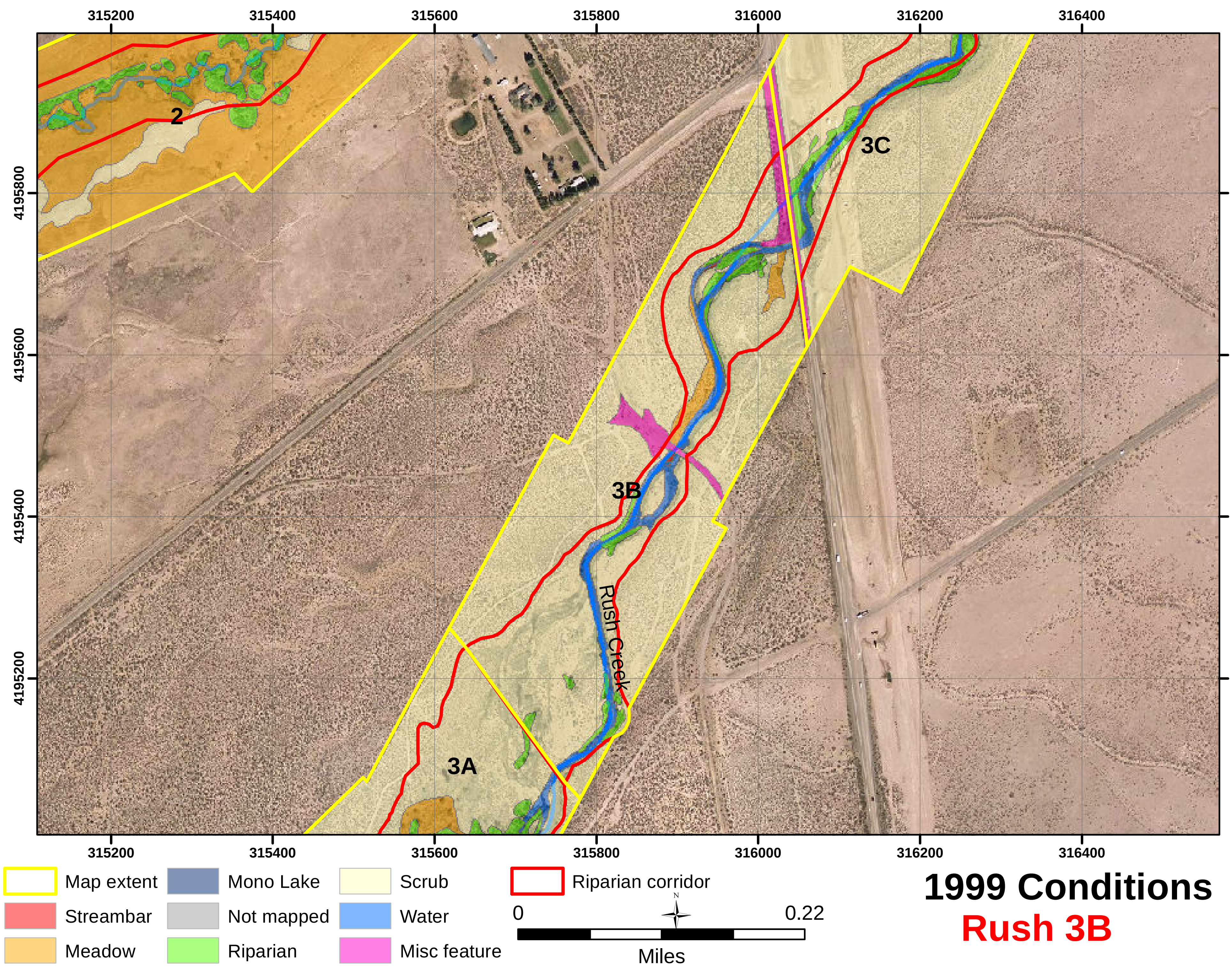


1999 Conditions

Rush 2

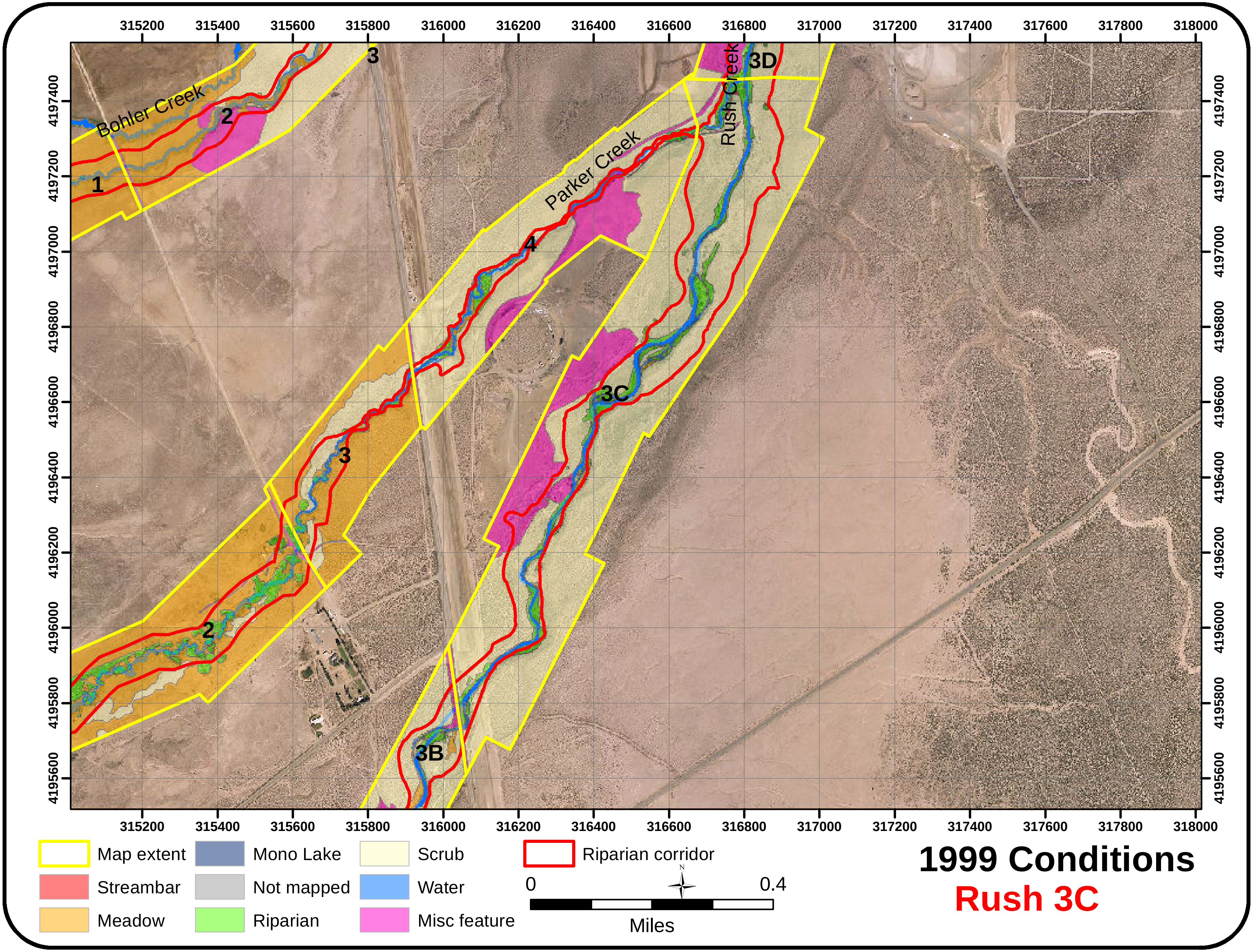


1999 Conditions
Rush 3A

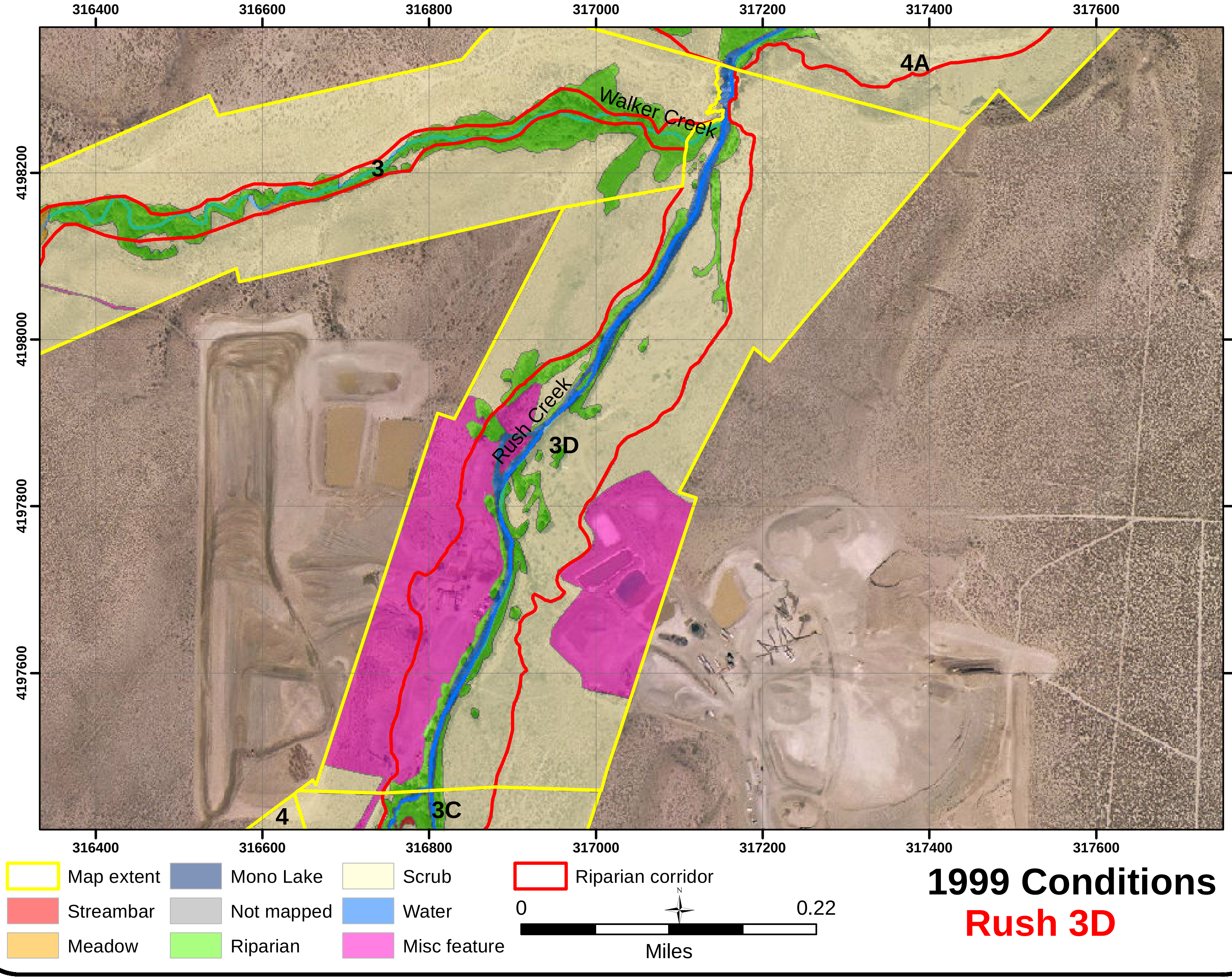


1999 Conditions

Rush 3B

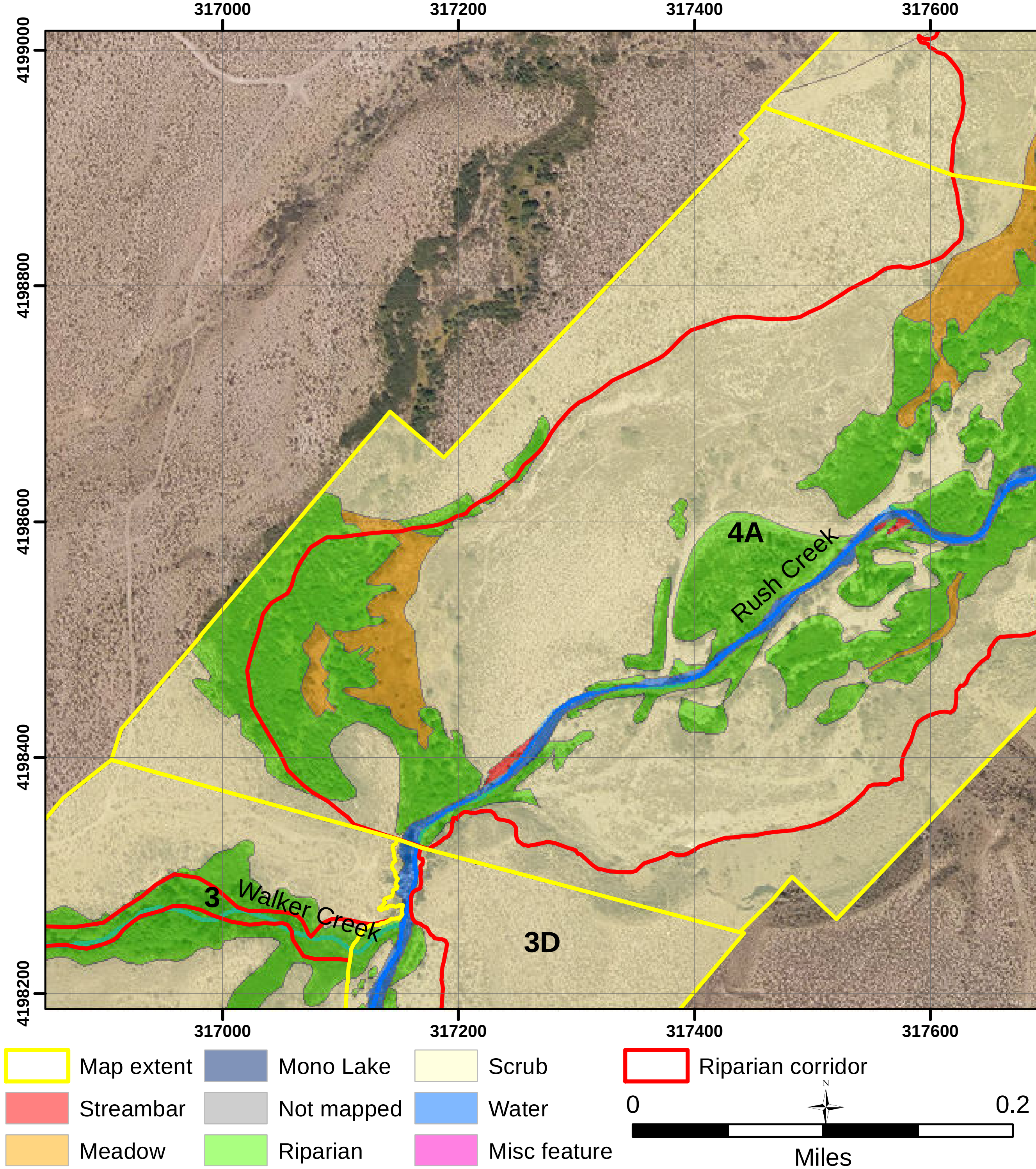


Bohler Creek
Parker Creek
Rush Creek
1
2
3
4
3B
3C
3D
315200
315400
315600
315800
316000
316200
316400
316600
316800
317000
317200
317400
317600
317800
318000
4197400
4197200
4197000
4196800
4196600
4196400
4196200
4196000
4195800
4195600
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.4
Miles
N
1999 Conditions
Rush 3C



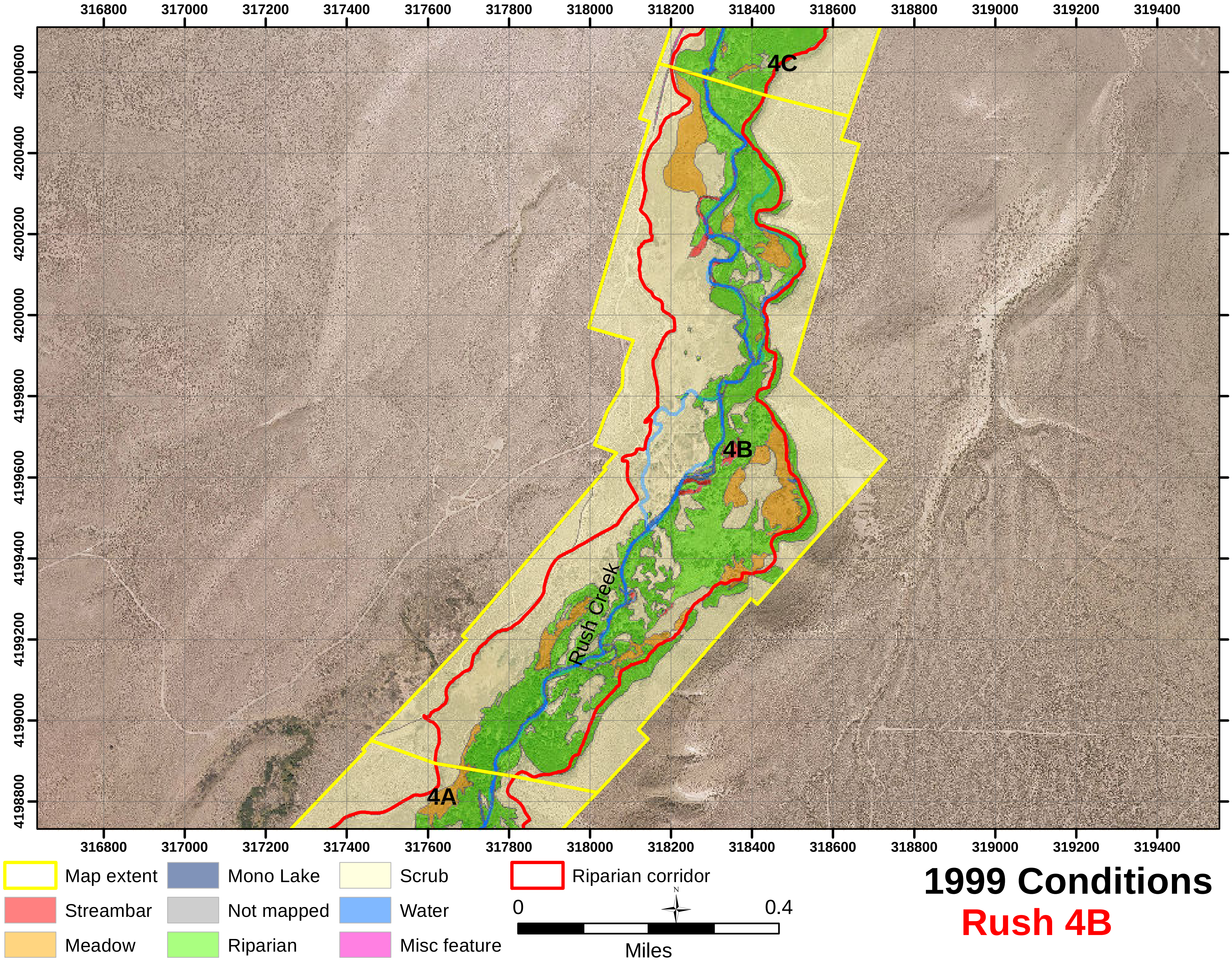
1999 Conditions

Rush 3D



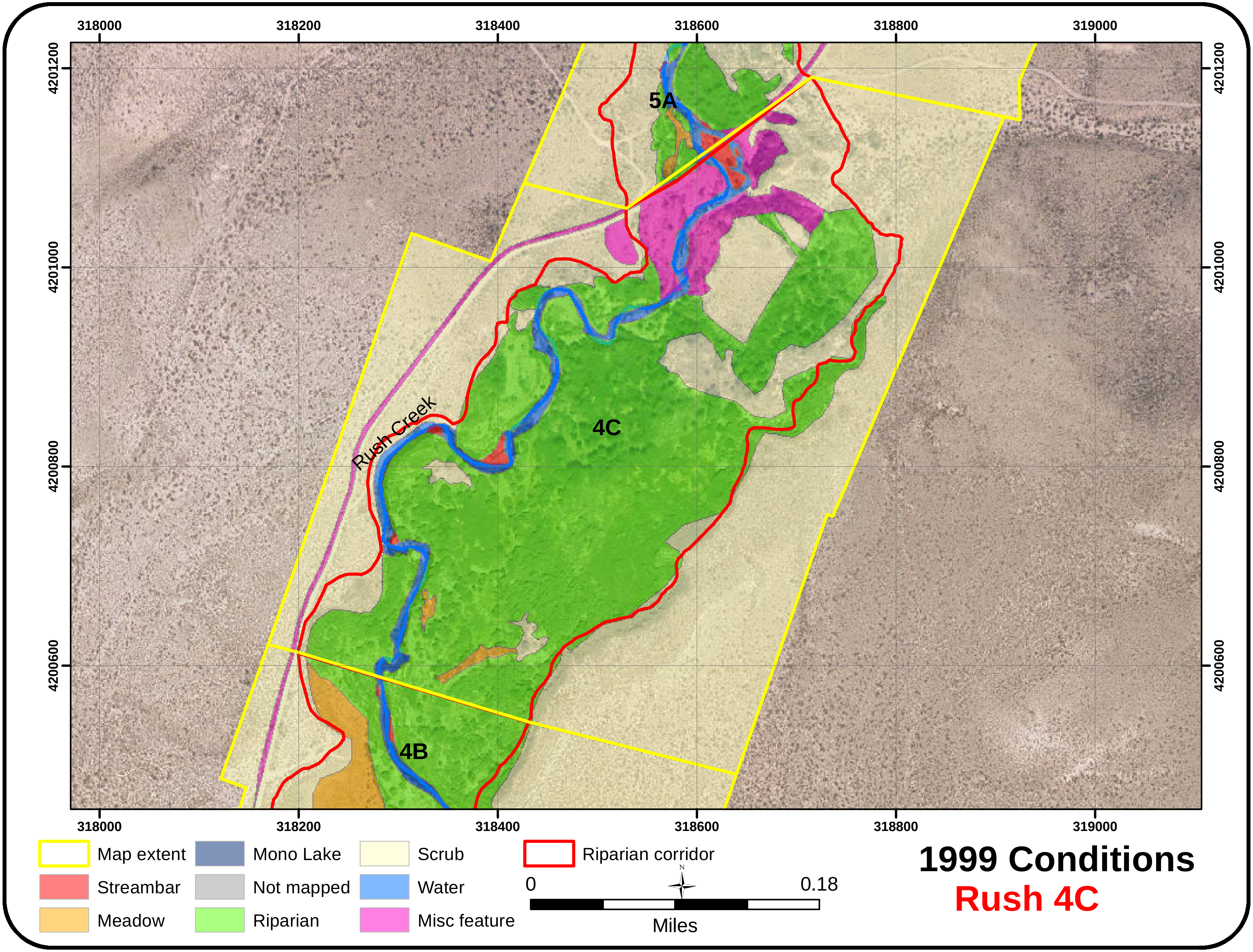
1999 Conditions

Rush 4A



1999 Conditions

Rush 4B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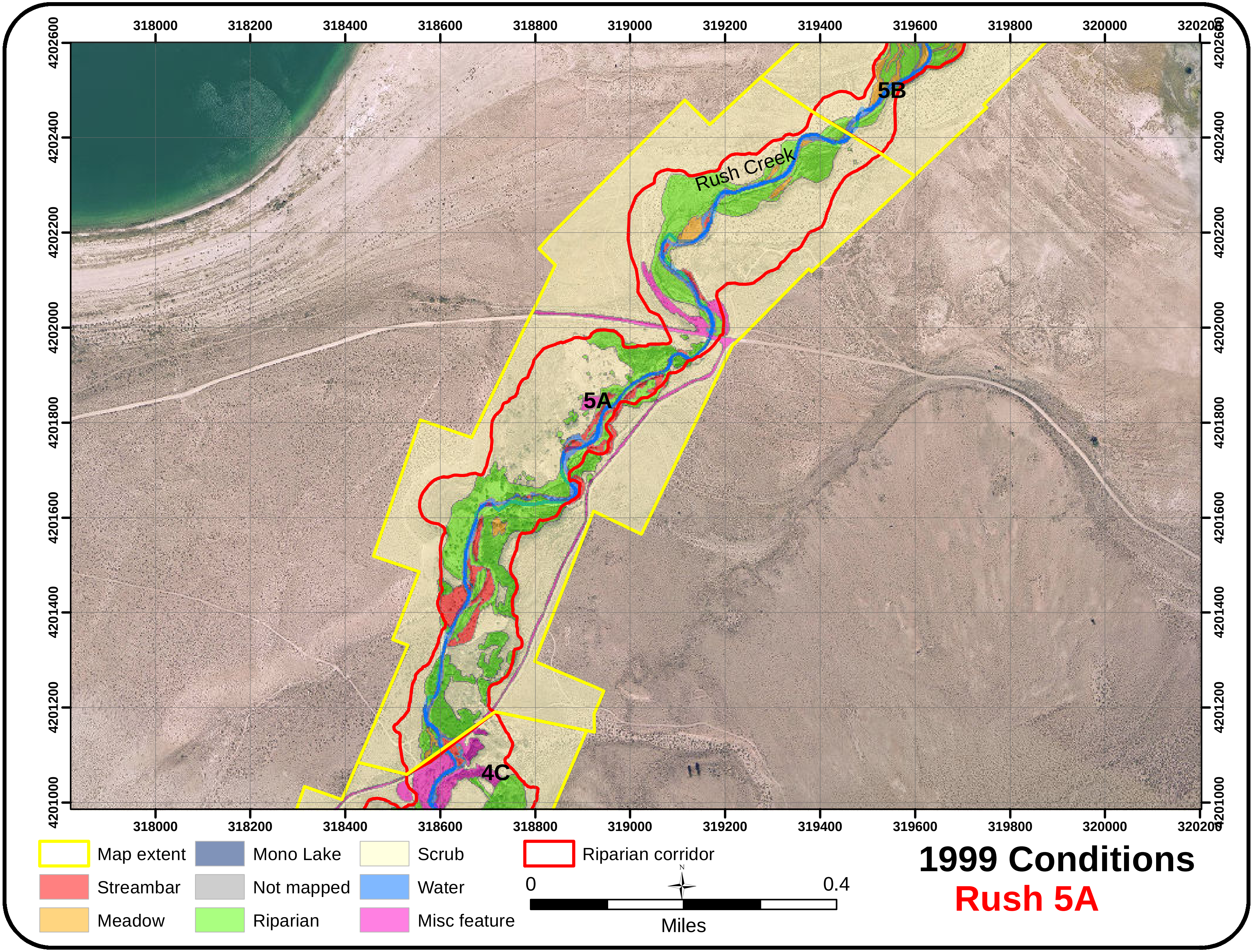
318200
318400
318600
318800
319000
4201200
4201000
4200800
4200600
5A
4C
4B
Rush Creek
Map extent
Mono Lake
Scrub
Riparian corridor
Streambar
Not mapped
Water
Misc feature
Meadow
Riparian
0
0.18
Miles
N
1999 Conditions
Rush 4C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318200
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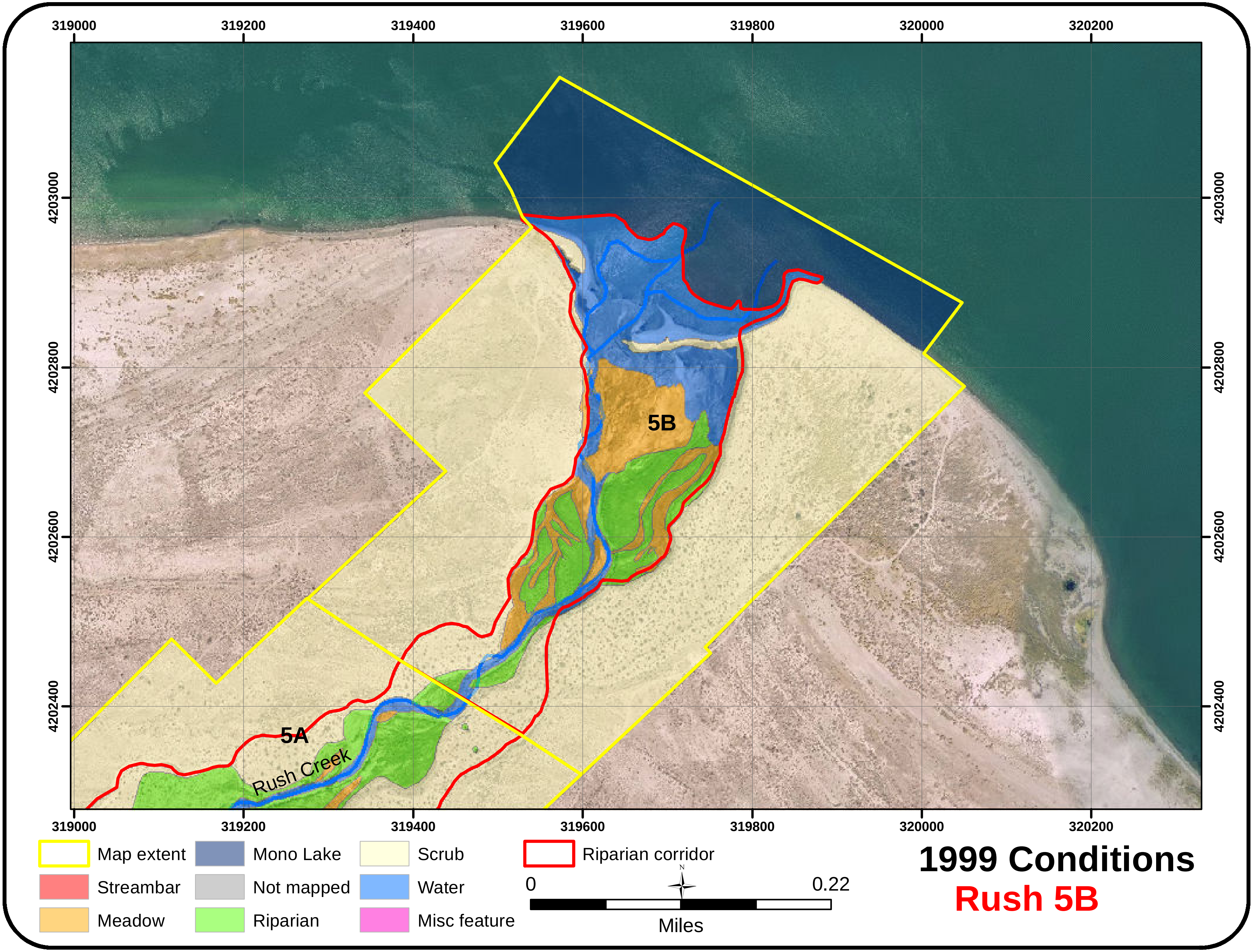
318600
318800
319000
319200
319400
319600
319800
320000
320200
4202600
4202400
4202200
4202000
4201800
4201600
4201400
4201200
4201000
5B
Rush Creek
5A
4C
Map extent
Mono Lake
Scrub
Riparian corridor
Streambar
Not mapped
Water
Meadow
Riparian
Misc feature
0
0.4
Miles
N
1999 Conditions
Rush 5A



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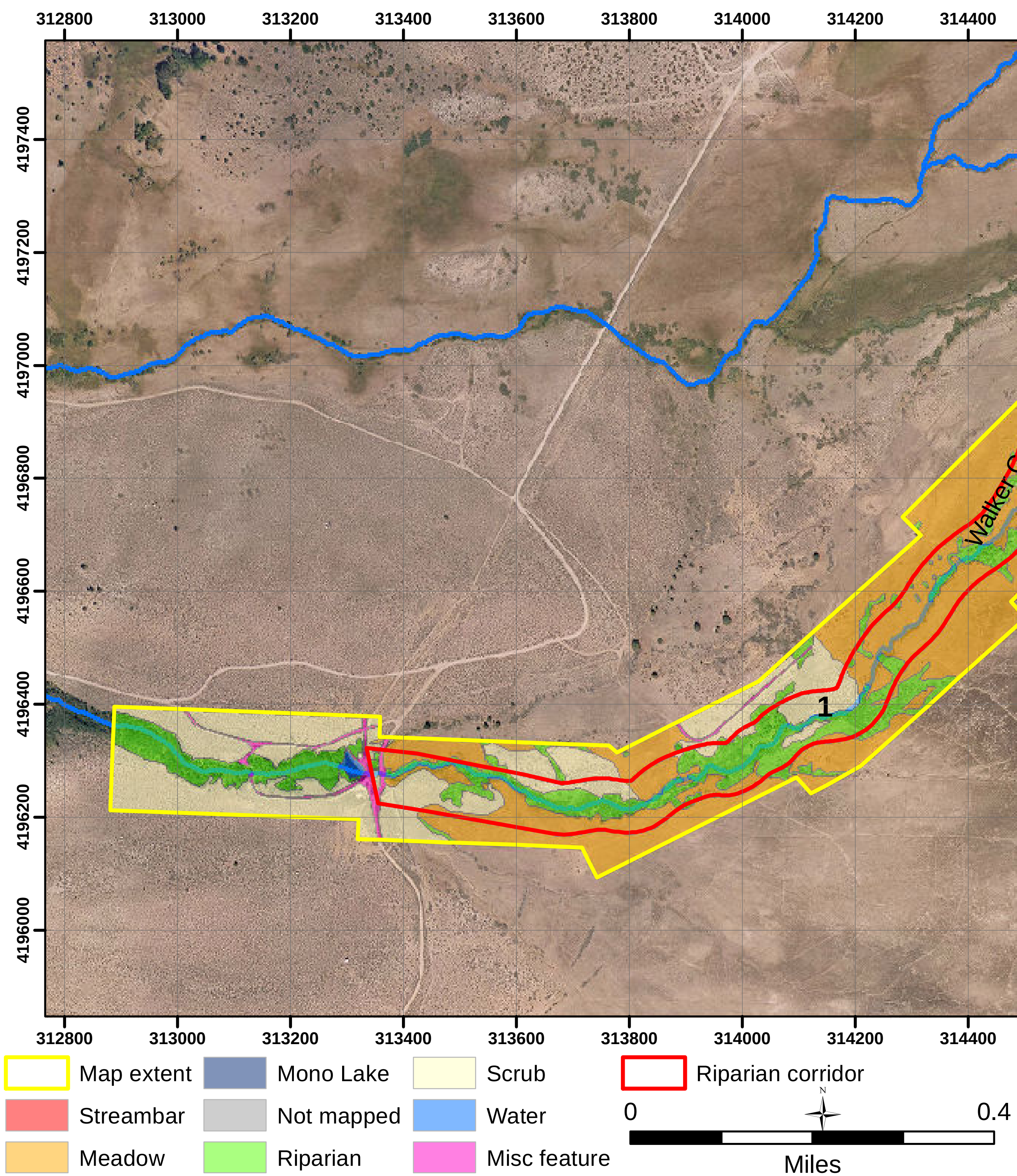
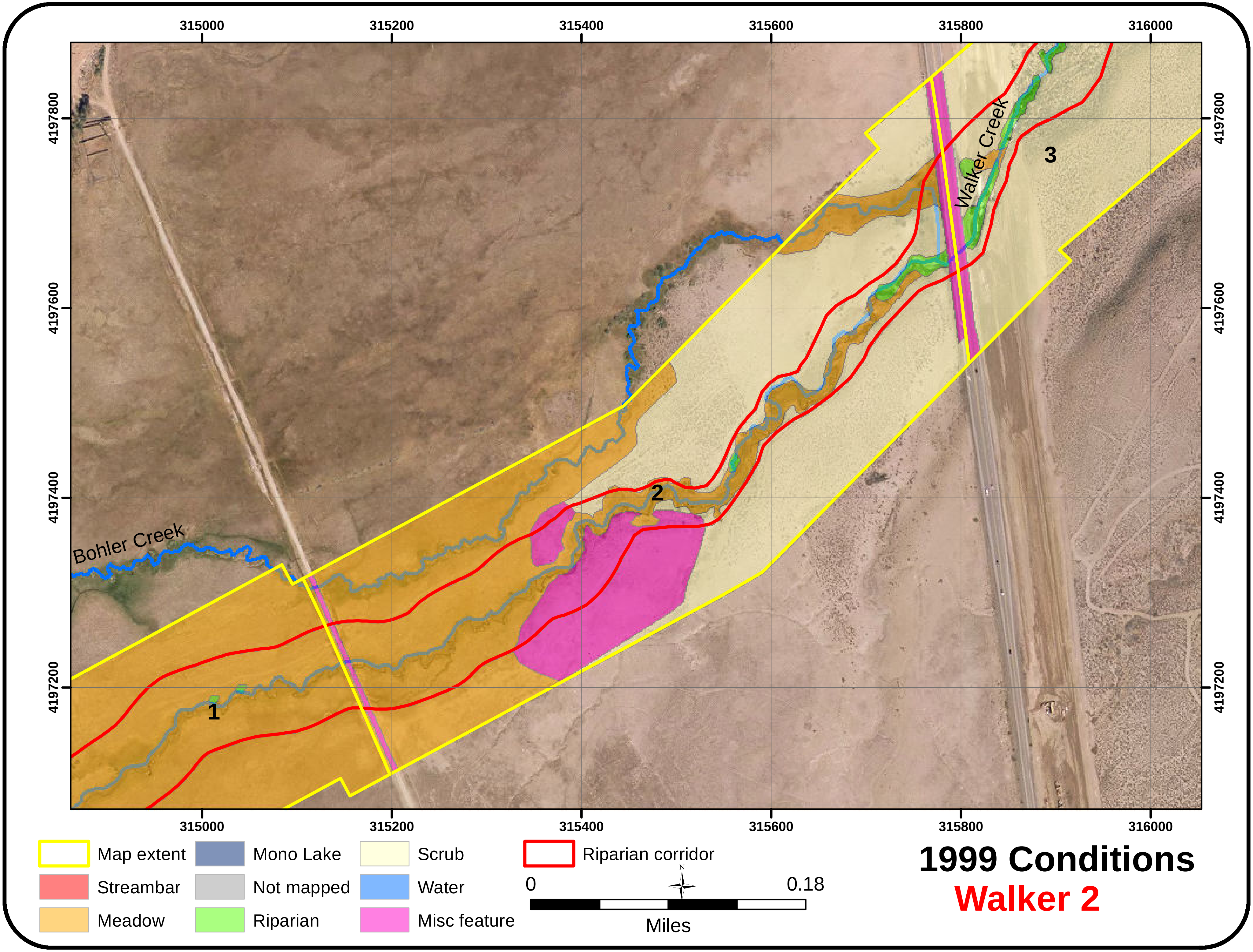
319200
319400
319600
319800
320000
320200
4203000
4202800
4202600
4202400
5B
5A
Rush Creek
Map extent
Mono Lake
Scrub
Riparian corridor
Streambar
Not mapped
Water
Meadow
Riparian
Misc feature
0
0.22
Miles
N
1999 Conditions
Rush 5B

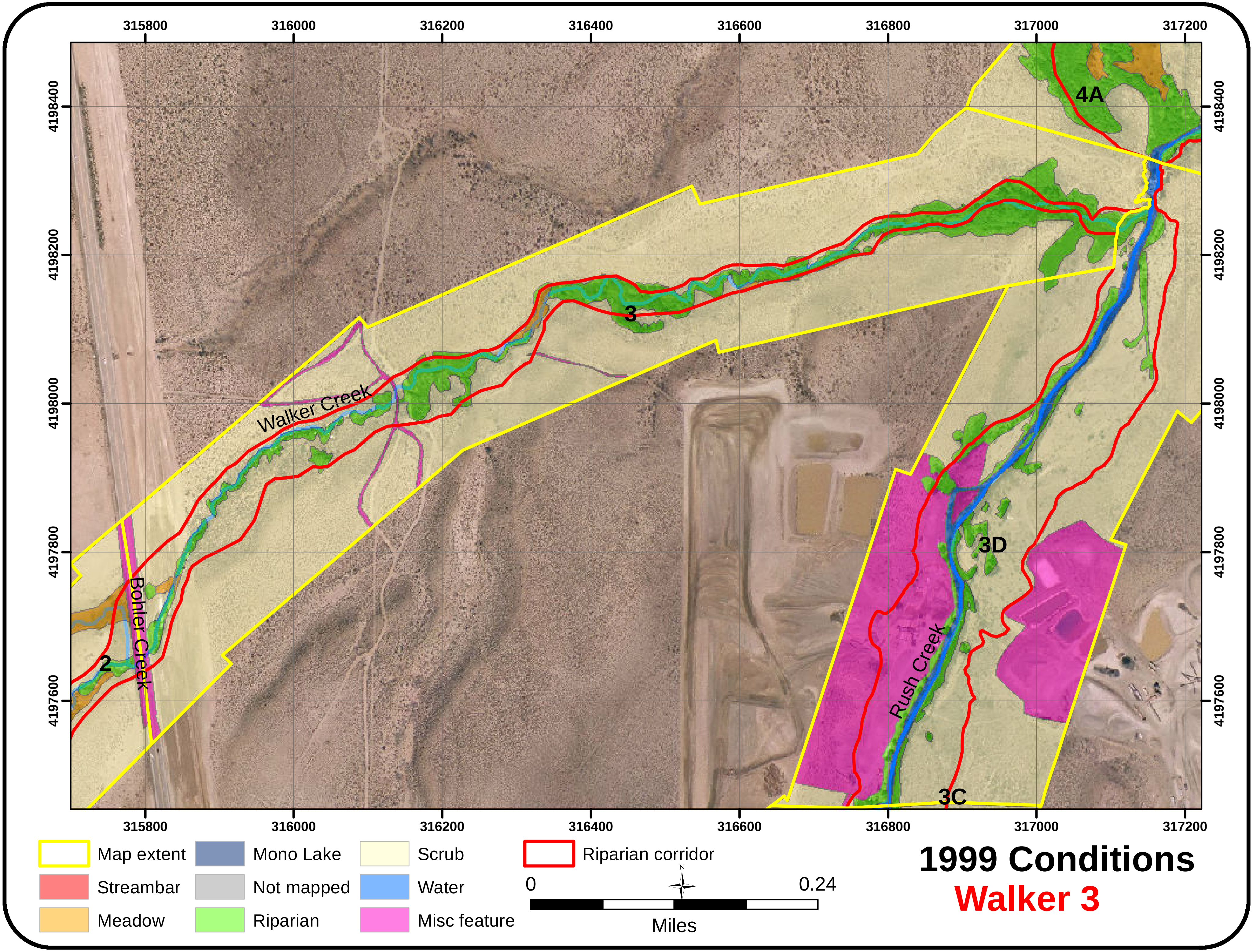


1999 Conditions

Walker 1



315000
315200
315400
315600
315800
316000
4197800
4197600
4197400
4197200
Bohler Creek
Walker Creek
1
2
3
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.18
Miles
N
1999 Conditions
Walker 2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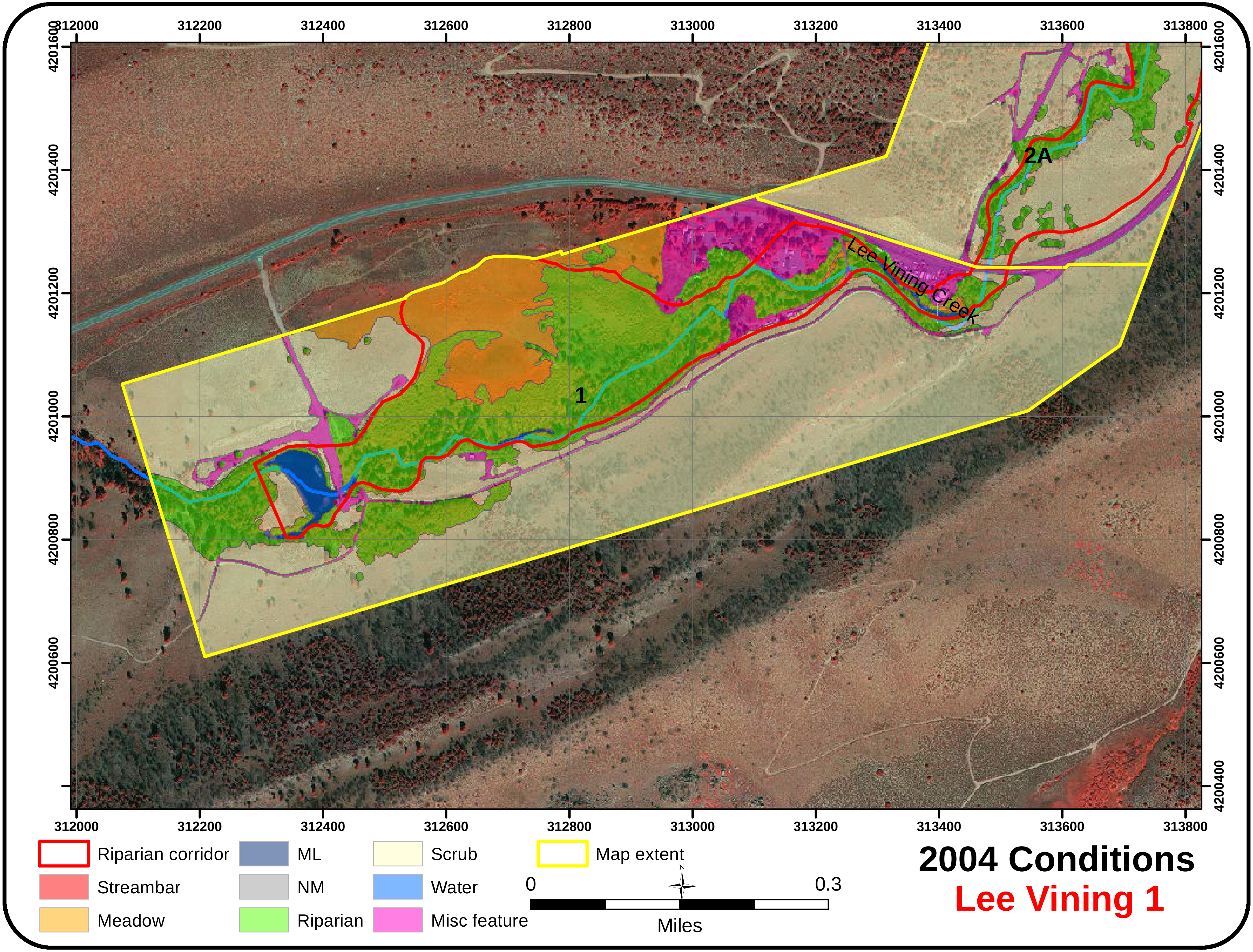
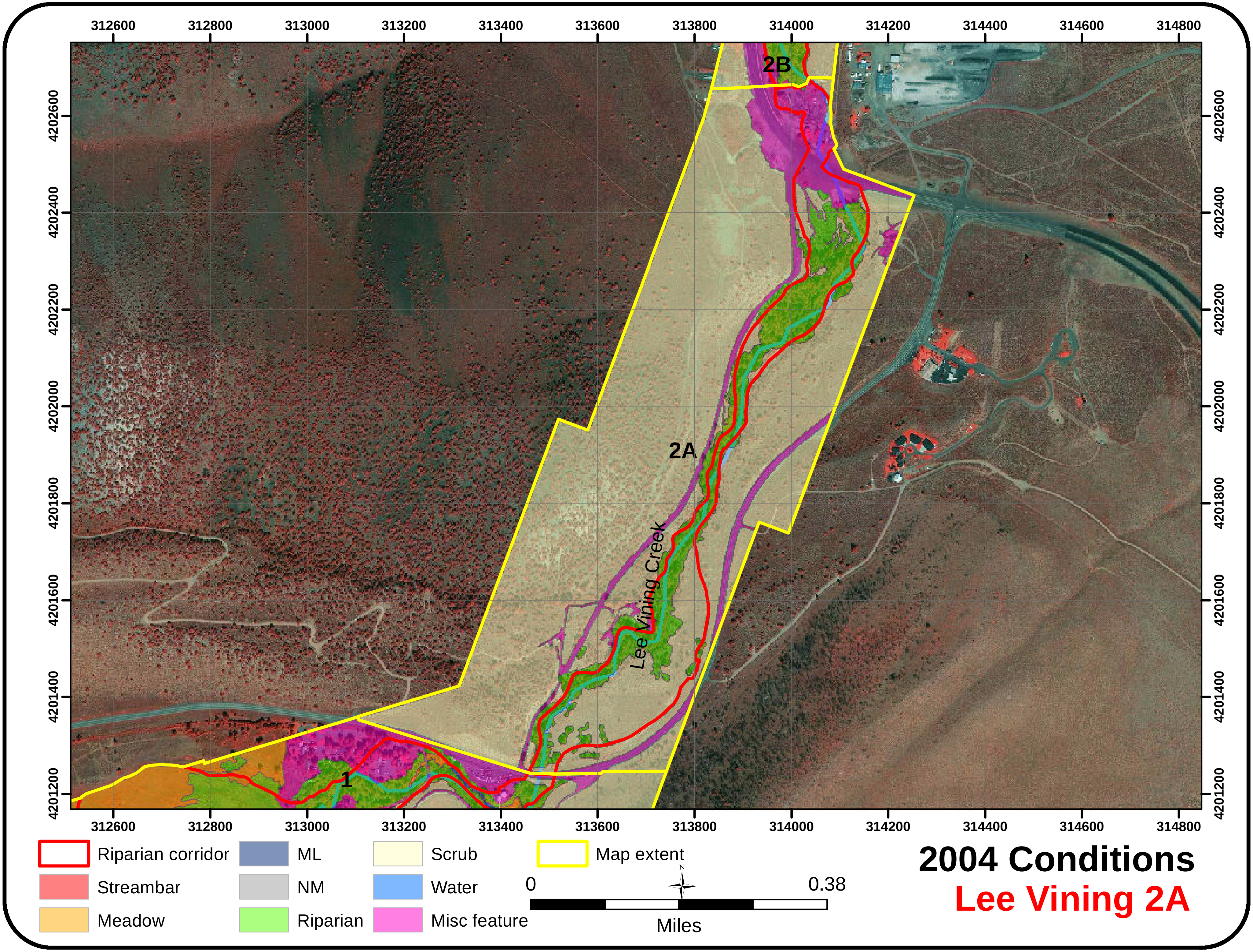
316000
316200
316400
316600
316800
317000
317200
4198400
4198200
4198000
4197800
4197600
4A
3
3D
2
3C
Walker Creek
Bohler Creek
Rush Creek
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.24
Miles
N
1999 Conditions
Walker 3

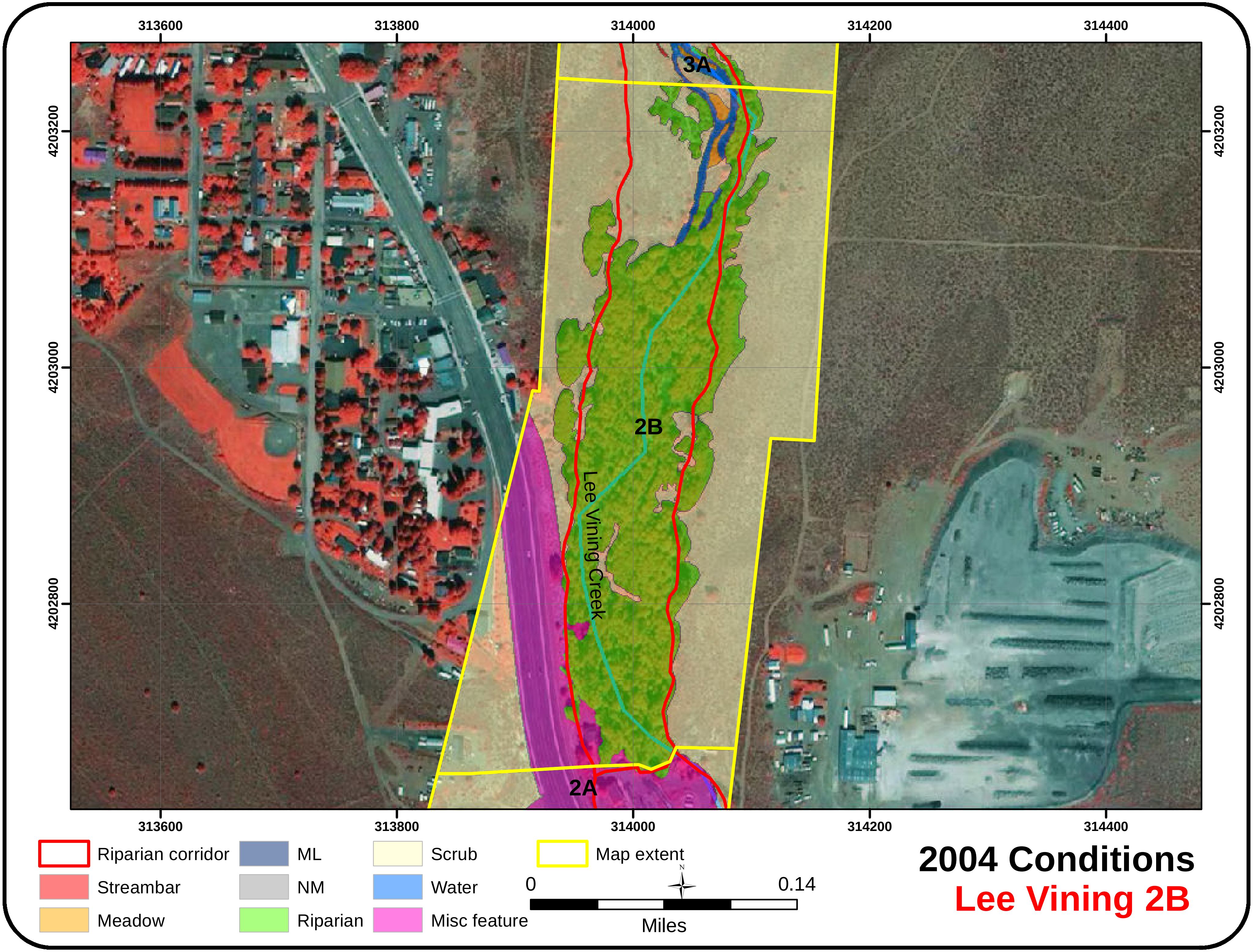
APPENDIX C
RIPARIAN MAPPING
2004 CONDITIONS

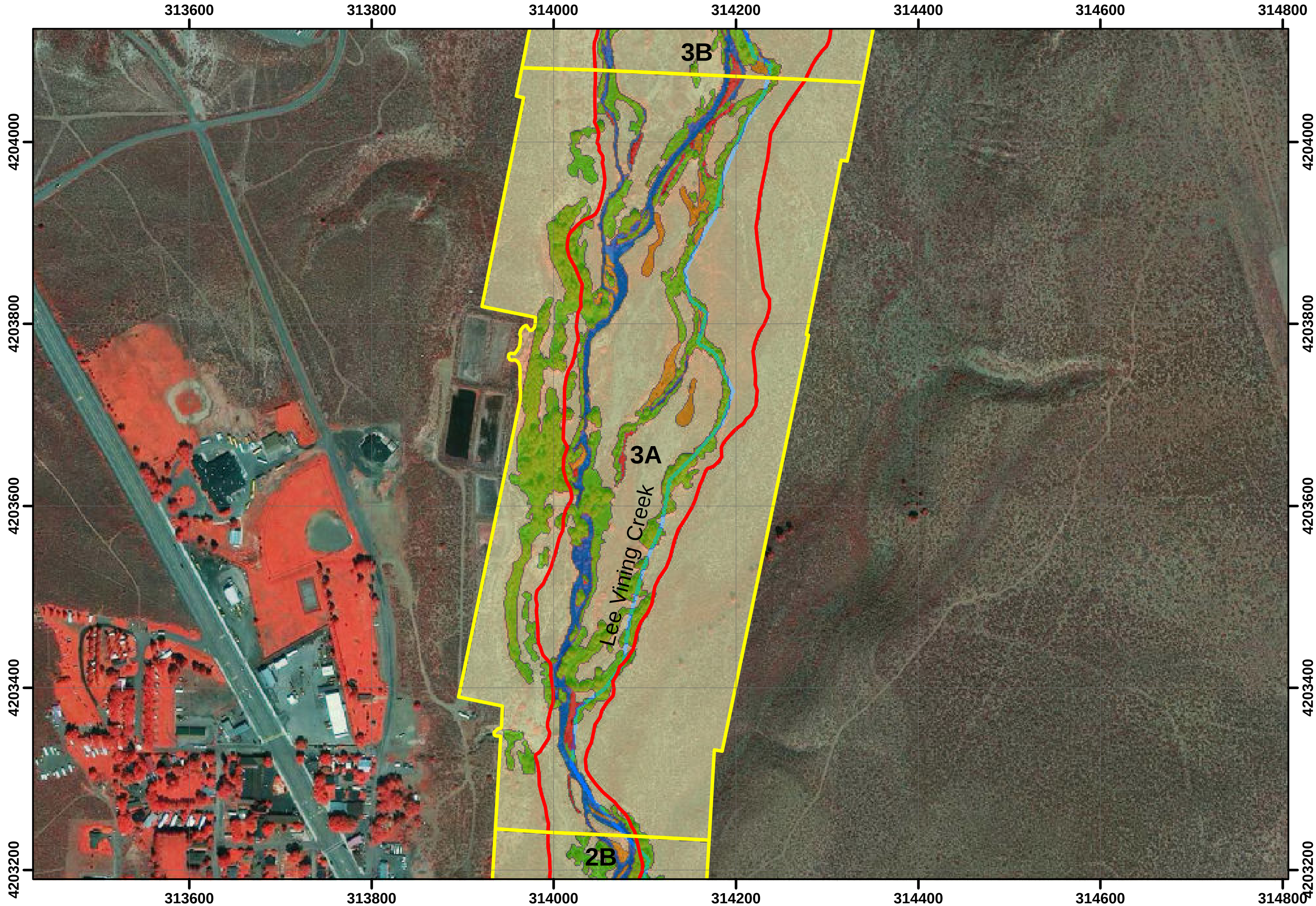


2004 Conditions

Lee Vining 1


2B
2A
1
Lee Vining Creek
312600
312800
313000
313200
313400
313600
313800
314000
314200
314400
314600
314800
4202600
4202400
4202200
4202000
4201800
4201600
4201400
4201200
Riparian corridor
Streambar
Meadow
ML
NM
Riparian
Scrub
Water
Misc feature
Map extent
0
0.38
Miles
N
2004 Conditions
Lee Vining 2A

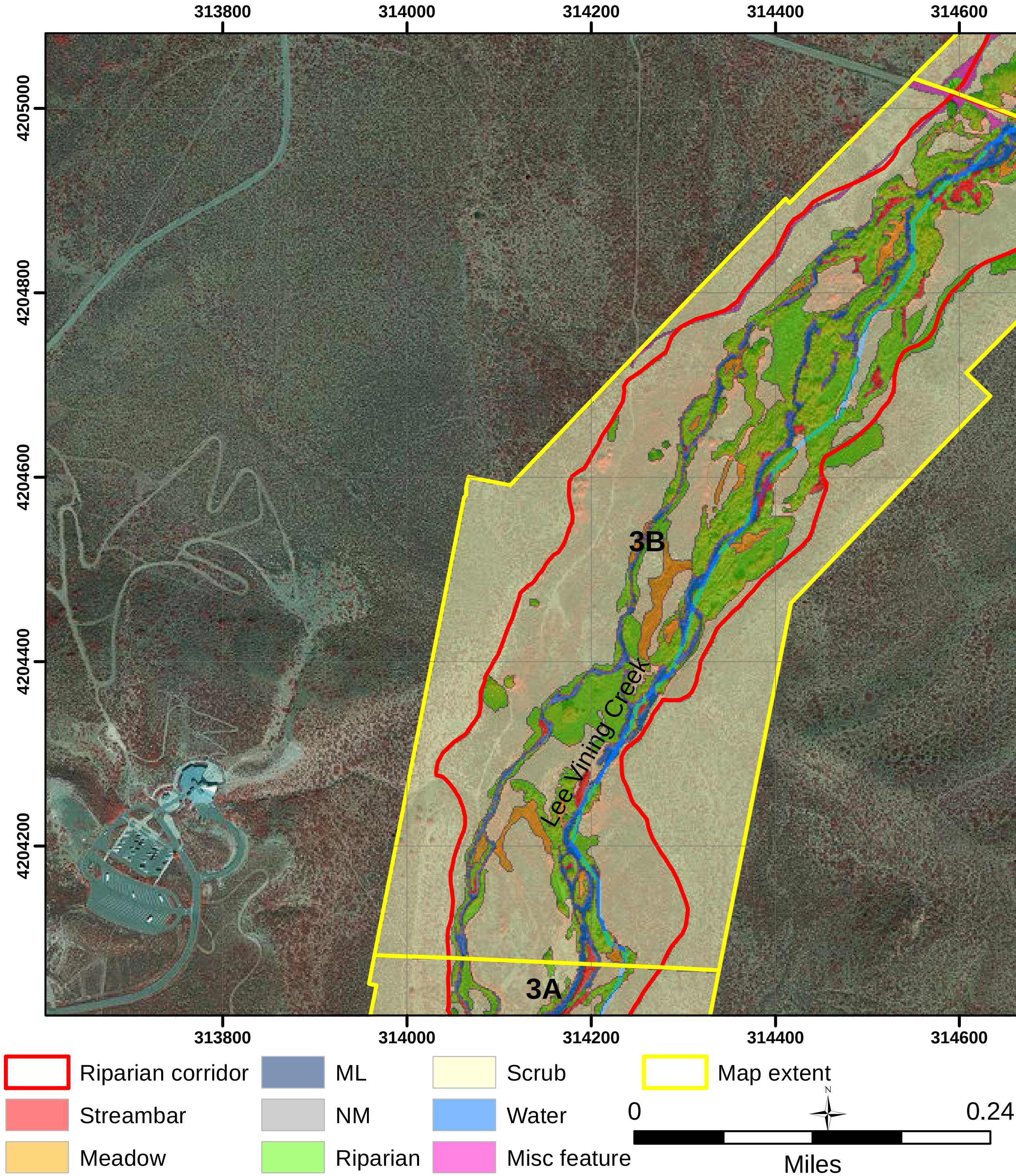

313600
313800
314000
314200
314400
4203200
4203000
4202800
3A
2B
2A
Lee Vining Creek
Riparian corridor
Streambar
Meadow
ML
NM
Riparian
Scrub
Water
Misc feature
Map extent
0
0.14
Miles
2004 Conditions
Lee Vining 2B



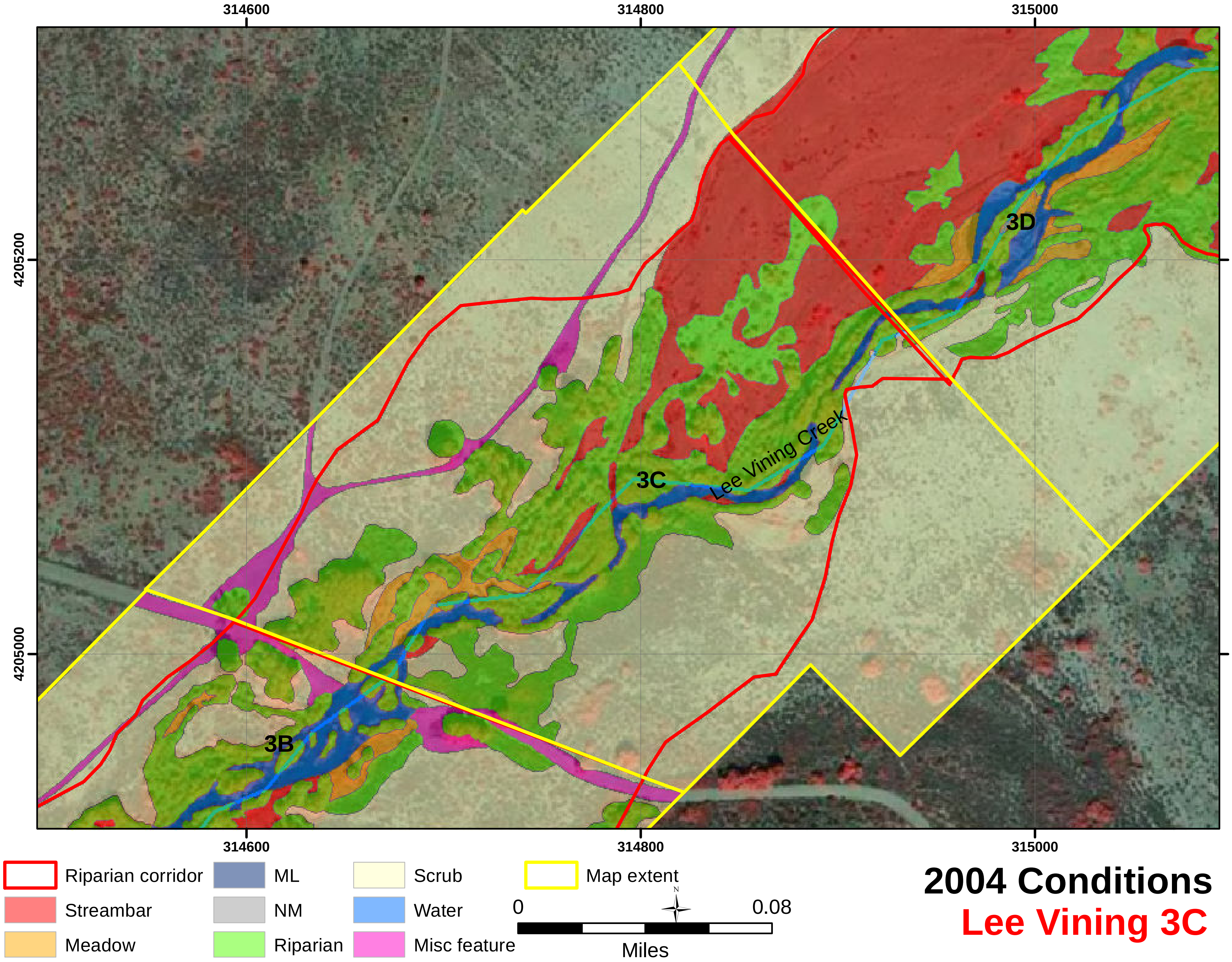
Riparian corridor
Streambar
Meadow
ML
NM
Riparian
Scrub
Water
Misc feature
Map extent

0 0.22
Miles

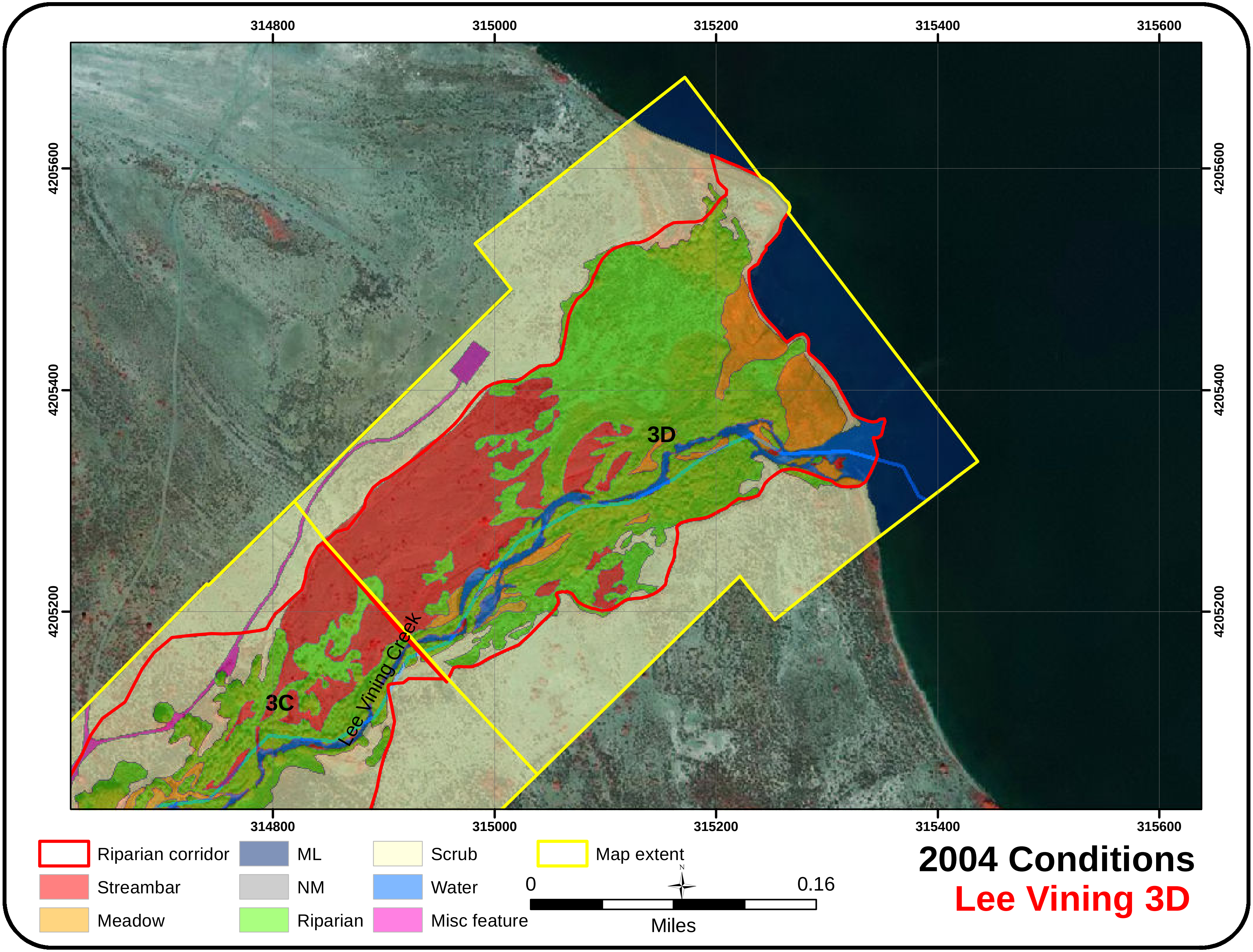
2004 Conditions
Lee Vining 3A



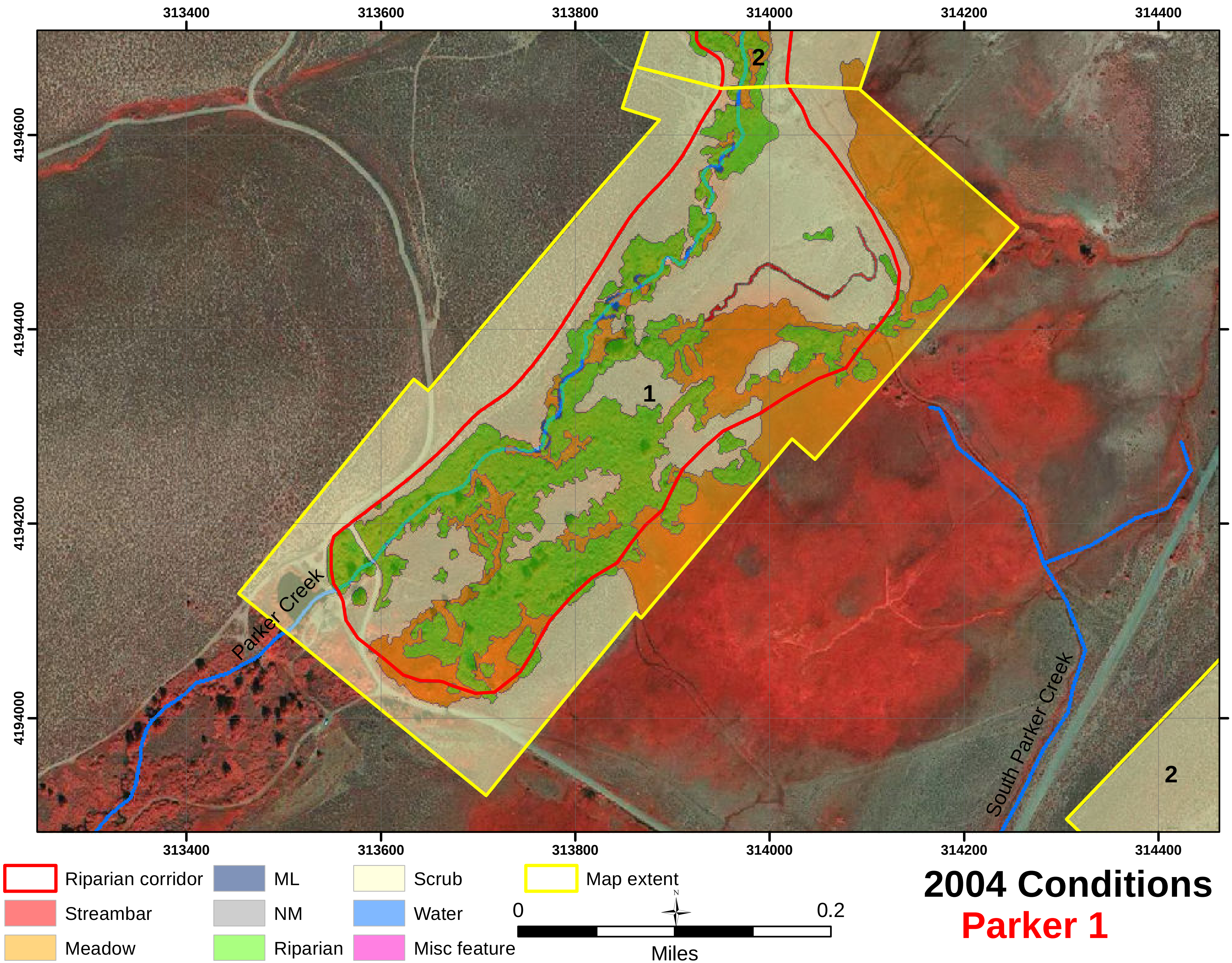
2004 Conditions
Lee Vining 3B



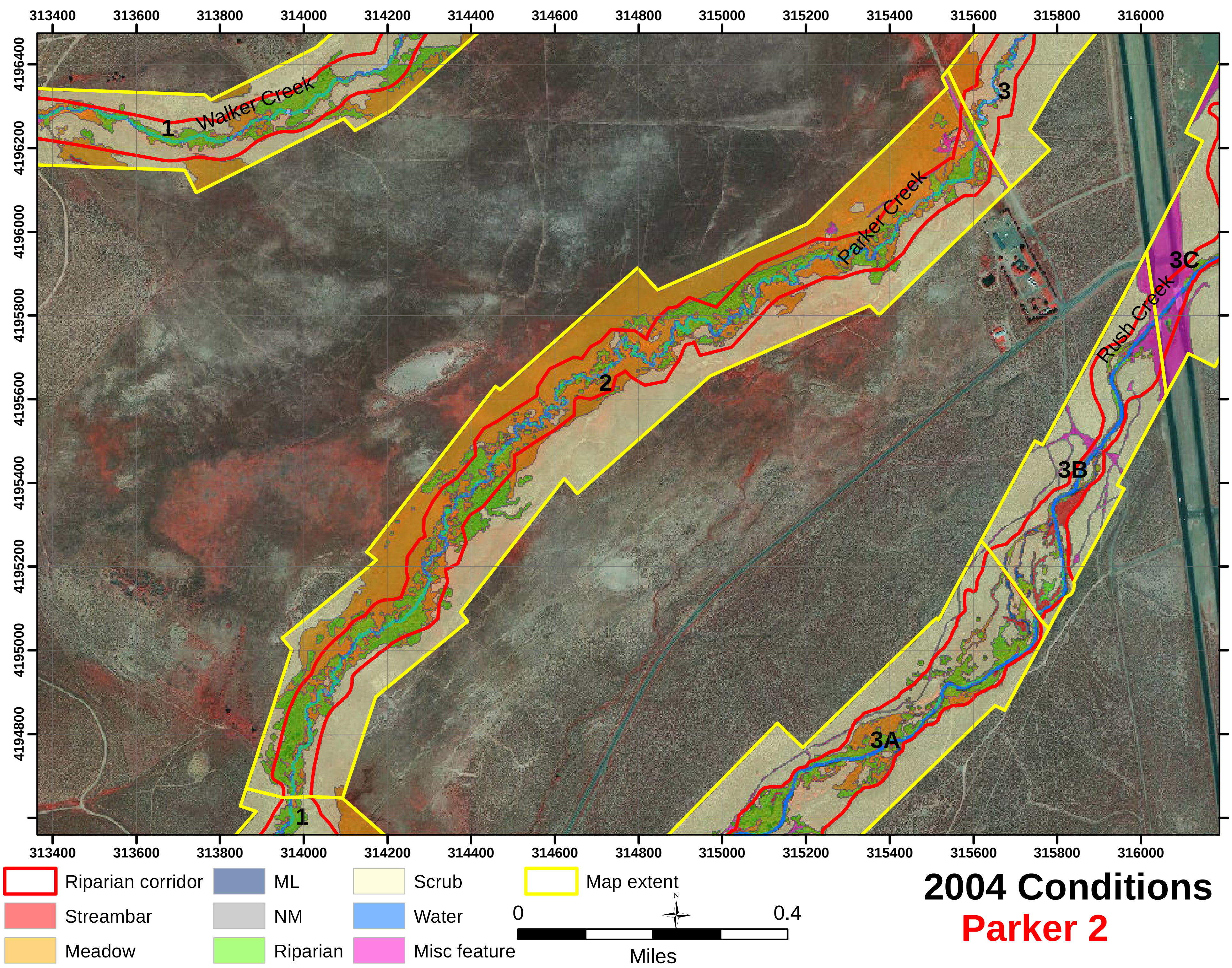
2004 Conditions
Lee Vining 3C



314800
315000
315200
315400
315600
4205600
4205400
4205200
3D
3C
Lee Vining Creek
Riparian corridor
Streambar
Meadow
ML
NM
Riparian
Scrub
Water
Misc feature
Map extent
0
0.16
Miles
N
2004 Conditions
Lee Vining 3D

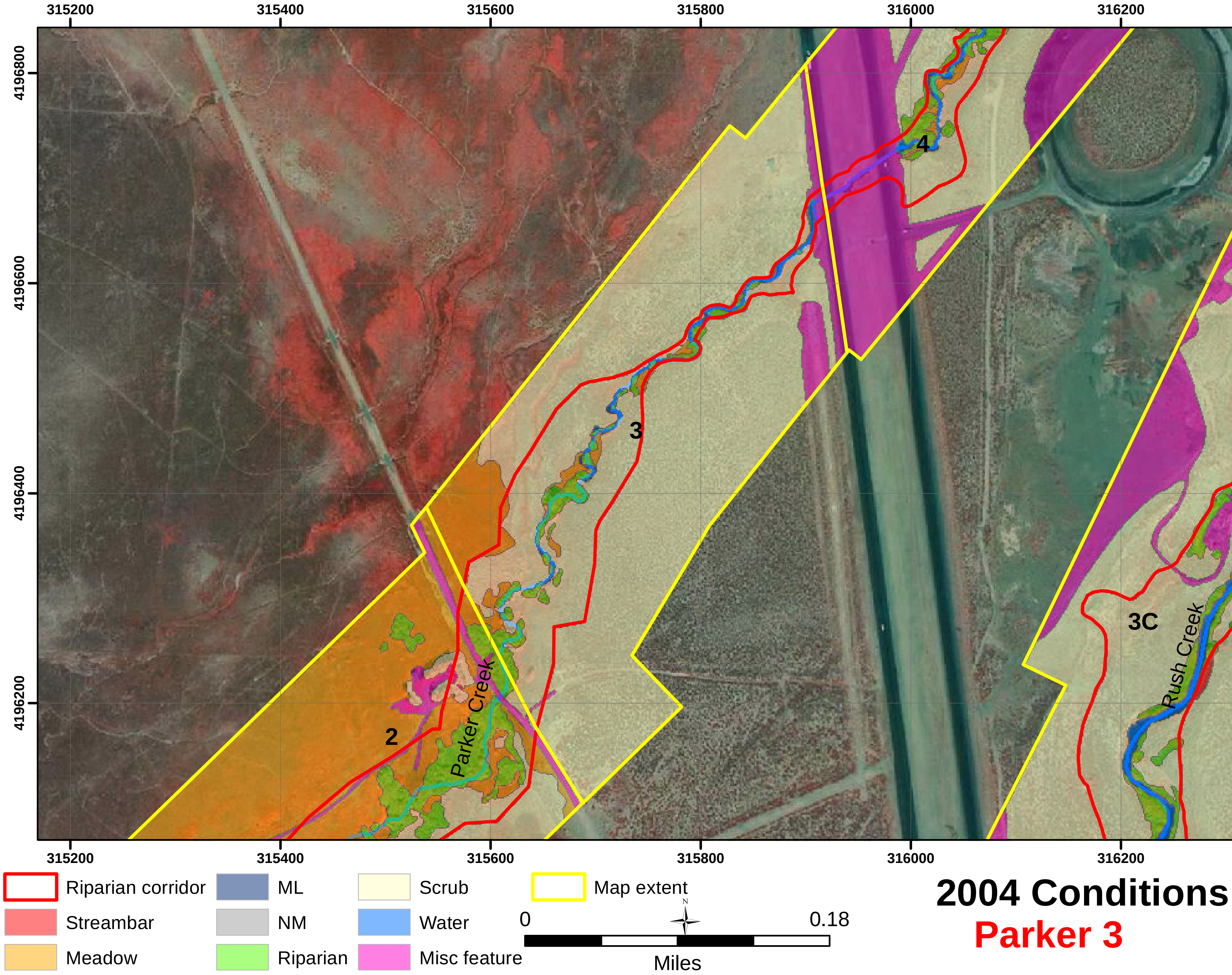


2004 Conditions
Parker 1



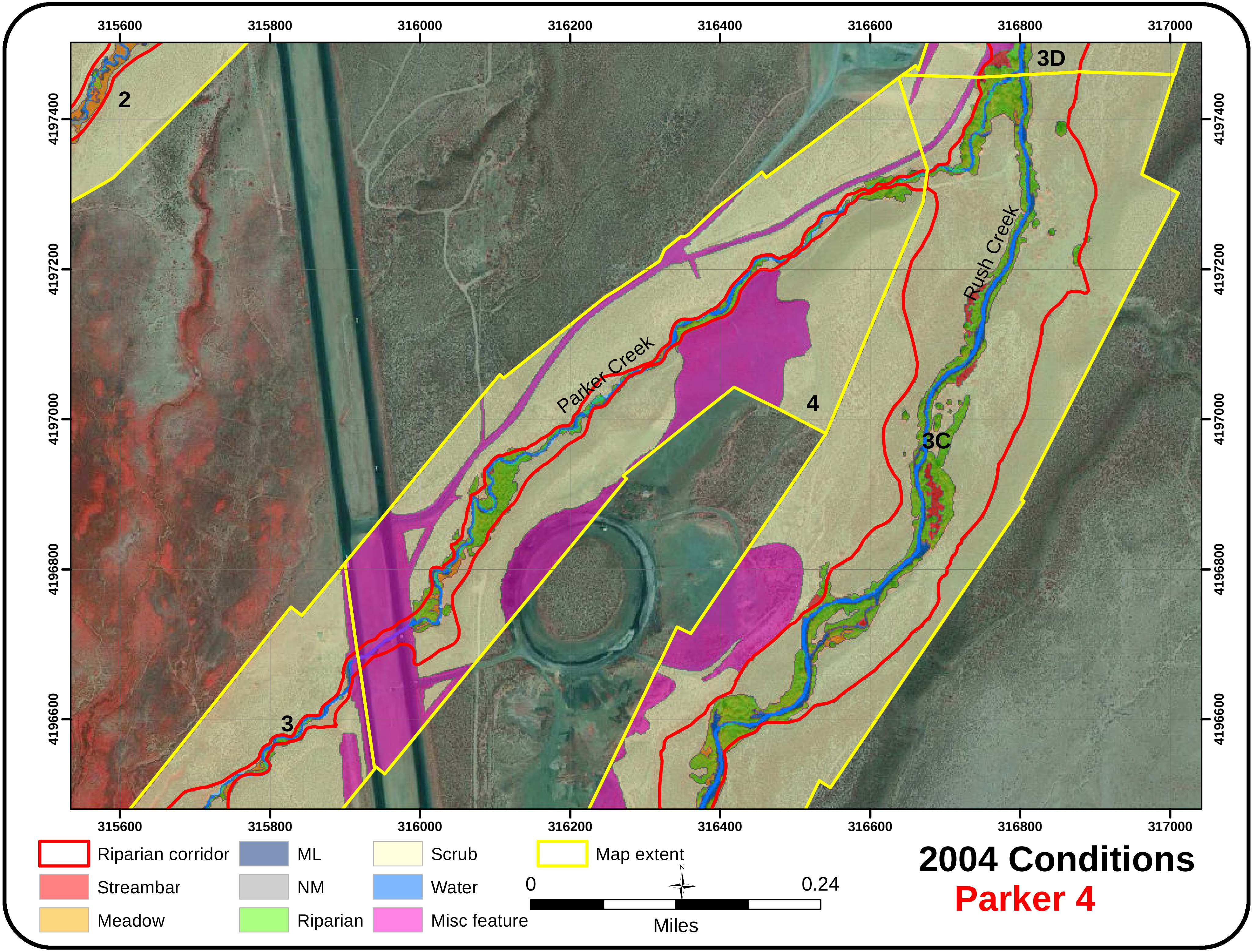
2004 Conditions

Parker 2



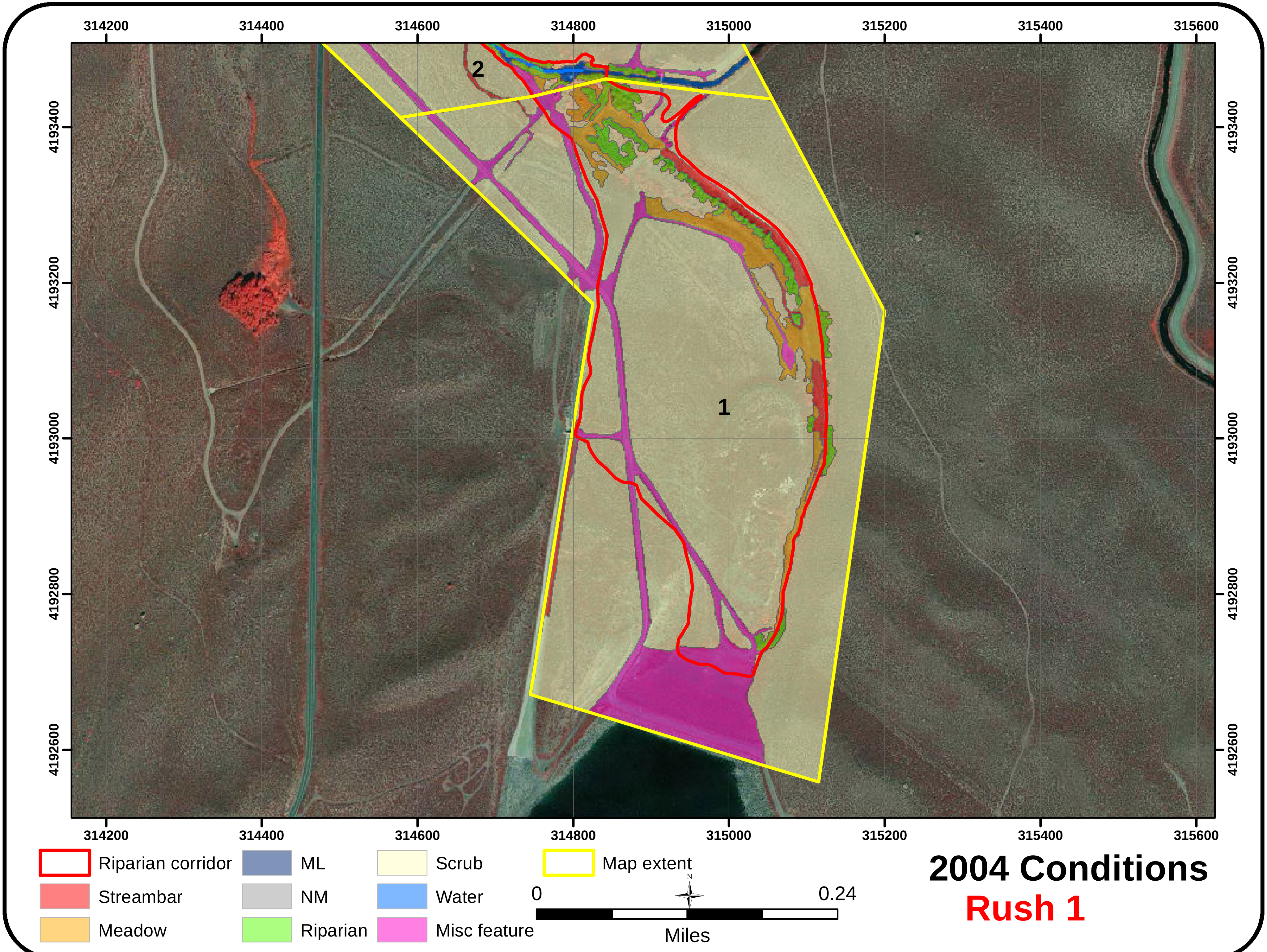
2004 Conditions

Parker 3



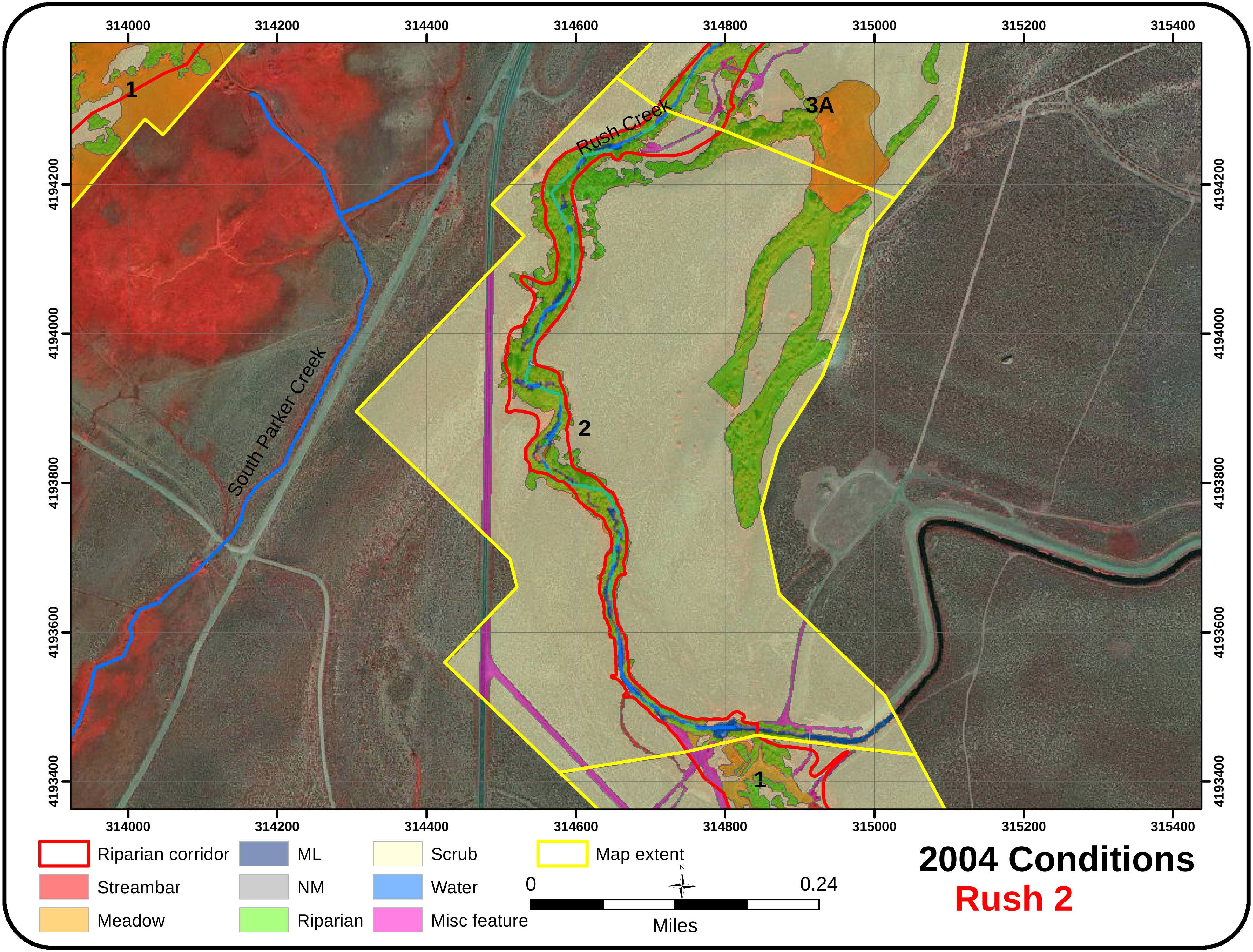
2004 Conditions

Parker 4



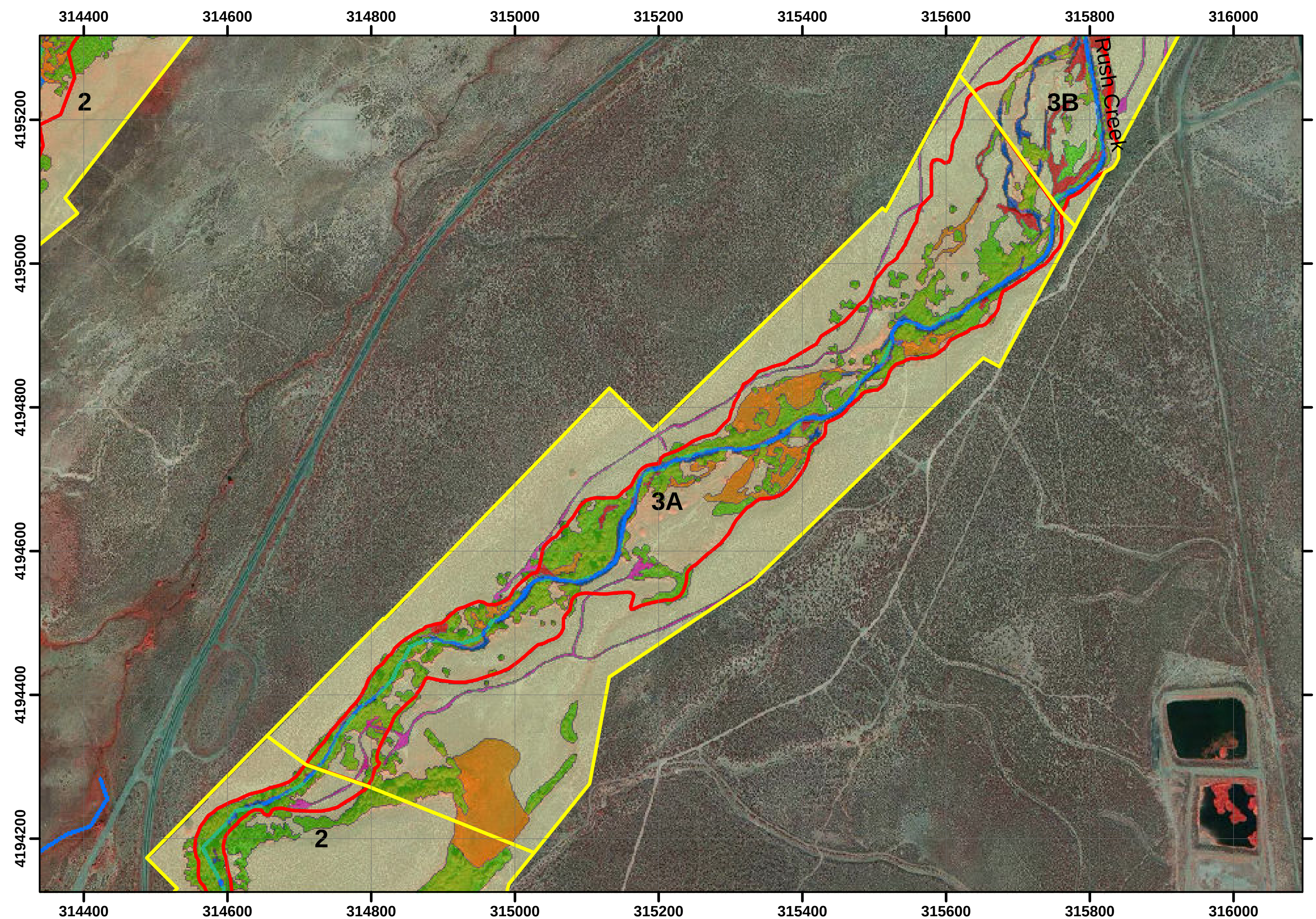
2004 Conditions

Rush 1



2004 Conditions

Rush 2

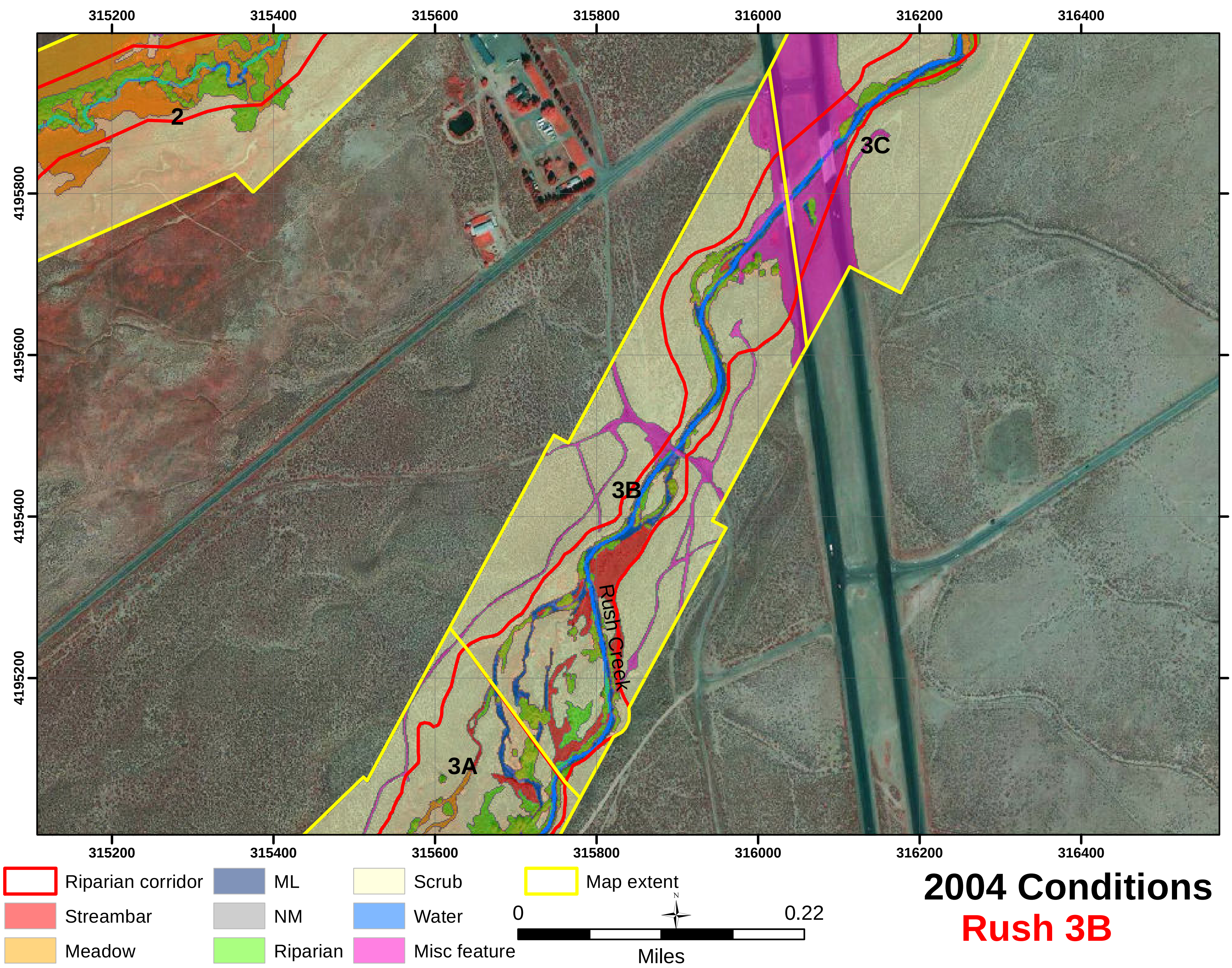


Riparian corridor
Streambar
Meadow
ML
NM
Riparian
Scrub
Water
Misc feature
Map extent

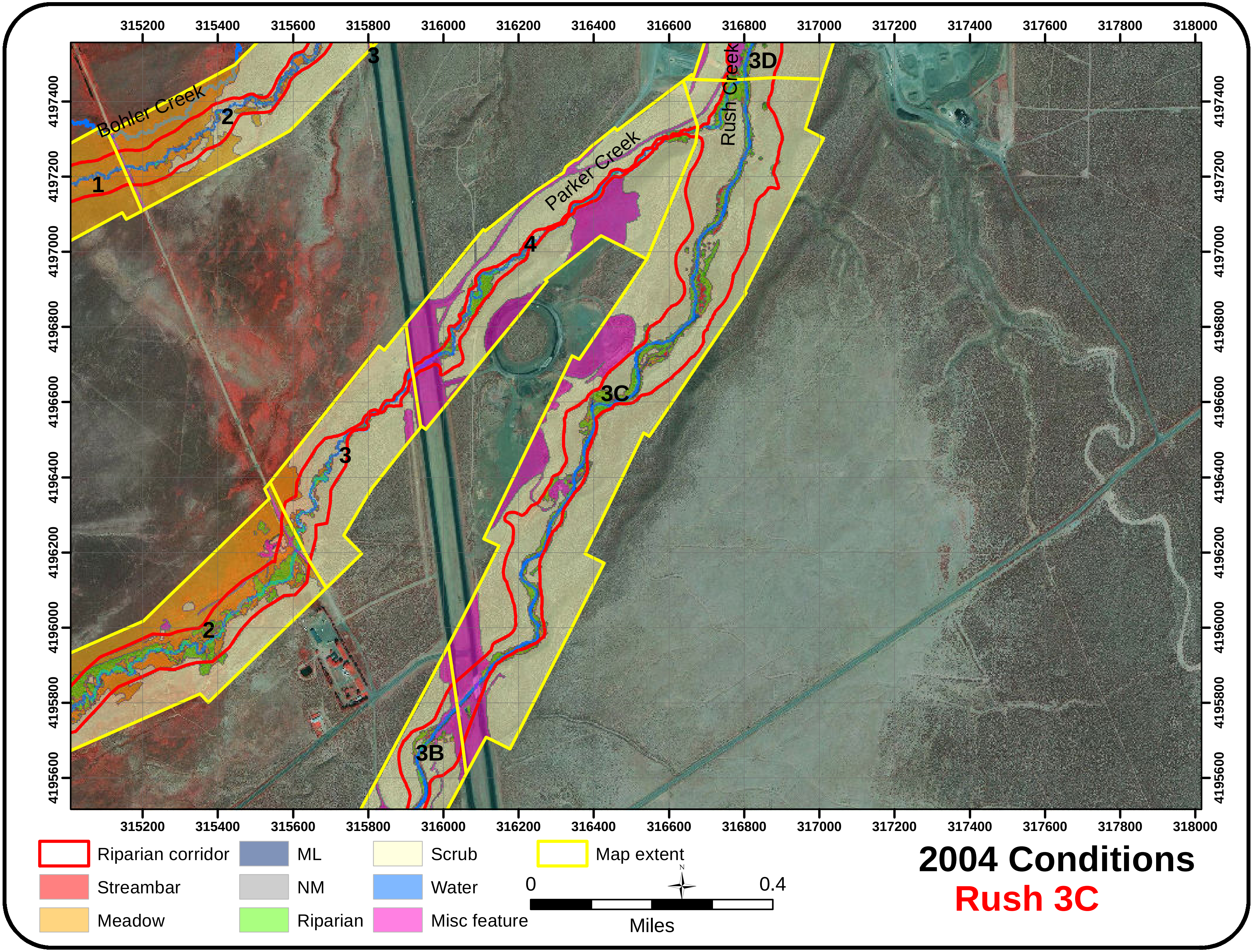
0 0.28
Miles

2004 Conditions

Rush 3A



2004 Conditions
Rush 3B



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315400
315600
315800
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316200
316400
316600
316800
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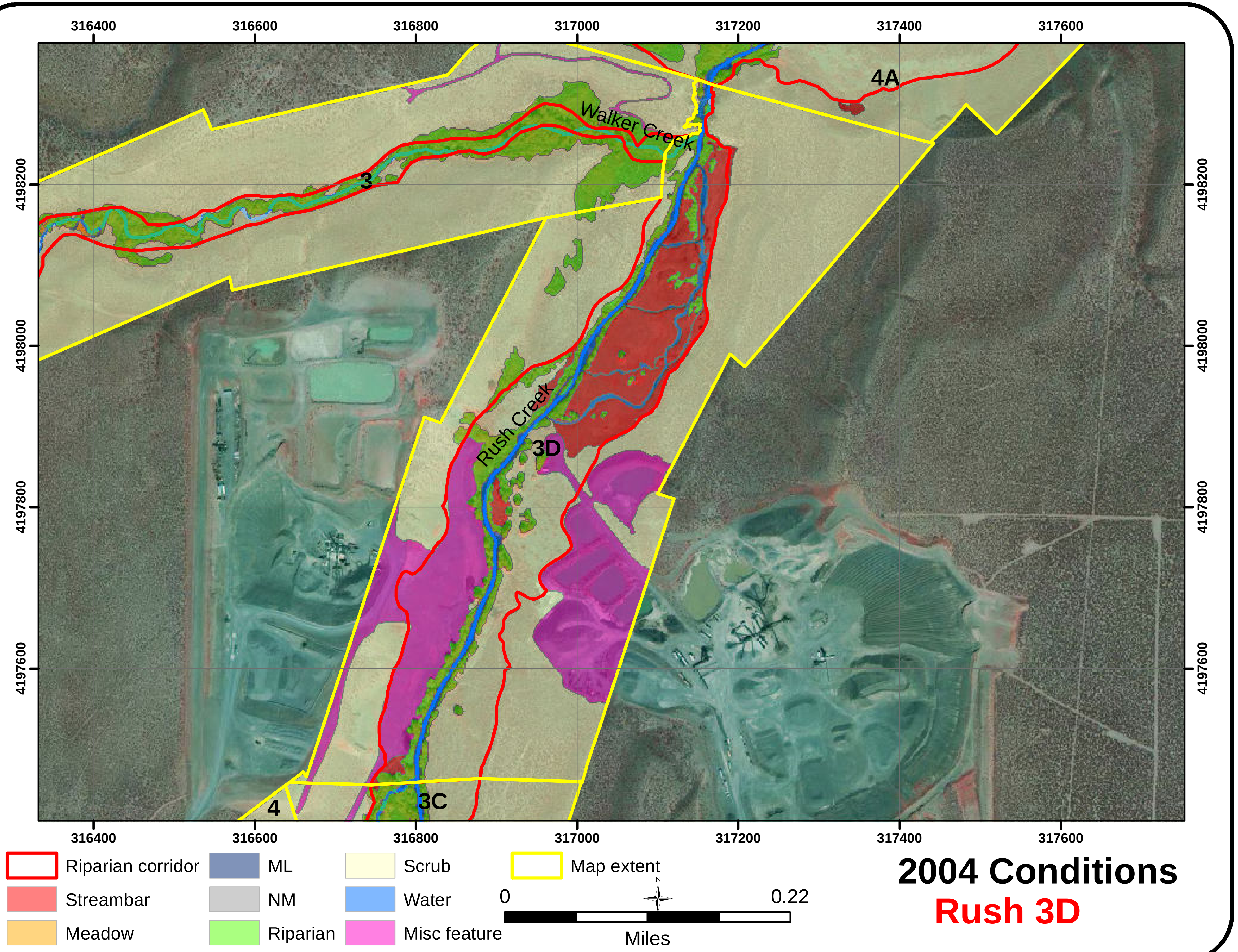
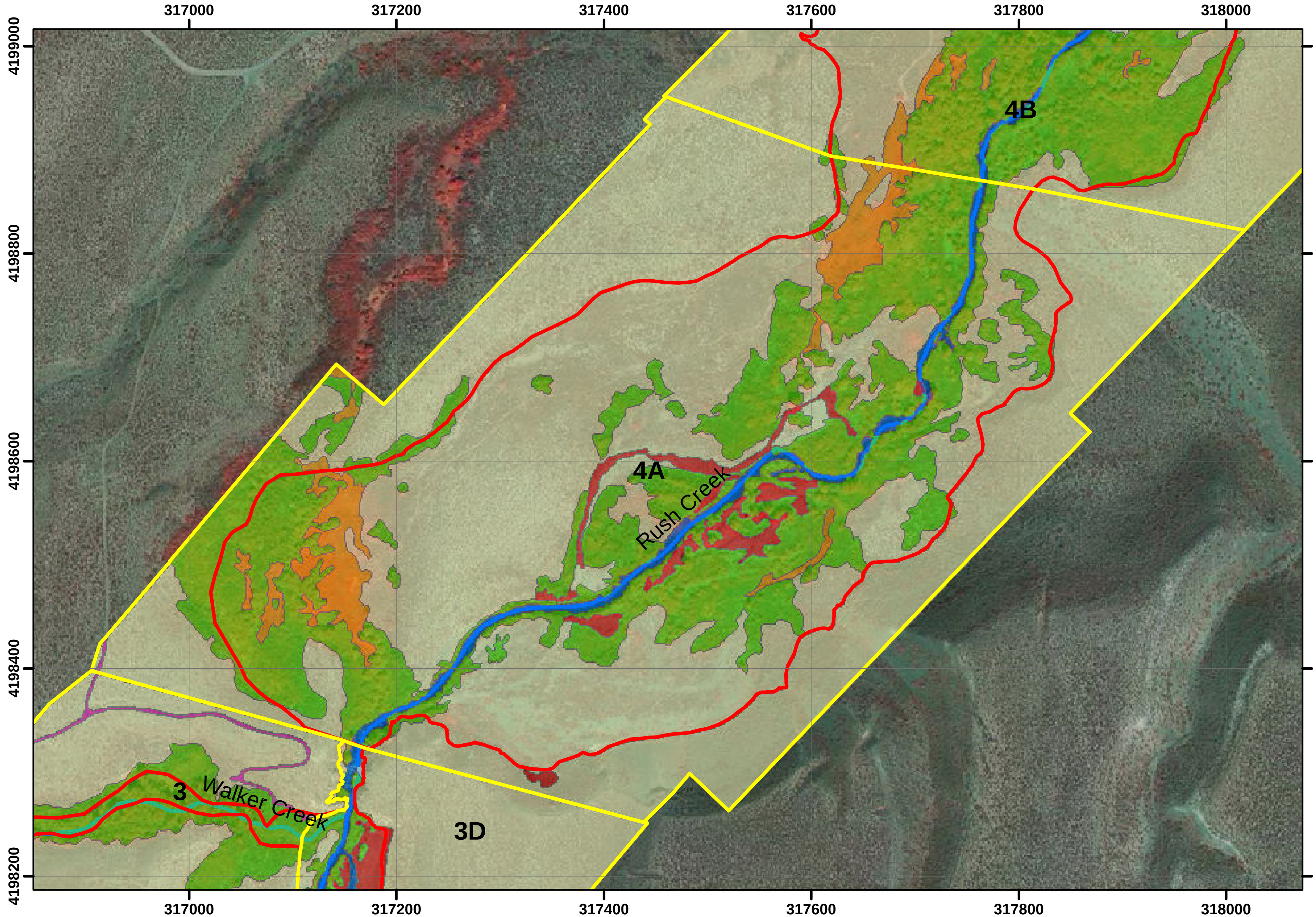
317200
317400
317600
317800
318000
4197400
4197200
4197000
4196800
4196600
4196400
4196200
4196000
4195800
4195600
Bohler Creek
Parker Creek
Rush Creek
1
2
3
4
3B
3C
3D
Riparian corridor
Streambar
Meadow
ML
NM
Riparian
Scrub
Water
Misc feature
Map extent
0
0.4
Miles
2004 Conditions
Rush 3C



2004 Conditions

Rush 3D

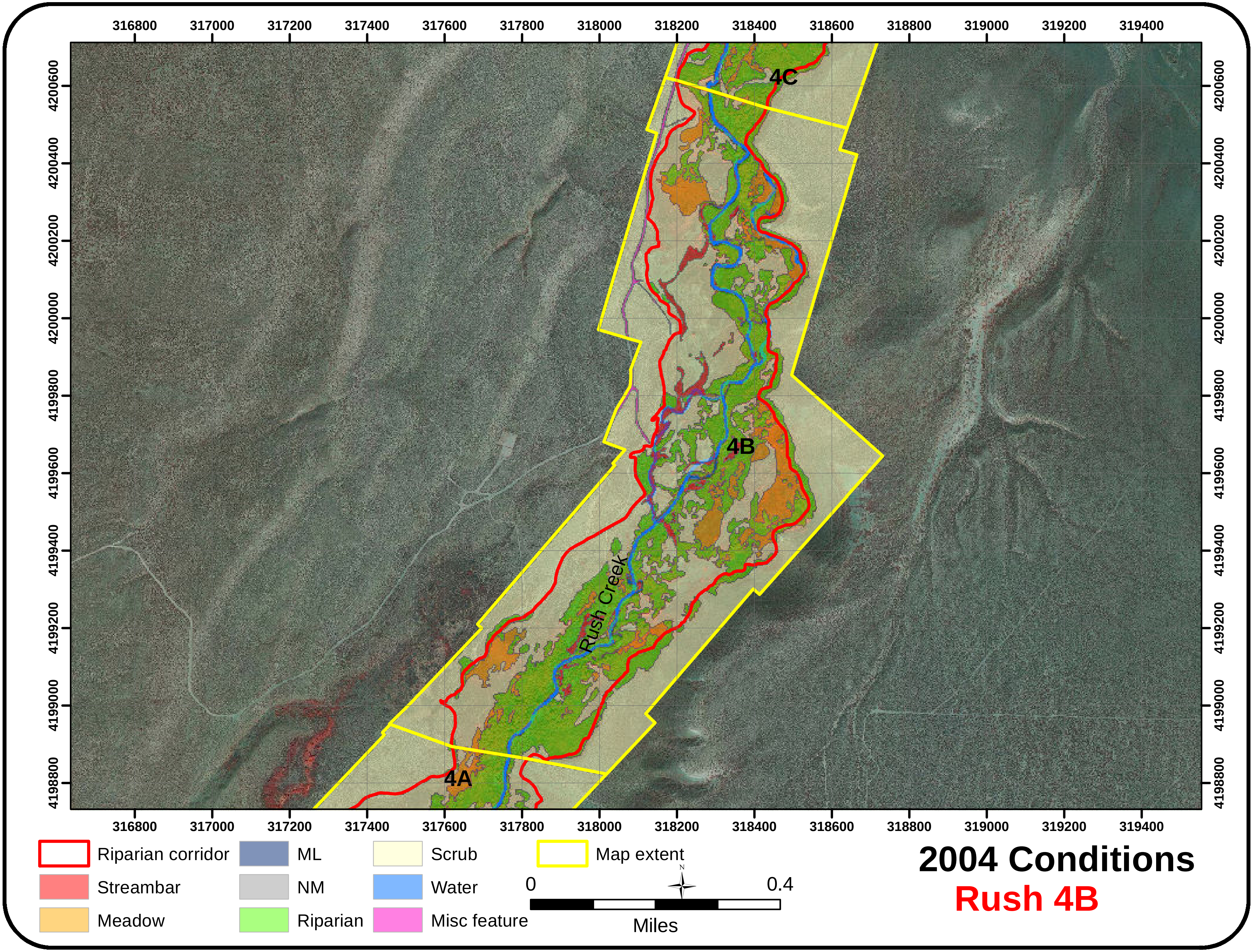


Riparian corridor
Streambar
Meadow
ML
NM
Riparian
Scrub
Water
Misc feature
Map extent

0 0.2
Miles

2004 Conditions

Rush 4A



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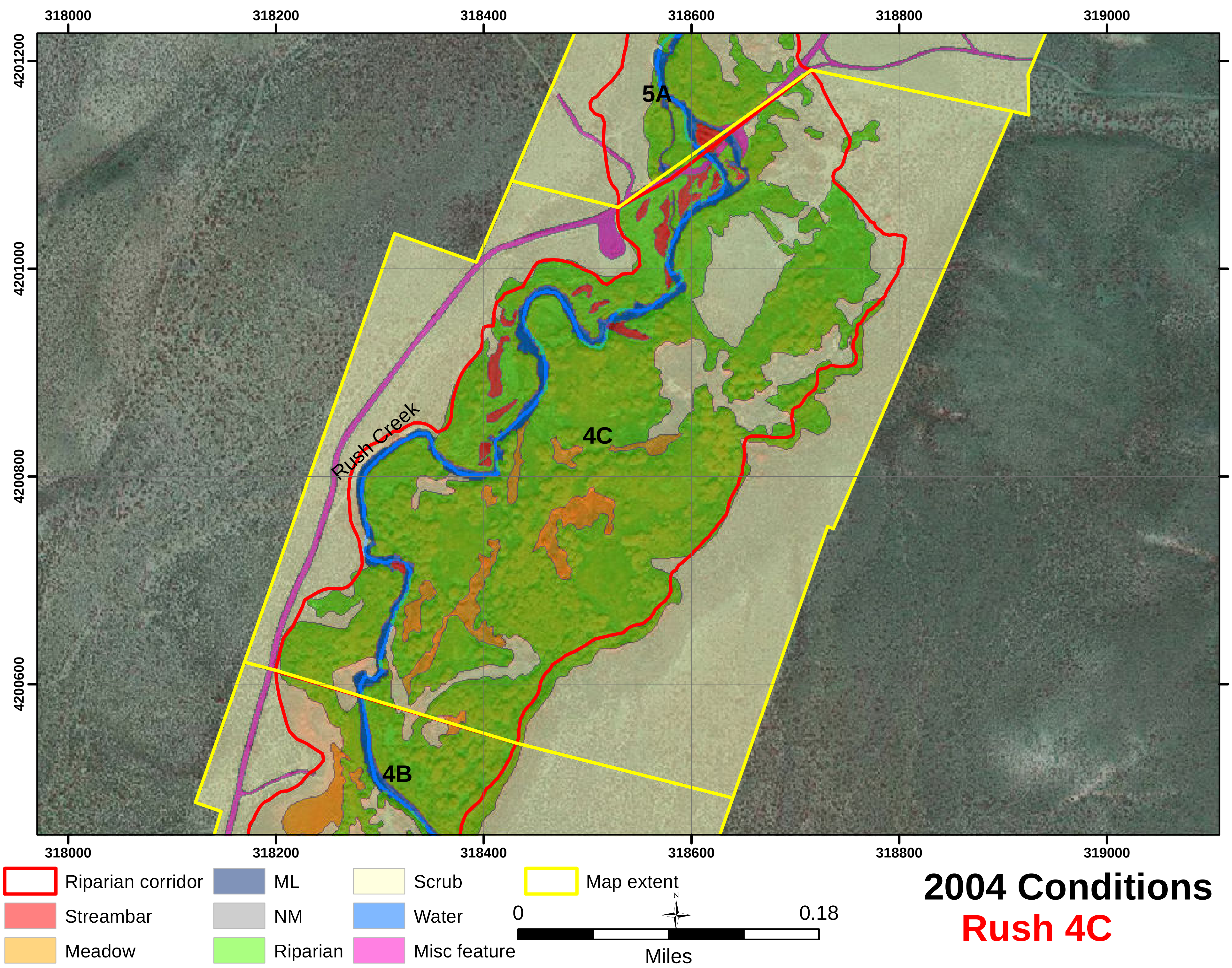
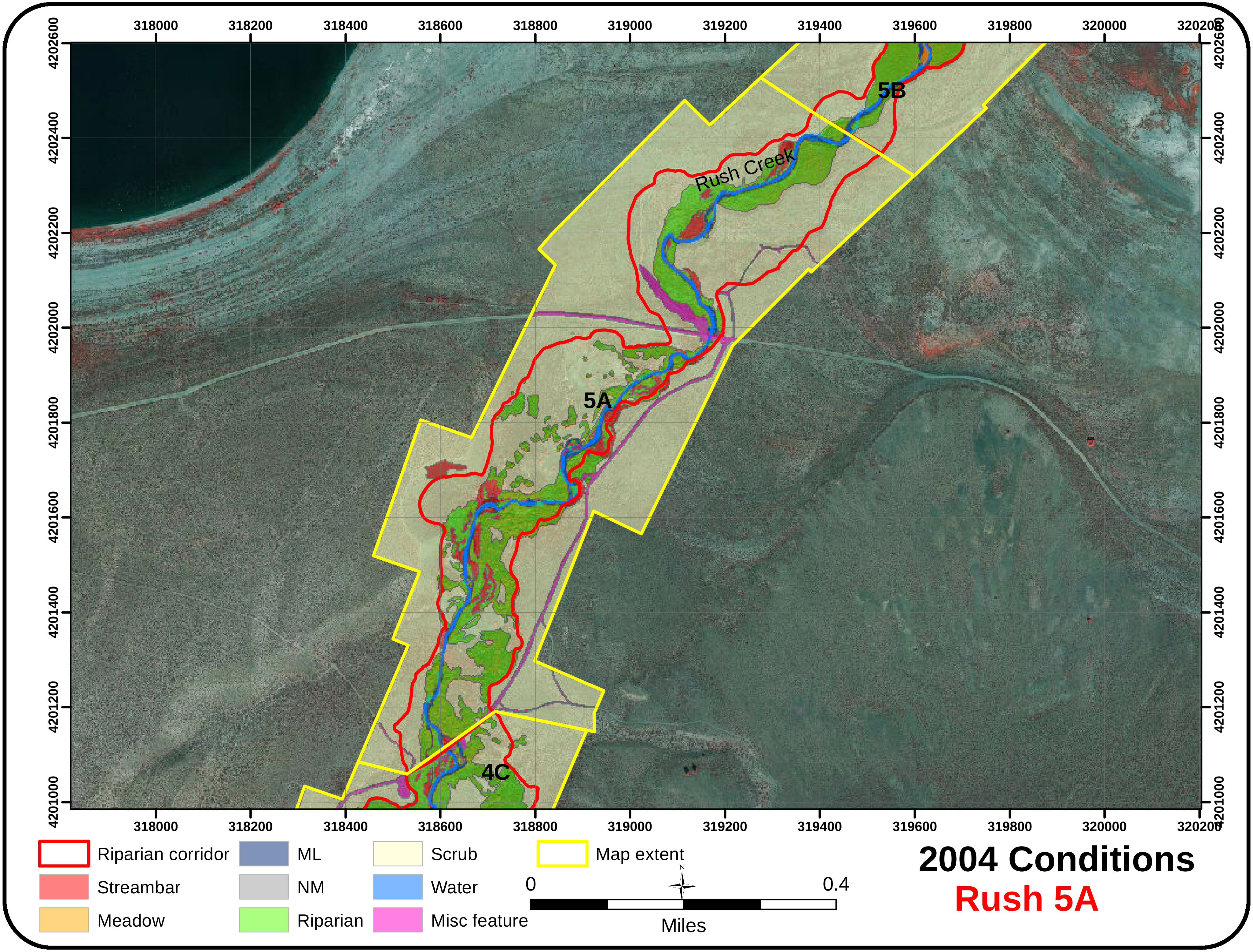
4200400
4200200
4200000
4199800
4199600
4199400
4199200
4199000
4198800
4C
4B
4A
Rush Creek
Riparian corridor
Streambar
Meadow
ML
NM
Riparian
Scrub
Water
Misc feature
Map extent
0
0.4
Miles
N
2004 Conditions
Rush 4B



2004 Conditions

Rush 4C



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319200
319400
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319800
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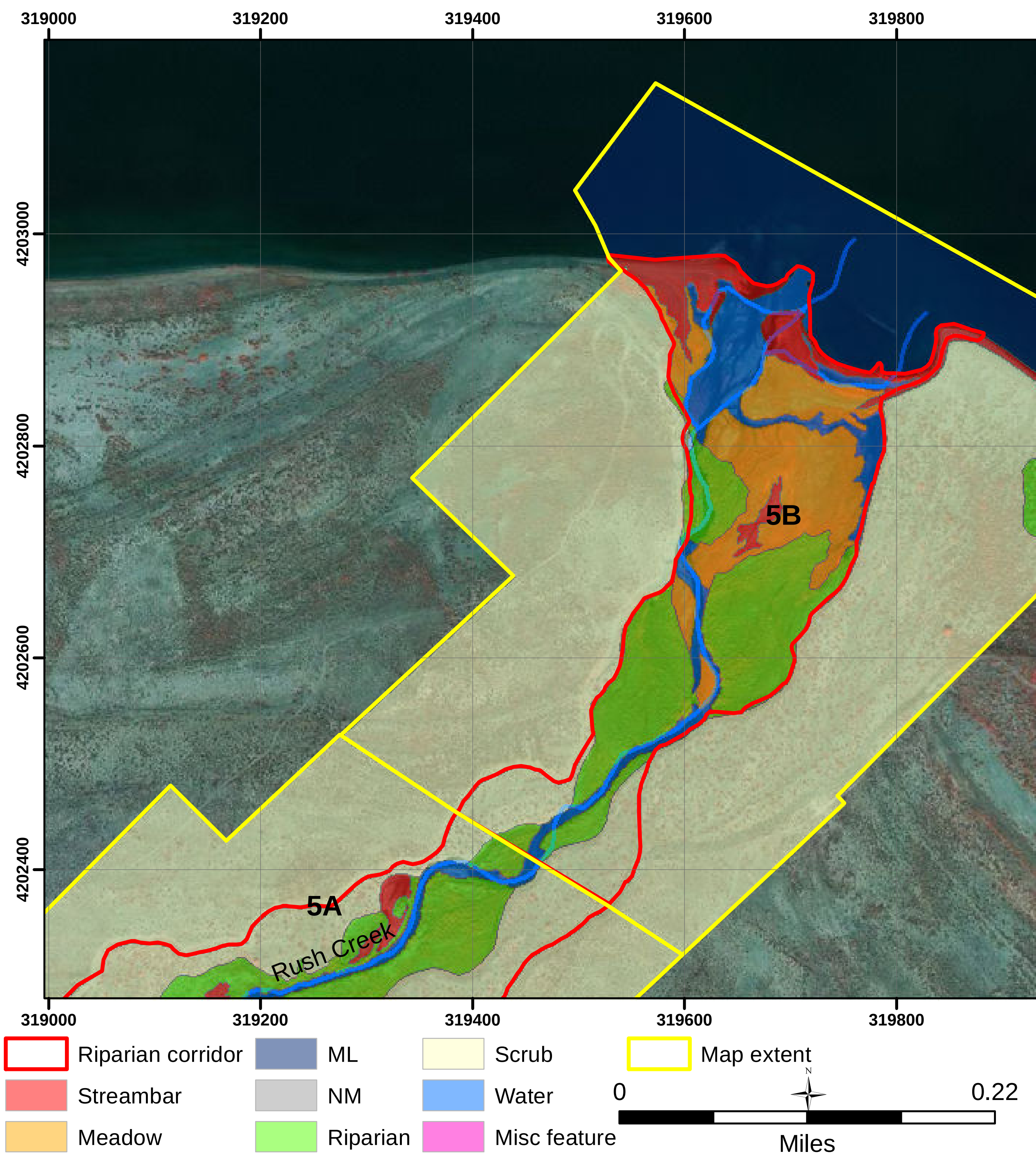
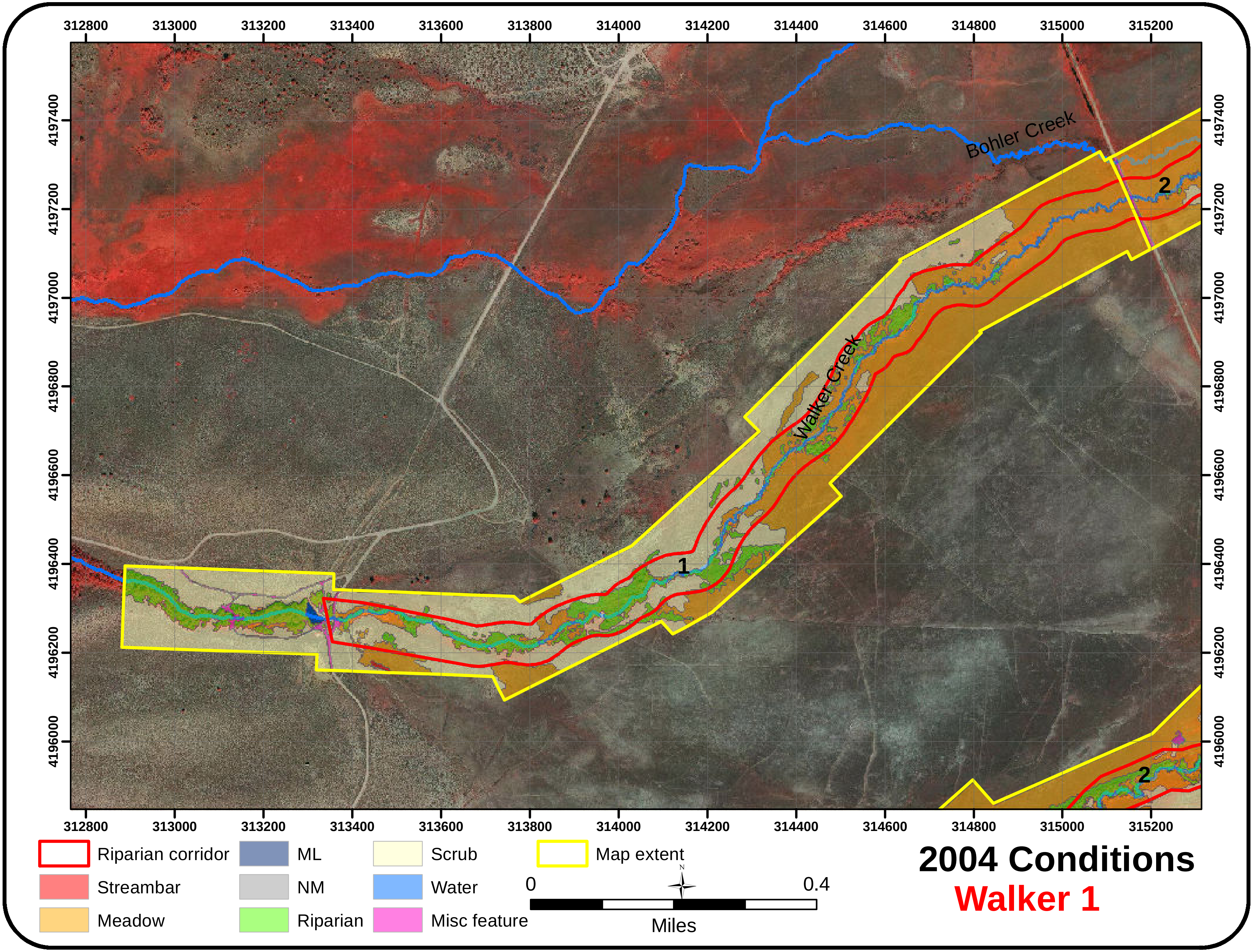
4201000
4201200
4201400
4201600
4201800
4202000
4202200
4202400
4202600
5B
Rush Creek
5A
4C
Riparian corridor
Streambar
Meadow
ML
NM
Riparian
Scrub
Water
Misc feature
Map extent
0
0.4
Miles
2004 Conditions
Rush 5A



2004 Conditions
Rush 5B



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314600
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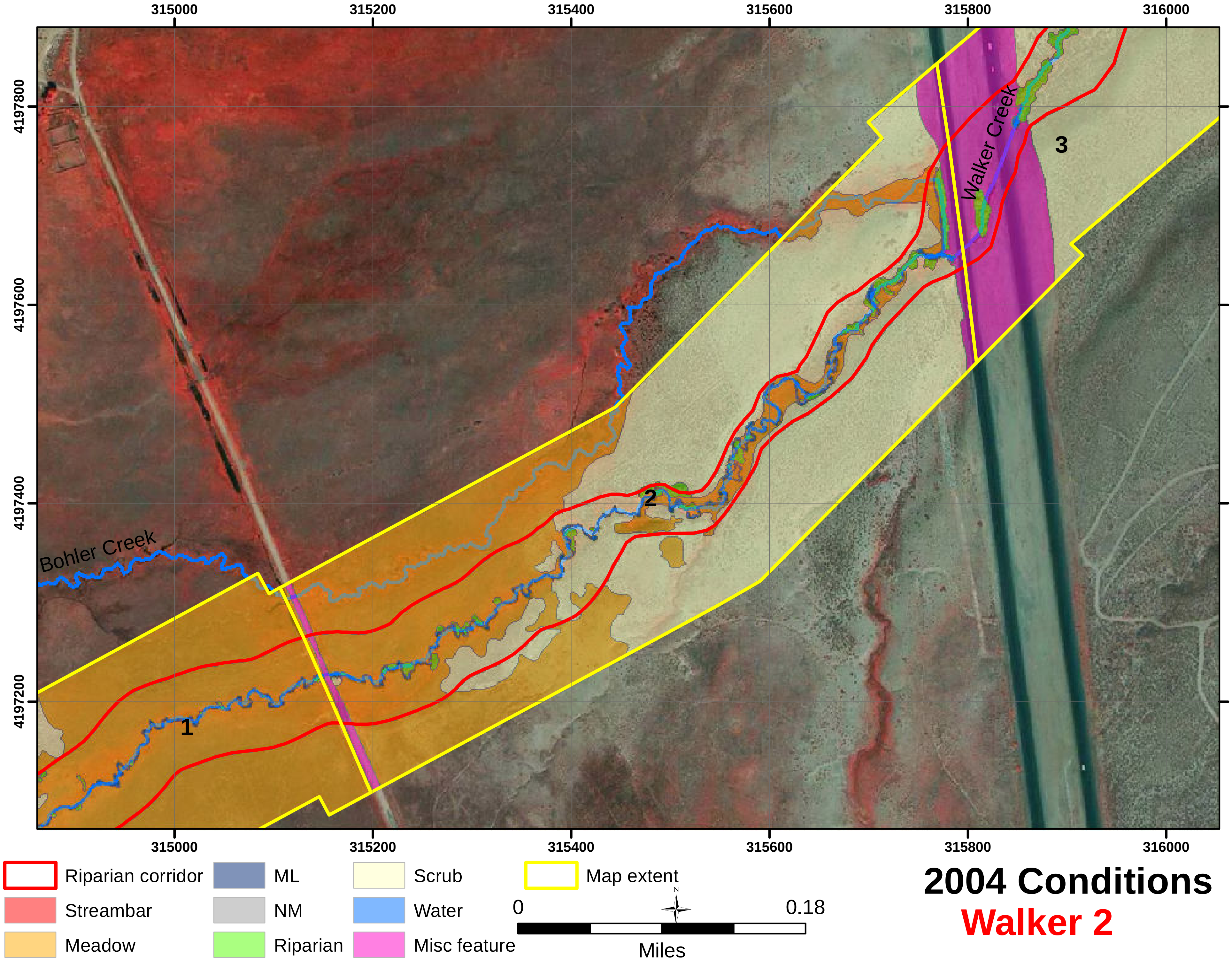
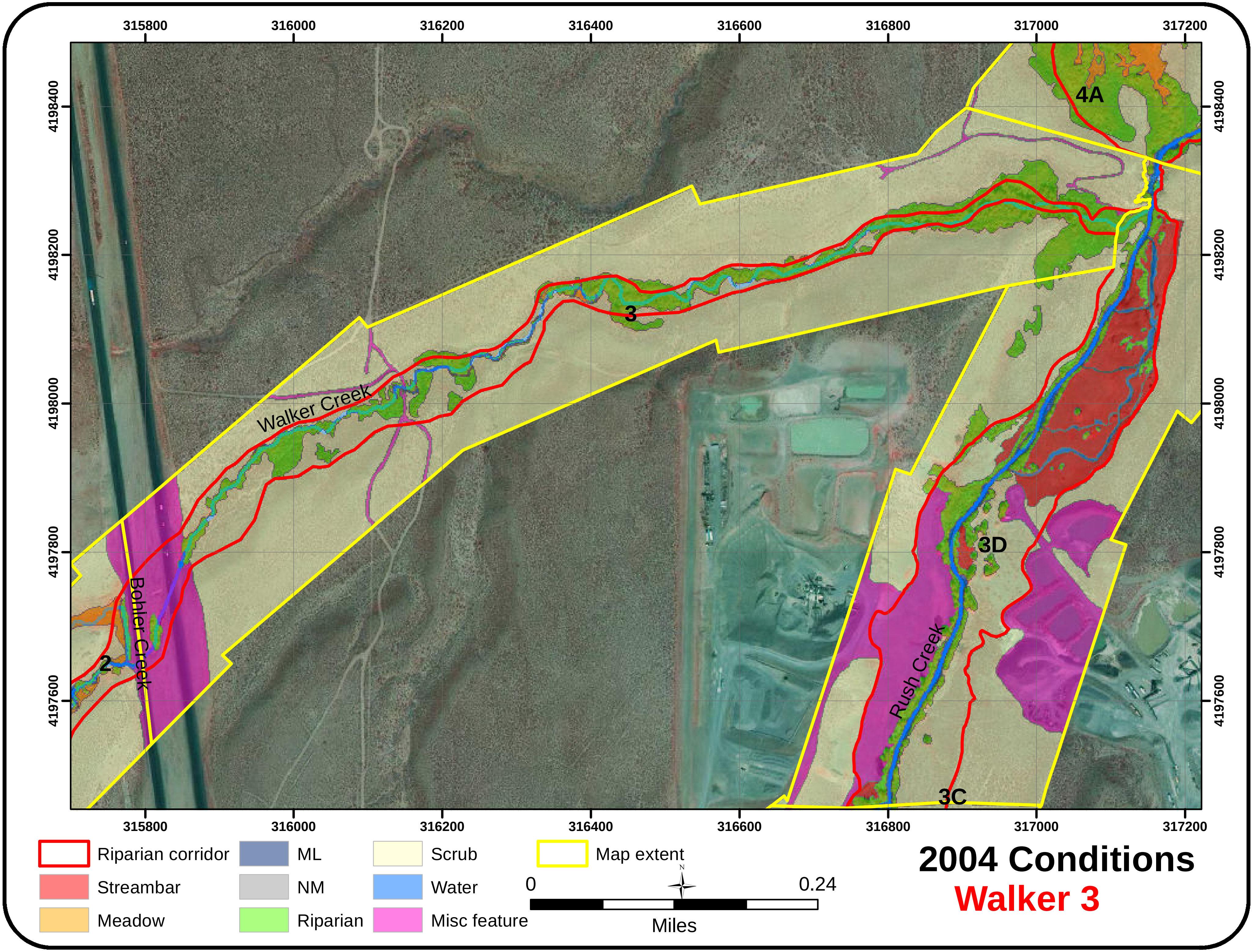
315000
315200
4197400
4197200
4197000
4196800
4196600
4196400
4196200
4196000
Bohler Creek
Walker Creek
1
2
2
Riparian corridor
Streambar
Meadow
ML
NM
Riparian
Scrub
Water
Misc feature
Map extent
0
0.4
Miles
N
2004 Conditions
Walker 1



2004 Conditions
Walker 2



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317200
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4198200
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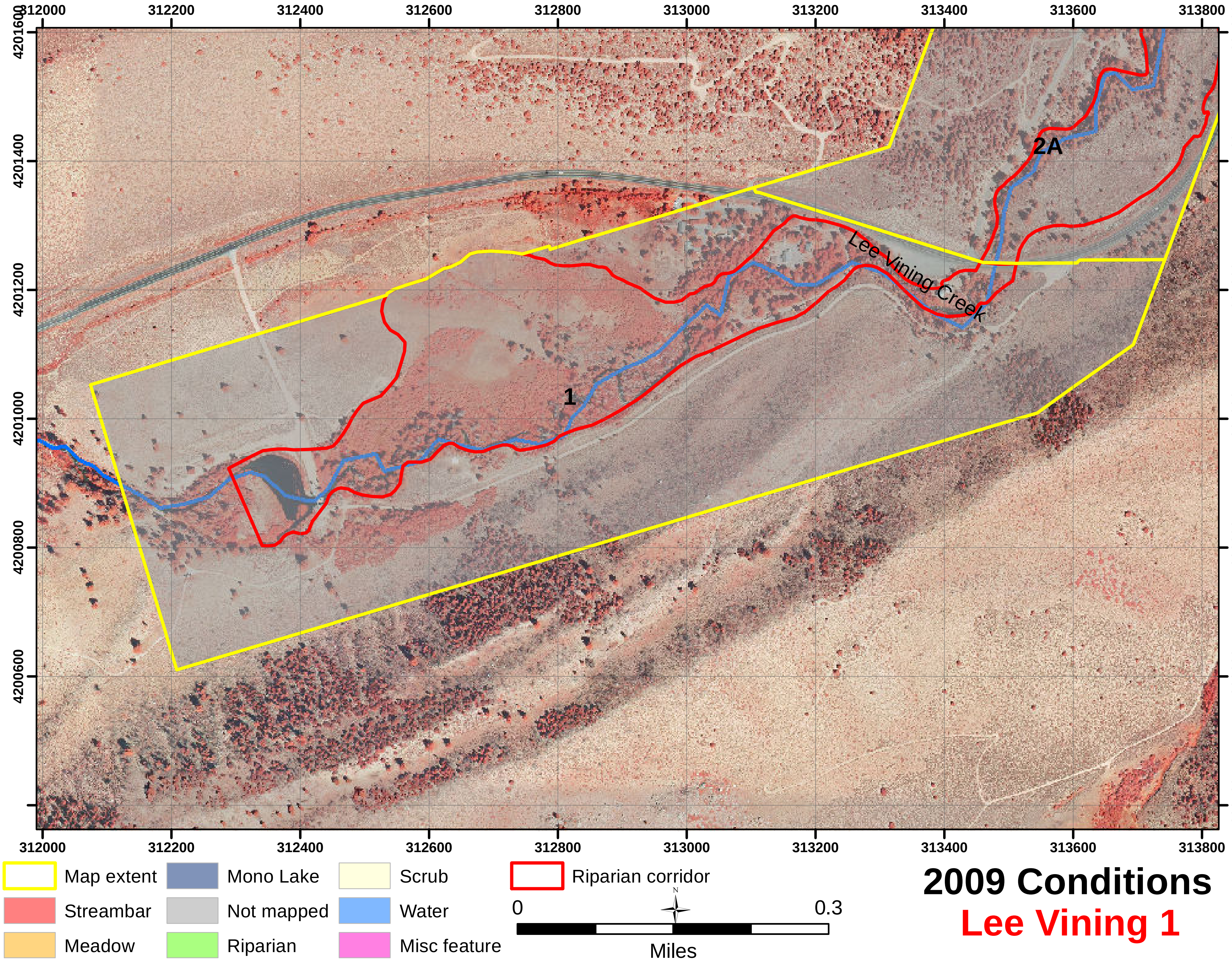
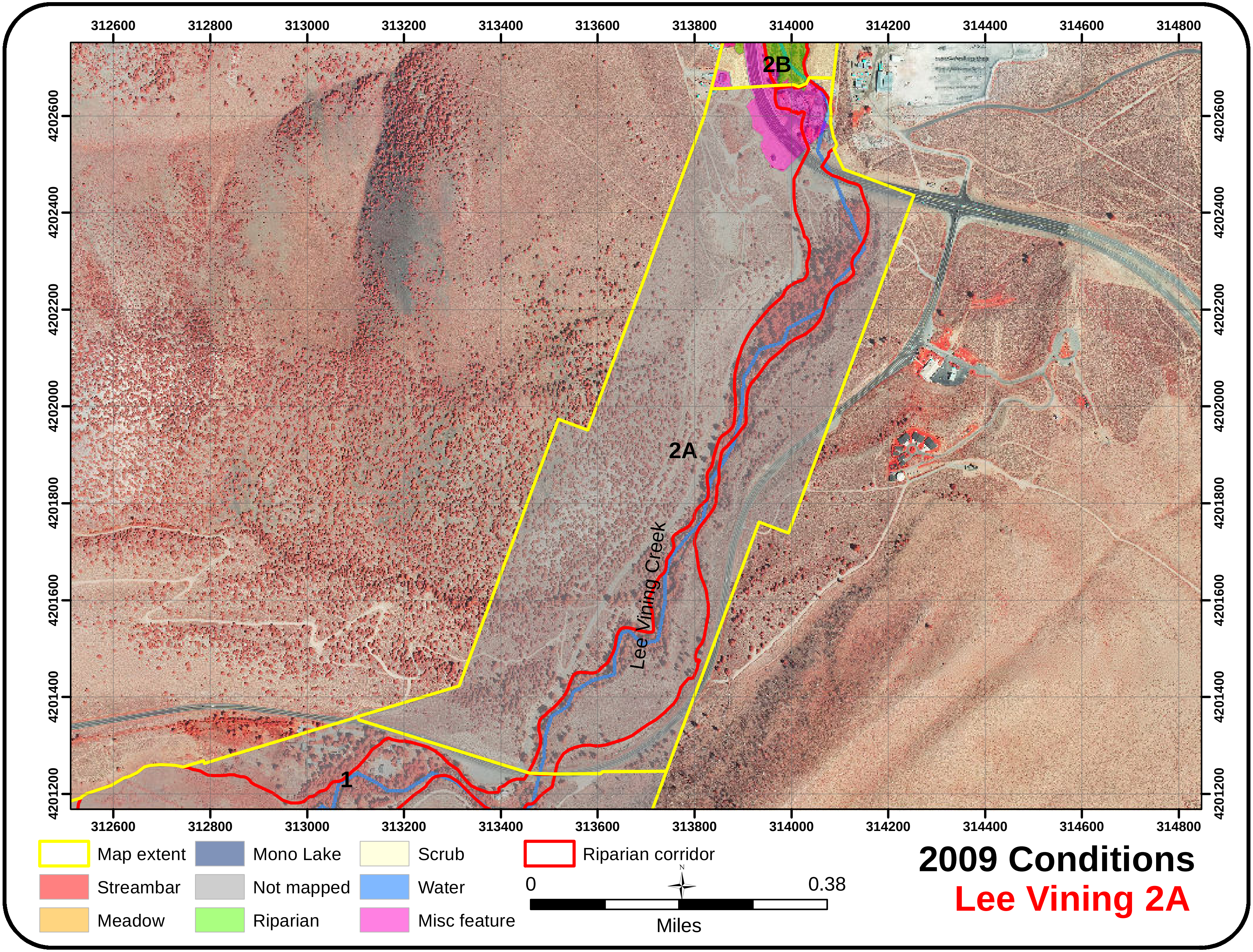
4197800
4197600
4A
3
3D
3C
2
Walker Creek
Bohler Creek
Rush Creek
Riparian corridor
Streambar
Meadow
ML
NM
Riparian
Scrub
Water
Misc feature
Map extent
0
0.24
Miles
2004 Conditions
Walker 3

APPENDIX D
RIPARIAN MAPPING
2009 CONDITIONS



2009 Conditions

Lee Vining 1



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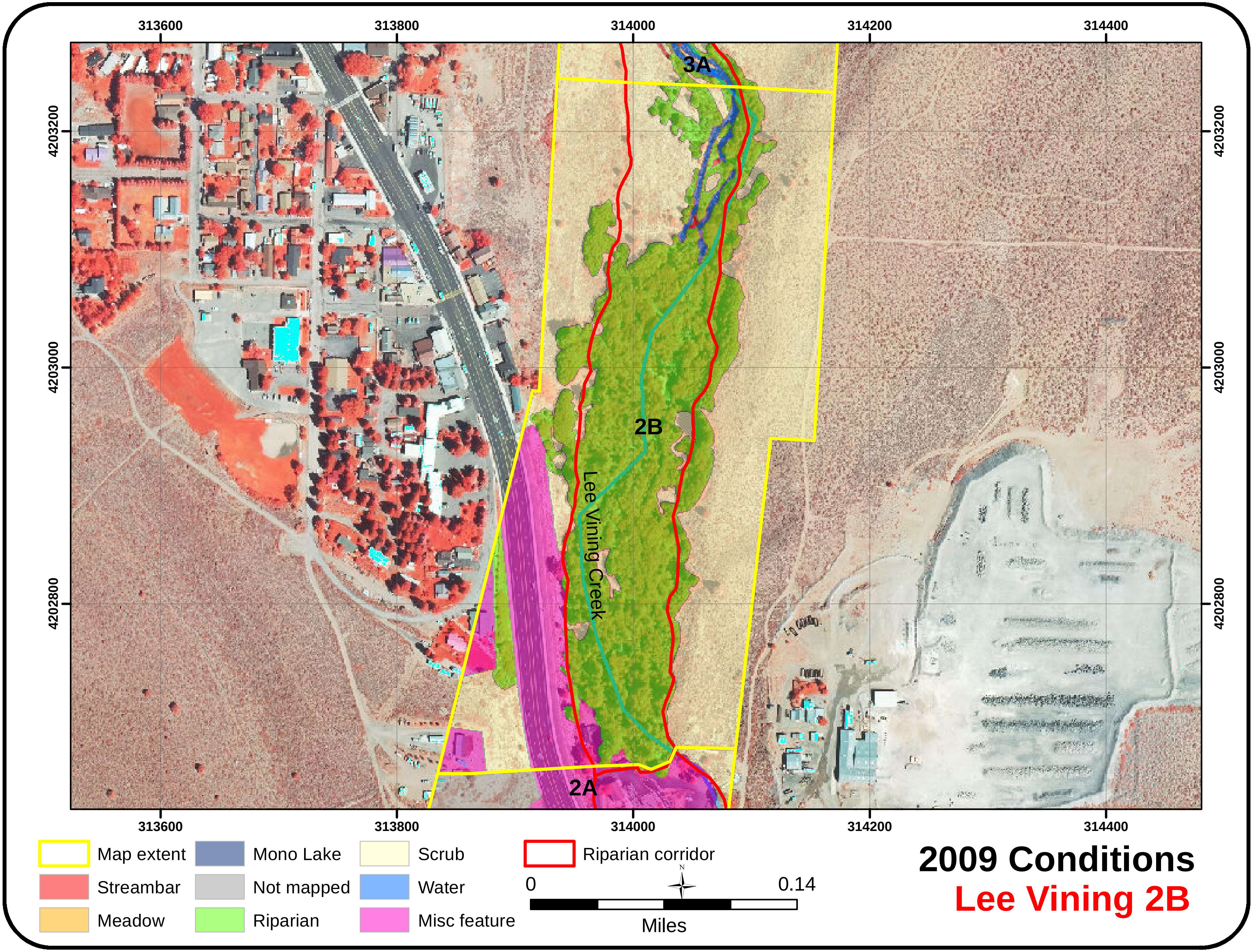
314400
314600
314800
4202600
4202400
4202200
4202000
4201800
4201600
4201400
4201200
2B
2A
1
Lee Vining Creek
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.38
Miles
N
2009 Conditions
Lee Vining 2A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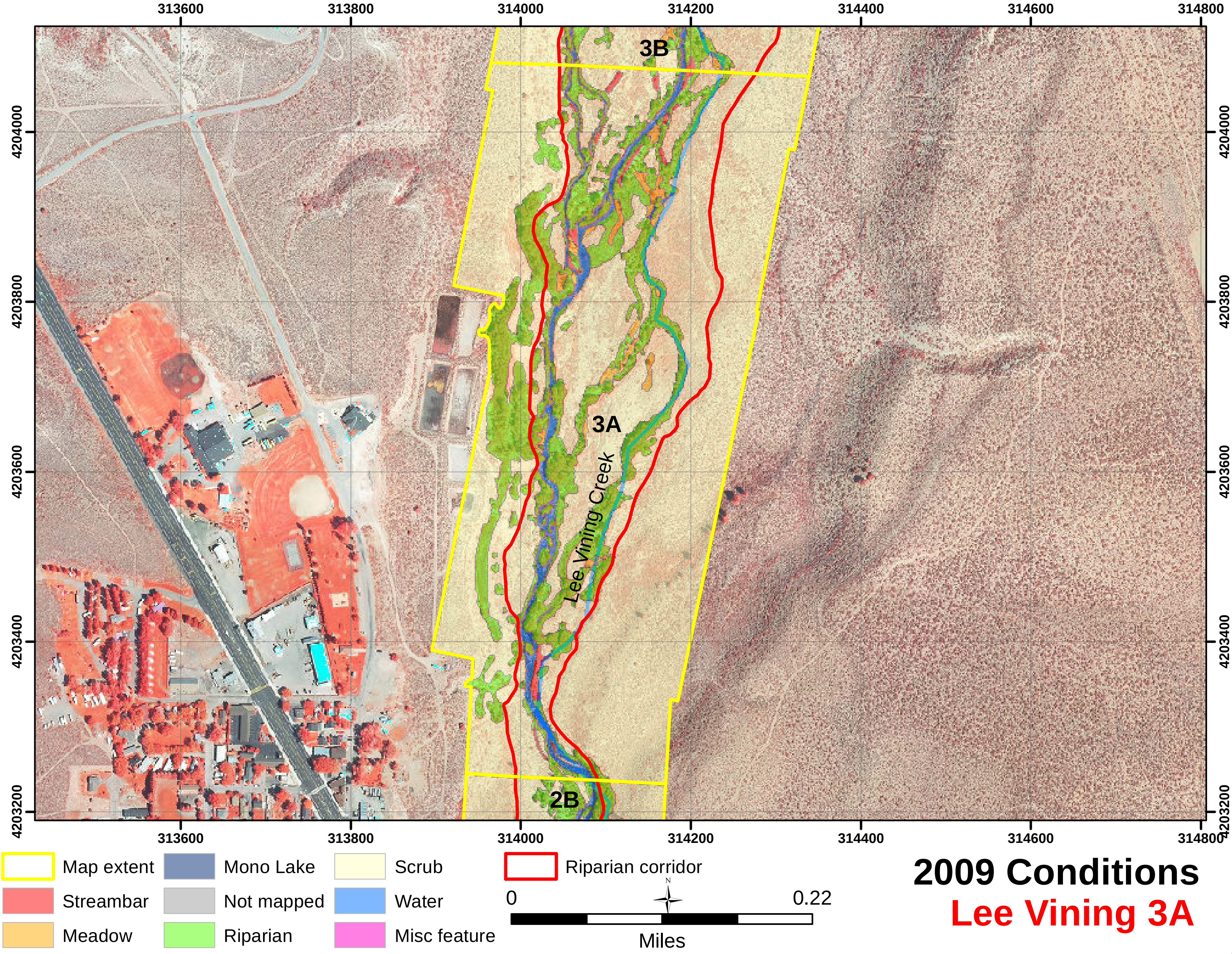
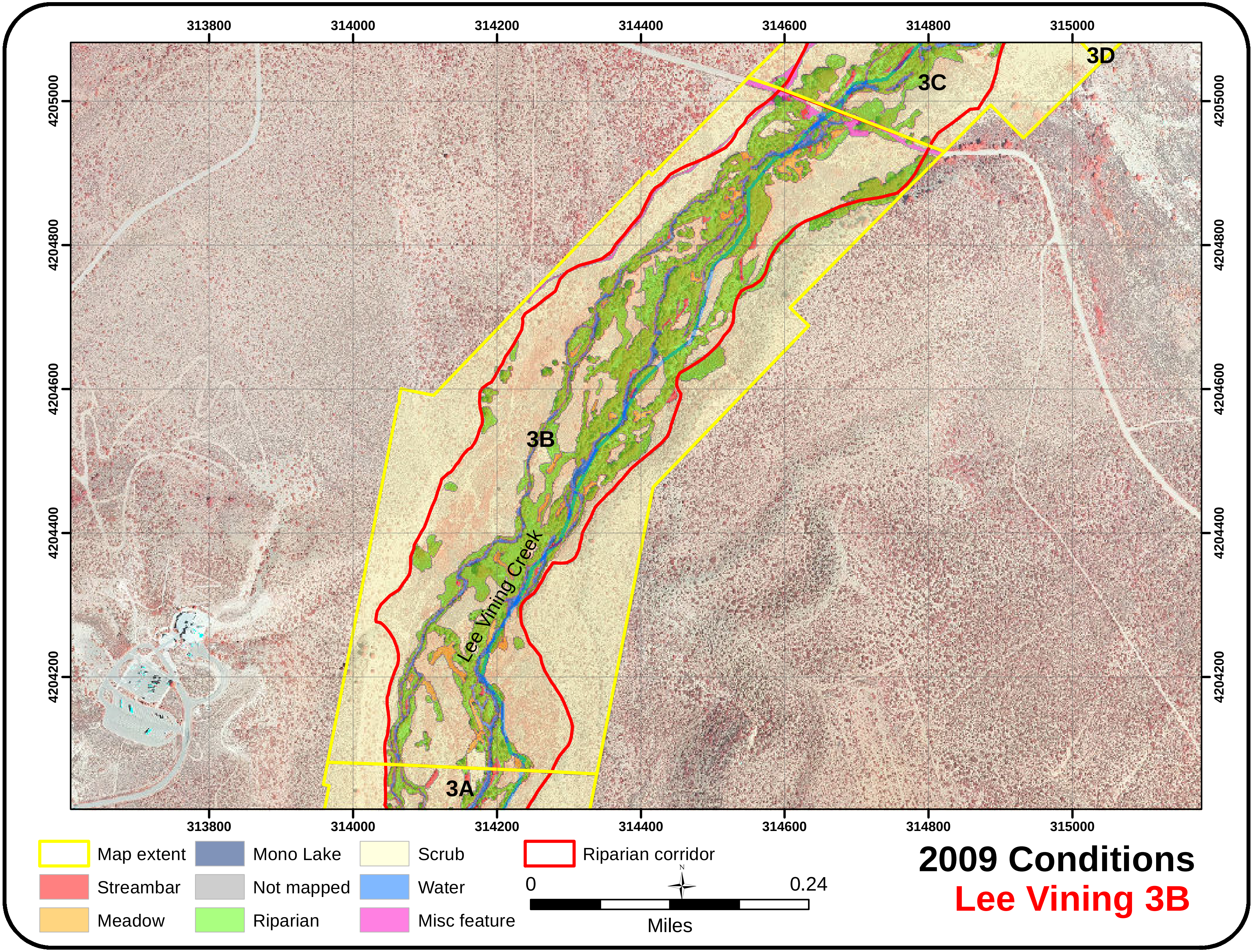
4203000
4202800
3A
2B
2A
Lee Vining Creek
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.14
N
Miles
2009 Conditions
Lee Vining 2B



2009 Conditions

Lee Vining 3A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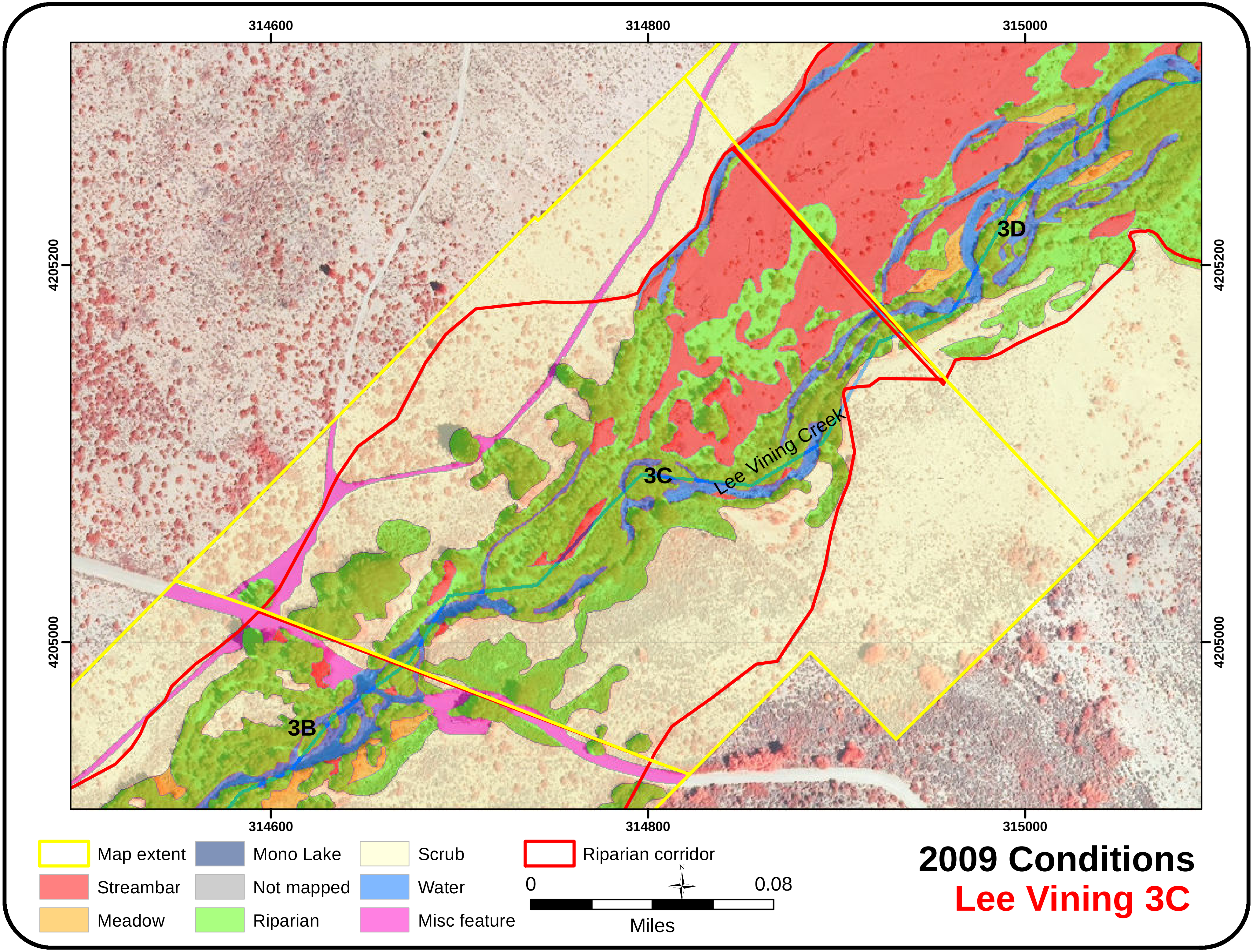
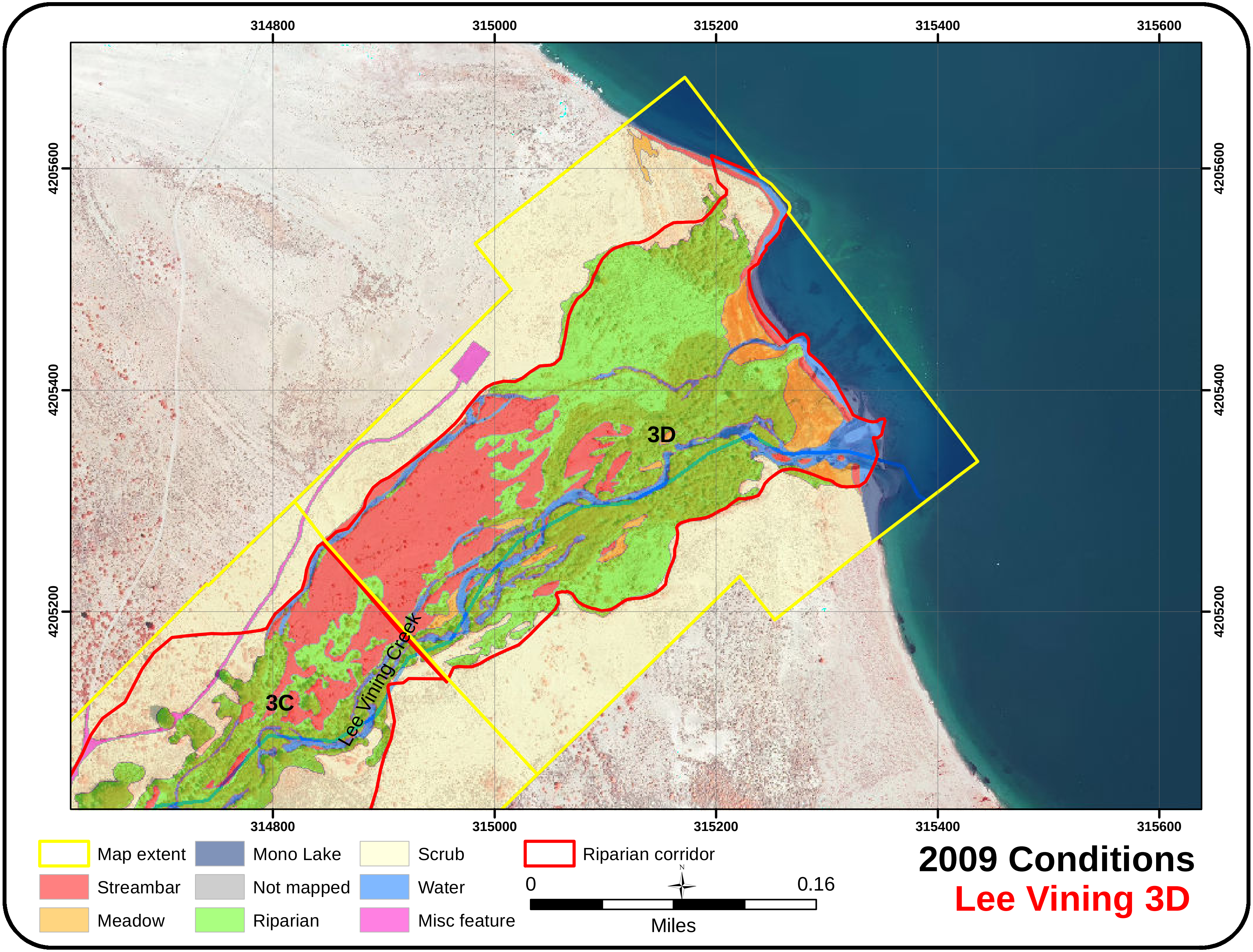
315000
4205000
4204800
4204600
4204400
4204200
3A
3B
3C
3D
Lee Vining Creek
Map extent
Mono Lake
Scrub
Riparian corridor
Streambar
Not mapped
Water
Meadow
Riparian
Misc feature
0
0.24
Miles
2009 Conditions
Lee Vining 3B

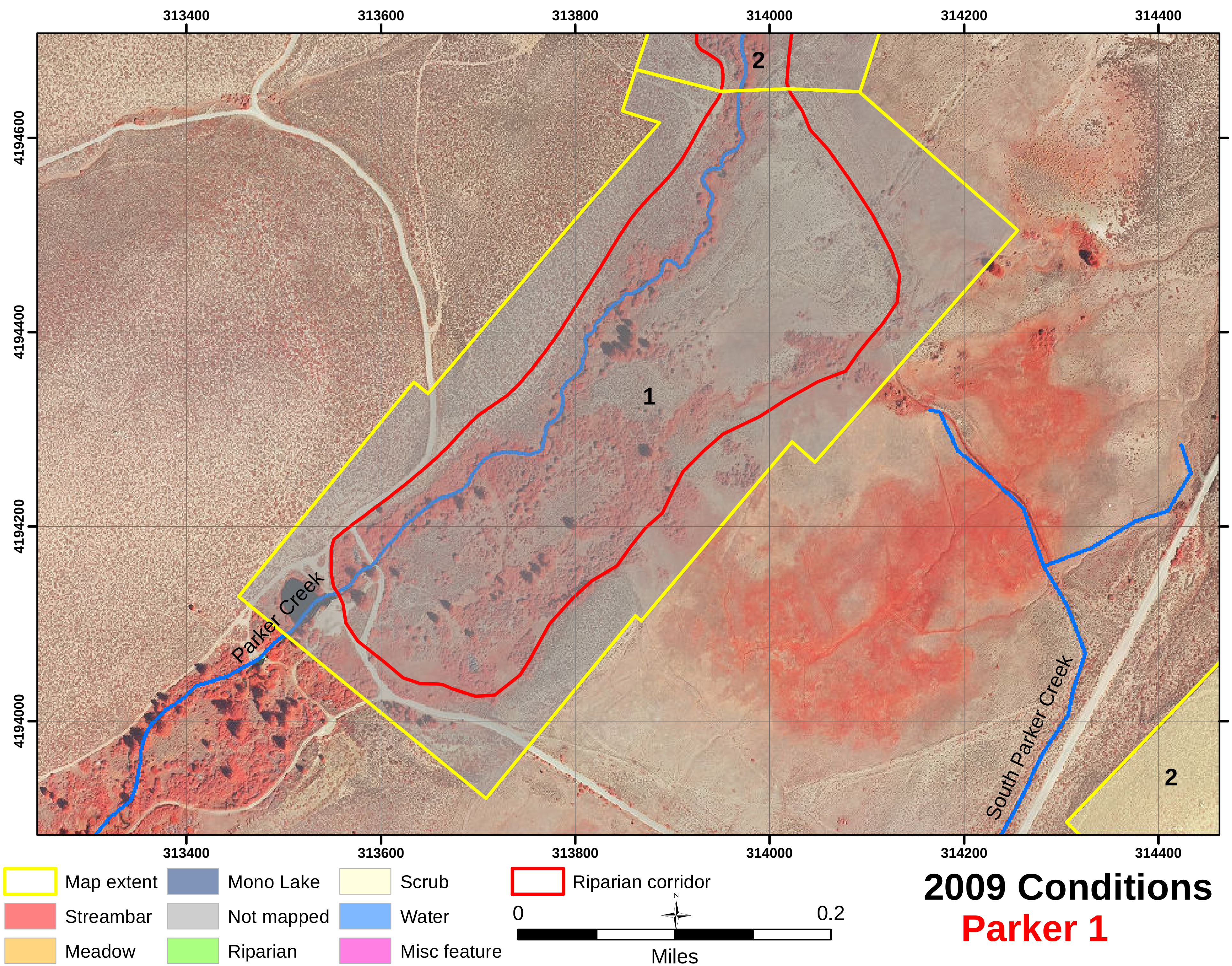


2009 Conditions
Lee Vining 3C



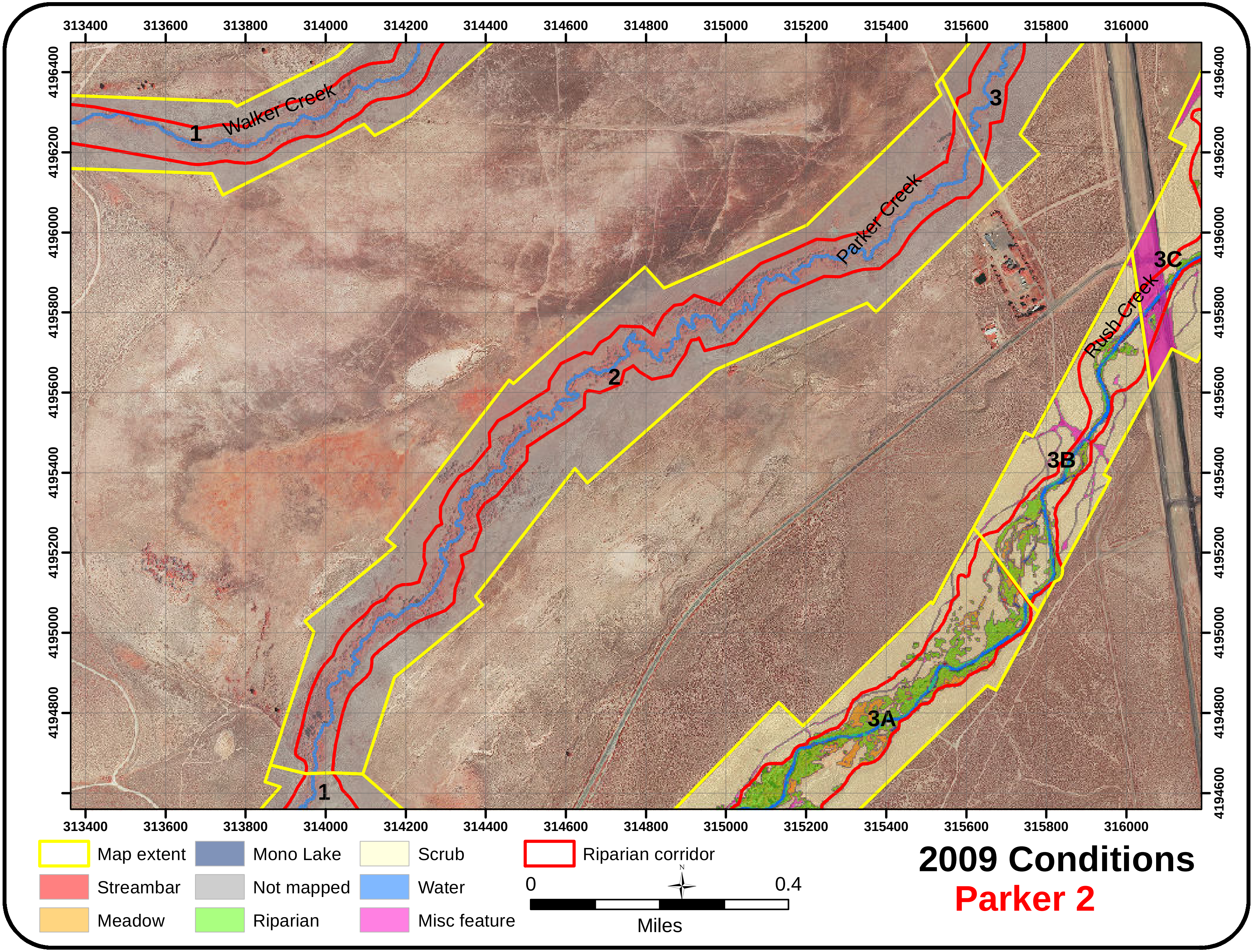
2009 Conditions

Lee Vining 3D



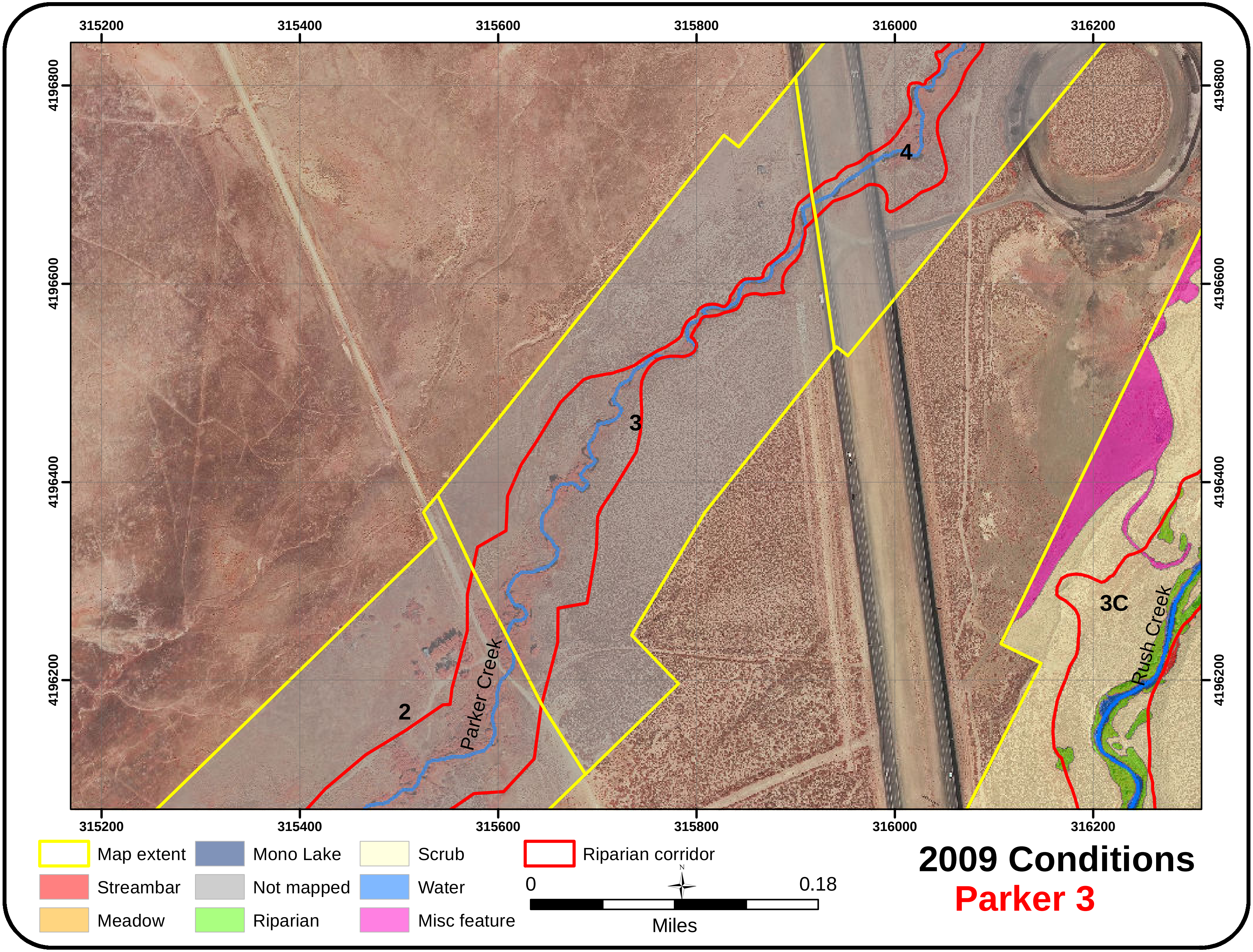
2009 Conditions

Parker 1



2009 Conditions

Parker 2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315400
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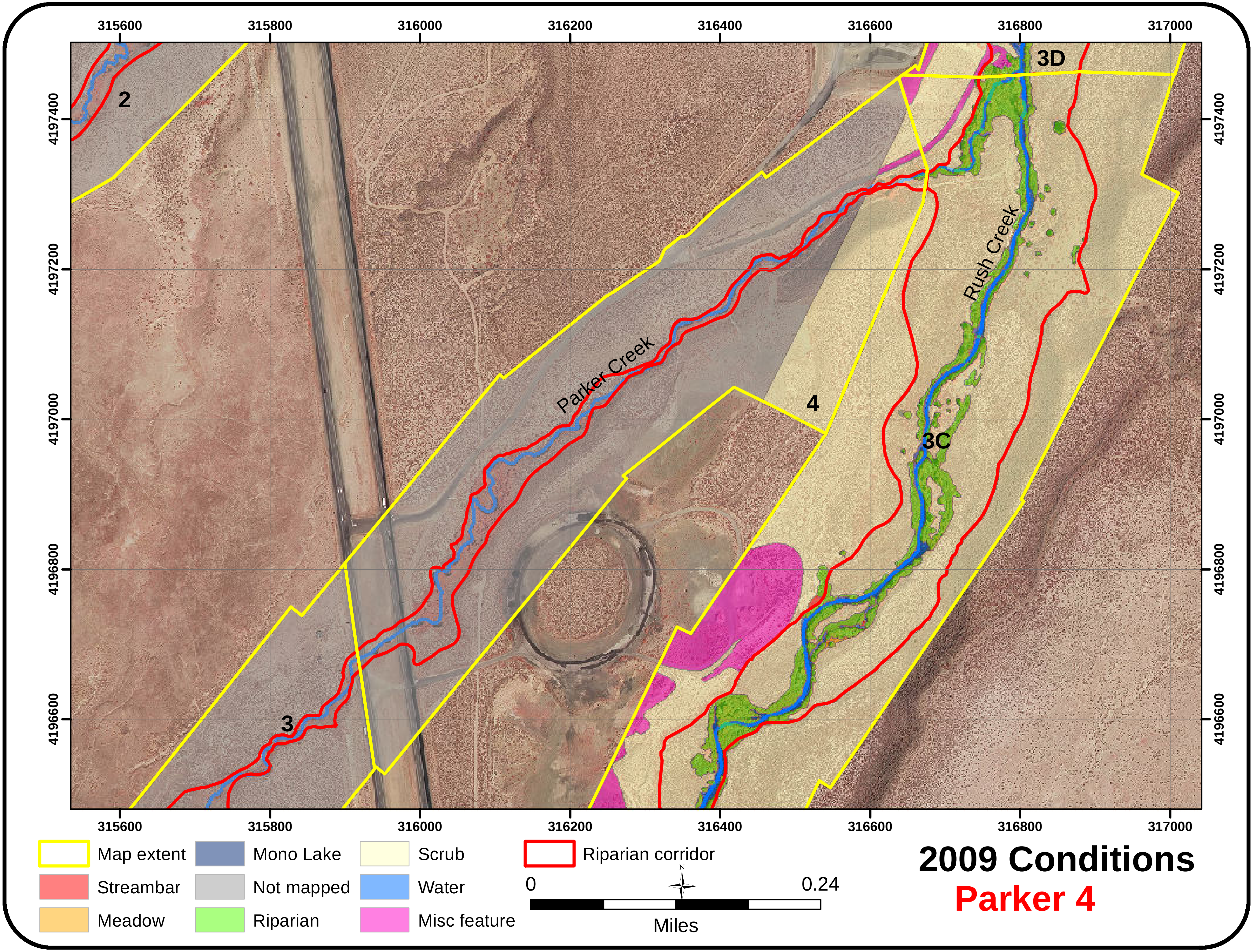
316200
4196800
4196600
4196400
4196200
2
3
4
3C
Parker Creek
Rush Creek
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.18
Miles
N
2009 Conditions
Parker 3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316800
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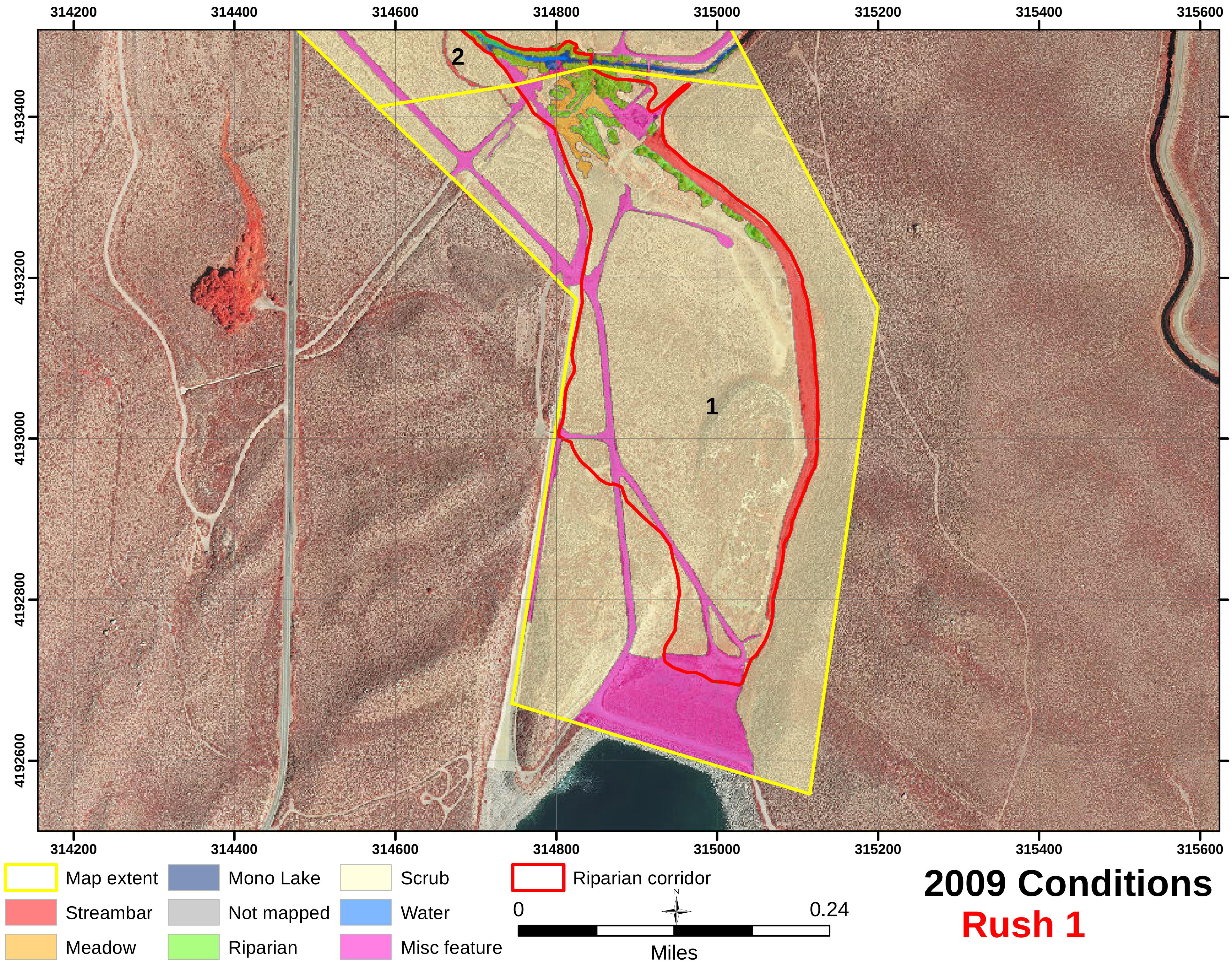
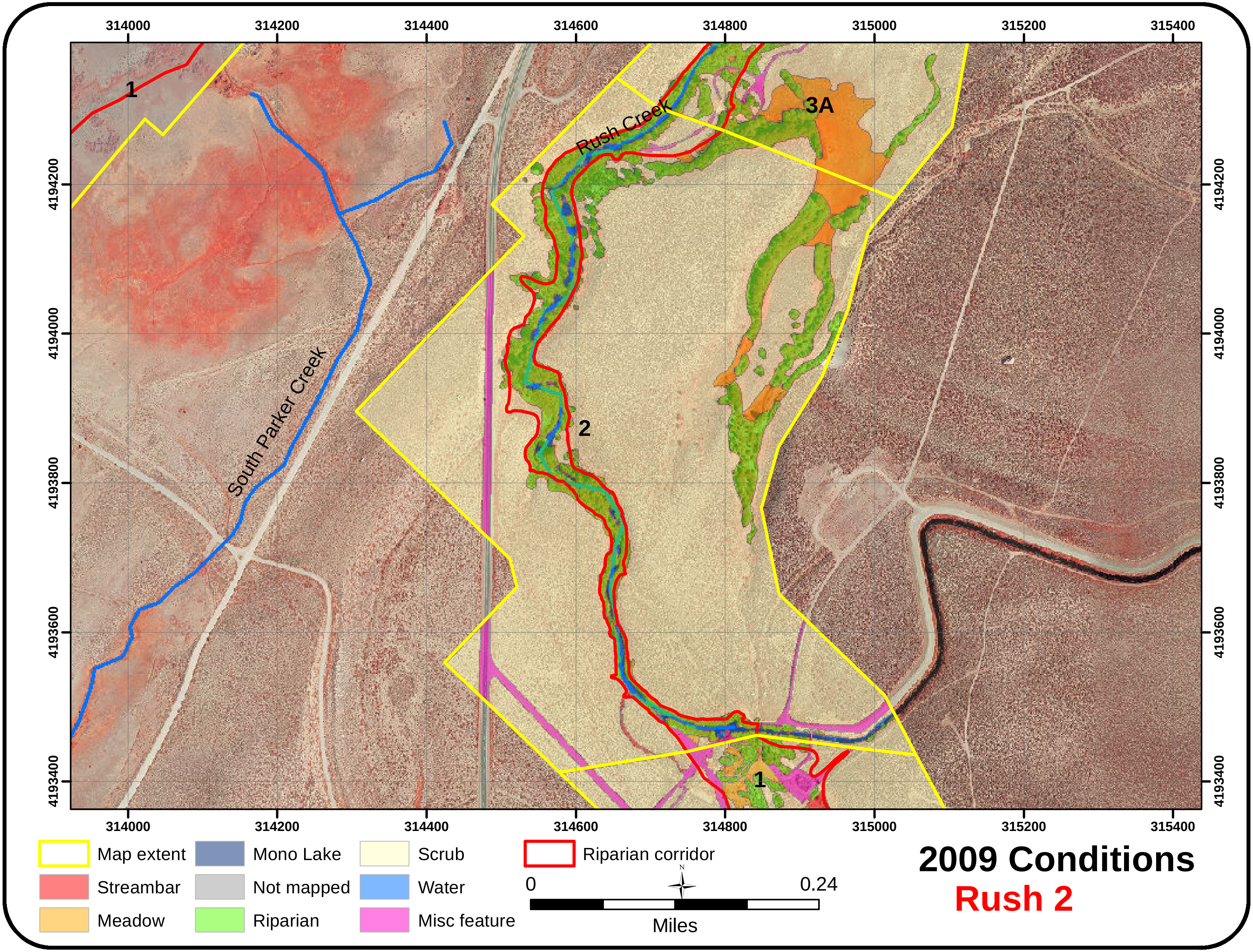
4197200
4197000
4196800
4196600
2
3
3D
3C
4
Parker Creek
Rush Creek
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.24
Miles
N
2009 Conditions
Parker 4



2009 Conditions

Rush 1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315400
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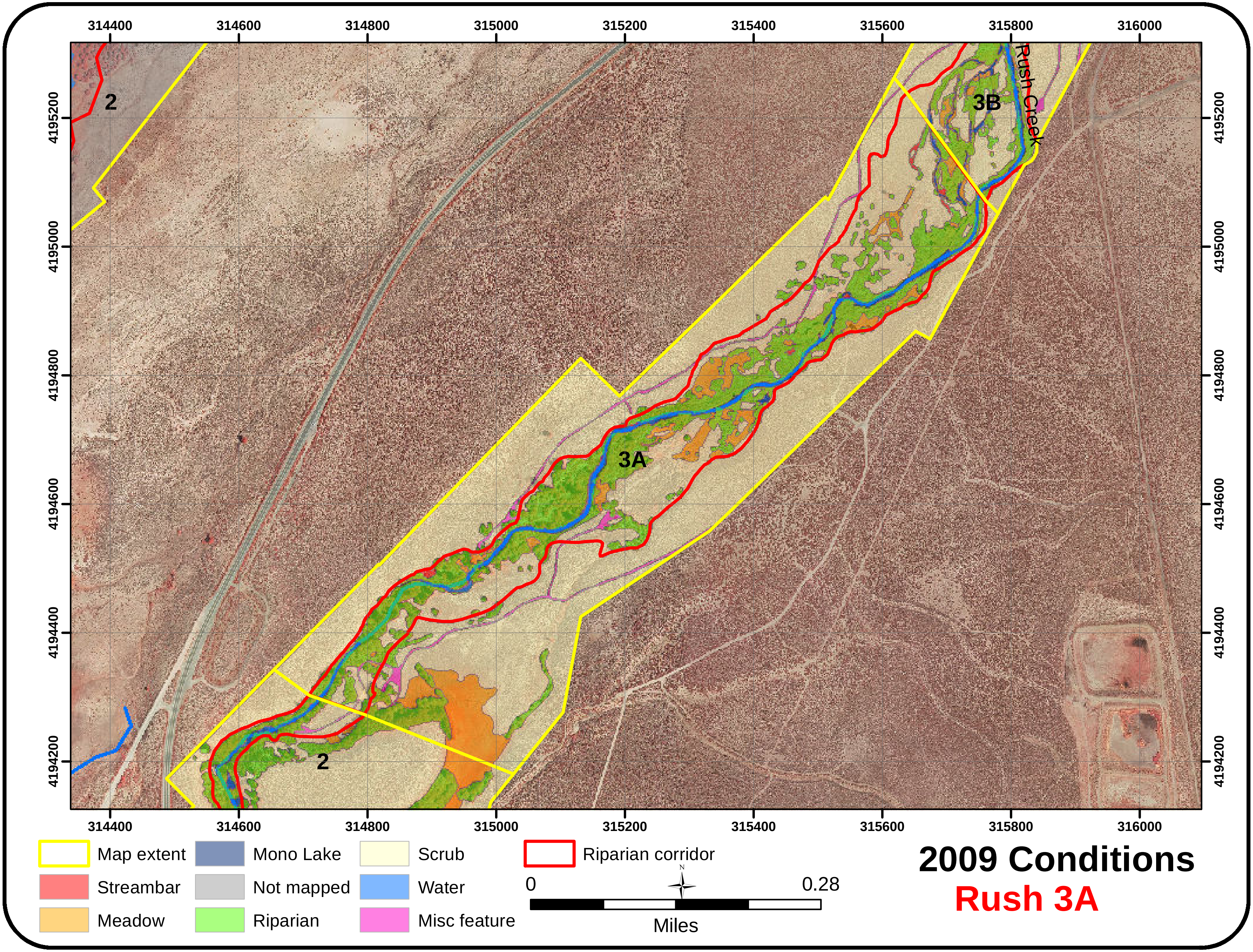
4194000
4193800
4193600
4193400
1
2
3A
Rush Creek
South Parker Creek
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.24
Miles
N
2009 Conditions
Rush 2



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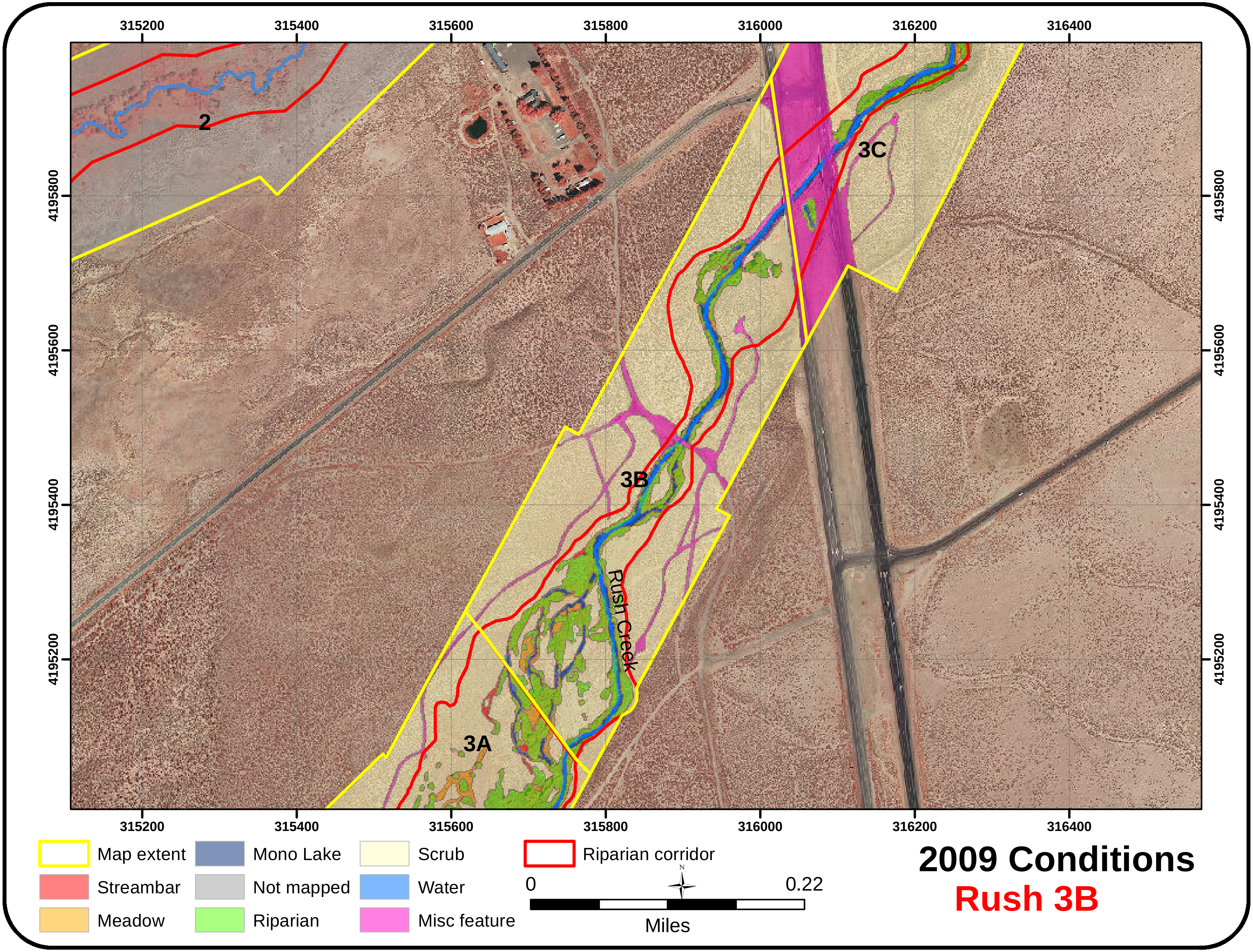
4194800
4194600
4194400
4194200
2
3B
Rush Creek
3A
2
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.28
Miles
2009 Conditions
Rush 3A



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316400
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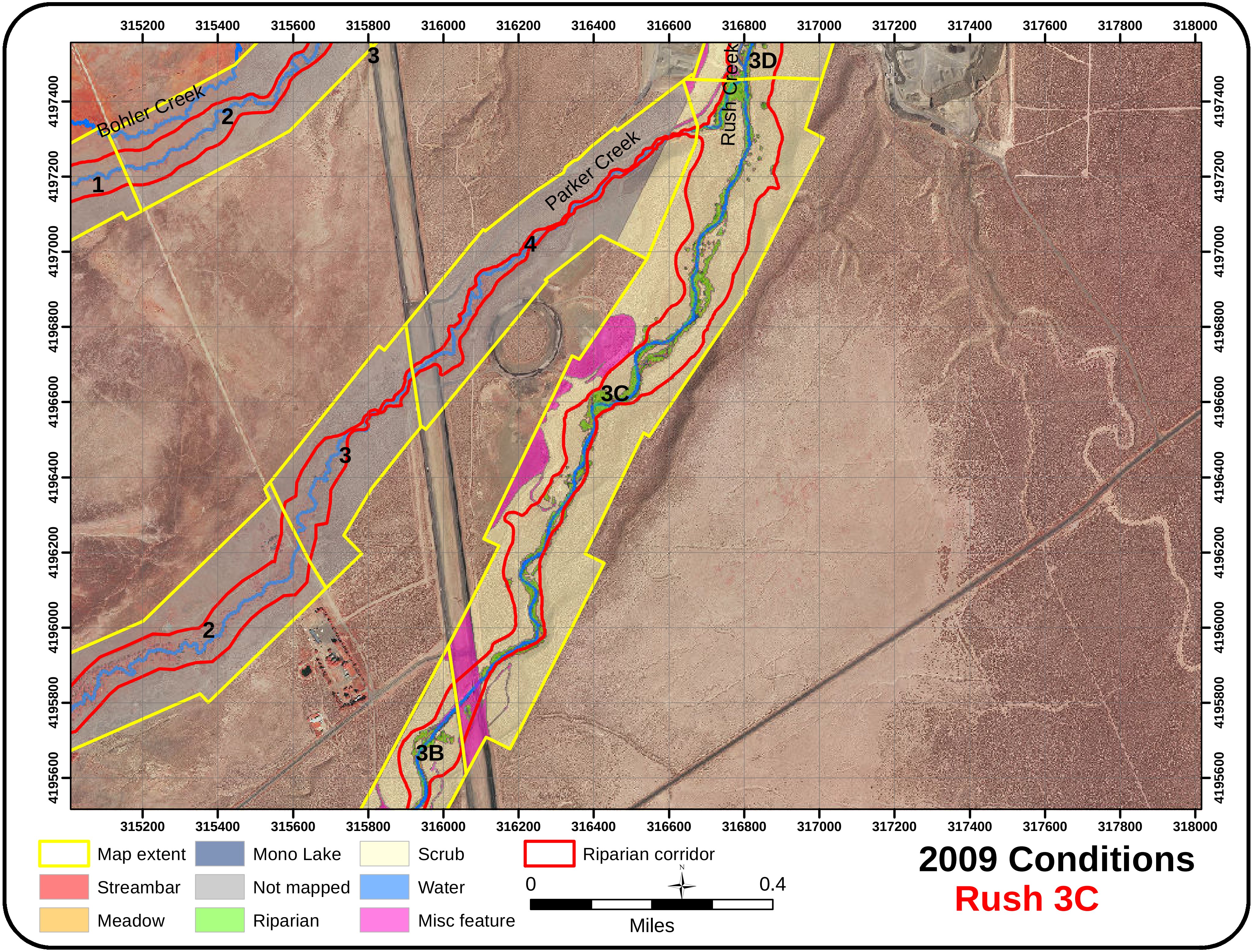
4195600
4195400
4195200
2
3C
3B
3A
Rush Creek
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.22
Miles
2009 Conditions
Rush 3B



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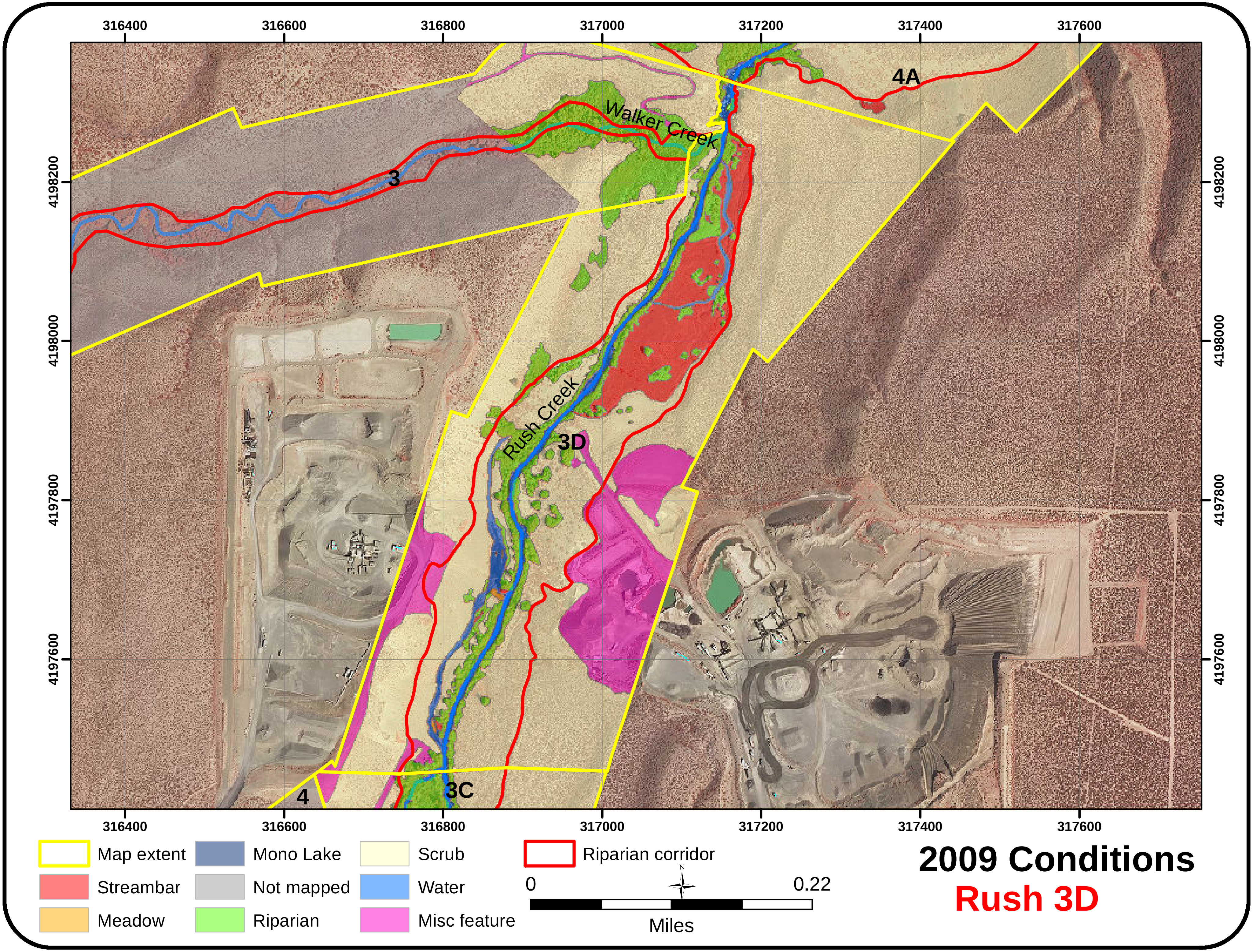
317600
317800
318000
4197400
4197200
4197000
4196800
4196600
4196400
4196200
4196000
4195800
4195600
Bohler Creek
Parker Creek
Rush Creek
1
2
3
4
3
2
3B
3C
3D
Map extent
Mono Lake
Scrub
Riparian corridor
Streambar
Not mapped
Water
Meadow
Riparian
Misc feature
0
0.4
Miles
N
2009 Conditions
Rush 3C



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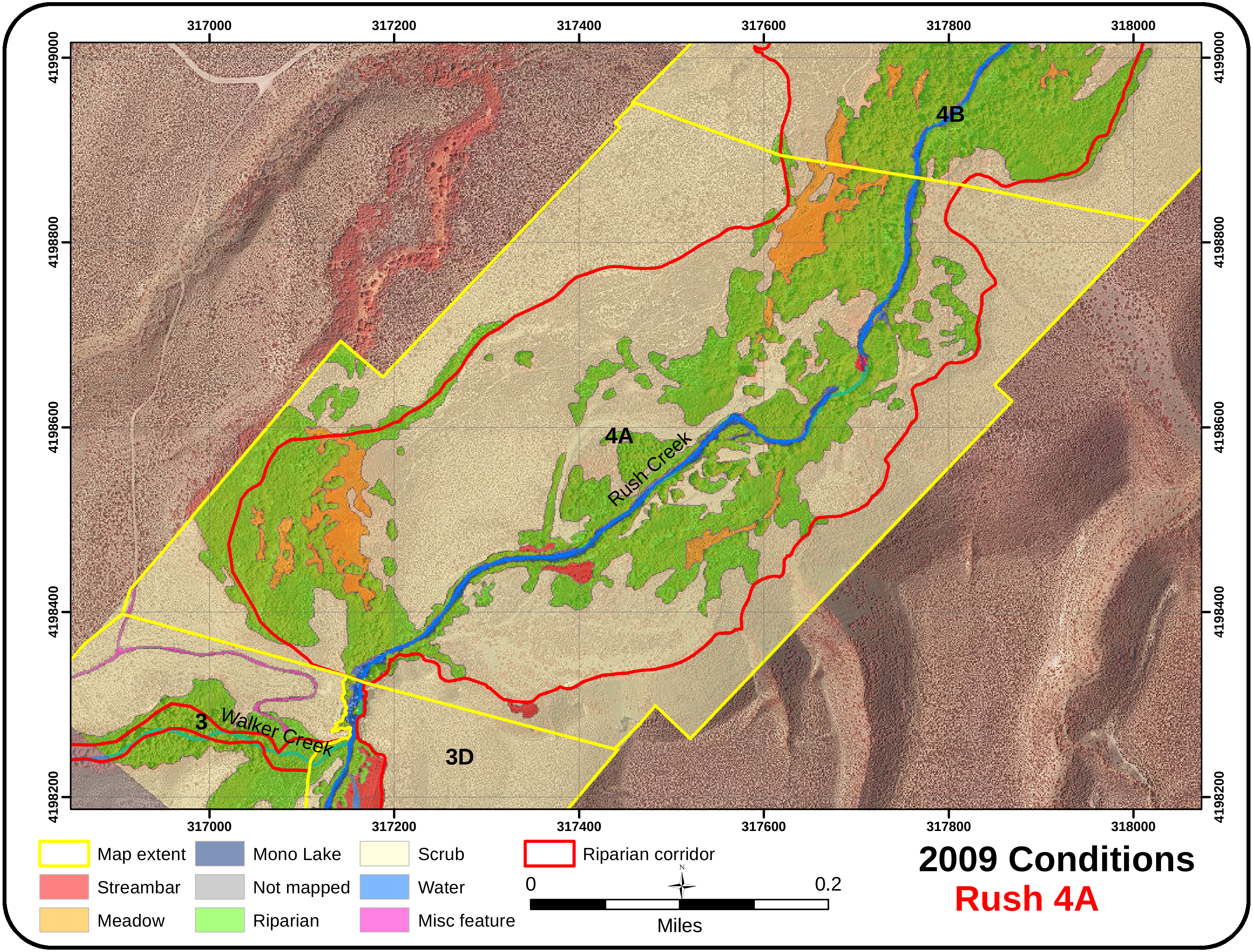
4198000
4197800
4197600
Walker Creek
Rush Creek
3
4A
3D
3C
4
Map extent
Mono Lake
Scrub
Riparian corridor
Streambar
Not mapped
Water
Meadow
Riparian
Misc feature
0
0.22
Miles
N
2009 Conditions
Rush 3D



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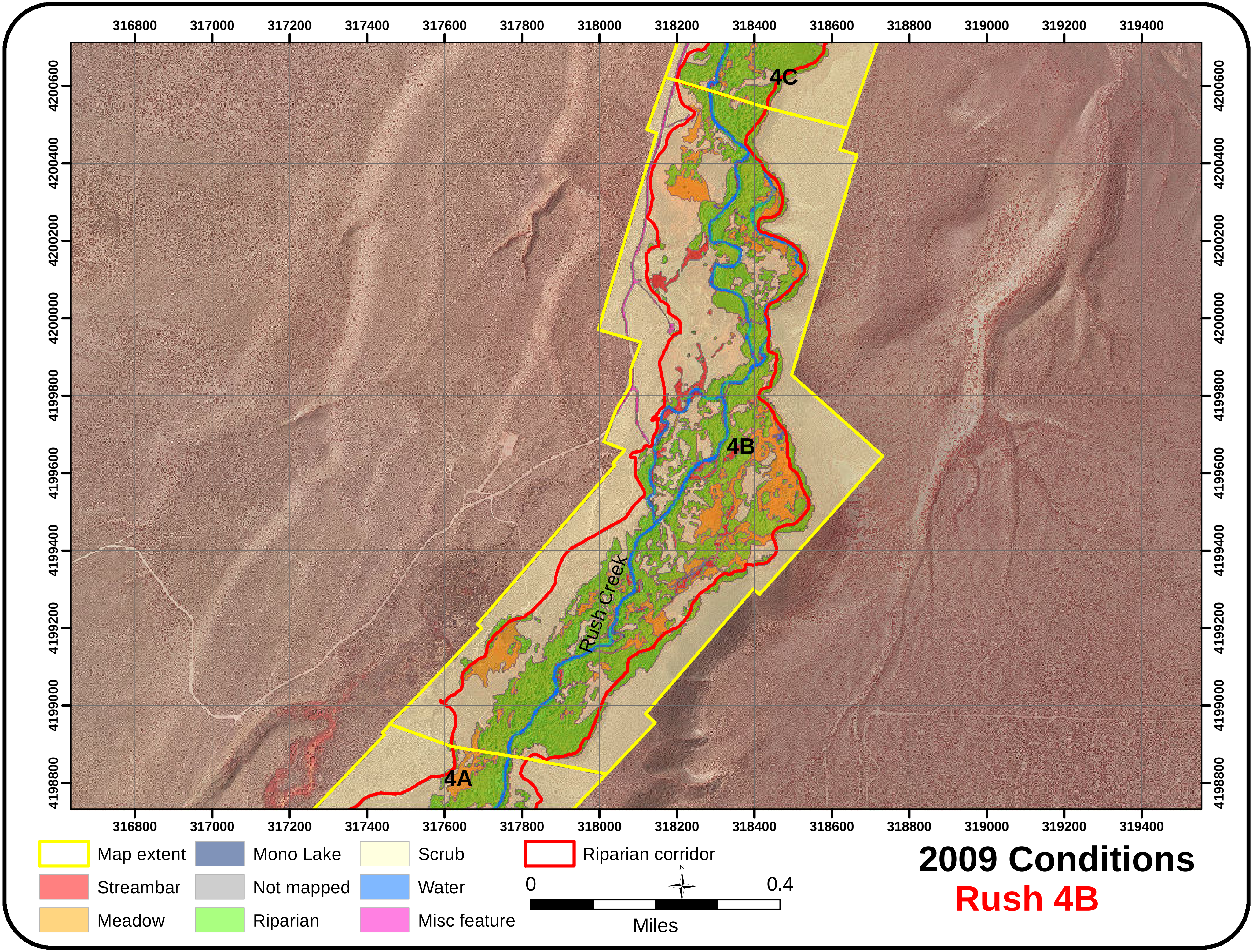
4198600
4198400
4198200
4B
4A
Rush Creek
3
Walker Creek
3D
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.2
Miles
N
2009 Conditions
Rush 4A



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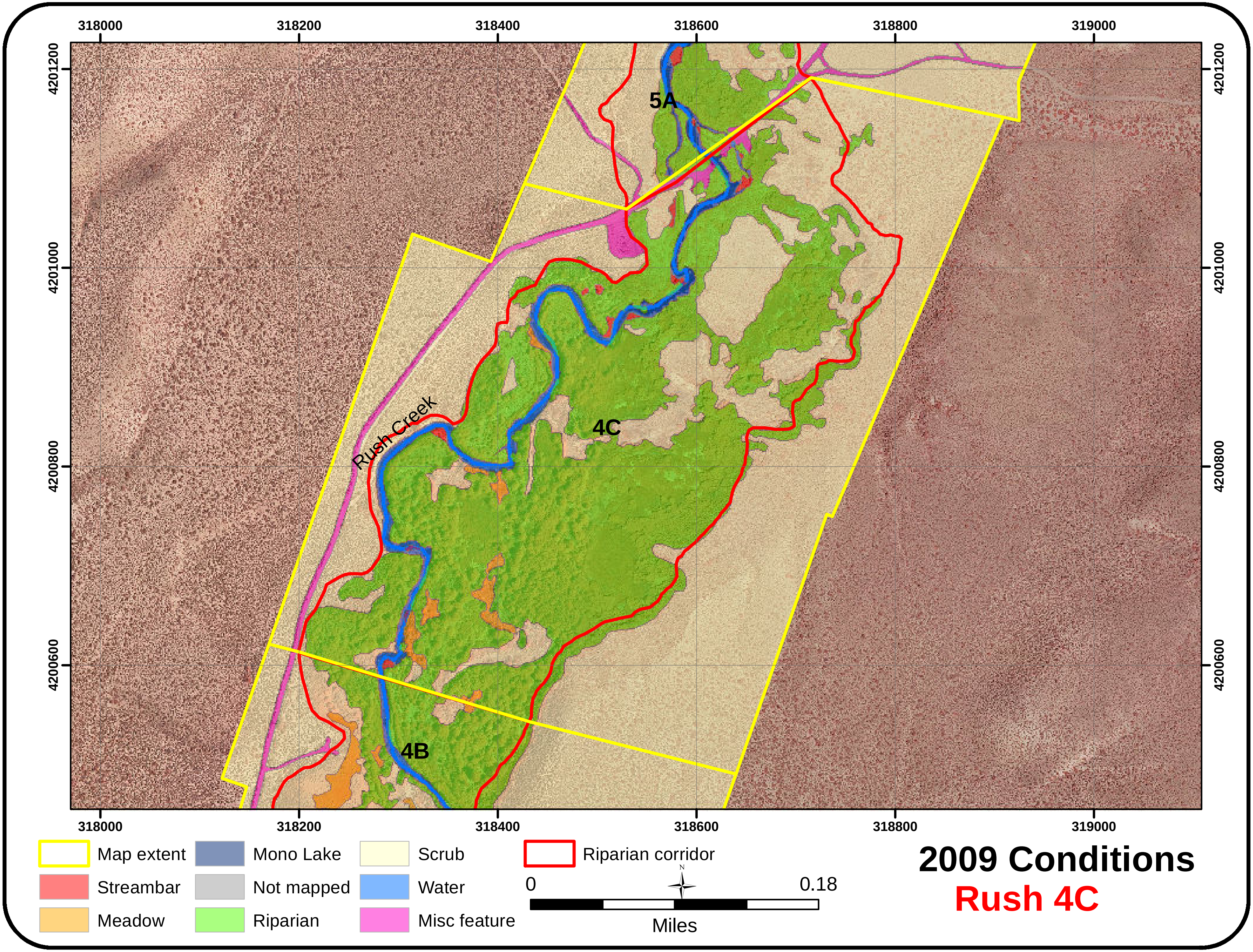
4200200
4200000
4199800
4199600
4199400
4199200
4199000
4198800
4C
4B
4A
Rush Creek
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.4
Miles
N
2009 Conditions
Rush 4B



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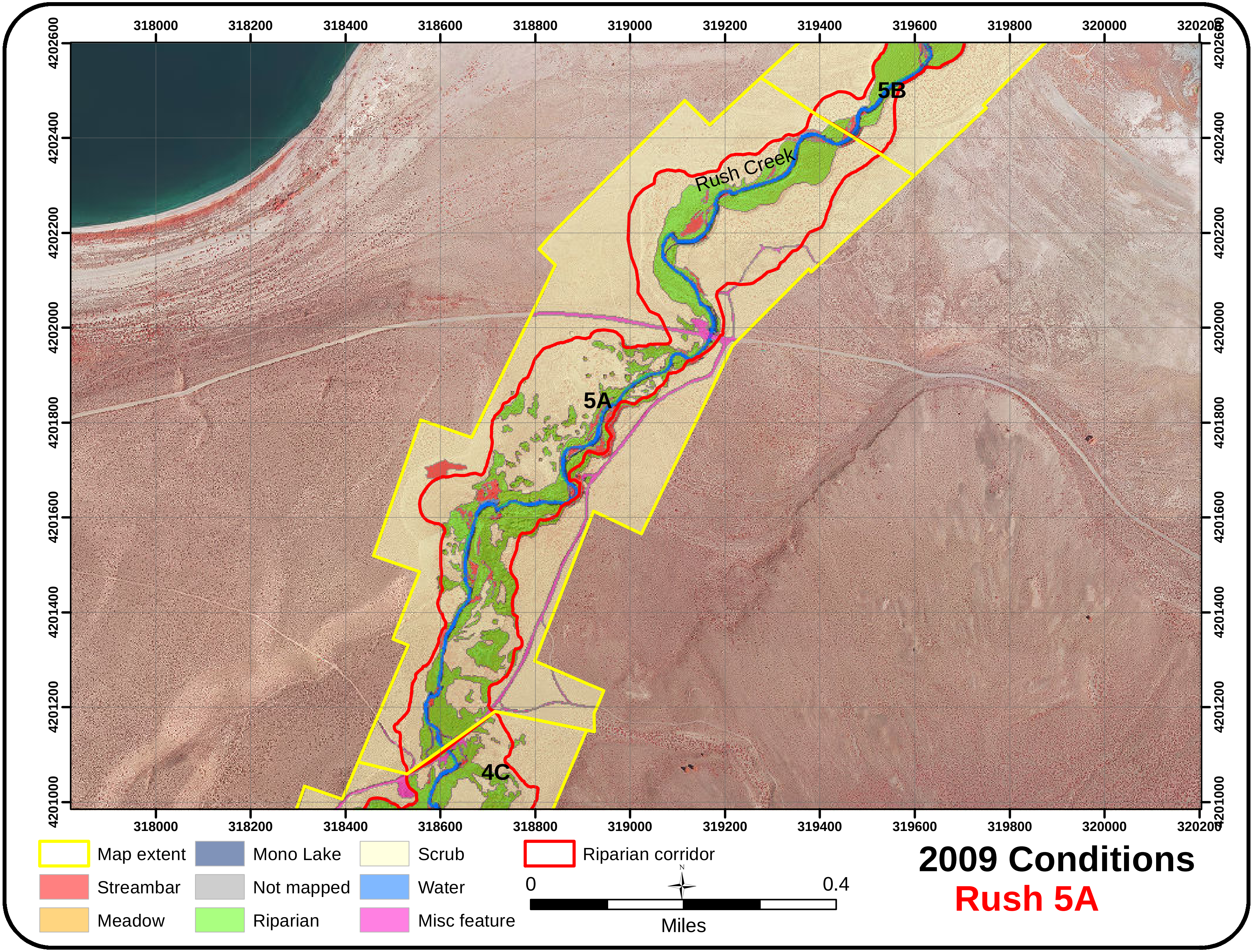
5A
4C
4B
Rush Creek
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.18
Miles
N
2009 Conditions
Rush 4C



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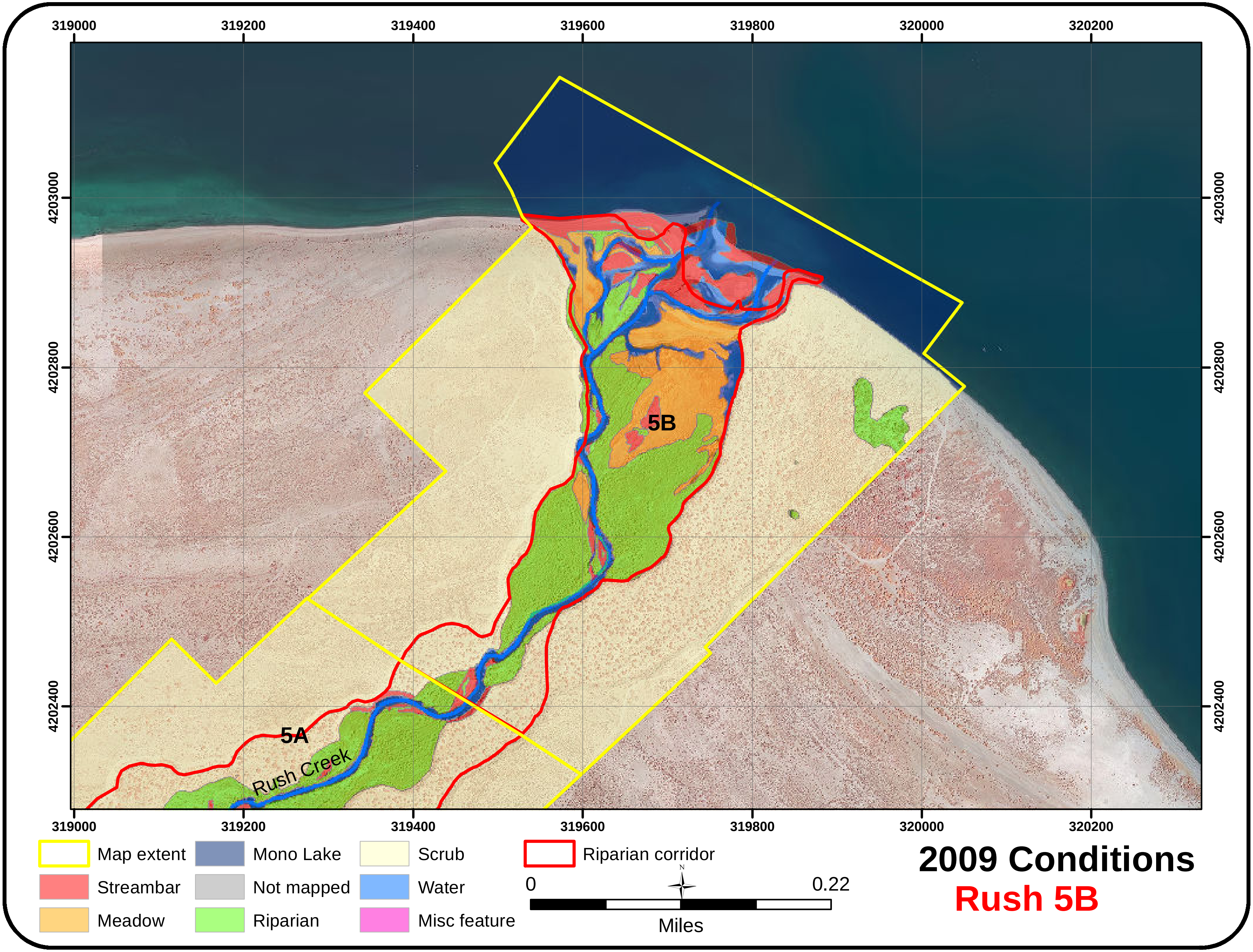
4202400
4202200
4202000
4201800
4201600
4201400
4201200
4201000
5B
Rush Creek
5A
4C
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.4
Miles
2009 Conditions
Rush 5A



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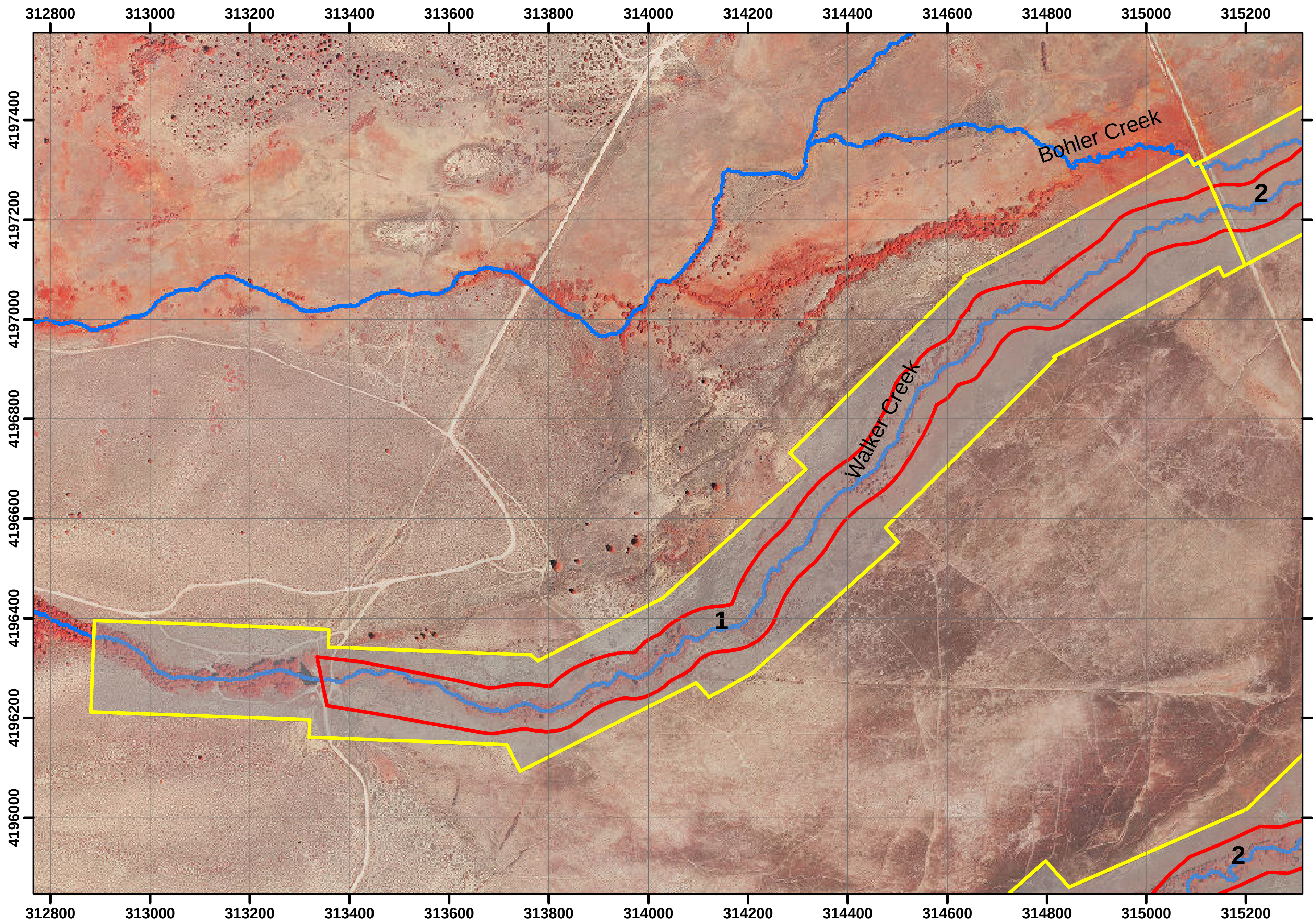
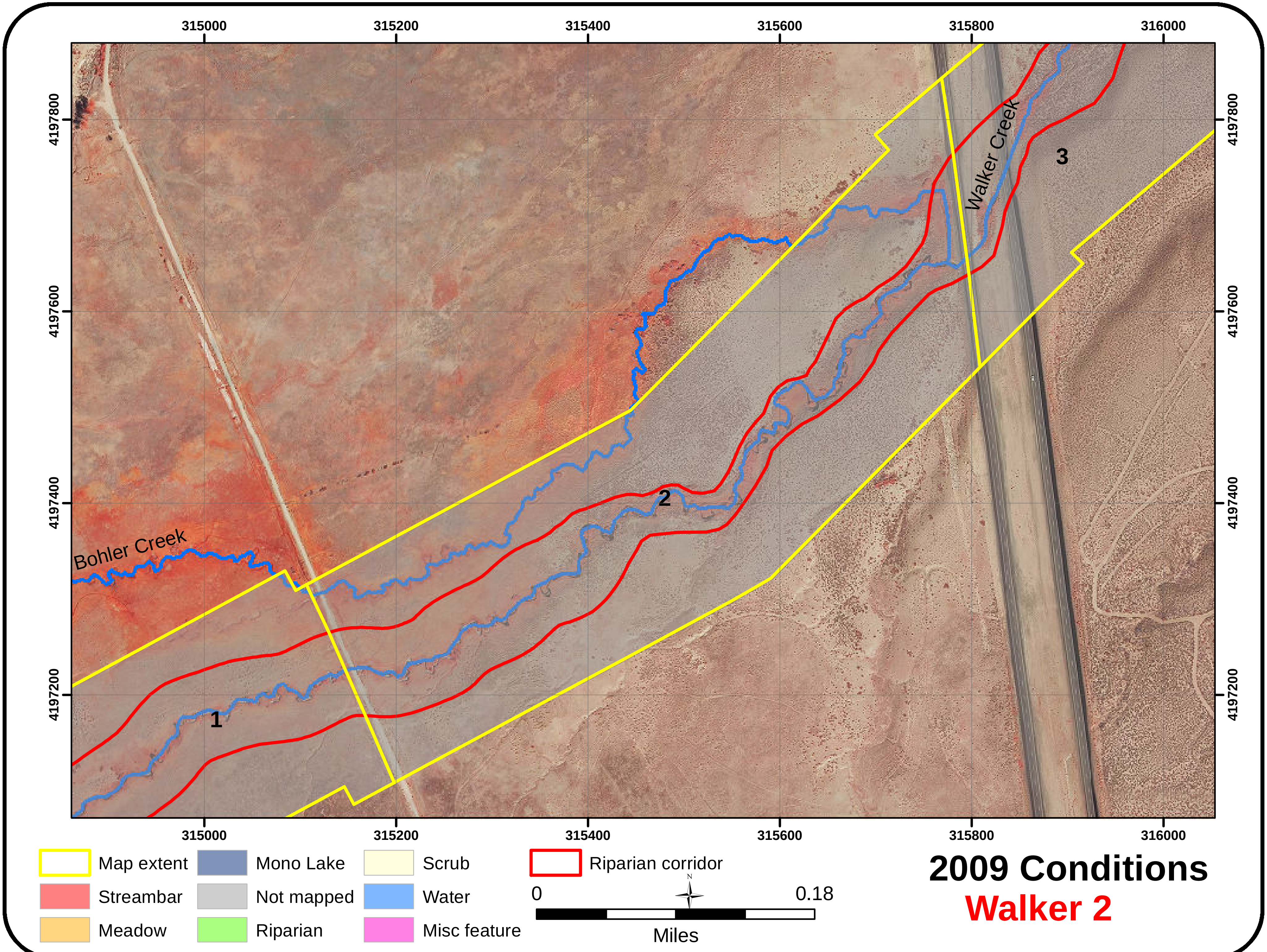
4202800
4202600
4202400
5B
5A
Rush Creek
Map extent
Mono Lake
Scrub
Riparian corridor
Streambar
Not mapped
Water
Meadow
Riparian
Misc feature
0
0.22
N
Miles
2009 Conditions
Rush 5B

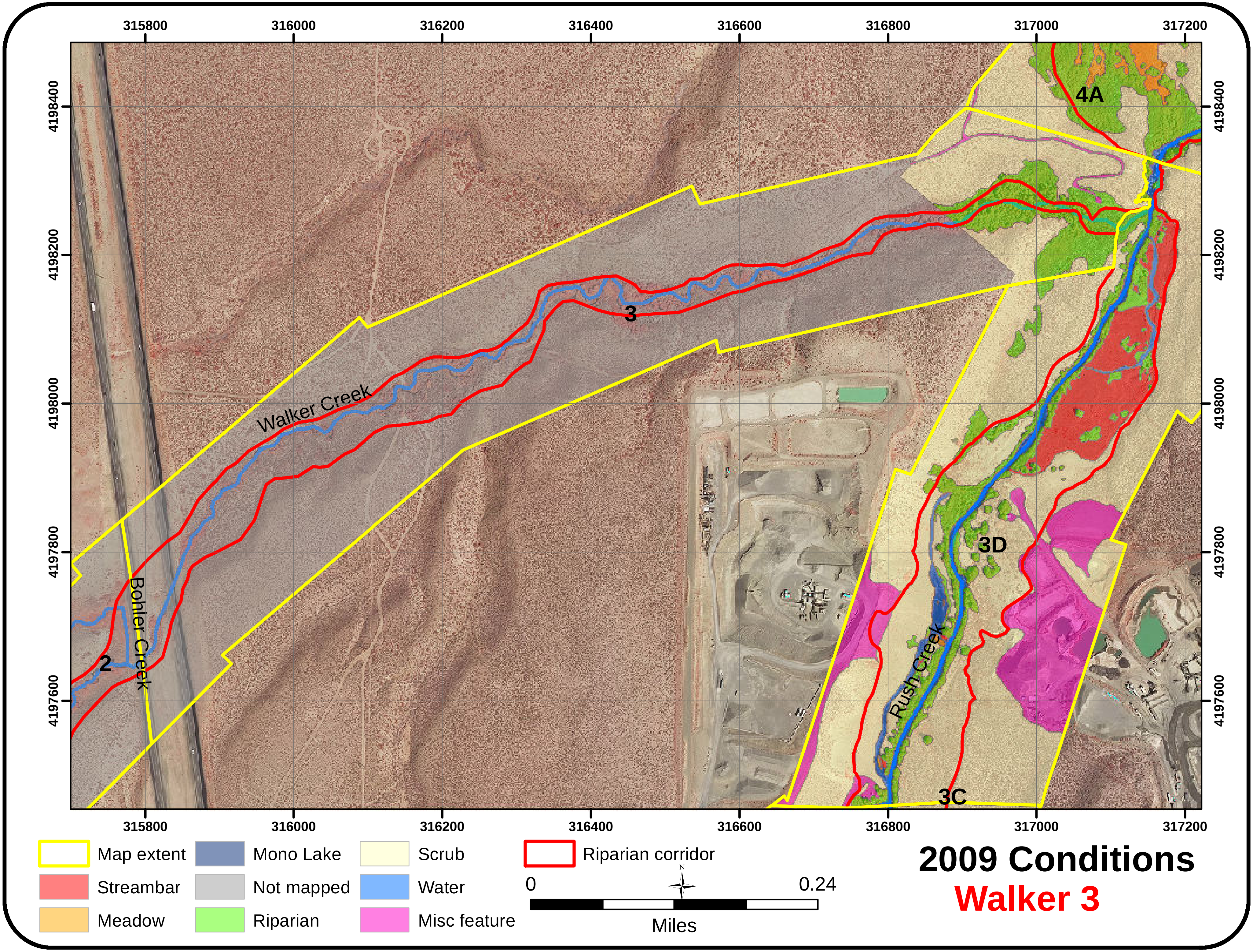


Map extent
Mono Lake
Scrub
Riparian corridor
Streambar
Not mapped
Water
Meadow
Riparian
Misc feature

0 0.4
Miles

2009 Conditions
Walker 1


315000
315200
315400
315600
315800
316000
4197800
4197600
4197400
4197200
Bohler Creek
Walker Creek
1
2
3
Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
0
0.18
Miles
N
2009 Conditions
Walker 2



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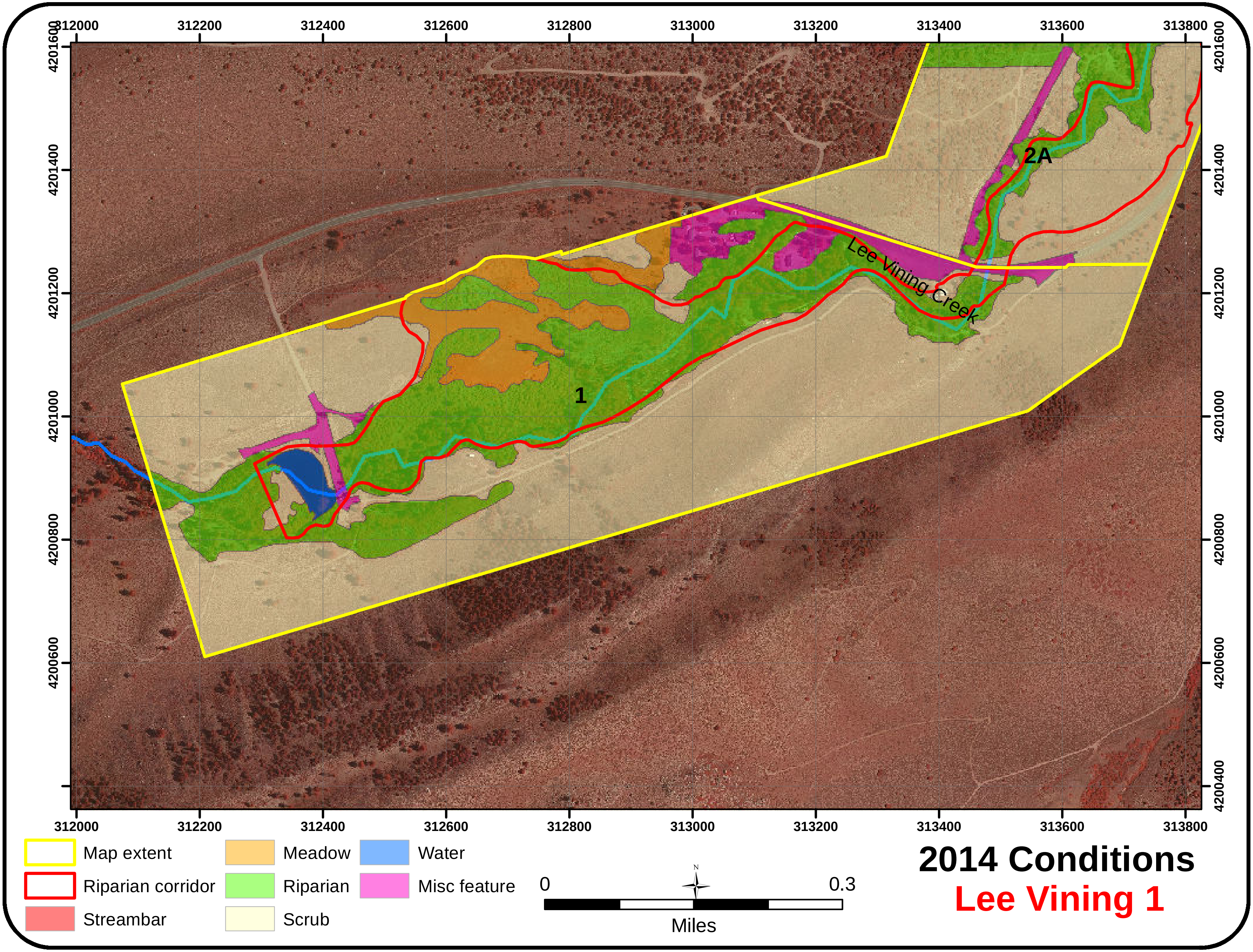
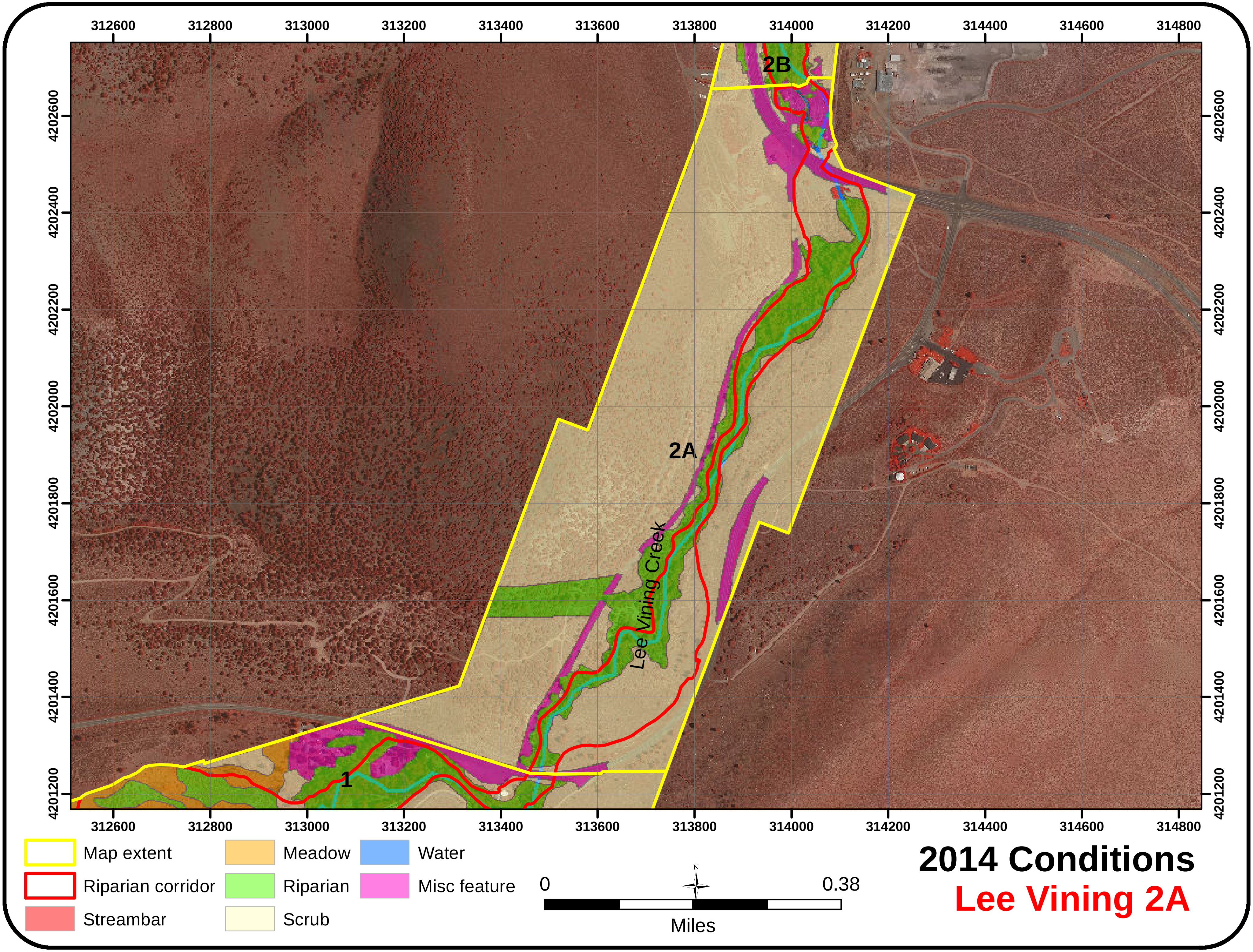
316600
316800
317000
317200
4198400
4198200
4198000
4197800
4197600
Walker Creek
Bohler Creek
Rush Creek
2
3
3C
3D
4A
Map extent
Mono Lake
Scrub
Riparian corridor
Streambar
Not mapped
Water
Meadow
Riparian
Misc feature
0
0.24
Miles
N
2009 Conditions
Walker 3

APPENDIX E
RIPARIAN MAPPING
2014 CONDITIONS



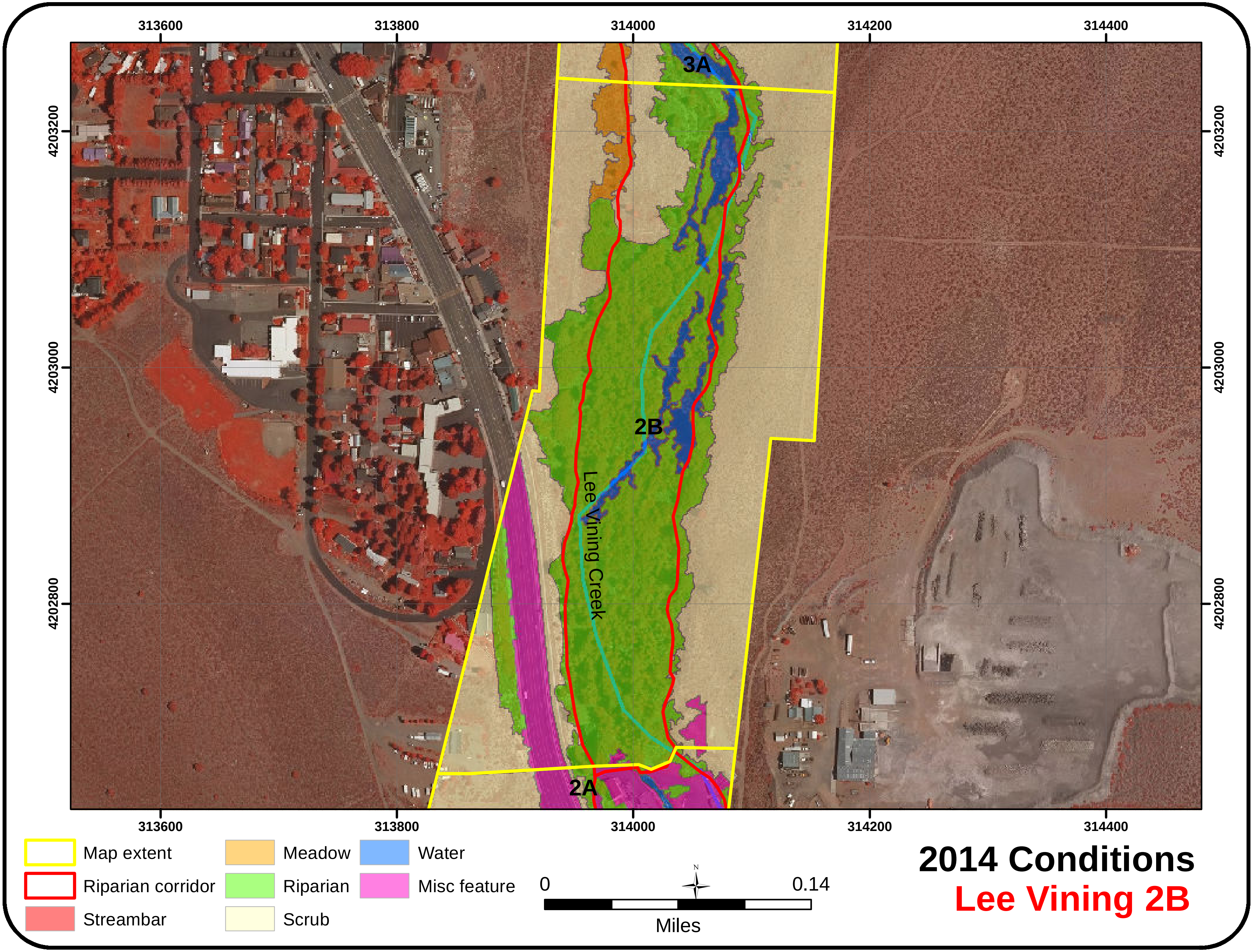
2014 Conditions

Lee Vining 1



2014 Conditions

Lee Vining 2A



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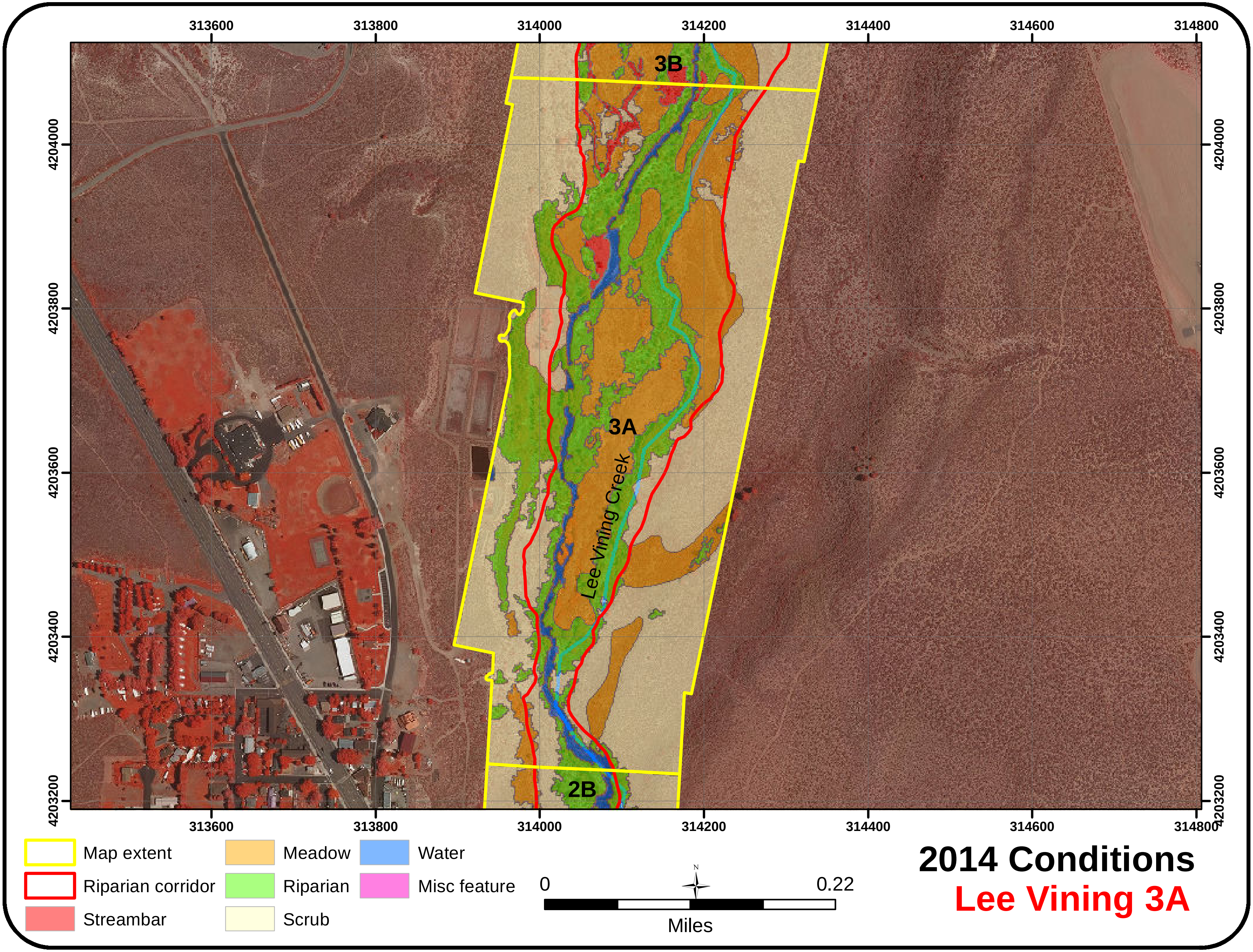
313800
314000
314200
314400
4203200
4203000
4202800
3A
2B
2A
Lee Vining Creek
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.14
Miles
N
2014 Conditions
Lee Vining 2B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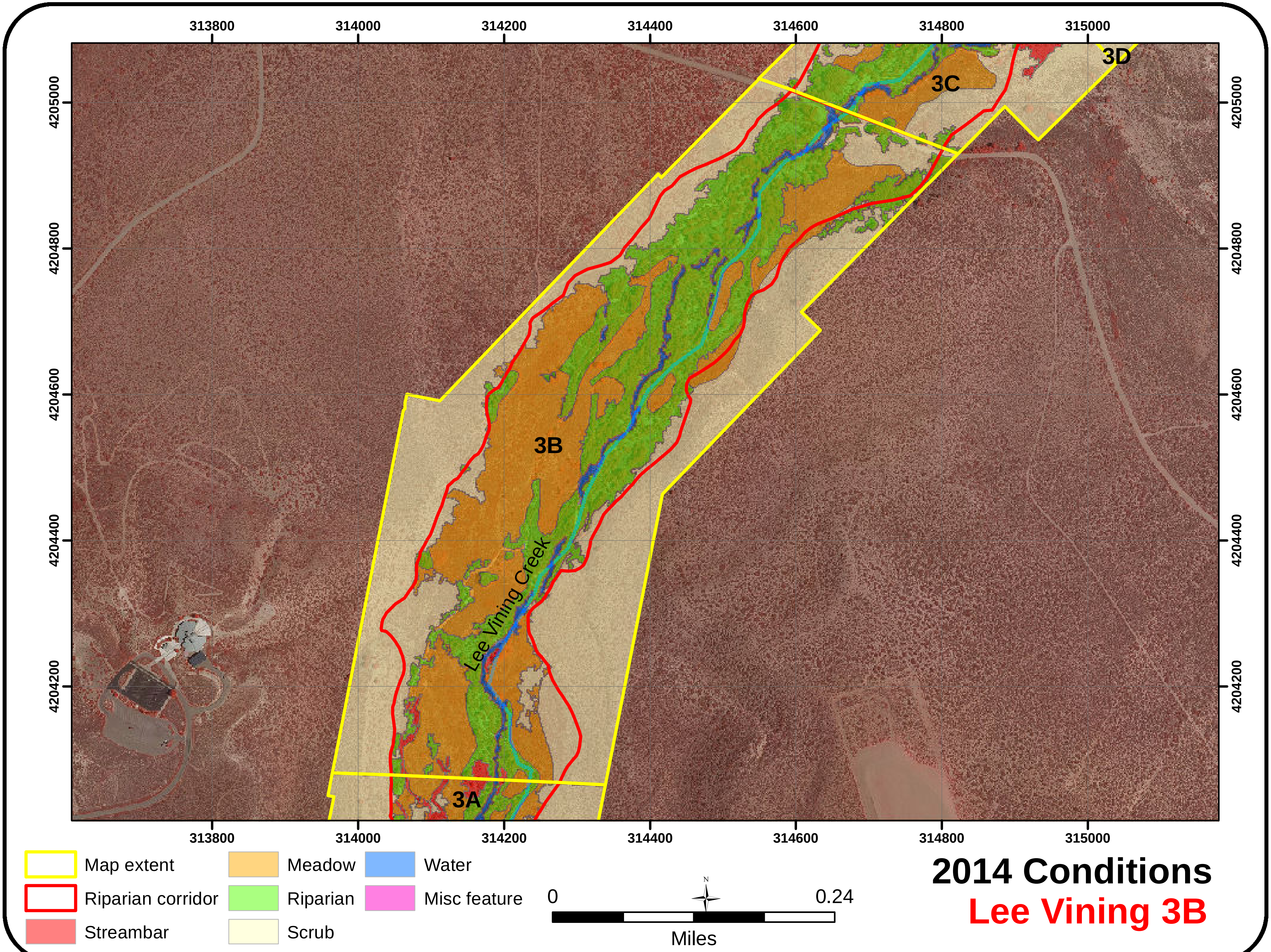
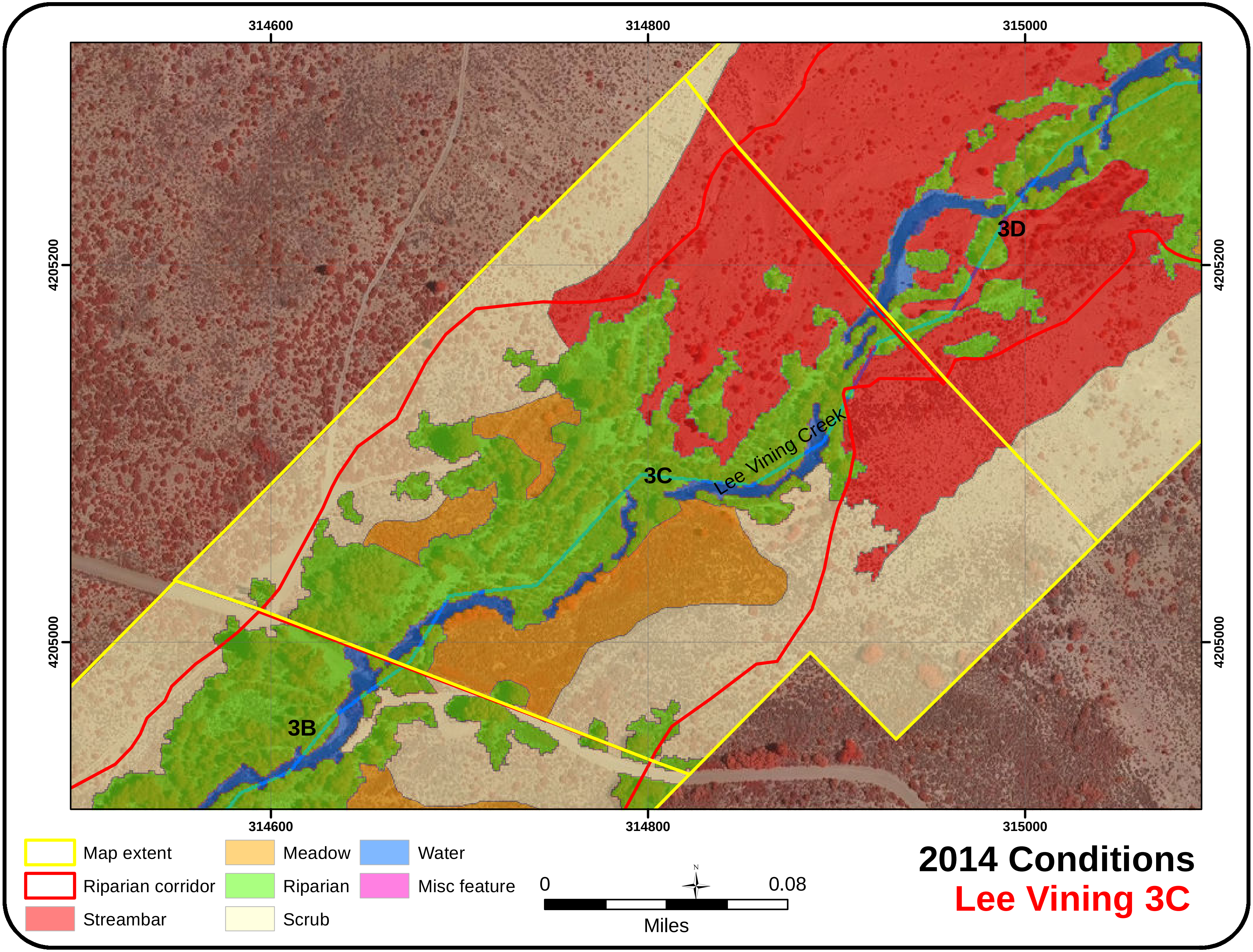
314200
314400
314600
314800
4204000
4203800
4203600
4203400
4203200
3B
3A
2B
Lee Vining Creek
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.22
Miles
N
2014 Conditions
Lee Vining 3A



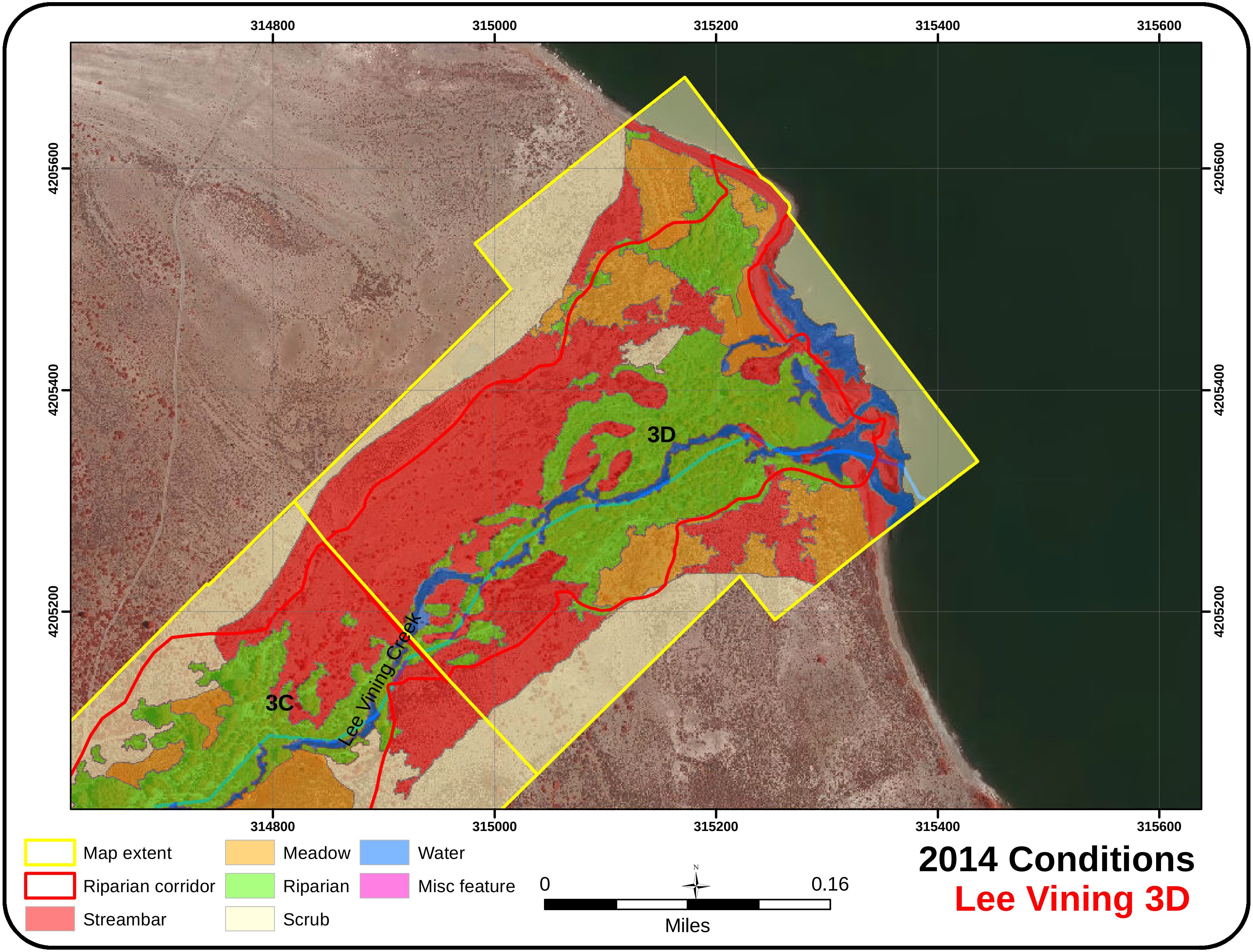
2014 Conditions

Lee Vining 3B

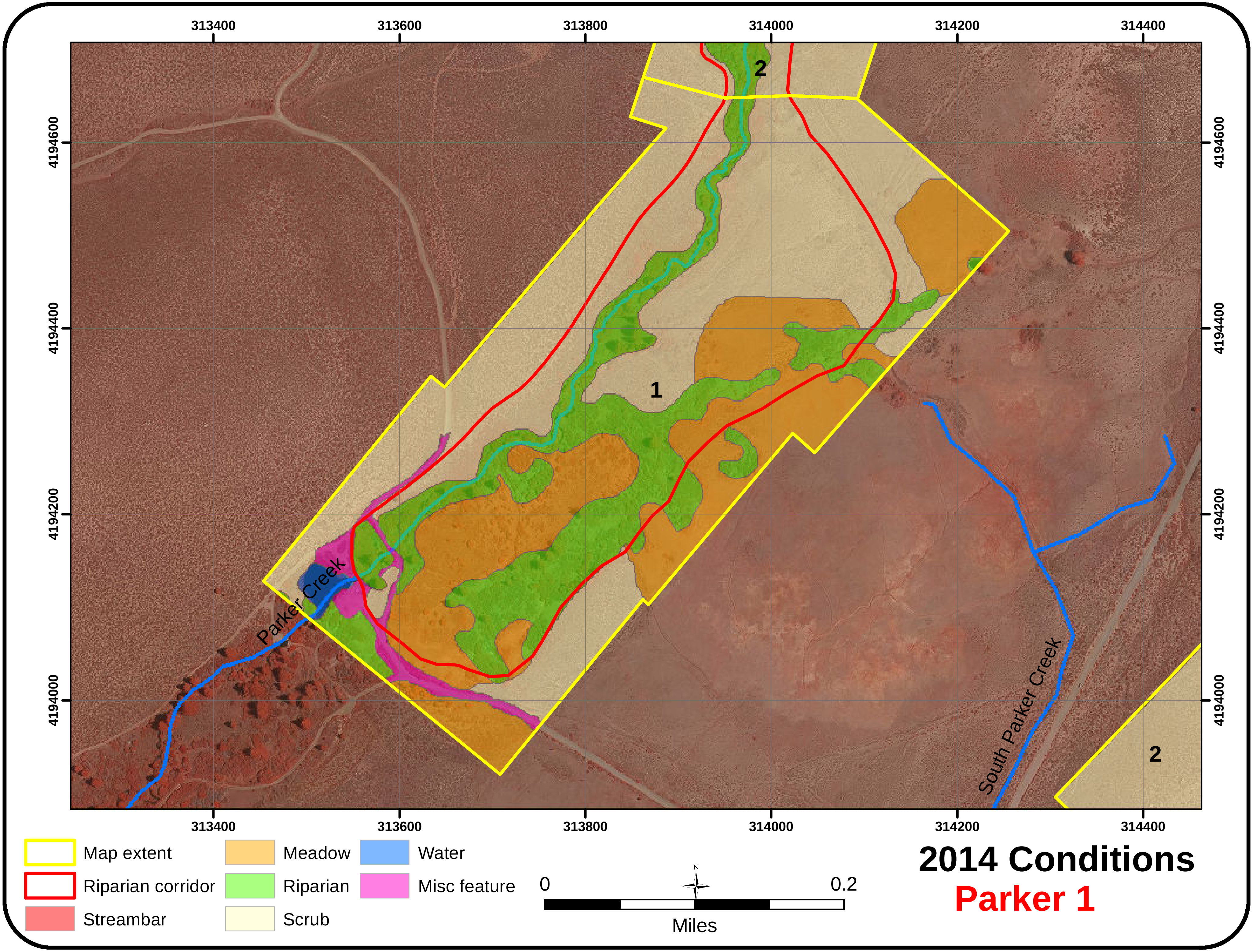


2014 Conditions

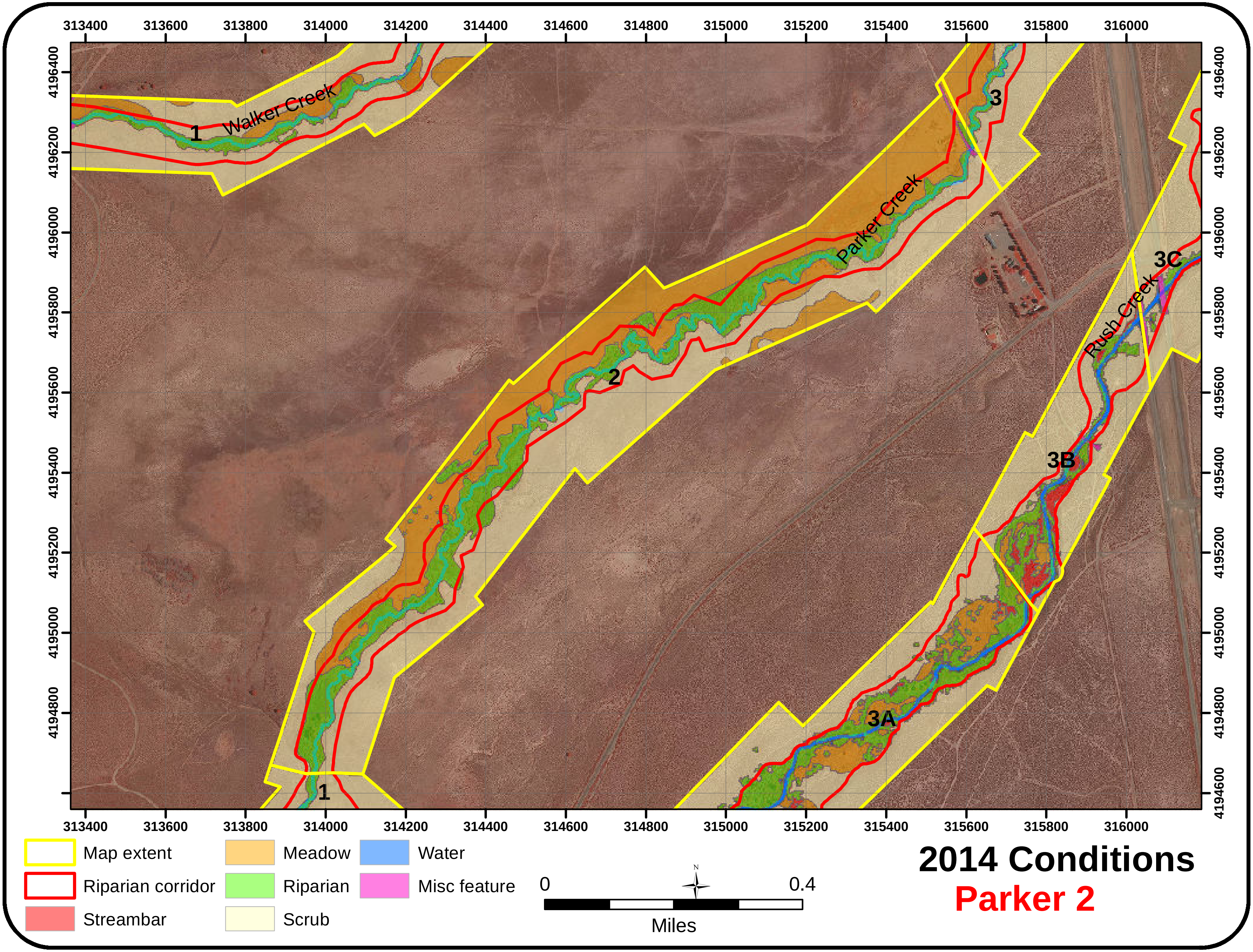
Lee Vining 3C



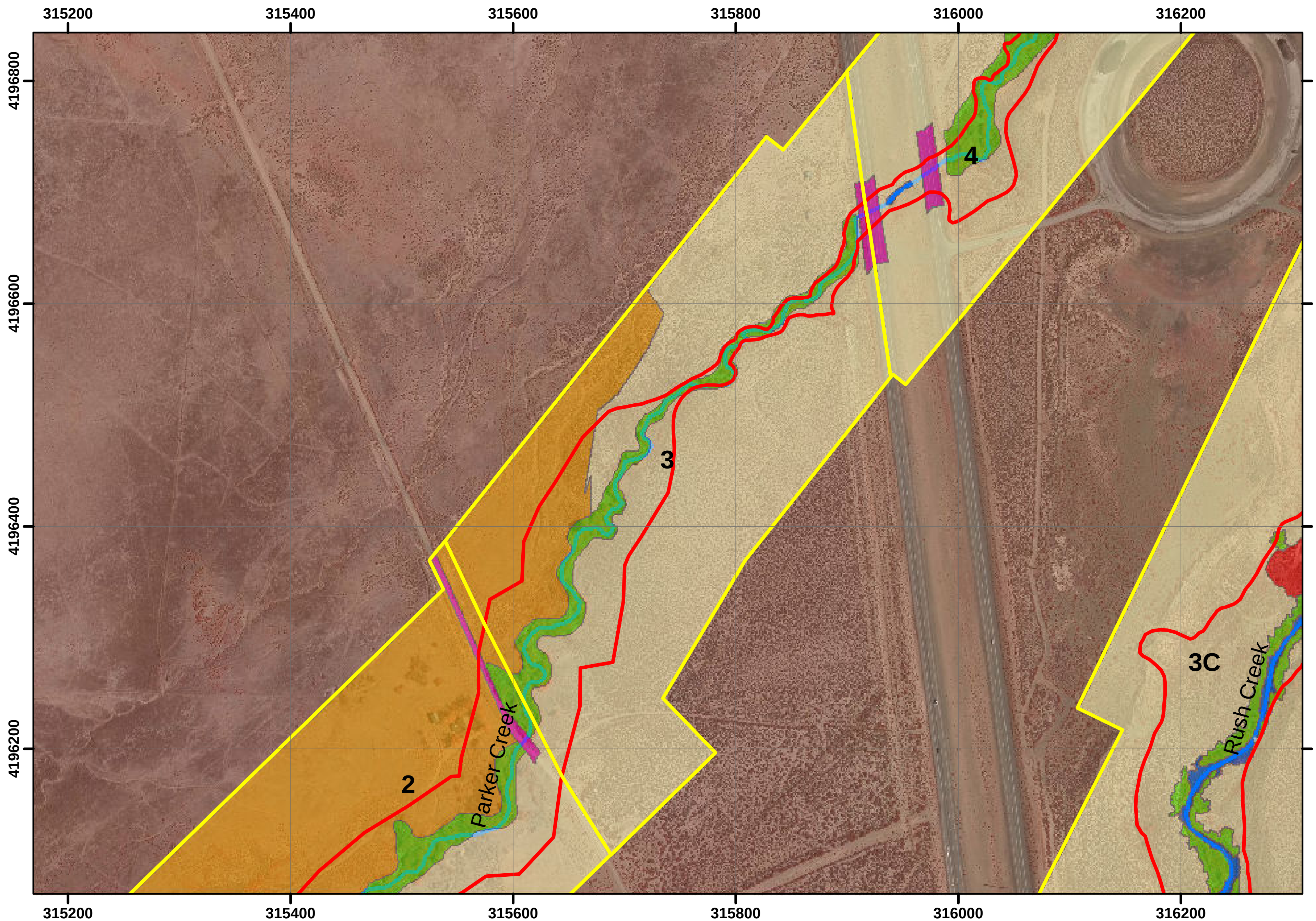
314800
315000
315200
315400
315600
4205600
4205400
4205200
3D
3C
Lee Vining Creek
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.16
Miles
N
2014 Conditions
Lee Vining 3D



2014 Conditions
Parker 1



Walker Creek
Parker Creek
Rush Creek
1
2
3
3A
3B
3C
313400
313600
313800
314000
314200
314400
314600
314800
315000
315200
315400
315600
315800
316000
4196400
4196200
4196000
4195800
4195600
4195400
4195200
4195000
4194800
4194600
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.4
Miles
N
2014 Conditions
Parker 2

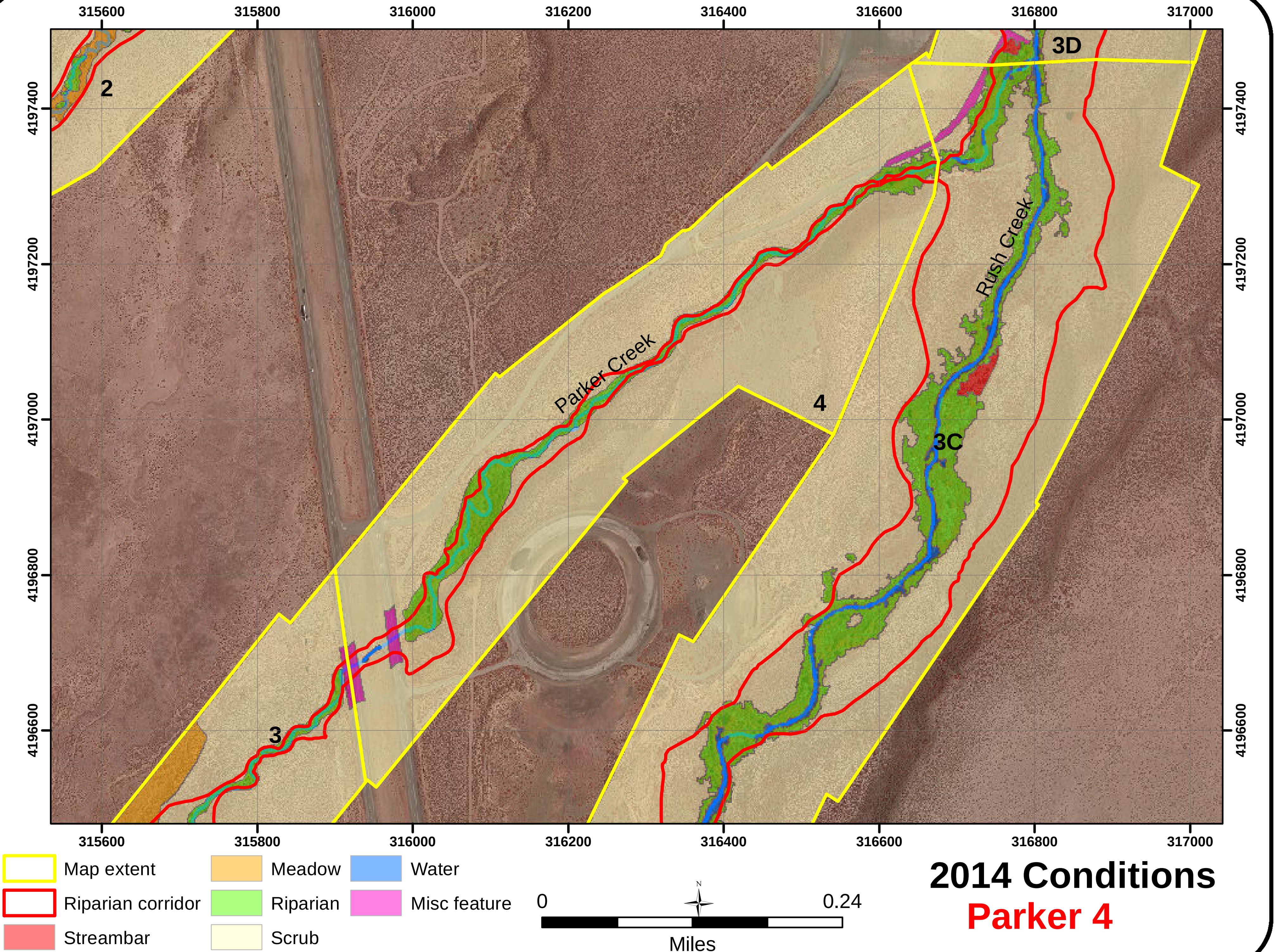


Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature

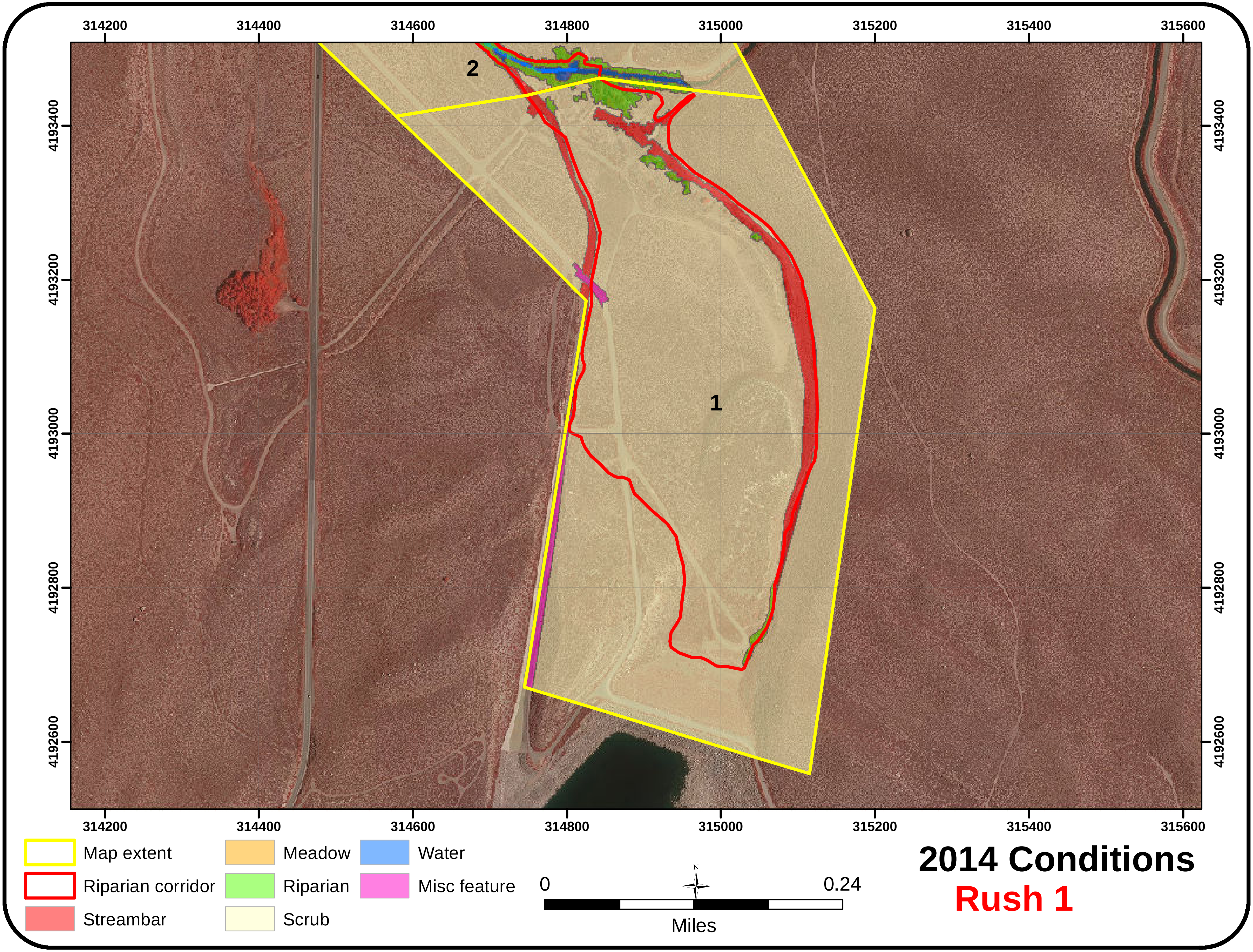
0 0.18
Miles

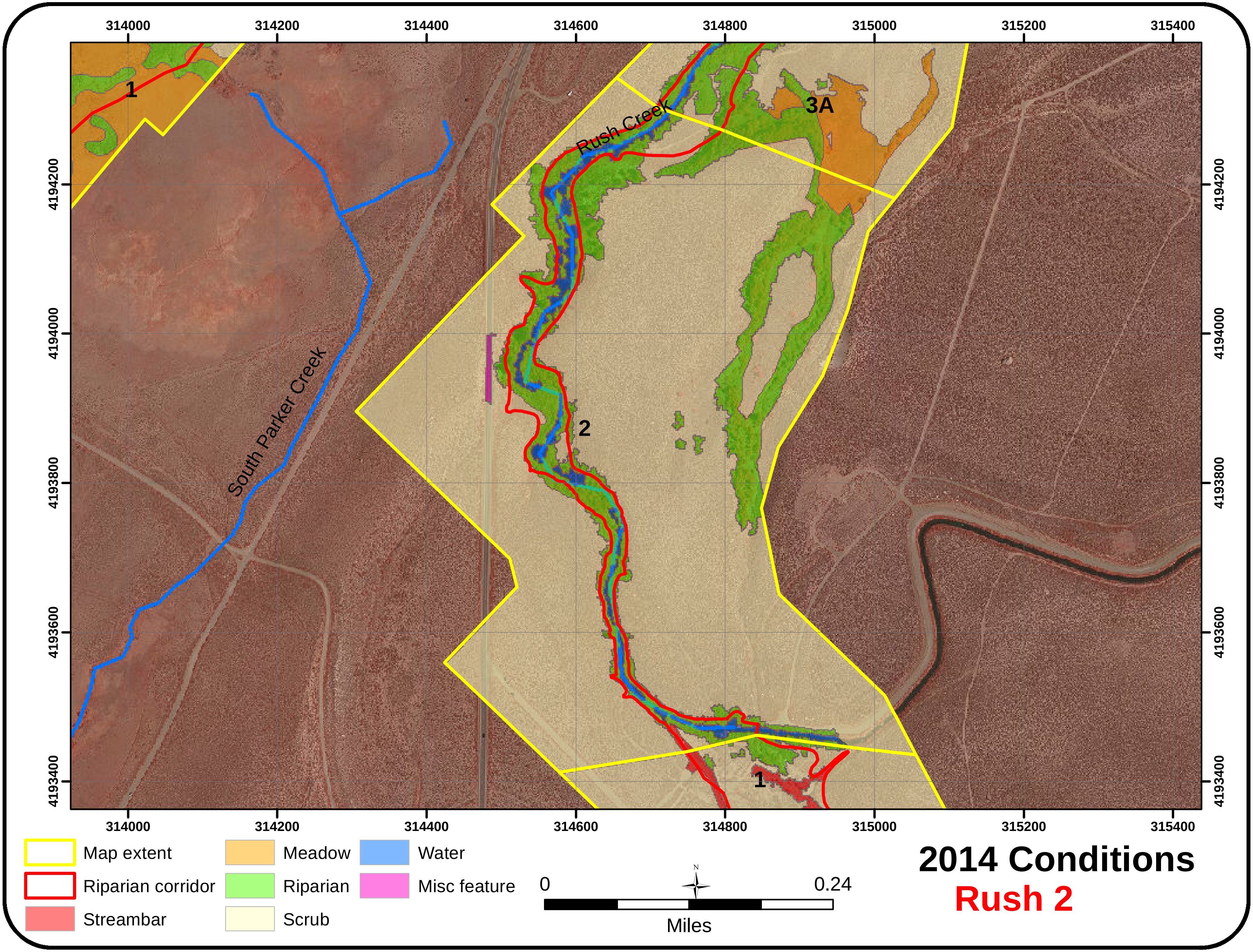
2014 Conditions

Parker 3



2014 Conditions
Parker 4


314200
314400
314600
314800
315000
315200
315400
315600
4193400
4193200
4193000
4192800
4192600
1
2
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.24
Miles
N
2014 Conditions
Rush 1



314000
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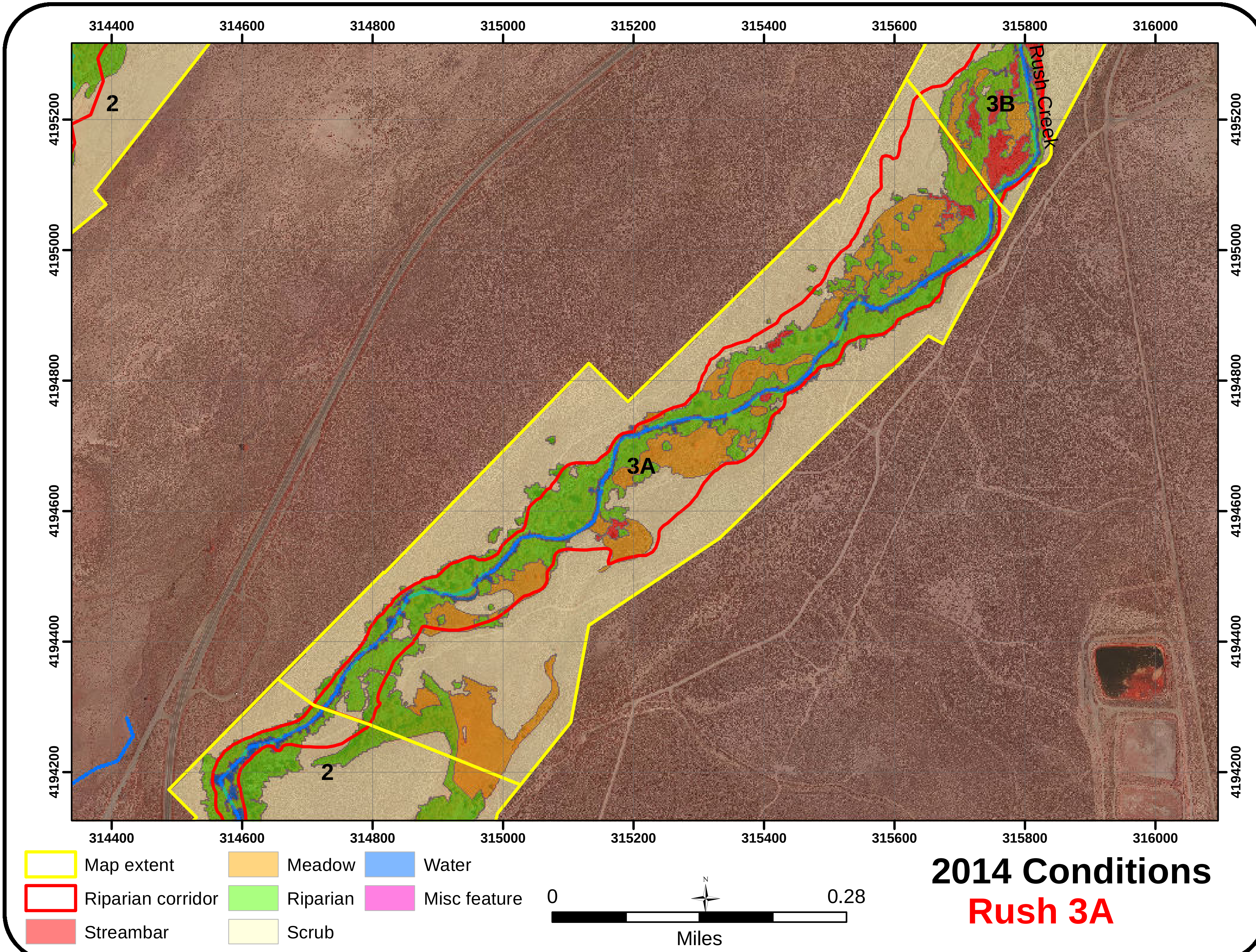
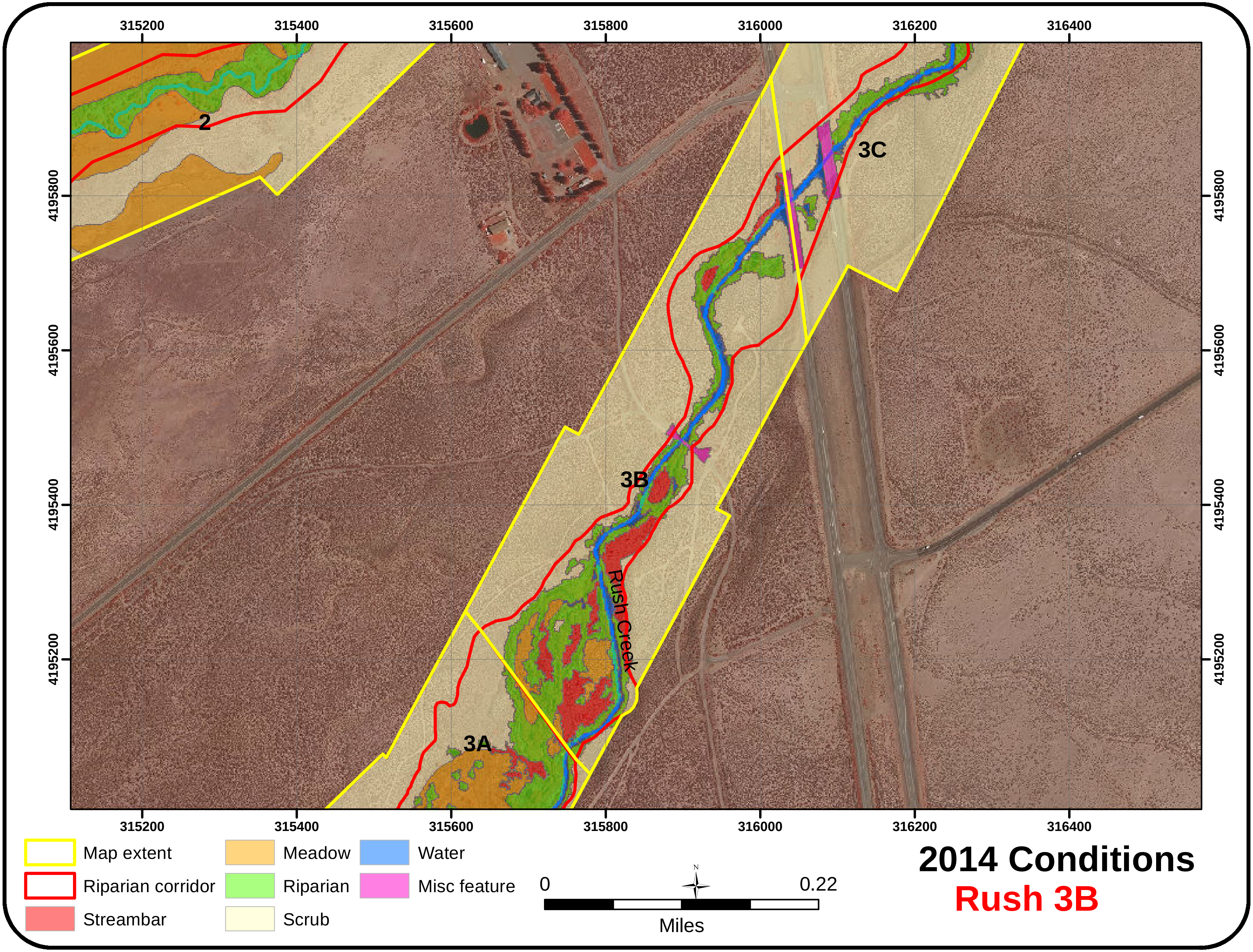
314800
315000
315200
315400
4194200
4194000
4193800
4193600
4193400
1
3A
Rush Creek
2
South Parker Creek
1
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.24
Miles
N
2014 Conditions
Rush 2

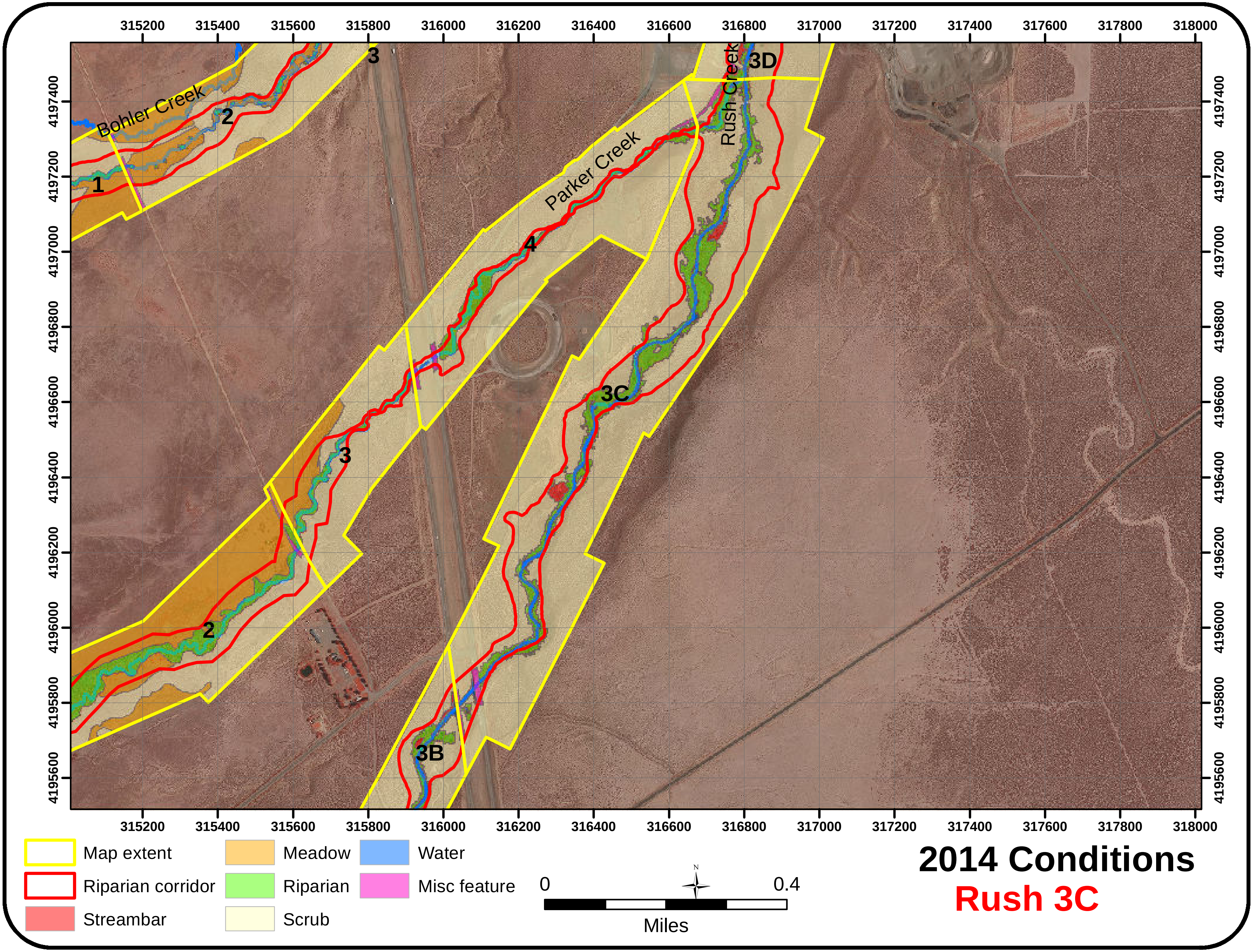


2014 Conditions
Rush 3A



2014 Conditions

Rush 3B



Bohler Creek
Parker Creek
Rush Creek
1
2
3
4
3B
3C
3D
315200
315400
315600
315800
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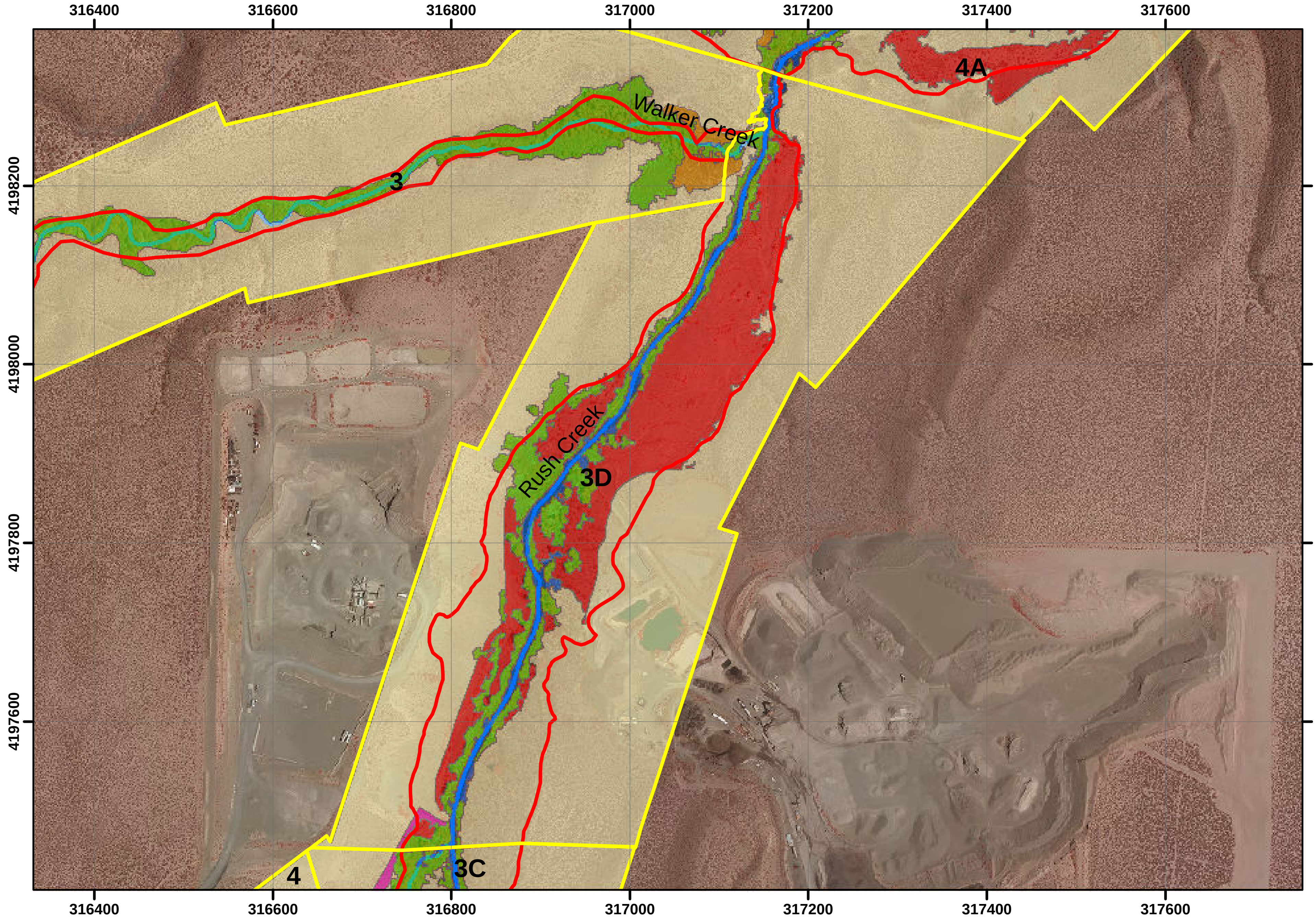
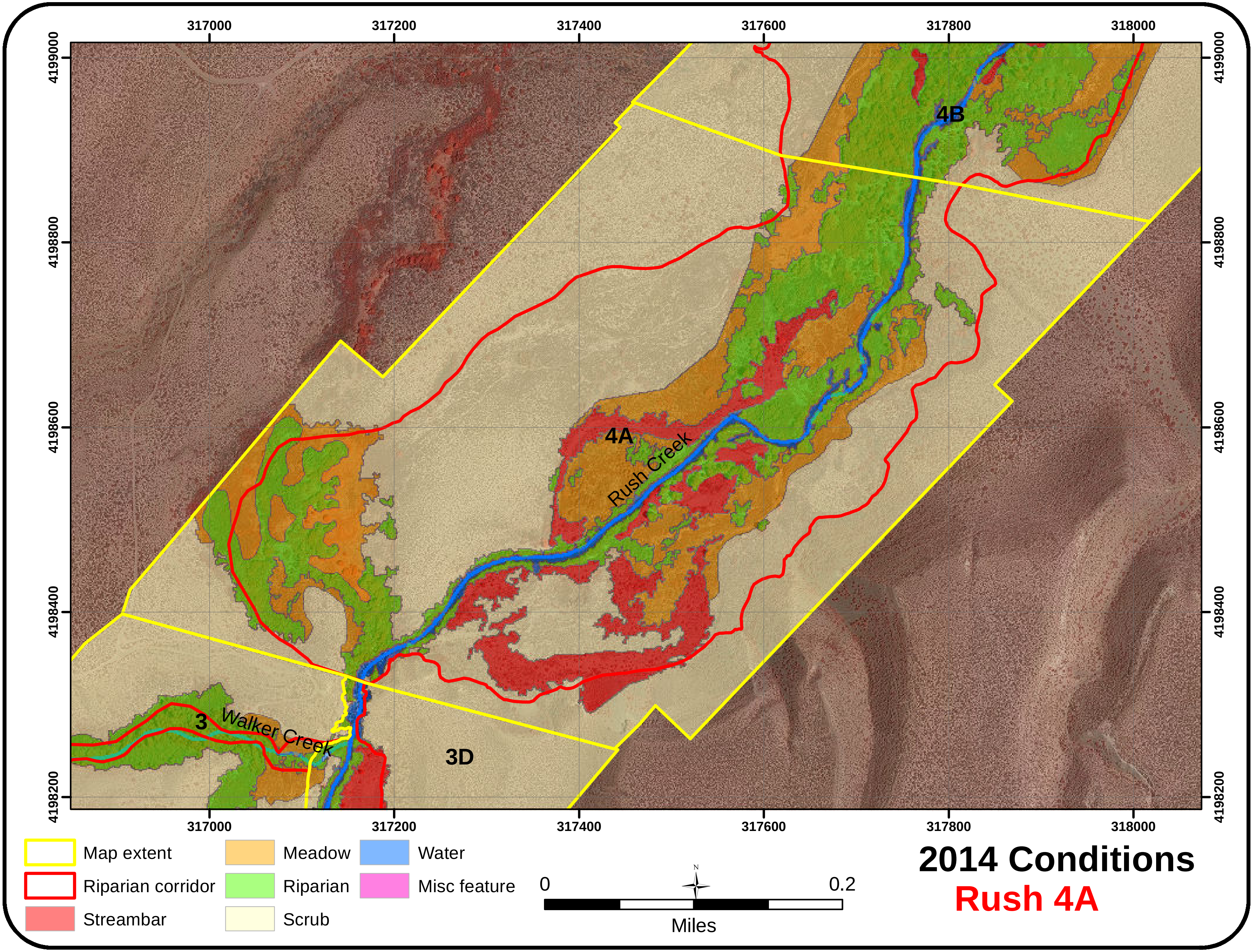
316200
316400
316600
316800
317000
317200
317400
317600
317800
318000
4197400
4197200
4197000
4196800
4196600
4196400
4196200
4196000
4195800
4195600
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.4
Miles
N
2014 Conditions
Rush 3C



Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature

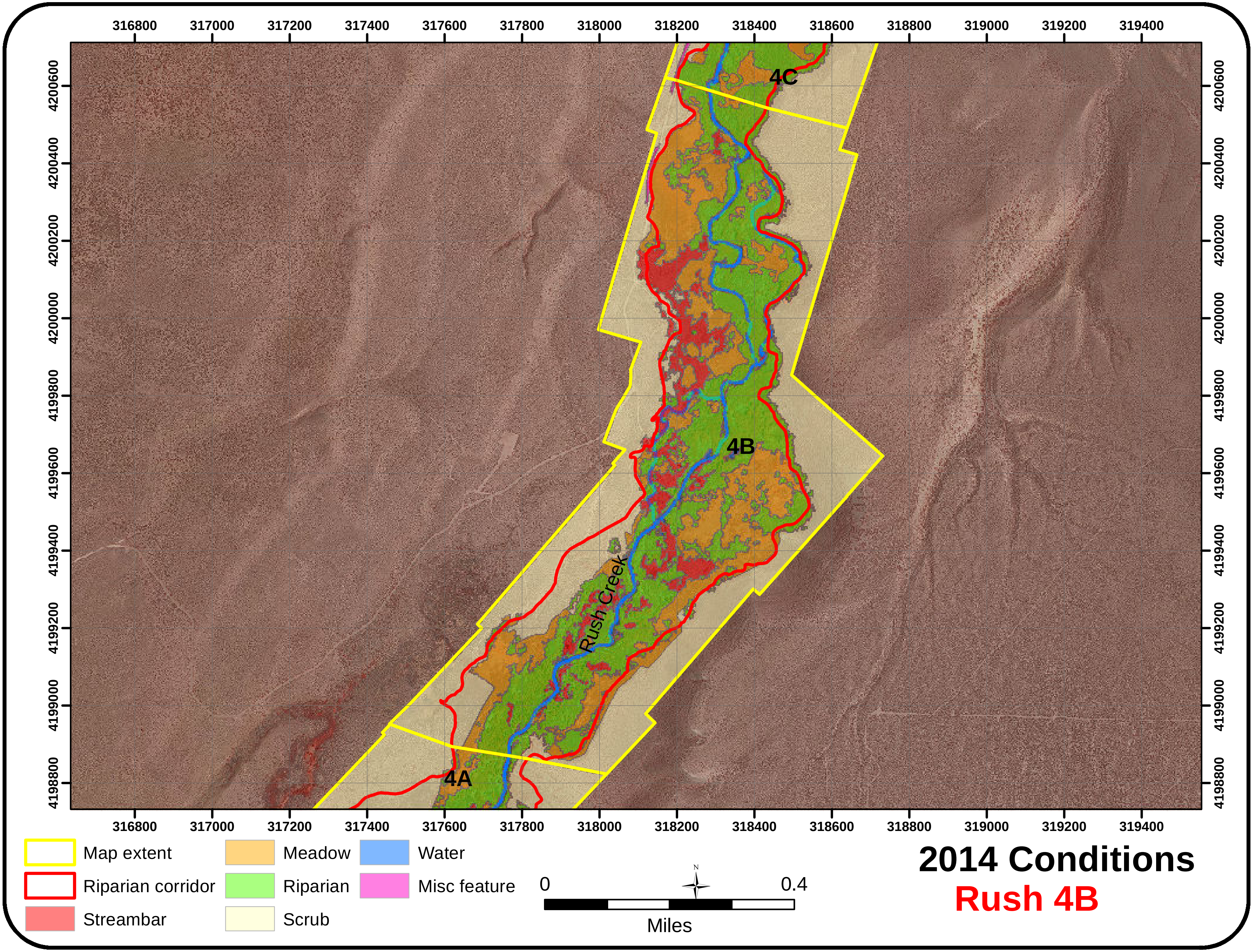
0 0.22
Miles

2014 Conditions
Rush 3D



2014 Conditions

Rush 4A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317400
317600
317800
318000
318200
318400
318600
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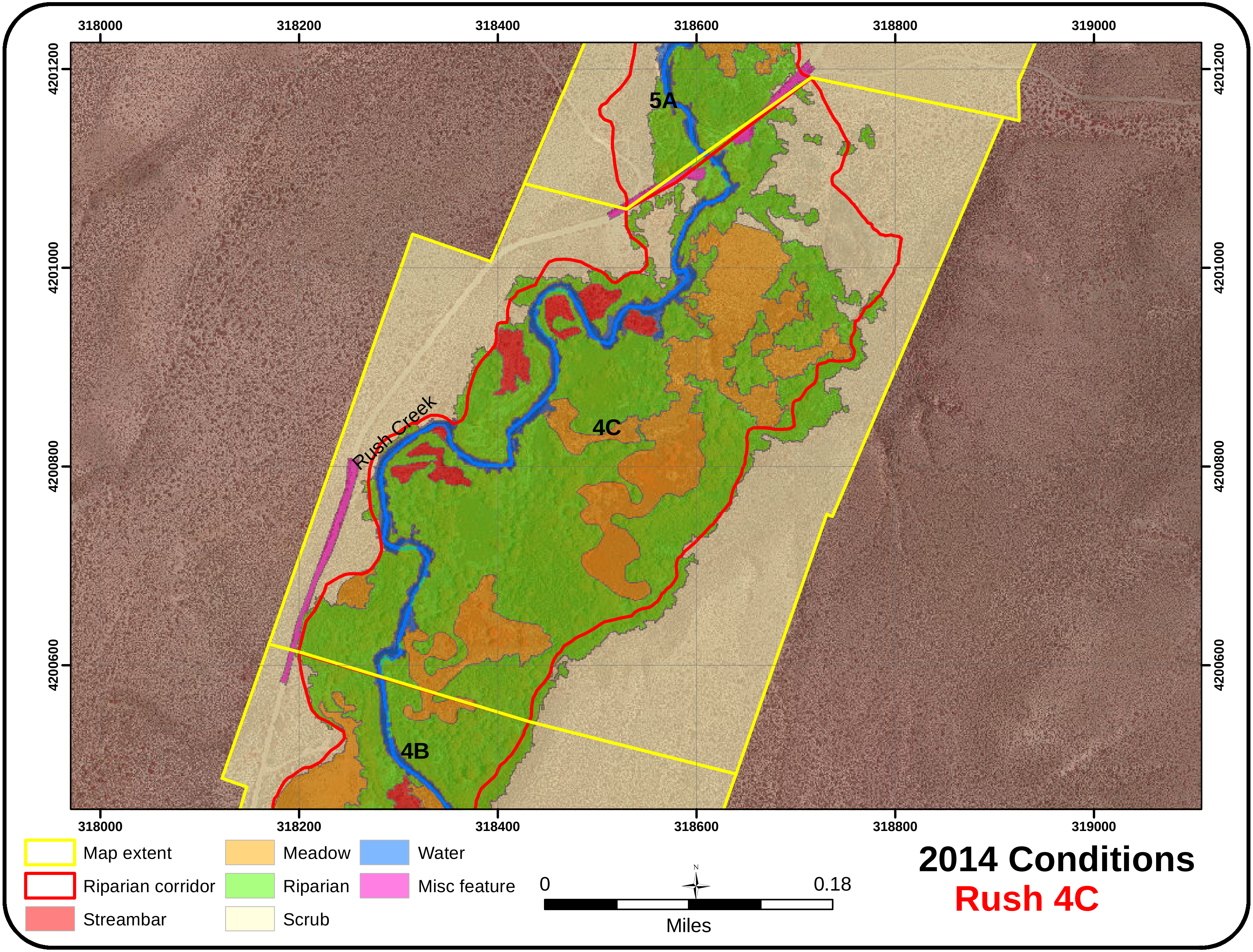
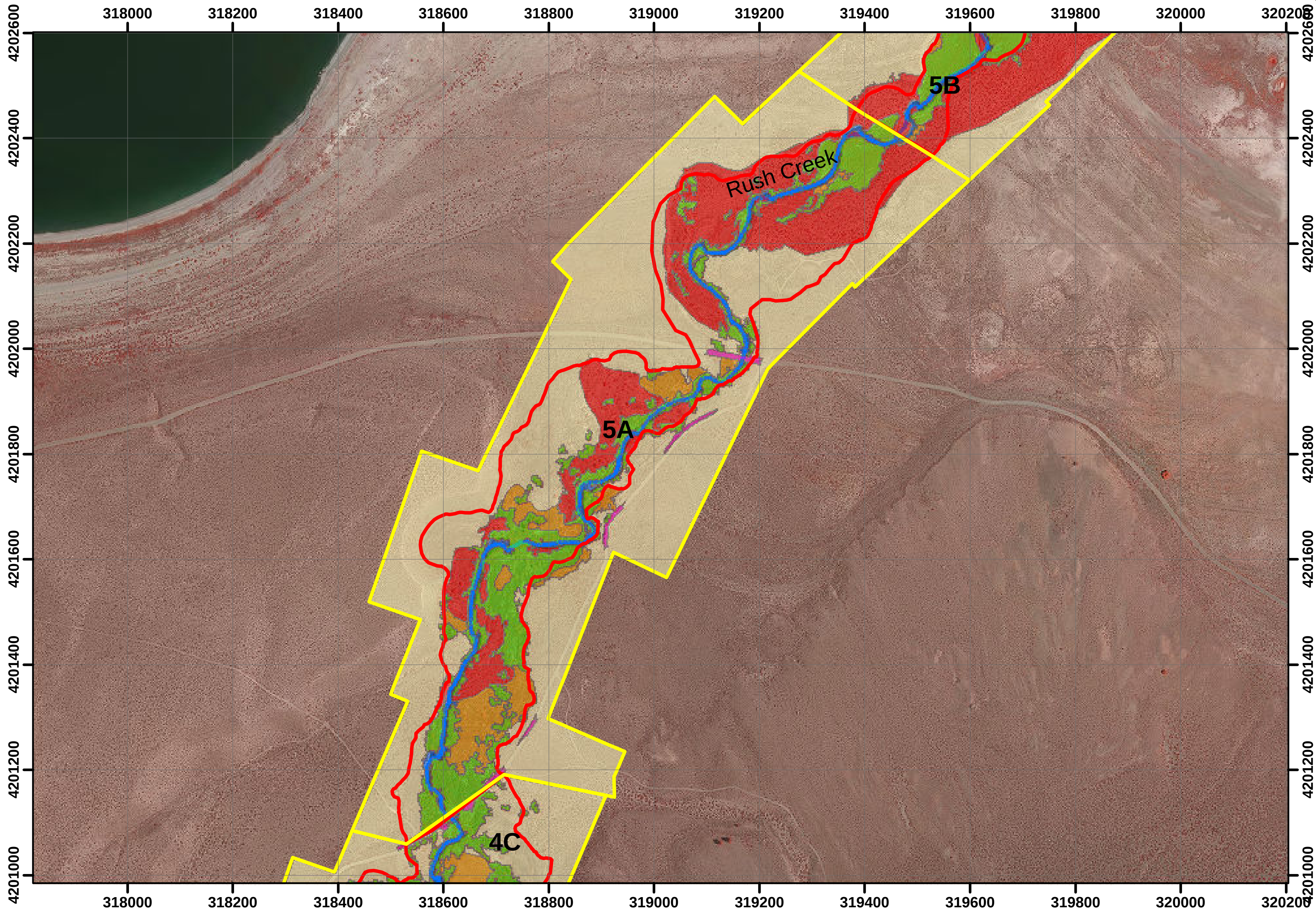
319000
319200
319400
4200600
4200400
4200200
4200000
4199800
4199600
4199400
4199200
4199000
4198800
4C
4B
4A
Rush Creek
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.4
Miles
N
2014 Conditions
Rush 4B



2014 Conditions

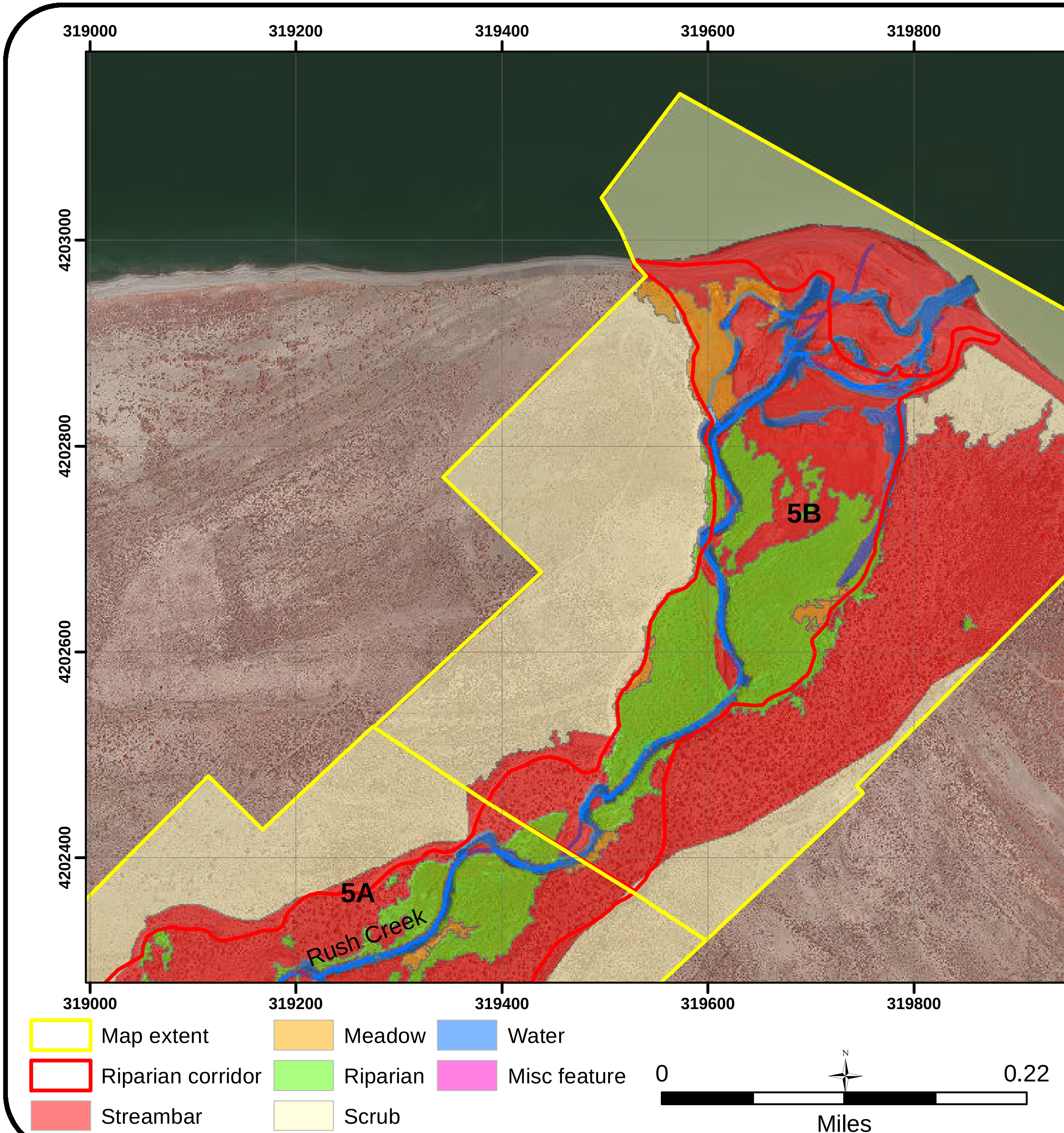
Rush 4C



Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature

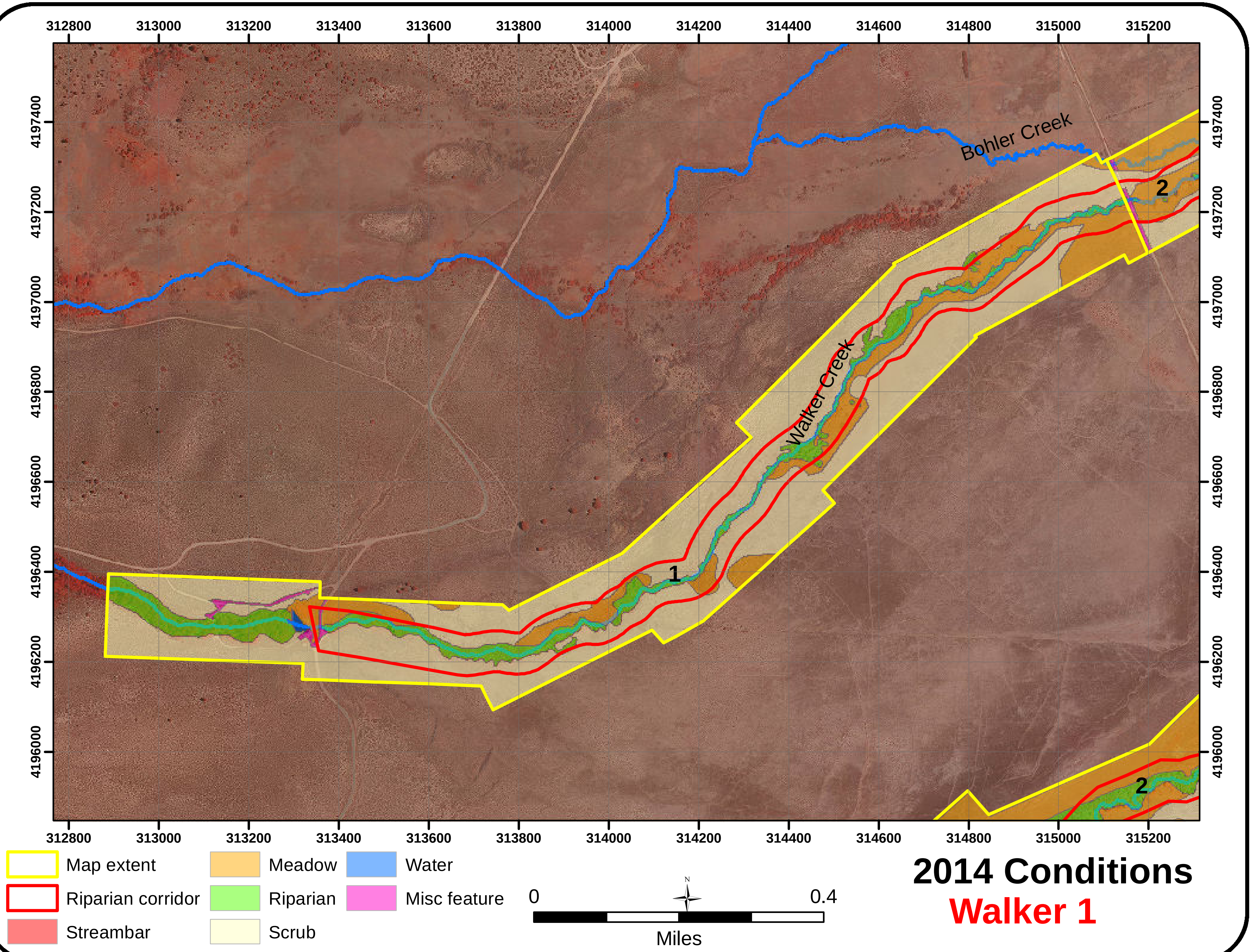
0 0.4
Miles

2014 Conditions
Rush 5A



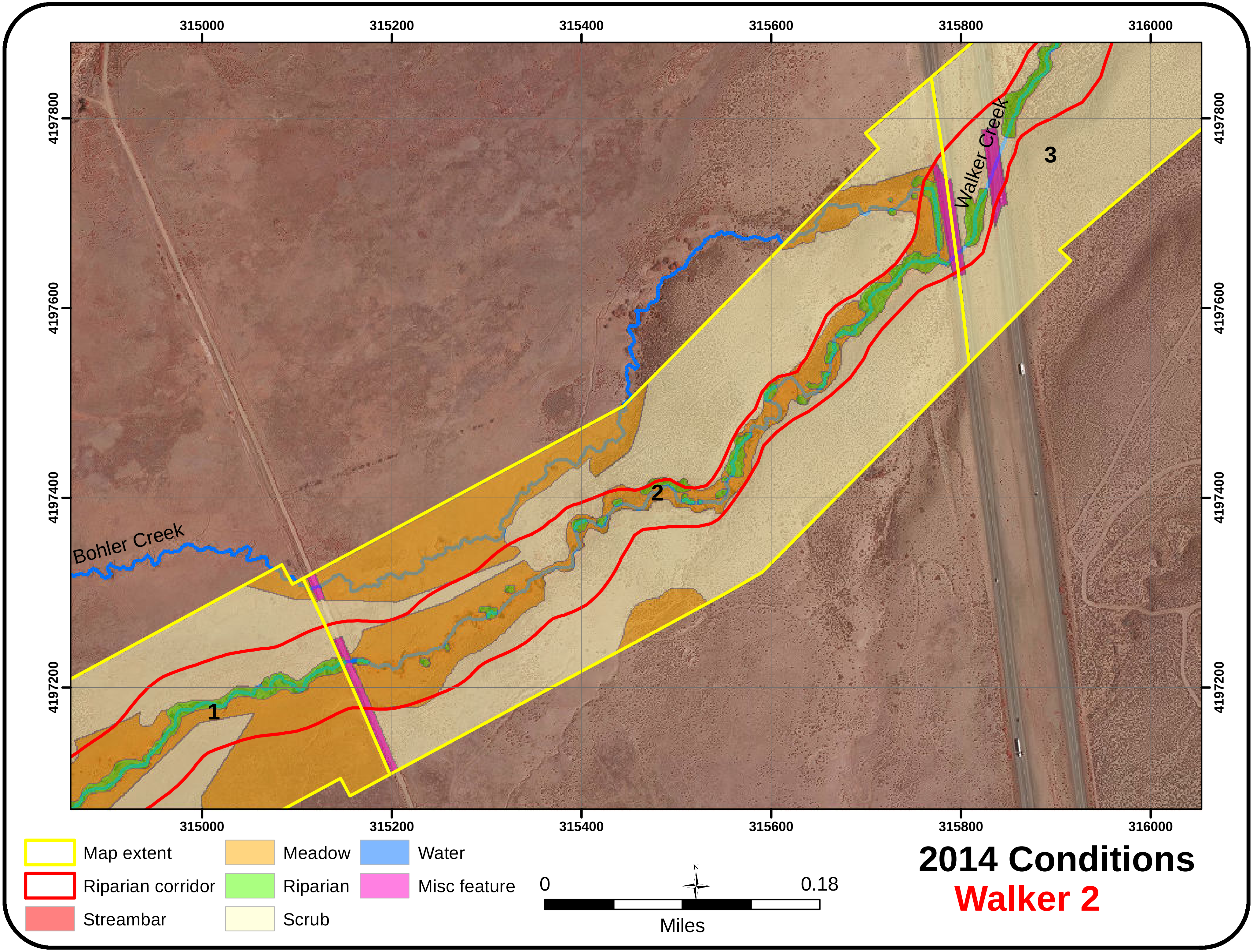
2014 Conditions

Rush 5B



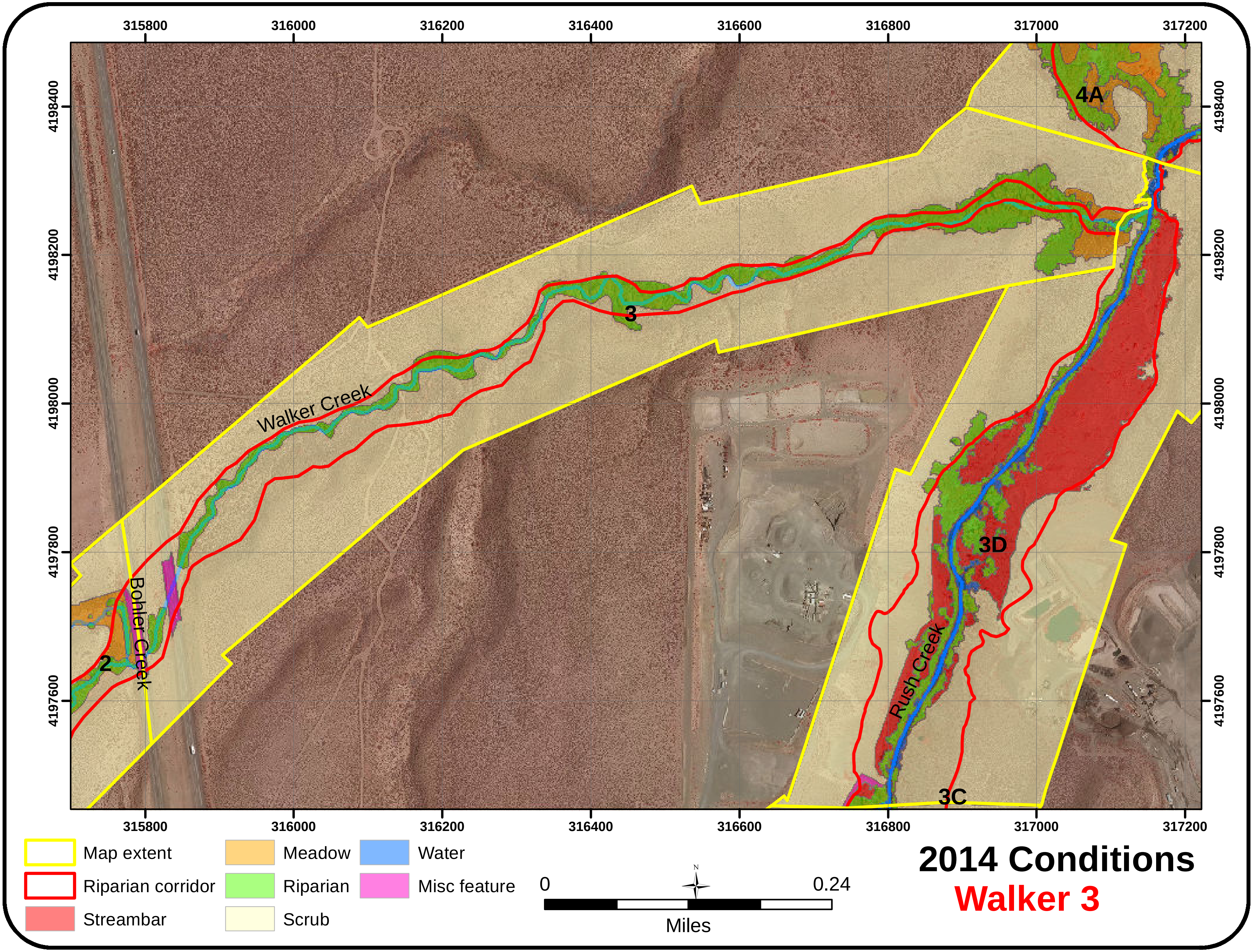
2014 Conditions

Walker 1



2014 Conditions

Walker 2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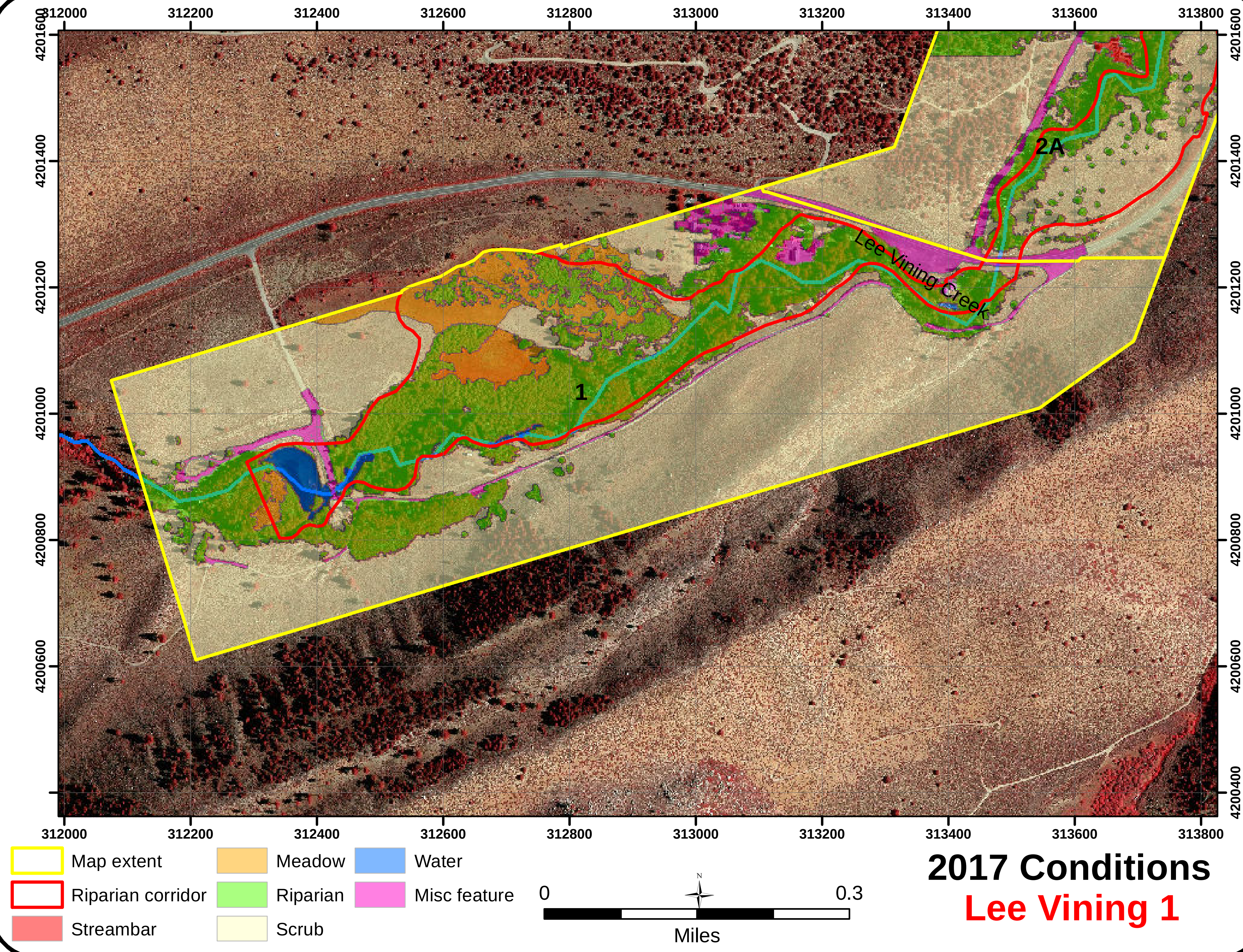
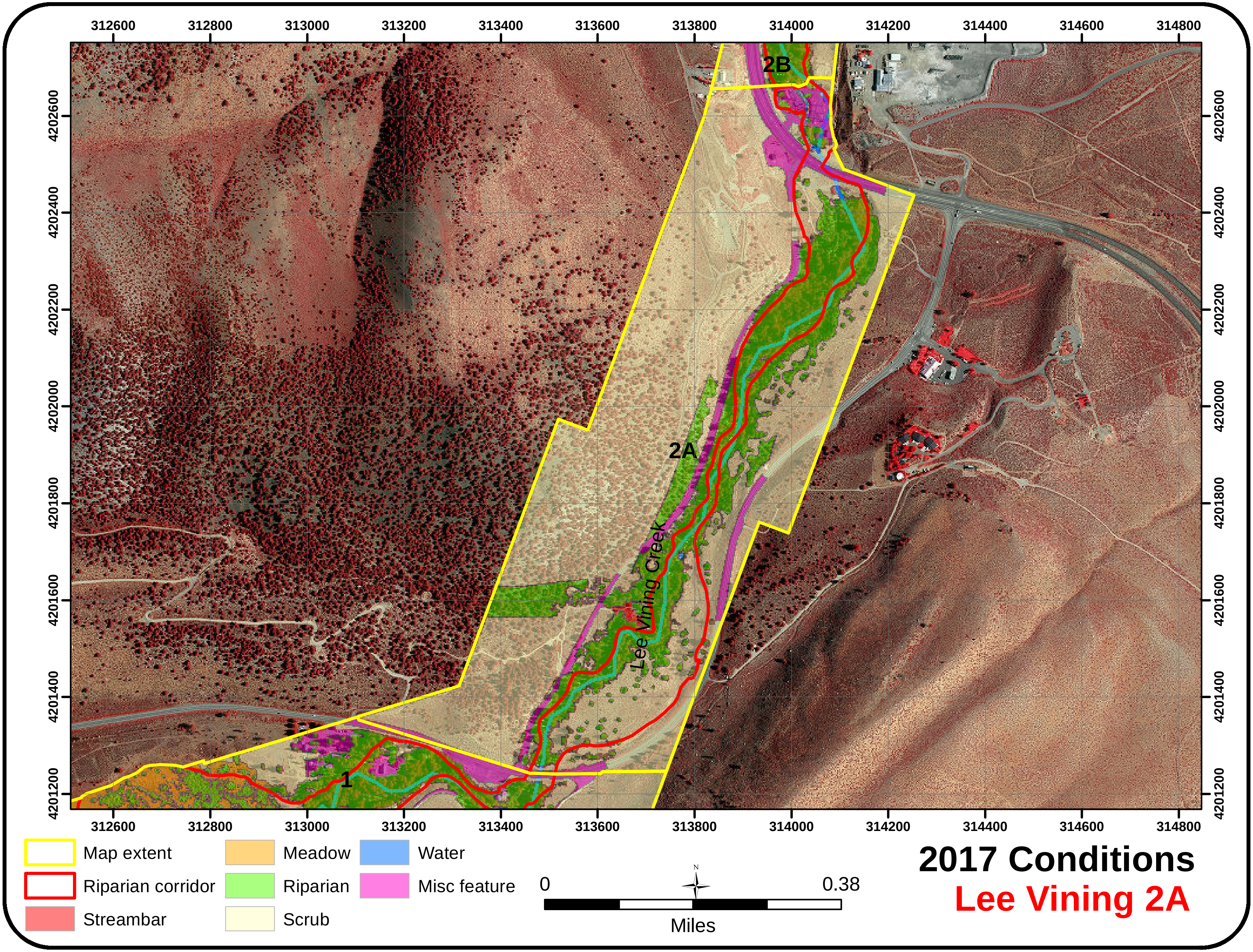
316000
316200
316400
316600
316800
317000
317200
4198400
4198200
4198000
4197800
4197600
4A
3
3D
3C
2
Walker Creek
Bohler Creek
Rush Creek
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.24
Miles
N
2014 Conditions
Walker 3

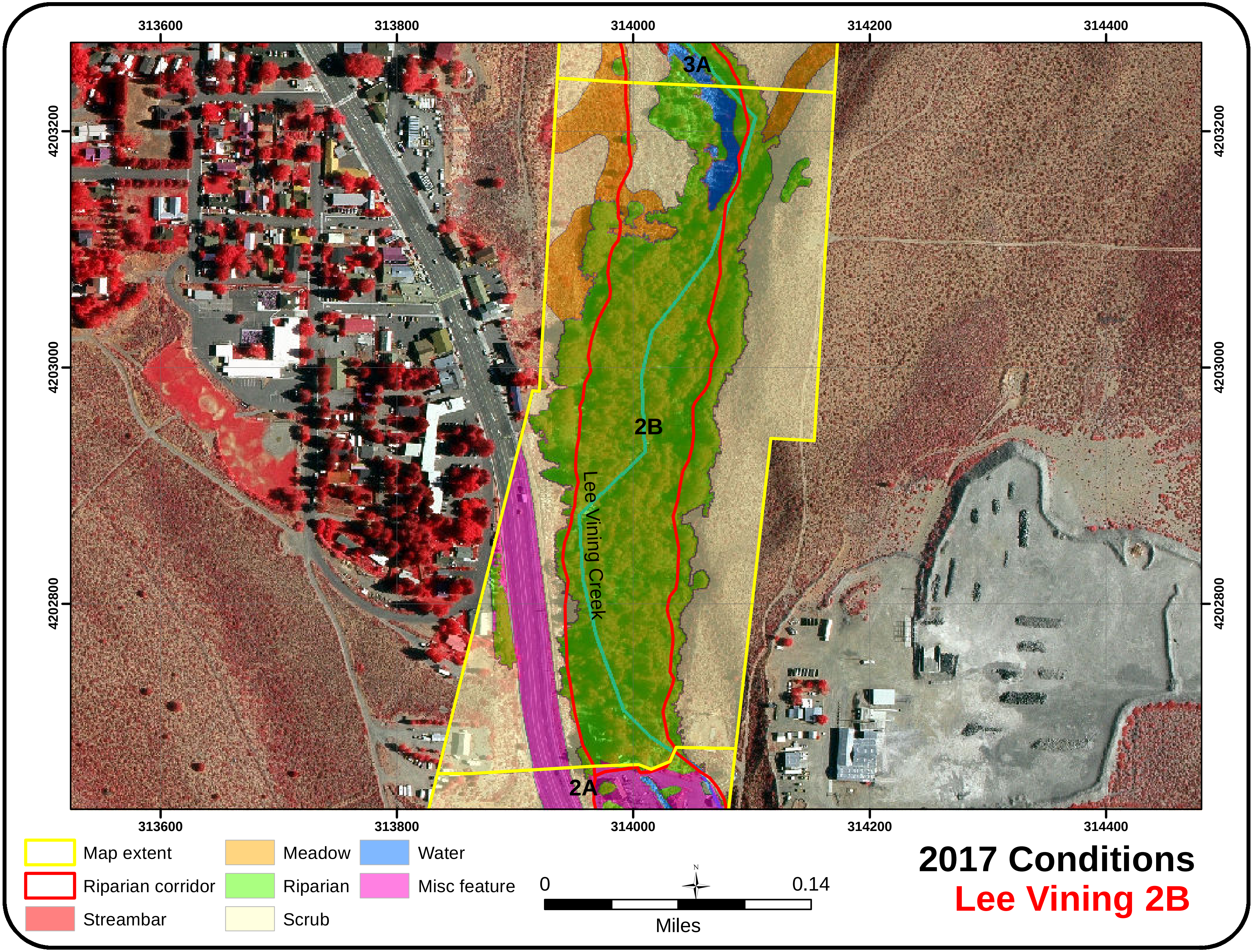
APPENDIX F
RIPARIAN MAPPING
2017 CONDITIONS

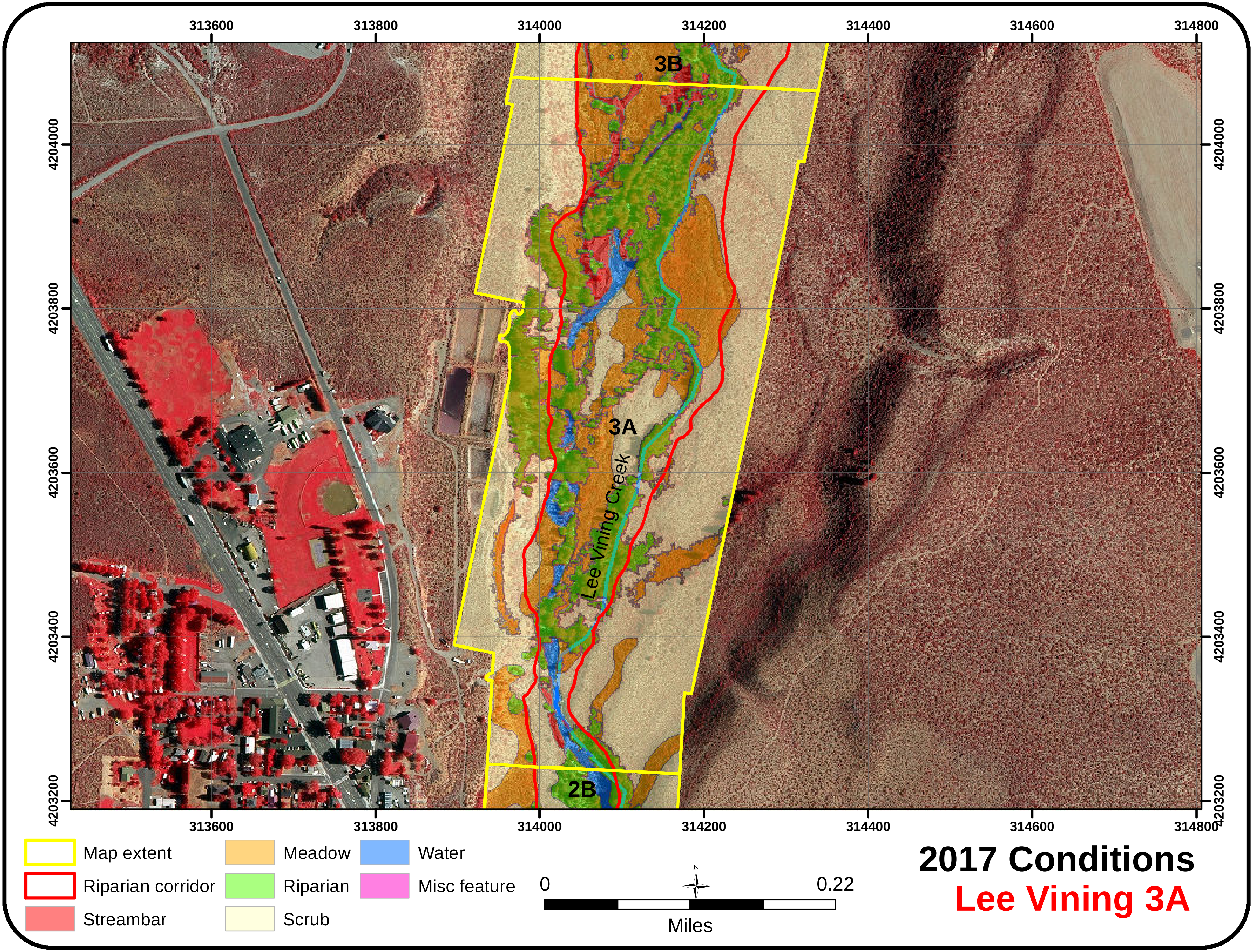


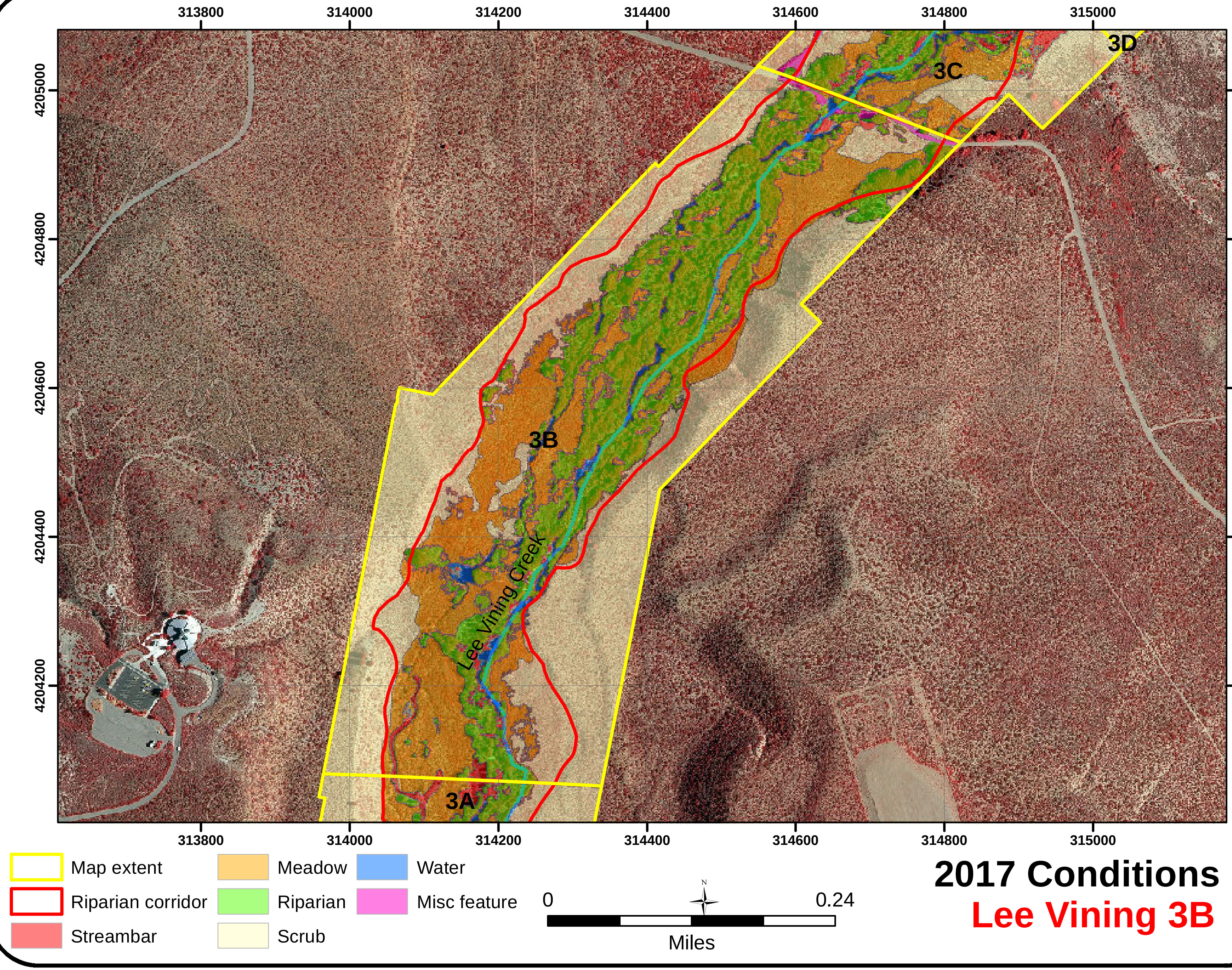
2017 Conditions

Lee Vining 1

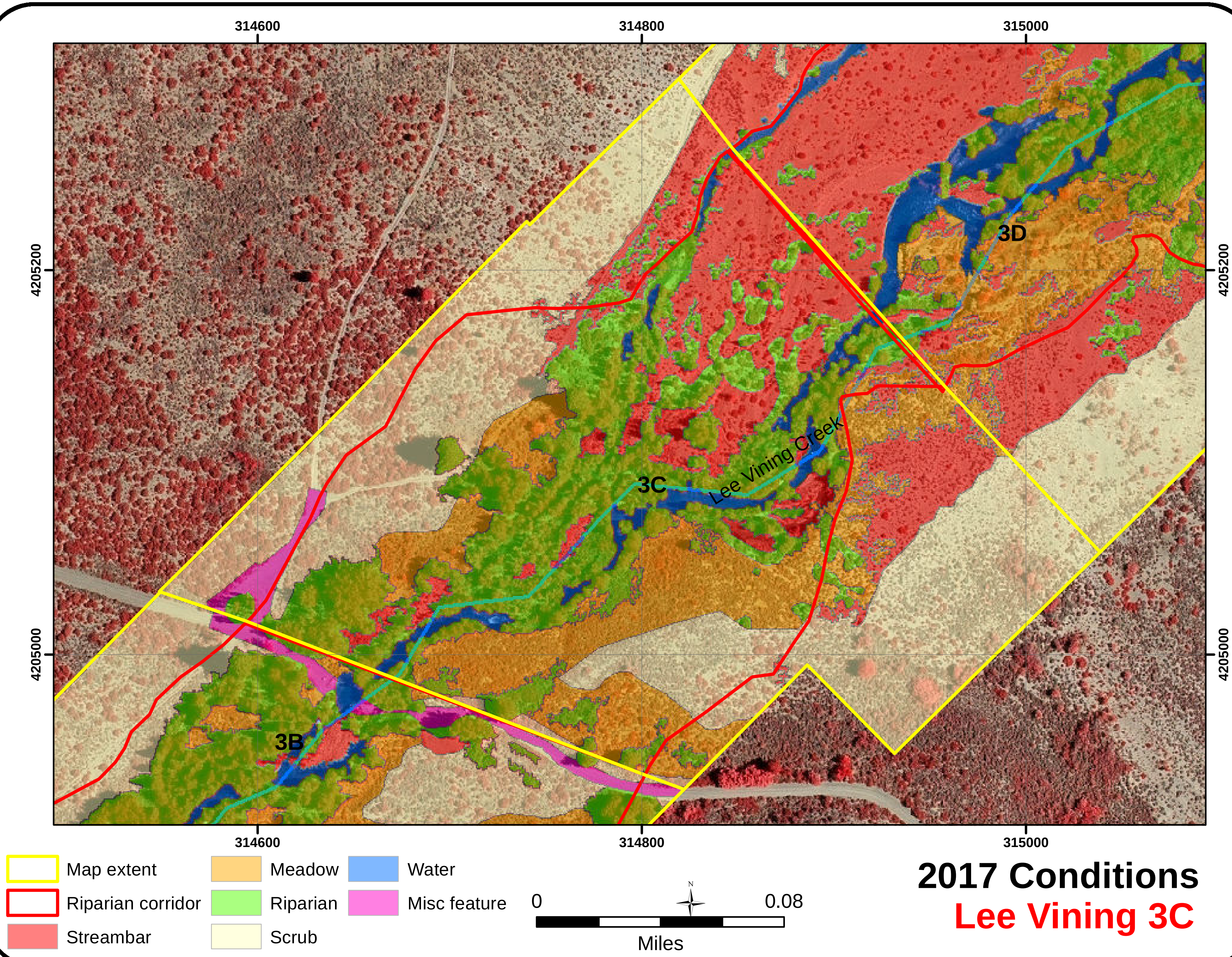

312600
312800
313000
313200
313400
313600
313800
314000
314200
314400
314600
314800
4202600
4202400
4202200
4202000
4201800
4201600
4201400
4201200
2B
2A
1
Lee Vining Creek
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.38
Miles
N
2017 Conditions
Lee Vining 2A


313600
313800
314000
314200
314400
4203200
4203000
4202800
3A
2B
2A
Lee Vining Creek
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.14
N
Miles
2017 Conditions
Lee Vining 2B

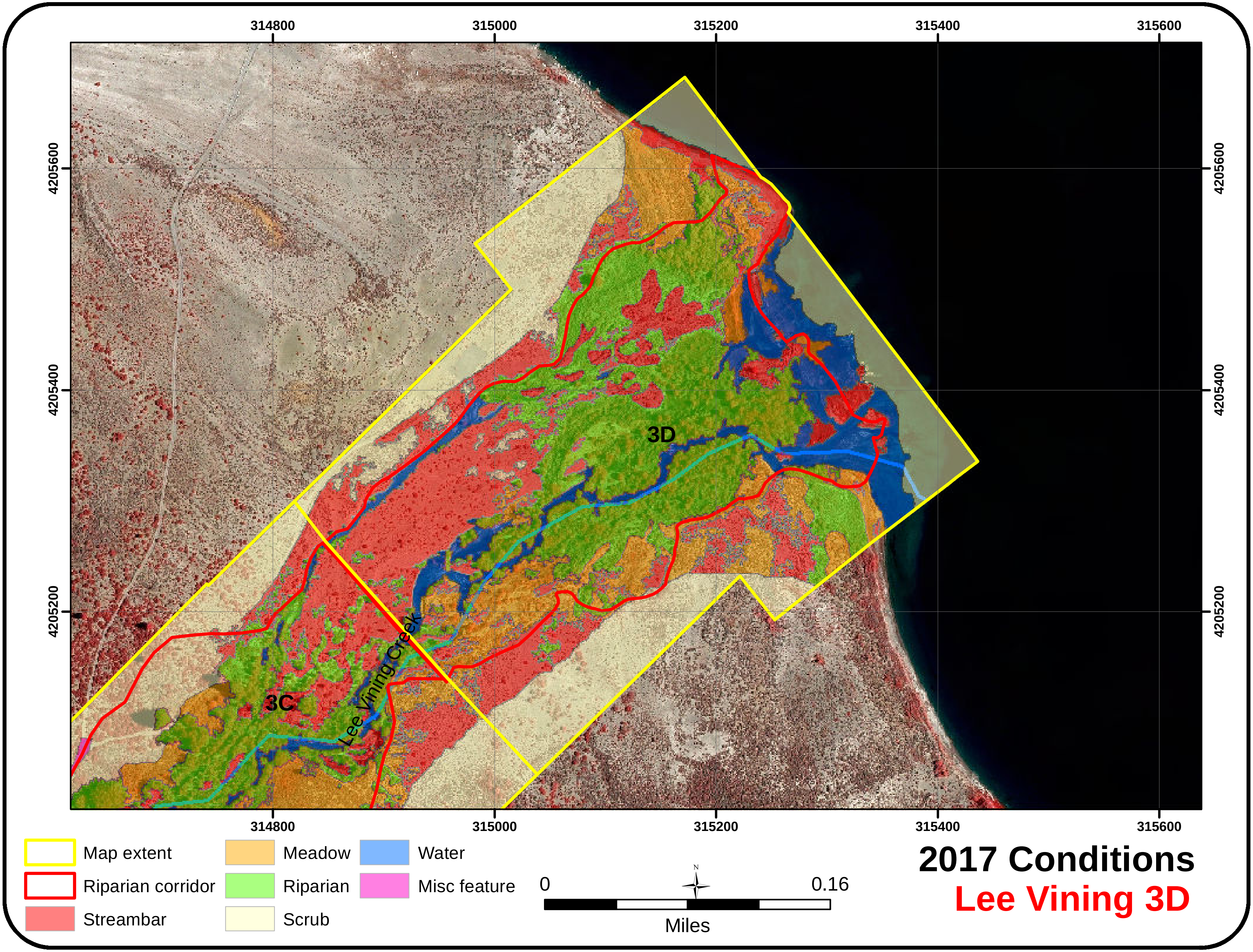

313600
313800
314000
314200
314400
314600
314800
4204000
4203800
4203600
4203400
4203200
3B
3A
2B
Lee Vining Creek
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
N
0
0.22
Miles
2017 Conditions
Lee Vining 3A



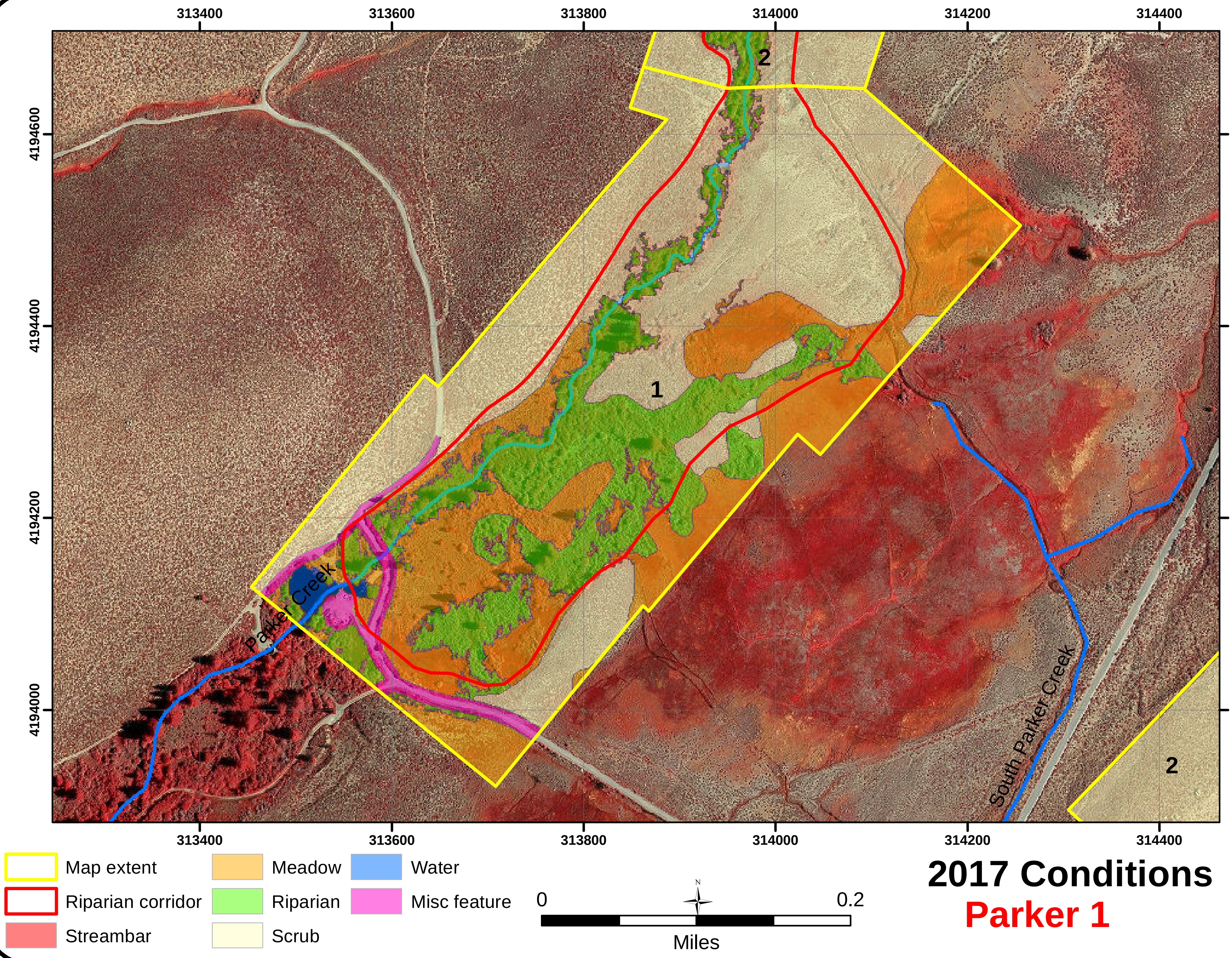
2017 Conditions
Lee Vining 3B



2017 Conditions
Lee Vining 3C

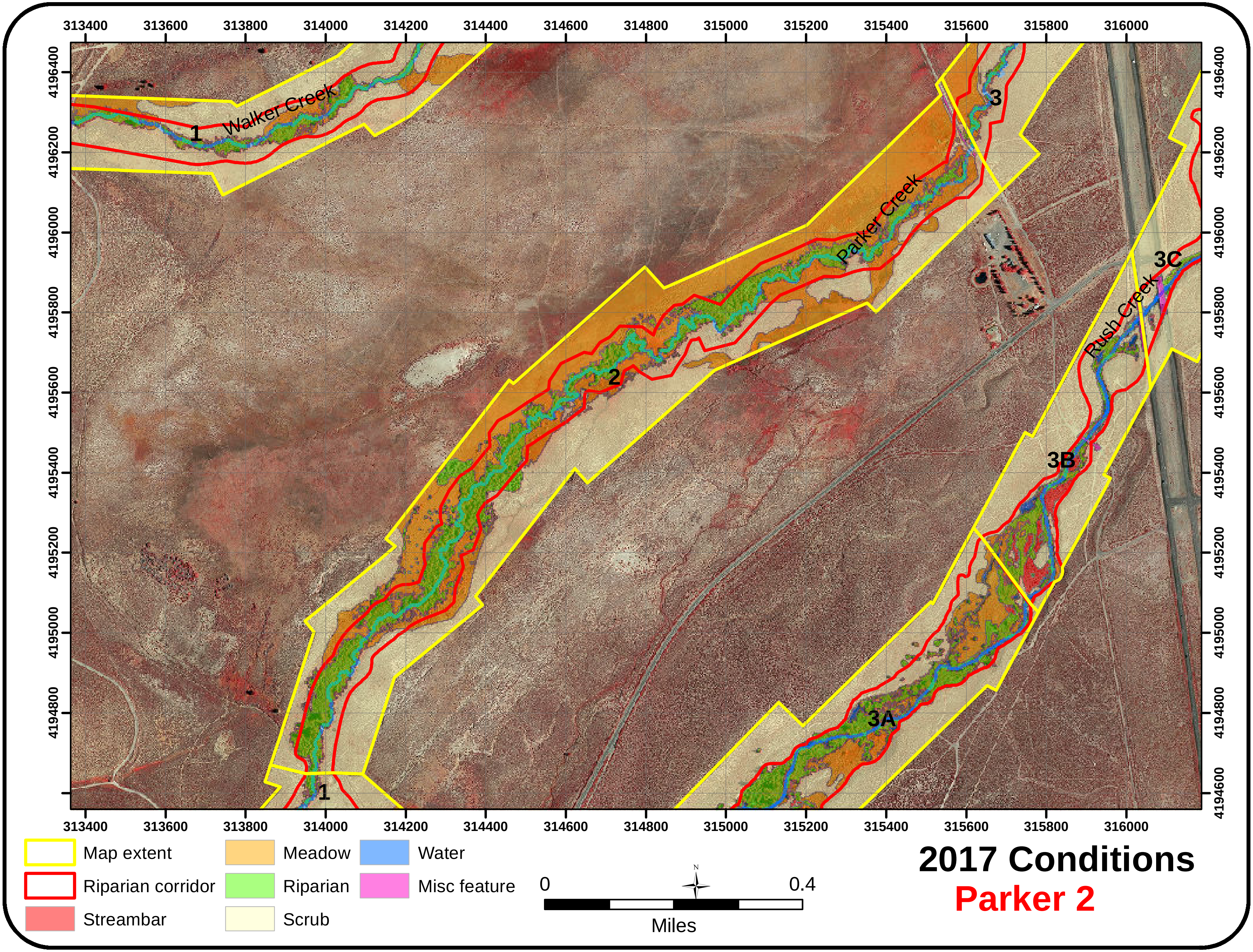


314800
315000
315200
315400
315600
4205600
4205400
4205200
3D
3C
Lee Vining Creek
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.16
N
Miles
2017 Conditions
Lee Vining 3D

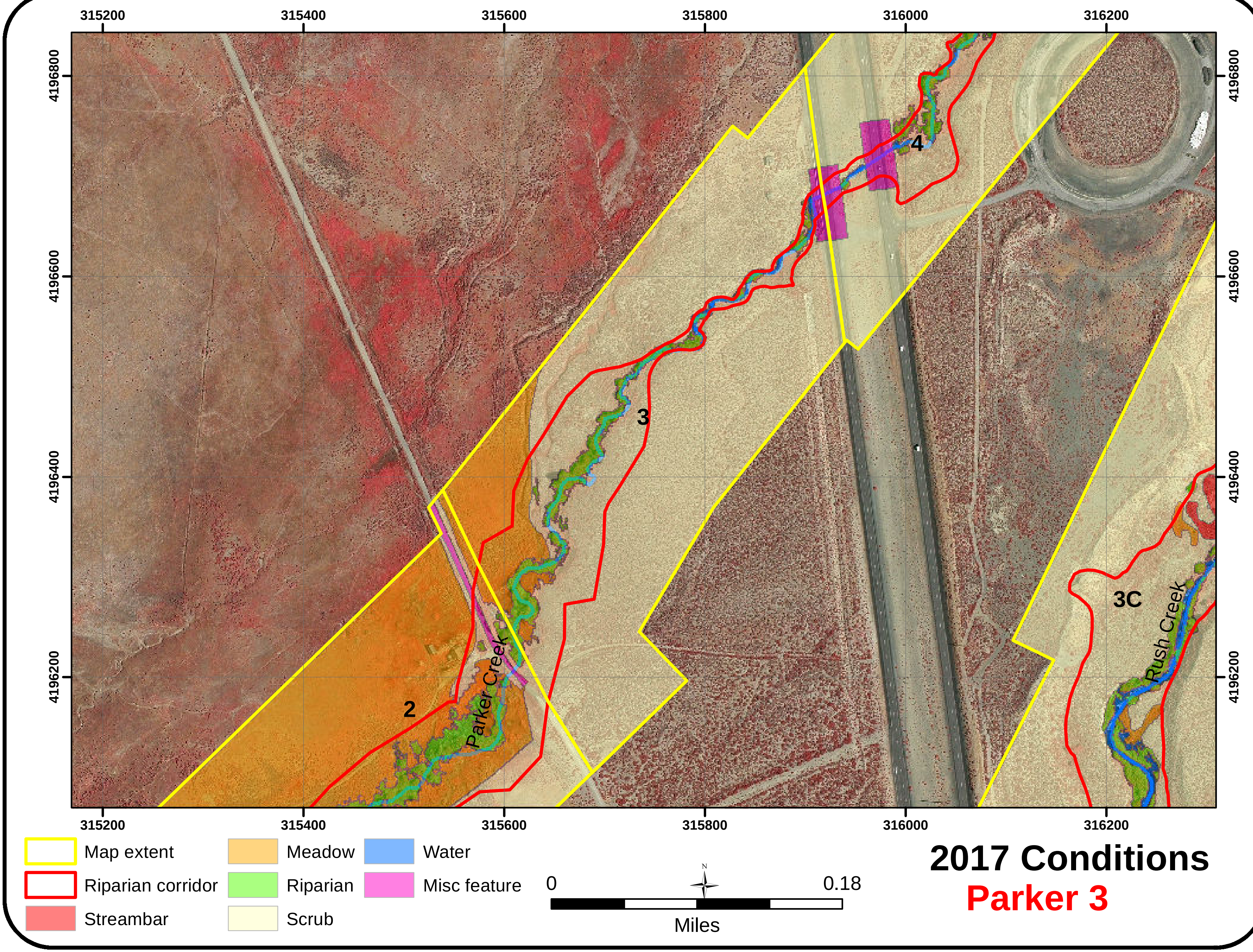


2017 Conditions

Parker 1

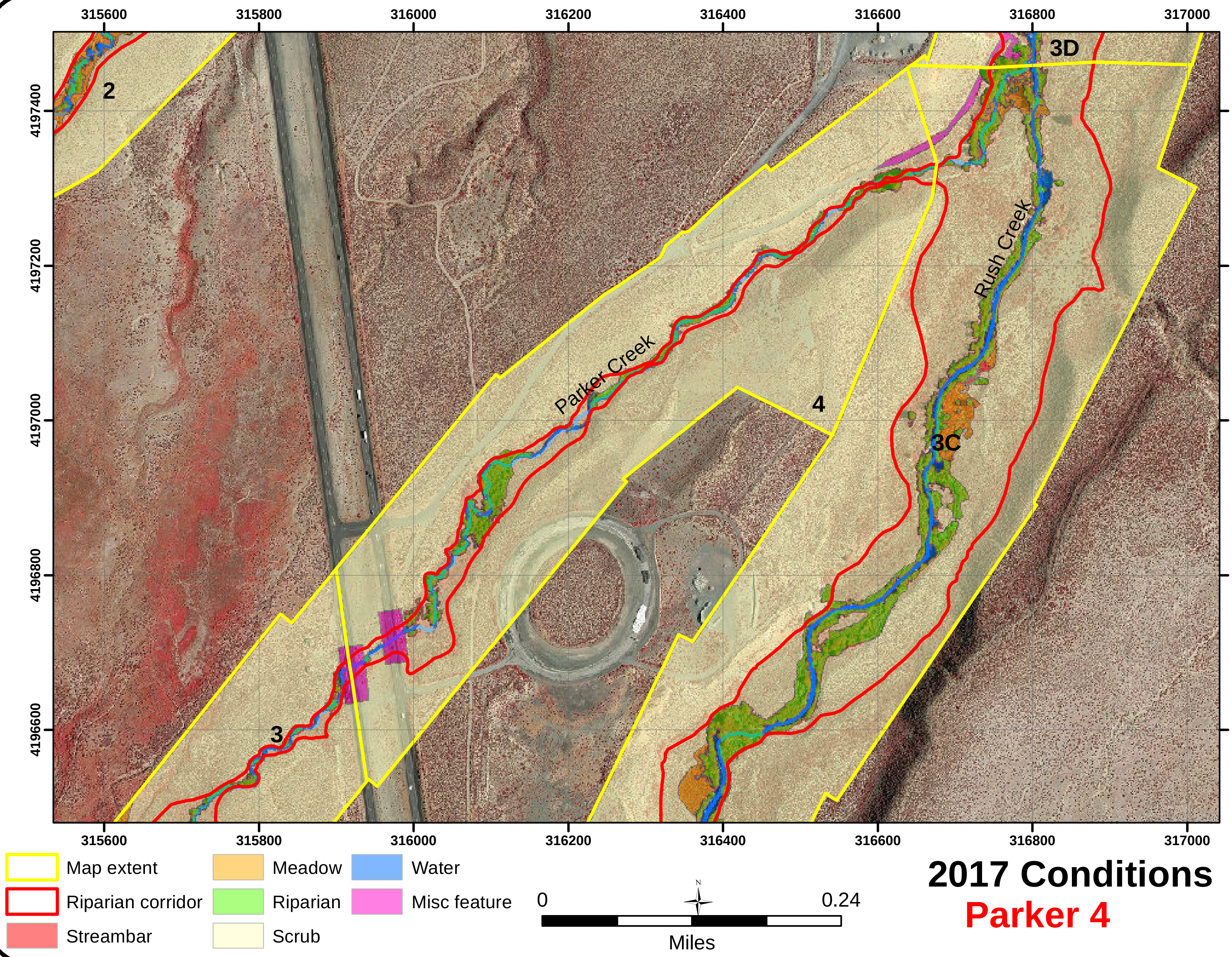


313400
313600
313800
314000
314200
314400
314600
314800
315000
315200
315400
315600
315800
316000
4194600
4194800
4195000
4195200
4195400
4195600
4195800
4196000
4196200
4196400
1
Walker Creek
2
Parker Creek
3
3A
3B
3C
Rush Creek
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.4
Miles
N
2017 Conditions
Parker 2



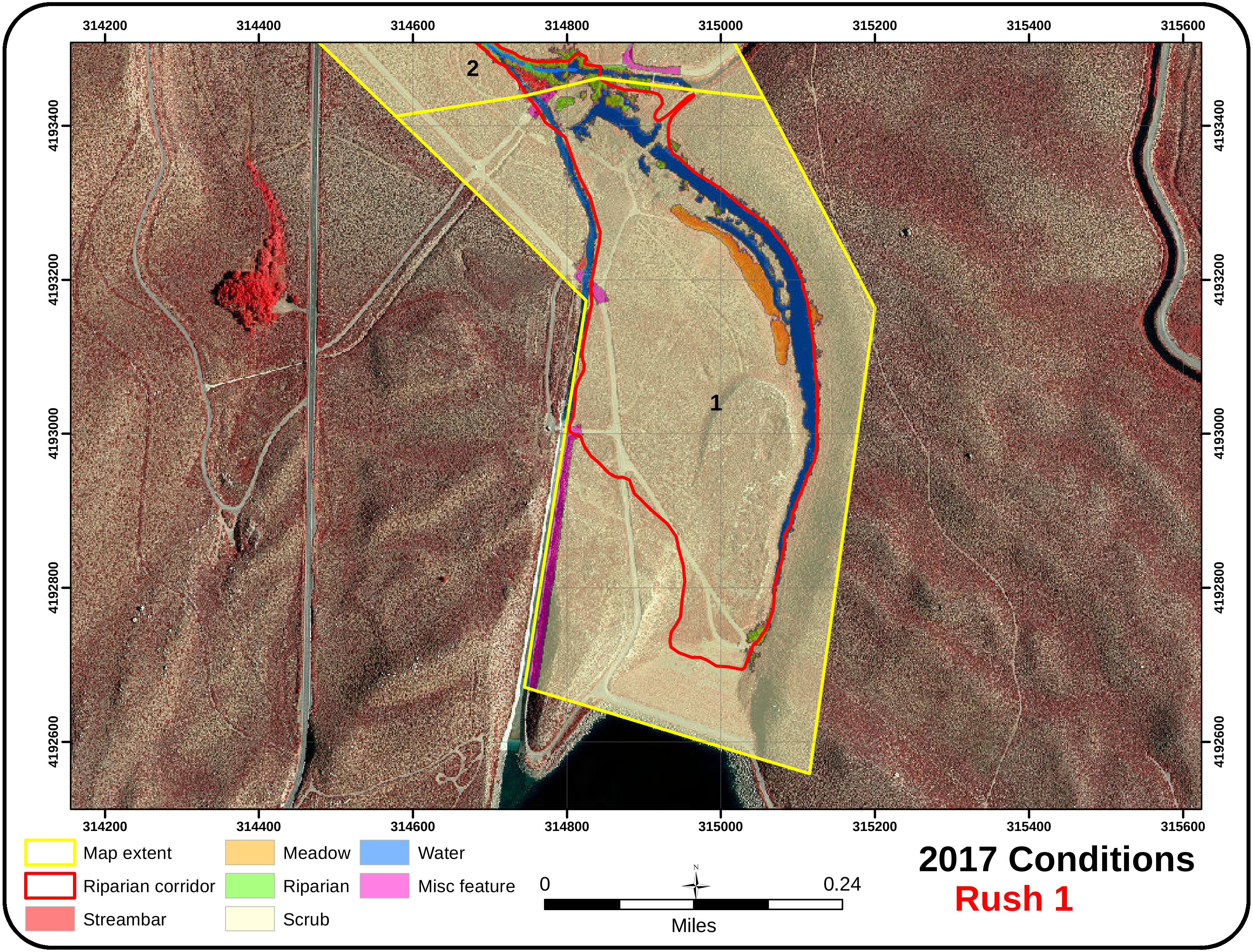
2017 Conditions

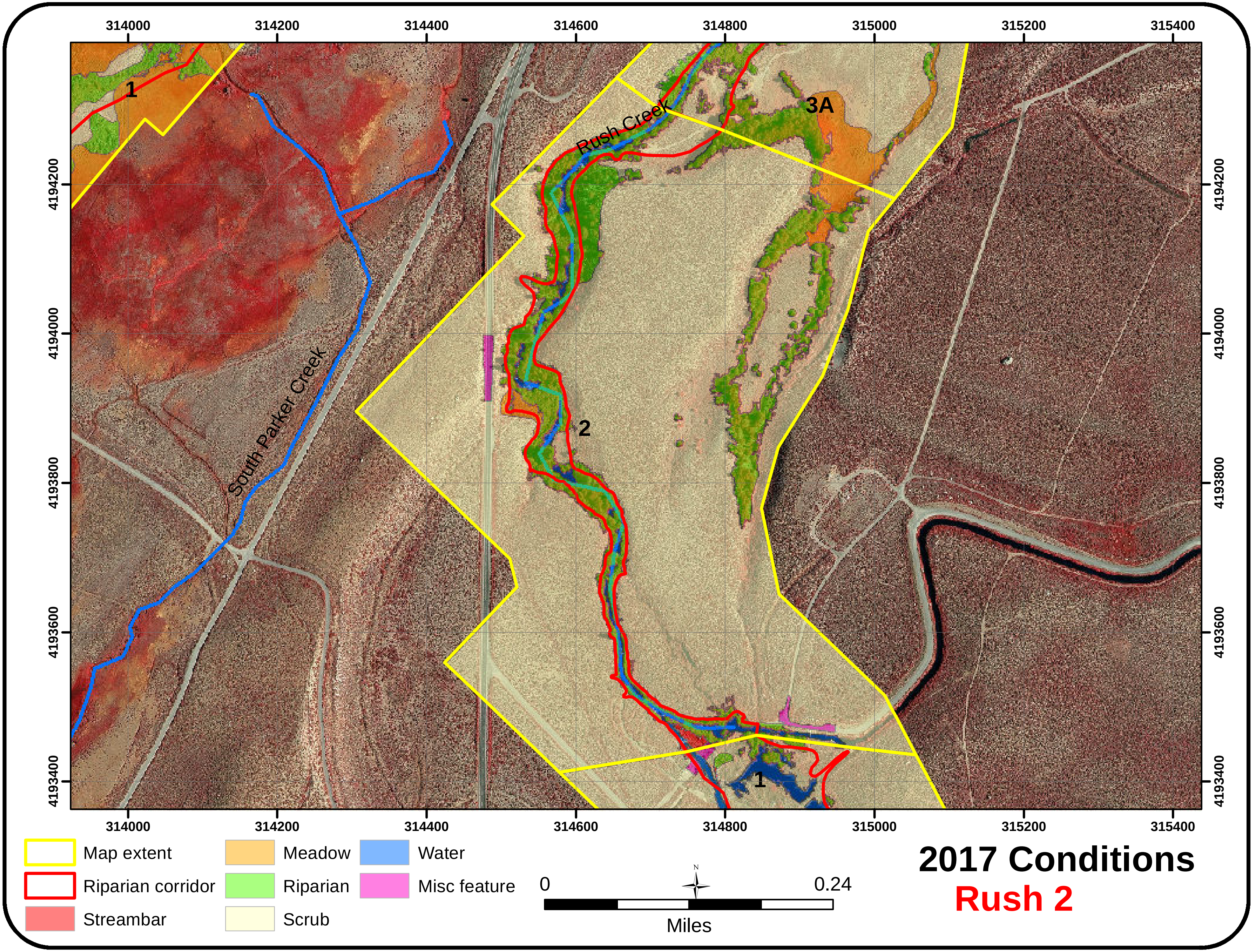
Parker 3



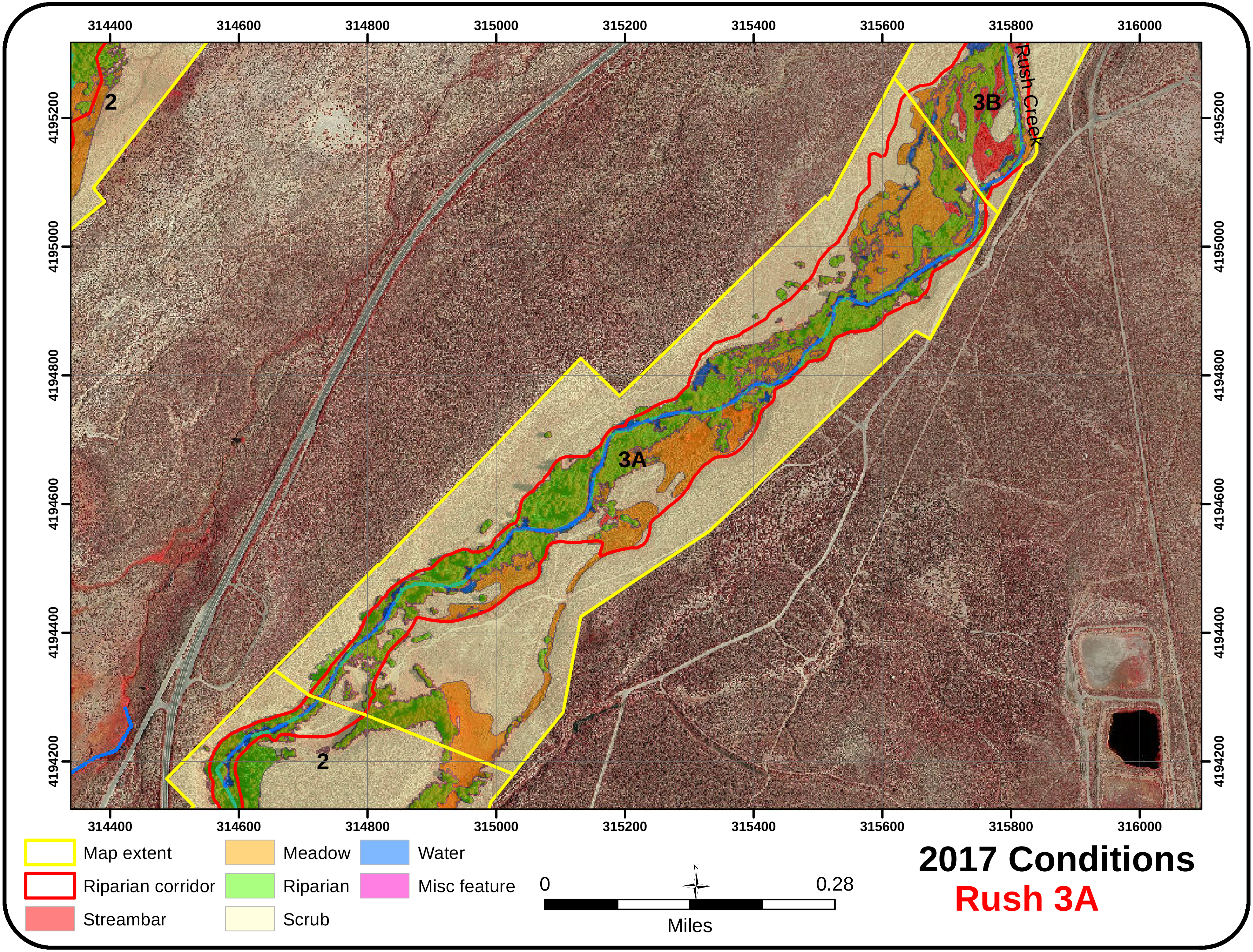
2017 Conditions

Parker 4


314200
314400
314600
314800
315000
315200
315400
315600
4193400
4193200
4193000
4192800
4192600
1
2
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
N
0
0.24
Miles
2017 Conditions
Rush 1



314000
314200
314400
314600
314800
315000
315200
315400
4194200
4194000
4193800
4193600
4193400
1
3A
2
1
Rush Creek
South Parker Creek
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.24
Miles
2017 Conditions
Rush 2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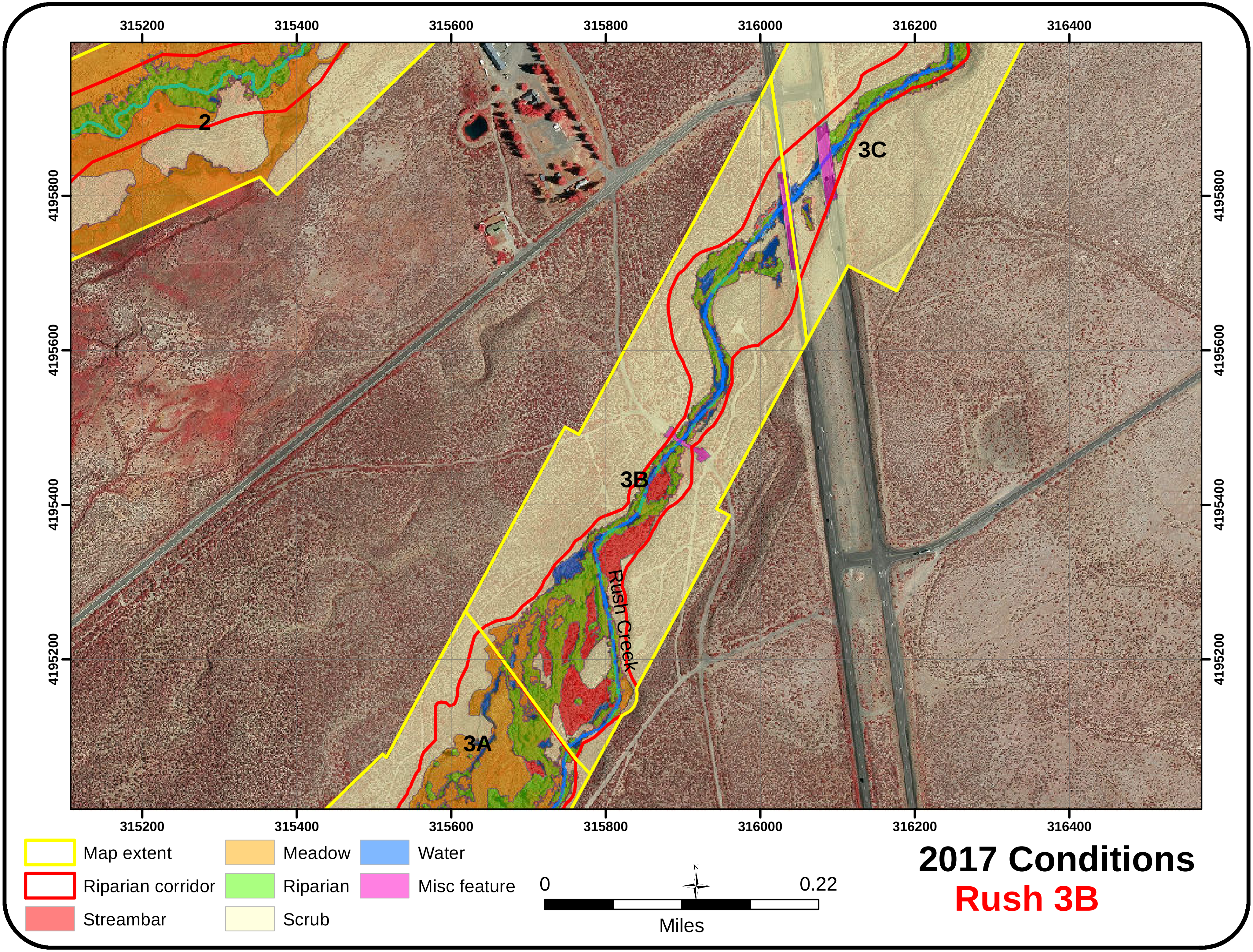
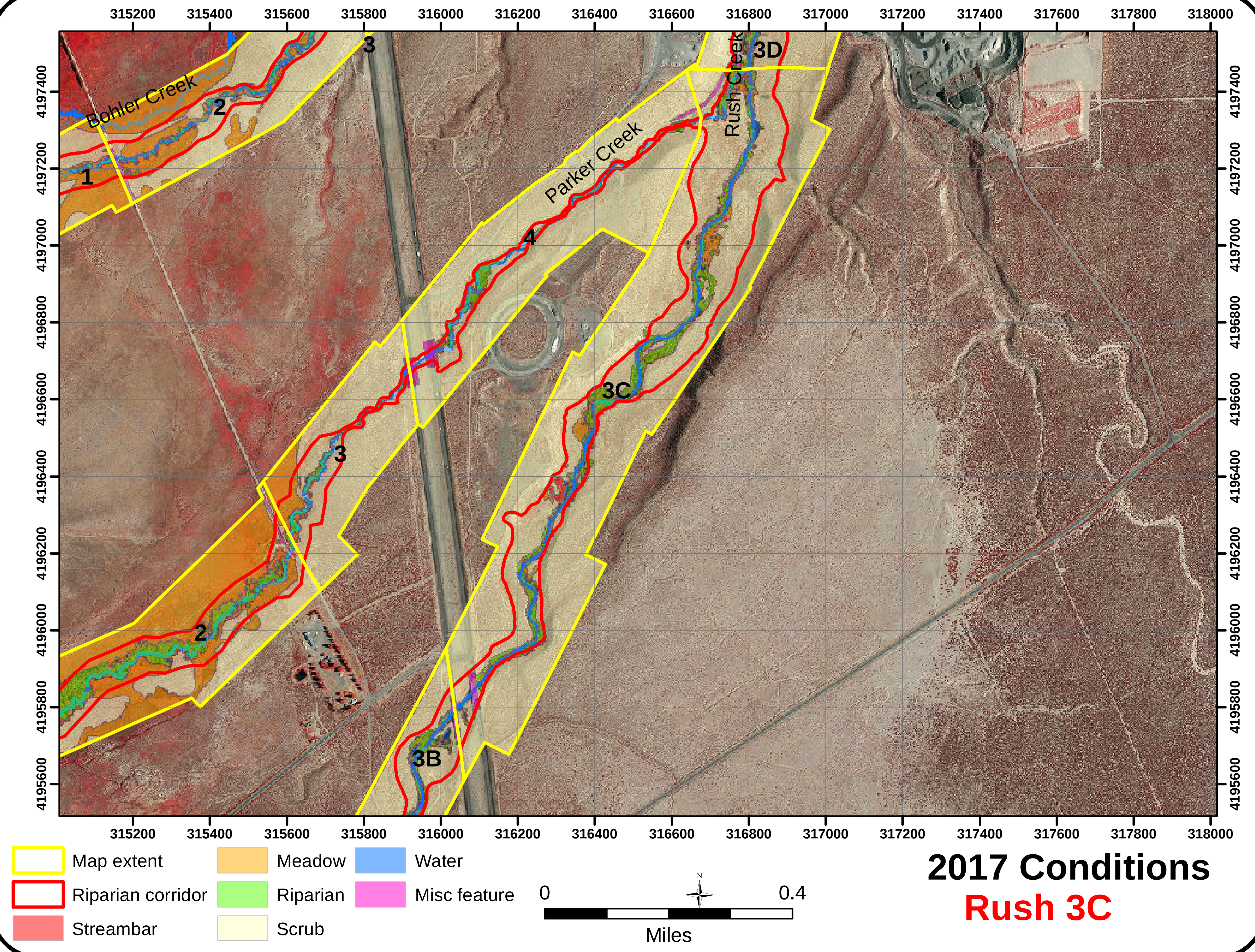
314600
314800
315000
315200
315400
315600
315800
316000
4195200
4195000
4194800
4194600
4194400
4194200
Rush Creek
3B
3A
2
2
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.28
Miles
N
2017 Conditions
Rush 3A

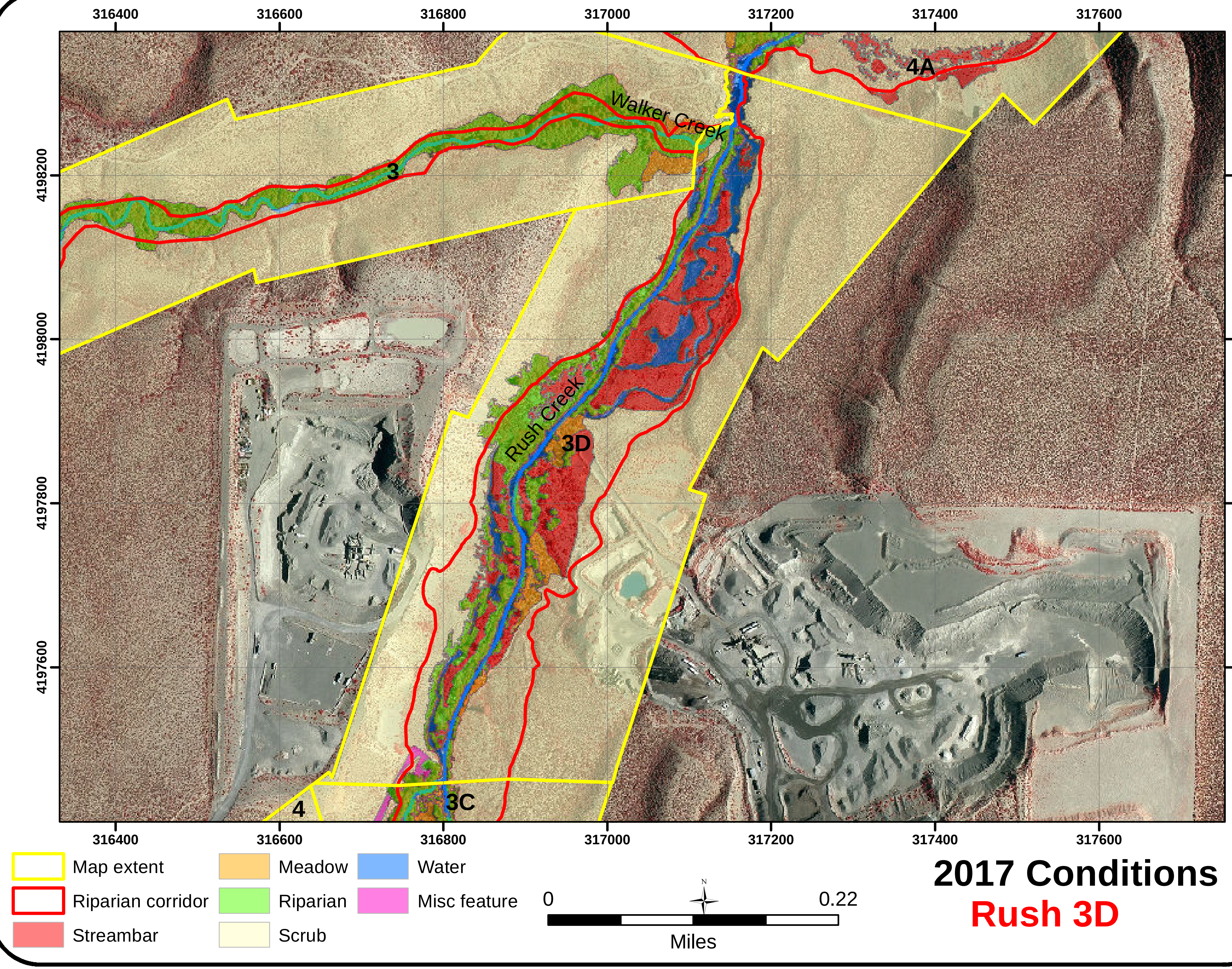


2017 Conditions
Rush 3B



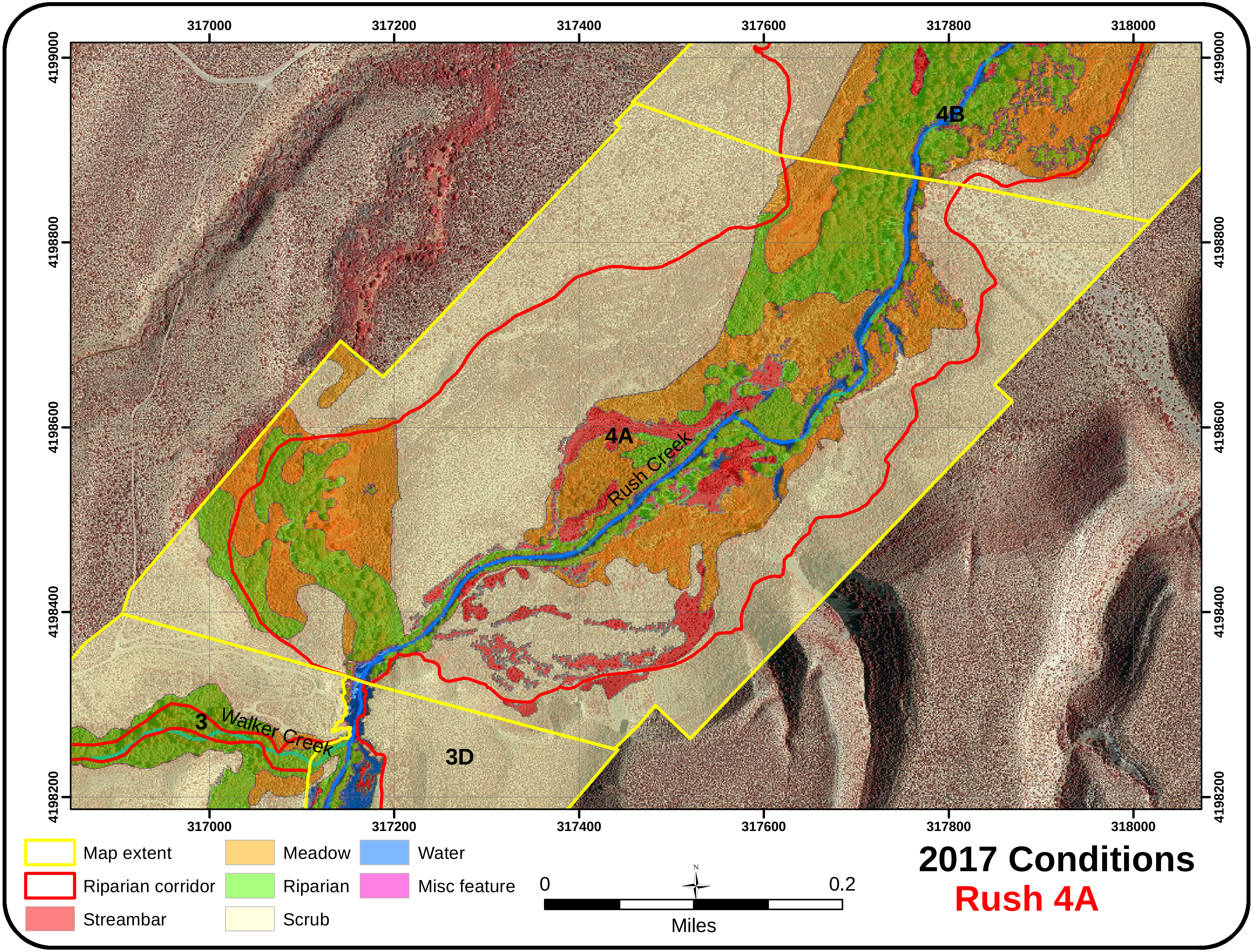
2017 Conditions

Rush 3C



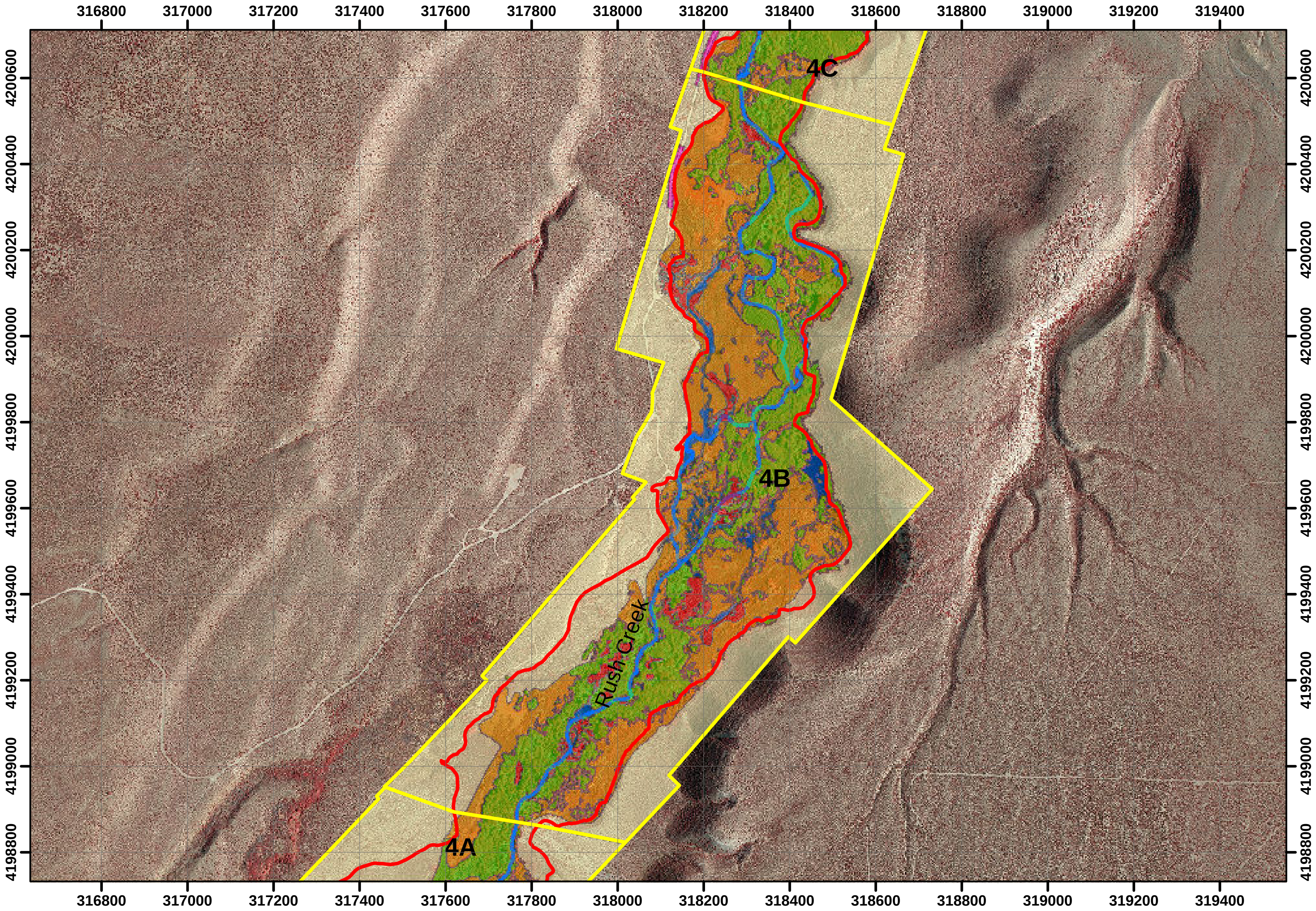
2017 Conditions

Rush 3D



2017 Conditions

Rush 4A

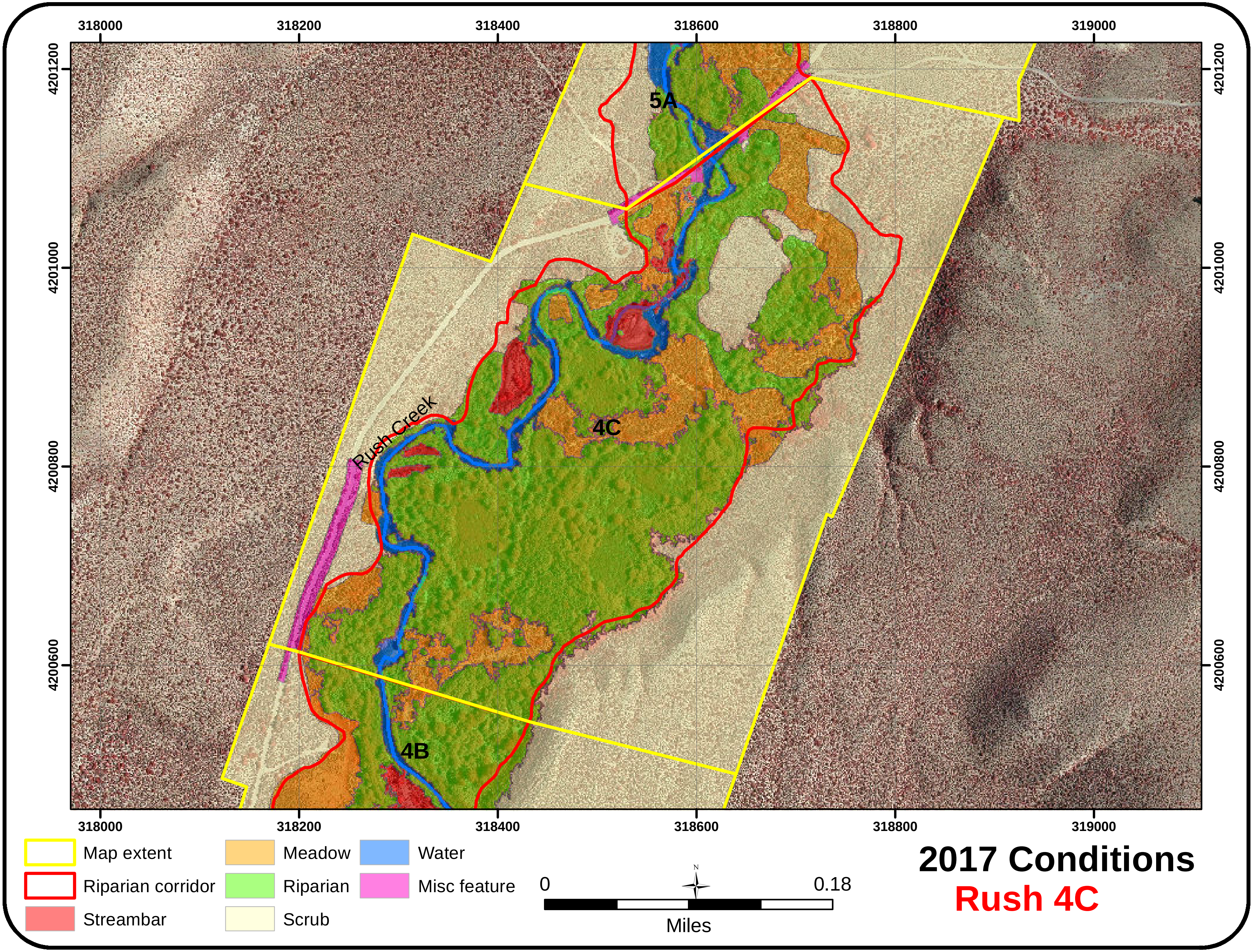


Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature

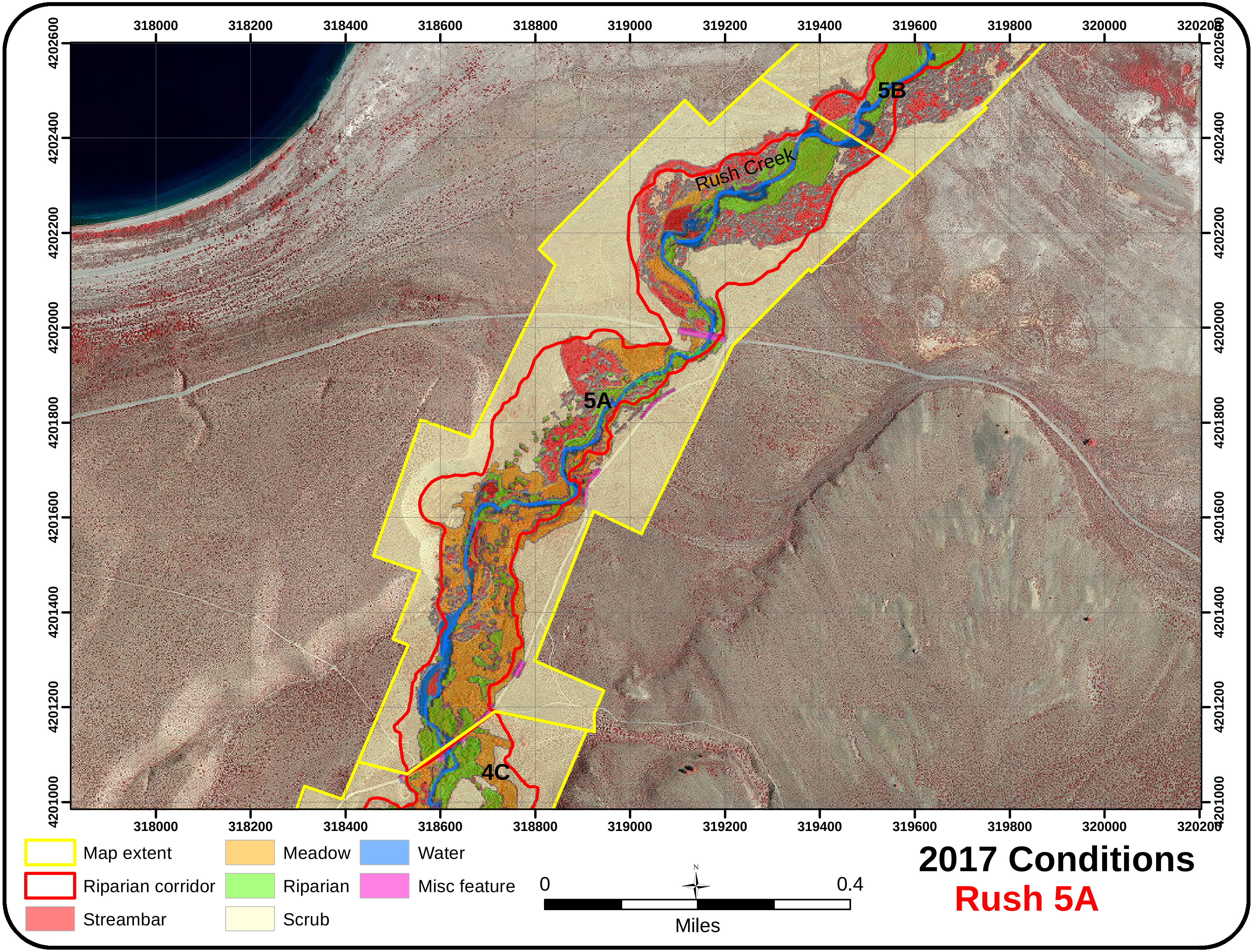
0 0.4
Miles

2017 Conditions

Rush 4B



318000
318200
318400
318600
318800
319000
4201200
4201000
4200800
4200600
5A
4C
4B
Rush Creek
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.18
Miles
N
2017 Conditions
Rush 4C



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318200
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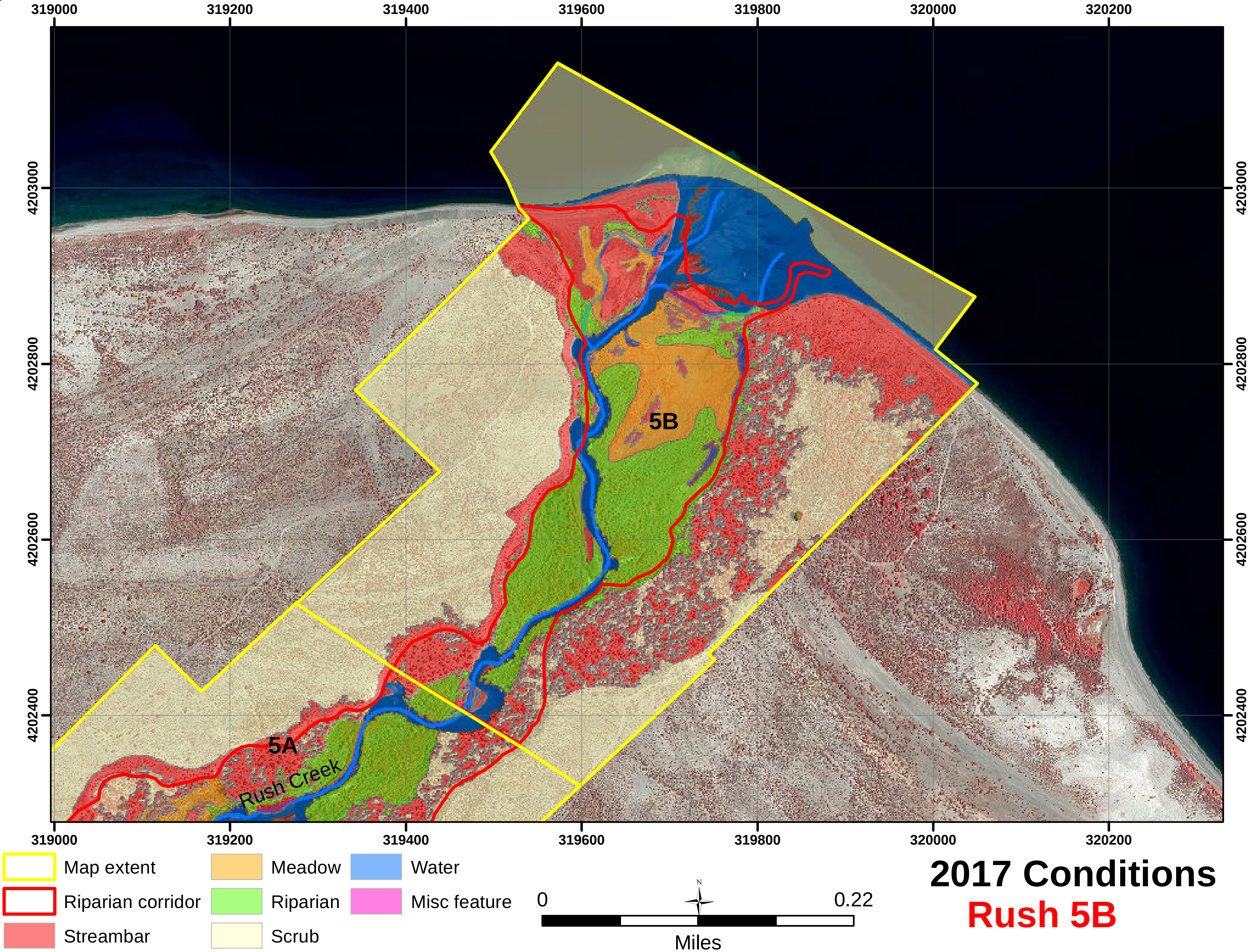
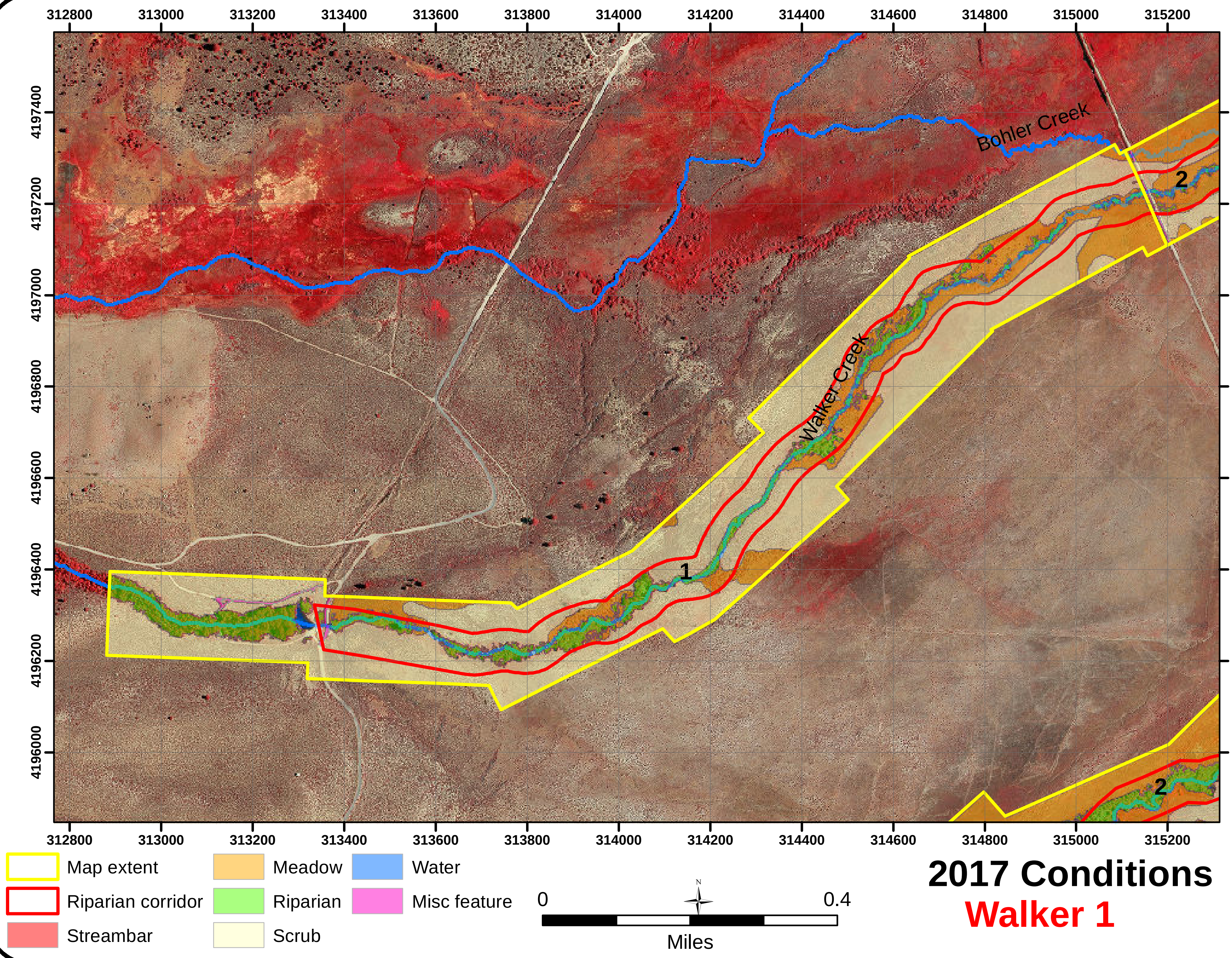
319400
319600
319800
320000
320200
4202600
4202400
4202200
4202000
4201800
4201600
4201400
4201200
4201000
5B
Rush Creek
5A
4C
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.4
Miles
N
2017 Conditions
Rush 5A

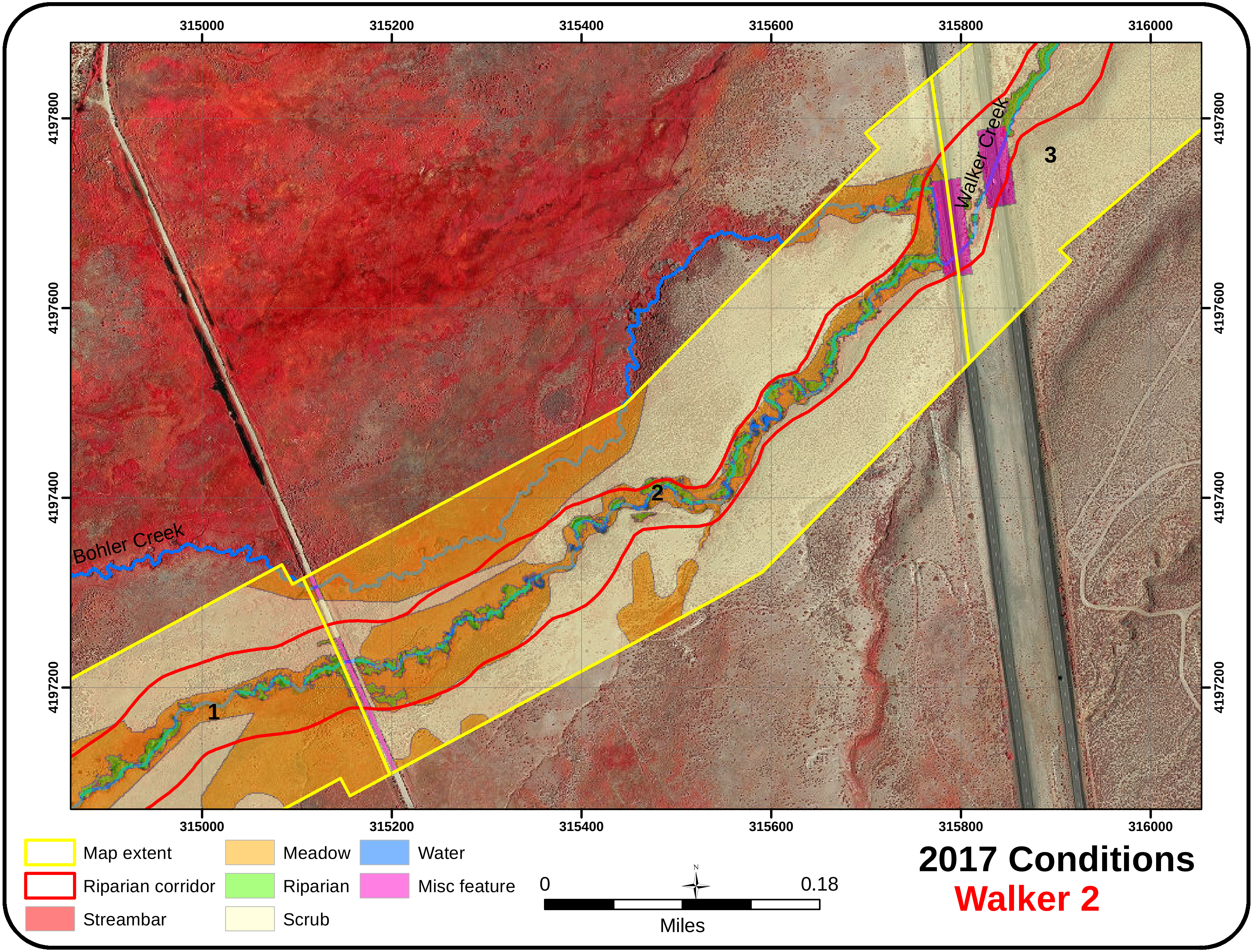


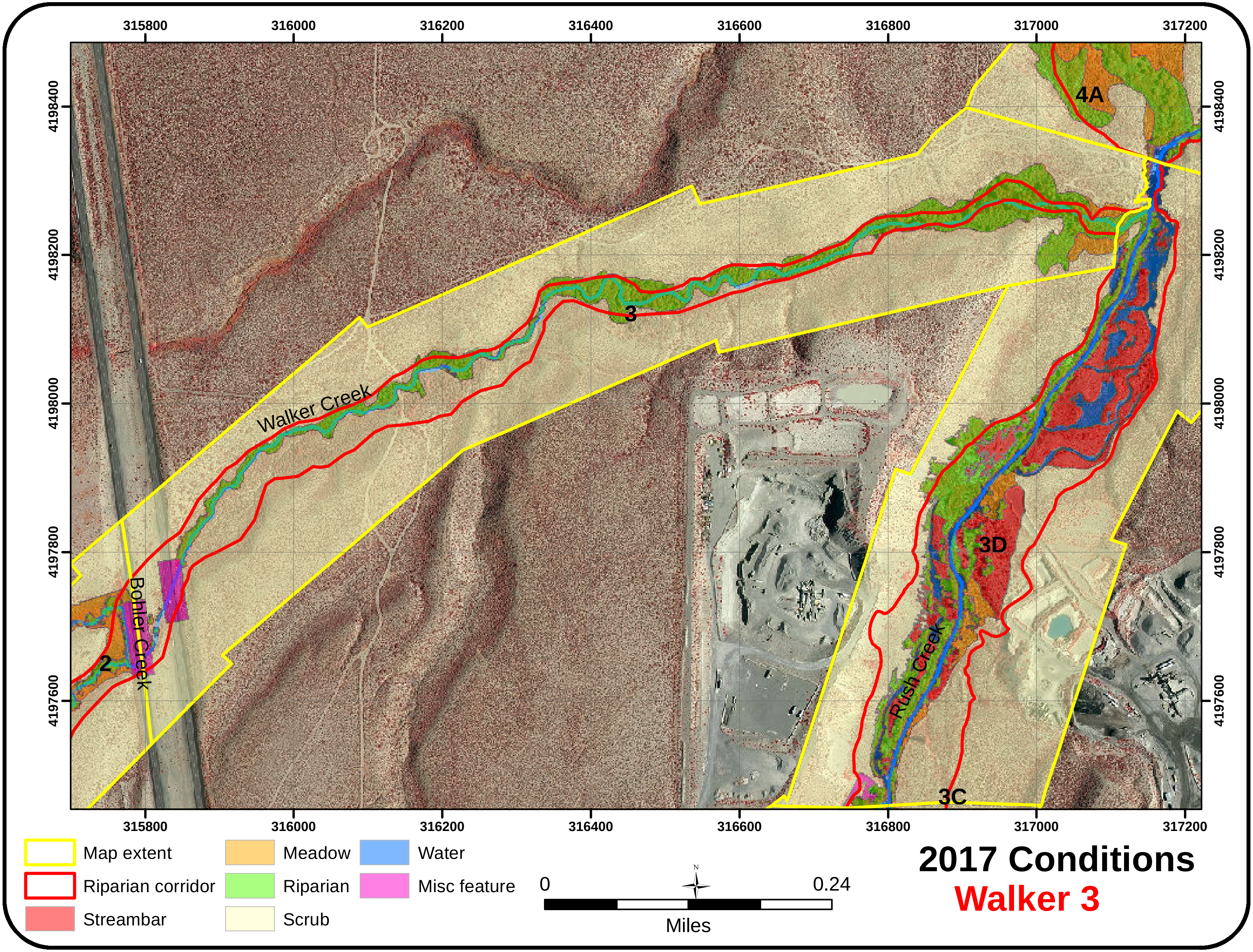
2017 Conditions

Rush 5B



2017 Conditions
Walker 1


315000
315200
315400
315600
315800
316000
4197800
4197600
4197400
4197200
Bohler Creek
Walker Creek
1
2
3
Map extent
Riparian corridor
Streambar
Meadow
Riparian
Scrub
Water
Misc feature
0
0.18
Miles
N
2017 Conditions
Walker 2



2017 Conditions

Walker 3

APPENDIX G
VEG TYPES IN RIPARIAN CORRIDOR
1929-2017 CONDITIONS

Table G-1. Area of vegetation types in riparian corridor by stream reach.

Stream	Reach	Veg Type	1929		1999		2004		2009		2014		2017	
			(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)
Lee Vining	1	Streambar	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lee Vining	1	Meadow	0.0	0.0	0.0	0.0	9.9	21.7	0.0	0.0	8.1	17.8	7.8	17.2
Lee Vining	1	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lee Vining	1	Not mapped	45.3	100.0	45.3	100.0	0.0	0.0	45.3	100.0	0.0	0.0	0.0	0.0
Lee Vining	1	Riparian	0.0	0.0	0.0	0.0	27.9	61.5	0.0	0.0	31.7	69.8	30.9	68.2
Lee Vining	1	Scrub	0.0	0.0	0.0	0.0	1.5	3.3	0.0	0.0	2.5	5.5	3.8	8.4
Lee Vining	1	Water	0.0	0.0	0.0	0.0	2.0	4.5	0.0	0.0	1.4	3.2	1.8	3.9
Lee Vining	1	Misc feature	0.0	0.0	0.0	0.0	4.1	9.0	0.0	0.0	1.7	3.7	1.0	2.2
Lee Vining	TOTAL		45.3	100.0	45.3	100.0	45.3	100.0	45.3	100.0	45.3	100.0	45.3	100.0
Lee Vining	2A	Streambar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.1	0.4
Lee Vining	2A	Meadow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lee Vining	2A	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lee Vining	2A	Not mapped	30.0	89.4	33.5	99.9	0.0	0.0	31.5	94.0	0.0	0.0	0.0	0.0
Lee Vining	2A	Riparian	0.7	2.0	0.0	0.0	15.7	46.9	0.0	0.1	15.3	45.6	18.6	55.3
Lee Vining	2A	Scrub	2.6	7.9	0.0	0.0	13.3	39.7	0.1	0.3	15.8	47.1	12.6	37.6
Lee Vining	2A	Water	0.1	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.6	0.3	0.8
Lee Vining	2A	Misc feature	0.2	0.5	0.0	0.0	4.5	13.4	1.9	5.6	2.1	6.3	2.0	5.9
Lee Vining	TOTAL		33.6	100.0	33.6	100.0	33.6	100.0	33.6	100.0	33.6	100.0	33.6	100.0
Lee Vining	2B	Streambar	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
Lee Vining	2B	Meadow	0.0	0.0	0.0	0.0	0.1	0.8	0.0	0.0	0.0	0.3	0.3	2.6
Lee Vining	2B	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lee Vining	2B	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lee Vining	2B	Riparian	9.0	68.8	9.1	69.7	10.1	77.0	10.4	79.3	10.5	80.2	11.3	86.9
Lee Vining	2B	Scrub	3.6	27.4	2.0	15.1	2.3	17.4	2.1	16.3	1.3	9.6	0.9	7.0
Lee Vining	2B	Water	0.5	3.8	1.6	12.5	0.3	2.5	0.3	2.2	1.3	9.6	0.5	3.5
Lee Vining	2B	Misc feature	0.0	0.0	0.3	2.5	0.3	2.3	0.3	2.0	0.0	0.3	0.0	0.1
Lee Vining	TOTAL		13.1	100.0	13.1	100.0	13.1	100.0	13.1	100.0	13.1	100.0	13.1	100.0
Lee Vining	3A	Streambar	0.2	0.6	0.3	1.0	0.5	1.7	0.5	1.7	0.8	2.8	1.5	4.8
Lee Vining	3A	Meadow	2.7	8.8	2.2	7.0	0.9	2.9	0.8	2.7	12.3	40.0	9.4	30.8
Lee Vining	3A	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lee Vining	3A	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lee Vining	3A	Riparian	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table G-1. Area of vegetation types in riparian corridor by stream reach.															
Stream	Reach	Veg Type	1929		1999		2004		2009		2014		2017	
			(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)
Lee Vining	3A	Scrub	18.5	60.4	11.3	36.8	6.9	22.4	9.5	30.9	12.2	39.9	12.0	39.1
Lee Vining	3A	Water	8.5	27.8	12.3	40.2	20.0	65.4	17.9	58.3	3.6	11.6	6.2	20.2
Lee Vining	3A	Misc feature	0.7	2.4	4.6	15.0	2.3	7.5	1.9	6.3	1.8	5.7	1.6	5.1
Lee Vining	TOTAL		30.6	100.0	30.6	100.0	30.6	100.0	30.6	100.0	30.7	100.0	30.7	100.0
Lee Vining	3B	Streambar	0.2	0.4	1.0	1.8	0.8	1.5	0.4	0.7	0.5	0.9	0.9	1.6
Lee Vining	3B	Meadow	10.9	19.4	4.5	8.1	1.8	3.2	1.4	2.5	21.4	38.3	18.1	32.3
Lee Vining	3B	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lee Vining	3B	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lee Vining	3B	Riparian	36.7	65.7	21.2	37.9	17.9	32.0	20.8	37.3	23.1	41.4	24.2	43.2
Lee Vining	3B	Scrub	6.7	12.0	23.6	42.2	31.3	56.1	30.0	53.6	9.2	16.4	11.0	19.6
Lee Vining	3B	Water	1.2	2.1	5.2	9.3	3.5	6.2	2.7	4.9	1.7	3.0	1.5	2.7
Lee Vining	3B	Misc feature	0.2	0.4	0.4	0.8	0.6	1.0	0.6	1.0	0.0	0.0	0.3	0.6
Lee Vining	TOTAL		55.9	100.0	55.9	100.0	55.9	100.0	55.9	100.0	55.9	100.0	55.9	100.0
Lee Vining	3C	Streambar	5.9	40.3	2.5	17.0	2.1	14.0	1.9	13.1	2.7	18.6	2.4	16.4
Lee Vining	3C	Meadow	2.8	19.2	0.3	2.1	0.3	2.0	0.0	0.0	2.5	16.9	2.9	19.8
Lee Vining	3C	Mono Lake	0.5	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lee Vining	3C	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lee Vining	3C	Riparian	4.5	30.6	5.2	35.6	5.4	36.8	5.7	38.6	5.6	38.1	6.0	40.7
Lee Vining	3C	Scrub	0.0	0.0	5.9	40.0	6.3	42.5	6.2	42.2	3.4	23.3	2.9	19.6
Lee Vining	3C	Water	0.8	5.5	0.8	5.1	0.4	2.6	0.6	4.3	0.4	3.0	0.5	3.3
Lee Vining	3C	Misc feature	0.1	0.7	0.0	0.2	0.3	2.1	0.3	1.8	0.0	0.0	0.0	0.3
Lee Vining	TOTAL		14.7	100.0	14.7	100.0	14.7	100.0	14.7	100.0	14.7	100.0	14.7	100.0
Lee Vining	3D	Streambar	0.0	0.0	5.0	20.0	6.0	23.9	5.4	21.5	10.6	42.2	6.6	26.4
Lee Vining	3D	Meadow	0.0	0.0	1.9	7.7	2.3	9.1	1.6	6.4	2.9	11.7	3.4	13.8
Lee Vining	3D	Mono Lake	24.9	99.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Lee Vining	3D	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lee Vining	3D	Riparian	0.0	0.0	12.4	49.5	13.2	52.5	14.3	56.8	9.7	38.6	11.7	46.9
Lee Vining	3D	Scrub	0.0	0.0	1.0	3.8	2.2	8.9	1.3	5.2	0.3	1.3	0.2	0.7
Lee Vining	3D	Water	0.2	0.7	4.8	19.0	1.4	5.5	2.5	10.1	1.5	6.1	3.1	12.2
Lee Vining	3D	Misc feature	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lee Vining	TOTAL		25.1	100.0	25.1	100.0	25.1	100.0	25.1	100.0	25.0	100.0	25.0	100.0

Table G-1. Area of vegetation types in riparian corridor by stream reach.

Stream	Reach	Veg Type	1929		1999		2004		2009		2014		2017	
			(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)
Lee Vining	ALL	Streambar	6.3	2.9	8.8	4.0	9.4	4.3	8.3	3.8	14.8	6.8	11.5	5.3
Lee Vining	ALL	Meadow	16.4	7.5	8.9	4.1	15.2	7.0	3.8	1.7	47.2	21.6	42.0	19.3
Lee Vining	ALL	Mono Lake	25.5	11.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lee Vining	ALL	Not mapped	75.3	34.5	78.8	36.1	0.0	0.0	76.8	35.2	0.0	0.0	0.0	0.0
Lee Vining	ALL	Riparian	50.9	23.3	48.0	22.0	90.2	41.3	51.2	23.5	95.8	43.9	102.8	47.1
Lee Vining	ALL	Scrub	31.4	14.4	43.7	20.0	63.8	29.2	49.2	22.5	44.8	20.5	43.4	19.9
Lee Vining	ALL	Water	11.3	5.2	24.7	11.3	27.7	12.7	24.1	11.0	10.1	4.6	13.8	6.3
Lee Vining	ALL	Misc feature	1.3	0.6	5.4	2.5	12.1	5.5	4.9	2.2	5.6	2.6	4.9	2.3
Lee Vining	ALL	TOT	218.4	100.0	218.4	100.0	218.4	100.0	218.4	100.0	218.3	100.0	218.3	100.0
Parker	1	Streambar	0.0	0.0	0.1	0.3	0.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Parker	1	Meadow	23.1	61.3	8.0	21.4	5.6	14.9	0.0	0.0	10.1	26.8	10.1	26.9
Parker	1	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parker	1	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	37.6	100.0	0.0	0.0	0.0	0.0
Parker	1	Riparian	6.1	16.2	14.1	37.4	14.6	38.8	0.0	0.0	12.5	33.4	13.0	34.5
Parker	1	Scrub	8.4	22.4	15.0	39.9	17.0	45.3	0.0	0.0	14.7	39.2	14.0	37.1
Parker	1	Water	0.0	0.0	0.0	0.0	0.2	0.5	0.0	0.0	0.0	0.0	0.1	0.1
Parker	1	Misc feature	0.0	0.0	0.4	1.0	0.0	0.0	0.0	0.0	0.3	0.7	0.5	1.4
Parker	TOTAL		37.6	100.0	37.6	100.0	37.6	100.0	37.6	100.0	37.6	100.0	37.6	100.0
Parker	2	Streambar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parker	2	Meadow	22.9	38.7	32.3	54.6	24.9	42.0	0.0	0.0	14.8	25.1	19.9	33.7
Parker	2	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parker	2	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	59.1	100.0	0.0	0.0	0.0	0.0
Parker	2	Riparian	35.6	60.2	22.1	37.3	23.8	40.3	0.0	0.0	28.6	48.3	29.3	49.5
Parker	2	Scrub	0.4	0.8	4.4	7.5	9.4	15.9	0.0	0.0	15.6	26.3	9.8	16.6
Parker	2	Water	0.0	0.0	0.0	0.0	0.7	1.2	0.0	0.0	0.0	0.0	0.0	0.1
Parker	2	Misc feature	0.2	0.4	0.4	0.6	0.4	0.6	0.0	0.0	0.2	0.3	0.1	0.2
Parker	TOTAL		59.1	100.0	59.1	100.0	59.1	100.0	59.1	100.0	59.2	100.0	59.2	100.0
Parker	3	Streambar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parker	3	Meadow	3.8	50.3	4.1	54.1	0.5	6.5	0.0	0.0	1.8	23.8	1.1	15.0
Parker	3	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parker	3	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	7.6	100.0	0.0	0.0	0.0	0.0
Parker	3	Riparian	2.4	32.0	0.7	9.8	1.0	12.8	0.0	0.0	1.9	25.6	1.4	18.3

Table G-1. Area of vegetation types in riparian corridor by stream reach.															
Stream	Reach	Veg Type	1929		1999		2004		2009		2014		2017	
			(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)
Parker	3	Scrub	1.3	17.8	2.1	28.2	5.7	74.9	0.0	0.0	3.8	50.0	4.9	64.2
Parker	3	Water	0.0	0.0	0.6	7.7	0.3	4.2	0.0	0.0	0.0	0.0	0.1	1.4
Parker	3	Misc feature	0.0	0.0	0.0	0.3	0.1	1.5	0.0	0.0	0.1	0.7	0.1	1.1
Parker	TOTAL		7.6	100.0	7.6	100.0	7.6	100.0	7.6	100.0	7.6	100.0	7.6	100.0
Parker	4	Streambar	0.0	0.0	0.1	1.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Parker	4	Meadow	0.5	8.8	0.4	7.2	0.1	2.3	0.0	0.0	0.0	0.0	0.0	0.0
Parker	4	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parker	4	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	6.0	96.5	0.0	0.0	0.0	0.0
Parker	4	Riparian	3.7	59.3	1.5	23.6	2.2	36.1	0.0	0.4	3.6	57.5	2.2	35.3
Parker	4	Scrub	1.9	30.9	2.4	39.0	2.4	39.3	0.2	3.0	2.4	38.9	3.5	56.0
Parker	4	Water	0.1	1.0	1.3	21.3	0.7	12.0	0.0	0.2	0.0	0.6	0.2	3.1
Parker	4	Misc feature	0.0	0.0	0.5	7.9	0.6	10.1	0.0	0.0	0.2	3.0	0.3	5.6
Parker	TOTAL		6.2	100.0	6.2	100.0	6.2	100.0	6.2	100.0	6.2	100.0	6.2	100.0
Parker	ALL	Streambar	0.0	0.0	0.2	0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Parker	ALL	Meadow	50.3	45.5	44.9	40.6	31.1	28.1	0.0	0.0	26.7	24.2	31.2	28.2
Parker	ALL	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parker	ALL	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	110.3	99.8	0.0	0.0	0.0	0.0
Parker	ALL	Riparian	47.8	43.2	38.3	34.7	41.6	37.7	0.0	0.0	46.6	42.2	45.8	41.5
Parker	ALL	Scrub	12.1	11.0	24.0	21.7	34.5	31.2	0.2	0.2	36.5	33.0	32.1	29.0
Parker	ALL	Water	0.1	0.1	1.9	1.7	2.0	1.8	0.0	0.0	0.0	0.0	0.4	0.4
Parker	ALL	Misc feature	0.2	0.2	1.2	1.1	1.1	1.0	0.0	0.0	0.7	0.6	1.1	1.0
Parker	ALL	TOT	110.5	100.0	110.5	100.0	110.5	100.0	110.5	100.0	110.5	100.0	110.5	100.0
Rush	1	Streambar	0.0	0.0	0.0	0.0	1.2	3.1	2.5	6.5	2.9	7.4	0.0	0.1
Rush	1	Meadow	0.0	0.0	0.0	0.0	3.9	10.0	0.8	2.0	0.0	0.0	1.0	2.7
Rush	1	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	1	Not mapped	34.1	87.7	38.0	97.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	1	Riparian	2.9	7.5	0.0	0.0	1.8	4.8	1.6	4.1	0.9	2.4	0.6	1.4
Rush	1	Scrub	0.8	2.1	0.8	2.1	28.8	74.1	30.7	79.1	34.9	90.0	33.0	84.9
Rush	1	Water	0.4	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	10.3
Rush	1	Misc feature	0.6	1.5	0.0	0.0	3.1	8.0	3.2	8.3	0.1	0.2	0.2	0.6
Rush	TOTAL		38.8	100.0	38.8	100.0	38.8	100.0	38.8	100.0	38.8	100.0	38.8	100.0
Rush	2	Streambar	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.8	0.2	1.7

Table G-1. Area of vegetation types in riparian corridor by stream reach.														
Stream	Reach	Veg Type	1929		1999		2004		2009		2014		2017	
			(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)
Rush	2	Meadow	0.0	0.2	0.0	0.0	0.1	1.4	0.1	0.6	0.0	0.0	0.2	1.9
Rush	2	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	2	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	2	Riparian	4.6	47.1	5.6	56.9	6.5	66.7	6.9	70.3	6.2	63.1	6.6	67.6
Rush	2	Scrub	4.2	42.7	2.6	26.1	1.7	17.7	1.5	15.4	1.3	13.3	1.4	14.6
Rush	2	Water	0.7	7.6	1.7	16.9	1.1	11.3	1.0	10.7	2.2	22.8	1.4	13.9
Rush	2	Misc feature	0.2	2.4	0.0	0.0	0.3	2.8	0.3	2.9	0.0	0.0	0.0	0.2
Rush	TOTAL		9.8	100.0	9.8	100.0	9.8	100.0	9.8	100.0	9.8	100.0	9.8	100.0
Rush	3A	Streambar	0.0	0.0	0.2	0.6	0.6	1.5	0.3	0.7	0.6	1.7	0.2	0.4
Rush	3A	Meadow	3.4	8.8	6.6	17.0	3.0	7.9	2.7	6.9	9.4	24.4	10.0	25.9
Rush	3A	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	3A	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	3A	Riparian	24.2	62.8	13.2	34.3	13.6	35.3	17.4	45.2	18.0	46.7	16.9	43.8
Rush	3A	Scrub	9.5	24.8	15.5	40.2	18.5	47.9	15.9	41.2	8.2	21.3	9.1	23.6
Rush	3A	Water	1.3	3.3	3.0	7.8	2.3	6.0	1.9	4.9	2.3	5.9	2.4	6.3
Rush	3A	Misc feature	0.1	0.3	0.0	0.0	0.5	1.3	0.4	1.0	0.0	0.0	0.0	0.0
Rush	TOTAL		38.5	100.0	38.5	100.0	38.5	100.0	38.5	100.0	38.6	100.0	38.6	100.0
Rush	3B	Streambar	0.2	1.2	0.0	0.1	1.7	9.5	0.0	0.2	2.7	15.0	2.5	14.0
Rush	3B	Meadow	1.6	8.8	0.7	4.2	0.0	0.3	0.3	1.7	1.0	5.9	0.8	4.2
Rush	3B	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	3B	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	3B	Riparian	3.7	20.8	1.1	6.4	2.8	15.7	5.0	28.2	6.2	34.7	5.3	30.0
Rush	3B	Scrub	10.6	59.4	13.2	74.2	9.7	54.3	10.2	57.2	6.3	35.3	7.1	40.2
Rush	3B	Water	0.8	4.5	2.1	11.8	2.1	11.9	1.7	9.4	1.4	7.8	1.7	9.5
Rush	3B	Misc feature	1.0	5.4	0.6	3.2	1.5	8.3	0.6	3.3	0.2	1.3	0.4	2.0
Rush	TOTAL		17.8	100.0	17.8	100.0	17.8	100.0	17.8	100.0	17.8	100.0	17.8	100.0
Rush	3C	Streambar	2.5	4.7	0.1	0.2	0.6	1.0	0.0	0.1	0.8	1.5	0.5	0.9
Rush	3C	Meadow	1.3	2.5	0.2	0.5	0.2	0.4	0.1	0.1	0.0	0.0	1.8	3.4
Rush	3C	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	3C	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	3C	Riparian	16.9	31.8	8.2	15.5	9.6	17.9	10.8	20.3	14.2	26.7	10.5	19.6
Rush	3C	Scrub	30.6	57.5	37.2	69.7	36.2	67.9	36.9	69.2	34.1	64.0	36.8	69.0

Table G-1. Area of vegetation types in riparian corridor by stream reach.															
Stream	Reach	Veg Type	1929		1999		2004		2009		2014		2017	
			(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)
Rush	3C	Water	1.9	3.5	5.2	9.8	4.0	7.5	3.5	6.6	3.5	6.6	3.2	6.1
Rush	3C	Misc feature	0.0	0.0	2.3	4.3	2.8	5.2	2.0	3.7	0.6	1.1	0.5	0.9
Rush	TOTAL		53.3	100.0	53.3	100.0	53.3	100.0	53.3	100.0	53.3	100.0	53.3	100.0
Rush	3D	Streambar	0.4	1.3	0.0	0.0	6.8	24.5	4.8	17.5	11.4	41.3	7.6	27.5
Rush	3D	Meadow	5.2	19.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.3	1.1	3.8
Rush	3D	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	3D	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	3D	Riparian	10.6	38.6	4.2	15.4	5.2	18.8	6.3	23.1	5.4	19.7	6.4	23.4
Rush	3D	Scrub	10.5	38.1	14.8	53.7	7.8	28.5	12.9	46.9	8.5	31.0	8.3	30.2
Rush	3D	Water	0.8	3.0	2.5	9.2	2.3	8.5	2.8	10.2	2.1	7.5	4.0	14.6
Rush	3D	Misc feature	0.0	0.0	6.0	21.7	5.4	19.7	0.6	2.2	0.1	0.3	0.1	0.4
Rush	TOTAL		27.5	100.0	27.5	100.0	27.5	100.0	27.5	100.0	27.5	100.0	27.5	100.0
Rush	4A	Streambar	0.3	0.5	0.2	0.4	1.8	2.8	0.3	0.4	7.3	11.0	4.9	7.3
Rush	4A	Meadow	13.9	20.8	3.8	5.6	3.3	5.0	3.5	5.3	12.5	18.7	15.5	23.3
Rush	4A	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	4A	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	4A	Riparian	36.0	54.1	22.5	33.8	25.2	37.9	25.1	37.7	14.9	22.3	13.6	20.4
Rush	4A	Scrub	15.5	23.2	38.0	57.1	34.5	51.9	36.2	54.3	30.1	45.1	30.9	46.4
Rush	4A	Water	0.9	1.4	2.1	3.1	1.7	2.5	1.5	2.3	1.9	2.9	1.7	2.6
Rush	4A	Misc feature	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	TOTAL		66.6	100.0	66.6	100.0	66.6	100.0	66.6	100.0	66.6	100.0	66.6	100.0
Rush	4B	Streambar	2.4	1.7	1.5	1.0	5.3	3.6	4.2	2.9	16.5	11.2	8.2	5.6
Rush	4B	Meadow	58.8	40.0	14.2	9.7	16.2	11.0	16.9	11.5	41.8	28.4	56.0	38.1
Rush	4B	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	4B	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	4B	Riparian	70.5	48.0	61.5	41.8	62.6	42.6	67.7	46.1	70.6	48.0	61.0	41.5
Rush	4B	Scrub	10.4	7.1	64.8	44.1	58.3	39.7	53.4	36.3	12.6	8.6	11.9	8.1
Rush	4B	Water	4.1	2.8	5.1	3.4	4.5	3.1	4.9	3.3	5.7	3.8	9.9	6.7
Rush	4B	Misc feature	0.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	TOTAL		147.0	100.0	147.0	100.0	147.0	100.0	147.0	100.0	147.1	100.0	147.1	100.0
Rush	4C	Streambar	1.6	3.7	0.3	0.7	0.8	2.0	0.2	0.6	1.4	3.2	1.4	3.3
Rush	4C	Meadow	2.3	5.4	0.3	0.6	1.8	4.2	0.6	1.5	9.0	21.2	7.9	18.6

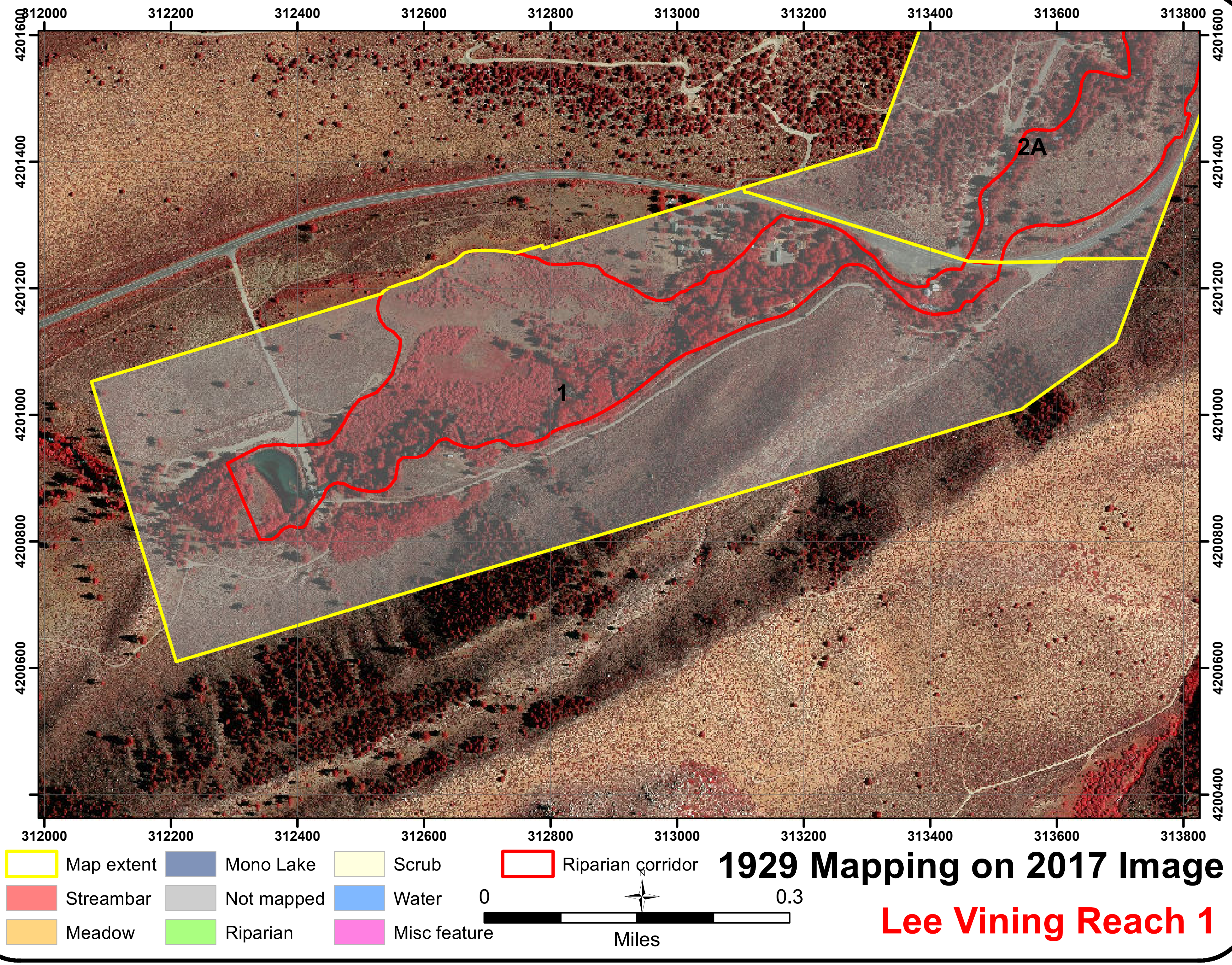
Table G-1. Area of vegetation types in riparian corridor by stream reach.														
Stream	Reach	Veg Type	1929		1999		2004		2009		2014		2017	
			(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)
Rush	4C	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	4C	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	4C	Riparian	28.0	66.2	28.5	67.3	29.9	70.6	29.1	68.9	24.8	58.4	26.1	61.3
Rush	4C	Scrub	8.5	20.0	8.2	19.3	7.7	18.2	10.1	23.9	4.7	10.9	4.7	11.0
Rush	4C	Water	1.2	2.9	2.2	5.1	2.0	4.6	1.9	4.5	2.4	5.6	2.2	5.3
Rush	4C	Misc feature	0.8	1.8	2.9	6.8	0.2	0.4	0.3	0.6	0.2	0.6	0.2	0.5
Rush	TOTAL		42.3	100.0	42.3	100.0	42.3	100.0	42.3	100.0	42.5	100.0	42.5	100.0
Rush	5A	Streambar	19.5	25.2	3.8	4.9	3.6	4.7	2.4	3.1	24.5	31.8	15.5	20.1
Rush	5A	Meadow	4.9	6.3	1.1	1.4	0.0	0.0	0.0	0.0	6.7	8.7	17.6	22.9
Rush	5A	Mono Lake	1.6	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	5A	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	5A	Riparian	32.6	42.3	26.4	34.1	26.2	33.9	27.0	34.9	20.1	26.0	16.4	21.3
Rush	5A	Scrub	15.6	20.2	40.0	51.8	41.6	53.8	43.1	55.7	21.3	27.6	20.9	27.2
Rush	5A	Water	2.7	3.5	4.4	5.7	4.1	5.3	3.8	5.0	4.1	5.3	6.0	7.8
Rush	5A	Misc feature	0.3	0.4	1.6	2.1	1.8	2.3	0.9	1.2	0.4	0.6	0.6	0.7
Rush	TOTAL		77.3	100.0	77.3	100.0	77.3	100.0	77.3	100.0	77.0	100.0	77.0	100.0
Rush	5B	Streambar	0.0	0.0	0.0	0.0	2.4	10.9	2.2	9.9	9.0	40.3	4.6	20.7
Rush	5B	Meadow	0.0	0.0	5.0	22.5	5.9	26.3	5.1	22.7	1.7	7.8	4.5	19.9
Rush	5B	Mono Lake	22.4	100.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Rush	5B	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	5B	Riparian	0.0	0.0	4.6	20.6	7.7	34.3	9.2	41.2	8.6	38.5	9.6	42.8
Rush	5B	Scrub	0.0	0.0	3.5	15.8	2.6	11.6	2.5	11.2	0.1	0.2	0.6	2.6
Rush	5B	Water	0.0	0.0	9.2	41.1	3.7	16.8	3.3	14.9	3.0	13.2	3.2	14.1
Rush	5B	Misc feature	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	TOTAL		22.4	100.0	22.4	100.0	22.4	100.0	22.4	100.0	22.4	100.0	22.4	100.0
Rush	ALL	Streambar	26.9	5.0	6.3	1.2	24.9	4.6	17.0	3.1	77.1	14.2	45.6	8.4
Rush	ALL	Meadow	91.3	16.9	31.9	5.9	34.5	6.4	30.1	5.6	82.3	15.2	116.4	21.5
Rush	ALL	Mono Lake	24.0	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	ALL	Not mapped	34.1	6.3	38.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rush	ALL	Riparian	230.2	42.5	175.9	32.5	191.1	35.3	206.3	38.1	189.9	35.1	172.9	31.9
Rush	ALL	Scrub	116.3	21.5	238.5	44.1	247.4	45.7	253.4	46.8	162.1	29.9	164.8	30.4
Rush	ALL	Water	14.9	2.7	37.4	6.9	27.9	5.1	26.4	4.9	28.5	5.3	39.8	7.3

Table G-1. Area of vegetation types in riparian corridor by stream reach.

Stream	Reach	Veg Type	1929		1999		2004		2009		2014		2017	
			(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)
Rush	ALL	Misc feature	3.7	0.7	13.4	2.5	15.5	2.9	8.3	1.5	1.7	0.3	1.9	0.4
Rush	ALL	TOT	541.4	100.0	541.4	100.0	541.4	100.0	541.4	100.0	541.5	100.0	541.5	100.0
Walker	1	Streambar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walker	1	Meadow	27.6	54.3	31.4	61.8	22.0	43.4	0.0	0.0	11.6	22.9	13.4	26.3
Walker	1	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walker	1	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	50.8	100.0	0.0	0.0	0.0	0.0
Walker	1	Riparian	23.2	45.7	13.7	27.0	12.0	23.6	0.0	0.0	10.6	20.8	10.8	21.3
Walker	1	Scrub	0.0	0.0	5.5	10.8	15.9	31.4	0.0	0.0	28.4	55.9	26.5	52.1
Walker	1	Water	0.0	0.0	0.0	0.0	0.7	1.3	0.0	0.0	0.0	0.0	0.0	0.0
Walker	1	Misc feature	0.0	0.0	0.2	0.4	0.1	0.3	0.0	0.0	0.1	0.3	0.1	0.3
Walker	TOTAL		50.8	100.0	50.8	100.0	50.8	100.0	50.8	100.0	50.8	100.0	50.8	100.0
Walker	2	Streambar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walker	2	Meadow	4.4	33.2	7.8	59.3	6.5	49.3	0.0	0.0	6.1	46.2	6.0	45.6
Walker	2	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walker	2	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	13.1	100.0	0.0	0.0	0.0	0.0
Walker	2	Riparian	7.0	53.3	0.3	2.6	0.7	5.7	0.0	0.0	1.5	11.1	2.0	14.9
Walker	2	Scrub	1.6	12.4	2.5	19.1	4.7	35.9	0.0	0.0	5.2	39.4	4.5	34.3
Walker	2	Water	0.0	0.0	0.0	0.0	0.7	5.2	0.0	0.0	0.0	0.1	0.2	1.4
Walker	2	Misc feature	0.1	1.1	2.5	19.0	0.5	4.0	0.0	0.0	0.4	3.4	0.5	3.9
Walker	TOTAL		13.1	100.0	13.1	100.0	13.1	100.0	13.1	100.0	13.1	100.0	13.1	100.0
Walker	3	Streambar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walker	3	Meadow	0.0	0.0	0.4	2.5	0.1	0.4	0.0	0.0	0.2	1.2	0.1	0.5
Walker	3	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walker	3	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	14.5	92.3	0.0	0.0	0.0	0.0
Walker	3	Riparian	10.8	68.4	7.1	45.1	6.8	42.9	1.2	7.7	6.1	38.7	6.2	39.4
Walker	3	Scrub	4.9	31.1	7.9	49.9	6.7	42.4	0.0	0.0	9.0	57.4	8.6	54.5
Walker	3	Water	0.1	0.5	0.0	0.0	0.2	1.4	0.0	0.0	0.0	0.0	0.0	0.1
Walker	3	Misc feature	0.0	0.0	0.4	2.5	2.0	12.9	0.0	0.0	0.4	2.7	0.9	5.4
Walker	TOTAL		15.7	100.0	15.7	100.0	15.7	100.0	15.7	100.0	15.7	100.0	15.7	100.0
Walker	ALL	Streambar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Walker	ALL	Meadow	31.9	40.1	39.5	49.6	28.6	35.9	0.0	0.0	17.9	22.5	19.4	24.4
Walker	ALL	Mono Lake	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

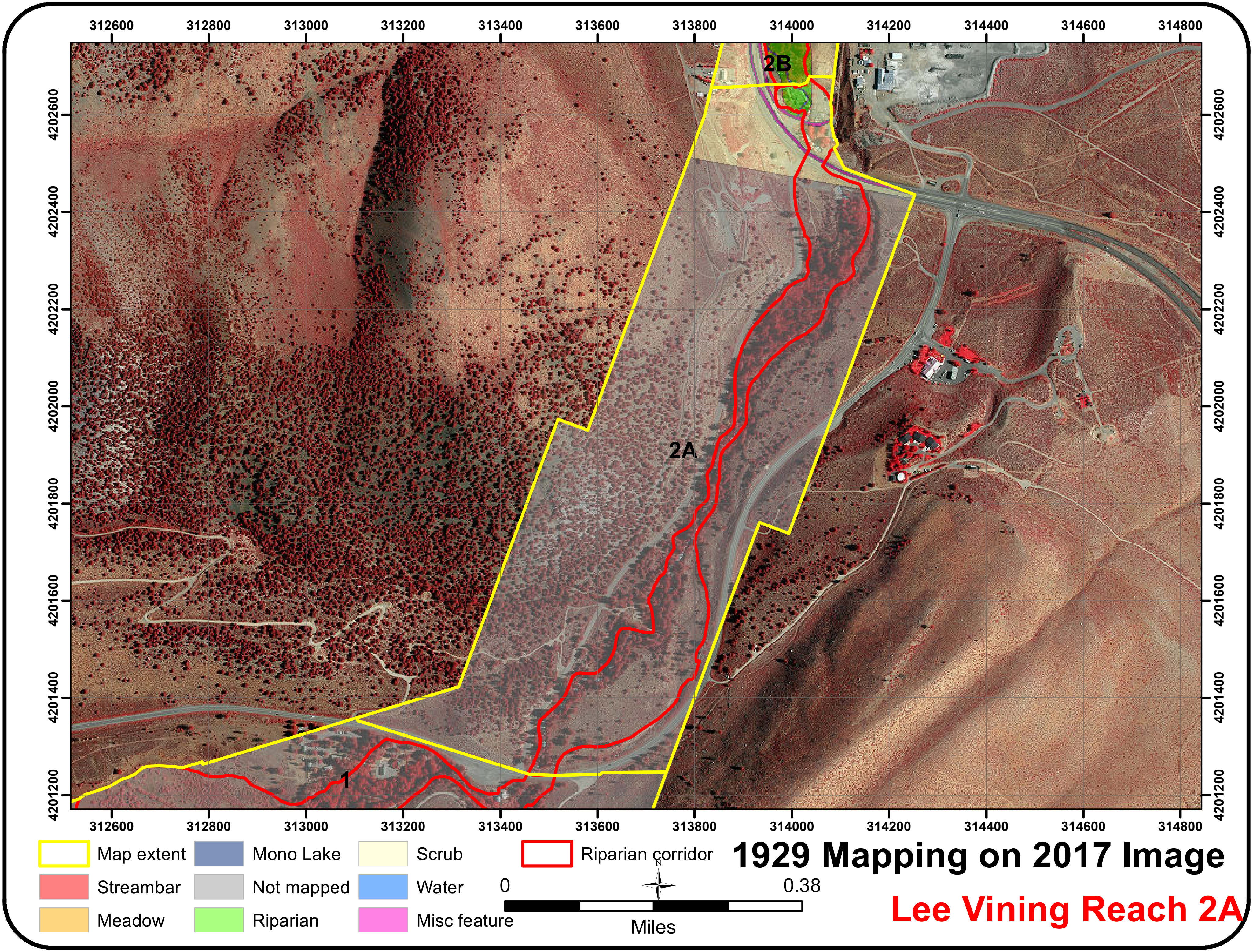
Table G-1. Area of vegetation types in riparian corridor by stream reach.														
Stream	Reach	Veg Type	1929		1999		2004		2009		2014		2017	
			(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)	(acre)	(%)
Walker	ALL	Not mapped	0.0	0.0	0.0	0.0	0.0	0.0	78.4	98.5	0.0	0.0	0.0	0.0
Walker	ALL	Riparian	41.0	51.4	21.1	26.5	19.5	24.5	1.2	1.5	18.1	22.8	19.0	23.8
Walker	ALL	Scrub	6.5	8.2	15.9	19.9	27.3	34.3	0.0	0.0	42.6	53.5	39.5	49.7
Walker	ALL	Water	0.1	0.1	0.0	0.0	1.6	2.0	0.0	0.0	0.0	0.0	0.2	0.3
Walker	ALL	Misc feature	0.1	0.2	3.1	3.9	2.7	3.4	0.0	0.0	1.0	1.3	1.5	1.9
Walker	ALL	TOT	79.6	100.0	79.6	100.0	79.6	100.0	79.6	100.0	79.6	100.0	79.6	100.0
ALL	ALL	Streambar	33.2	3.5	15.3	1.6	34.5	3.6	25.3	2.7	91.9	9.7	57.1	6.0
ALL	ALL	Meadow	189.9	20.0	125.2	13.2	109.4	11.5	33.9	3.6	174.1	18.3	209.0	22.0
ALL	ALL	Mono Lake	49.5	5.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL	ALL	Not mapped	109.4	11.5	116.8	12.3	0.0	0.0	265.5	28.0	0.0	0.0	0.0	0.0
ALL	ALL	Riparian	369.9	38.9	283.4	29.8	342.4	36.0	258.7	27.2	350.5	36.9	340.5	35.8
ALL	ALL	Scrub	166.3	17.5	322.1	33.9	373.1	39.3	302.8	31.9	285.9	30.1	279.8	29.5
ALL	ALL	Water	26.3	2.8	64.1	6.7	59.0	6.2	50.5	5.3	38.6	4.1	54.1	5.7
ALL	ALL	Misc feature	5.4	0.6	23.0	2.4	31.4	3.3	13.2	1.4	9.0	0.9	9.4	1.0
ALL	ALL	TOT	949.9	100.0	949.9	100.0	949.9	100.0	949.9	100.0	950.0	100.0	950.0	100.0

APPENDIX H
RIPARIAN MAPPING
1929 MAPPING ON 2017 IMAGE



1929 Mapping on 2017 Image

Lee Vining Reach 1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4201600
4201400
4201200
2B
2A
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Map extent
Streambar
Meadow
Mono Lake
Not mapped
Riparian
Scrub
Water
Misc feature
Riparian corridor
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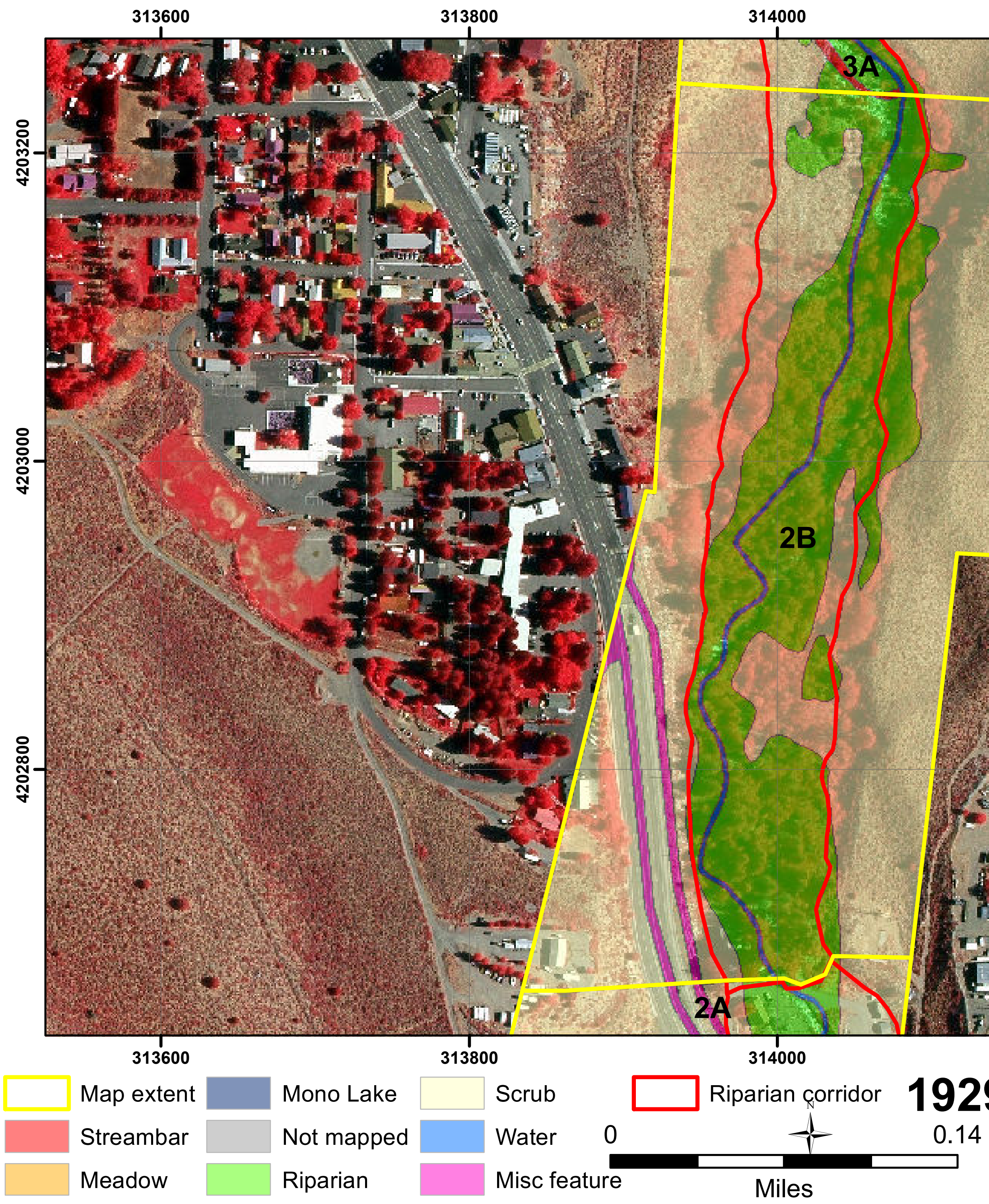
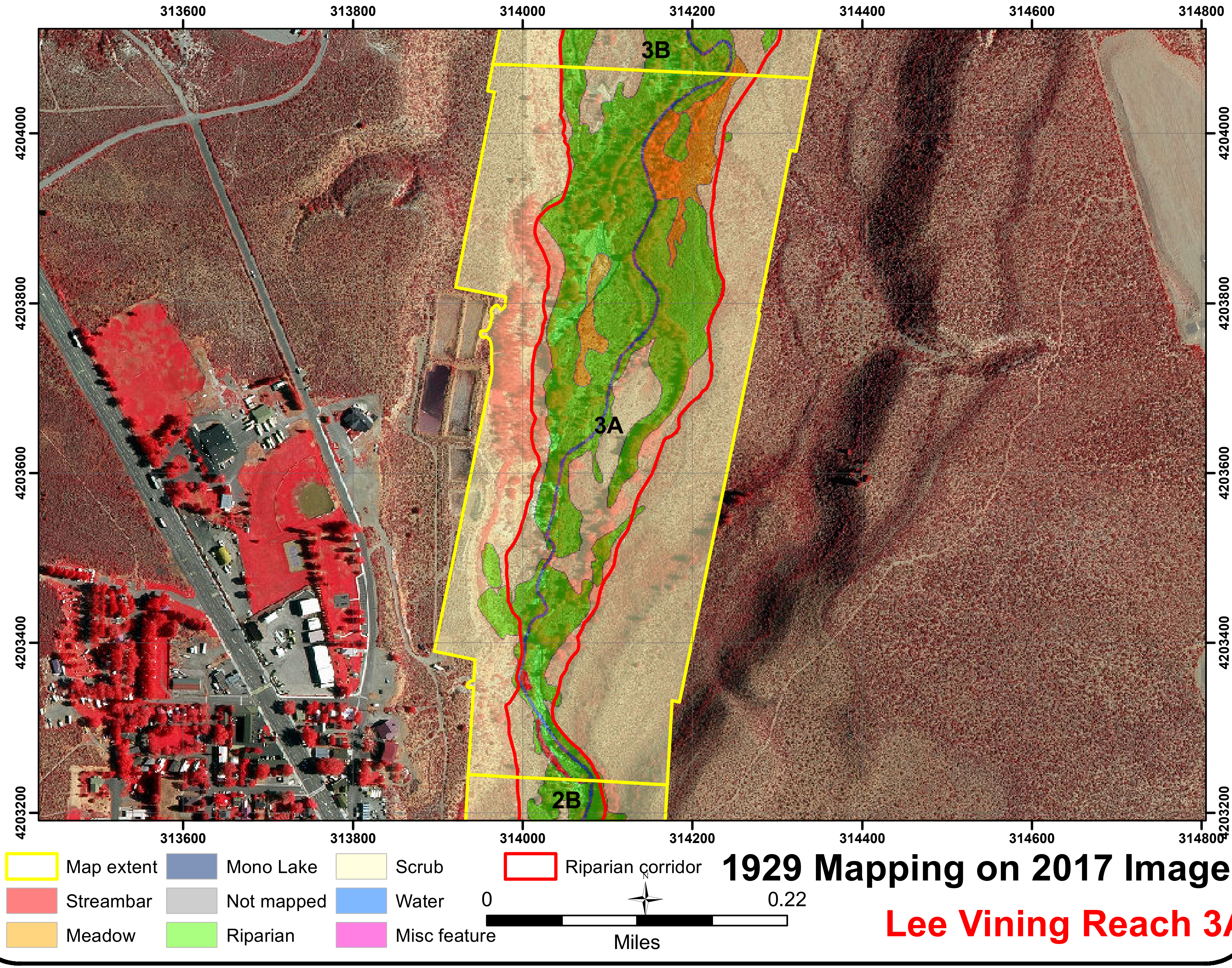
0.38
Miles
N
1929 Mapping on 2017 Image
Lee Vining Reach 2A



1929 Mapping on 2017 Image

Lee Vining Reach 2B



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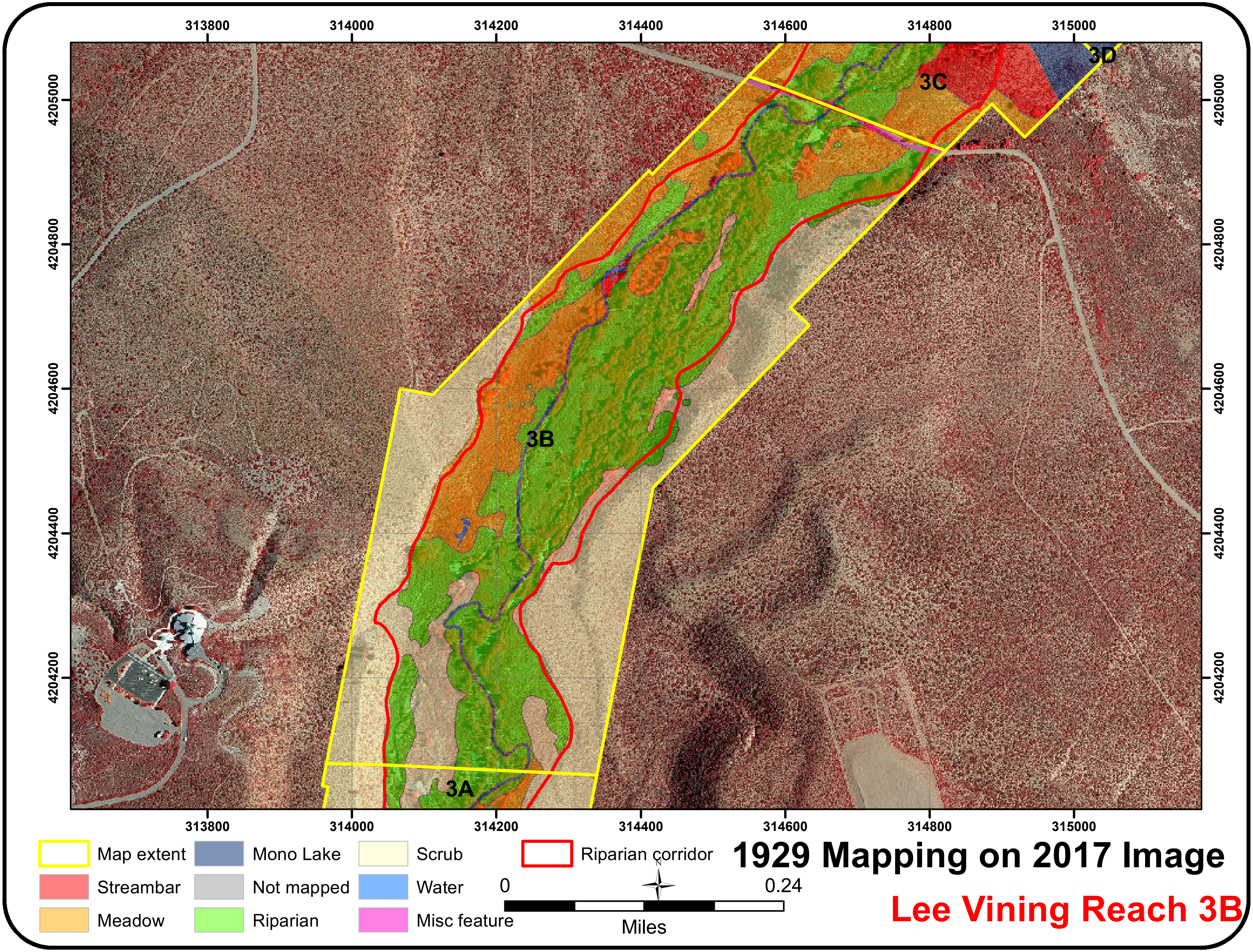

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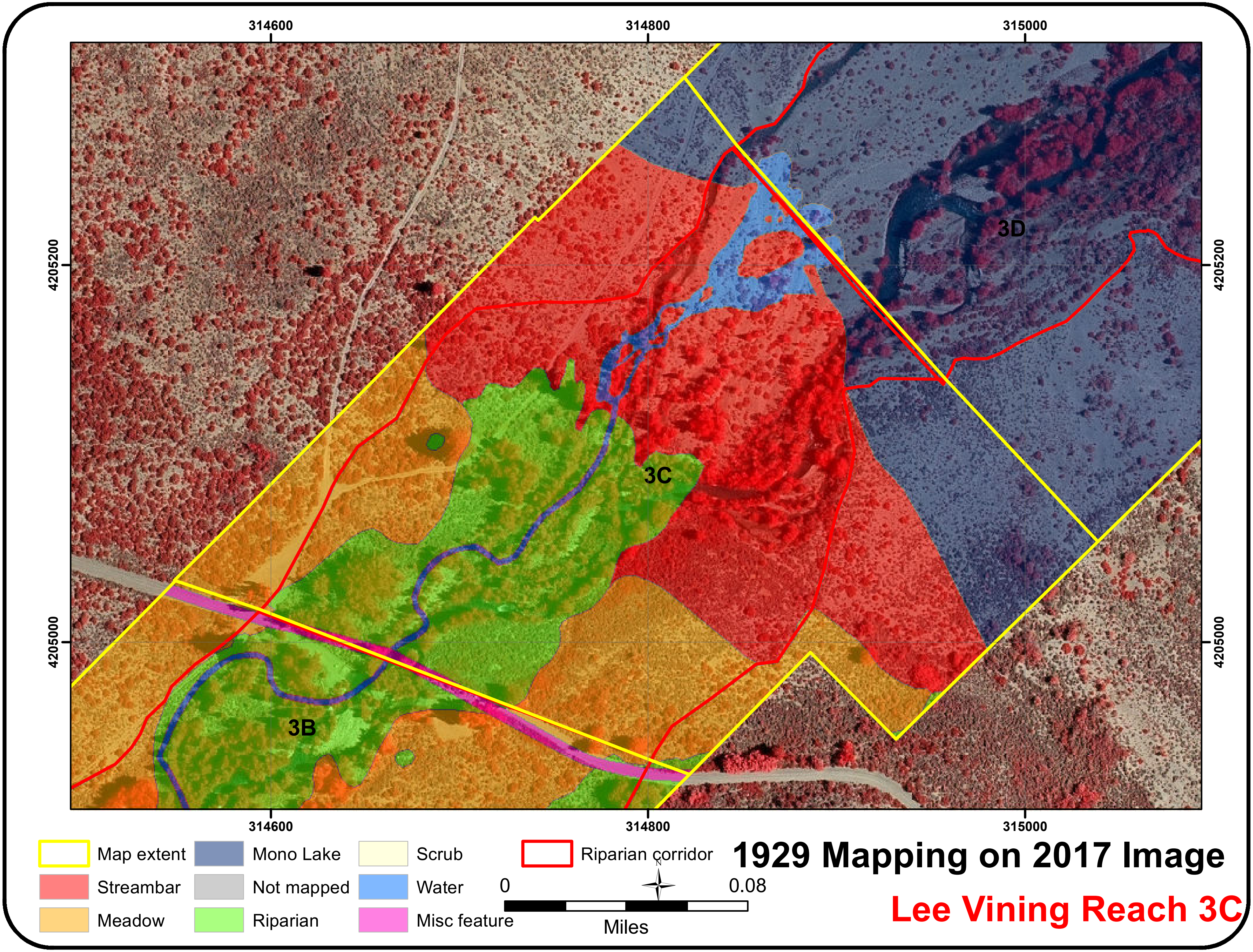

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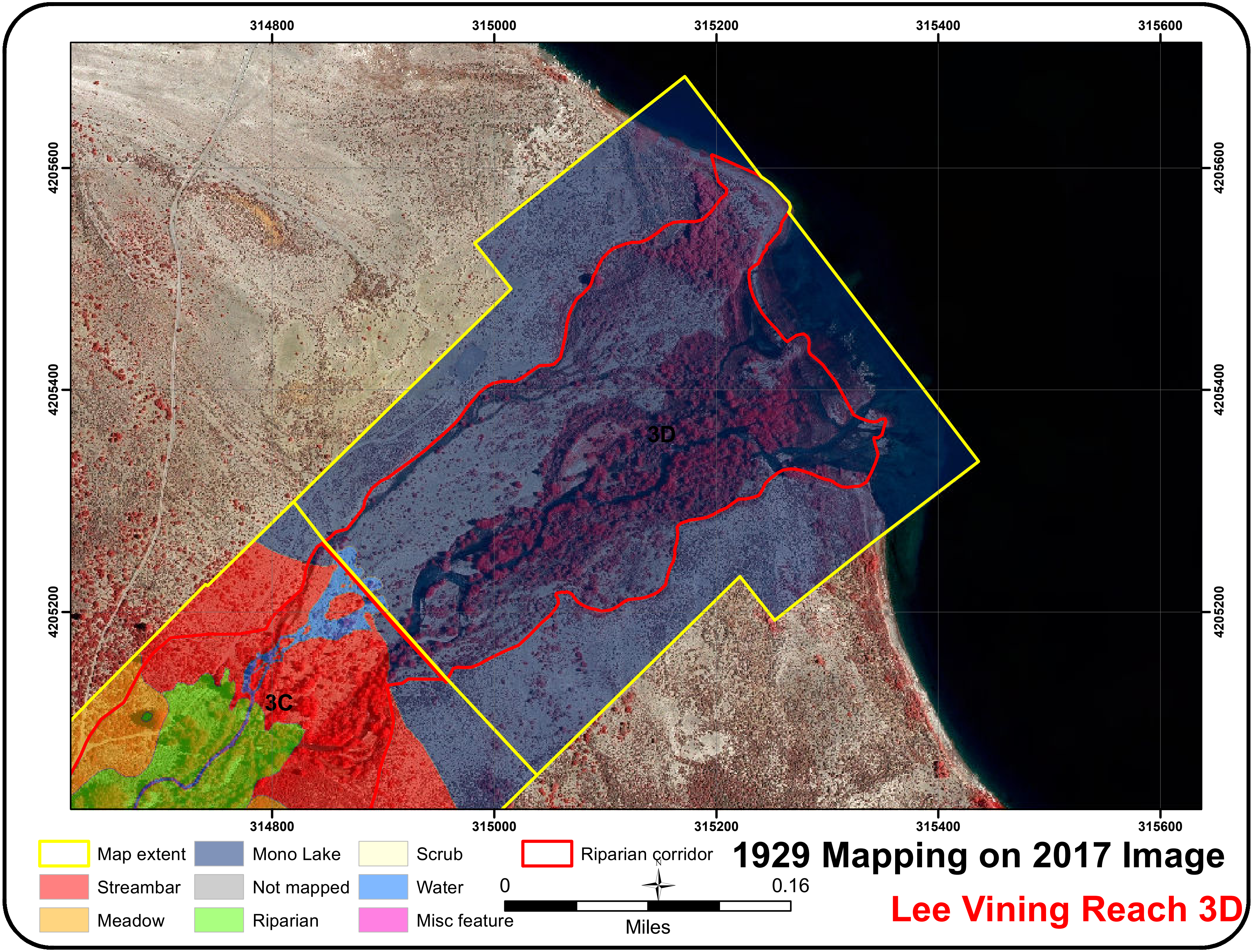

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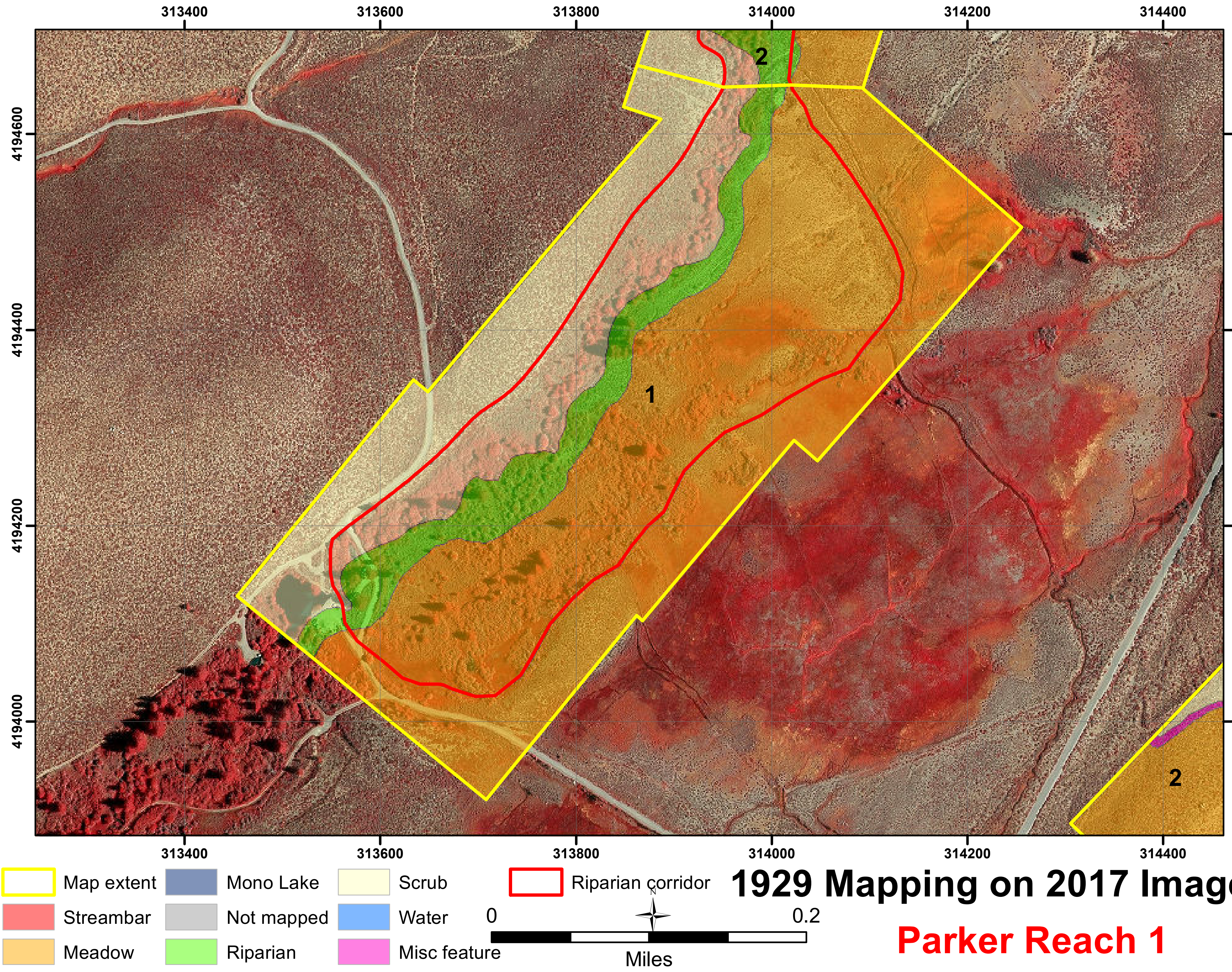

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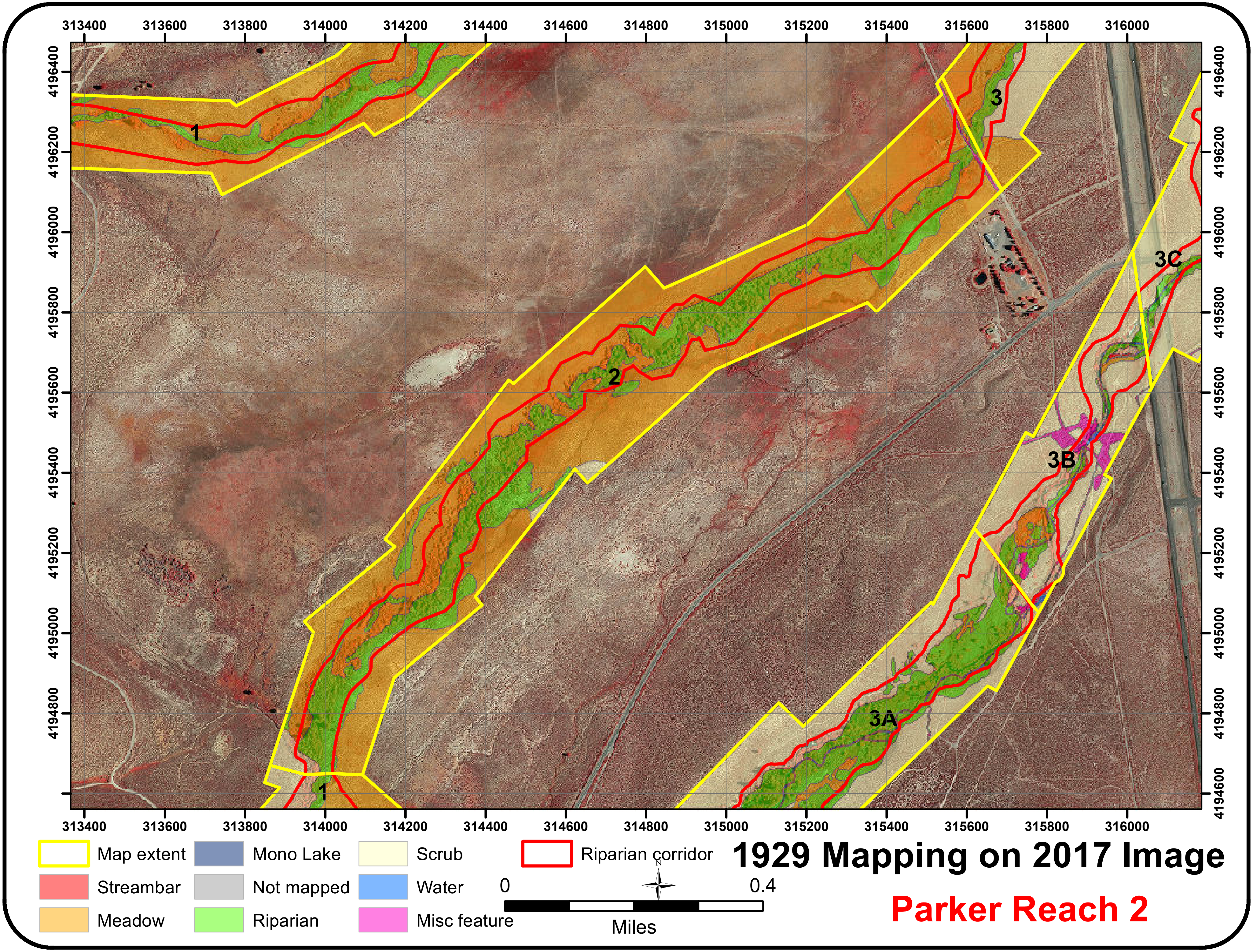

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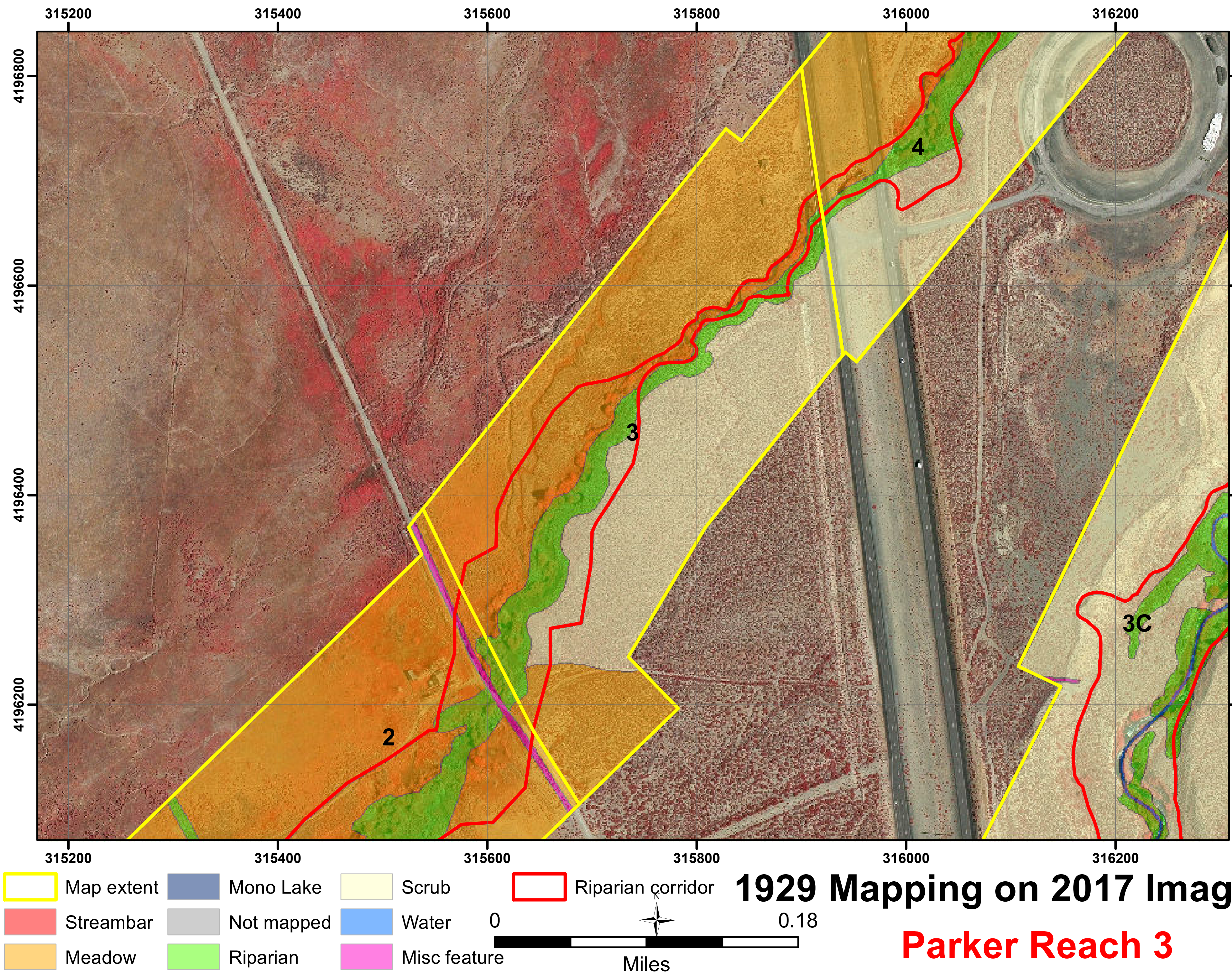

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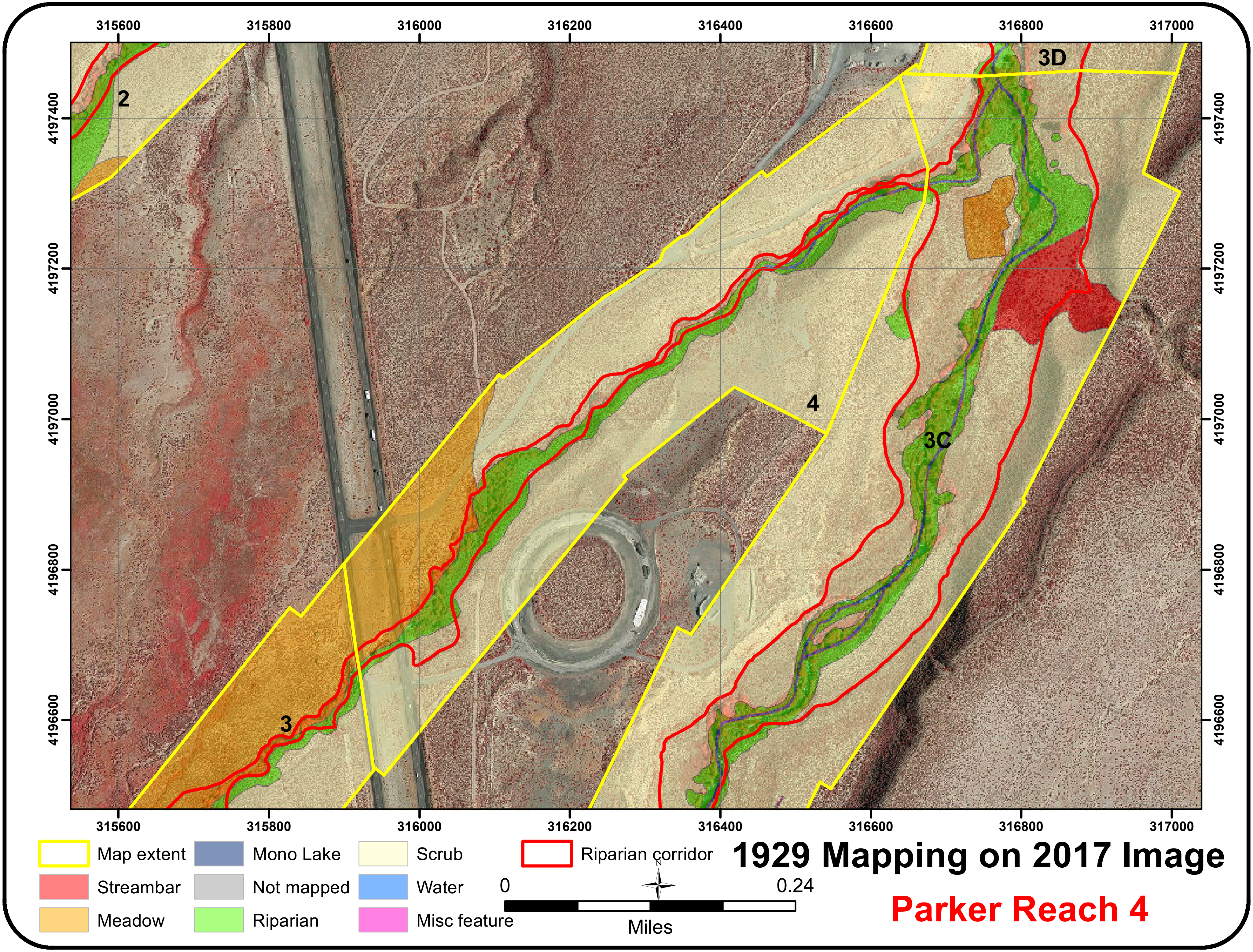

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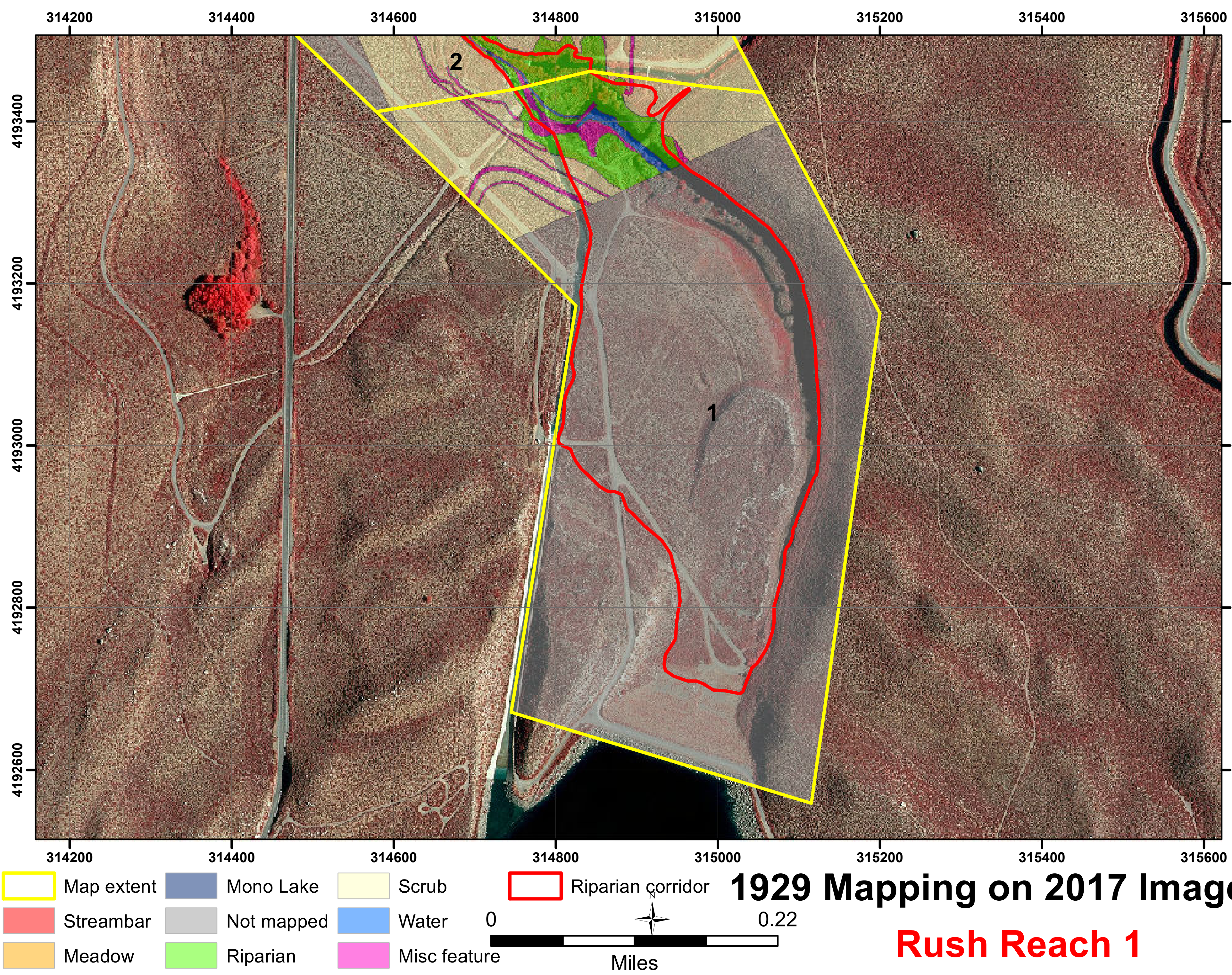

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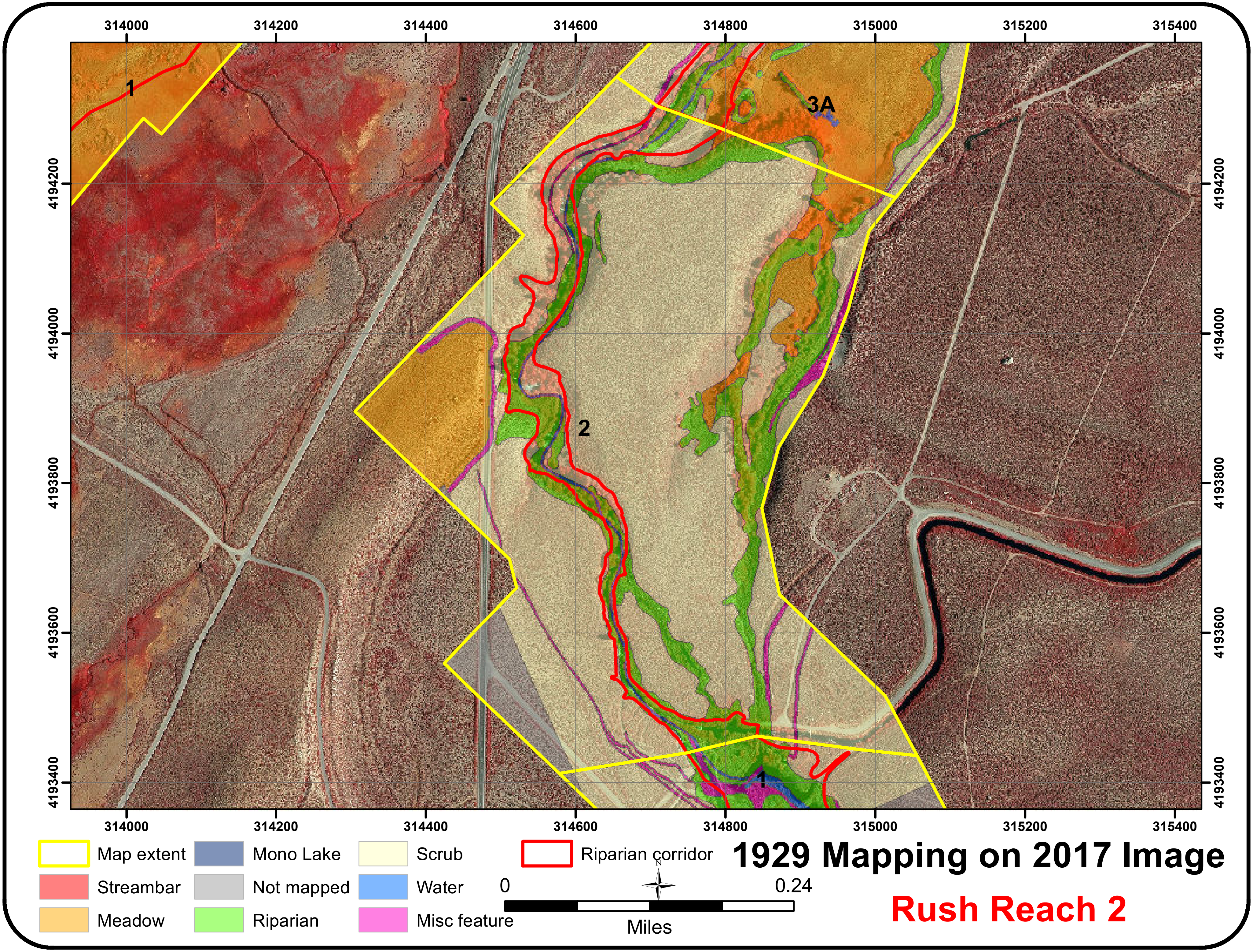
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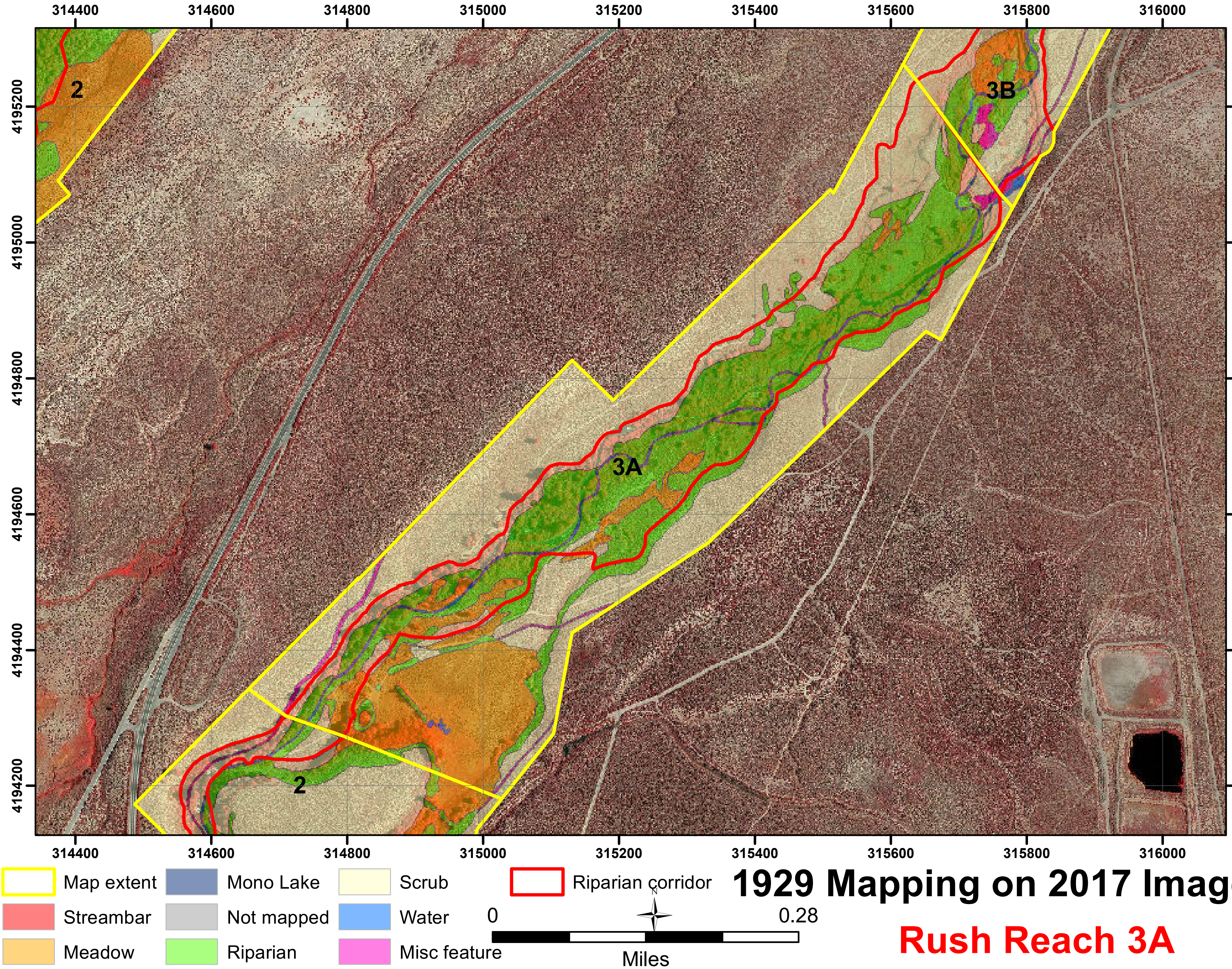

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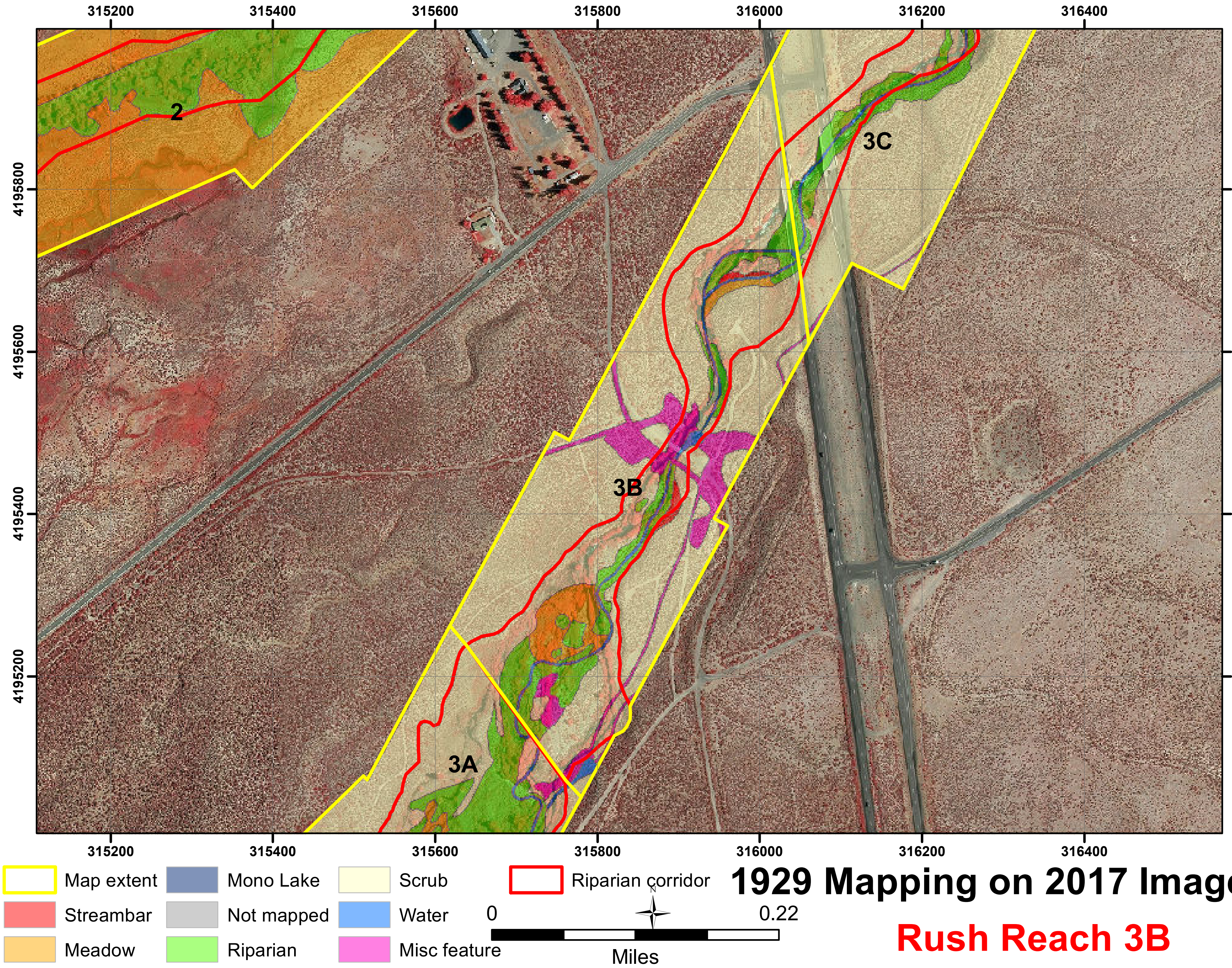

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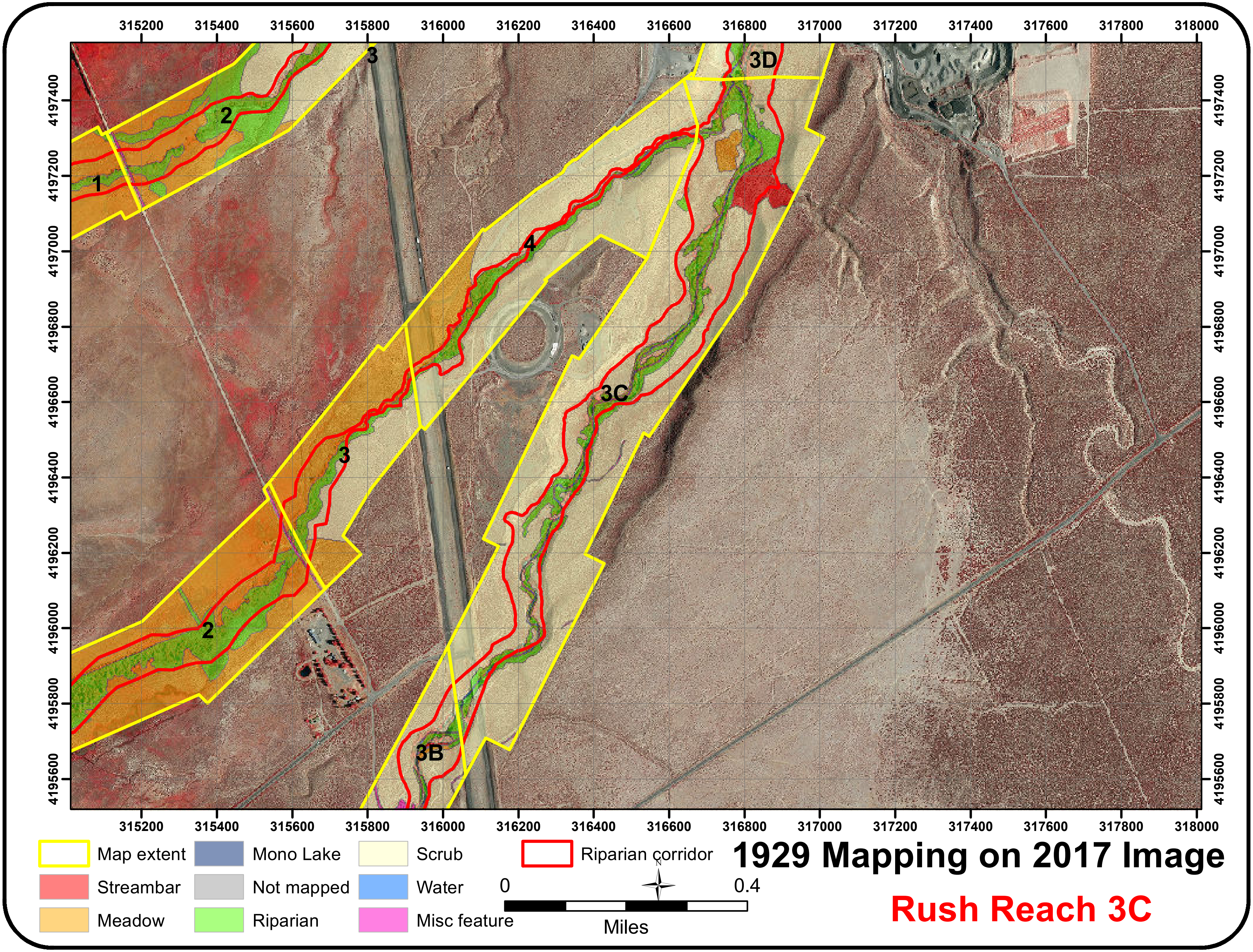

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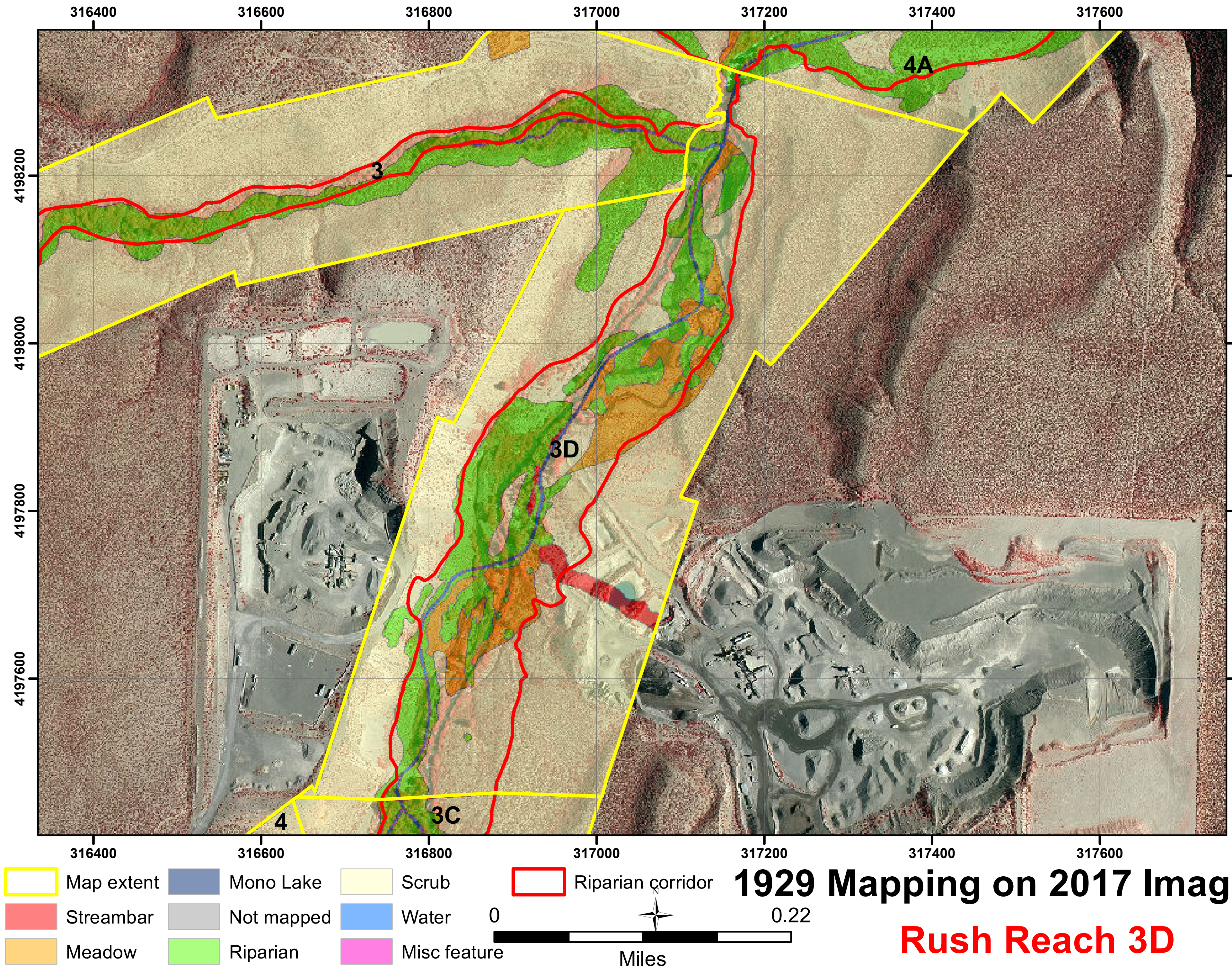

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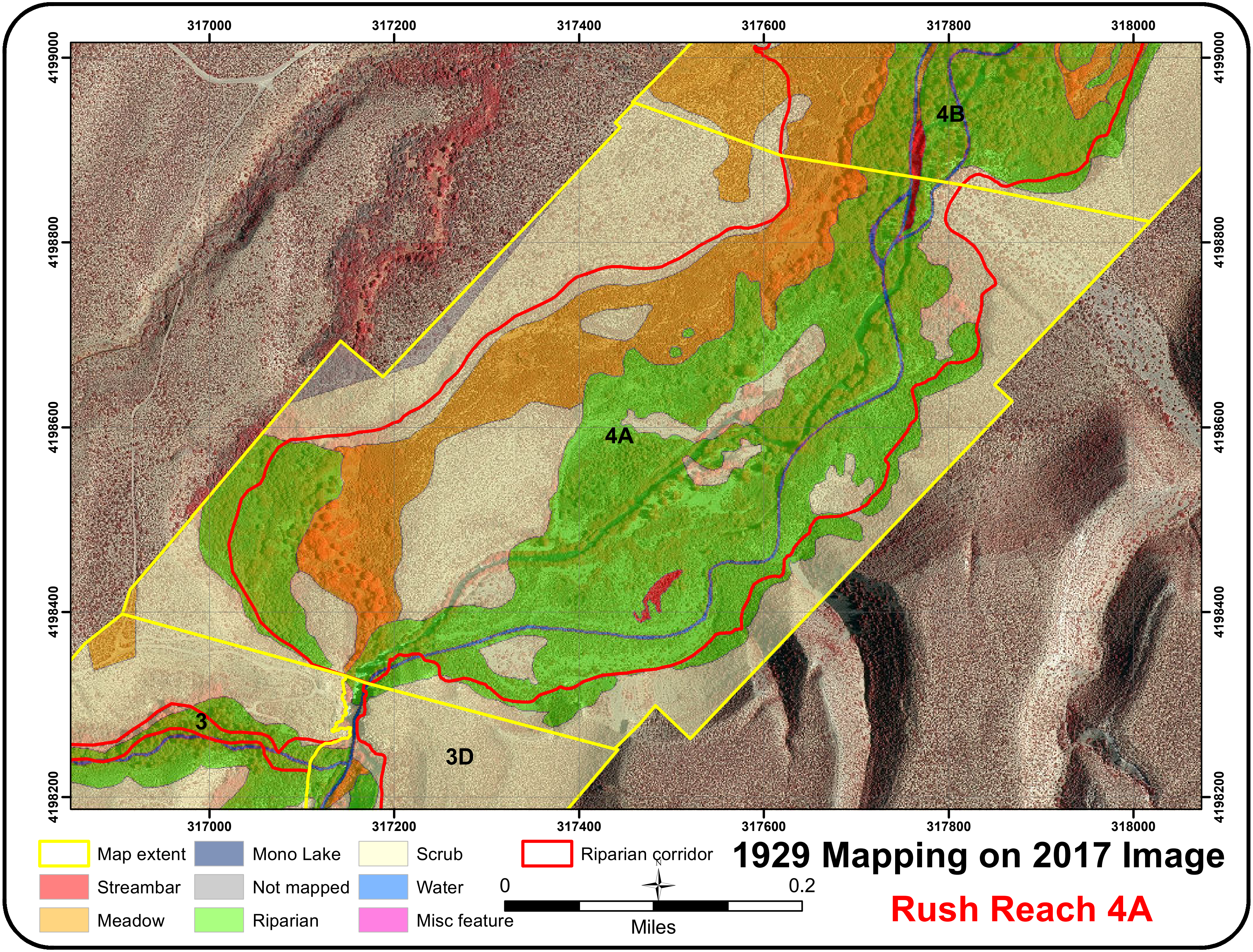

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Mono Lake
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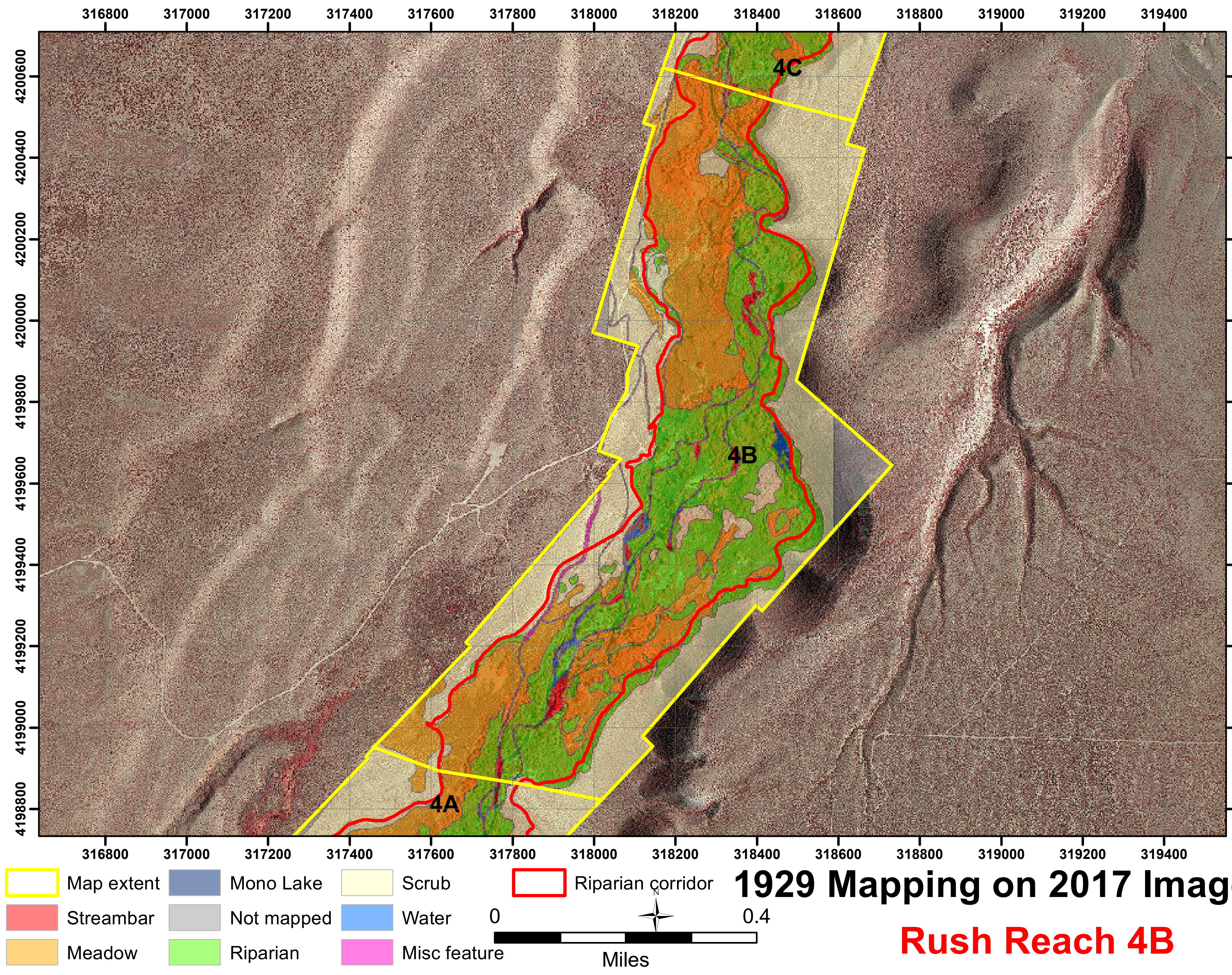

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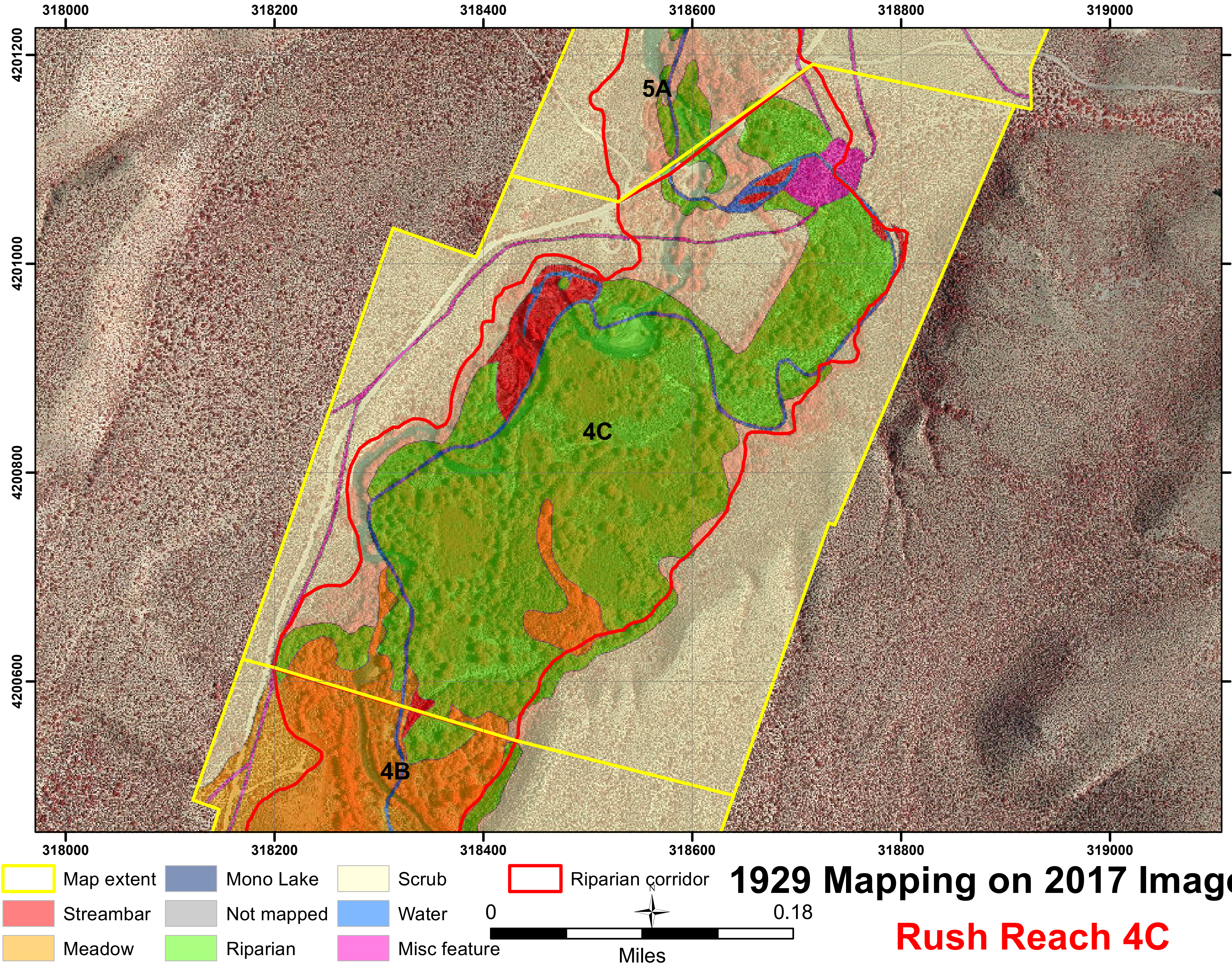
APPENDIX H
RIPARIAN MAPPING
2017 CONDITIONS



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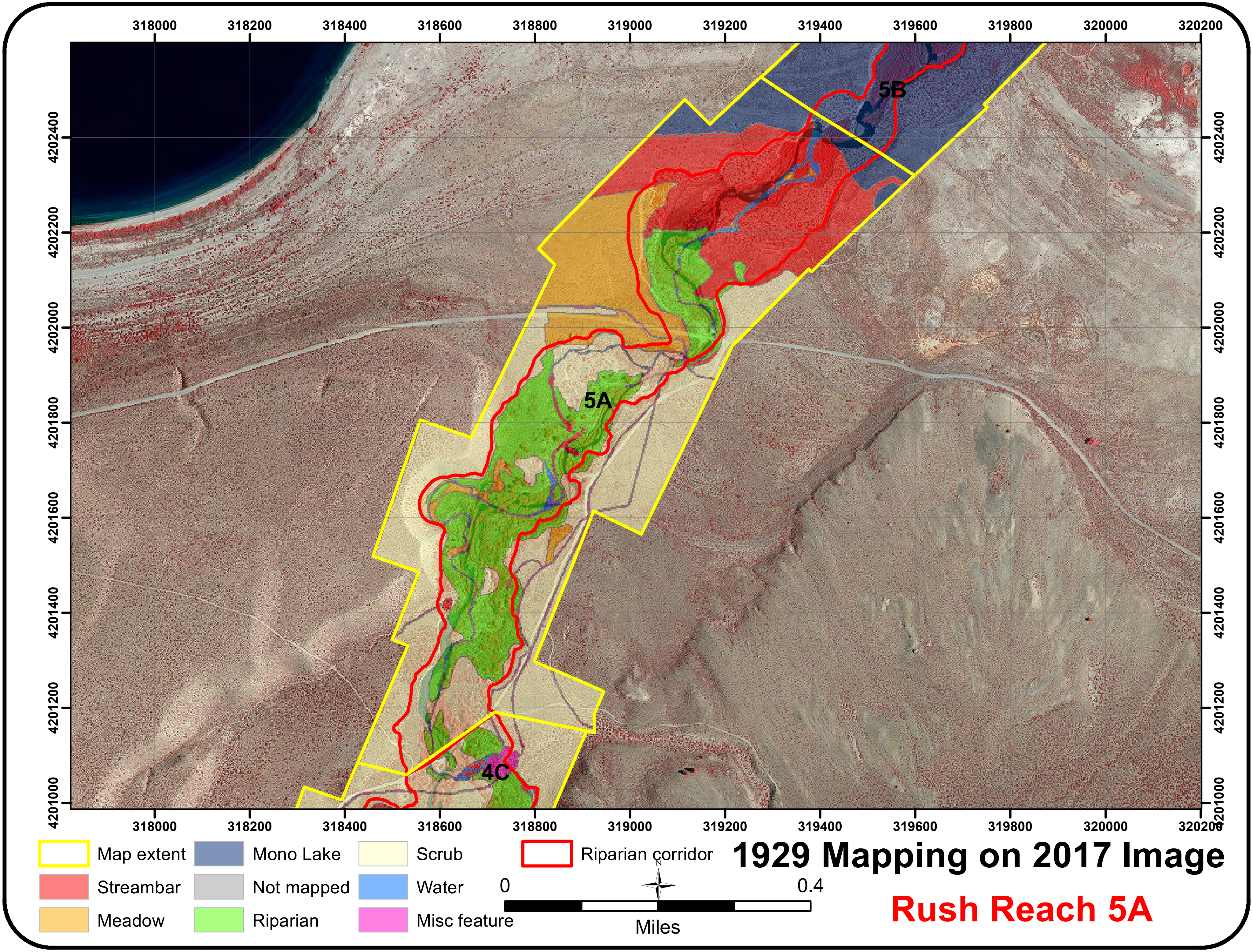
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4C
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Mono Lake
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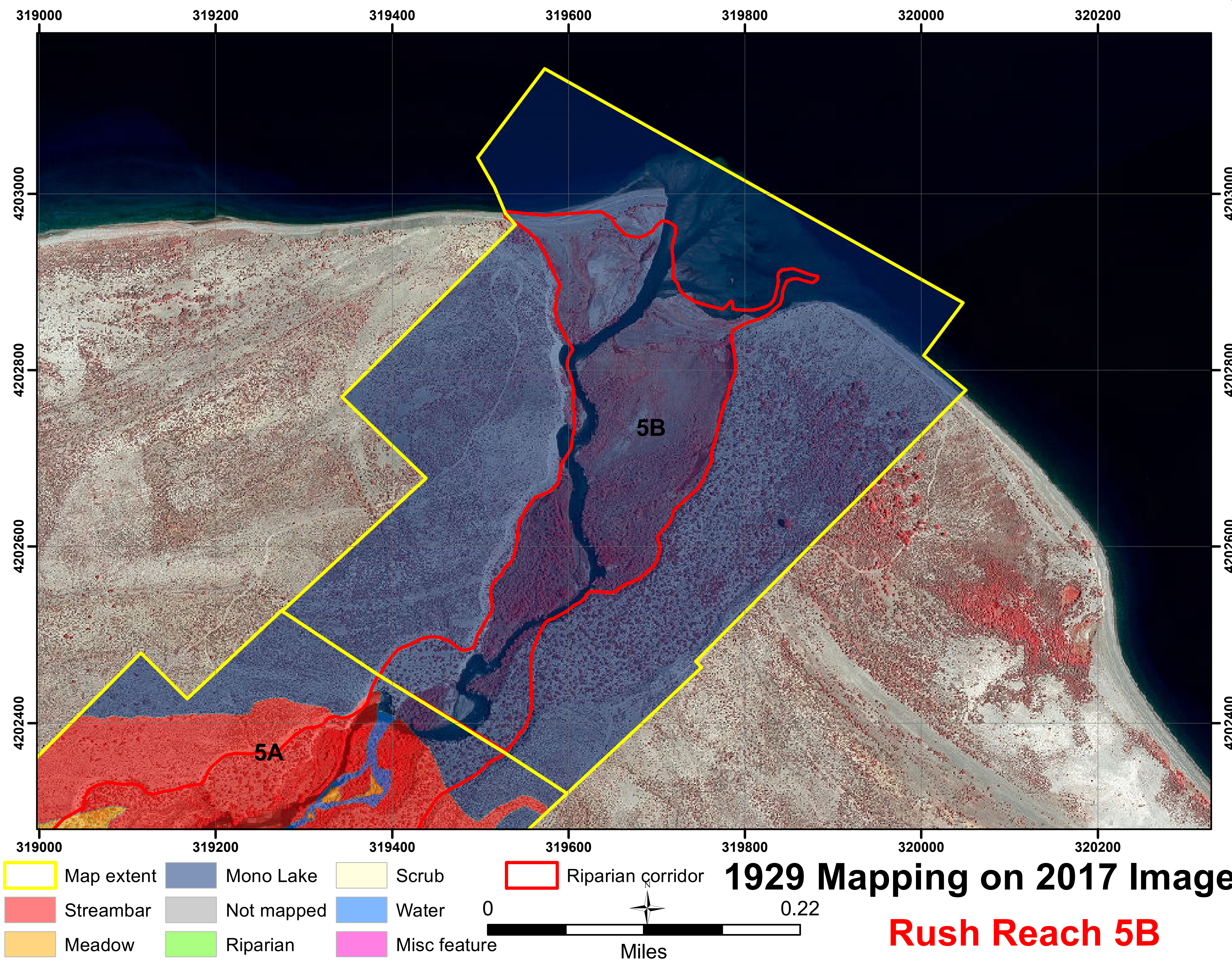

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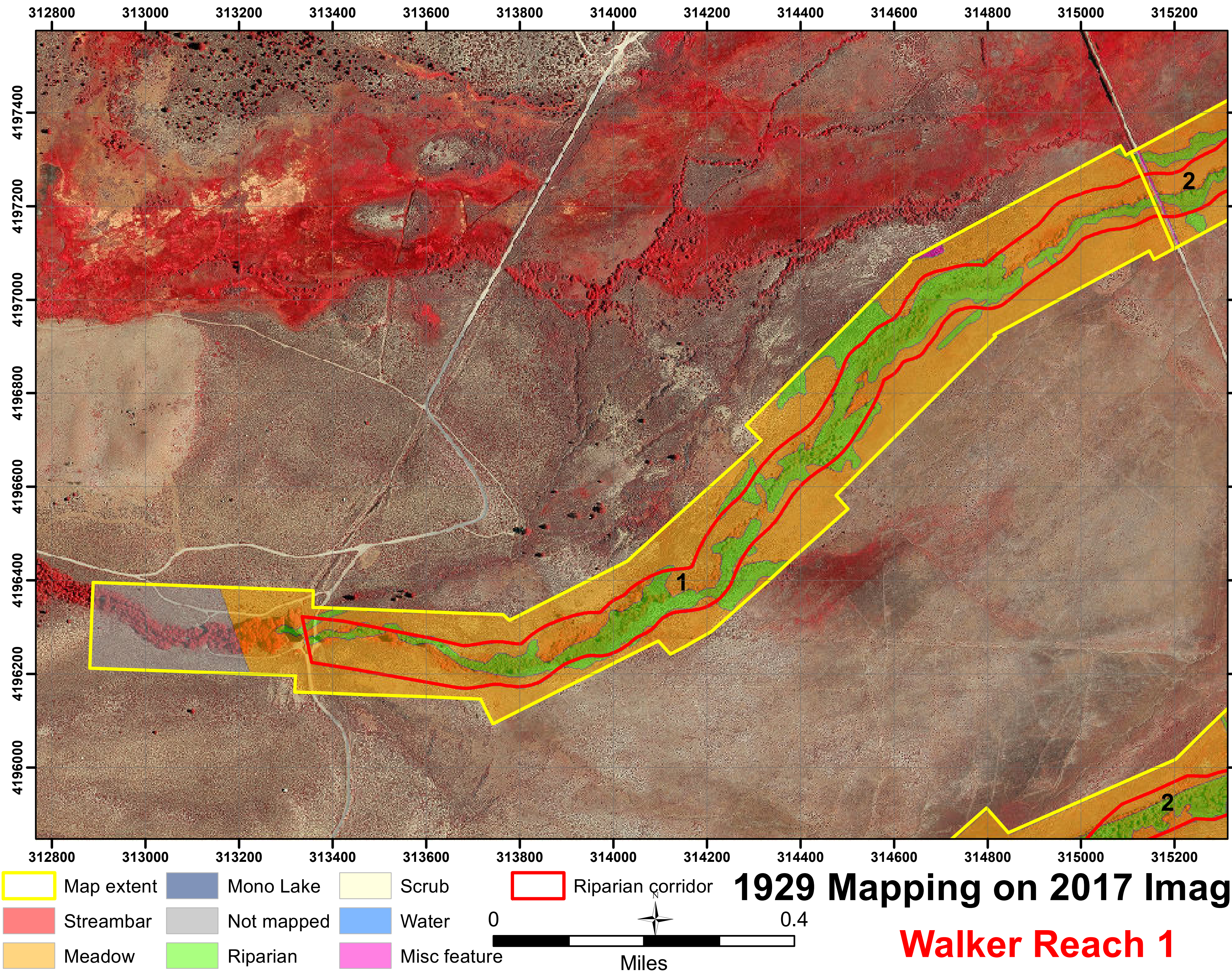

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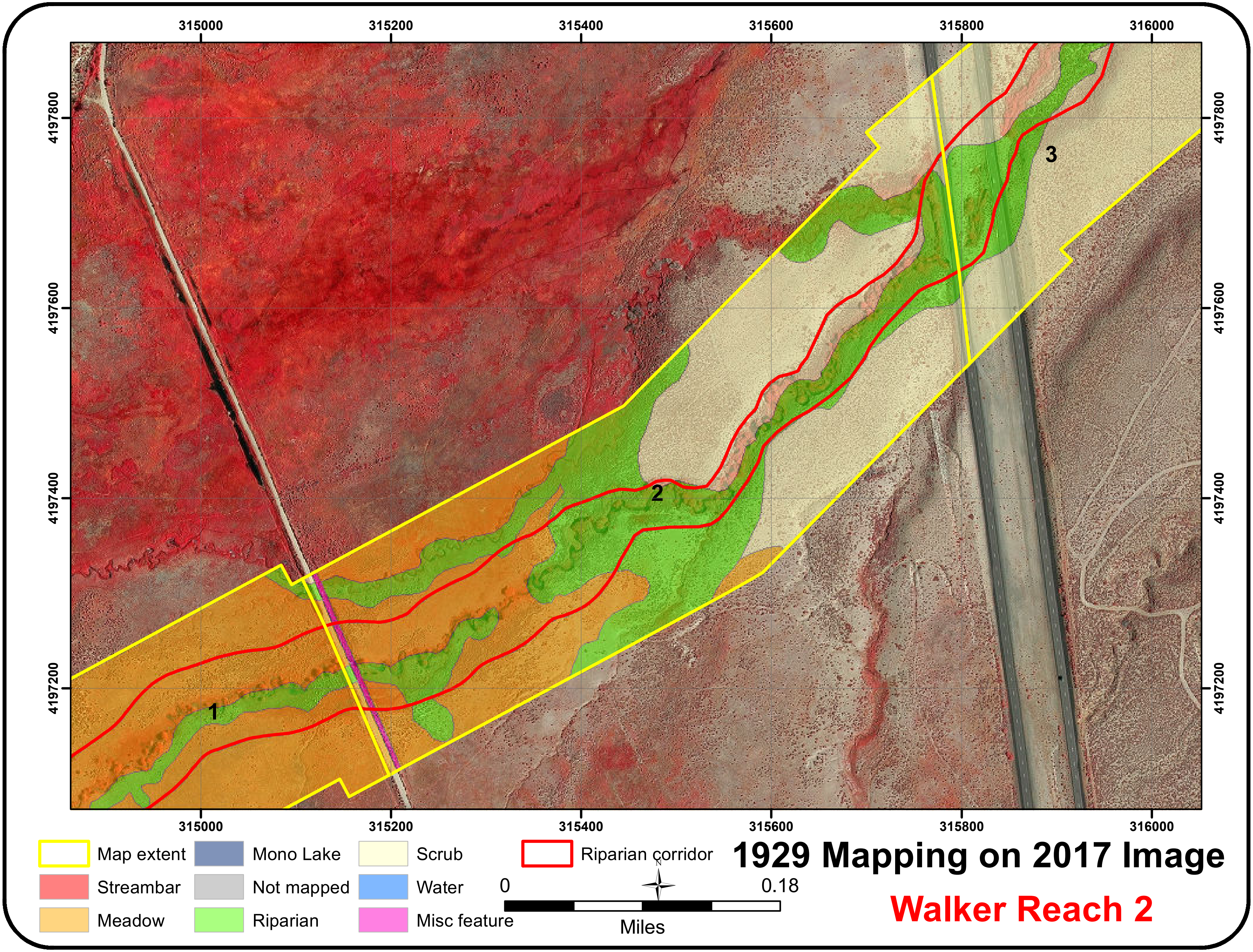
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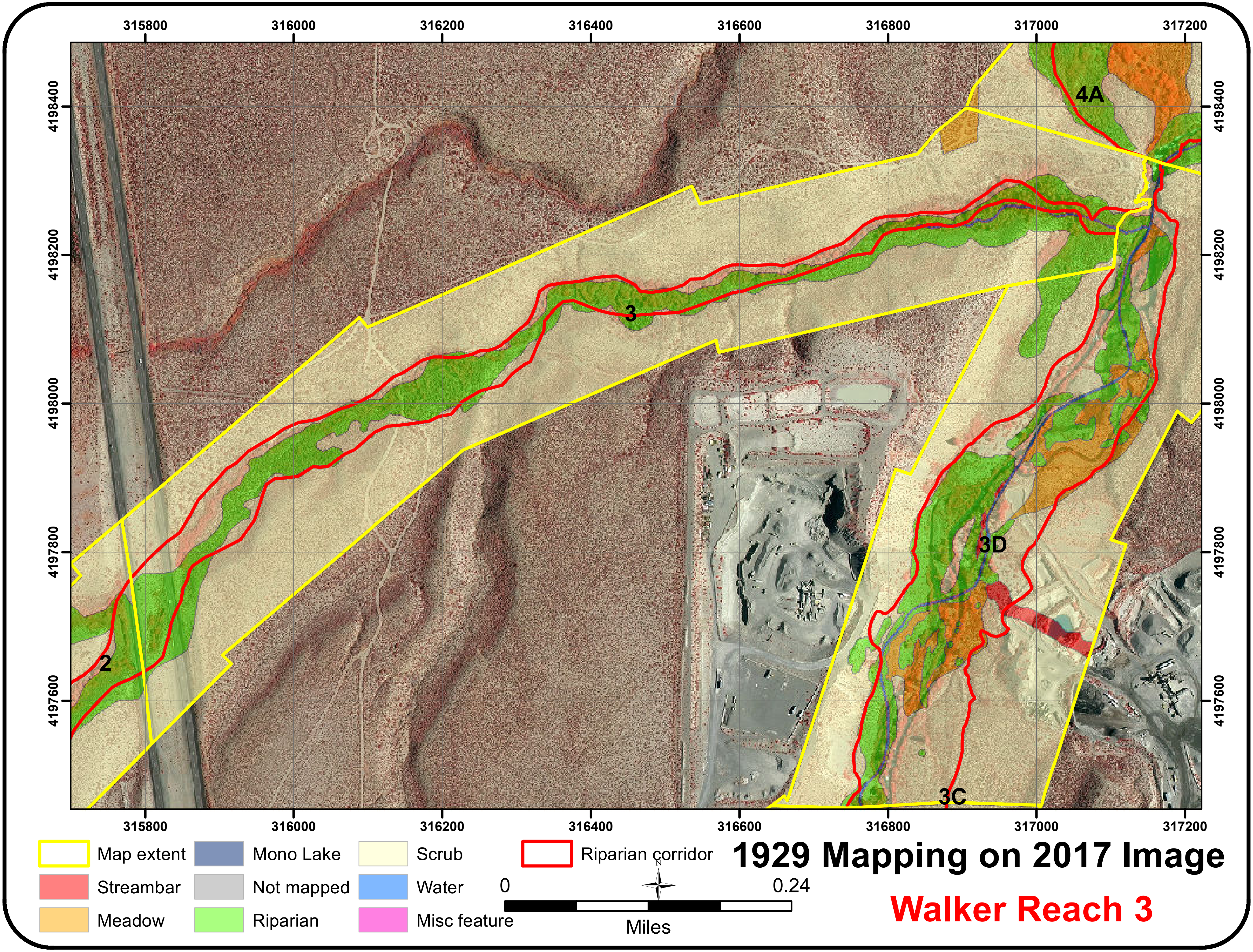
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Miles
1929 Mapping on 2017 Image
Walker Reach 3

Section 5

Mono Basin Waterfowl Habitat Restoration

2017 Compliance and Periodic Overview Report

Mono Basin Waterfowl Habitat Restoration

2017 Compliance and Periodic Overview Report

Prepared for the State Water Resources Control Board

In 2017 the Los Angeles Department of Water and Power (LADWP) conducted monitoring in compliance with the 1996 Mono Basin Waterfowl Habitat Restoration Plan (Plan) (LADWP 1996) and State Water Resources Control Board Order WR 98-05 (SWRCB 1998). Monitoring conducted in 2017 by LADWP included:

- Monthly Mono Lake elevation readings
- Daily stream flows in Rush, Lee Vining, Parker and Walker Creeks
- Lake limnology including meteorological, physical/chemical, phytoplankton, and brine shrimp population monitoring
- Summer waterfowl ground surveys and documentation of habitat use
- Fall aerial waterfowl surveys at Mono Lake, Bridgeport Reservoir and Crowley Reservoir
- Still-image photography of waterfowl habitats at Mono Lake, Bridgeport Reservoir and Crowley Reservoir
- Surveillance for saltcedar (*Tamarix* spp.)

The Periodic Overview Report summarizes restoration actions taken under Order 98-05 and the results of the monitoring program since its inception. This report is also being submitted as the annual compliance report as 2017 data are presented. The Periodic Overview Report includes recommendation to increase effectiveness of various monitoring tasks, and to reduce the cost of the monitoring project, while continuing to provide indices to track restoration progress.

Hydrological Summary

The 2017 runoff year in the Mono Basin (April 1, 2017 - March 31, 2018) was an “extreme wet” year type with 176% of average runoff predicted. This was only the second extreme wet runoff year to occur in the Mono Basin since implementation of Order 98-05.

Since implementation of the Plan, fluctuations in lake level have occurred primarily due to variation in water years. , and the lake level has been decreasing on average. During a period of extended drought from 2012-2016, the lake elevation dropped almost 7 feet to a low of 6,377.1 feet in January 2017, the lowest level since Decision 1631 placed limitations on water exports by the City of Los Angeles from the Mono Basin. Due to the extreme wet year runoff, Mono Lake rose 4.5 feet in 2017 to 6,381.6 feet in September.

Limnology Summary

The *Artemia* population has been greatly influenced by the Mono Lake mixing regime. Since 1995, there have been five meromictic events, the latest commencing as a result of the extreme wet year of 2017. *Artemia* populations have demonstrated a response to the breakdown of meromixis with population peaks during the year following the breakdown of meromixis. The magnitude of the peaks has been positively correlated with duration of meromixis. The last two meromixis events, which only lasted 1 to 2 years, have resulted in shorter peaks. There has been a temporal shift in the peak abundance of instars and adults as monthly peaks are occurring earlier in the year.

The data suggest that Mono Lake is potentially becoming more saline for a given lake level, as compared to the period of the 1990's through 2010. Salinity has been demonstrated to adversely affect the survival, growth, reproduction, and cyst hatching of *Artemia*. Five years of drought between 2012 and 2016 resulted in the lake level declining from 6,383.6 feet in April 2012 to 6,376.8 feet in October 2016, and an increase in salinity from 75.7 g/L in 2012 to 96.6 g/L in 2017. During this period of increasing salinity, the abundance of *Artemia* also declined. In 2017, with the second largest input on record into Mono Lake, salinity decreased to 80.9 g/L by September, and the *Artemia* population showed some recovery.

Vegetation Summary

Vegetation mapping data and modeling predictions suggest that lakewide, Mono Lake landtypes may respond to changes in lake elevation in somewhat predictable ways, although not all shoreline subareas have responded similarly to changes in lake elevation. The riparian deltas have shown a response to the reestablishment of perennial flow, as bare ground and dead plant cover have declined substantially. The overall decline in lake elevation observed since 1998 has resulted in two significant trends along the shoreline: significant increases in barren playa, and decreases in lake-fringing ponds.

Waterfowl Summary

Mono Lake supports a small breeding waterfowl population that has averaged 150 pairs, and can be considered important only from a very local standpoint. The breeding waterfowl community has demonstrated a positive response to the primary waterfowl habitat restoration objective of increasing the level of Mono Lake. There may be a lower threshold of lake elevation below which changes in the breeding habitat become more significant. This lower threshold appears to be around 6,382 feet, as below that elevation, all waterfowl breeding parameters have shown a decline.

Between 2002 and 2017, six fall aerial surveys of the shoreline and open-water areas of Mono Lake were conducted annually. Three indices of the annual waterfowl population were developed: total waterfowl, peak waterfowl, and a population estimator, based on arrivals and departures. The yearly total waterfowl has averaged 26,479. Peak numbers have averaged 8,764, ranging from a low of 3,293 to a high of 17,844. The population estimator, which is the most conservative estimate of annual fall waterfowl use, indicates that an average of 9,651 waterfowl (range 3,460-18,590) have visit Mono Lake each fall during the time period 2002-2017.

There has been a downward trend in total fall waterfowl use at Mono Lake over the 2002-2017 period. There has been no trend in Northern Shoveler numbers, however Ruddy Duck numbers at Mono Lake have declined significantly over time. Total fall waterfowl use has not been directly correlated with lake elevation, however Ruddy Duck numbers have been positively correlated with lake elevation. Total fall waterfowl numbers have been correlated with the biomass and fecundity of *Artemia*, one of the two most abundant aquatic invertebrate species found in Mono Lake.

Recommendations

In light of the extended time period required for restoration, and the level of monitoring that has been conducted to date, recommendations for a less-frequent but more focused approach for the monitoring program are included. Following an analysis of the data collected under the Plan, recommendations were developed for the monitoring of lake limnology and secondary producers, the vegetation status in riparian and lake fringing wetland habitats, and waterfowl populations. These recommendations include spatial and temporal reductions in monitoring effort, and refinements in monitoring protocols. The analysis took into consideration the need to monitor to a level that would allow a comparison of key indices to evaluate the restoration progress. It is also recommended that the second year of the waterfowl time budget study be completed as required by Order 98-05, and that a short-term hypopycnal area investigation be completed.

I look forward to discussing the proposals, and any concerns regarding the changes with the SWRCB.

Debbie House

Debbie House

Interim Mono Basin Waterfowl Monitoring Program Director

Los Angeles Department of Water and Power (LADWP). 1996. *Mono Basin Waterfowl Habitat Restoration Plan.* Prepared for the State Water Resources Control Board. In response to Mono Lake Basin Water Right Decision 1631.

Los Angeles Department of Water and Power (LADWP). 2000. *Mono Basin Implementation Plan*. To comply with State Water Resources Control Board Decision 1631 and Order No. 98-05 and 98-07.

State Water Resources Control Board (SWRCB). 1998. Order WR 98-05. Order requiring stream and waterfowl habitat restoration measures. September 2, 1998.

Mono Basin Waterfowl Habitat Restoration Program Periodic Overview Report

Prepared by:
Deborah House, Mono Basin Waterfowl Program Director
Motoshi Honda, Watershed Resources Specialist
Los Angeles Department of Water and Power
Bishop, CA 93514

Prepared for the State Water Resources Control Board
And Los Angeles Department of Water and Power

May 2018

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EXECUTIVE SUMMARY

In 1983, National Audubon Society v. Superior Court (1983), resulted in the California State Water Resources Control Board (SWRCB) reevaluating the effect of water diversions by the City of Los Angeles (City) on the public trust values of Mono Lake. SWRCB Decision 1631, signed in 1994, amended the City's water rights, establishing instream flow requirements for the Mono Basin creeks, and placing limitations on water exports from the basin. Order WR 98-05 (SWRCB 1995) directed the Los Angeles Department of Water and Power (LADWP) to implement waterfowl habitat restoration measures and monitoring to mitigate the loss of waterfowl habitat in the Mono Basin from diversions. This report summarizes the status of waterfowl habitat restoration measures required in Order 98-05, and the results of monitoring conducted under the Mono Basin Waterfowl Habitat Restoration Plan (Plan) (LADWP 1996) since implementation.

Although the restoration of waterfowl habitat is not yet complete, LADWP's compliance with Decision 1631 and Order 98-05 has resulted in ecological benefits for the Mono Basin. The monitoring programs are providing a dataset composed of data collected on a consistent basis, from which ecological trends in the Mono Basin can be evaluated.

Significant restoration accomplished in the Mono Basin has included the reestablishment of perennial flows in Rush Creek, Lee Vining Creek, Parker Creek and Walker Creek. In Rush Creek, all channel openings required under the Plan have also been completed. An outstanding issue is the continued financial assistance available from LADWP for the purpose of waterfowl habitat improvement at the County Ponds or Black Point, and the recovery of Mono Lake to the average target lake elevation of 6,392 feet.

Climatic factors may be influencing Mono Lake and its recovery. Mono Lake has not yet reached the target lake elevation, even though initial modeling predicted this restoration objective would be met in approximately 20 years (or by 2015). From 1998 to 2017, Mono Lake has experienced four periods of increasing elevation, and three subsequent decreases, through a total elevation range of 8.0 feet. Fluctuations in lake level have occurred primarily due to variation in water years, and the lake level has been decreasing on average since implementation of the Plan. During a period of extended drought from 2012-2016, the lake elevation dropped almost 7 feet to a low of 6,377.1 feet in January 2017, the lowest level since implementation of the Order. Based on an assessment of runoff data dating back to the late 1930's, it appears that dry years are becoming drier in recent history, thus inhibiting the recovery to the target level. Weather data indicate that since 1995, the summer minimum temperatures have been above their long-term average. More recently, the winter minimum temperatures have also shown a trend of being above their long-term average.

The *Artemia* population has been greatly influenced by the Mono Lake mixing regime. The mixing regime of Mono Lake is driven by the amount of freshwater input, and above normal runoff years result in a stratification of the lake (meromixis). Since 1995, there have been five meromictic events, the latest commencing as a result of the extreme wet year of 2017. During years of meromixis, nutrients accumulate in the bottom layer. During periods of below normal runoff years, meromixis breaks, the lake turns over, and the nutrients become available throughout the water column. *Artemia* populations have demonstrated a response to this breakdown of meromixis with population peaks during the year following the breakdown of meromixis. The magnitude of the peaks has been positively correlated with duration of meromixis. The last two meromixis events, which only lasted 1 to 2 years, have resulted in shorter peaks.

There has been a clear temporal shift in peak abundance of instars and adults as monthly peaks are occurring earlier in the year. There appear to be three distinct periods of instar and adult abundance patterns; 1) later season occurrence between 1987 and 1994, 2) a transition between 1995 and 2003, and 3) and earlier season occurrence since 2004.

As is typical of closed basin systems, the salinity of Mono Lake increases with decreases in lake volume or inputs. Our analysis suggests that Mono Lake is potentially becoming more saline for a given lake level, as compared to the period of the 1990’s through 2010. Salinity has been demonstrated to adversely affect the survival, growth, reproduction, and cyst hatching of *Artemia*. Five years of drought between 2012 and 2016 resulted in the lake level declining from 6,383.6 feet in April 2012 to 6,376.8 feet in October 2016, and an increase in salinity from 75.7 g/L in 2012 to 96.6 g/L in 2017. During this period of increasing salinity, the abundance of *Artemia* also declined. In 2017, with the second largest input on record into Mono Lake, salinity decreased to 80.9 g/L by September, and the *Artemia* population showed some recovery. Thus, despite the observed fluctuation in salinity observed, the *Artemia* population has shown some resiliency.

Vegetation mapping data and modeling predictions suggest that lakewide, Mono Lake landtypes may respond to changes in lake elevation in somewhat predictable ways, although not all shoreline subareas have responded similarly to changes in lake elevation. The riparian deltas have shown a response to the reestablishment of perennial flow, as bare ground and dead plant cover have declined substantially over time. The lake elevation changes observed since 1998 have resulted in two significant trends with decreasing lake elevations: significant increases in barren playa, and decreases in lake-fringing ponds.

Waterfowl surveys conducted pursuant to Order 98-05 and the Plan have provided detailed information not previously available for waterfowl populations at Mono Lake. Mono Lake supports a small breeding waterfowl population that has averaged 150 pairs, and can be considered important only from a very local standpoint, as a breeding population of this size does not contribute significantly to waterfowl numbers from a population standpoint. The breeding waterfowl community has demonstrated a positive response to the primary waterfowl habitat restoration objective of increasing the level of Mono Lake. Larger breeding populations, more broods and larger brood sizes have been seen with increases in lake elevation. There may be a lower threshold of lake elevation below which changes in the breeding habitat become more significant. This lower threshold appears to be around 6,382 feet, as below that elevation, all waterfowl breeding parameters have shown a decline. The range of elevations over which observations have occurred has been fairly limited, as the majority of the observations have taken place at lake elevations between approximately 6,382 and 6,383.5 feet. Whether further increases in lake elevation beyond 6,385 feet will provide additional benefits or be detrimental to breeding waterfowl populations is uncertain.

Between 2002 and 2017, six fall aerial surveys of the shoreline and open-water areas of Mono Lake have been conducted each year. The regular schedule of fall surveys conducted from 2002-2017 has allowed for the calculation of waterfowl population indices for Mono Lake not previously available. Three indices of the annual waterfowl population were developed: total waterfowl, peak waterfowl, and a population estimator, based on arrivals and departures. The yearly total waterfowl has averaged 26,479. Peak numbers have averaged 8,764, ranging from a low of 3,293 to a high of 17,844. The population estimator, which is the most conservative estimate of annual fall waterfowl use, indicates that an average of 9,651 waterfowl (range 3,460-18,590) visit Mono Lake each fall. There has been a downward trend in total fall waterfowl use at Mono Lake over the 2002-2017 period.

The Northern Shoveler has accounted for over 80% of dabbling ducks and 50% of all waterfowl recorded. Annual total Northern Shoveler counts have averaged 13,451 (range 4,733-27,400). Divers, comprised of almost exclusively Ruddy Duck, accounted for 36% of all waterfowl. Annual total Ruddy Duck counts have averaged 9,739 (range 2,507-27,357). There has been no trend in Northern Shoveler numbers, however Ruddy Duck numbers at Mono Lake have declined significantly over time.

Total fall waterfowl use has not been directly correlated with lake elevation, and lake elevation has explained 57% of the variation in the number of Ruddy Ducks at Mono Lake. Ruddy Duck numbers have been highest when the lake elevation has been above approximately 6382.0 feet. Numbers have declined substantially at lake elevations below approximately 6380 feet. Higher total waterfowl numbers have occurred at elevations between 6,381 feet and 6,383 feet, but lake levels above 6,383 feet have not resulted in higher numbers of waterfowl. Most observations have been made within a narrow two-foot elevation range of 6,381-6,383 feet.

Total fall waterfowl numbers have been correlated with the biomass and fecundity of *Artemia*. Lakewide, mean biomass in August and the mean of August/September were both positively correlated with total waterfowl use. Shrimp fecundity, or the mean number of cysts produced in September has been correlated with the waterfowl numbers in that month.

Mono Lake is deep, highly saline, with limited shallow shoreline areas. These features limit the habitat quality for waterfowl, and may ultimately limit recovery of waterfowl populations. With exception of the Ruddy Duck, most waterfowl use at Mono Lake occurs in lake-fringing ponds, or very near to shore. By and large, the near shore areas used by waterfowl are shallow, have gentle offshore gradients, and fresh water spring, creek or brackish water input. There has been no evidence that waterfowl use of shoreline areas has been directly responsive to the magnitude of creek flows, or that waterfowl will respond directly to the presence of hypopycnal areas.

In light of the extended time period required for restoration, and the level of monitoring that has been conducted to date, recommendations for a less-frequent but more focused approach for the long-term monitoring of waterfowl habitat in the Mono Basin were developed. Following an analysis of the data collected under the Plan, recommendations were developed for the monitoring of lake limnology and secondary producers, the vegetation status in riparian and lake fringing wetland habitats, and waterfowl populations. It is also recommended that the second year of the waterfowl time budget study be completed as required by Order 98-05, and that a short-term hypopycnal area investigation be completed.

1.0 INTRODUCTION

Mono Lake is a large terminal saline lake situated on the western edge of the Great Basin in Mono County, California. Mono Lake is widely known for its value to migratory waterbirds, as it supports up to 30% percent of the North American Eared Grebe (*Podiceps nigricollis*) population, the largest nesting population of California Gulls (*Larus californicus*) in California (Winkler 1996), and up to 140,000 Wilson's (*Phalaropus tricolor*) and Red-necked Phalaropes (*P. lobatus*) during fall migration (Jehl 1986, Jehl 1988).

The Intermountain West region, bounded by the Sierra Nevada range and Cascades on the west and Rocky Mountains to the east, includes the vast arid landscapes of the Great Basin, Columbia Basin, Colorado Plateau, and the Wyoming Basin (Ivey 2005). The Intermountain West Region includes a variety of wetland habitats and some other waterbodies of importance to waterfowl including the Klamath Basin, Great Salt Lake, and Malheur Basin. Wetlands of this region can be highly productive, and are considered of high value to waterbirds due to their rarity in the landscape (Intermountain West Joint Venture 2013).

Mono Lake is a highly productive, deep-water saline lake and one of the oldest lakes in North America. Worldwide saline inland waters comprise almost as much total volume as fresh water systems (Timms 2005, Williams 2002), yet their ecology is not well-studied (Williams 2002). As a whole, saline lakes are more diverse systems than fresh water lakes, as they can vary substantially in terms of salinity, mineral content, and the productivity and composition of primary and secondary producers. Saline lakes may be permanent, seasonal, or episodic in occurrence. Saline lakes are highly productive ecological systems (Jellison et al. 1998), however productivity can be influenced by factors such as salinity, water depth, and temperature, water influx and evaporation on a seasonal, annual, and inter-annual basis. Saline lakes often respond rapidly to environmental changes, with one of the most influential being alterations to the hydrological budget (Jehl 1988, Williams 2002). Water demands for agriculture, human development and recreation are also impacting saline lakes globally (Wurtsbaugh et al. 2017).

Water diversions by the City of Los Angeles (City) from 1941 to 1982 led to a 45-foot decline in lake elevation, a 30% reduction in surface area, and substantial environmental damage (SWRCB 1996). After a series of lawsuits and extended court hearings, Decision 1631 by the State Water Resources Control Board (SWRCB) ordered a reduction in diversions by the City, and for the Los Angeles Department of

Water and Power (LADWP) to conduct restoration and monitoring of Mono Lake ecological resources.

Although very limited quantitative data were available, the evidence presented to the SWRCB suggested that Mono Lake once supported a much larger waterfowl population. The diversion-induced impacts to waterfowl were believed to have been more significant than for other waterbird species. As restoration was not expected to restore all pre-diversion waterfowl habitat, Decision 1631 also required LADWP to prepare a waterfowl restoration plan to mitigate the permanent loss of waterfowl habitat.

SWRCB Order 98-05 was adopted on September 2, 1998 and defined waterfowl restoration measures and elements of the waterfowl habitat monitoring program for Mono Lake. This report summarizes restoration actions taken under Order 98-05 and results of the monitoring program since its inception. It also provides recommendations for the program.

2.0 LEGAL FRAMEWORK

2.1 Legal History

In 1941, the City began diverting water from Lee Vining Creek, Rush Creek, Walker Creek, and Parker Creek to Grant Lake Reservoir for municipal water supply. From Grant Lake, water is exported out of the Mono Basin through the Mono Craters Tunnel where it empties into the upper Owens River, upstream of Crowley Reservoir. The initial water rights license in 1934, and subsequent licenses issued by the SWRCB in 1974, authorized the City to export up to 147,700 acre-feet a year from the Mono Basin for the purpose of the beneficial use as a municipal water supply.

From 1941-1970, when the City was exporting an annual average of 56,000 acre-feet, the lake dropped over 29 feet (LADWP data, from “Mono Basin Monthly”). In 1970, the completion of the second aqueduct in the Owens Valley expanded the capacity of the system, resulting in an increase in diversions and frequent full diversion of flows from Lee Vining, Walker, Parker and Rush Creek (SWRCB 1994). From 1970 to 1989, Mono Lake dropped another 12.6 feet as yearly exports averaged 82,000 acre-feet, with a peak export of 140,756 acre-feet in 1979. Levels dropped to a record low of 6,372.0 feet in 1982.

In 1979, the National Audubon Society (Audubon) filed suit with the Superior Court of California against the City (National Audubon Society v. Superior Court), arguing that the diversions in the Mono Basin were resulting in environmental damage and were a violation of the Public Trust Doctrine. The Public Trust Doctrine had been held to protect the public interest in navigation, commerce, and fishing on navigable waters. The use of the Public Trust Doctrine had recently been expanded in California in 1971 to include fish, wildlife, habitat and recreation. The Audubon case was the first to examine the relationship between the Public Trust Doctrine and the California appropriative water rights.

In 1983, the California Supreme Court ruled in favor of Audubon, and also ruled that the SWRCB has the jurisdiction to take into consideration the effect of water diversions on public trust values when issuing water rights licenses. A second lawsuit in 1985 (California Trout v. State Water Resources Control Board) resulted in a ruling requiring the SWRCB to add additional conditions to the City’s water rights license regarding the reestablishment and maintenance of a fishery in compliance with state Fish and Game Code, and a fishery comparable to that which existed prior to diversions (SWRCB 1994).

In December 1989, a preliminary injunction was passed by the Superior Court requiring LADWP to flow sufficient water down the creeks to maintain the lake level at or above 6,377 feet. As such, exports from the Mono Basin were halted for five years (1990-1995) due to this preliminary injunction until the lake reached 6,377 feet.

As part of its review of the City's water rights license, the SWRCB directed the preparation of an Environmental Impact Report (EIR). The EIR was completed in 1993, and identified measures to avoid, reduce, or mitigate potential impacts from water diversion and exports from the Mono Basin. Following release of the EIR, the SWRCB held evidentiary hearings in Sacramento from October 1993 to February 1994, prior to issuing a new water rights license. The new water rights license would have new instream flow requirements for protection of fisheries, and specify a required water surface elevation to protect public trust resources. The purpose of the hearings was for the SWRCB to gather additional information and allow public comment regarding these issues. During the hearings, testimony was provided by more than 125 witnesses, and over 1,000 exhibits were introduced into evidence (SWRCB 1994). The parties (Parties) who participated in the evidentiary hearing were the California Air Resources Board, the California Department of Fish and Game (DFG), the California State Lands Commission, the California Department of Parks and Recreation, California Trout, Inc. (Cal Trout), the City of Los Angeles and the City of Los Angeles Department of Water and Power (LADWP), the Great Basin Unified Air Pollution Control District (GBUAPCD), Haselton Associates, the National Audubon Society, the Mono Lake Committee, the Sierra Club, the Metropolitan Water District of Southern California (MWD), the U. S. Fish and Wildlife Service, the United States Forest Service (USFS), and the U. S. Environmental Protection Agency.

2.2 SWRCB Water Rights Decision 1631

On September 28, 1994, the SWRCB amended the City's water rights with the Mono Lake Basin Water Right Decision 1631 (Decision 1631) (SWRCB 1994) by establishing instream flow requirements for the Mono Basin creeks for fishery protection and placing limitations on water exports from the basin until the surface elevation of 6,391 feet, which would trigger new export criteria. The water diversion criteria set forth in Decision 1631 were intended to result in a long-term average water elevation of 6,392 feet. The water elevation was expected to reach the trigger elevation in approximately 18-28 years, depending upon future hydrology (SWRCB 1994).

The export allowances of Decision 1631 are as follows and are applicable until the water level of Mono Lake reaches 6,391 feet:

1. Water export is prohibited when the lake is below or projected to fall below 6,377 feet, at any time during the runoff year of April 1 through March 31.
2. If the water level is expected to remain at or above 6,377 feet throughout the runoff year, up to 4,500 acre-feet of water per year may be diverted.
3. If the water level is at or above 6,380 feet and below 6,391 feet, up to 16,000 acre-feet per year may be diverted.

Water diversion criteria applicable after the water level of Mono Lake reaches 6,391 feet:

1. Once the water level of Mono Lake has reached an elevation of 6,391 feet, no diversions shall be allowed any time that the water level falls below 6,388 feet.
2. Once a water level of 6,391 feet has been reached and the lake level has fallen below 6,391, export is limited to 10,000 acre-feet per year provided that the water level is at or above 6,388 feet and less than 6,391 feet.
3. When the water level of Mono Lake is at or above 6,391 feet on April 1, all available water in excess of the amount needed to maintain the required fishery protection flows and the channel maintenance and flushing flows, up to the amounts otherwise authorized (32,000 acre-feet) may be diverted.

Decision 1631 also required the City to prepare and submit to the SWRCB for approval, stream and waterfowl habitat restoration plans, the objectives of which were to restore, preserve, and protect the streams and fisheries in Rush Creek, Lee Vining Creek, Walker Creek, and Parker Creek, and to help mitigate the loss of waterfowl habitat due to the diversion of water under the existing water rights license (SWRCB 1994). Decision 1631 provided specific requirements for each of these plans.

The required waterfowl habitat restoration plan was to include consideration of, and make recommendations for, measures to promote restoration of lake-fringing waterfowl habitat. The plan was to identify specific restoration actions, as well as their estimated costs, water requirements, and implementation schedules. The plan was also required to provide a method for monitoring the results and progress of the proposed restoration projects.

Decision 1631 relied on the “physical solution” doctrine as the basis for requiring the City to prepare a waterfowl habitat restoration plan. The application of the physical solution doctrine is to attempt to resolve disputes involving competing uses of water by finding a physical solution that promotes maximum beneficial use of the State’s water resources yet protects other competing resources. The waterfowl restoration plan was to propose reasonable, financially feasible waterfowl habitat restoration measures which have minimum potential for causing adverse environmental impacts (Order 98-05). Following Decision 1631, LADWP retained a group of three waterfowl experts (Roderick C. Drewien, Frederic S. Reid, and Thomas D. Ratcliff) to develop a waterfowl habitat restoration proposal. These three scientists produced the primary technical document for the development of the Mono Basin Waterfowl Restoration Plan (Plan) submitted to the SWRCB by the City in 1996. There was considerable disagreement among parties regarding the Plan during the hearings with the SWRCB, and subsequently the City and several parties proposed that the SWRCB adopt a revised approach to restoration, outlined in the Mono Basin Waterfowl Habitat Restoration Foundation Conceptual Agreement (Conceptual Agreement). However, this Conceptual Agreement was also opposed by Mono County and some Mono County residents and organizations.

During the hearings, SWRCB evaluated the waterfowl scientists’ report, LADWP’s proposed plan, and the Conceptual Agreement, and determined that some of the habitat restoration proposals presented in each of these documents did not comply with the requirements of Decision 1631. Subsequently, the SWRCB issued Order 98-05 in 1998, which defined the waterfowl restoration habitat restoration measures and associated monitoring to be conducted to comply with Decision 1631.

2.3 SWRCB Order 98-05

Lengthy hearings weighing the waterfowl restoration plans and the Conceptual Agreement led to the SWRCB evaluating restoration measures to be taken that would comply with Decision 1631. As noted in Order 98-05, and recognized in the restoration plans, maintaining an average lake elevation of 6,392 feet, and the returns of flows in the tributary streams would be the most significant restoration measures to be taken for the benefit of waterfowl habitat. In addition to raising the lake elevation, and the stream restoration efforts, Order 98-05 included the following measures to be undertaken by LADWP:

1. reopen distributaries in the Rush Creek bottomlands,
2. provide financial assistance for the restoration of waterfowl habitat at the County Ponds and Black Point or other lake-fringing wetland area,

3. participation in a prescribed burn program subject to applicable permitting and environmental review requirements;
4. participation in exotic species control efforts if an interagency program is established in the Mono Basin; and
5. a comprehensive waterfowl and waterfowl habitat monitoring program.

Sections 3.0 and 4.0 of this report discuss the implementation of these restoration measures and the monitoring since the adoption of Order 98-05.

3.0 WATERFOWL HABITAT RESTORATION MEASURES

The Mono Basin Waterfowl Habitat Restoration Plan was completed by LADWP for the SWRCB (LADWP 1996) on February 29, 1996. The Plan was based, in part on the waterfowl scientists' report prepared by Drewien, Reid, and Ratcliff (1996). The waterfowl scientists report provided a detailed assessment of numerous possible waterfowl restoration measures for the Mono Basin. The Plan was circulated to the Parties by the SWRCB for comments. Based on the extensive comments received, the SWRCB conducted an evidentiary hearing in early 1997. In reviewing waterfowl habitat restoration proposals, the SWRCB was required to consider the potential adverse environmental effects of the proposed restoration measures, the economic feasibility, and reasonableness, and the extent to which the proposed restoration measures complied with Decision 1631 (SWRCB 1998). A primary concern raised by those objecting to the Plan related to the proposal to rewater Mill Creek, and the potential environmental effect such an action could have on the Wilson Creek wetlands and delta area.

Several of the Parties developed a proposed settlement agreement which called for LADWP to pay $3.6 million into a Mono Basin Waterfowl Habitat Restoration Foundation and developed a Waterfowl Habitat Restoration Foundation Conceptual Agreement (conceptual agreement). Payment into this foundation would have relieved the City of any waterfowl habitat restoration obligations, with the exception of work in the Rush Creek bottomlands. The SWRCB determined that the conceptual agreement did not comply with Decision 1631, as specific restoration measures, costs, schedules, and water requirements were not identified. In addition, the proposed settlement included the rewatering of Mill Creek.

The SWRCB recognized that the neither the Plan nor the conceptual agreement fully complied with Decision 1631. Consequently, not all restoration measures described in the Plan or the conceptual agreement were required. In Order 98-05, the SWRCB identified the required restoration measures to be undertaken by LADWP.

Table 1 describes each restoration measure required under Order 98-05 and supported the Plan, providing a brief discussion on LADWP's progress to date and the current status. Some of these projects have been completed, some are ongoing, and other have been determined by the stakeholders to be unfeasible. Further discussion of each of the measures is provided in the text below.

Table 1. Mono Basin Waterfowl Habitat Restoration Activities

Mono Basin Waterfowl Habitat Restoration Activities *(as described in SWRCB Order 98-05 and the Mono Basin Waterfowl Habitat Restoration Plan dated February 29, 1996, where relevant)*				
Activity	**Goal**	**Description**	**Progress to Date**	**Status**
Rewatering Distributary Channels to Rush Creek (below the Narrows)	To restore waterfowl and riparian habitat in the Rush Creek bottomlands.	Rewater the Channel 4bii complex	Rewatering of side channels was evaluated in 2002 by the State Appointed Stream Scientists and LADWP. At that time, rewatering of the 4bii channel was deferred because natural revegetation of riparian and wetland species was occurring. The area was reevaluated in 2007 and rewatering was completed in March 2007.	Complete
		Rewater the Channel 8 complex, unplugged lower section	In 2002, the sediment plug was removed and the 8 channel was widened at the upstream end. In contrast to rewatering for constant flow, the final design called for flows overtopping the bank and flowing into the 8 channel at approximately 250 cfs and above. Woody debris was spread and willows were transplanted along new banks following excavation. Further rewatering of Rush Creek side channel complex 8 was deferred by the Stream Scientists. Final review was conducted by McBain and Trush. After presentation of the final review, LADWP followed the recommendations of the Stream Scientists and SWRCB approved the plan. Side channel 8 was rewatered in March 2007.	Complete
		Rewater the Channel 10 complex	Rewatering of side channels was evaluated in 2002 by the State Appointed Stream Scientists and LADWP. At that time, it was determined that rewatering the 10 channel complex would result in detrimental impacts to reestablished fishery and riparian habitats. Therefore, there have been no further actions taken to rewater this channel. Project considered complete.	Complete

Mono Basin Waterfowl Habitat Restoration Activities, cont. *(as described in SWRCB Order 98-05 and the Mono Basin Waterfowl Habitat Restoration Plan dated February 29, 1996, where relevant)*				
Activity	**Goal**	**Description**	**Progress to Date**	**Status**
Rewatering Distributary Channels to Rush Creek (below the Narrows)	To restore waterfowl and riparian habitat in the Rush Creek bottomlands.	Rewater Channel 11, unplugged lower portion	Rewatering of side channels was evaluated in 2002 by the State Appointed Stream Scientists and LADWP. At that time, it was determined that there would be little benefit to unplugging the 11 channel compared to the impacts to reestablished riparian vegetation from mechanical intrusion. Further evaluation was conducted by the Stream Scientists. After presentation of the final review, LADWP followed the recommendations of the Stream Scientists not to rewater the channel. This item is now approved by SWRCB and was therefore considered complete in 2008.	Complete
		Rewater the Channel 13 complex	Rewatering of side channels was evaluated in 2002 by the State Appointed Stream Scientists and LADWP. At that time, it was determined that the 13 channel would not be stable or persist in the long term and riparian vegetation was already rapidly regenerating in this reach. Therefore, there have been no further actions taken to rewater the 13 channel. Project is considered complete.	Complete

Mono Basin Waterfowl Habitat Restoration Activities, cont. (as described in SWRCB Order 98-05 and the Mono Basin Waterfowl Habitat Restoration Plan dated February 29, 1996, where relevant)				
Activity	**Goal**	**Description**	**Progress to Date**	**Status**
Financial Assistance to USFS for Waterfowl Habitat Improvement Projects at County Ponds and Black Point areas	To support repairs and improvement of infrastructure on USFS land in the County Ponds area.	Upon request of the United States Forest Service (USFS), Licensee (LADWP) shall provide financial assistance in an amount up to $250,000 for repairs and improvements to surface water diversion and distribution facilities and related work to restore or improve waterfowl habitat on USFS land in the County Ponds area.	LADWP was to make available a total of $275,000 for waterfowl restoration activities in the Mono Basin per Order 98-05. This money was to be used by the USFS if they requested the funds by December 31, 2004. Afterwards, any remaining funds are to be made available to any party wishing to do waterfowl restoration in the Mono Basin after SWRCB review. USFS has requested funds for a project estimated at $100,000. MLC has requested that the remainder of the funds be applied toward the total cost of the Mill Creek Return Ditch upgrade which would provide benefits for waterfowl habitat. These funds will continue to be budgeted by LADWP until such a time that they have been utilized. Currently, this money has tentatively been included in the 2013 Settlement Agreement as part of Administrative Monitoring Accounts to be administered by a Monitoring Administration Team (MAT).	In Progress
	To support waterfowl habitat improvement projects on USFS land in the Black Point area.	Upon request of the USFS, Licensee (LADWP) shall provide financial assistance in an amount up to $25,000 for waterfowl habitat improvements on USFS land in the Black Point area.		

Mono Basin Waterfowl Habitat Restoration Activities, cont. *(as described in SWRCB Order 98-05 and the Mono Basin Waterfowl Habitat Restoration Plan dated February 29, 1996, where relevant)*				
Activity	**Goal**	**Description**	**Progress to Date**	**Status**
Prescribed Burn Program	To enhance lake-fringing marsh and seasonal wet meadow habitats for waterfowl	The licensee shall proceed with obtaining the necessary permits and approval for the prescribed burning program described in the Mono Basin Waterfowl Habitat Restoration Plan dated February 29, 1996 and provide the SWRCB a copy of any environmental documentation for the program. Following review of the environmental documentation, the SWRCB may direct Los Angeles to proceed with implementation of the prescribed burning program pursuant to D1631 and Order 98-05, or modify the program.	LADWP began a prescribed burn program with limited success. LADWP requested to remove this item from the requirements in 2002 and the SWRCB instead ruled that the prescribed burn program will be deferred until Mono Lake reaches the target elevation. Once Mono Lake reaches the target elevation, LADWP will reassess the prescribed burn program. Based on results from the assessment, LADWP will either reinstate the program or request relief from the SWRCB from this requirement.	Deferred
Saltcedar Eradication Program	To control non-native vegetation in the Mono Basin	In the event that an interagency program is established for the control or elimination of saltcedar or other non-native vegetation deemed harmful to waterfowl habitat in the Mono Basin, Licensee (LADWP) shall participate in that program and report any work it undertakes to control saltcedar or other non-native vegetation.	LADWP continues treatment of saltcedar as needed. Progress of the salt cedar eradication efforts is reported in the annual reports following the vegetation monitoring efforts. This item will continue until notice from SWRCB is received that LADWP's obligation for this in the Mono Basin is complete.	Ongoing

3.1 Target Lake Elevation

The export criteria of Decision 1631 were developed to result in an eventual long-term average lake water elevation of 6,392 feet (SWRCB 1996). In determining the most appropriate water level for the protection of public trust resources at Mono Lake, the SWRCB recognized that there was no single lake elevation that would maximize protection and accessibility to all public trust resources (SWRCB). Decision 1631 stated that maximum restoration of waterfowl habitat would require restoring the lake elevation to 6,405 feet. Raising the lake elevation to 6,405 feet however, would have precluded use of any water from the Mono Basin by the City of Los Angeles for municipal needs, and inhibited public access to South Tufa, the most frequently visited tufa site. Furthermore, it was determined that a lake elevation of 6,390 feet would accomplish the restoration of some waterfowl habitat, and it was believed that there were opportunities to restore additional habitat, mitigating the loss. The target level of 6,392 feet was established as the average target elevation as it would also provide for compliance with federal air quality standards.

Raising the level of Mono Lake to an average elevation 6,392 feet was identified as the restoration measure with the highest priority for waterfowl habitat restoration. This measure is expected to restore the largest acreage and diversity of waterfowl habitat (LADWP 1996). The tiered export criteria of Decision 1631 was projected to result in the lake reaching the target level within 12 to 33 years (2008-2029).

3.2 Rewatering of Rush Creek Distributaries

The most important restoration achievement in Rush Creek was the establishment of perennial flow. The rewatering of side channels in Rush Creek was intended to improve waterfowl habitat by complementing the changes induced by a rising lake level. Side channel openings in the Rush Creek bottomlands were intended to provide small flows for restoration of waterfowl habitat in off-channel wetlands. Under the Stream Restoration Plan, rewatering of the 4Bii, and channels 8 and 10 has been completed. Some channels initially identified for restoration were not rewatered due to concerns raised by the stream scientists regarding potential impacts to the fisheries.

3.3 Financial Assistance for Waterfowl Habitat Improvement at County Ponds and the Black Point Area

The Plan included a recommendation to develop and implement the DeChambeau Ponds-County Ponds Restoration Projects. These ponds are under the jurisdiction of the U.S. Forest Service. The projects were expected to mitigate the loss of pond habitat that will not be restored at the target lake elevation. The restoration ponds were expected to require ongoing maintenance. LADWP was to make available a total of $275,000 for waterfowl restoration activities in the Mono Basin per Order 98-05. This money was to be used by the USFS if they requested the funds by December 31, 2004. Afterwards, any remaining funds are to be made available to any party wishing to do waterfowl restoration in the Mono Basin after SWRCB review. USFS has requested funds for a project estimated at $100,000. MLC has requested that the remainder of the funds be applied toward the total cost of the Mill Creek Return Ditch upgrade which would provide benefits for waterfowl habitat. These funds will continue to be budgeted by LADWP until such a time that they have been utilized. Currently, this money has tentatively been included in the 2013 Settlement Agreement (SWRCB 2013) as part of Administrative Monitoring Accounts to be administered by a Monitoring Administration Team (MAT). Under the 2013 Settlement Agreement, the Waterfowl Monitoring Director may recommend use of the funds authorized by Order 98-05 for the purpose of improving waterfowl habitat on U.S. Forest Service lands or elsewhere in the Mono Basin. This director or subconsultants shall be responsible to comply with any permitting requirements, and Licensee shall support such permitting and provide land access as necessary.

The DeChambeau Ponds are a complex of five artificial ponds. As many as seven small ponds existed initially, with water supplied from a deep well, in addition to water from Wilson Creek via diversions from the Mill Creek system (LADWP 1996). The DeChambeau Ponds were initially created at the onset of trans-basin diversions in the 1940s (LADWP 1996). By 1992, only two ponds held water due to deterioration in the water delivery system and levees. In the mid-1990's, the U.S. Forest Service partnered with Caltrans, the Mono Lake Committee, and Ducks Unlimited to restore DeChambeau ponds. Project goals included the creation of seasonal waterfowl habitat consisting of semi-permanent (Ponds 1 and 2), and seasonal impoundments (Ponds 3-5), as well as adjacent seasonal wet meadow and willow habitat (LADWP 1996, USDA Forest Service 2004). Restoration work was completed and included installing a well, an underground water delivery system and redeveloping levees (LADWP 1996).

The two County Ponds lie in a natural basin and former lagoon that is approximately 20 acres in total area (LADWP 1996), which dried as the lake level dropped below 6,405 feet in the 1950s. The County Ponds were temporarily re-flooded on an occasional basis after that time with water diverted from Wilson Creek, until an underground pipeline was installed to deliver water from DeChambeau Pond 4 to the pond complex (USDA Forest Service 2005) in the late 1990s. A clay sealant was also applied to County Pond East at that time in order to reduce water use. Under Order 98-05, the City may provide financial assistance to the U.S.F.S. for repairs to water diversion and distribution facilities and for related waterfowl habitat restoration work at the County Ponds.

The Plan also described potential restoration in the Black Point area. This project would entail maintaining up to 20 acres of shallow, seasonal wetlands in the Black Point area using an existing artesian well (LADWP 1996).

3.4 Develop and Implement Prescribed Burn Program

The intent of this recommendation was to enhance lake-fringing wetland marsh and seasonal wet meadow habitats for waterfowl. This program was suspended indefinitely, as it was agreed by the Parties that the cost, risk and potential effects on other species outweighed the short-term benefit that burning might provide.

3.5 Saltcedar Eradication Program

While there was no specific purpose related to waterfowl habitat stated, LADWP included in the Plan a provision to cooperatively address invasive species, including tamarisk (*Tamarix* spp.), in the event that an interagency program is established. Tamarisk has been encountered infrequently around Mono Lake. California State Parks has been actively conducting surveillance for and treatment of saltcedar outbreaks. LADWP staff have also conducted surveillance surveys for saltcedar along the riparian corridors and treated saltcedar as encountered.

4.0 WATERFOWL HABITAT RESTORATION MONITORING PROGRAM

The Plan and SWRCB Order WR 98-05 also directed LADWP to conduct monitoring to assess the success of waterfowl habitat restoration efforts, evaluate the effects of changes in the Mono Lake area, and plan for future restoration activities. Components of the waterfowl habitat monitoring plan include hydrology, limnology, the vegetation status of riparian and lake-fringing wetlands, and waterfowl population surveys. Each of these required monitoring components are described in detail in the following sections. Table 2 provides a brief description of the monitoring components, their required frequency under the Plan and Order 98-05, and the dates that each monitoring task has been performed to date.

The remainder of this report provides a synthesis of all data collected under the Mono Basin Waterfowl Habitat Monitoring Program.

Table 2. Mono Basin Habitat Restoration Monitoring Program

Mono Basin Habitat Restoration Monitoring Program *(as described in SWRCB Order 98-05 and the Waterfowl Habitat Restoration Plan dated February 29, 1996)*			
Monitoring Component	**Description**	**Required Frequency**	**Dates Monitoring Performed**
Hydrology	Lake Elevation	Weekly through one complete wet/dry cycle after the lake level has stabilized.	Monthly data collected 1936-present; ongoing
	Stream Flows	Daily through one complete wet/dry cycle after the lake level has stabilized.	Daily data collected 1935-present; ongoing
	Spring Surveys	Five year intervals (August) through one complete wet/dry cycle after the lake level has stabilized.	1999, 2004, 2009, 2014; ongoing
Lake Limnology and Secondary Producers	Meteorological data, data on physical and chemical environment of the lake, phytoplankton, and brine shrimp population levels.	Annually (monthly February-December) until the lake reaches a relatively stable level. LADWP will evaluate monitoring at that time and make a recommendation to the SWRCB whether or not to continue.	1987-present; ongoing
Vegetation Status in Riparian and Lake Fringing Wetland Habitats	Establishment and monitoring of vegetation transects and permanent photopoints in lake fringing wetlands	Five year intervals or after extremely wet year events (whichever comes first) until 2014. LADWP will evaluate the need to continue this program in 2014 and present findings to SWRCB.	2000, 2005, 2010, 2015; ongoing
	Aerial photographs of lake fringing wetlands and Mono Lake tributaries	Five year intervals until target lake elevation of 6,392 feet is achieved.	1999, 2005, 2009, 2014; ongoing

Mono Basin Habitat Restoration Monitoring Program *(as described in SWRCB Order 98-05 and the Waterfowl Habitat Restoration Plan dated February 29, 1996)*			
Monitoring Component	**Description**	**Required Frequency**	**Dates Monitoring Performed**
Waterfowl Population Surveys and Studies	Fall aerial counts	Two counts conducted every other year October 15-November 15. All waterfowl population survey work will continue until 2014, through one complete wet/dry cycle after the target lake elevation of 6,392 feet is achieved. Since 2002, six counts per year at Mono Lake, Bridgeport Reservoir and Crowley Reservoir	Annually; ongoing
	Aerial photography of waterfowl habitats	Conducted during or following one fall aerial count.	Annually; ongoing
	Ground counts	Total of eight ground counts annually (two in summer, six in fall). All waterfowl population survey work will continue until 2014, or through one complete wet/dry cycle after the target lake elevation of 6,392 feet is achieved. Since 2002, three summer ground counts have been conducted. Fall ground counts were replaced with six aerial counts.	Annually; ongoing
	Waterfowl time activity budget study	To be conducted during each of the first two fall migration periods after restoration plans are approved, and then again when the lake is at or near the target elevation.	Conducted one of two fall migration periods in 2000

4.1 Hydrology

Background

The largest lake in Mono County, Mono Lake has an east-west dimension of 13 miles, a north-south dimension of over nine miles (Raumann et al. 2002), and a circumference of approximately 40 miles. Within the hydrographically closed Mono Basin, all surface and groundwater drains towards Mono Lake. With an average depth of over 60 feet and a maximum depth of approximately 150 feet (Russell 1889), Mono Lake is a large, moderately deep terminal saline lake (Jellison and Melack 1993, Melack 1983). The deepest portions of the lake are found south and east of Paoha Island in the Johnson and Putnam Basins, respectively (Raumann et al. 2002). Shallower water and a more gently sloping shoreline is more typical of the north and east shores (Vorster 1985, Raumann et al. 2002).

The hydrologic components monitored at Mono Lake are lake elevation, stream flows and springs. The monitoring of the hydrologic components of the Waterfowl Habitat Restoration Program has been conducted by LADWP hydrographers.

Lake Elevation

Since Mono Lake lies in a closed basin with no outlet, lake elevation is driven by inflow from surface water, precipitation, ground water, and evaporative losses (Vorster 1985). Climatic variation in the late Pleistocene and Holocene periods resulted in an extreme high stand of 7,200 feet, and an extreme low of an approximately 6,368 foot lake elevation (Scholl et al. 1967 in Vorster). In historic times, lake level and salinity has fluctuated in response to climate variation (SWRCB 1994).

Stream Flow

Perennial creeks tributary to Mono Lake originate on the east slope of the Sierra Nevada. There are five primary creeks in the Mono Basin: Rush, Lee Vining, Mill, Parker, and Walker Creeks - three of which (Rush, Lee Vining and Mill) reach the western shoreline of Mono Lake. Parker and Walker Creeks are tributary to Rush Creek. These streams are primarily snow-melt fed systems, with peak flows typically occurring in June or July, especially in normal-to-wet years for the larger creeks, but peak flows may occur in April or May (Beschta 1994) in dry years or for the smaller creeks. Rush Creek is the largest tributary, accounting for approximately 50% of stream-flow contributions. Rush Creek was permanently re-watered in 1982, but the two tributaries to Rush Creek (Parker Creek and Walker Creek), did not get re-watered until 1990. Lee Vining Creek was re-watered in 1986. Prior to 1990, the combined input to Mono Lake from Rush and Lee Vining Creeks was lower due to export from Los Angeles (Figure 1). Flows in these creeks were more variable, occurring mainly during wet years.

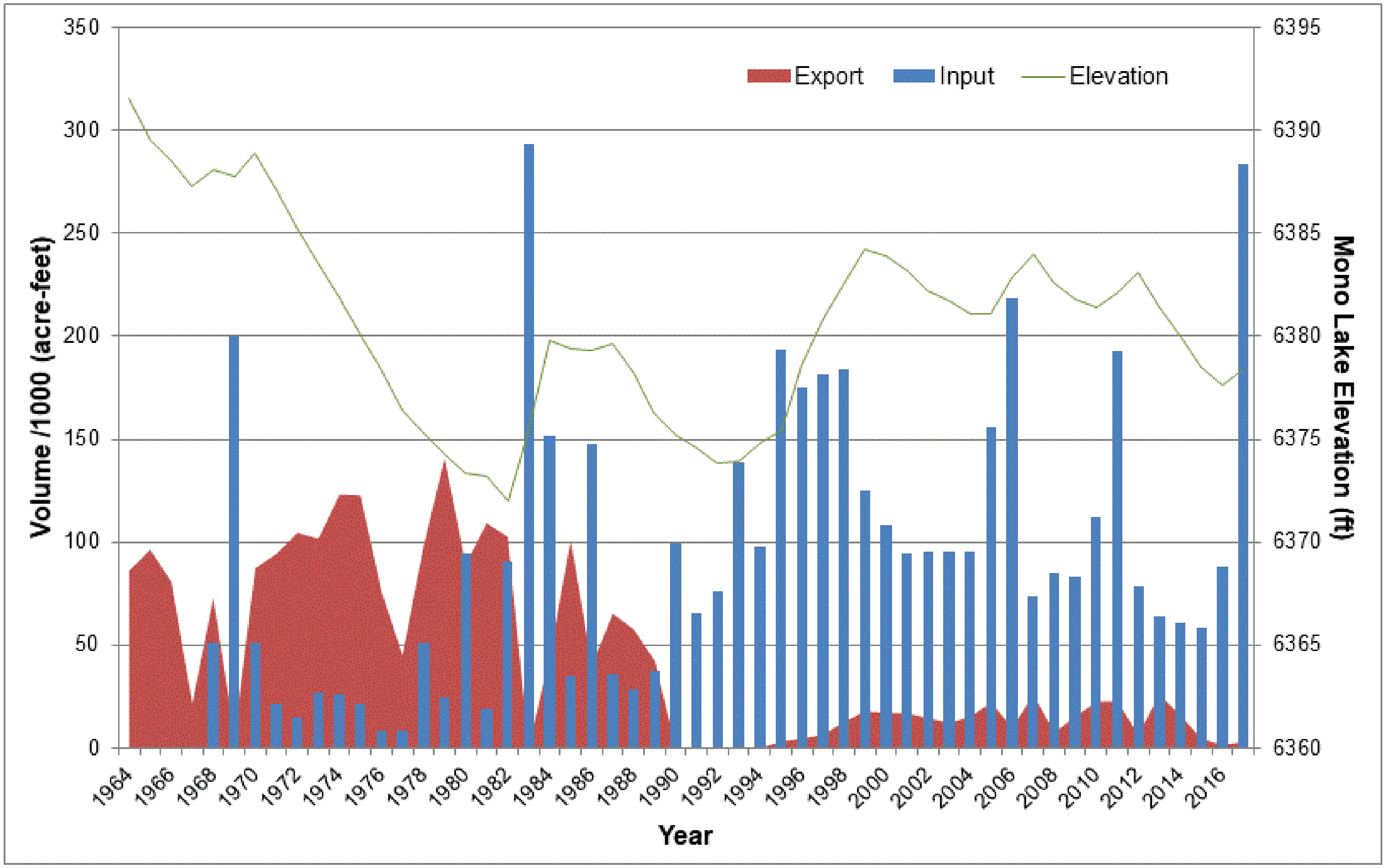


Figure 1. Annual Export of Water from Mono Lake Tributaries

Input to Mono Lake from Rush Creek and Lee Vining Creek and surface elevation from 1963-2017 reported in acre-feet per water year (October-September).

Springs

Numerous springs exist in the Mono Basin, and unlike the perennial creeks, are found all around the lakeshore. These shoreline springs are important waterfowl habitat, supporting wetland vegetation and invertebrate populations, and providing fresh water resources. Russell (1889) provides the earliest information on the springs surrounding Mono Lake, while a study by Lee in 1969 provided a more comprehensive study upon which later monitoring studies were based (LADWP 1987). The shoreline springs at Mono Lake have been classified into the following types (LADWP 1987, Jones and Stokes Associates, Inc. 1993):

1) **lakeshore water table springs** – shallow groundwater sources underlain by low permeability substrates, and surfacing in areas of high permeability sediments; groundwater source is an unconfined nearshore water table or a shallow, confined aquifer;
2) **deltaic artesian springs** – the spring type that produce the largest flows in the Mono Basin; originate in deep confined aquifers; discharge is expected to be responsive to lake elevation changes;
3) **deep fracture artesian** – deep ground water sources with a long flow path; springs surface primarily at faults; waters are of higher temperature and mineral content; these springs would be most susceptible to flow changes resulting from geologic events; and
4) **fractured-rock gravity-flow** – occur along the fault scarp at the base of the Sierra Nevada, just west of Highway 395; discharge is through fractured rocks in the fault zone and numerous springs daylight onshore east of the highway as ground water encounters low permeability lake bed sediments and are forced to the surface; recharge is from snow melt and rainfall and these spring types are expected to be responsive to changes in runoff due to their short, highly permeable flow paths.

4.1.1 Hydrologic Monitoring Methodologies

Mono Lake Elevation Monitoring

The elevation of Mono Lake is measured manually on a biweekly basis, at a staff gauge located near the Old Marina along the west shore. Lake elevation monitoring data are used for determining progress in meeting the targeted lake level, for determining appropriate export amounts, and for providing environmental data to evaluate the response of biological indicators including secondary producers, vegetation, and waterfowl.

Stream Flow Monitoring

Stream flow monitoring is conducted along the five perennial creeks– Rush, Lee Vining, Mill, Parker, and Walker Creek. There are eight gauging stations which track Mono Lake inflow along the tributaries: six are operated and maintained by LADWP and two are operated and maintained by Southern California Edison. At each station, flow is measured at 15-minute intervals and converted into daily flow, which is used to calculate monthly and annual inflow into Mono Lake. Stream flow data are used for determining compliance with the Stream Restoration Plan, and to provide environmental data to evaluate the response of biological indicators.

Spring Monitoring

Springs are monitored to evaluate changes in spring flow, temperature, and water quality relative to lake elevation. Springs surveys have been conducted every five years by LADWP hydrologists. Since the implementation of the Plan, monitoring has been conducted in 2004, 2009, and 2014 (LADWP 2014a). Thirty-five springs at Mono Lake were selected for monitoring, including 11 in DeChambeau Creek area (DECR), three in DeChambeau Embayment (DEEM), four at Simons Spring (SISP), two at South Tufa (SOTU), two in the South Shore Lagoons area (SSLA), five at Warm Springs (WASP), five along the West Shore (WESH), and three at Wilson Creek (WICR) (Figure 5.4). Spring surveys are conducted in late fall (October or November) and include measurements of the flow, temperature, and electrical conductivity (µS/cm).

4.1.2 Hydrology Data Summary and Analysis

Lake Elevation

Monthly Mono Lake elevation data were summarized for the time period 1998-2017, or since implementation of Order 98-05. Simple linear regression was used to describe lake elevation changes since implementation of the Order. Patterns of lake elevation change were evaluated on a yearly and monthly basis. To elucidate the differences in patterns observed, water years were further categorized as to runoff year type as found in Order 98-05. The runoff year is April 1 to March 31, and runoff year type is based on the LADWP April 1 Mono Basin runoff forecast, although adjustments may be made on May 1. Runoff year type is based on a comparison of the total acre-feet of predicted runoff to the 1941-1990 average runoff of 122,124 acre-feet (Table 3).

Table 3. Runoff Water Year Types

Water Year Type	April 1 Runoff Forecast
Dry	<68.5% of average runoff*
Dry/Normal	between 68.5% and 82.5% of average runoff
Normal	between 82.5% and 107% of average runoff
Wet/Normal	between 107% and 136.5% of average runoff
Wet	between 136.5% and 160% of average runoff
Extreme Wet	> 160% of average runoff

*average runoff based on 1941-1990 average runoff of 122,124 acre-feet

Streams

The real-time station flow data were converted into daily flow, which was used to calculate monthly and annual inflow into Mono Lake. Inflow from Rush Creek is estimated by summing Mono Gate One Return Ditch (STAID 5007), Grant Lake Spill (STAID5078), Parker Creek below Conduit (STAID5003) and Walker Creek below Conduit (STAID5002). Lee Vining Creek below Conduit (STAID5009) and Dechambeau Creek above Diversion (STAID5049) are used to estimate inflow from Lee Vining and Dechambeau Creeks, respectively. The above gauging stations are operated and maintained by LADWP. The inflow from Mill and Wilson Creeks cannot be precisely known due to discontinuation of gauging stations; thus, the inflow is estimated by summing outflow of Lundy Lake through Mill Creek and through the power plant into Wilson Creek. Currently both stations are operated and maintained by Southern California Edison. Dechambeau, Mill, and Wilson Creeks lose water through diversion before reaching Mono Lake; however, flow from Log Cabin Creek and a series of springs located in the northwest corner of the lake may make up the loss.

Springs

The locations of all previously identified springs (LADWP 1987, LADWP 2014a) and new springs observed during waterfowl surveys were compiled and mapped. A lack of specific location information prevented the mapping of all spring recorded historically. To better understand the resources available to waterfowl, the mapped springs were classified by salinity class using Stewart and Kantrud (1971) (Table 4). The salinity classes used (measured as electrical conductivity in units of micro-Siemans per centimeter [µS/cm]) are defined in the following table.

In order to account for any fluctuations in specific conductance (i.e. salinity) that may occur during periods of consecutive drought, the more liberal “extreme range” was used for classification of Mono Lake springs.

Table 4. Salinity Ranges Used for Classifying Mono Lake Springs

Salinity Class	*Normal Range*	*Extreme Range*
Fresh	<40-500 µS/cm	<40-700 µS/cm
Slightly brackish	500-2,000 µS/cm	300-2,200 µS/cm
Moderately brackish	2,000-5,000 µS/cm	1,000-8,000 µS/cm
Brackish	5,000-15,000 µS/cm	1,600-18,000 µS/cm
Subsaline	15,000-45,000 µS/cm	3,500-70,000 µS/cm
Saline	45,000-100,000+ µS/cm	20,000-100,000+ µS/cm

Historic data as well as data from the LADWP spring monitoring program were compiled for the 36 springs being monitored under the Plan. Historic flow and conductivity data for years prior to implementation of the Plan were compiled from LADWP (1987). Flow and conductivity data for 2004, 2009, and 2014 are from the LADWP monitoring conducted under the Plan. All flow data were standardized to gallons per minute (GPM). Conductivity values are presented as µS/cm. The total measured flow and mean conductivity of the monitored springs by shoreline subarea were calculated.

4.1.3 Hydrology Results

Lake Elevation

From 1998 to 2017, Mono Lake has experienced four periods of increasing elevation, and three subsequent decreases, through a total elevation range of 8.0 feet (Figure 2). The most recent increase occurred in 2017 in response to the extreme wet year of 2016-2017. The highest elevation the lake has achieved since 1998 has been 6,385.1 feet which occurred in July 1999, and August 2006. During a period of extended drought from 2012-2016, the lake elevation dropped almost 7 feet to a low of 6,377.1 feet in January 2017, the lowest level since implementation of the Order. Despite the four periods of rise in lake level that were observed, there has been an overall pattern of decreasing lake elevation.

The lake elevation tends to be most stable in the winter months of January through the end of March, showing slight declines in early spring, especially in dry to wet/normal years (Figure 2). Increasing evapotranspiration rates in early spring may lead to a slight decrease in lake levels, however in extreme wet years, the lake level has not shown the same decrease. In dry to normal years, early runoff will cause a slight increase by June, however this bump in elevation is slightly later in wet/normal years. In extreme wet years, large increases in lake elevation have been observed from July into August.

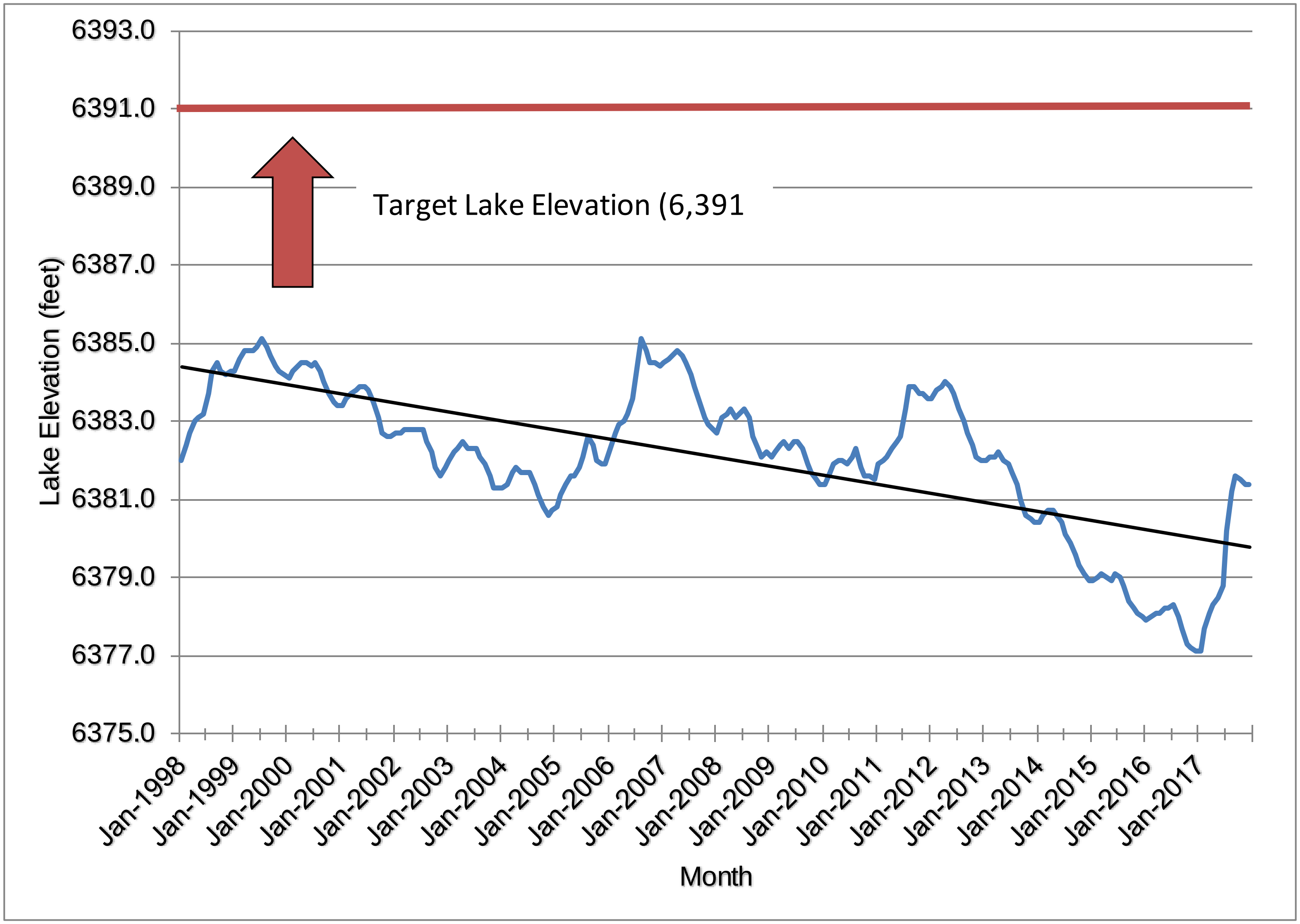


Figure 2. Mono Lake Elevation – 1998-2017

Since implementation of Order WR 98-05, four wet periods of lake level increases have been seen. Despite this, there is a negative trend in lake elevation, and as of 2017, Mono Lake was nearly 10 feet below the target level.

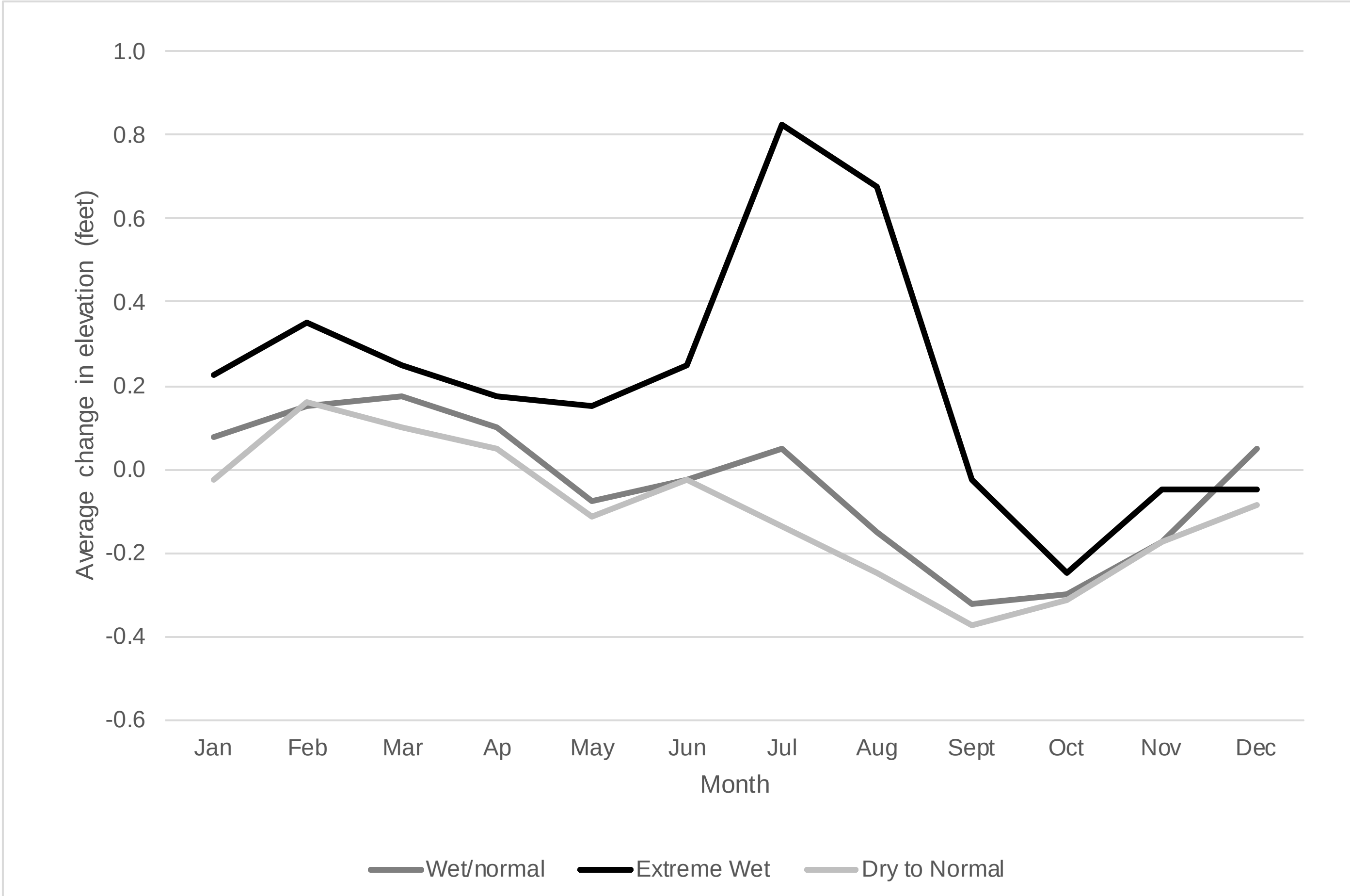


Figure 3. Monthly Pattern of Lake Elevation Changes by Runoff Year Type

Dry to normal category includes Dry, Dry/Normal and Normal Years as the pattern is similar among these three year types.

Stream Flows

Prior to 1990, the combined input to Mono Lake from Rush and Lee Vining Creeks was lower and more sporadic, mainly occurring during wet years, due to export to Los Angeles (see Figure 1). Decision 1631 and Order 98-05 dictated the instream flows (or base flows) and channel maintenance flows (or peak flow) for Lee Vining Creek, Rush Creek, Parker and Walker Creek. Instream and channel maintenance flows for other tributaries to Mono Lake were not specified by the Order.

Since 1990, Rush Creek has averaged 63,128 acre-foot discharge annually while Lee Vining Creek has averaged 39,490 acre-foot (Table 5). The highest annual input on record is 185,473 acre-foot in 1983 for Rush Creek and 91,133 acre-feet in 2017 for Lee Vining Creek. Dechambeau Creek has averaged 826 acre-feet since 1944 and has contributed less than 1% of total annual input since 1990. The combined flow of Mill and Wilson Creeks has averaged 18,763 acre-feet since 1968 and has contributed approximately 15% each year to annual input since 1990.

In the Mono Basin, runoff year types are cyclical, with wet years followed by dry years. In the late 1930s to early 1940s, the late 1970s to 1980s, and the late 1990s, the wet periods lasted longer than they have as of late (Figure 4). Dry and dry/normal years have been the most frequent runoff year type occurring in the Mono Basin since 1990, as for the last 13 of 28 years runoff has been less than 82.5% of normal, or more frequently, less than 68% of normal. Furthermore, in 18 of the last 28 years, runoff was less than 95% of the overall average of 95%. Two extreme wet years have been experienced since Order 98-05, including runoff year 2006 and 2017. Between 1990 and 1999, the runoff was 102% of the long-term average. In contrast, between 2000 and 2016, average runoff was 85%, during which only 4 years show runoff above 100% of the long-term mean. The extreme wet year of 2017 had runoff of 176% of normal.

Table 5. Annual Flow of Five Mono Lake Tributaries in Acre-Feet, Based on Water Year

Year	Rush Creek	Lee Vining Creek	Dechambeau Creek	Mill Creek	Wilson Creek
1990	71,047	18,644	326	489	8,626
1991	35,714	20,562	265	513	8,213
1992	44,632	20,799	179	501	10,089
1993	77,461	42,279	440	1,798	16,912
1994	56,776	29,377	451	516	10,603
1995	94,596	66,443	911	10,203	21,697
1996	91,842	56,284	1,244	4,566	20,992
1997	82,424	66,317	1,486	4,623	26,290
1998	93,178	62,335	1,326	6,017	21,097
1999	58,047	46,204	1,151	1,459	18,013
2000	50,497	40,432	750	1,252	15,118
2001	49,357	31,034	576	773	12,500
2002	45,900	36,599	406	788	11,920
2003	49,028	30,778	530	1,108	14,091
2004	47,644	31,872	550	159	14,956
2005	72,766	55,367	995	6,823	19,817
2006	108,899	75,861	1,460	10,085	22,064
2007	38,428	24,091	998	1,267	8,906
2008	45,159	25,632	588	2,557	10,708
2009	36,570	30,654	586	3,658	12,111
2010	57,622	34,776	672	4,314	15,015
2011	96,433	65,454	1,151	7,588	22,409
2012	46,535	19,487	927	2,369	8,904
2013	34,776	18,320	476	2,179	8,237
2014	31,893	20,048	340	1,979	6,560
2015	32,754	16,525	273	1,806	6,679
2016	44,242	28,421	276	2,751	12,481
2017	145,349	91,133	1,433	19,550	25,861

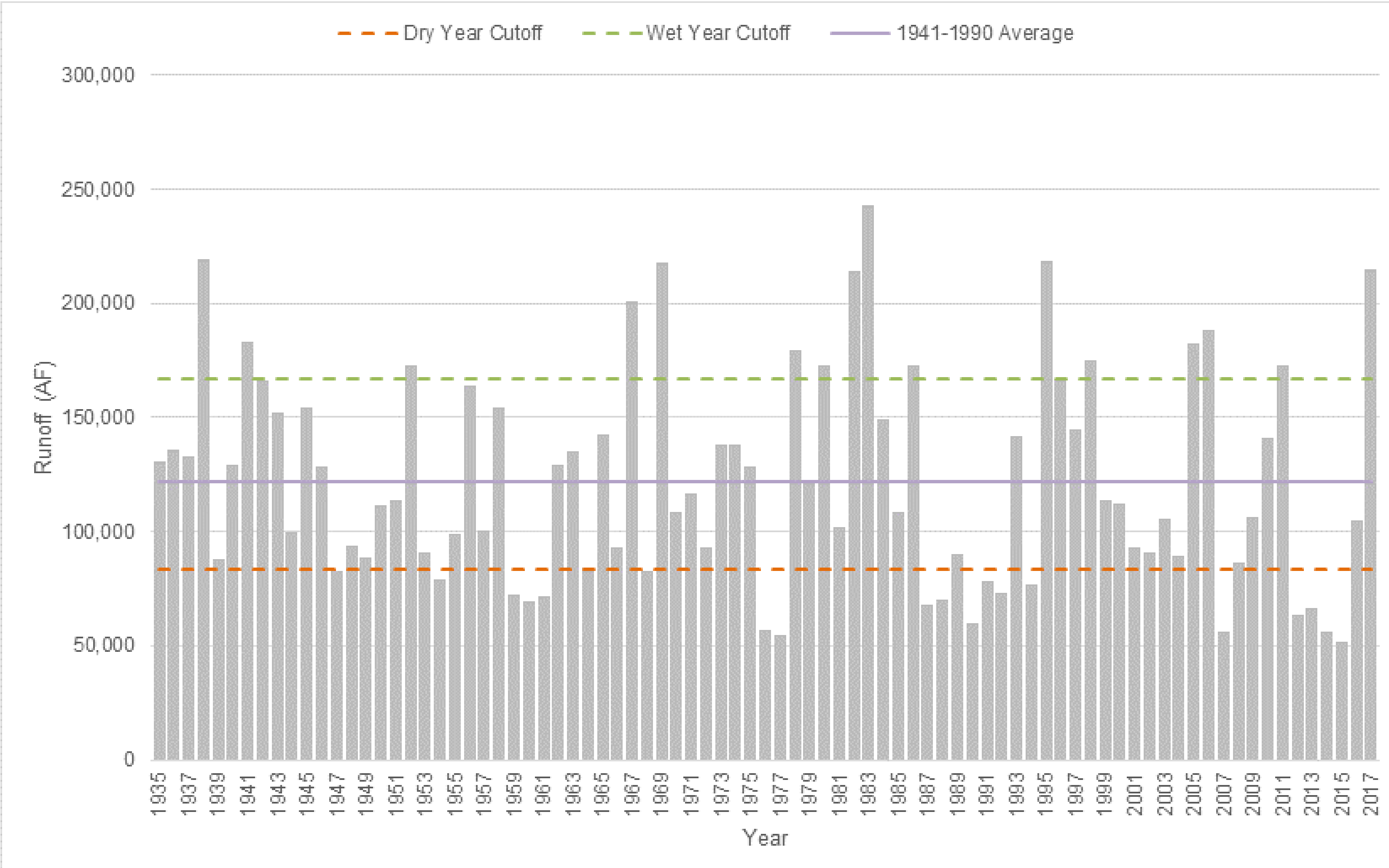


Figure 4. Mono Basin Runoff Based on Runoff–Year for Entire Period of Record 1935-2017

Springs

Almost 200 springs have been identified in the Mono Basin (LADWP 1987). Of these, location information was specific enough for 92 springs to allow for mapping (Figure 5). Springs are concentrated along the west and northwest shore, south shoreline, east shore at Warm Springs, and the northcentral shoreline.

The historic data on spring flow and conductivity is very limited as data prior to 2004 are not available for all of the monitored springs, and springs for which there is data, were visited only once or twice between 1967 and 2004 (Tables 6 and 7). Spring monitoring under the Plan has provided more complete and consistent record since 2004.

The highest measured spring flow has been at DeChambeau Creek, where a total of 10 springs are being monitored (Figure 6). All of the springs in the DeChambeau Creek subarea are fresh water springs with a measured median flow of 1,728 gpm. Historic flow measurements are available for four of the ten monitored springs. Significant decreases in spring flow have been observed for several of the springs in the DeChambeau Creek area including County Park #1, #2, and #4 and #9 and Villette Spring. County Park #5 and #6 have shown a slight increase. Since 2004, the spring monitoring data also indicates an overall decrease in spring flow in this area (Figure 6). There has been no change in the average conductivity (Figure 7).

The trend in spring flow data for DeChambeau Embayment cannot be evaluated as the flow has been too low to measure. Coyote Marsh has been fresh to slightly brackish, while all other springs are moderately brackish. The mean conductivity of spring flow has increased in the shoreline subarea since 2004 (Figure 7)

The spring flow data for the Simons Spring area suggests that there has been variability in flows of the freshwater springs monitored there. The conductivity values reported since 2004 have been significantly lower than historic values for most of the springs in the Simons Springs area. There has been no change in the mean conductivity of the spring flow at Simons Spring.

Two of the four mapped springs at South Tufa are monitored, and these moderately brackish springs have a combined output of 145 gpm. Spring flow at South Tufa has increased over the 1967 values, and has been stable since 2004. The increase observed shown in Figure 6 for 2014 is because the decline in lake elevation exposed Hot Tufa Tower springs and allowed sampling. The conductivity of the Southern Comfort Spring has shown a slight increase in salinity over time.

Two of nine mapped springs are monitored in the South Shore Lagoons area – Goose Springs and Sand Flat Spring. Spring flow for the two South Shore Lagoons springs has remained fairly stable. The spike in conductivity reported for Sandflat appears anomalous, and may represent a data entry error.

At Warms Springs, of the ten moderately brackish springs that have been mapped, five are monitored. The median measured flow of these five springs has been 80 gpm. Spring flow at Warm Springs showed a large drop off in 2014. As flows have declined, mean conductivity of the springs at Warm Springs has been increasing.

Along the West Shore, five of 10 of the mapped springs are monitored, including Andy Thom Creek. Spring flow has been variable, peaking in 2009. The salinity of these fresh water springs has been stable.

In the Wilson Creek area, two of eight mapped springs are monitored with a median spring flow of over 900 gpm. Although not being monitored, Black Point Seep also contributes significantly to the fresh water resources in this area, with an average measured flow of approximately 250 gpm. These two springs are the largest springs along the south shore, with a median flow of 565 gpm. Spring flow has declined over the last three monitoring periods, and in 2014 was 40% lower than that measured in 2004.

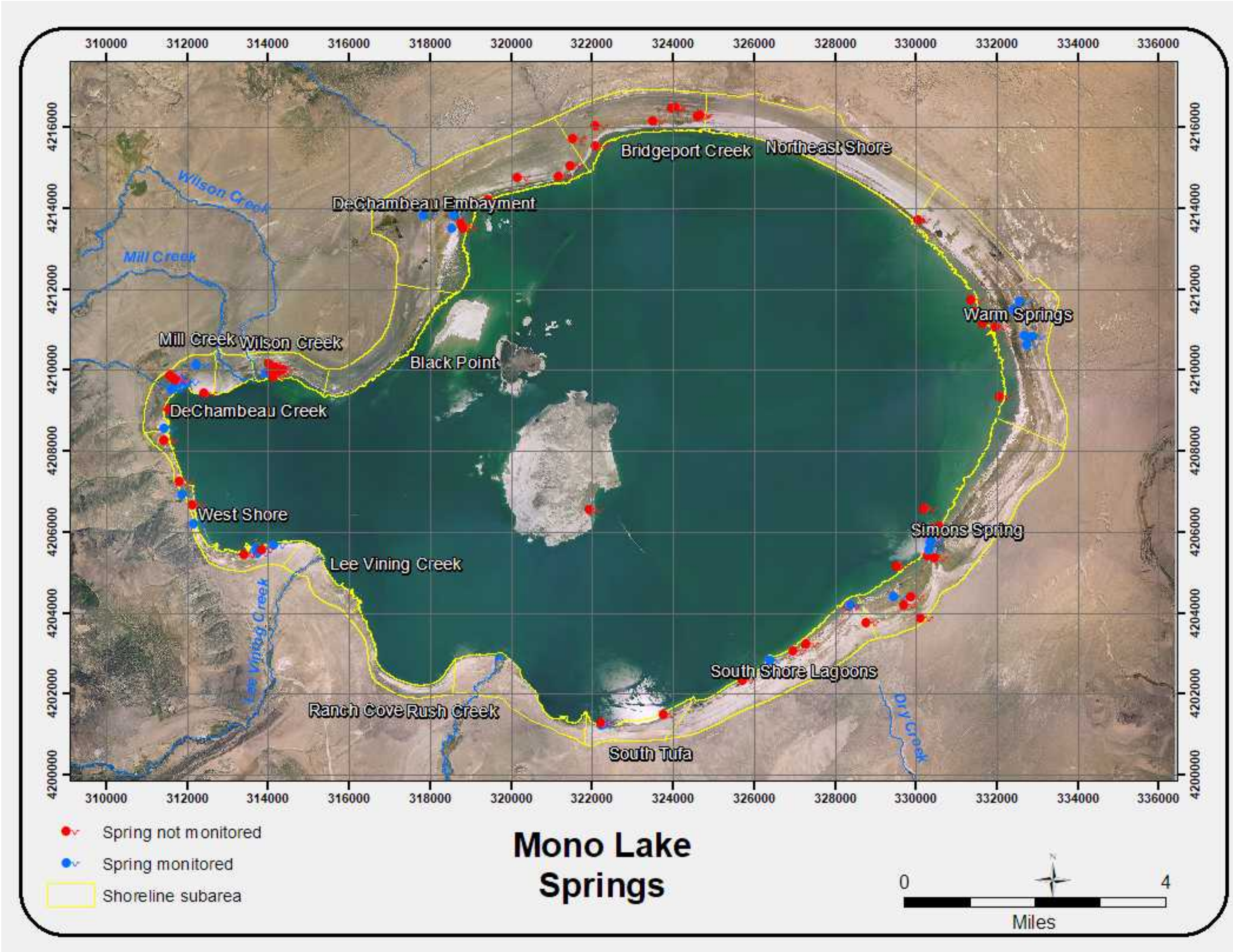


Figure 5. Map of Mono Lake Spring Locations Compiled from LADWP 1987 and LADWP 2014a

Only springs whose location could be determined from the available information are included. Springs monitored under the Plan are indicated.

Table 6. Historic and Current Flow Data for the 36 Springs Monitored Under the Plan

Flow in gallons per minute (GPM).

Shoreline Subarea	Spring Name	1967	1968	1981	1982	1984	1986	1991	2004	2009	2014
DeChambeau Creek	County Park #1						323.0		44.9	44.9	35.9
	County Park #2						628.0		44.9	44.9	35.9
	County Park #3								44.9	44.9	44.9
	County Park #4								323.2	278.3	44.9
	County Park #5								22.4	35.9	89.8
	County Park #6								67.3	67.3	143.6
	County Park #7								130.2	112.2	161.6
	County Park #8								466.8	300.7	552.1
	County Park #9								502.7	412.9	89.8
	Shrimp Farm Spring				220.0		202.0		219.9	170.6	193.0
	Villette Spring			435.0			458.0		tr	tr	dry
DeChambeau Embayment	Coyote Marsh								tr	tr	tr
	Martini Spring								tr	tr	tr
	Perseverance								tr	tr	tr
	Solo Tufa Tower Spring		0						submerged	submerged	ND
Simons Spring	Abalos Spring				60.0		112.0		22.4	44.9	44.9
	Crooked Channel				50.0				44.9	89.8	89.8
	Sandpiper Channel				70.0		14.0		157.1	255.8	175.0
	Teal Spring			225.0		0.6	251.0		89.8	89.8	89.8
South Tufa	Hot Tufa Tower	16			0.0				submerged	submerged	89.8
	Southern Comfort Spring	32			30.0				44.9	67.3	67.3
South Shore Lagoons	Goose Spring (E)			525.0			422.0		520.6	547.6	507.2
	Sandflat Spring						36.0	65.0	tr	tr	44.9
Warm Springs	Bug Warm Spring				0.0		14.0		tr	9.0	tr
	Pebble Spring				0.0		0.0		vegetated	vegetated	0.0
	Twin Warm Spring						0.0		67.3	98.7	13.5
	Warm Spring "B"								314.2	260.3	23.3
	Warm Springs Marsh Channel				30.0		22.0		49.4	vegetated	tr
West Shore	Andy Thom Creek								211.0	368.0	121.2
	Babylon Tufa Tower Spring				290.0		274.0		76.3	237.9	116.7
	Charlie's Spring	160					14.0		tr	35.9	22.4
	Fractured Rock Spring #2				190.0		211.0		215.4	242.4	157.1
	Lee Vining Delta Spring				0.0				134.6	130.2	130.2
Wilson Creek	Black Point Seep (Scoria Tufa?)								269.3	251.3	242.4
	Gull Bath (E)						193.0		1000.9	830.3	628.4
	Gull Bath (W)						319.0		291.7	80.8	103.2

ND= No data

tr=trace flow, unmeasurable

Table 7. Historic and Current Conductivity Data for the 36 Springs Monitored Under the Plan

Conductivity values are represented as µS/cm.

Shoreline Subarea	Spring Name	1967	1968	1981	1982	1984	1986	1991	2004	2009	2014
DeChambeau Creek	County Park #1						380		190	140	140
	County Park #2						260		120	130	140
	County Park #3								190	180	190
	County Park #4								185	180	220
	County Park #5								140	170	210
	County Park #6								140	140	180
	County Park #7								130	180	170
	County Park #8								140	180	160
	County Park #9								120	145	130
	Shrimp Farm Spring				240		280		175	170	140
	Villette Spring			130			120		100	120	dry
DeChambeau Embayment	Coyote Marsh								480	600	480
	Martini Spring			1850					2000	2200	2300
	Perseverance								1100	1800	2200
	Solo Tufa Tower Spring		2975						submerged	submerged	ND
Simons Spring	Abalos Spring				620		680		380	380	415
	Crooked Channel				1060				480	390	410
	Sandpiper Channel				4210		2600		540	540	560
	Teal Spring			463		470	520		360	320	350
South Tufa	Hot Tufa Tower	2851		2600	2640				submerged	submerged	2600
	Southern Comfort Spring	3223			5730				2200	2400	2700
South Shore Lagoons	Goose Spring (E)			636			620		440	460	490
	Sandflat Spring						350	420	ND	ND	4000
Warm Springs	Bug Warm Spring				3250		2700		2700	3200	3500
	Pebble Spring				1780		1500		1500	1700	1080
	Twin Warm Spring						3400		2400	3300	3500
	Warm Spring “B”								2200	3000	3400
	Warm Springs Marsh Channel				3940		4600		3300	ND	4800
West Shore	Andy Thom Creek								42	40	40
	Babylon Tufa Tower Spring				200		240		140	140	120
	Charlie’s Spring	303					130		90	82	90
	Fractured Rock Spring #2			362	390		310		310	330	340
	Lee Vining Delta Spring			362	193				240	270	200
Wilson Creek	Black Point Seep (Scoria Tufa?)								160	175	180
	Gull Bath (E)						220		140	160	170
	Gull Bath (W)						200		155	175	185
ND= No data	ND= No Data										

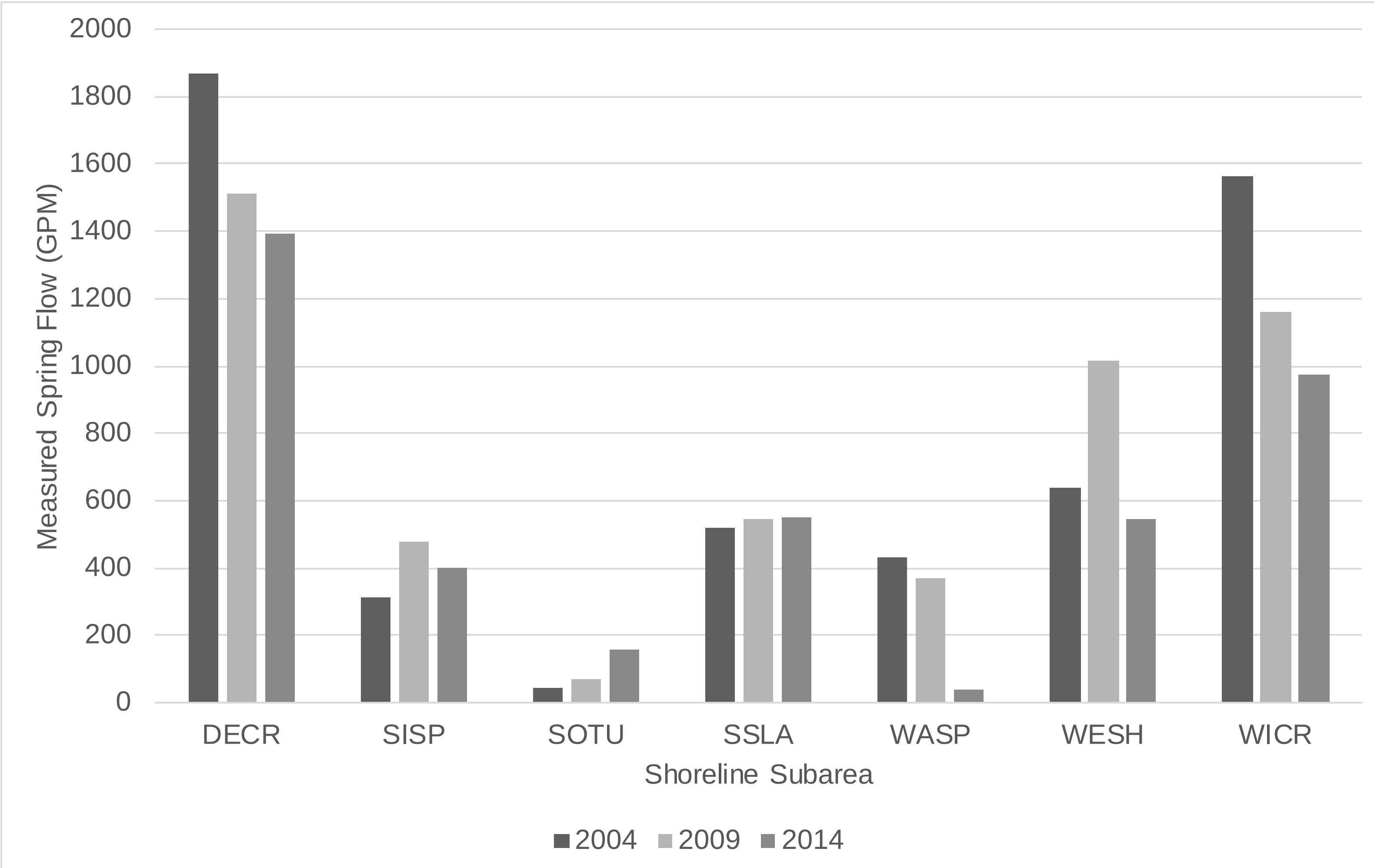


Figure 6. Total Measured Flow of Monitored Springs by Shoreline Subarea

Total measured flow calculated from LADWP spring monitoring data.

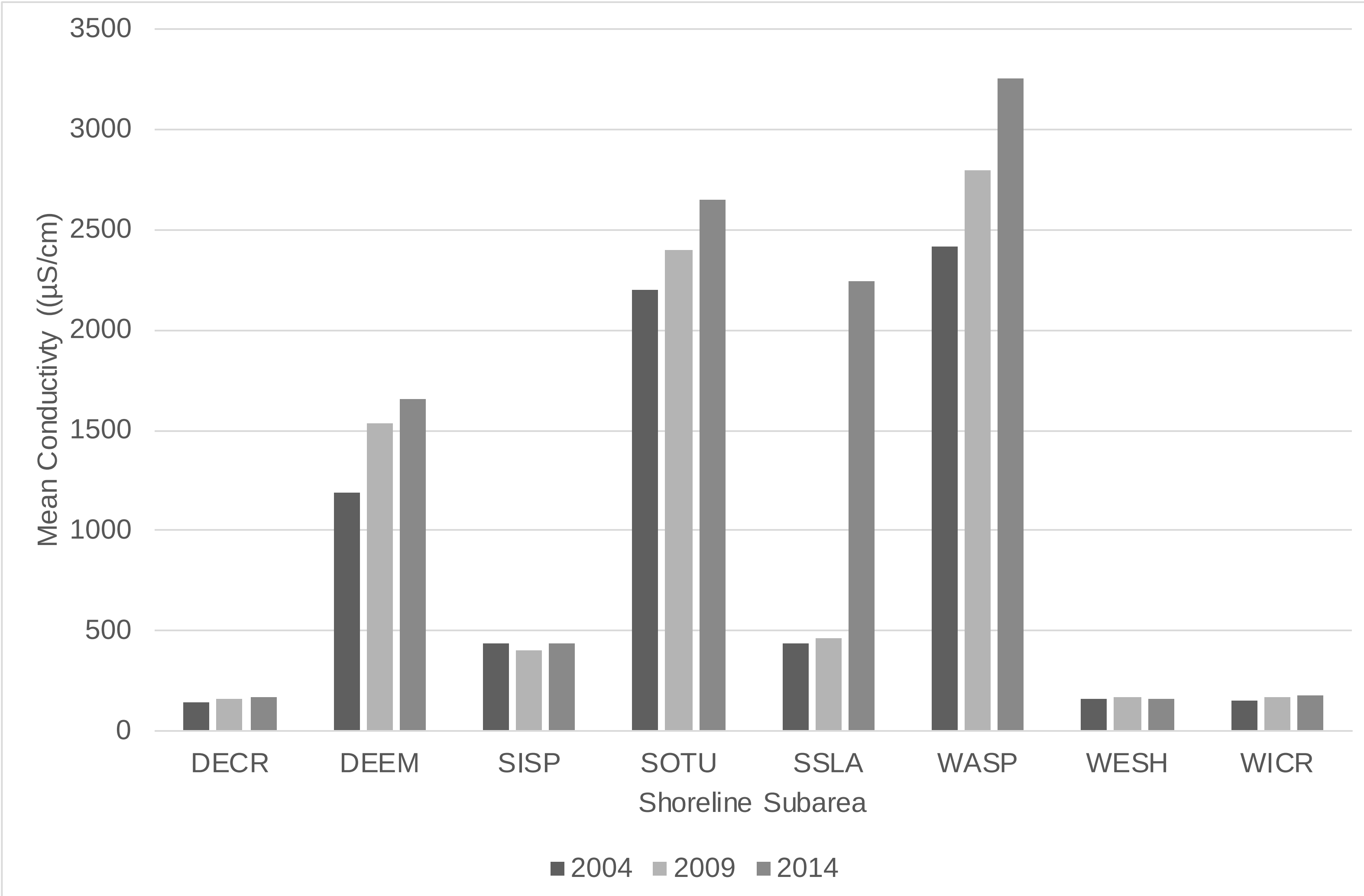


Figure 7. Mean Conductivity of Measured Springs

Mean conductivity calculated from LADWP spring monitoring data.

4.1.4 Hydrology Discussion

Lake Elevation

Following the preliminary injunction in 1989, and Decision 1631, there have been a series of wet and dry periods that have affected the elevation of Mono Lake. Although modeling predicted reaching the target lake elevation in approximately 20 years (or by 2015), this restoration action is taking longer than predicted by the early models, as Mono Lake has not yet reached the target lake elevation. Since 1995, exports have averaged 13,000 acre-feet. Fluctuations have occurred primarily due to variation in water years, however the lake level has been decreasing on average (Figure 2).

Stream Flows

The Mono Basin runoff follows a dry period interrupted by a short wet period except in the late 1930s to early 1940s, the late 1970s to 1980s, and the late 1990s when a wet period is found to last longer. Since both Lee Vining and Rush Creeks has been permanently re-watered, 32% of years are found as “Dry” compared to 18% for years prior to 1990 meanwhile 25% of years are found as either “Wet” or “Extreme Wet” after the permanent re-watering compared to 18% for prior to 1990. The average percent normal runoffs for all year types between pre and post re-watering periods are similar, but these averages diverge when a period between 2000 and 2017 is compared to the pre re-watering period especially for the dry year type. The average percent normal for dry years since 2000 is 48% compared to 58% between 1935 and 1999. It appears dry years are becoming drier in recent years. Drier condition may not greatly affect Rush Creek as instream flow or base flow only follow runoff year types not magnitude of runoff; however, this is not the case for other tributaries, including Parker and Walker Creeks, two tributaries to Rush Creek. Pre- and post re-watering comparison for stream flow is not meaningful; however, streamflow reflects the Mono Basin Runoff, and lower streamflow may be expected during dry years.

Springs

The spring monitoring data suggests a decrease in total measured spring flow at two west shore sites- DeChambeau Creek and Wilson Creek and at Warm Springs. The same pattern is not seen at the springs measured along the West Shore or the south shore sites. The reason for these changes are not clear. Lake level has also been declining overall since 2004, and may partly explain the decreases observed. In the DeChambeau Creek area, significant decreases were seen in Villette Spring, a spring that contributed over 400 gpm to Mono Lake in the 1980’s. During the LADWP spring surveys, it has been noted that the spring had been dammed, and the flows diverted. Daily, seasonal, and yearly fluctuations in spring flow at these sites is unknown however. The mean conductivity of the brackish springs at all shoreline areas has been increasing, but no such change in conductivity has been observed in the freshwater springs. Daily, seasonal, and yearly fluctuations in conductivity of these springs unknown, however, these changes have been coincident with the trend of increasing salinity of Mono Lake. Continued monitoring will be important to determine the response of springs to lake level changes.

4.2 Limnology

Mono Lake supports a relatively simple yet productive aquatic ecosystem. Benthic and planktonic algae form the foundation of the food chain in the lake. The phytoplankton community is primarily composed of coccoid chlorophytes (*Picosystis* spp.), coccoid cyanobacteria, and several diatoms (primarily *Nitzschia* spp.) (Jellison and Melack 1993). Filamentous blue-green algae (*Oscillatoria* spp.) and filamentous green algae (*Ctenocladus circinnatus*) and the diatom *Nitzchia frustulum* dominant the benthic algal community. The most abundant secondary producer in the pelagic zone is the Mono Lake brine shrimp (*Artemia monica*). In the littoral zone, secondary producers including the alkali fly (*Ephydra hians*), long-legged fly (*Hydrophorus plumbeus*), biting midges (*Cuciloides occidentalis*), and deer fly (*Chrysops* spp.) graze on benthic algae (Jones and Stokes Associates, Inc 1993).

Within the hydrographically closed Mono Basin, the particular water chemistry of Mono Lake is influenced by climate, water inputs, evaporative losses, and the chemical composition of the surrounding soils and rocks. The waters are saline and alkaline, and contain high levels of sulfates, chlorides, and carbonates. For the period 1938-1950, the salinity of Mono Lake was approximately 50 g/L, and by 1964 salinity had increased to 75 g/L, and up to 100 g/L by 1982 (Vorster 1985). Since implementation of Decision 1631, the salinity has varied from 72 to 97 g/L, which is approximately two to three times as salty as ocean water. The lake water is also highly alkaline, with a pH of approximately 10, due to the high levels of carbonates dissolved in the water.

The limnological monitoring program at Mono Lake is one component of the Plan and is required under SWRCB Order No. 98-05. The purpose of the limnological monitoring program as it relates to waterfowl is to assess limnological and biological factors that may influence waterfowl use of lake habitat (LADWP 1996). The limnological monitoring program has four components: meteorology, physical/chemical analysis, chlorophyll *a*, and brine shrimp population monitoring.

An intensive limnological monitoring program at Mono Lake has been funded by Los Angeles Department of Water and Power since 1982. The Marine Science Institute (MSI), University of California, Santa Barbara served as the principle investigator, and Sierra Nevada Aquatic Research Laboratory (SNARL) provided field sampling and laboratory analysis technicians until July 2012. After receiving training in limnological sampling and laboratory analysis methods from the scientists and staff at MSI and SNARL, LADWP Watershed Resources staff assumed responsibility for the program, and have been conducting the limnological monitoring program at Mono Lake since July of 2012.

Laboratory support including the analysis of ammonium and chlorophyll *a* has been provided by Environmental Science Associates (ESA), Davis, California since 2012.

This report summarizes monthly field sampling for the year of 2017, and discusses the results in the context of the entire period of record. In addition to the report summarizing Mono Lake conditions in 2017, past findings are also summarized to demonstrate long term trends in the *Artemia* population and Mono Lake water parameters to gain deeper insights into the mechanisms of *Artemia* population dynamics. This report also presents recommendations for the program.

4.2.1 Limnological Monitoring Methodologies

Methodologies for both the field sampling and the laboratory analysis followed those specified in *Field and Laboratory Protocols for Mono Lake Limnological Monitoring* (*Field and Laboratory Protocols*) (Jellison 2011). The methods described in *Field and Laboratory Protocols* are specific to the chemical and physical properties of Mono Lake and therefore may vary from standard limnological methods (e.g. Strickland and Parsons 1972). The methods and equipment used by LADWP to conduct limnological monitoring are consistent and follow those identified in *Field and Laboratory Protocols* except where noted below.

Meteorology

One meteorological station on Paoha Island provided weather data. The Paoha Island measuring station is located approximately 30 m from shore on the southern tip of the island. The base of the station is at 1,948 m (6,391 feet) above sea level, several meters above the current surface elevation of the lake. Sensor readings are made every second and stored as either ten-minute averages or hourly values in a Campbell Scientific CR 1000 datalogger. Data are downloaded to a storage module, which is collected periodically during field sampling visits.

At the Paoha Island station, wind speed and direction (RM Young wind monitor) are measured by sensors at a height of 3 m above the surface of the island and are averaged over a 10-minute interval. During the 10-minute interval, maximum wind speed is also recorded. Using wind speed and direction measurements, the 10-minute wind vector magnitude and wind vector direction are calculated. Hourly measurements of photosynthetically available radiation (PAR, 400 to 700nm, Li-Cor 192-s), 10-minute averages of relative humidity and air temperature (Vaisalia HMP35C), and total rainfall (Campbell Scientific TE525MM-L tipping bucket) are also stored. The minimum detection limit for the tipping bucket gage is 1 mm of water. The tipping bucket is not heated; therefore the instrument is less accurate during periods of freezing due to the sublimation of ice and snow.

In addition to the Paoha Island station, monthly total precipitation has been recorded at the LADWP Cain Ranch site since May 1931. The monthly average maximum and minimum temperatures dating from October 1950 were obtained from the Western Regional Climate Center (www.wrcc.dri.edu) and analyzed to gain better insight as to climatic trends.

Field Sampling

Sampling of the physical, chemical and biological properties of the water including the *Artemia* community was conducted at 12 buoyed stations at Mono Lake (Figure 8). The water depth at each station at a lake elevation of 1,946 m (6384.5 feet) is indicated on Figure 8. Stations 1-6 are considered western sector stations, and stations 7-12 are eastern sector stations. Surveys are generally conducted around the 15th of each month and the 2017 sampling dates are listed in Table 8. In 2017, Station 5 was not sampled in March due to low fuel level. Station 3 was not sampled in June due to high wind. No dissolved oxygen was measured in November due to malfunction of the YSI instrument.

Table 8. Mono Lake Limnology Sampling Dates for 2017

MONTH	SAMPLING DATE
Feb	2/14/2017
Mar	3/14/2017
Apr	4/21/2017
May	5/19/2017
Jun	6/15/2017
Jul	7/19/2017
Aug	8/17/2017
Sep	9/13/2017
Oct	10/16/2017
Nov	11/21/2017
Dec	12/13/2017

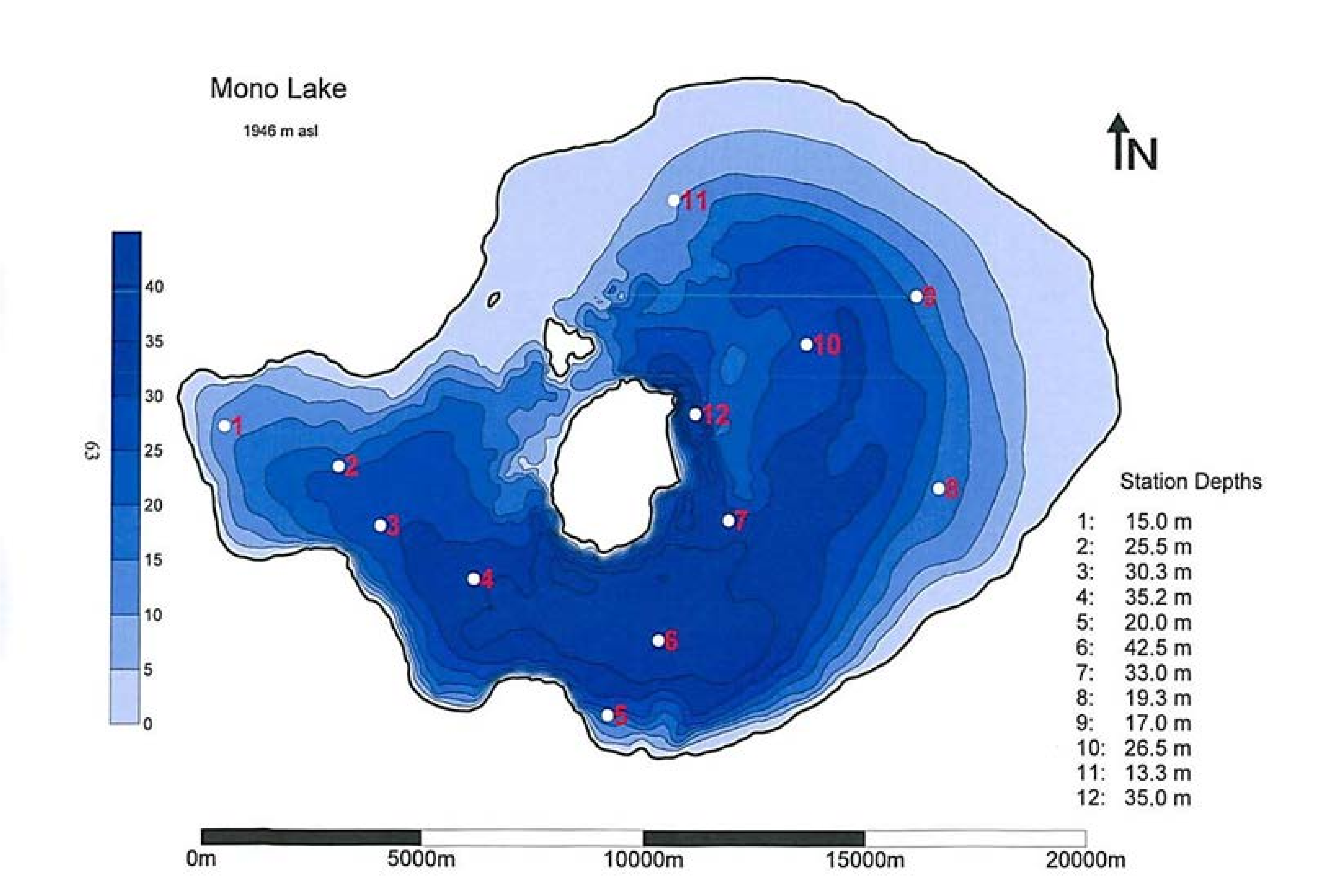


Figure 8. Sampling Stations at Mono Lake and Associated Station Depths

Physical and Chemical

Sampling of the physical and chemical properties include lake transparency, water temperature, conductivity, dissolved oxygen, and nutrients (ammonium). Lake transparency was measured at all 12 stations using a Secchi disk.

Conductivity

A high-precision conductivity temperature-depth (CTD) profiler was used to record conductivity at 9 stations (2, 3, 4, 5, 6, 7, 8, 10 and 12). During sampling, the CTD was initially lowered just below the surface of the water for 40 seconds during the pump delay time. The CTD was then lowered at a rate of approximately 0.5 meters/second with data collected at approximately 12.5 centimeter depth intervals. The Seabird CTD used in 2017 is programmed to collect data at 250 millisecond intervals. Conductivity data was collected from the CTD field sampling device on a monthly basis.

Dissolved Oxygen

Dissolved oxygen has been measured at one centrally located station (Station 6) with a Yellow Springs Instruments Rapid Pulse Dissolved Oxygen Sensor (YSI model 6562). Readings were taken at one-meter intervals and at 0.5-meter intervals in the vicinity of the oxycline and other regions of rapid change. Data are reported for one-meter intervals only.

Ammonium Sampling

Monitoring of ammonium in the epilimnion was conducted using a 9-m integrated sampler at stations 1, 2, 5, 6, 7, 8, and 11. Ammonium was sampled at eight discrete depths (2, 8, 12, 16, 20, 24, 28, and 35 meters) at Station 6 using a vertical Van Dorn sampler. Samples for ammonium analyses were filtered through Gelman A/E glass-fiber filters, and following collection, immediately placed onto dry ice and frozen in order to stabilize the ammonium content (Marvin and Proctor 1965). Ammonium samples were transported on dry ice back to the laboratory transfer station. The ammonium samples were stored frozen until delivered to the University of California Davis Analytical Laboratory (UCDAL) located in Davis, California. Samples were stored frozen until analysis.

Starting in August 2012, the methodology used by UCDAL for ammonium was flow injection analysis. In July 2012, this method was tested on high salinity Mono Lake water and was found to give results comparable to previous years. This method has detection limits of approximately 2.8 µM. Immediately prior to analysis, frozen samples were allowed to thaw and equilibrate to room temperature, and were shaken briefly to homogenize. Samples were heated with salicylate and hypochlorite in an alkaline phosphate buffer (APHA 1998a, APHA 199b, Hofer 2003, Knepel 2003). EDTA

(Ethylenediaminetetraacetic acid) was added in order to prevent precipitation of calcium and magnesium, and sodium nitroprusside was added in order to enhance sensitivity. Absorbance of the reaction product was measured at 660 nm using a Lachat Flow Injection Analyzer (FIA), QuikChem 8000, equipped with a heater module. Absorbance at 660 nm is directly proportional to the original concentration of ammonium, and ammonium concentrations were calculated based on absorbance in relation to a standard solution.

Chlorophyll a Sampling

Monitoring of chlorophyll *a* in the epilimnion was conducted using a 9-m integrated sampler at stations 1, 2, 5, 6, 7, 8, and 11. Chlorophyll was sampled at station 6 at seven discrete depths (2, 8, 12, 16, 20, 24, and 28 meters) using a vertical Van Dorn sampler. Water samples were filtered into opaque bottles through a 120 µm sieve to remove all life stages of *Artemia*. Chlorophyll *a* samples were kept cold and transported on ice back to the laboratory transfer station located in Sacramento, CA.
The determination of chlorophyll *a* was done by fluorometric analysis following acetone extraction. Fluorometry was chosen, as opposed to spectrophotometry, due to higher sensitivity of the fluorometric analysis, and because data on chlorophyll *b* and other chlorophyll pigments were not needed.

At the laboratory transfer station in Sacramento, water samples (200 mL) were filtered onto Whatman GF/F glass fiber filters (nominal pore size of 0.7 µm) under vacuum. Filter pads were then stored frozen until they could be mailed overnight in dry ice to the University of Maryland Center for Environmental Science Chesapeake Biological Laboratory (CBL), located in Solomons, Maryland. Sample filter pads were extracted in 90% acetone and then refrigerated in the dark for 2 to 24 hours. Following refrigeration, the samples were allowed to warm to room temperature, and then centrifuged to separate the sample material from the extract. The extract for each sample was then analyzed on a fluorometer. Chlorophyll *a* concentrations were calculated based on output from the fluorometer. Throughout the process, exposure of the samples to light and heat was avoided.

The fluorometer used in support of this analysis was a Turner Designs TD700 fluorometer equipped with a daylight white lamp, 340-500 nm excitation filter and >665 nm emission filter, and a Turner Designs Trilogy fluorometer equipped with either the non-acid or the acid optical module.

Artemia Population Sampling

The *Artemia* population was sampled by one vertical net tow at each of 12 stations (Figure 8). Samples were taken with a plankton net (0.91 m x 0.30 m diameter, 118 µm

Nitex mesh) towed vertically through the water column. Samples were preserved with 5% formalin in Mono Lake water.

An 8x to 32x stereo microscope was used for all *Artemia* analyses. Depending on the density of shrimp, counts were made of the entire sample or of a subsample made with a Folsom plankton splitter. When shrimp densities in the net tows were high, samples were split so that approximately 100-200 individuals were subsampled. Shrimp were classified as nauplii (instars 1-7), juveniles (instars 8-11), or adults (instars >12), according to Heath's classification (Heath 1924). Adults were sexed and the reproductive status of adult females was determined. Non-reproductive (non-ovigerous) females were classified as empty. Ovigerous females were classified as undifferentiated (eggs in early stage of development), oviparous (carrying cysts) or ovoviviparous (naupliar eggs present).

An instar analysis was completed for seven of the twelve stations (Stations 1, 2, 5, 6, 7, 8, and 11). Nauplii at these seven stations were further classified as to specific instar stage (1-7). Biomass was determined from the dried weight of the shrimp tows at each station. After counting, samples were rinsed with tap water and dried in aluminum tins at 50°C for at least 48 hours. Samples were weighed on an analytical balance immediately upon removal from the oven.

Artemia Fecundity

When mature females were present, an additional net tow was taken from four western sector stations (1, 2, 5 and 6) and three eastern sector stations (7, 8 and 11) to collect adult females for fecundity analysis including body length and brood size. Live females collected for fecundity analysis were kept cool and in low densities during transport to the LADWP laboratory in Bishop, CA.

Immediately upon return to the laboratory, ten females from each sampled station were randomly selected, isolated into individual vials, and preserved with 5% formalin. Female length was measured at 8X from the tip of the head to the end of the caudal furca (setae not included). Egg type was noted as undifferentiated, cyst, or naupliar. Undifferentiated egg mass samples were discarded. Brood size was determined by counting the number of eggs in the ovisac and any eggs dropped in the vial. Egg shape was noted as round or indented.

4.2.2 Limnology Data Summary and Analysis

Meteorology

The daily mean wind speed, maximum mean wind speed, and relative humidity were calculated from 10-minute averaged data from the Paoha Island site. Winter temperature was calculated by averaging the monthly average maximum (or minimum) temperature from December of the previous year and January and February of the subsequent year. More specifically, the monthly average from December 2016 was combined with the monthly average from January and February 2017 to obtain the winter average for 2017. Summer temperature was calculated as the average monthly temperature between June and August. Annual precipitation is a sum of precipitation occurring within one calendar year.

Physical and Chemical
An ammonium profile was developed from the samples taken at the eight discrete depths. A chlorophyll profile was developed from the samples taken at the seven discrete depths. In situ, conductivity measurements at Station 6 were corrected for temperature (25˚C) and reported at one meter intervals beginning at one meter in depth down to the lake bottom. Salinity expressed in g/L was calculated based on the equation presented by Jellison in past compliance reports.

Salinity and Mono Lake Elevation

High salinity negatively affects survival, growth, reproduction, and cyst hatching of *Artemia* in Mono Lake (Starrett and Perry 1985, Dana and Lenz 1986). Negative effects are accentuated when salinity approaches the tolerance level, which ranges from 159 g/L to 179 g/L (Dana and Lenz 1986). Even though the salinity level in Mono Lake has not neared the tolerance level, the salinity level has declined considerably since exporting water from the Mono Basin has started. The pre-diversion salinity was estimated to be 48 g/L (Dana and Lenz 1986) at a lake level around 6,417 feet. As of December 2017, salinity ranged between 81.3 g/L and 94.3 g/L at Station 6 at the lake level of 6,381 feet. An analysis of salinity levels and Mono Lake elevation was conducted to estimate salinity level at the target Mono Lake level of 6,392 feet. Lake elevation data was obtained directly from the LADWP database records. Annual lake elevation for year-to-year comparison was calculated based on the average April (water year) daily measurements. Simple linear regression was performed between monthly lake elevations and monthly salinity readings at 3 different depth categories for 9 stations where CTD was deployed. The depth categories included 0 m to 10 m, 10 m to 20 m, and deeper than 20 m.

Artemia Population Statistics

Calculation of long-term *Artemia* population statistics followed Jellison and Rose (2011). Daily values of adult *Artemia* between sampling dates were linearly interpolated in Microsoft Excel. The mean, median, peak and centroid day (calculated center of abundance of adults) were then calculated for the time period May 1 through November 30. Long-term values were determined by calculating the mean, minimum, and maximum values for these parameters for the time period 1979-2017.

Artemia Population Peak

Meromixis has been demonstrated to affect the *Artemia* population in Mono Lake as stratification prevents the release of hypolimnetic ammonium during meromixis. During periods of meromixis, ammonium accumulates in the hypolimnion. With a deepening chemocline, ammonium supply to the epilimnion or mixolimnion increases. This process also allows oxygenation of the hypolimnion, which remains suboxic to anoxic during meromixis. Usually one year after the breakdown of meromixis, *Artemia* population booms. In this section annual *Artemia* population mean during monomixis and meromixis was quantitatively compared to ammonium, Mono Lake input, and salinity to illustrate the importance of the lake mixing regime to *Artemia* population dynamics.

A Temporal Shift in Monthly Artemia Population

A temporal shift in peak *Artemia* population or centroid has been noted by Jellison in previous years' compliance reports. LADWP also reported a continuation of this trend in the *Artemia* instar population (LADWP 2017). Two water parameters, chlorophyll *a* and temperature, have been demonstrated to affect development of *Artemia*. For instance, spring generation *Artemia* raised at high food densities develop more quickly and begin reproducing earlier. In addition, the abundance of algae may likely affect year-to-year changes in *Artemia* abundance (Jellison and Melack 1993). Cysts of Mono Lake brine shrimp require 3 months of dormancy in cold (<5°C) water to hatch (Dana 1981, Thun and Starrett 1986).and the summer generation of *Artemia* grows much more quickly than the spring counterpart because of warmer epilimnetic water temperature (Jellison et al. 1991). For adult development, summer epilimnetic water temperature could affect *Artemia* abundance even though other factors such as food availability confounds growth rate (Jones and Stokes Associates 1994). In this section, monthly *Artemia* abundance (adult and instar) was quantitatively and qualitatively compared to monthly readings of chlorophyll *a* and temperature in order to understand the mechanisms associated with the temporal shifts in *Artemia* population abundance.

Because of the important relationship between water and ambient temperature (Jellison et al. 1989a; Jellison et al. 1990), simple linear regression was performed to examine the relationship between monthly water temperature readings at various depths and monthly ambient temperature readings. The relationships would provide better understanding of the effect of a changing climate on Mono Lake *Artemia* populations

4.2.3 Limnology Results

Meteorology

Wind Speed, relative humidity, air temperature and precipitation data from the weather station at Paoha Island are summarized below for 2017.

Wind Speed and Direction

Mean daily wind-speed varied from 0.97 to 13.12 m/sec in 2017, with an overall mean for this time period of 3.69 m/sec (Figure 9). The daily maximum 10-min wind speed (5.56 m/sec) on Paoha Island averaged almost twice as much as the mean daily wind speed. The maximum recorded 10-min reading of 30.31 m/sec occurred on the afternoon of November 17. As has been the case in previous years, winds were predominantly from the south (mean 194.3 degrees).

Air Temperature

Daily air temperatures as recorded at Paoha Island in 2017 ranged from a low of -12.23°C on January 25, to a high of 32.84°C on July 21 (Figure 10). Daily average winter temperature (January through February) ranged from -7.75°C to 7.93°C with an average maximum daily temperature of 8.64°C, much higher than previously recorded values. The average maximum daily summer temperature (June through August) was 28.02°C, while the average minimum daily summer temperature was 12.44°C.

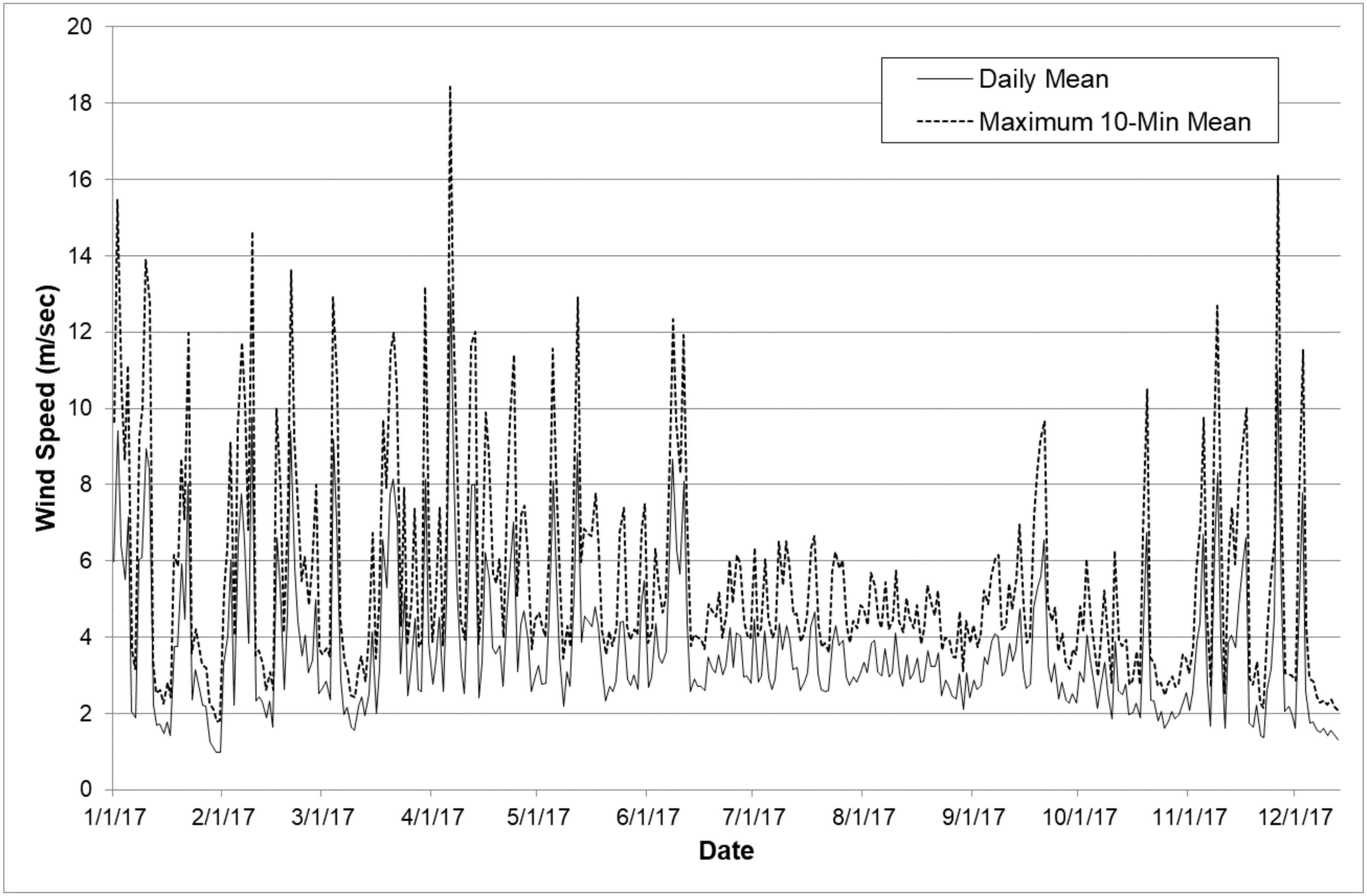


Figure 9. Daily Mean and Mean Maximum 10-Minute Wind Speed
Recorded at Paoha Island from January 1 to December 13, 2017

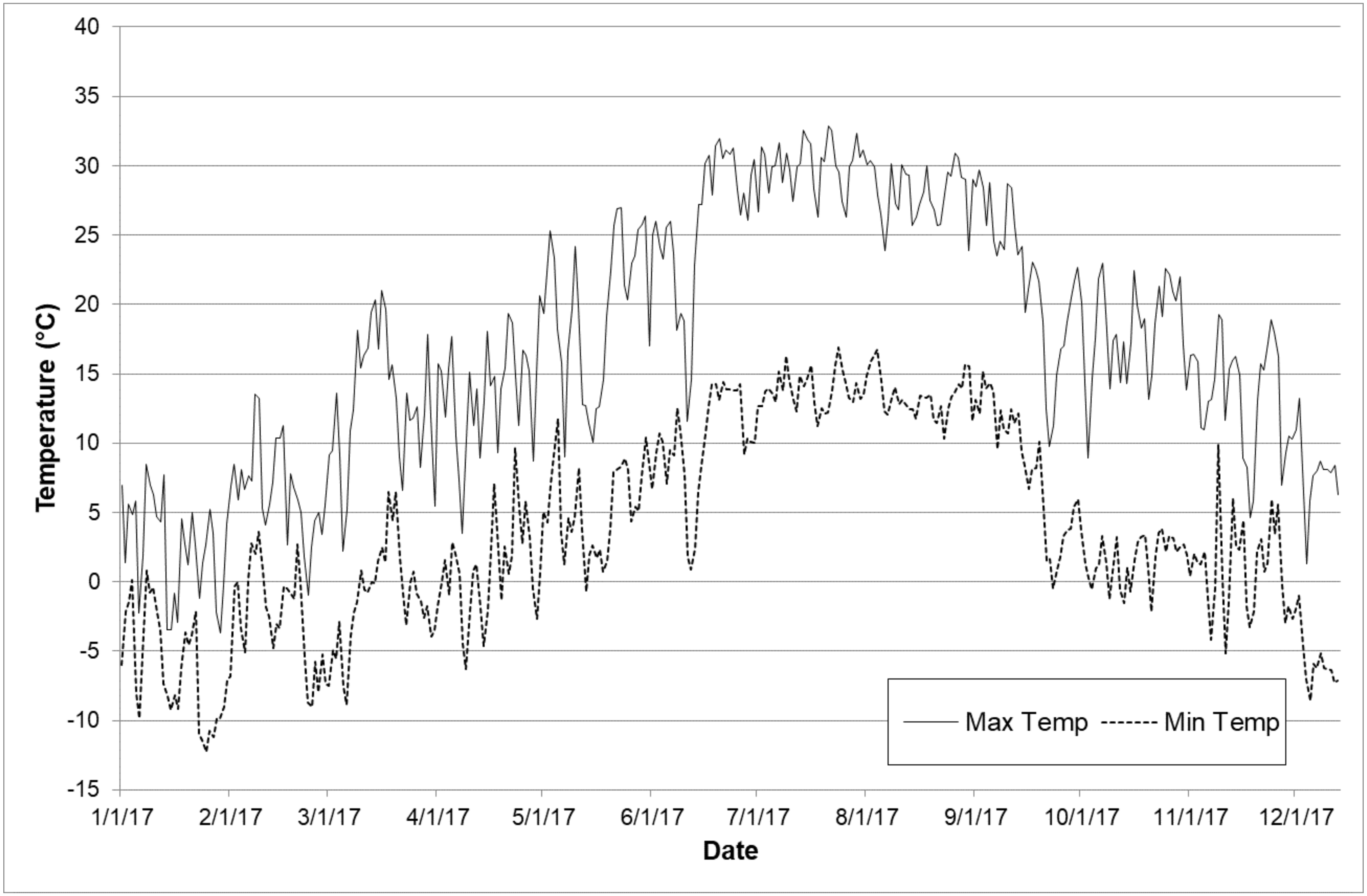


Figure 10. Minimum and Maximum Daily Temperature (°C)

Recorded at Paoha Island from January 1 to December 13, 2017

Relative Humidity and Precipitation

The mean relative humidity for the period between January 1 and December 13, 2017 was 57% (Figure 11). The total precipitation during the same period measured at Paoha Island was 325 mm. Precipitation events were more frequent in winter, spring, and fall. The largest single day total precipitation of 97 mm was recorded on October 20 (Figure 12). In January and February, 57 mm of precipitation was recorded. Spring months produced 130 mm of precipitation followed by much lower summer month precipitation (21 mm). Fall precipitation increased to 116 mm due to the single event on October 10. December precipitation was 1 mm. The greatest frequency of days with precipitation (13) occurred in the month of February.

Long Term Trend

The winter of 2016-17 followed the warmest winter since 1951 (2014-15) and the relatively warm winter of 2015-16. The winter of 2016-17 was not as warm as these two previous years due in part to much more frequent winter storms. Winter precipitation in 2016-17 (10.9 in) was ranked 9 in 86 years and was 217% of the long term average (5.0 in) while summer precipitation was ranked 71 in 86 years and was 34% of the long term average. The winter preceding the 2017 monitoring year was wetter and cooler, and summer of 2017 was warmer and drier.

There is no clear long-term trend for average summer and winter temperatures except for average summer minimum temperature ($r=0.55$, $p<0.0001$, $df=67$) (Figure 13, Figure 14). A combination of above average summer minimums since 1995, and below average summer minimum temperature during the earlier part of the record (between 1962 and 1987), contributed to this significant positive trend of increasing minimum summer temperatures. The average winter minimum temperature has been above the long-term average (-6.1°C) for the three winters prior to the winter of 2017-18, and the winter of 2014-15 was particularly warm as the highest average minimum since 1951 was recorded.

Since 1998 and before the winter of 2016-17, only three winters showed precipitation above the long-term average of 86 years (5.0 in); 2004-5, 2005-6, and 2007-8 (Figure 15). The average winter precipitation for the past 10 years (2007 through 2016), excluding 2011 has been 8.3 inches, 75% of the long term average. Since 1990, only eight years show precipitation above the long-term average; however, four out of five summers show precipitation close to or above the long-term average during the severe drought between 2012 and 2016.

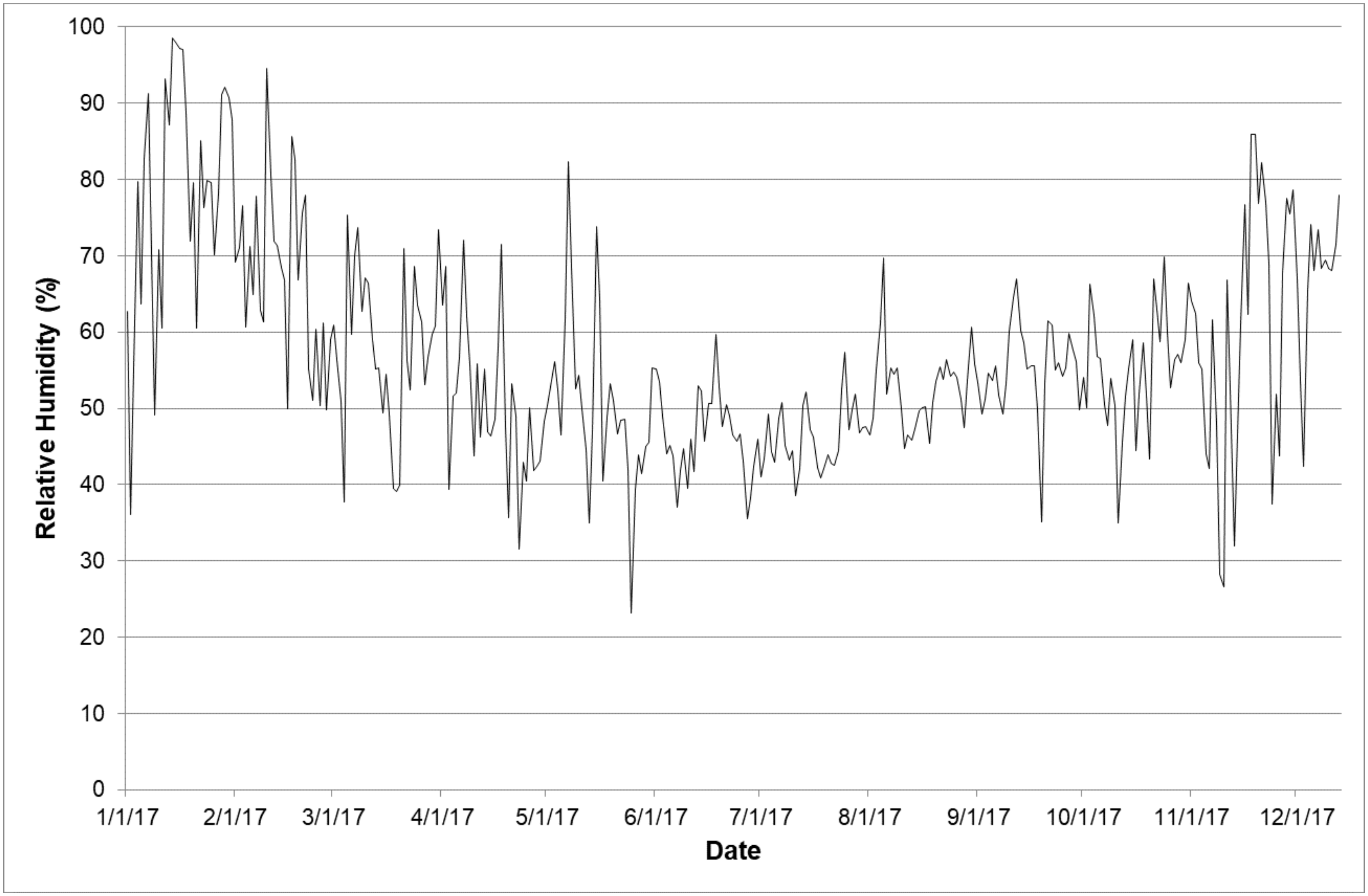


Figure 11. Mean Relative Humidity (%) as Recorded at Paoha Island From January 1 to December 13, 2017

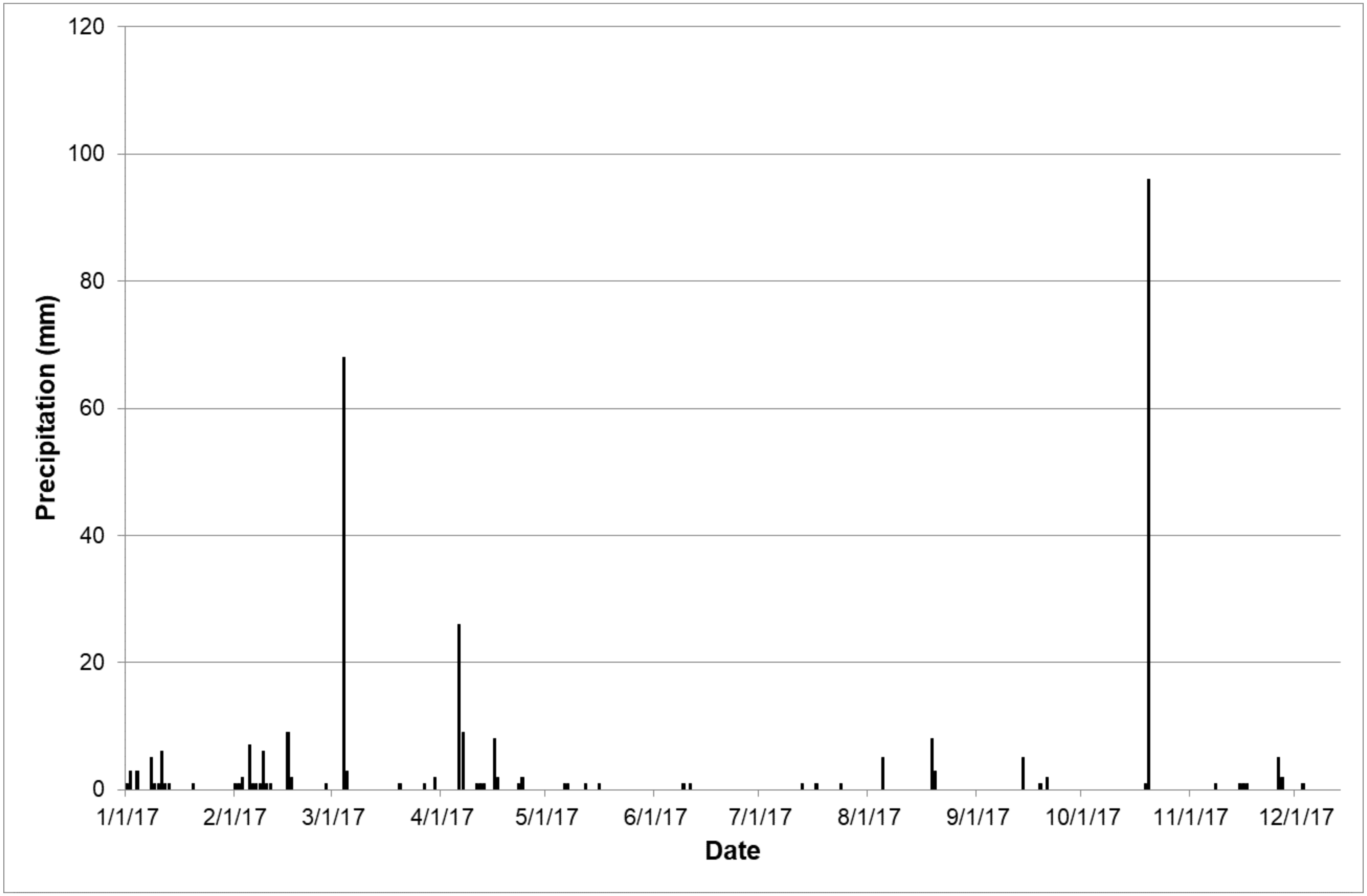


Figure 12. Precipitation (mm) as Recorded at Paoha Island

From January 1 to December 13, 2017

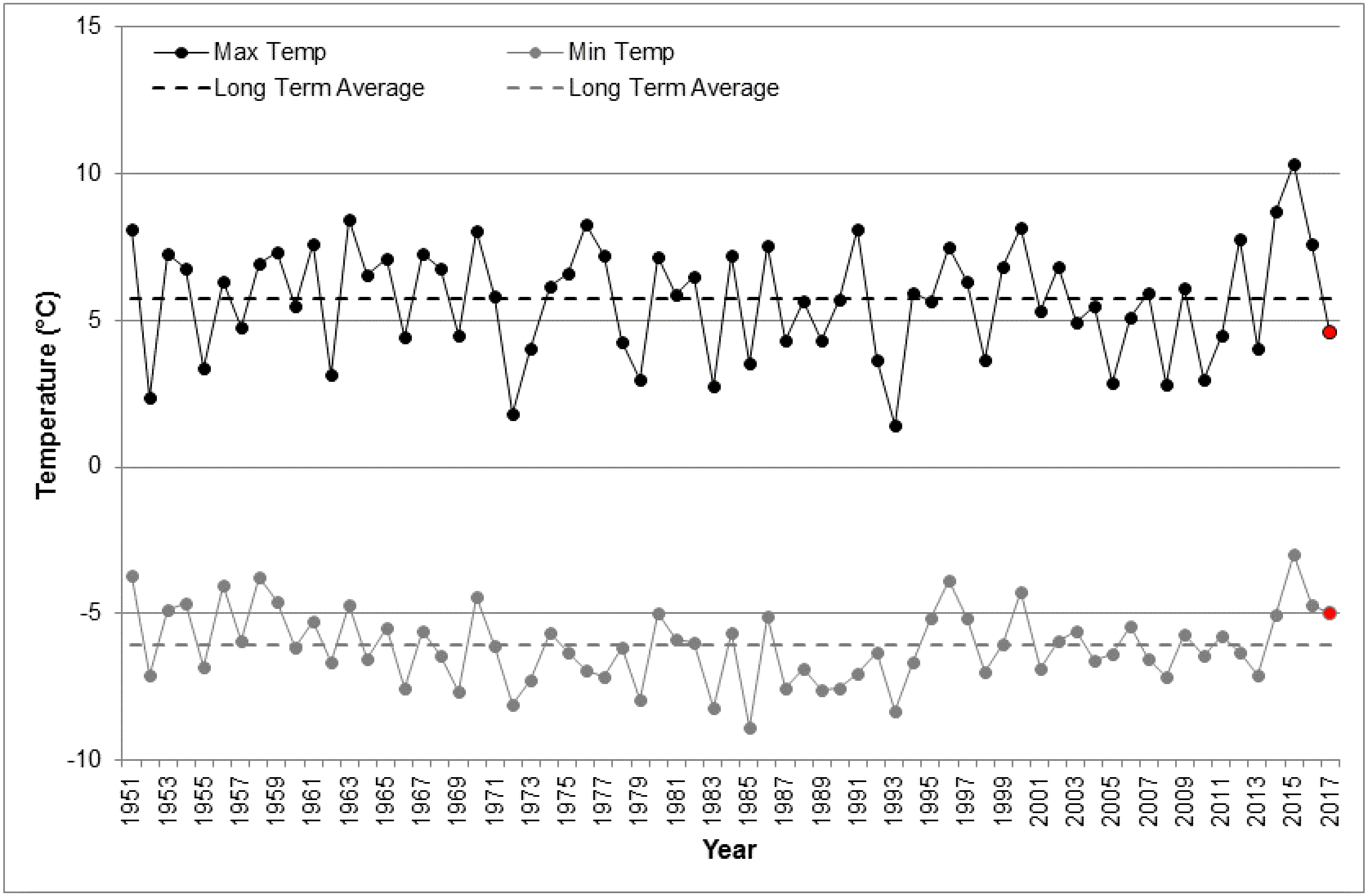


Figure 13. Average Winter Temperatures (December through February) Since 1951

Temperature was recorded at Mono Lake (Station Number 045779-3) between 1951 and 1988 and at Lee Vining (Station Number 044881) since 1989; data obtained from Western Regional Climate Center

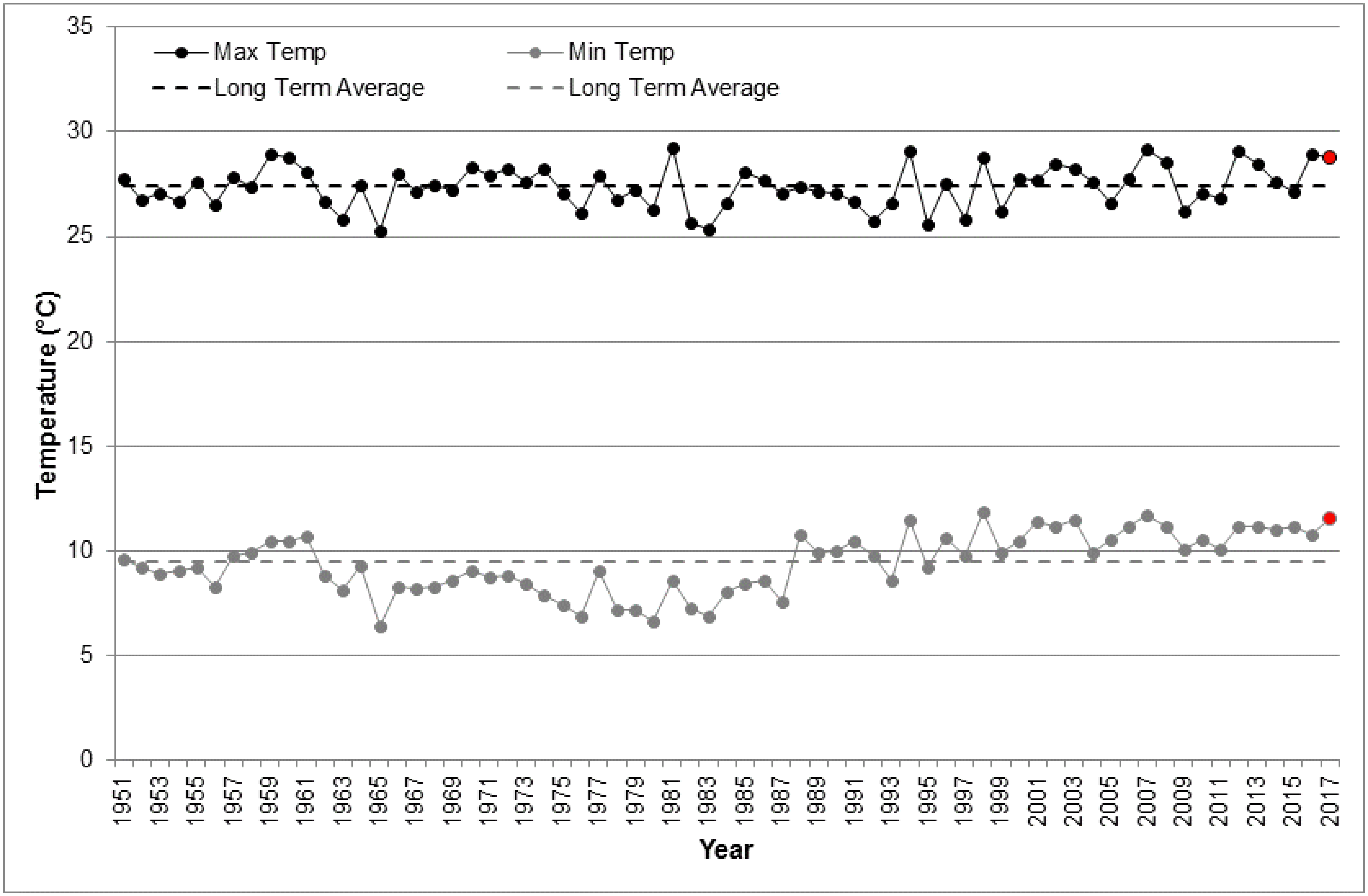


Figure 14. Average Summer Temperatures (June Through August) Since 1951

Temperature was recorded at Mono Lake (Station Number 045779-3 obtained) between 1951 and 1988 and at Lee Vining (Station Number 044881) since 1989; data obtained from Western Regional Climate Center

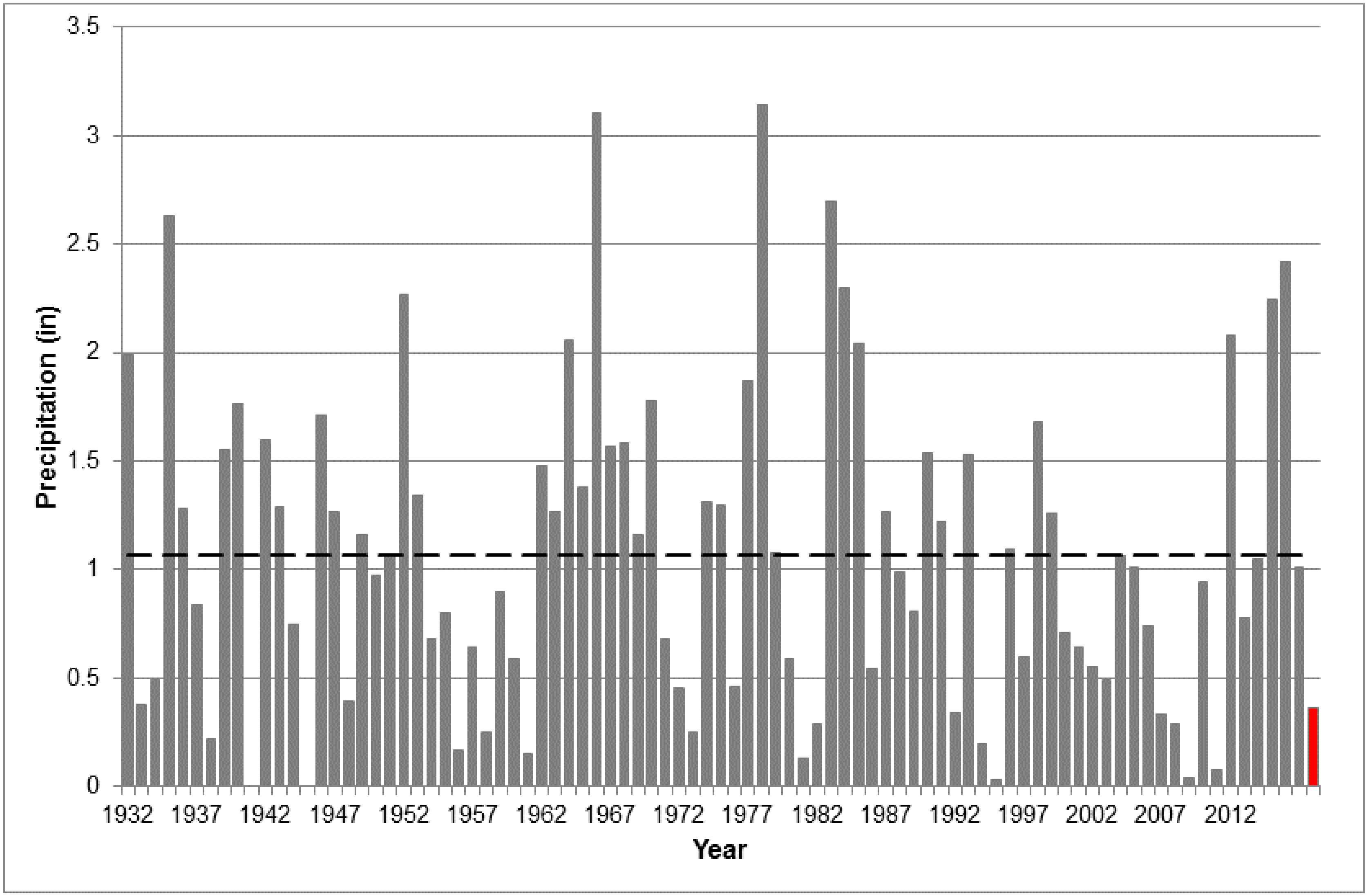


Figure 15. Total Summer Precipitation (June to August) Recorded at LADWP Cain Ranch (1932-2017)

The broken line represents the long-term mean precipitation value (1931-2017)

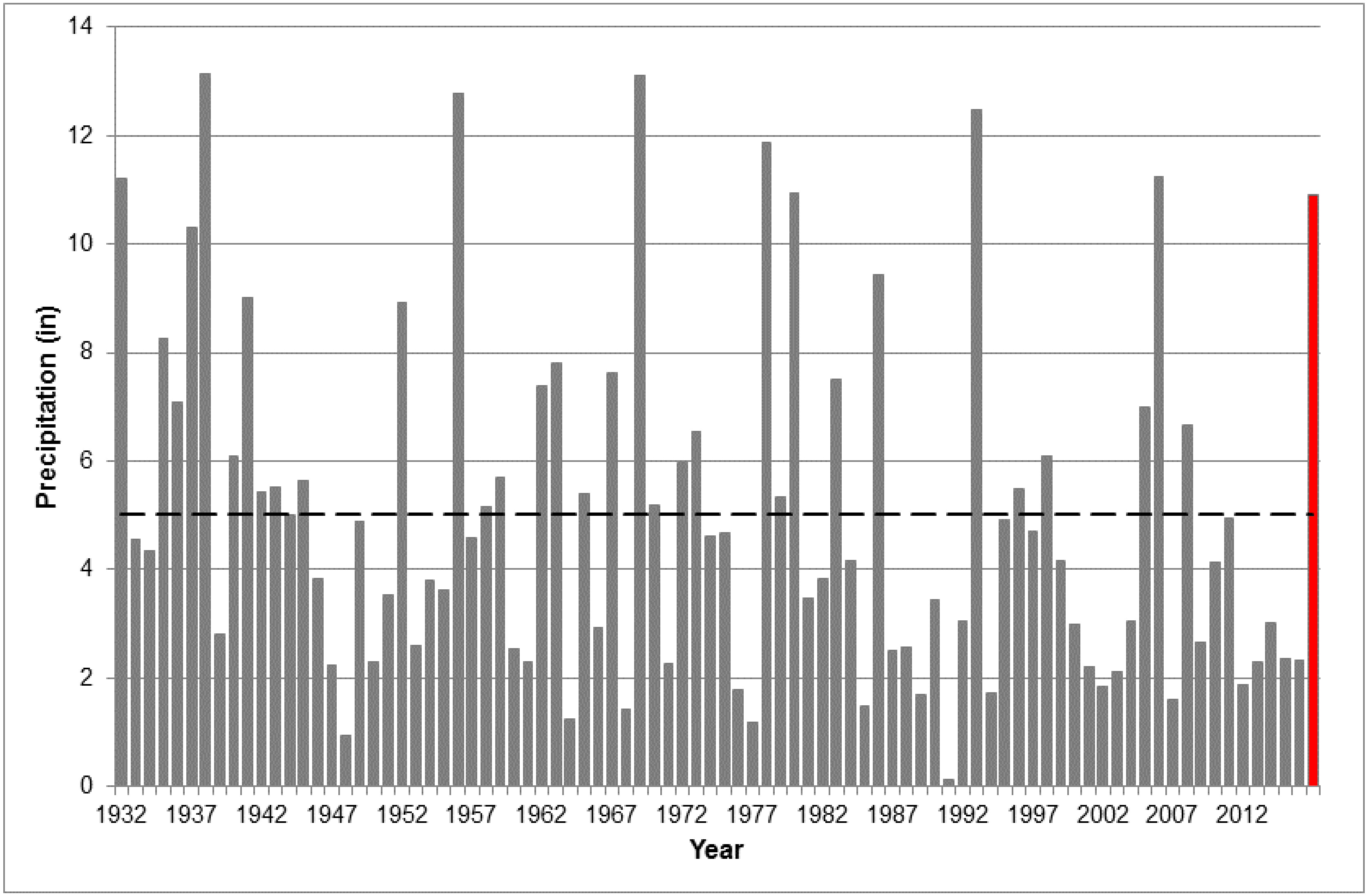


Figure 16. Total Winter Precipitation (December to February) Recorded at LADWP Cain Ranch (1932-2017)

The broken line represents the long-term mean precipitation value (1931-2017)

Physical and Chemical

Surface Elevation

The average monthly surface elevation of Mono Lake in January 2017 was 6,377.2 feet, very similar to the January lake levels of the previous two years. Water Year 2016-17 was second wettest on record in terms of input from two major tributaries (Rush and Lee Vining Creeks) at 317% of the long-term average. The lake level rose 4 feet from January to the year's peak at 6,381.2 feet in September, and remained just above 6,381 feet for the rest of 2017. For 2017, the greatest monthly change in surface elevation of 1.3 feet occurred between June and July during and after the peak runoff.

Figure 17 shows lake elevation and the mixing regime observed each year from 1981 through 2017. The first meromictic regime was recorded in 1983. As will be discussed later, Mono Lake finally broke a monomictic mixing regime which started in 2012 and lasted for 5 years.

Transparency

The transparency of Mono Lake during the summer of 2017 improved from 0.39 m in June to 3.53 m in July, and the maximum transparency observed in 2017 of 5.78 m occurred in September (Table 9, Figure 18). Transparency from February through May remained below 1 meter. As *Artemia* grazing reduced midsummer phytoplankton, lakewide transparency and Secchi depth increased from July through October. Beginning in 2014, the depth of maximum transparency observed each year had progressively become more shallow; 1.5 m in 2014, 0.9 m in 2015 and 0.6 m in 2016. This trend, however was reversed in 2017 even though transparency was still lower than historical values (Table 10,
Figure 19). Mono Lake input from the main tributaries peaked in June 21 with an estimated combined flow of 1,411 cfs, and remained above 400 cfs through August. *Artemia* population abundance was higher than the previous three years, as will be discussed in later sections. A combination of the above two factors may have contributed to the improved clarity observed in 2017.

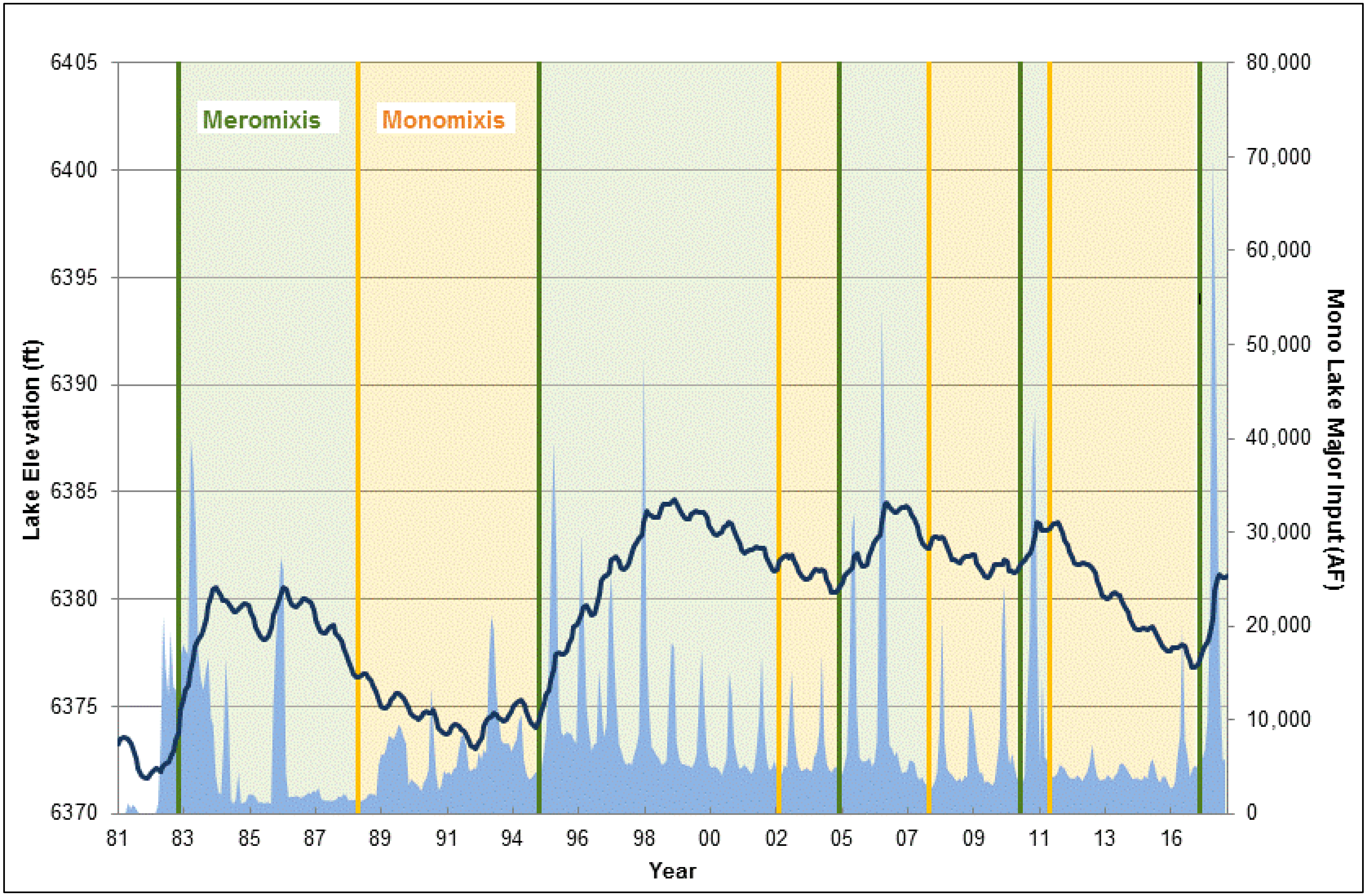


Figure 17. Surface Elevation, Mixing Regime and Combined Inflow of Rush and Lee Vining Creeks Since 1981

*Green indicates meromixis while orange indicates monomixis

Table 9. Secchi Depths (m) Between February and December in 2017

	Sampling Month										
Station	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Western Sector											
1	0.4	0.6	0.4	0.4	0.4	3.7	5.2	5.7	5.1	0.6	0.7
2	0.4	0.5	0.3	0.4	0.4	3.3	5	6	4.5	0.9	0.6
3	0.4	0.4	0.3	0.3		3.6	4.9	6.5	4.2	0.9	0.6
4	0.35	0.5	0.3	0.3	0.4	4	5.4	6.3	4.5	0.95	0.6
5	0.4		0.3	0.4	0.4	4	5.5	6.5	4	0.9	0.7
6	0.4	0.45	0.2	0.4	0.4	3.4	5.3	6.6	4.3	0.8	0.6
AVG	0.39	0.49	0.30	0.37	0.40	3.67	5.22	6.27	4.43	0.84	0.63
SE	0.01	0.03	0.03	0.02	0.00	0.12	0.09	0.14	0.15	0.05	0.02
Eastern Sector											
7	0.4	0.4	0.3	0.35	0.4	3.5	4.9	6.2	3.5	0.9	0.7
8	0.4	0.5	0.3	0.4	0.4	3.6	5	5.7	3.5	0.9	0.6
9	0.4	0.45	0.4	0.4	0.4	3.4	5	5.7	3.5	0.95	0.7
10	0.4	0.6	0.3	0.35	0.4	3.3	5.2	5.4	2.7	0.9	0.7
11	0.4	0.5	0.4	0.4	0.4	3	5	3.7	2.4	0.9	0.7
12	0.35	0.5	0.3	0.4	0.3	3.6	5	5.1	2.6	0.8	0.7
AVG	0.39	0.49	0.33	0.38	0.38	3.40	5.02	5.30	3.03	0.89	0.68
SE	0.01	0.03	0.02	0.01	0.02	0.09	0.04	0.35	0.21	0.02	0.02
Total Lakewide											
AVG	0.39	0.49	0.32	0.38	0.39	3.53	5.12	5.78	3.73	0.87	0.66
SE	0.01	0.02	0.02	0.01	0.01	0.08	0.06	0.23	0.25	0.03	0.01

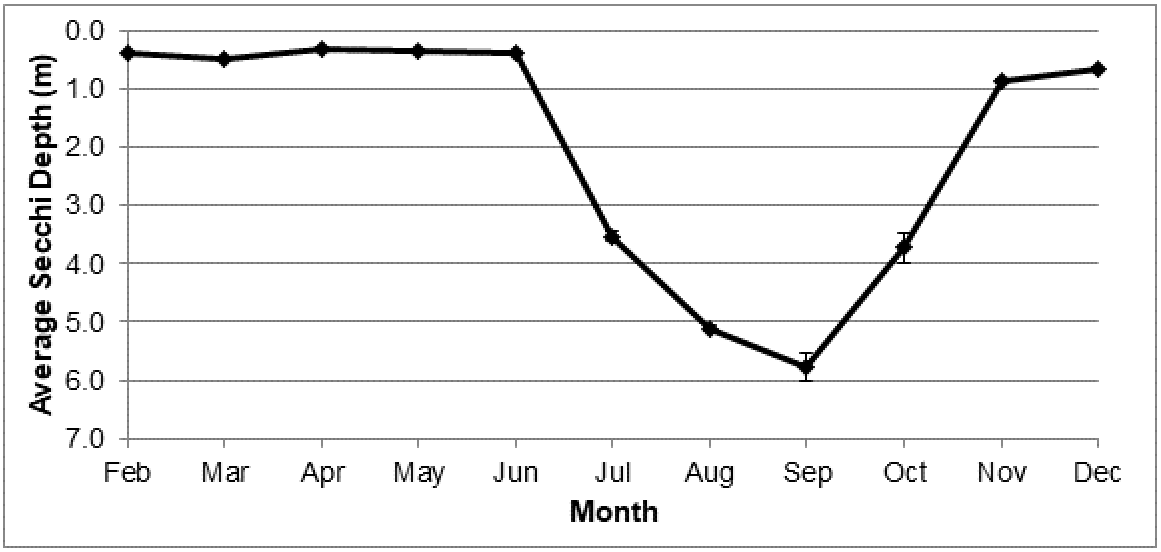


Figure 18. Lakewide Average Secchi Depths (m) and Standard Error for 2017

Table 10. Average Secchi Depths (m), All 12 Stations Since 1987

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	1.1	1.0	1.2	5.3	8.9	9.3	***9.4***	6.7	5.4		1.4
1988	1.0	1.1	1.3	5.2	8.6	***8.9***	7.3	1.7	1.0	0.7	0.7
1989	0.7	1.0	0.8	0.7	3.2	9.9	***11.6***	10.9	9.1	3.9	1.8
1990	1.7	1.1	1.5	3.8	5.1	7.3	7.9	***8.9***	1.7	1.5	1.5
1991	1.5	1.2	1.2	1.6	5.6	8.1	***8.2***	6.8	3.9	1.2	1.0
1992	1.1	1.2	1.7	7.3	7.7	***8.6***	7.5	6.9	3.4	1.5	1.1
1993		1.1	1.0	3.3	6.3	5.8	***6.8***	5.1	4.2	2.5	1.5
1994	1.3	1.3	1.5	5.8	7.8	***8.2***	7.5	5.1	1.5		1.6
1995		1.3			6.7	7.6	***7.9***	6.1	3.6		2.7
1996	1.6	1.5	1.7	8.5	9.1	***10.9***	10.3	8.1		2.6	2.8
1997	2.0	1.9	3.0	8.3	9.6	***9.7***	7.4	6.4	2.6		2.0
1998	1.6	2.0	2.3	4.8	10.4	***11.9***	11.3	9.7	7.2		2.3
1999	1.9	1.8	1.9	2.8	9.9	***11.5***	11.2	9.8	5.9	2.6	1.5
2000	1.3	1.6	1.2	4.9	7.1	***7.5***	6.2	5.4	2.8	1.3	1.3
2001	1.3	1.2	1.4	5.7	9.9	***10.8***	10.2	6.5	2.7	1.4	1.1
2002	1.1	1.1	1.1	2.0	***9.2***	8.0	7.2	2.2	1.2	0.9	
2003	1.0	1.0	0.8	1.2	3.9	4.3	***5.5***	3.5	0.9	0.6	0.9
2004	0.8	0.7	0.8	2.2	9.1	***10.3***	9.3	2.0	0.9	0.9	0.9
2005		0.7	0.7	1.3	3.8	7.3	***7.5***	5.0	1.5	0.9	1.0
2006	0.8	0.7	0.6	2.6	7.1	***8.8***	7.9	6.3	2.1	1.9	1.4
2007	1.4	1.4	1.3	6.2	***10.9***	10.5	8.5	2.5	1.0	1.0	1.1
2008	0.9	0.8	0.8	1.4	3.9	4.8	***4.9***	1.4	0.8	0.7	1.0
2009	0.7	0.7	0.7	1.6	5.9	***6.6***	5.7	3.4	0.9	0.8	0.9
2010		0.8	0.7	0.6	1.9	***6.3***	5.1	1.7	0.9	0.9	0.8
2011		0.7	0.6	0.8	1.9	6.1	***7.8***	6.1	3.6	1.6	1.0
2012	0.8	0.8	0.8	0.9	2.8	***5.2***	3.8	2.0	0.8	0.8	0.7
2013	0.5	0.6	0.4	1.2	2.6	***5.1***	4.7	1.6	0.7	0.6	0.7
2014	0.6	0.5	0.5	0.5	0.9	***1.5***	0.7	0.6	0.5	0.5	0.6
2015	0.4	0.4	0.5		0.6	***0.9***	0.5	0.5	0.5	0.5	0.6
2016	0.4	0.3		0.4	0.5	***0.6***	0.6	0.5	0.4	0.5	0.4
2017	0.4	0.5	0.3	0.4	0.4	3.5	5.1	***5.8***	3.7	0.9	0.7

Bold italic numbers indicate maximum values for the year.

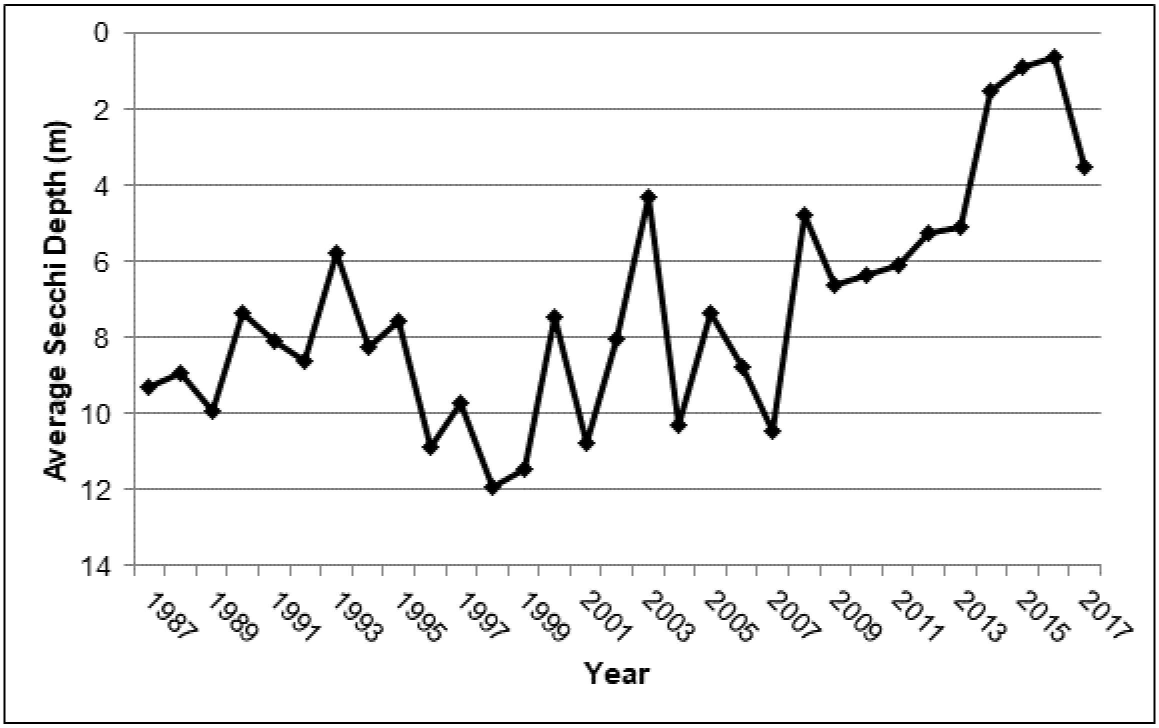


Figure 19. July Lakewide Average Secchi Depths (m) Since 1987

Water Temperature

The water temperature data from Station 6 (Table 11) indicate that, in 2017, Mono Lake started to become thermally stratified in spring, and remained somewhat stratified throughout the remainder of the year (Figure 20). By mid-June, the thermocline formed at 6 to 7 m (as indicated by the greater than 1°C change per meter depth), and remained between 9 and 12 m into November. Warm water in the shallow depths migrated downward but remained above 12 m throughout the year due to the chemocline at that depth. Holomixis never occurred in 2017.

Average water temperatures in the epilimnion and hypolimnion remained mostly below normal throughout 2017 (Table 12 and Table 13). Higher than normal epilimnion water temperature in March is most likely due to the warmer and drier conditions that prevailed in March. Both November and December were warmest on record; yet, the epilimnion water temperature remained below normal, most likely due to a large influx of freshwater throughout summer months. The recent warming trend in the hypolimnion that had started in 2015 was not observed in 2017. The establishment of a chemocline in 2017 contributed to the lowering of the water temperatures in the hypolimnion.

Table 11. Station 6 Water Temperature (°C), February-December, 2017

Depth (m)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3.1	3.6	8.6	12.5	15.9	23.2	22.6	20.1	12.6	8.4	5.8
2	3.1	3.0	8.4	12.6	15.1	23.3	22.6	20.3	12.5	8.4	5.9
3	3.0	2.9	7.9	12.6	14.8	23.4	22.9	20.3	12.5	8.5	5.7
4	2.8	2.8	7.7	12.3	14.7	21.1	23.1	21.7	12.7	8.4	5.7
5	2.7	2.8	7.6	12.2	14.4	18.0	20.5	22.9	13.5	8.3	5.7
6	2.6	2.8	7.4	11.5	13.6	16.4	16.9	21.2	15.7	8.5	5.7
7	2.6	2.9	7.0	10.5	11.6	13.1	13.6	17.2	16.4	8.9	5.7
8	2.6	2.9	6.8	9.8	10.4	11.8	11.8	13.8	15.4	9.3	5.4
9	2.5	2.9	6.7	9.1	9.4	10.5	10.5	11.5	12.2	9.5	5.4
10	2.5	2.9	6.8	8.4	8.8	9.5	9.2	9.4	10.5	10.8	6.8
11	2.5	2.9	6.4	7.8	8.2	9.0	8.6	8.6	9.3	10.2	8.3
12	2.5	2.9	6.3	7.3	7.4	8.2	7.8	7.3	8.1	8.6	8.5
13	2.5	2.8	6.0	6.3	6.6	7.1	7.1	6.7	7.5	7.9	7.9
14	2.6	2.7	5.7	6.0	6.0	6.4	6.5	6.2	6.9	7.2	7.2
15	2.6	2.8	5.3	5.5	5.9	5.7	6.1	5.9	6.4	6.9	6.8
16	2.6	2.8	5.0	5.1	5.5	5.4	5.7	5.6	6.1	6.5	6.6
17	2.6	2.8	4.7	4.9	5.2	5.2	5.4	5.6	6.0	6.1	6.1
18	2.6	2.7	4.2	4.7	4.9	5.1	5.1	5.2	5.6	5.9	6.0
19	2.6	2.7	4.0	4.4	4.8	5.0	4.9	5.1	5.4	5.7	5.8
20	2.6	2.8	3.6	4.3	4.6	4.9	4.9	5.0	5.3	5.6	5.7
21	2.6	2.8	3.4	4.1	4.5	4.8	4.9	5.0	5.1	5.5	5.5
22	2.6	2.8	3.3	4.0	4.4	4.7	4.8	4.9	5.1	5.5	5.5
23	2.6	2.8	3.3	3.8	4.4	4.6	4.7	4.9	5.0	5.4	5.4
24	2.7	2.8	3.3	3.8	4.3	4.5	4.6	4.8	4.9	5.3	5.3
25	2.7	2.9	3.2	3.7	4.1	4.5	4.5	4.8	4.8	5.3	5.2
26	2.8	2.9	3.2	3.7	4.1	4.4	4.5	4.7	4.8	5.1	5.2
27	3.0	2.9	3.1	3.6	4.0	4.4	4.4	4.6	4.7	5.1	5.1
28	3.0	2.9	3.1	3.5	3.9	4.3	4.4	4.6	4.7	5.0	5.1
29	3.1	2.9	3.1	3.5	3.9	4.3	4.3	4.5	4.6	4.9	5.0
30	3.1	3.0	3.1	3.5	3.8	4.2	4.3	4.4	4.6	4.9	5.0
31	3.2	3.0	3.1	3.4	3.8	4.2	4.3	4.3	4.6	4.8	5.0
32	3.2	3.0	3.1	3.4	3.7	4.2	4.3	4.3	4.5	4.8	5.0
33	3.3	3.0	3.0	3.4	3.7	4.1	4.2	4.2	4.5	4.8	4.9
34	3.3	3.0	3.1	3.4	3.7	4.0	4.2	4.2	4.5	4.8	4.9
35	3.3	3.0	3.0	3.3	3.7	4.0	4.2	4.2	4.5	4.7	4.9
36	3.4	3.0	3.1	3.3	3.7	4.0	4.2	4.2	4.4	4.7	4.9
37	3.4	3.0	3.0	3.3	3.7	4.0	4.1	4.2	4.4	4.7	4.8
38	3.4	3.0	3.0	3.3	3.7	4.0	4.1	4.2	4.4	4.7	4.8
39	-	-	-	-	-	-	4.1	4.2	4.4	4.6	4.8
40	-	-	-	-	-	-	-	-	-	-	4.8

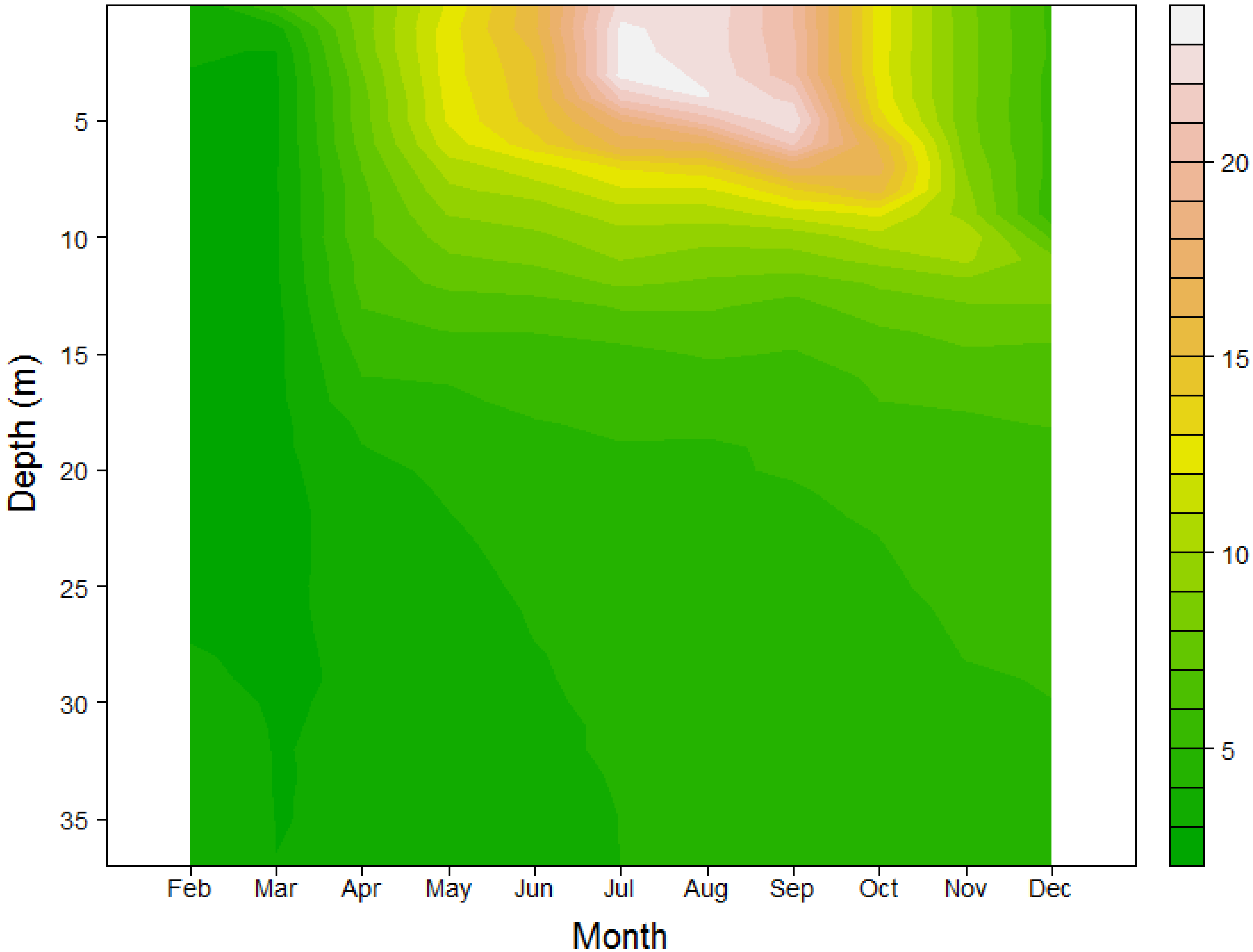


Figure 20. Station 6 Temperature Profile (°C), February-December, 2017

Table 12. Station 6 Average Water Temperature (°C), Between 1 and 10 m, 1991-2017

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	***3.2***	3.2	6.1	8.9	15.2	***19.8***	***20.1***		***16.3***	***9.9***	6.0
1992	***3.5***	***5.4***	***9.0***	***14.4***	***16.6***	18.9	***21.0***	17.4	***15.3***	***10.4***	5.5
1993		3.0	7.1	11.1	15.2		19.8	***19.0***	***15.6***	***11.7***	4.6
1994	2.3	***4.7***	***8.5***	***12.1***							
1995		***5.0***	6.0			17.1	***20.1***	***19.1***	***15.2***		***8.9***
1996	***4.0***	3.8	***7.5***	***12.7***	***16.8***	***20.0***	***21.1***			***9.6***	***6.6***
1997	***3.1***	***4.4***	***8.1***		***15.7***	18.7	19.8	17.4	11.6		***6.4***
1998	1.8	***4.5***	7.1	10.0	14.2	***20.1***	***21.0***	***19.3***	***14.1***		5.6
1999	2.2	***4.3***	5.4	10.2	14.4	***20.0***	18.5	18.1	***15.0***	***11.9***	***7.2***
2000	***3.2***	***5.3***	***8.5***	10.9	***17.2***	***19.8***	***20.2***	17.2	***14.7***		***6.2***
2001	1.6	3.0	6.3	***12.8***	***16.9***	***19.7***	***20.6***	18.1	***14.7***	***11.0***	***6.6***
2002	2.5	3.1	***8.1***	11.2	***17.2***	***21.3***	***20.9***	17.4	***14.1***	8.9	
2003	***3.5***	***5.7***	7.2	10.5	***16.5***	***20.1***	19.9	***18.7***	***15.6***	8.4	5.6
2004	2.9	4.2	***8.2***	***11.7***	***16.5***	19.0	***20.2***	***18.2***	***14.2***	8.2	5.4
2005		***4.9***	6.1	***11.7***	15.5	19.0	***20.8***	17.7	12.7	***9.6***	5.6
2006	***3.4***	3.0	6.7	***12.8***	***15.8***	***20.1***	***20.7***	***18.7***	14.0	9.1	4.7
2007	2.1	4.2	7.2	***12.4***	15.1	***20.0***	***20.3***	***20.1***	11.8	***9.7***	***6.5***
2008		3.7	***7.7***	***12.8***	***16.7***	***20.6***	***21.5***	18.0	12.2	9.4	
2009	***3.0***	***4.6***	6.4	***13.7***	15.6	***20.1***	19.6	***18.6***	12.2	8.7	4.6
2010		***4.4***	5.4	8.9	14.8	***20.2***	***21.6***	17.4	***15.3***	6.5	5.7
2011		***4.5***	6.4	9.1	13.6	18.2	***20.8***	***19.2***	***14.4***	***9.8***	3.8
2012	2.8	4.1	6.5	11.1	***15.9***	19.1	***21.0***	***20.1***	***15.7***	***10.4***	***6.5***
2013	1.8	4.0	***8.8***	***12.1***	***17.2***	***19.5***	19.8	17.3	11.6	8.6	***6.3***
2014	***4.2***	***5.5***	***7.6***	10.2	15.4	18.6	18.9	17.5	***14.9***	***10.4***	***8.0***
2015	***5.5***	***5.9***	6.9	***13.4***	14.3	15.7	17.4	16.0	***14.3***	***9.8***	5.4
2016	***3.1***	***5.0***	***8.8***	11.0	14.5	18.4	19.3	17.0	11.4	7.9	5.9
2017	2.8	2.9	***7.5***	11.1	12.9	17.0	17.4	17.8	13.4	8.9	5.8
Average	3.0	4.3	7.2	11.5	15.6	19.2	20.1	18.1	14.0	9.5	6.0
Correlation	0.19	0.12	0.00	-0.02	-0.35	-0.32	-0.36	-0.20	-0.42	-0.44	-0.13

Bold

Bald italic numbers indicate values above the long term average listed toward the bottom of the table.

Table 13. Station 6 Average Water Temperature (°C), Between 11 and 38 m, 1991-2017

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	2.1	2.7	3.2	4.4	***5.5***	***6.3***	***6.6***		***8.5***	***9.2***	***5.9***
1992	2.6	2.7	3.0	3.6	4.3	***6.1***	6.0	7.0	***7.9***	***8.3***	5.5
1993		1.7	2.0	3.5	4.5		5.4	5.8	6.3	6.0	4.6
1994	2.5	2.6	3.0	3.5							
1995		3.1	3.3			5.0	5.7	5.9	6.0		5.7
1996	***4.6***	***4.6***	***5.0***	***5.8***	***6.3***	***6.9***	***7.1***			6.8	***5.9***
1997	***4.6***	***4.6***	***4.8***		***5.5***	5.8	6.4	6.9	6.7		***5.8***
1998	***3.9***	***3.9***	***4.3***	4.6	***5.5***	***6.1***	6.4	6.8	6.8		5.3
1999	***3.9***	***4.4***	***4.8***	***5.4***	***6.2***	***6.6***	***7.7***	***7.7***	***8.2***	7.4	***5.9***
2000	***4.3***	***4.3***	***4.8***	***6.0***	***6.5***	***7.2***	***8.4***	***8.0***	***8.1***		5.7
2001	3.1	3.1	3.5	3.9	4.2	4.9	5.5	6.3	6.5	6.2	5.4
2002	2.8	***3.3***	***3.9***	4.5	5.1	5.6	6.0	6.9	6.9	6.8	
2003	***3.4***	***3.6***	***4.2***	***5.2***	***5.5***	5.9	6.5	7.1	7.8	***8.7***	5.6
2004	2.7	2.7	3.5	4.4	5.0	***6.1***	***6.6***	***7.2***	7.8	***8.5***	5.3
2005		2.1	2.9	3.5	3.9	4.7	5.3	5.6	6.0	5.9	5.2
2006	***3.9***	***3.5***	***4.3***	4.5	4.9	5.4	5.7	5.8	6.0	5.9	5.2
2007	***3.4***	3.2	3.8	4.4	5.0	***6.1***	***7.1***	***7.6***	***8.7***	***9.9***	***6.5***
2008		1.8	3.0	***5.1***	5.1	***6.2***	***6.8***	***8.2***	***9.8***	***9.4***	
2009	2.6	3.0	3.8	***4.9***	***5.7***	***6.1***	***6.5***	***7.4***	***9.0***	***8.7***	4.9
2010		2.6	3.3	***4.7***	***6.0***	***6.2***	***7.3***	***7.7***	***7.9***	6.5	***5.9***
2011		2.8	3.5	4.6	***5.8***	***6.3***	***6.6***	6.9	6.9	6.6	5.4
2012	***3.8***	***3.6***	***4.8***	***6.2***	***6.9***	***8.8***	***9.6***	***10.2***	***10.6***	***10.0***	***6.5***
2013	1.7	2.1	2.9	3.4	4.3	4.9	5.2	***7.5***	***9.7***	***8.5***	***5.7***
2014	***3.6***	***3.8***	***4.3***	***5.2***	***6.1***	6.0	***6.8***	***8.4***	***10.4***	***10.3***	***8.0***
2015	***4.5***	***4.6***	***5.9***	***6.7***	***6.8***	***6.9***	***7.2***	***8.6***	***9.1***	***9.7***	5.4
2016	2.5	***3.3***	***4.5***	***4.8***	***5.6***	5.9	6.3	6.7	***9.6***	7.8	***5.8***
2017	2.9	2.9	3.8	4.3	4.6	4.9	5.0	5.0	5.3	5.7	5.7
Average	3.3	3.2	3.9	4.7	5.4	6.0	6.5	7.1	7.9	7.8	5.7
Correlation	-0.05	-0.01	0.28	0.31	0.19	0.01	0.10	0.29	0.40	0.19	0.28

Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Conductivity

In 2017, epilimnetic specific conductivity began to decrease in April with onset of a snowmelt driven runoff, and continued to decline through September. The lowest conductivity at any depth in September of 2017 was 74.3 mS/cm (Table 14, Figure 21). The largest vertical range in specific conductivity (17.9 mS/cm) was observed in September as well, and a vertical range above 10 mS/cm persisted between July and November. Rapid changes in specific conductivity remained between 7 and 10 m from July throughout the end of year, indicating the existence of a chemocline at these depths.

Table 14. Station 6 Conductivity (mS/cm at 25°C), Between February and December, 2017

Depth (m)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	92.8	92.0	88.5	86.3	84.4	75.7	74.5	74.3	77.7	81.6	82.4
2	92.9	93.1	88.5	86.3	84.2	76.7	74.6	74.3	77.7	82.0	82.6
3	93.1	93.1	88.9	86.3	84.7	80.6	77.7	74.3	77.7	82.1	82.4
4	93.4	93.3	89.2	86.4	84.7	81.1	82.1	80.1	77.9	82.0	83.8
5	93.5	93.2	89.2	86.7	84.7	82.6	82.2	82.6	82.7	82.2	83.8
6	93.6	93.3	89.2	86.8	85.4	84.3	83.4	81.6	83.6	82.4	83.8
7	93.7	93.2	89.3	87.4	86.5	85.5	85.8	83.6	84.6	82.5	83.8
8	93.7	93.2	89.6	87.9	87.5	86.3	86.4	85.1	84.0	82.9	83.7
9	93.8	93.2	89.8	88.4	88.3	86.7	86.9	85.6	85.8	84.0	84.0
10	93.9	93.2	89.6	88.6	88.4	87.9	87.8	87.0	86.6	86.9	88.0
11	93.9	93.2	89.8	89.1	88.7	88.3	88.3	87.1	87.9	86.7	88.9
12	93.9	93.2	89.8	89.2	89.1	89.0	88.8	89.0	88.6	88.1	87.6
13	93.9	93.3	90.2	90.2	89.8	88.6	89.2	89.7	89.1	88.8	88.6
14	93.9	93.4	90.4	90.2	90.5	89.9	89.8	90.2	89.6	89.3	89.0
15	93.9	93.4	90.8	90.6	90.5	90.8	90.2	90.3	90.2	89.5	89.6
16	93.9	93.4	91.2	91.1	90.8	91.0	90.6	90.7	90.4	89.8	89.6
17	93.9	93.4	91.4	91.4	91.0	91.1	90.9	90.6	90.4	90.3	90.3
18	94.0	93.5	92.0	91.5	91.3	91.2	90.9	91.0	90.7	90.4	90.2
19	94.0	93.5	91.7	91.8	91.4	91.4	91.2	91.2	90.9	90.7	90.6
20	94.0	93.5	92.7	91.9	91.7	91.4	91.3	91.3	91.0	90.8	90.6
21	94.0	93.6	92.8	92.1	91.8	91.5	91.3	91.3	91.2	90.8	90.8
22	94.1	93.6	93.1	92.2	91.9	91.6	91.4	91.4	91.3	90.9	90.9
23	94.1	93.7	93.1	92.5	91.9	91.6	91.5	91.4	91.3	90.9	90.9
24	94.1	93.8	93.1	92.5	92.0	91.8	91.6	91.5	91.4	91.1	91.0
25	94.1	93.8	93.1	92.6	92.1	91.8	91.7	91.5	91.4	91.1	91.1
26	94.3	93.7	93.2	92.6	92.2	91.9	91.7	91.6	91.5	91.2	91.1
27	94.0	93.8	93.3	92.7	92.3	91.9	91.8	91.6	91.6	91.3	91.2
28	94.0	93.8	93.3	92.8	92.4	92.0	91.8	91.7	91.6	91.3	91.2
29	93.9	93.8	93.4	92.8	92.4	91.9	91.9	91.8	91.7	91.4	91.3
30	93.9	93.8	93.4	92.9	92.5	92.1	91.9	91.9	91.7	91.5	91.3
31	93.9	93.8	93.4	92.9	92.5	92.2	91.9	92.0	91.7	91.5	91.4
32	93.9	93.8	93.4	93.0	92.6	92.1	92.0	92.0	91.8	91.5	91.4
33	93.8	93.8	93.4	93.0	92.6	92.1	92.0	92.1	91.8	91.5	91.4
34	93.8	93.8	93.4	93.0	92.7	92.2	92.0	92.1	91.8	91.5	91.4
35	93.8	93.8	93.5	93.1	92.7	92.3	92.0	92.1	91.8	91.6	91.4
36	93.8	93.8	93.4	93.1	92.7	92.3	92.0	92.1	91.9	91.6	91.4
37	93.8	93.8	93.5	93.1	92.7	92.3	92.1	92.1	91.9	91.7	91.5
38	93.7	93.8	93.5	93.1	92.7	92.3	92.1	92.1	91.9	91.7	91.5
39	-	-	-	-	-	-	92.1	92.1	91.9	91.7	91.5
40	-	-	-	-	-	-	-	-	-	-	91.5
Range	1.4	1.8	5.0	6.8	8.5	16.6	17.6	17.9	14.3	10.1	9.2

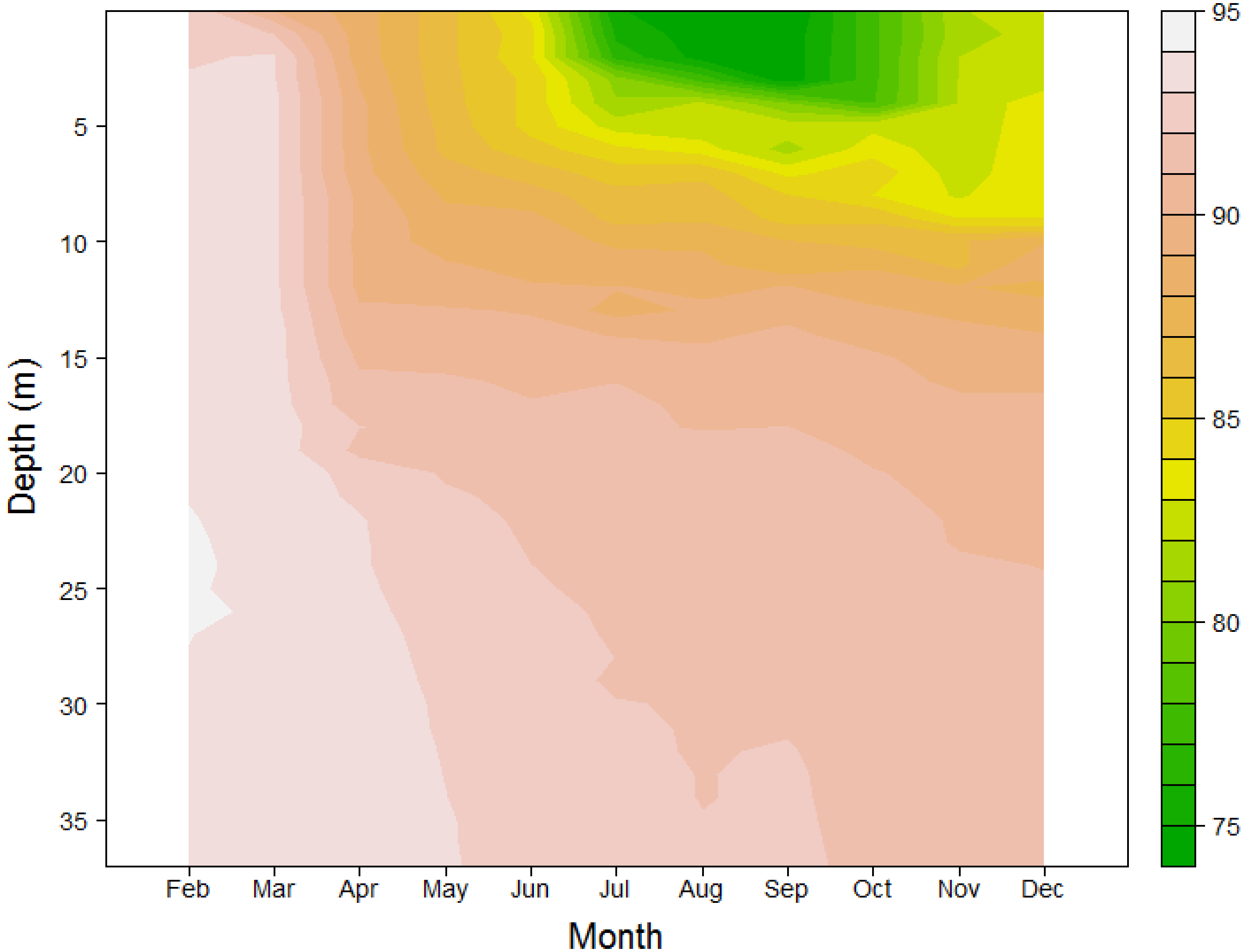


Figure 21. Station 6 Conductivity (mS/cm) Profile, Between February and December, 2017

Salinity

Salinity in the epilimnion was found to be lower in 2017 from May through December than that observed in 2016 (Tables 15 and 16) due to the much higher runoff in 2017. Between September and December 2017, epilimnetic salinity was below the long-term average for the first time since 2014. Salinity in the hypolimnion remained higher than normal for all months and also higher than 2016 levels except November and December when the chemocline weakened slightly due to decreased input of freshwater into Mono Lake. The rising trend of hypolimnetic salinity, which had started at the end of meromixis in 2008, continued in 2017. Furthermore, the highest hypolimnetic salinity value for each respective month since 1991 was found for all but one month in 2017. The highest hypolimnetic salinity level since 1991 was observed in February of 2017 (94.1 g/L), breaking the last years' record of 93.7 g/L.

Mono Lake water was less saline at shallower depths but continued to become more saline at deeper depths. Due to the extremely dry condition that persisted between 2012 and 2015, the lake level dropped from 6,383.5 feet in May 2012 to 6,377.0 feet in December 2016. During the same period, the salinity level increased from 72.6 g/L (July 2012) to 91.4 g/L in the epilimnion, and from 80.6 g/L (July 2012) to 91.5 g/L in the hypolimnion. As a result, the salinity level at the beginning of 2017 was higher than any other monitoring years since 1991 throughout the water column. This, along with establishment of the chemocline, was attributable to a rising trend of salinity in the hypolimnion.

Table 15. Station 6 Average Salinity (g/L); 1-10 m, Adjusted to 25°C, 1991-2017

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	***91.5***	***91.4***	***92.0***	***93.0***	***94.2***	***95.6***	***96.4***		***96.2***	***94.6***	***93.9***
1992	***92.2***	***92.5***	***93.3***	***94.8***	***95.6***	***96.5***	***97.6***	***97.2***	***97.1***	***95.6***	***94.5***
1993		***91.6***	***92.1***	***93.4***	***94.2***		***94.6***	***94.9***	***94.4***	***93.7***	***92.4***
1994	***91.1***	***91.7***	***91.7***	***92.3***							
1995		***91.3***	***91.2***			***89.8***	***87.6***	***87.5***	***87.2***		***86.5***
1996	***85.0***	***83.9***	***83.9***	***83.9***	***84.0***	***83.1***	***83.7***			83.6	82.9
1997	80.2	79.9	80.2		79.3	79.2	79.2	79.8	80.1		79.8
1998	78.2	78.3	77.8	78.2	77.8	76.6	75.2	75.4	75.2		75.6
1999	75.0	75.1	75.3	75.6	75.8	76.0	76.6	76.9	77.2	77.1	77.1
2000	76.0	76.5	76.8	77.4	77.7	78.1	78.9	79.0	79.1		78.9
2001	78.4	78.1	78.4	78.6	79.4	80.1	80.6	81.4	80.8	80.9	80.4
2002	79.9	79.9	80.1	80.4	81.2	***82.6***	***83.1***	***83.5***	83.2	82.5	
2003	81.1	81.1	81.1	81.7	82.1	***83.2***	***83.8***	***84.4***	***84.2***	82.7	82.4
2004	82.3	81.6	82.4	82.8	83.4	***84.0***	***84.9***	***85.3***	***85.1***	83.7	83.6
2005		81.7	82.1	82.4	82.4	82.0	81.8	82.1	82.4	82.1	81.4
2006	80.6	80.1	80.3	79.8	78.9	77.0	76.4	77.0	77.3	77.4	77.3
2007	77.2	77.2	77.9	78.3	79.2	80.3	81.5	81.7	80.8	80.3	80.6
2008		79.3		80.6	80.6	75.4	74.3	82.4	81.8	81.3	
2009		81.0	80.9	81.6		77.7	78.8	81.1	82.9	82.4	82.0
2010		80.9	81.2	81.7	82.3	76.2	74.1	***83.4***	82.9	82.0	81.9
2011		81.0	80.7	80.5	80.9	78.3	75.3	78.2	78.7	78.3	78.6
2012	78.1	78.4	78.7	79.4	80.5		75.7	77.8	83.3	***84.9***	***87.1***
2013			***85.8***	***84.4***	***84.3***	79.0	78.7	***85.2***	***86.7***	***88.3***	***89.9***
2014		***89.8***	***88.5***	***87.2***	***86.4***	80.0	80.7	***84.9***			
2015					***88.3***	***88.2***	***88.8***	***89.6***	***89.8***	***91.3***	***94.5***
2016	***96.5***	***94.4***	***91.5***	***90.2***	***89.2***	***88.7***	***89.4***	***90.8***	***92.0***	***93.8***	***95.4***
2017	***97.1***	***96.6***	***91.6***	***89.1***	***87.6***	***83.8***	***83.0***	81.3	82.1	82.9	83.8
Average	83.5	83.7	83.8	83.6	83.5	82.1	82.3	83.4	84.2	84.7	84.4

Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Table 16. Station 6 Average Salinity (g/L); 11-38 m; Adjusted to 25°C, 1991-2017

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1991	***91.5***	***91.5***	***91.6***	***91.9***	***92.4***	***92.4***	***92.6***		***93.4***	***94.3***	***93.9***
1992	***92.5***	***92.5***	***92.4***	***92.5***	***92.6***	***93.0***	***93.2***	***93.9***	***94.2***	***94.9***	***94.6***
1993		***92.9***	***92.7***	***92.7***	***93.3***		***93.0***	***93.1***	***93.2***	***93.2***	***92.5***
1994	***91.4***	***91.3***	***91.3***	***91.4***							
1995		***93.3***	***93.2***			***92.6***	***92.6***	***92.5***	***92.4***		***92.2***
1996	***91.2***	***90.9***	***90.6***	***90.4***	***90.3***	***89.9***	***90.3***			***89.7***	***89.4***
1997	***88.6***	***88.4***	***88.2***		***87.9***	***87.8***	***87.6***	***87.6***	***87.0***		86.8
1998	86.1	86.0	85.8	***85.6***	85.3	85.2	85.0	85.1	85.3		84.6
1999	83.1	83.3	82.8	82.7	81.8	83.4	83.2	83.7	83.0	83.7	83.5
2000	82.7	83.1	82.2	82.9	83.1	82.7	82.1	83.2	83.5		83.7
2001	83.2	83.5	83.2	83.3	83.0	83.0	82.6	82.9	82.7	83.3	83.2
2002	82.7	82.7	82.5	81.7	82.3	82.3	82.3	82.6	82.8	82.9	
2003	81.9	81.7	81.6	81.3	81.4	81.8	81.8	82.0	82.5	83.2	83.0
2004	82.4	82.2	82.1	82.3	82.2	82.2	82.6	82.8	83.5	84.1	83.7
2005		82.9	82.6	83.3	82.5	82.3	82.7	82.7	82.8	82.7	82.5
2006	81.5	81.0	80.8	80.6	80.5	80.5	80.6	80.6	80.5	80.3	80.2
2007	79.5	79.0	79.0	78.8	79.1	78.8	79.3	79.4	80.2	80.6	80.4
2008		79.4		79.9	80.0	78.3	78.0	78.1	80.4	81.5	
2009		80.9	80.9	81.0		81.0	81.3	81.2	82.2	82.6	82.3
2010		81.6	81.5	81.3	81.5	81.7	80.6	81.8	81.9	82.1	82.1
2011		81.1	80.9	80.8	80.9	80.8	80.8	80.7	80.8	80.4	79.8
2012	79.2	78.7	78.7	78.8	79.0		83.3	83.4	84.0	85.3	***87.3***
2013			***90.6***	***90.1***	***89.4***	***89.1***	***88.5***	***87.6***	***87.4***	***88.4***	***90.4***
2014		***91.8***	***91.2***	***89.7***	***90.0***	***88.1***	***89.4***	***87.2***			
2015					***91.8***	***91.6***	***90.2***	***90.0***	***90.8***	***91.4***	***94.5***
2016	***97.4***	***96.3***	***94.9***	***94.7***	***93.9***	***93.5***	***93.4***	***93.1***	***92.4***	***93.9***	***95.5***
2017	***97.8***	***97.4***	***95.9***	***95.3***	***94.8***	***94.4***	***94.2***	***94.2***	***93.9***	***93.5***	***93.4***
Average	86.6	86.1	86.3	85.6	85.8	85.7	85.8	85.4	85.9	86.3	86.9

Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Dissolved Oxygen

In 2017, dissolved oxygen (DO) concentrations in the upper mixed layer (< 11 m) ranged from 0.7 to 7.3 mg/L, with the high concentrations slowly migrating downward throughout the year; the upper 5 m in early spring (February and March), between 6 m and 7 m in July, between 8 and 9 m in October, and back up to the upper 5 m in December (Table 17, Figure 22). A strong chemocline had established between 7 m and 8 m in July and remained between 10 m and 11 m for the remainder of 2017. The lowest epilimnetic values occurred during the August and September surveys when dissolved oxygen was 3.4-3.5 mg/L in the upper 5 m of the water column. Hypolimnetic DO concentration was anoxic (<0.5 mg/L) or suboxic (<1.5 mg/L) beginning in April throughout 2017. The anoxic condition was found at 8-9 m in July and August and lowered to 9-10 m in September. The absence of autumn holomixis resulted in the anoxic condition remaining below 10 m to the end of the year.

Average DO concentrations in the upper mixing layer (depth between 1 and 10 m) ranged from 3.3 mg/L in June and September to 7.1 mg/L in October in 2017, and remained mostly below the long term average (Table 18). Below 10 m, average DO concentrations remained either suboxic or anoxic throughout 2017 and the average for 2017 was lowest since 1994 (Table 19). In 2017, the meromictic regime prevailed and the chemocline had established around 10 m of depth. This depth is shallower compared to the chemocline depths observed in past despite of 317% of Mono Lake input. The chemocline could widen or weaken depending on runoff condition of 2018.

Table 17. Station 6 Dissolved Oxygen* (mg/L); February to December, 2017

Depth (m)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov†	Dec
1	5.2	6.9	4.6	4.6	4.9	3.6	3.5	3.4	6.9	-	7.3
2	5.1	6.6	4.4	3.8	5.1	3.7	3.5	3.4	6.9	-	7.4
3	4.8	6.5	4.4	3.8	5.3	3.7	3.5	3.4	6.9	-	7.3
4	4.3	4.8	4.2	3.5	4.4	3.8	3.4	3.4	7.0	-	7.0
5	4.1	4.6	3.7	3.2	4.1	5.1	3.5	3.4	7.0	-	7.0
6	3.8	4.2	3.6	3.0	3.3	7.9	5.3	3.9	7.1	-	6.9
7	3.6	3.5	3.4	2.4	2.7	7.8	6.1	4.6	7.2	-	6.8
8	3.2	2.6	3.4	2.0	1.5	1.0	4.0	5.4	8.1	-	6.8
9	3.0	2.2	3.2	5.2	0.8	0.7	0.8	1.6	8.3	-	6.8
10	2.8	2.1	3.0	4.5	0.7	0.7	0.3	0.4	5.9	-	6.6
11	2.5	2.0	3.0	4.3	0.8	0.7	0.2	0.4	1.6	-	3.2
12	2.4	1.7	2.8	3.4	0.9	0.8	0.1	0.3	0.7	-	1.1
13	2.2	1.7	2.8	3.1	1.0	0.9	0.1	0.3	0.6	-	0.6
14	2.1	1.6	2.7	2.5	1.2	0.9	0.1	0.4	0.5	-	0.4
15	2.0	1.6	2.3	2.1	1.3	0.9	0.1	0.4	0.5	-	0.4
16	1.8	1.6	1.9	1.7	1.4	0.8	0.1	0.5	0.4	-	0.3
17	1.7	1.6	1.8	1.5	1.1	0.8	0.1	0.5	0.4	-	0.3
18	1.6	1.5	1.4	1.2	1.1	0.8	0.1	0.4	0.4	-	0.3
19	1.4	1.5	1.2	1.0	1.1	0.9	0.1	0.4	0.4	-	0.2
20	1.4	1.5	1.0	0.9	1.1	0.9	0.1	0.4	0.3	-	0.2
21	1.3	1.4	1.0	0.9	1.2	0.9	0.1	0.4	0.3	-	0.2
22	1.3	1.4	0.9	0.8	1.2	1.0	0.0	0.4	0.3	-	0.2
23	1.3	1.3	0.7	0.6	1.2	1.0	0.0	0.4	0.3	-	0.2
24	1.2	1.3	0.7	0.3	1.3	1.0	0.0	0.4	0.3	-	0.2
25	1.2	1.3	0.7	0.5	1.3	1.0	0.0	0.4	0.3	-	0.2
26	1.2	1.1	0.6	0.4	1.4	1.0	0.0	0.4	0.3	-	0.1
27	1.3	1.1	0.6	0.4	1.4	1.0	0.0	0.4	0.3	-	0.1
28	1.3	1.1	0.5	0.2	1.4	1.1	0.0	0.4	0.3	-	0.1
29	1.4	1.0	0.5	0.2	1.4	1.1	0.0	0.4	0.2	-	0.1
30	1.3	1.0	0.5	0.2	1.5	1.1	0.0	0.4	0.2	-	0.1
31	1.2	0.9	0.4	0.1	1.5	1.1	0.0	0.4	0.2	-	0.1
32	1.2	0.9	0.4	0.1	1.5	1.1	0.0	0.4	0.2	-	0.1
33	1.1	0.8	0.4	0.1	1.5	1.1	0.0	0.3	0.2	-	0.1
34	1.0	0.7	0.4	0.1	1.6	1.1	0.0	0.3	0.2	-	0.1
35	0.7	0.7	0.4	0.1	1.6	1.2	0.0	0.3	0.2	-	0.1
36	0.5	0.7	0.4	0.0	1.6	1.2	0.0	0.3	0.2	-	0.1
37	0.4	0.7	0.4	0.0	1.6	1.2	0.0	0.3	0.2	-	0.1
38	0.4	0.7	0.4	0.0	1.6	1.2	0.0	0.3	0.2	-	0.0
39	0.4	0.8	-	-	1.6	1.3	0.0	0.3	0.2	-	0.0
40	0.4	0.7	-	-	1.6	1.3	-	0.3	0.2	-	0.0

*****YSI probe error (+/- 0.2 mg/L).
†DO from November was not measured due to malfunction of YSI.

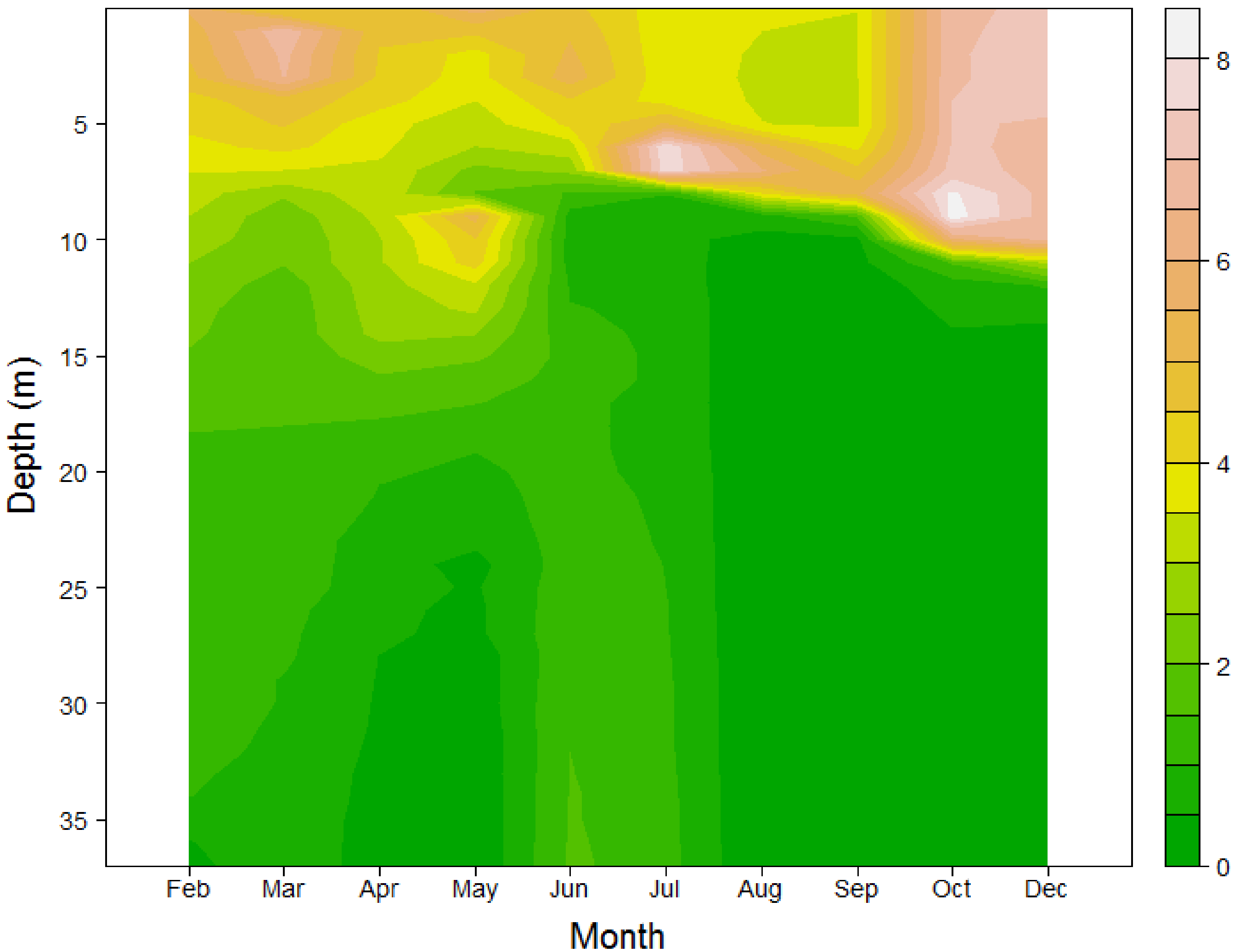


Figure 22. Station 6 Dissolved Oxygen (mg/L) Profile; February through December, 2017

Dissolved oxygen was not monitored in November due to malfunction of YSI.

Table 18. Station 6 Average Dissolved Oxygen (mg/L); 1-10 m; 1991-2017

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
1994					3.1	***4.2***	4.0	3.8	***6.3***		4.0	4.2
1995		***7.4***			***4.2***	4.0	***4.5***	***4.8***	***5.6***		4.4	***5.0***
1996	***6.5***	6.0	***6.3***	***5.2***	***5.4***	***5.0***	***4.8***	***4.7***		***6.4***	***5.5***	***5.6***
1997	***8.7***	***6.8***	***6.4***	5.2	***5.1***	***5.1***	***4.9***		***5.7***		***5.5***	***5.9***
1998	***7.1***	***8.7***	***7.3***	***5.7***	***5.0***	***4.9***	***4.9***	***5.0***	***5.1***		***5.4***	***5.9***
1999	5.7	***7.0***	***6.6***	***6.0***	***4.8***	***4.7***	***4.7***	***4.6***	***4.7***		***5.0***	***5.4***
2000		***7.0***	***7.3***	4.9	***4.8***	***4.7***	***4.8***	***5.2***	***6.7***	***5.0***	***5.7***	***5.6***
2001	***6.3***	***7.9***	***9.6***	5.2	***5.9***	***4.4***	4.1	***4.7***	***4.7***	***4.3***	2.6	***5.4***
2002	5.8	5.5	5.8	5.0	3.0	***4.3***	3.9	4.1	3.3	3.1		4.4
2003	5.1	5.9	4.9	***7.2***	***5.1***	***4.8***	***4.6***	***5.0***	***4.6***	0.3	1.8	4.5
2004	***7.0***	***7.6***	5.5	3.8	2.1	3.5	***4.4***	***4.5***	3.8	2.9	3.7	4.4
2005		***7.2***	6.1	4.9	***4.3***	3.2	4.3	***5.4***	***5.0***	***5.6***	***5.0***	***5.1***
2006	***7.4***	4.6	5.9	5.2	3.6	3.4	3.7	3.8	***4.5***	***4.4***	4.7	4.7
2007	6.0	***6.9***	***6.3***	5.0	3.6	3.5	3.8		1.4	2.7	4.1	4.3
2008		***7.3***	***6.7***	4.5	***4.4***	3.9	***4.4***	***4.8***	3.1	3.3		4.7
2009	5.0	***6.5***	***6.2***	4.9	3.0	3.3	***4.5***	4.0	3.0	2.3	***5.2***	4.4
2010		***6.9***	5.9	***6.3***	***5.1***	3.4	***4.5***	***4.9***	***5.1***	3.0	4.1	***4.9***
2011		6.0	***6.3***	4.7	***5.0***	4.0	***4.4***	***4.6***			3.8	***4.8***
2012			***6.5***	***5.7***		***5.3***	***5.5***	4.2	***4.4***	2.8	***5.3***	***5.0***
2013	***10.1***	***9.8***	***11.0***	***11.5***	***4.2***	***5.4***	***7.0***	***8.2***	2.7	1.0	0.9	***6.5***
2014	2.3	1.2	2.4	***5.3***	0.7	1.0	0.4	2.3	2.5	***12.0***	4.1	3.1
2015	4.4	6.3	3.5	2.0	***4.9***	***5.5***	3.8	***4.6***	2.5	2.0	2.2	3.8
2016	5.6	4.4	5.8	2.9	***4.5***	2.5	3.1	2.6	3.7	***4.4***	1.6	3.7
2017	4.0	4.4	3.8	3.6	3.3	3.8	3.4	3.3	***7.1***		***7.0***	4.4
Average	6.1	6.4	6.2	5.2	4.1	4.1	4.3	4.5	4.4	3.9	4.2	4.8

Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Table 19. Station 6 Average Dissolved Oxygen (mg/L); 11-38 m; 1991-2017

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
1994					0.9	0.9	***2.1***	1.1	***4.5***		***3.9***	***2.2***
1995		2.1			***1.7***	1.4	***2.1***	1.3	1.2		1.5	1.6
1996	2.4	2.1	***2.8***	1.9	***2.2***	1.6	***2.0***	***2.1***		***3.1***	***3.2***	***2.3***
1997	2.9	2.1	***2.6***	***3.3***	***2.7***	***3.4***			***3.7***		***3.6***	***3.0***
1998	***4.0***	***3.6***	***4.1***	***3.7***	***2.8***	***3.2***	***3.0***	***3.7***	***2.4***		***4.1***	***3.5***
1999	***4.2***	***4.7***	***4.1***	***3.3***	***2.9***	***3.2***	***3.1***	***2.4***	***3.6***		***4.2***	***3.6***
2000		***3.3***	2.2	***3.0***	***3.1***	***2.4***	***2.2***	***2.2***	1.3	***3.3***	***3.3***	***2.6***
2001	***4.5***	***3.3***	***3.0***	1.5	1.1	1.6	***2.2***	***2.2***	1.4	***2.2***	***2.9***	***2.3***
2002	***3.2***	***3.0***	1.8	1.8	0.8	1.2	1.2	1.4	1.3	1.7		1.8
2003	0.7	0.9	0.7	1.7	0.8	***2.0***	1.2	1.3	***2.0***	0.0	1.7	1.2
2004	***4.2***	2.7	1.2	1.4	0.6	0.7	0.9	***2.3***	***2.4***	1.4	***3.1***	1.9
2005		2.1	1.5	0.8	***1.8***	1.2	1.6	***2.1***	***2.5***	1.2	***3.5***	1.8
2006	2.4	***3.4***	***3.2***	1.8	***1.8***	0.9	1.2	***2.6***	1.3	1.6	***3.9***	***2.2***
2007	1.6	1.9	1.9	***2.4***	1.5	1.7	1.1		1.5	1.1	***3.7***	1.8
2008		***3.7***	2.2	1.4	0.8	***2.4***	1.7	1.8	1.4	***3.0***		2.0
2009	***5.2***	***4.6***	***3.0***	1.3	1.2	***1.7***	1.7	1.7	***1.8***	***3.3***	***4.9***	***2.8***
2010		***3.7***	***2.6***	***2.4***	***2.1***	***2.1***	***3.1***	***2.3***	***2.3***		***2.8***	***2.6***
2011		***4.8***	***3.7***	***2.2***	***1.9***	***2.6***	***4.8***	***3.1***			***3.2***	***3.3***
2012			2.3	***2.1***		0.9	***2.7***	1.4	1.7	1.3	***4.9***	2.2
2013	***9.0***	***6.5***	***5.2***	***4.6***	1.1	***2.3***	1.1	***2.4***	1.1	0.7	0.1	***3.1***
2014	2.0	0.2	0.7	1.9	0.0	0.3	0.0	0.3	0.2	***2.8***	***4.1***	1.1
2015	0.6	2.6	2.1	0.7	1.2	1.2	1.4	0.9	0.9	0.6	0.7	1.2
2016	3.0	***3.2***	2.4	0.6	***1.6***	0.9	1.3	0.8	0.7	1.3	1.0	1.5
2017	1.4	1.2	1.1	0.9	1.3	1.0	0.1	0.4	0.4		0.3	0.8
Average	3.2	3.0	2.5	2.0	1.6	1.7	1.8	1.8	1.8	1.8	2.9	2.2

Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Ammonium

Ammonium levels were low (<2.8 µM) throughout the water column for most of February to April of 2017 (Table 20, Figure 23). Epilimnetic ammonium levels slightly increased in May as *Artemia* activity increased, but was quickly depleted. Epilimnetic ammonium levels remained below the detectable limit of 2.8 µM throughout the year. Below 10 m of depth, ammonium levels continued to increase as *Artemia* carcasses and fecal pellets sank. At the depth of 28 m, the ammonium level rose from below the detectable limit, to 45.5 µM in December. Holomixis never occurred in 2017 as the lake remained stratified throughout the year at a depth of around 10 m. A very low epilimnetic ammonium level was observed across the other six stations (Table 21).

Average ammonium values between the depths of 1 m and 10 m were mostly at or below the detectable level except for May. The detectable level of 2.8 µM makes a historical comparison difficult especially for the epilimnion as an arbitrary value (2 µM) has been substituted for <2.8 µM, which may not reflect actual values. Historically, average ammonium values less than 1 µM have been recorded. The May epilimnetic value in 2017 was definitively higher than the long-term average, but it is rather inconclusive for other months (Table 22). In spite of the onset of meromixis and continuous accumulation of ammonium below 10 m, hypolimnetic ammonium levels remained below the long term average and much lower than historical levels found during meromictic years from summer to winter months (Table 23). During the second meromixis event between 1995 and 2002, hypolimnetic ammonium levels remained above 100 µM with a monthly average as high as 296 µM in February 2001. The hypolimnetic accumulation level in 2017 was lower than during two brief meromixis events in 2005-2007 and 2011. It is also notable that the large meromixis event between 1995 and 2002 appears to have had a longer lasting effect on hypolimnetic ammonium levels as the hypolimnetic ammonium levels remained much higher than past 5 years. Lower accumulation of ammonium in recent years may be attributable to a lack or meromixis or/and weaker meromixis event preceding the monomixis. As a result, a strong negative trend is observed for all months.

Table 20. Station 6 Ammonium (µM), Between February and December, 2017

Depth (m)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	-	-	-	-	-	-	-	-	-	-	-
2	<2.8	<2.8	<2.8	7.2	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8
3	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-
8	3.9	<2.8	<2.8	3.3	<2.8	2.8	<2.8	<2.8	<2.8	<2.8	<2.8
9	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-
12	2.8	<2.8	<2.8	3.3	2.8	8.3	11.6	16.6	18.3	15.0	16.6
13	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
16	<2.8	<2.8	<2.8	3.9	3.3	5.0	20.0	20.5	26.1	31.0	11.1
17	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
20	<2.8	2.8	<2.8	3.3	4.4	11.6	24.9	24.9	13.3	35.5	36.6
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
24	3.3	<2.8	2.8	3.9	8.3	12.8	17.7	27.7	24.4	39.4	41.6
25	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-
28	2.8	<2.8	<2.8	5.5	7.2	10.5	19.4	25.5	22.7	43.8	45.5

Laboratory detection limit of 2.8µm.

Table 21. 9-Meter Integrated Values for Ammonium (µm) Between February and December, 2017

Station	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8
2	<2.8	<2.8	<2.8	2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8
5	2.8	NA	<2.8	3.3	2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8
6	<2.8	<2.8	<2.8	3.3	<2.8	<2.8	2.8	<2.8	<2.8	<2.8	<2.8
7	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8
8	<2.8	<2.8	<2.8	3.3	<2.8	2.8	<2.8	<2.8	<2.8	<2.8	<2.8
11	<2.8	<2.8	<2.8	3.3	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8	<2.8
Mean	2.8	<2.8	<2.8	3.2	2.8	2.8	2.8	<2.8	<2.8	<2.8	<2.8
SE	NA	NA	NA	0.11	NA	NA	NA	NA	NA	NA	NA

Laboratory detection limit of 2.8µm.

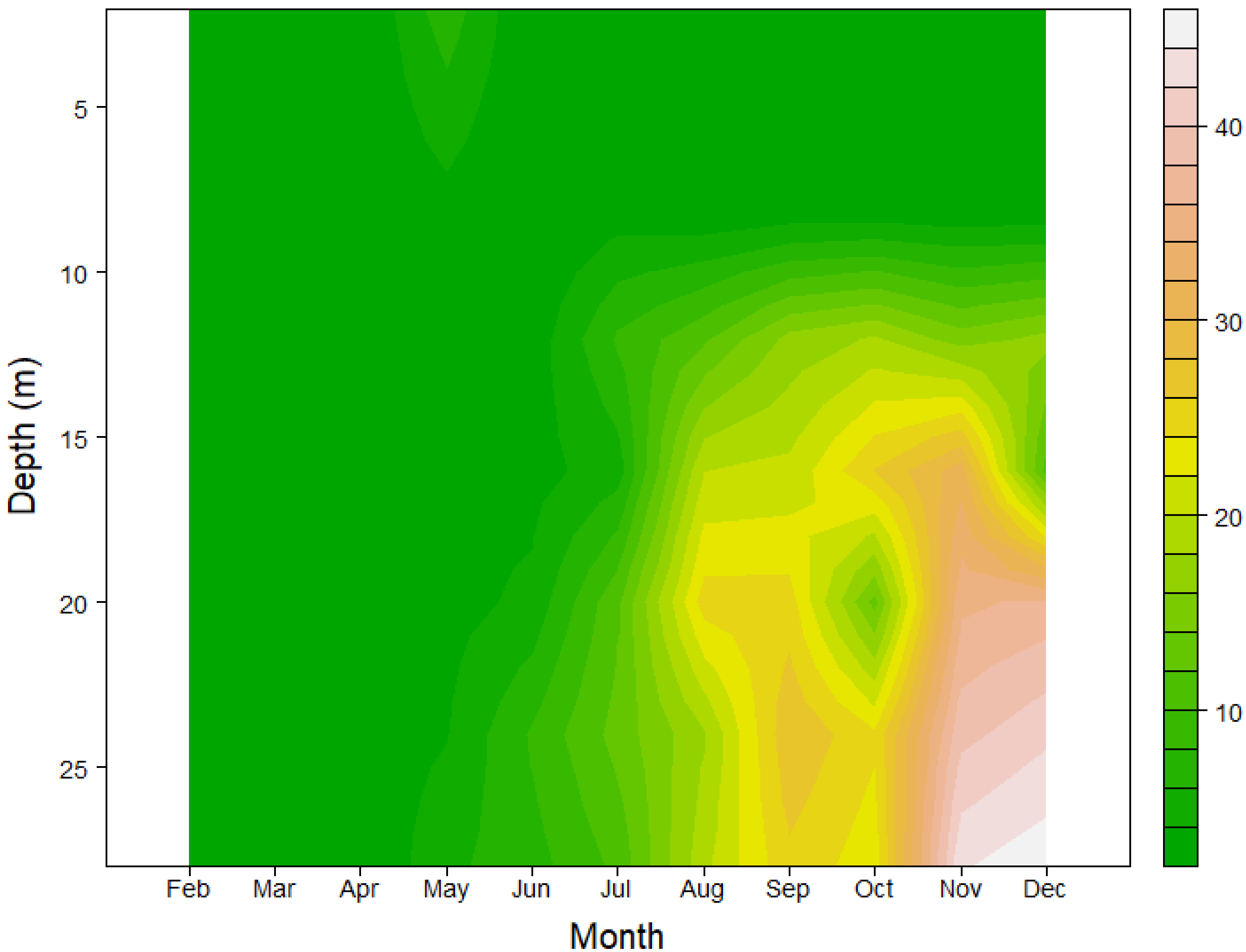


Figure 23. Station 6 Ammonium (µm) Profiles, Between February and December, 2017

Table 22. Station 6 Average Ammonium (µm), Between 1 m and 10 m Since 1994

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994					***11.2***	***4.1***	***2.7***	***2.6***	0.6		***10.0***
1995		1.4			1.6	2.2	1.4	1.0	0.5		0.5
1996	0.6	0.6	0.9	2.0	1.5	2.0	1.4	1.1		0.8	0.7
1997	0.8	0.6	0.7	0.7	0.5	0.5	0.8	0.8	0.6		0.7
1998	0.7	0.6	0.8	0.9	2.1	0.9	0.7	0.8	0.6		0.6
1999	0.6	0.6	0.6	0.9	2.4	0.8	0.5	0.9	0.9		0.5
2000	0.5	0.9	0.9	0.6	1.8	0.5	0.6	0.6	0.7	0.6	1.0
2001	0.1	0.8	0.5	1.8	3.6	2.5	1.0	0.8	1.2	1.1	2.1
2002	1.9	0.7	0.7	0.5	***8.5***	3.2	0.6	1.3	***3.0***	1.2	
2003	1.7	1.1	***1.9***	1.1	1.2	0.3	***2.3***	0.5	0.6	***30.1***	
2004	***8.4***	0.6	0.1	***10.3***	***19.2***	***15.7***	***6.5***	0.7	***2.3***	***9.2***	***13.8***
2005		0.9	1.1	1.2	1.0	***6.1***	1.8	1.1	1.0	1.2	1.1
2006	1.0	0.5	0.9	1.0	2.6	***4.7***	1.9	1.2	0.1	1.2	1.2
2007	0.7	1.0	***1.3***	1.7	***6.3***	3.1	0.6	0.3	***6.9***	2.2	***6.4***
2008		1.0	0.2	1.2	3.0	2.7	1.0	0.9	0.6	0.4	
2009	0.9	***3.5***	0.2	1.8	***5.5***	***7.0***	1.9	0.6	***2.6***	***5.2***	1.4
2010		1.1	0.4	0.5	0.7	1.9	0.5	0.7	0.8	3.8	1.0
2011		0.4	0.7	0.8	0.9	2.5	0.4	1.1	0.8	0.9	2.3
2012	0.8	0.7	0.3	0.7	0.8	1.5	***4.4***	***4.4***	***7.8***	4.4	***4.4***
2013	***6.1***	***6.4***	***4.2***	***2.8***	***6.9***	***6.7***	***3.1***	***2.8***	***2.8***	2.8	2.8
2014	2.4	***2.0***	***2.0***	2.0	3.3	3.3	***2.7***	***3.6***	***2.4***	3.9	***5.6***
2015	***5.5***	***6.1***	***5.3***	***6.4***	***5.5***	***6.9***	***7.2***	***9.4***	***9.7***	***13.6***	***8.3***
2016	***14.1***	***10.8***	***2.7***	***3.6***	2.0	3.0	***2.4***	***2.0***	2.0	2.0	2.0
2017	***2.9***	***2.0***	***2.0***	***5.3***	2.0	2.4	2.0	***2.0***	2.0	2.0	2.0
Average	2.8	1.9	1.3	2.2	3.9	3.5	2.0	1.7	2.2	4.6	3.2

Bold italic numbers indicate values above the long term average listed toward the bottom of the table.
An arbitrary value of 2 was used for values below the laboratory detection limit of 2.8µm.

Table 23. Station 6 Average Ammonium (µm), Between 11 m and 28 m, Since 1994

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994					16	25	18	22	17		10
1995		8.7			29	27	24	23	33		34
1996	32	43	47	52	43	***62***	63	60		***81***	***73***
1997	75	***77***	***88***	***90***	***86***	***94***	***117***	***108***	***118***		***111***
1998	***156***	***127***	***135***	***155***	***135***	***128***	***171***	***135***	***135***		***160***
1999	***157***	***163***	***131***	***156***	***207***	***210***	***163***	***134***	***288***		***248***
2000	***171***	***221***	***218***	***112***	***126***	***123***	***113***	***155***	***167***	***226***	***295***
2001	***296***	***294***	***272***	***216***	***190***	***213***	***310***	***218***	***254***	***215***	***371***
2002	***209***	***176***	***217***	***175***	***216***	***176***	***244***	***263***	***209***	***177***	
2003	***168***	***103***	60	***63***	***73***	***71***	57	***91***	***81***	27	
2004	19	26	26	29	39	48	53	58	55	21	20
2005		22	21	26	28	39	39	43	48	***57***	34
2006	27	24	17	15	22	28	34	31	37	***54***	50
2007	44	43	54	52	***64***	55	60	57	36	7.8	6.3
2008		2.1	7.0	15	21	30	41	47	24	0.6	
2009	1.2	1.5	2.5	6.6	14	18	37	45	22	1.6	1.9
2010		4.1	5.4	5.6	7.9	22	34	43	53	4.2	3.3
2011		0.7	0.5	3.6	3.4	11	37	57	49	***57***	43
2012	21	8.2	2.2	6.6	14	27	28	31	29	4.5	4.8
2013	6.3	6.4	6.2	2.8	11	13	13	19	8.8	2.8	2.8
2014	2.0	2.2	3.4	4.5	8.1	12	20	17	13	3.3	4.0
2015	5.8	7.3	6.0	11	15	22	24	22	21	11	10.0
2016	12	13	4.1	4.7	5.5	11	18	17	4.9	2.2	2.0
2017	2.6	2.2	2.2	4.0	5.2	9.6	19	23	21	33	30
Average	78.0	59.8	60.2	54.8	57.5	61.5	72.5	71.6	75.0	52.0	72.1
Correlation	-0.64	-0.56	-0.66	-0.73	-0.53	-0.55	-0.45	-0.46	-0.54	-0.65	-0.48

Bold italic numbers indicate values above the long term average listed toward the bottom of the table.
An arbitrary value of 2 was used for values below the laboratory detection limit of 2.8µm.

Chlorophyll a

Seasonal changes were noted in the phytoplankton community, as measured by chlorophyll *a* concentration (Table 24, Table 25, Figure 24). At Station 6 during the February and March surveys, chlorophyll levels throughout water column were uniform, averaging 43.5 µg/L (Table 24). In May chlorophyll levels started to increase at 2 m with warming temperatures, but quickly dropped as time progressed with increasing *Artemia* grazing. Chlorophyll ranged from 1.0 µg/L to 1.9 µg/L between July and October. As the *Artemia* population increased in summer, clarity of the lake improved which resulted in deeper penetration of sunlight and higher chlorophyll levels at 8 m in July and August. During both July and August, the chlorophyll level at 2 m was 1.3 µg/L and 1.9 µg/L respectively; however, at 8 m these numbers were 79.8 µg/L and 53.3 µg/L respectively. In September and October, chlorophyll was also depleted at 8 m. Chlorophyll levels in the epilimnion started to recover in November. The epilimnetic chlorophyll level (between 2 and 8 m) was highest in April (51.2 µg/L) and lowest in September (1.8 µg/L) while the hypolimnetic chlorophyll level (≤12 m) was highest in November (72.4 µg/L) and lowest in October (38.2 µg/L).

Within the epilimnion, lakewide mean chlorophyll levels decreased throughout the spring and reached their lowest level at 3.7 µg/L in October as *Artemia* grazing intensified (Table 25). Chlorophyll levels at the surface (2 m) declined dramatically from 63.0 µg/L in April to 1.3 µg/L in July and remained around 1.0 µg/L until November. Because of high chlorophyll levels at 8 m in July and August, the epilimnetic chlorophyll levels were not found as low as the historical summer levels (Table 26). Improvement in Secchi readings during summer months was, however, noticeable compared to last 3 monitoring years as the maximum depth improved from 1 m between 2014 and 2016 to 5.8 m in 2017.

Chlorophyll levels in the epilimnion appeared to be lower during the last prolonged meromixis, increased at the end of the meromixis, and remained so until present (Table 26). The timing of peak chlorophyll levels varies over time. Between 2003 and 2009 peaks tend to occur in spring before *Artemia* grazing while the timing has shifted to November or December between 2014 and 2015, after *Artemia* grazing. Mean *Artemia* abundance between 2014 and 2016 was the lowest abundance for a 3-year period on record. Low population and earlier *Artemia* peaks may have attributed for higher chlorophyll levels throughout summer months and peaks in late fall or winter. In 2017 chlorophyll levels were higher than normal throughout spring and summer months but abruptly declined in September and remained below normal for the rest of the year. Unusually high chlorophyll levels observed in July and August of 2017, even with much improved transparency as compared to past three years, resulted in much higher epilimnetic chlorophyll level in July and August. A similar trend of the epilimnetic chlorophyll levels was observed for the entire lake (Table 27); chlorophyll levels in the hypolimnion tend to decline during meromixis and tend to increase during monomixis. There appears to be 1 or 2 years of time lag between the end of meromixis and low chlorophyll level; as a result peaks tend to occur 3 or 4 years after the brief trough. Hypolimnetic chlorophyll levels in 2017 were lower than the previous three years, but mostly remained above the long-term average of a respective month (Table 28).

Table 24. Station 6 Chlorophyll *a* (µg /L), Between February and December, 2017

Depth (m)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	-	-	-	-	-	-	-	-	-	-	-
2	42.6	46.4	63.0	25.8	9.9	1.3	1.9	1.0	1.1	17.0	25.7
3	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-
8	41.8	48.2	39.3	32.6	35.5	79.8	53.3	2.6	2.8	25.7	26.3
9	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-	-
12	40.8	43.3	52.1	36.0	43.3	62.0	74.7	53.8	37.3	90.2	78.2
13	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-
16	41.6	46.9	38.8	38.6	40.6	48.7	76.1	59.9	45.5	73.7	35.2
17	-	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-
20	46.6	43.7	48.3	40.3	60.5	75.9	77.8	30.7	34.8	78.0	80.2
21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-
24	29.2	47.7	57.8	46.3	43.3	59.4	62.4	36.4	34.1	61.5	77.9
25	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-
28	42.8	47.9	61.0	46.7	67.5	44.0	66.6	26.5	39.2	58.6	74.3

Table 25. 9-Meter Integrated Values for Chlorophyll *a* (µg/L), Between February and December, 2017

Station	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	34.3	42.6	35.0	33.0	26.8	25.5	6.2	1.3	2.8	19.9	29.8
2	45.0	40.9	37.3	29.1	27.7	21.6	6.6	5.7	3.7	21.2	27.3
5	42.7	NA	37.6	38.1	17.0	4.5	9.7	4.8	2.6	19.5	23.5
6	45.8	47.1	58.7	29.7	23.0	17.8	16.0	5.4	2.6	22.2	25.6
7	42.3	51.1	54.9	31.0	14.8	14.4	14.3	4.4	3.9	17.2	23.0
8	51.7	31.6	39.5	25.3	21.1	23.4	13.0	1.4	4.6	17.5	22.2
11	49.6	49.7	58.1	32.1	22.7	20.5	8.2	7.5	5.9	17.1	21.9
Mean	44.5	43.9	45.9	31.2	21.9	18.3	10.6	4.4	3.7	19.2	24.8
SE	2.1	2.9	4.1	1.5	1.8	2.7	1.5	0.9	0.5	0.8	1.1

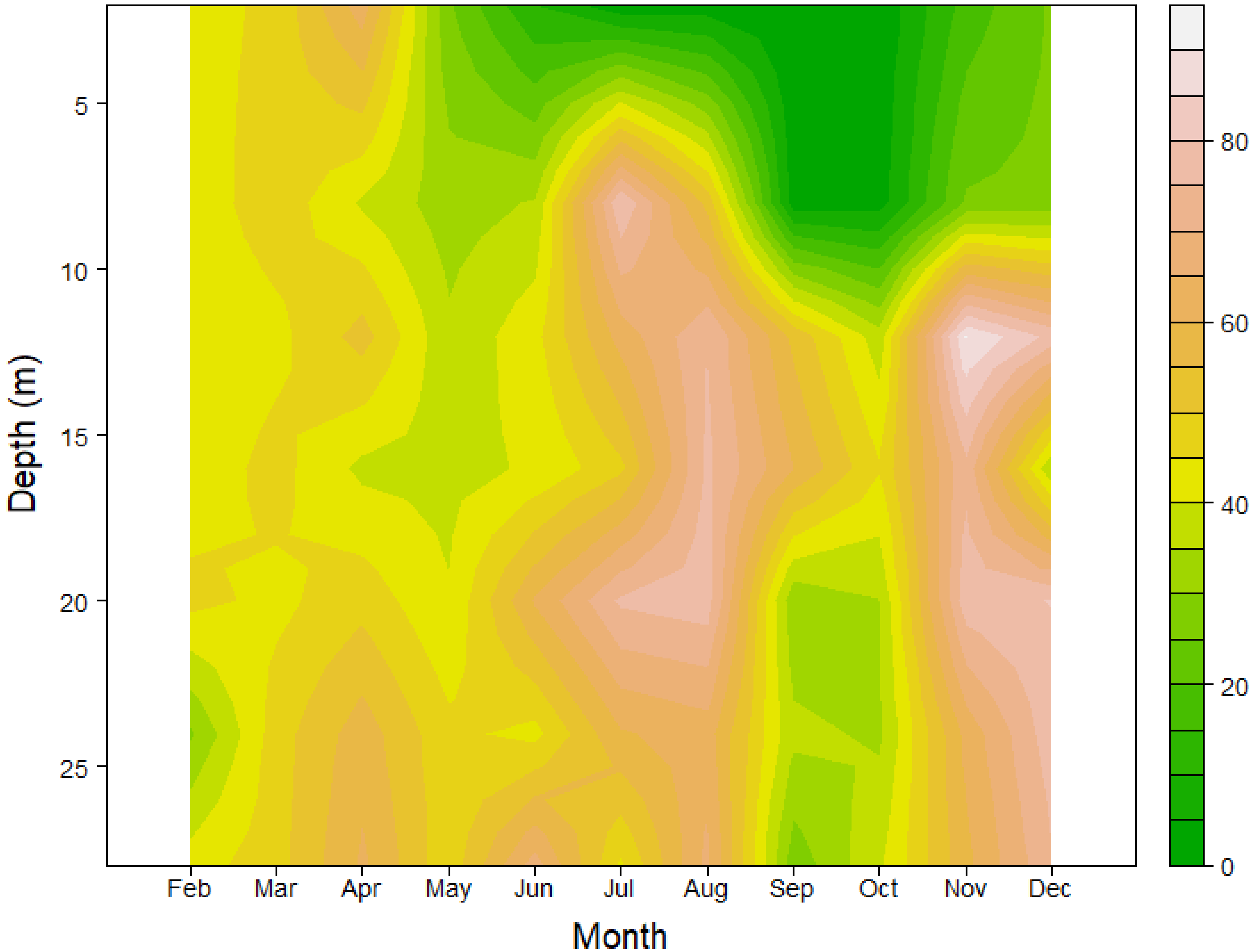


Figure 24. Station 6 Chlorophyll *a* (µg/L) Profiles, Between February and December, 2017

Table 26. Station 6 Average Chlorophyll *a* (µg/L), Between 1 m and 10 m, Since 1994

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994					0.5	2.6	2.2	1.7	***49.0***		30.0
1995		***55.7***			1.5	0.9	1.2	1.0	7.6		6.1
1996	15.6	12.1	23.0	0.7	0.9	1.0	2.1	1.7		11.2	7.7
1997	24.1	7.8	2.7	0.7	1.6	0.7	0.5	1.4	26.7		8.1
1998	16.9	10.0	5.8	2.4	0.6	1.0	1.0	1.8	1.6		7.8
1999	12.2	16.7	13.4	4.6	1.1	1.5	2.1	1.4	3.5		25.8
2000	17.6	12.3	22.8	6.2	2.1	1.8	2.9	4.2	6.9	46.5	***53.7***
2001	36.1	34.2	14.7	4.4	3.1	0.7	1.5	2.2	4.8	28.4	***50.5***
2002	***67.8***	***59.8***	36.9	18.4	0.8	1.7	2.4	7.4	***33.5***	***80.2***	
2003	***70.3***	***48.6***	***69.3***	***79.7***	***9.3***	***7.4***	3.5	***17.8***	***47.5***	***55.9***	***57.2***
2004	***98.1***	***92.1***	***57.3***	7.3	0.6	2.1	3.2	2.8	***50.3***	***61.1***	***70.3***
2005		***59.4***	***74.5***	17.2	5.3	1.1	2.0	2.3	17.8	40.4	***63.4***
2006	***67.7***	***60.8***	***52.1***	***25.9***	2.4	2.1	1.7	3.3	8.5	11.4	29.3
2007	23.6	21.1	20.3	2.7	1.1	1.5	3.0	***12.0***	***45.4***	***73.0***	***57.3***
2008		***56.8***	37.1	9.0	4.0	3.2	4.2	***16.9***	***49.1***	***92.0***	
2009	***88.4***	***85.2***	***76.0***	***43.3***	3.1	2.1	4.9	11.1	***51.6***	***79.1***	***88.5***
2010		***67.3***	***65.1***	***65.9***	***9.2***	2.9	2.3	***15.0***	31.5	***65.8***	***78.1***
2011		***77.8***	***72.0***	***64.0***	***25.4***	1.8	2.3	3.9	5.0	15.2	41.0
2012	***56.2***	***66.5***	***67.5***	***53.8***	***8.2***	3.3	3.5	4.8	***45.4***	48.8	41.7
2013	46.4	40.7	38.0	22.8	3.2	1.8	3.9	***18.1***	***39.9***	50.5	***52.3***
2014	***53.8***	***55.3***	***57.2***	***30.9***	***13.1***	***9.3***	***28.1***	***52.1***	***72.9***	***92.2***	***93.5***
2015	***80.7***	***63.7***	***56.7***	***34.8***	***34.0***	***32.8***	***34.8***	***61.1***	***73.8***	***85.0***	***97.7***
2016	***59.5***	***49.7***	40.9	***36.8***	***28.1***	***18.1***	***16.8***	***32.7***	***53.9***	***69.5***	***77.8***
2017	42.2	47.3	***51.2***	***29.2***	***22.7***	***40.5***	***27.6***	1.8	1.9	21.3	26.0
Average	48.7	47.9	43.4	25.5	7.6	5.9	6.6	11.6	31.6	54.1	48.3

Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Table 27. Lakewide Average 9 m Integrated Chlorophyll *a* (µg/L)

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987				0.7	1.1	0.8	0.8	2.3	3.9	19.2	29.7
1988	24.7	***55.3***	31.1	10.9	0.6	***3.4***	***9.8***	***24.0***	***40.7***	***51.7***	40.8
1989	35.9	36.7	***63.3***	***47.2***	***29.0***	0.6	0.4	0.5	1.2	13.4	***46.2***
1990	***51.3***	***78.7***	***44.9***	15.0	2.2	1.1	1.5	1.6	***41.2***	21.7	32.5
1991	***65.5***	***52.3***	***51.9***	***32.5***	1.4	1.6	3.6	2.0	7.2	***55.7***	***72.4***
1992	***93.8***	***57.4***	23.1	0.4	1.5	1.4	1.3	2.9	16.5	38.1	***49.0***
1993		***109.3***	***87.9***	***24.8***	0.5	2.8	2.3	3.3	6.4	14.1	18.0
1994	***65.4***	***79.0***	39.0	3.9	0.4	1.3	1.9	6.3	***48.9***		28.5
1995		***65.5***			0.5	0.5	1.3	1.2	14.9		6.4
1996	16.2	11.7	7.3	0.6	0.9	1.2	1.4	2.4		12.3	7.8
1997	20.6	7.1	3.2	0.7	1.1	0.5	0.6	1.7	***48.3***		42.1
1998	15.8	11.8	0.9	1.9	0.7	0.9	1.0	2.3	2.2		7.4
1999	11.5	18.0	13.2	4.9	1.2	1.1	1.6	1.8	3.7		25.5
2000	16.5	12.2	20.4	4.0	1.6	1.3	1.5	3.1	7.2	43.7	***50.2***
2001		23.9	13.5	2.3	1.3	1.2	1.3	3.5	6.6	31.5	***53.0***
2002	***72.5***	***57.2***	22.3	10.3	0.7	1.1	4.2	***11.3***	***36.8***	***76.3***	
2003	***69.4***	48.4	***67.6***	***77.7***	6.2	***5.1***	3.3	***22.6***	***52.8***	***56.5***	***53.5***
2004	***101.4***	***97.5***	***60.8***	14.7	0.4	1.4	2.1	4.3	***48.9***	***63.3***	***69.9***
2005		***60.4***	***73.5***	18.8	4.1	1.0	2.2	3.5	18.1	40.7	
2006	***61.1***	***63.6***	***53.6***	***26.8***	1.9	2.0	2.1	3.2	8.3	11.3	25.8
2007	21.8	18.7	18.1	1.8	0.9	1.1	2.4	***10.8***	***45.3***	***71.1***	
2008		49.1	40.5	20.1	***6.8***	***3.6***	3.2	***17.7***	***48.5***	***91.5***	
2009	***86.3***	***84.1***	***69.8***	***35.2***	2.9	1.9	4.7	9.7	***54.0***	***78.7***	
2010		***66.4***	***66.8***	***64.2***	***13.0***	2.5	3.6	***13.8***	28.3	***67.1***	***79.1***
2011		***77.2***	***71.3***	***58.5***	***29.1***	1.6	1.9	3.2	4.8	14.6	40.1
2012	***58.2***	***63.5***	***69.7***	***40.6***	***8.8***	2.3	3.2	6.6	***39.6***	48.0	***47.1***
2013	47.4	34.8	39.2	18.1	3.3	1.6	3.1	***14.4***	***42.6***	***51.1***	***55.5***
2014	***57.7***	***52.8***	***54.4***	***31.3***	***13.7***	***8.5***	***24.2***	***50.9***	***64.7***	***86.6***	***97.7***
2015	***72.4***	***71.4***	***56.6***	***28.7***	***18.4***	***15.4***	***30.5***	***65.1***	***71.1***	***98.2***	***97.1***
2016	***55.4***	***55.1***	***45.0***	***36.5***	***29.1***	***15.4***	***17.0***	***33.2***	***68.5***	***79.5***	***68.2***
2017	44.0	43.7	***46.5***	***30.6***	***20.0***	***15.9***	***8.6***	3.7	3.5	18.5	24.8
Average	50.6	52.1	43.3	22.1	6.6	3.2	4.7	10.7	29.5	48.3	44.9

Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Table 28. Station 6 Average Chlorophyll *a* (µg/L), Between 11 m and 28 m, Since 1994

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1994					35.2	22.5	25.0	17.8	41.2		31.3
1995		49.1			24.6	14.1	16.0	24.1	33.7		29.7
1996	30.2	36.1	24.6	25.9	25.5	22.3	23.4	24.7		33.2	26.2
1997	48.2	43.0	30.0	26.9	33.8	28.6	27.4	17.5	22.5		23.8
1998	30.1	33.2	35.8	45.5	20.5	21.8	24.9	27.9	29.3		28.4
1999	23.0	23.8	25.8	21.8	36.0	25.6	18.8	23.5	20.8		29.9
2000	23.8	26.5	33.8	33.8	19.8	32.9	31.7	36.6	23.1	37.7	49.3
2001	40.3	35.8	34.6	37.1	33.6	13.7	10.4	14.6	17.7	25.2	46.3
2002	***67.4***	***53.0***	***54.9***	35.6	18.9	29.9	21.8	27.7	25.2	***62.9***	
2003	48.6	41.6	40.7	***63.1***	***68.9***		***46.1***	34.4	36.1	***60.6***	48.8
2004	***64.7***	***59.8***	***62.1***	***59.2***	42.3	27.8	28.6	33.8	40.6	54.8	***58.5***
2005		***55.1***	***62.1***	***54.5***	***48.2***	33.4	33.3	***42.6***	37.6	41.2	51.5
2006	***51.8***	***59.6***	***59.3***	***55.1***	39.7	34.7	33.3	***45.7***	***42.7***	41.3	38.3
2007	37.3	34.1	38.3	38.8	24.6	21.8	25.2	24.1	40.7	58.2	***64.2***
2008		***86.5***	***50.8***	44.1	42.0	38.1	***45.0***	35.2	***45.5***	***83.0***	
2009	***85.1***	***91.5***	***83.1***	***77.9***	***75.4***	***70.6***	***62.1***	***56.6***	***57.9***	***78.4***	***82.7***
2010		***69.6***	***68.6***	***73.2***	***67.0***	***65.5***	***57.4***	***58.4***	***53.8***	***66.5***	***77.1***
2011		***81.3***	***75.1***	***74.3***	***68.7***	***57.2***	***60.3***	***61.5***	***58.2***	***67.0***	50.3
2012	***50.7***	***60.4***	***69.8***	***52.4***	***49.6***	***45.7***	20.6	20.3	35.5	48.8	47.0
2013	47.9	39.7	37.7	37.9	37.0	36.7	***43.0***	***39.5***	***43.1***	50.9	***57.5***
2014	***63.5***	***55.8***	***60.5***	43.7	***55.8***	***69.3***	***78.8***	***70.1***	***69.3***	***87.9***	***96.7***
2015	***72.2***	***79.1***	***60.2***	***60.4***	***66.9***	***91.8***	***88.6***	***90.3***	***98.3***	***90.4***	***99.7***
2016	***60.9***	47.9	45.5	44.8	***61.6***	***51.8***	***56.6***	***55.5***	***56.1***	***81.9***	***63.6***
2017	40.2	45.9	***51.6***	41.6	***51.1***	***58.0***	***71.5***	***41.5***	38.2	***72.4***	***69.1***
Average	49.2	52.5	50.2	47.6	43.6	39.7	39.6	38.5	42.0	60.1	53.2

Bold italic numbers indicate values above the long term average listed toward the bottom of the table.

Artemia Population Analysis and Biomass

Artemia population data is presented in Table 29 through Table 31 with lakewide means, sector means, associated standard errors, and percentage of population by age class. As discussed in previous reports (Jellison and Rose 2011), zooplankton populations can exhibit a high degree of spatial and temporal variability. In addition, when sampling, local convergences of water masses may concentrate shrimp above overall means. For these reasons, Jellison and Rose (2011) have cautioned that the use of a single level of significant figures in presenting data is inappropriate, and that the reader should always consider the standard error associated with *Artemia* counts when making inferences from the data.

Artemia Population

Hatching of overwintering cysts had already initiated by February as the mid-February sampling detected an instar lakewide mean abundance of 9,916 +/- 3,148 m^{-2}. Almost all the instars in mid-February were instar age classes 1 and 2. Instar abundance increased through spring to a peak of 66,481 +/- 16,402 m^{-2} in April. Between February and April, adults continued to be essentially absent. A peak monthly abundance of total *Artemia* for the entire lake occurred in April (66,507 +/-16,399 m^{-2}) instead of May as was the case in 2016. Adults started to mature in June as a proportion of adult increased from 3% in May to 92% in August. The instar analysis indicated a diverse age structure of instars 1-7 and juveniles (instars 8-11) starting in April and lasting to July when abundance of each age class started to decline even though all age classes existed. In June, females with cysts were first recorded. Females with cyst abundance peaked at 9,661 +/- 1,834 m^{-2} in July and high abundance was maintained through October. By July reproduction decreased significantly, with instars and juveniles comprising only 26% of the population compared to 97% in May. The highest adult *Artemia* abundance occurred in July (26,064 +/- 4,879 m^{-2}) and remained above 10,000 m^{-2} through October. In November and December, adult *Artemia* abundance was found to still be above 1,000 m^{-2}.

Table 29. Lakewide and Sector *Artemia* Population Means (per m ^{2} or m^{-2}), 2017

	Instars		Adult	Adult	Adult Female	Ad Female Ovigery Classification				Total
	1-7	8-11	Total	Males	Total	empty	undif	cysts	naup	*Artemia*
Lakewide										
Feb	9,916	0	11	0	11	11	0	0	0	9,927
Mar	41,568	0	0	0	0	0	0	0	0	41,568
Apr	66,481	27	0	0	0	0	0	0	0	66,507
May	27,096	7,968	986	496	490	463	27	0	0	36,050
Jun	7,632	11,147	23,541	13,481	10,060	5,848	1,556	1,771	885	42,321
Jul	5,785	3,554	26,064	13,316	12,749	1,323	763	9,661	1,002	35,403
Aug	1,052	920	24,224	13,751	10,474	2,168	1,008	6,629	668	26,197
Sep	712	224	16,794	9,166	7,628	668	457	6,245	258	17,730
Oct	1,112	268	11,621	5,914	5,706	492	208	4,868	139	13,001
Nov	2,256	429	3,948	1,843	2,105	38	88	1,941	38	6,633
Dec	2,250	432	1,645	866	778	25	52	690	11	4,326
Western Sector										
Feb	3,077	0	3	0	3	3	0	0	0	3,080
Mar	5,316	0	0	0	0	0	0	0	0	5,316
Apr	16,100	54	0	0	0	0	0	0	0	16,154
May	22,803	5,714	309	241	67	67	0	0	0	28,826
Jun	2,897	5,419	13,307	7,726	5,580	3,273	1,180	778	349	21,623
Jul	7,008	5,394	37,584	19,460	18,124	2,269	1,109	13,335	1,412	49,986
Aug	1,134	1,361	29,392	16,914	12,478	3,100	1,563	6,856	958	31,887
Sep	819	290	21,035	11,356	9,680	731	529	8,092	328	22,145
Oct	1,223	366	13,461	6,982	6,478	819	202	5,256	202	15,049
Nov	1,916	391	4,134	1,972	2,162	57	95	1,972	38	6,440
Dec	1,610	510	2,098	1,137	961	16	44	889	13	4,219
Eastern Sector										
Feb	16,755	0	19	0	19	19	0	0	0	16,773
Mar	71,777	0	0	0	0	0	0	0	0	71,777
Apr	116,861	0	0	0	0	0	0	0	0	116,861
May	31,388	10,221	1,663	751	912	858	54	0	0	43,273
Jun	12,368	16,875	33,776	19,235	14,541	8,424	1,932	2,763	1,422	63,018
Jul	4,562	1,714	14,545	7,171	7,373	378	416	5,987	592	20,821
Aug	970	479	19,057	10,587	8,470	1,235	454	6,403	378	20,506
Sep	605	158	12,553	6,976	5,577	605	384	4,399	189	13,316
Oct	1,002	170	9,780	4,846	4,934	164	214	4,481	76	10,953
Nov	2,596	466	3,762	1,714	2,048	19	82	1,909	38	6,825
Dec	2,889	353	1,191	596	596	35	60	492	9	4,433

Table 30. Standard Errors (SE) of Sector *Artemia* Population Means (per m ^{2} or m^{-2})

From Table 29, Lakewide and Sector *Artemia* Population Means (per m ^{2} or m^{-2}), 2017.

	Instars		Adult	Adult	Adult Female	Ad Female Ovigery Classification				Total
	1-7	8-11	Total	Males	Total	empty	undif	cysts	naup	*Artemia*
Lakewide										
Feb	3,148	0	7	0	7	7	0	0	0	3,154
Mar	21,624	0	0	0	0	0	0	0	0	21,624
Apr	16,402	27	0	0	0	0	0	0	0	16,399
May	4,221	1,830	359	177	232	232	27	0	0	6,042
Jun	3,390	2,829	5,577	3,128	2,507	1,429	286	574	294	11,297
Jul	845	960	4,879	2,428	2,620	541	156	1,834	205	6,321
Aug	150	210	2,151	1,317	906	369	214	502	142	2,284
Sep	91	58	1,969	1,003	1,052	106	93	913	41	2,081
Oct	92	53	1,041	563	521	322	29	384	34	1,121
Nov	314	75	327	167	188	12	15	170	9	546
Dec	385	58	297	170	130	10	8	131	4	532
Western Sector										
Feb	518	0	3	0	3	3	0	0	0	518
Mar	1,490	0	0	0	0	0	0	0	0	1,490
Apr	6,553	54	0	0	0	0	0	0	0	6,604
May	5,007	1,539	122	106	53	53	0	0	0	6,375
Jun	396	645	825	669	202	310	142	233	113	1,444
Jul	1,409	1,632	7,036	3,219	4,210	962	230	2,965	299	9,386
Aug	270	320	2,306	1,511	843	427	159	243	182	2,288
Sep	154	108	2,734	1,200	1,641	132	160	1,427	61	2,941
Oct	148	79	1,247	734	615	642	50	357	54	1,289
Nov	252	90	527	248	288	19	21	246	14	730
Dec	227	79	519	289	232	8	14	233	6	785
Eastern Sector										
Feb	4,964	0	13	0	13	13	0	0	0	4,976
Mar	36,214	0	0	0	0	0	0	0	0	36,214
Apr	11,200	0	0	0	0	0	0	0	0	11,200
May	6,779	3,214	608	318	402	413	54	0	0	9,955
Jun	6,438	4,656	9,709	5,417	4,426	2,497	532	1,001	503	19,700
Jul	749	205	1,466	685	958	65	77	780	166	1,623
Aug	154	120	2,087	1,160	1,137	263	231	1,014	150	2,182
Sep	89	40	1,545	1,034	705	175	103	515	43	1,614
Oct	103	46	1,363	631	760	41	35	680	26	1,479
Nov	570	125	424	232	267	13	23	258	14	874
Dec	661	78	194	117	85	18	6	70	6	791

Table 31. Percentage in Different Classes for *Artemia* Population Means, 2017
From Table 29, Lakewide and Sector *Artemia* Population Means (per m ^{2} or m^{-2}), 2017.

	Instars		Instar	Adult	Adult	Adult Female	Ad Female Ovigery Classification				Ovigerous
	1-7	8-11	%	Total	Males	Total	empty	undif	cysts	naup	Female%
Lakewide											
Feb	100	0	100	0.1	0	0.1	100	0	0	0	0
Mar	100	0	100	0	0	0	0	0	0	0	0
Apr	100	0.04	100	0	0	0	0	0	0	0	0
May	75	22	97	3	1	1	95	100	0	0	5
Jun	18	26	44	56	32	24	58	37	42	21	42
Jul	16	10	26	74	38	36	10	7	85	9	90
Aug	4	4	8	92	52	40	21	12	80	8	79
Sep	4	1	5	95	52	43	9	7	90	4	91
Oct	9	2	11	89	45	44	9	4	93	3	91
Nov	34	6	40	60	28	32	2	4	94	2	98
Dec	52	10	62	38	20	18	3	7	92	1	97
Western Sector											
Feb	100	0	100	0.1	0	0.1	100	0	0	0	0
Mar	100	0	100	0	0	0	0	0	0	0	0
Apr	100	0.3	100	0	0	0	0	0	0	0	0
May	79	20	99	1	1	0.2	100	0	0	0	0
Jun	13	25	38	62	36	26	59	51	34	15	41
Jul	14	11	25	75	39	36	13	7	84	9	87
Aug	4	4	8	92	53	39	25	17	73	10	75
Sep	4	1	5	95	51	44	8	6	90	4	92
Oct	8	2	11	89	46	43	13	4	93	4	87
Nov	30	6	36	64	31	34	3	4	94	2	97
Dec	38	12	50	50	27	23	2	5	94	1	98
Eastern Sector											
Feb	100	0	100	0.1	0	0.1	100	0	0	0	0
Mar	100	0	100	0	0	0	0	0	0	0	0
Apr	100	0	100	0	0	0	0	0	0	0	0
May	73	24	96	4	2	2	94	100	0	0	6
Jun	20	27	46	54	31	23	58	32	45	23	42
Jul	22	8	30	70	34	35	5	6	86	8	95
Aug	5	2	7	93	52	41	15	6	89	5	85
Sep	5	1	6	94	52	42	11	8	88	4	89
Oct	9	2	11	89	44	45	3	4	94	2	97
Nov	38	7	45	55	25	30	1	4	94	2	99
Dec	65	8	73	27	13	13	6	11	88	2	94

Instar Analysis

The instar analysis, conducted at seven stations, shows patterns similar to those shown by the lakewide and sector analysis, but provides more insight into *Artemia* reproductive cycles occurring at the lake (Table 32). Instars 1 were most abundant in March while instars 2 peaked more broadly over March and April as overwintering cysts were hatching. By May all age classes of instars 1-7 and juveniles were present and comprised approximately 97% of the *Artemia* population while adults comprised the remainder (3%). A proportion of instars and juvenile combined fell to 44% in June and down to 5% by September. The presence of late stage instars and juveniles throughout the monitoring year indicate survival and recruitment into the population. Adult abundance decreased from 95% in September to 38% in December while instar and juvenile age classes increased from 5% to near 62% over the same period. Instar abundance peaked in April and immediately started to decline recording the lowest abundance in September. Since September, instar abundance of both age classes rebounded indicating late hatching of the second generation even though there was no distinct peak found indicating higher generations.

Biomass

Mean lakewide *Artemia* biomass remained above 10 g/m^{-2} between June and September peaking at 19.8 g/m^{-2} in July (Table 33). Mean biomass was only slightly below 10 g/m^{-2} in October (9.6 g/m^{-2}) and sharply declined in November reaching 1.6 g/m^{-2} in December. Unlike the 2016 peak, the 2017 mean biomass was higher in the western sector than in the eastern sector, similar to the pattern observed in 2015. Higher biomass in the western sector was observed between July and October and again in December.

Table 32. Lakewide *Artemia* Instar Abundance (m^{-2}), 2017

	Instars									
	1	2	3	4	5	6	7	8-11	Adults	Total
Mean										
Feb	6,231	124	0	0	0	0	0	0	0	6,355
Mar	26,449	23,865	2,017	0	0	0	0	0	0	52,330
Apr	13,613	21,937	18,158	11,296	1,472	92	0	46	0	66,614
May	333	11,164	7,140	2,403	1,575	759	1,173	7,795	805	33,147
Jun	2,001	1,173	322	1,127	1,771	1,472	1,886	11,061	21,799	42,610
Jul	411	1,383	1,015	1,469	389	302	605	3,781	27,418	36,774
Aug	43	378	248	130	119	22	130	1,080	24,955	27,105
Sep	43	178	184	97	5	38	178	275	17,728	18,727
Oct	119	411	324	151	65	43	108	324	12,758	14,303
Nov	470	832	664	286	167	70	124	459	3,922	6,995
Dec	300	489	443	246	176	103	119	381	1,410	3,665
Standard Error										
Feb	1,503	25	0	0	0	0	0	0	0	1,524
Mar	18,785	18,198	1,775	0	0	0	0	0	0	38,721
Apr	5,064	7,287	7,279	4,959	1,001	92	0	46	0	24,058
May	100	2,807	1,877	851	676	338	582	3,019	529	9,482
Jun	1,398	240	116	718	1,217	1,046	1,411	4,028	8,034	17,838
Jul	200	194	135	226	147	87	262	1,525	7,248	9,066
Aug	28	86	63	107	52	22	51	340	2,896	3,127
Sep	22	59	74	27	5	22	59	91	3,187	3,401
Oct	61	51	43	33	24	21	22	61	1,085	1,144
Nov	138	186	197	22	16	28	69	95	525	801
Dec	158	295	74	29	58	28	26	58	375	584
Percentage in different age classes										
Feb	51	46	4	0	0	0	0	0	0	
Mar	98	2	0	0	0	0	0	0	0	
Apr	20	33	27	17	2	0.1	0	0.1	0	
May	1	34	22	7	5	2	4	24	2	
Jun	5	3	1	3	4	3	4	26	51	
Jul	1	4	3	4	1	1	2	10	75	
Aug	0.2	1	1	0.5	0.4	0.1	0.5	4	92	
Sep	0.2	1	1	1	0.03	0.2	1	1	95	
Oct	1	3	2	1	0.5	0.3	1	2	89	
Nov	7	12	9	4	2	1	2	7	56	
Dec	8	13	12	7	5	3	3	10	38	

Table 33. 2017 Mean *Artemia* Biomass (g/m^2)

Month	Lakewide	Western Sector	Eastern Sector
Feb	0.12	0.08	0.17
Mar	2.12	0.16	3.76
Apr	2.19	0.49	3.88
May	2.49	1.64	3.34
Jun	10.4	5.26	15.6
Jul	19.8	28.7	11.0
Aug	14.4	16.6	12.1
Sep	10.8	12.5	9.01
Oct	9.56	11.1	7.99
Nov	3.32	3.23	3.41
Dec	1.59	2.00	1.19

Reproductive Parameters and Fecundity Analysis

By June, fecund females were plentiful enough to conduct the fecundity analysis (Table 29, Table 34, and Figure 25). In mid-June approximately 42% of females were ovigerous, with 42% oviparous (cyst-bearing), 9% ovoviviparous (naupliar eggs) and 15% undifferentiated eggs. From July through December, over close to 90% of females were ovigerous with the majority (80-94%) oviparous.

The lakewide mean fecundity showed a declining pattern from June to September and then sharply increased in October. The lakewide mean fecundity was initially 36.4 +/- 1.2 egg per brood in June, decreased to 20.7 +/- 0.7 eggs per brood in August, and rebounded to 34.2 +/- 1.7 in September. Although fecund females were documented during the population analysis in October, the densities were too low to conduct the analysis. The majority of fecund females (>63%) were oviparous between July and September. Little difference was observed in fecundity between the western and eastern sectors. Typically, mean female lengths are positively correlated with mean eggs per brood, and 2017 followed this pattern. The largest mean females were found in June (10.0 mm) when the mean brood size was largest (36.4 +/- 1.2 eggs per brood).

Table 34. *Artemia* Fecundity Summary, Recorded in 2017

	# of Eggs/Brood				Female Length (mm)		
Month	Mean	SE	% Cyst	% Indented	Mean	SE	n
Lakewide							
Jun	36.4	1.2	92.8	27.5	10.0	0.1	7
Jul	26.8	1.1	97.2	61.1	9.2	0.1	7
Aug	22.5	0.9	98.6	64.8	9.2	0.1	7
Sep	20.7	0.7	98.6	63.4	9.1	0.1	7
Oct	34.2	1.7	95.2	59.7	9.5	0.2	6
Western Sector							
Jun	37.6	1.3	97.5	27.5	10.1	0.1	4
Jul	27.9	1.5	100	58.5	9.3	0.1	4
Aug	20.1	1.1	100	65.0	9.1	0.1	4
Sep	20.0	1.0	97.6	61.0	9.1	0.1	4
Oct	33.4	2.3	100	57.5	9.5	0.3	4
Eastern Sector							
Jun	34.8	2.2	86.2	27.6	9.9	0.1	3
Jul	25.3	1.7	93.5	64.5	9.1	0.1	3
Aug	25.6	1.4	96.8	64.5	9.4	0.2	3
Sep	21.7	1.0	100	66.7	9.2	0.2	3
Oct	35.7	2.4	86.4	63.6	9.6	0.2	2

"n" represents number of stations sampled. 10 individuals were sampled at each station with the exception of 9 individuals on June 20th at Station 11 and Sept 19th at Station 7 due to undifferentiated egg types.

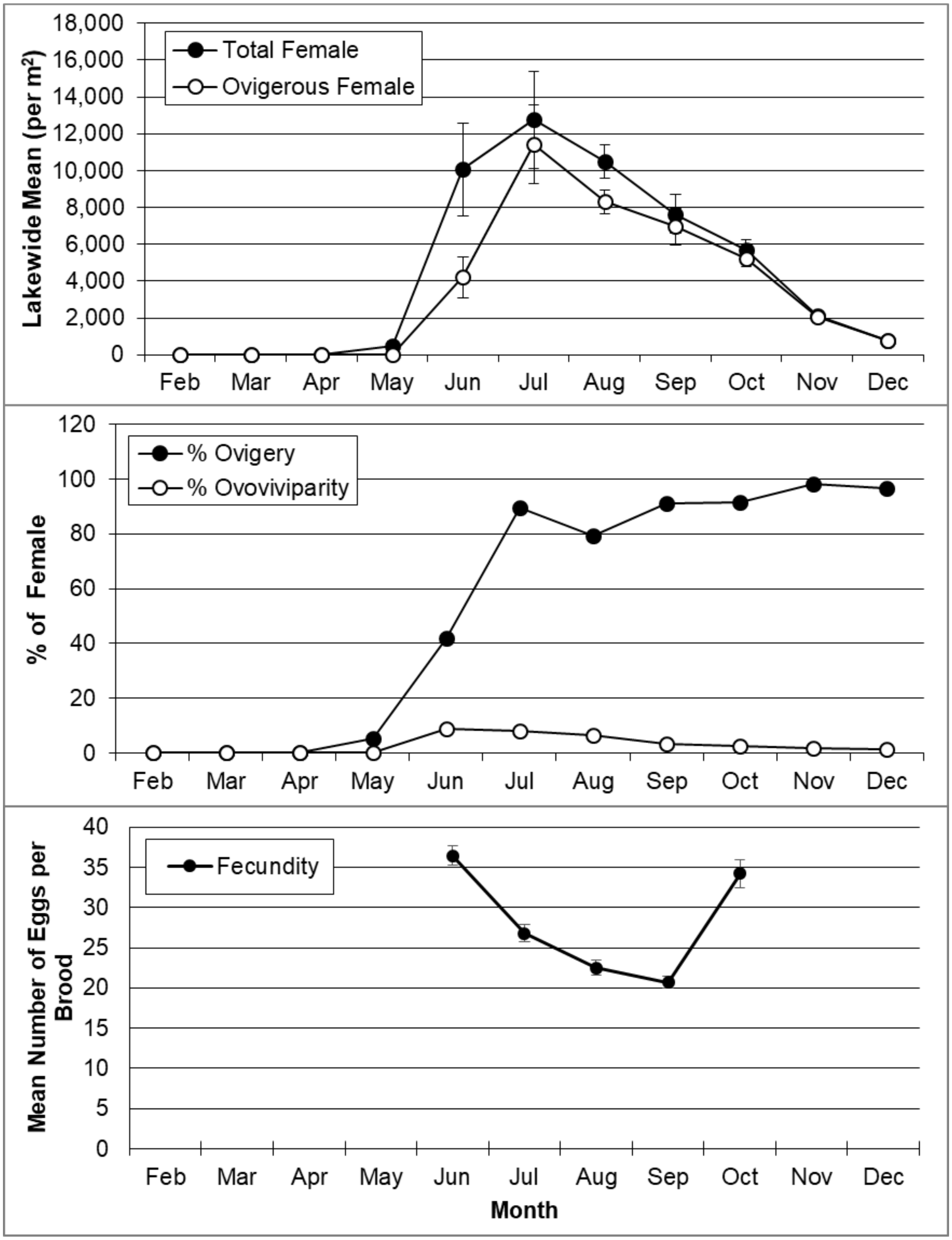


Figure 25. *Artemia* Reproductive Parameters and Fecundity Between June and October, 2017

Artemia Population Statistics

The year 2017 marked the second consecutive year with increasing mean adult *Artemia* after the lowest mean on record was observed in 2015 (Table 35). The mean and median adult abundance in 2017 was 15,158 m^{-2} and 15,536 m^{-2}, respectively, and remained below the long-term average in spite of the upward trend. Due to low abundance during the previous three years, the four-year running average between 2014 and 2017 was lowest on record for mean and median. The centroid is the calculated center of abundance of adults. The second year in row the centroid day, however, did not follow the declining trend; instead it remained above 220 days (221 days in 2017, and August 8), 36 days later than 185 days recorded in 2015 and 11 days later than the long-term average of 210 days which corresponds to July 28 or 29 depending on whether a year is a leap year or not (Figure 26). The mean, median, peak and centroid data for 2015 was misreported in the 2015 annual report and has been corrected and reported in this document. The corrected mean, median and peak are higher by 12%, 4% and 21% respectively.

Years following the onset of monomixis have coincided with high adult *Artemia* abundance at Mono Lake as nutrients which are previously contained in the hypolimnion become fully available for phytoplankton throughout the water column (Figure 27). The long-term data show 1989 and 2004 as the second and third highest adult densities recorded between 1979 and 2017. It appears the longer the period of meromixis, the higher the peak of *Artemia* population when meromixis breaks. The last two meromixis events, which only lasted 1 to 2 years, resulted in shorter peaks. Mono Lake became meromictic in 2017 for the fifth time on record, and eventually will lead to a peak. The magnitude of that peak will depend on the duration of the current meromixis.

Table 35. Summary Statistics of Adult *Artemia* Abundance Between May 1 and November 30; 1979-2017

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
2006	21,518	20,316	55,748	186
2007	18,826	17,652	41,751	186
2008	11,823	12,524	27,606	189
2009	25,970	17,919	72,086	181
2010	14,921	7,447	46,237	191
2011	21,343	16,893	48,918	194
2012	16,324	11,302	53,813	179
2013	26,033	31,275	54,347	196
2014	13,467	7,602	42,298	194
2015	7,676	5,786	18,699	185
2016	10,687	10,347	18,498	220
2017	15,158	15,536	26,064	221
Mean	18,951	17,676	43,714	210
Min	7,676	5,786	18,498	179
Max	36,643	36,909	105,245	252

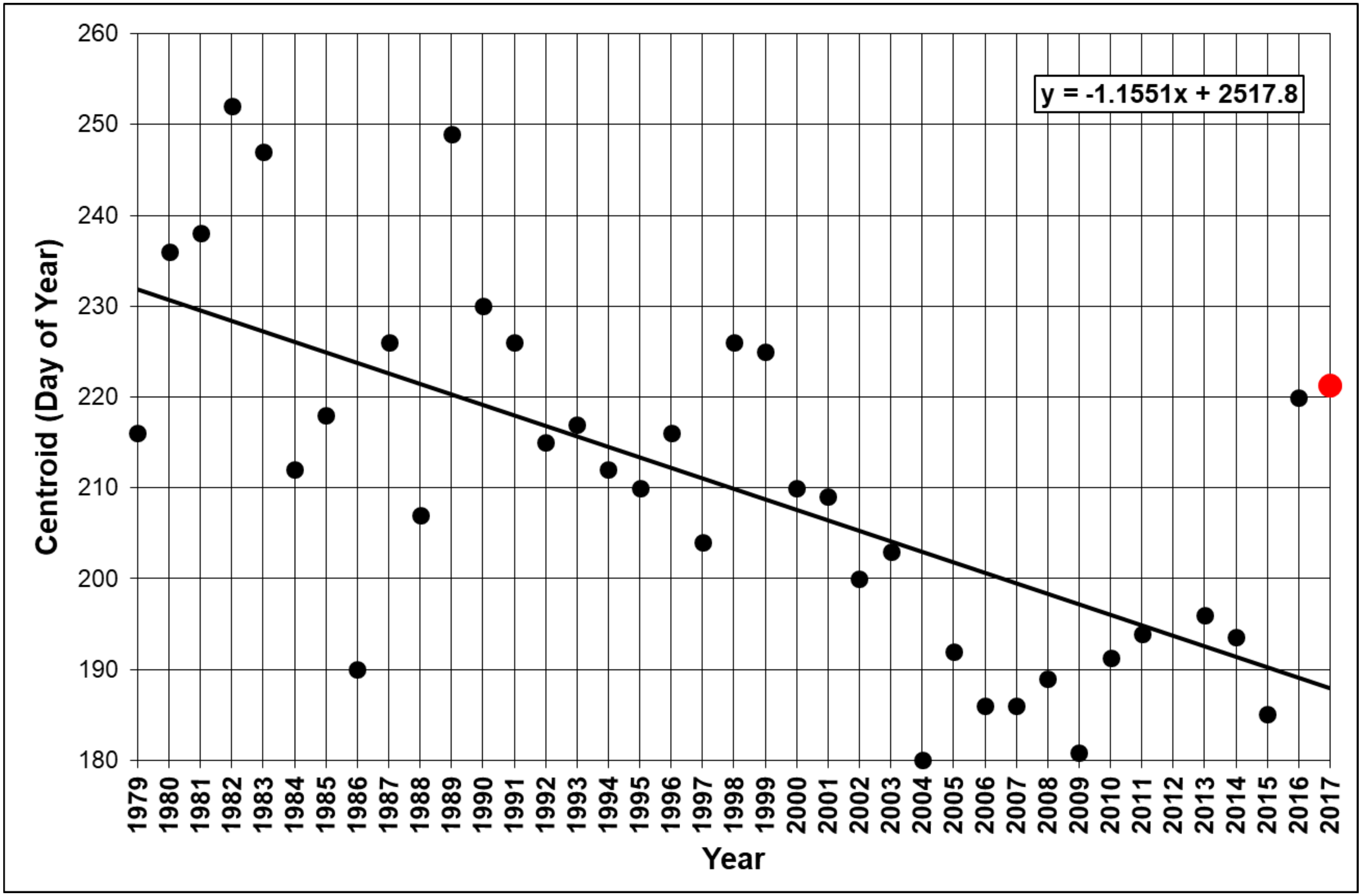


Figure 26. Population Centroid of Adult *Artemia* Since 1987

Red dot indicates value in 2017

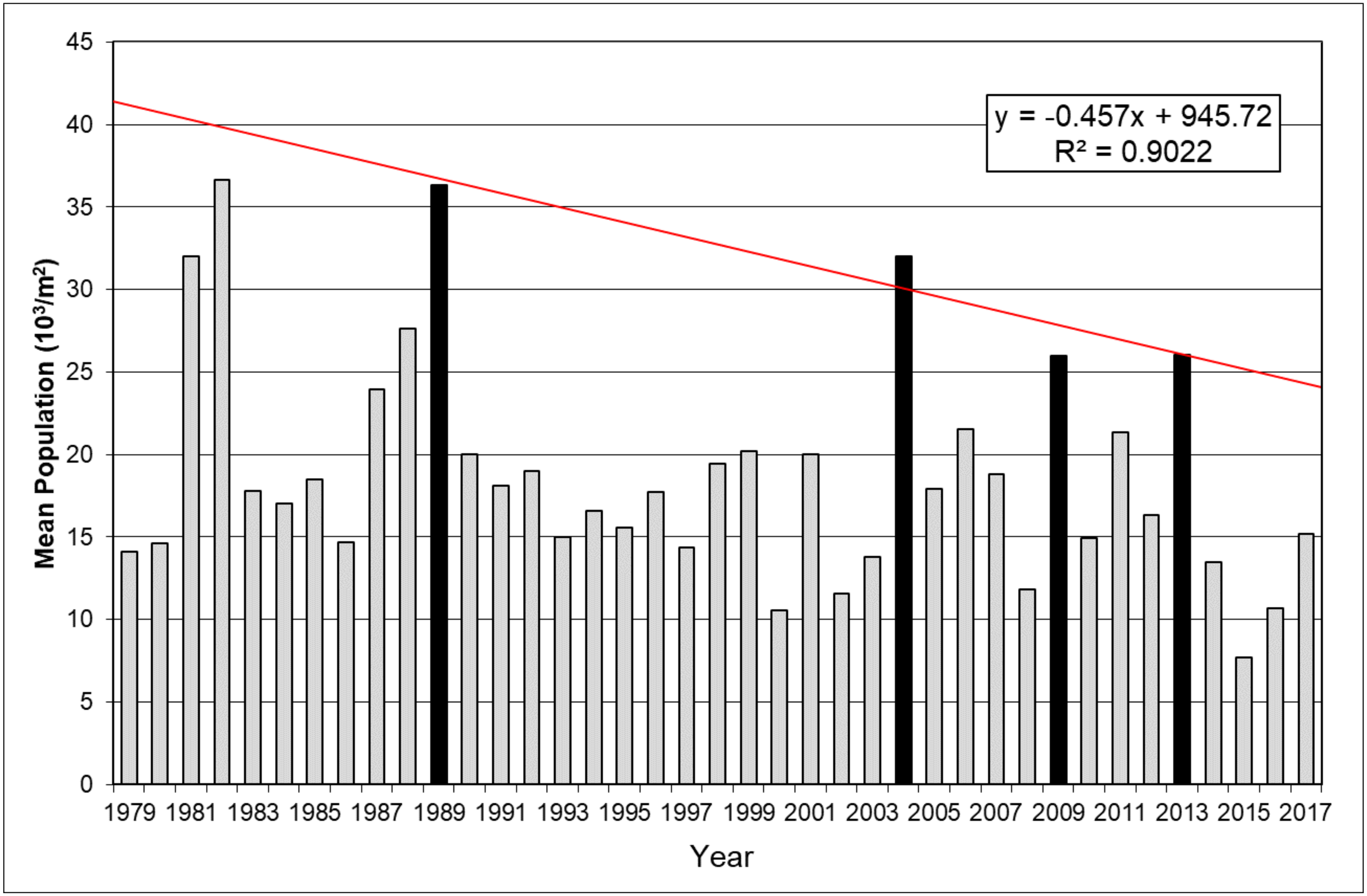


Figure 27. Lakewide Adult *Artemia* Population Mean (per m^{-2}); May through November; 1979-2017

Years with a darker color indicates years with peak *Artemia* abundance occurring subsequent to onset of monomixis. The red line indicates a temporal trend of peak *Artemia* abundance.

The examination of monthly average *Artemia* abundance reveals a temporal shift in peak monthly abundance to earlier months for both adult and instars (Table 36 and Table 37). In 2017 peak monthly average adult *Artemia* occurred in July while peak monthly average instar was observed in April. Table 36 can be broken down into three distinct periods:

1) between 1987 and 1994 (the period representing the end of the first recorded meromixis between 1983 and 1987, the breakdown of meromixis between 1988 and 1989, and after the breakdown),

2) between 1995 and 2003 (the period representing the second recorded meromixis between 1995 and 2002 and the first year of the breakdown in 2003), and

3) 2004 to present (mostly monomictic state with two short meromixis.

During the first period, the above average monthly abundance was mostly occurring between August and November. With onset of the meromixis in 1995, timing of the above average monthly abundance shifted slightly earlier to July. Starting in 2004, the above average monthly abundance started to mainly occur between May and July. A comparison of adult population abundance between May to July (summer) and August to November (fall) shows a similar pattern as the average abundances between these two periods were similar throughout the 1990s and started to diverge greatly after 2003, but started to converge again in 2016 (Figure 29). In 2017 monthly abundance was found above long term average for final three months of the year (October to December). The 2017 peak was broader similar to what was found in 2016 but higher, indicating longer survivorship of adult or/and continuous hatching of cysts or nauplii (Figure 29).

In 2017 monthly average instar peaked in April and both March and April's monthly averages were found above average (Table 37). The peak in April was comparable to the peaks from the last two years and the April abundance was ranked 6 out of 31 years. The average instar abundance between February and May was above the long term average but much lower than 2014 and 2016, but higher than 2015. As the case of adult monthly abundance November and December show above long term average monthly abundance. Due to meromixis creating anoxic conditions below 10 m in depth, those hatches were most likely nauplii.

Table 36. Monthly Adult *Artemia* Average Abundance; Stations 1-12; 1987-2017

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987				7934	24733	**41366**	**39313**	**27179**	**18366**	**11579**	
1988	3			11378	**71292**	**33277**	**33580**	**21108**	**14915**	3231	
1989				1312	11273	21097	**67268**	**92491**	**38991**	**26455**	**10673**
1990	**21**		77	14181	13841	27472	**30753**	**31783**	**16775**	**9985**	**7930**
1991				710	20920	28758	**32629**	**23061**	**13974**	**6492**	**1826**
1992			256	**19590**	22724	29513	**26789**	**20426**	**14467**	**7917**	**6064**
1993				11983	21896	18383	18106	16104	**11747**	**9945**	11
1994			22	14761	24986	24957	19952	17145	**10686**		31
1995					18716	26077	17106	17099	5555		34
1996	**15**			11531	25462	**34242**	**29098**	**17326**		**5496**	24
1997	4			14706	18321	24891	**31791**	13576	35		22
1998	2			88	22228	29603	**37556**	**29735**	**16119**		121
1999					17077	**37227**	22892	**29281**	**9991**	3055	25
2000				5022	15664	22384	18940	9131	4901	116	60
2001				11945	23971	**38035**	**37800**	**20299**	6444	23	30
2002	7			2614	24909	21853	25533	4961	79	10	
2003	2			9379	26065	21834	25136	10908	3042		
2004			**22052**	**63528**	**73883**	**47338**	**36412**	9215	2245	122	40
2005		3	3	**25902**	**41247**	**37840**	**26838**	13058	3073	189	40
2006	**35**	**22**	5	**35381**	**47480**	**41355**	25124	14148	2316	18	7
2007				**21180**	**40107**	**38353**	24165	3799	939	22	10
2008				**20418**	27606	20366	16777	4992	89	20	
2009	**35**	**17**		**43099**	**72086**	**45231**	18645	9058	2981	235	20
2010				1462	**39933**	**46237**	11714	4732	773	92	55
2011			3	**19524**	**48918**	**48491**	19296	14088	5540	414	27
2012	3		2	**53813**	**31375**	10288	13920	11224	5312	253	104
2013	**27**			**31415**	**39759**	**54347**	**45152**	12449	2349	35	44
2014	6			832	**33535**	**42298**	10776	4019	553	106	66
2015	**32**	3	396	14782	18699	17406	5839	2289	239	44	38
2016				3005	18498	17393	16643	10204	**7786**	1338	246
2017	11			986	23541	26064	24224	16794	**11621**	**3948**	**1645**
Average	14	11	2535	16292	30992	31419	26122	17151	7730	3505	1123
Correlation	0.31	-0.38	0.03	0.24	0.22	0.14	-0.51	-0.56	-0.64	-0.67	-0.50

Table 37. Monthly *Artemia* Instar Average Abundance; Stations 1-12; 1987-2017

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	3274	22280	18455	**33650**	13325	5925	1717	453	**1999**	**9234**	
1988	355	**50215**	**46799**	26918	24703	5709	**4834**	1339	**2624**	1157	
1989	32	17849	9274	2894	**250883**	7136	990	172	875	1477	**5099**
1990	2016	7520	12020	**89708**	**234839**	**12393**	**7100**	1137	**1875**	**3600**	**8755**
1991	5653	**33584**	26635	31953	39478	**18016**	3556	953	1411	**3831**	**3559**
1992	6601	14832	26507	28901	14298	5429	**6057**	**1956**	**3373**	**9640**	**15292**
1993		12093	20130	12534	**67073**	**22433**	**10842**	**4178**	**5111**	**9281**	**1864**
1994	6117	18246	29263	13192	**45758**	**13839**	**7540**	**3737**	**3684**		598
1995		14805			20867	**20106**	**8312**	**1767**	**1860**		465
1996	**12224**	24888	**73528**	26955	10009	3073	2349	768		1888	1002
1997	6846	11268	**34988**	33174	11868	5436	**3914**	1127	882		587
1998	**11195**	21950	**49570**	**53763**	18043	4236	2473	1456	659		1251
1999	**27123**	**32557**	**33291**	**54655**	11436	5619	1942	1482	1112	1637	501
2000	**12458**	14168	19382	24515	**93119**	**9512**	2916	**2559**	**2056**	340	513
2001	3400	3245	30129	**36009**	23085	7760	3293	**2458**	**2795**	288	404
2002	909	20696	**36881**	18312	**66237**	**9968**	2425	1559	218	96	
2003	3167	4398	15307	6619	**90316**	**42364**	**8756**	**2255**	1198		13
2004	**47324**	**68746**	**49108**	20711	15225	5674	3427	**2410**	857	233	256
2005		**31791**	**33588**	9893	15480	**11522**	**6895**	**2881**	**2559**	1261	282
2006	**13707**	**46843**	**92894**	10110	12237	**10060**	3611	**2218**	869	349	879
2007	2713	14375	**51898**	**45667**	24936	**10429**	2830	1135	624	104	101
2008	1097	10651	26663	13410	**83541**	**13551**	**6834**	**2269**	193	34	60
2009	**19308**	**43317**	**54145**	27311	11107	6948	2354	**2592**	1522	599	483
2010		**31387**	**64588**	**67005**	9188	3957	2760	**2161**	723	223	280
2011		**39946**	**110161**	**97512**	15686	4715	2126	**2990**	**2188**	869	724
2012	**12928**	**31185**	**40216**	29567	18390	1157	1167	1266	**1633**	404	800
2013	1461	28106	**81355**	30181	11858	3579	1336	1103	985	219	807
2014	**35352**	**150909**	**119732**	**60416**	3783	555	712	476	521	44	148
2015	10098	18530	**66841**	24856	19088	2193	826	573	178	148	354
2016	**22463**	**59643**	**64266**	**40664**	14567	3573	744	449	844	1701	1616
2017	9916	**41568**	**66481**	27096	7632	5785	1052	712	1112	**2256**	**2250**
Average	10682	30374	46803	33272	41873	9118	3732	1696	1551	1958	1748
Correlation	0.37	0.39	0.65	0.13	-0.41	-0.28	-0.45	-0.07	-0.48	-0.59	-0.47

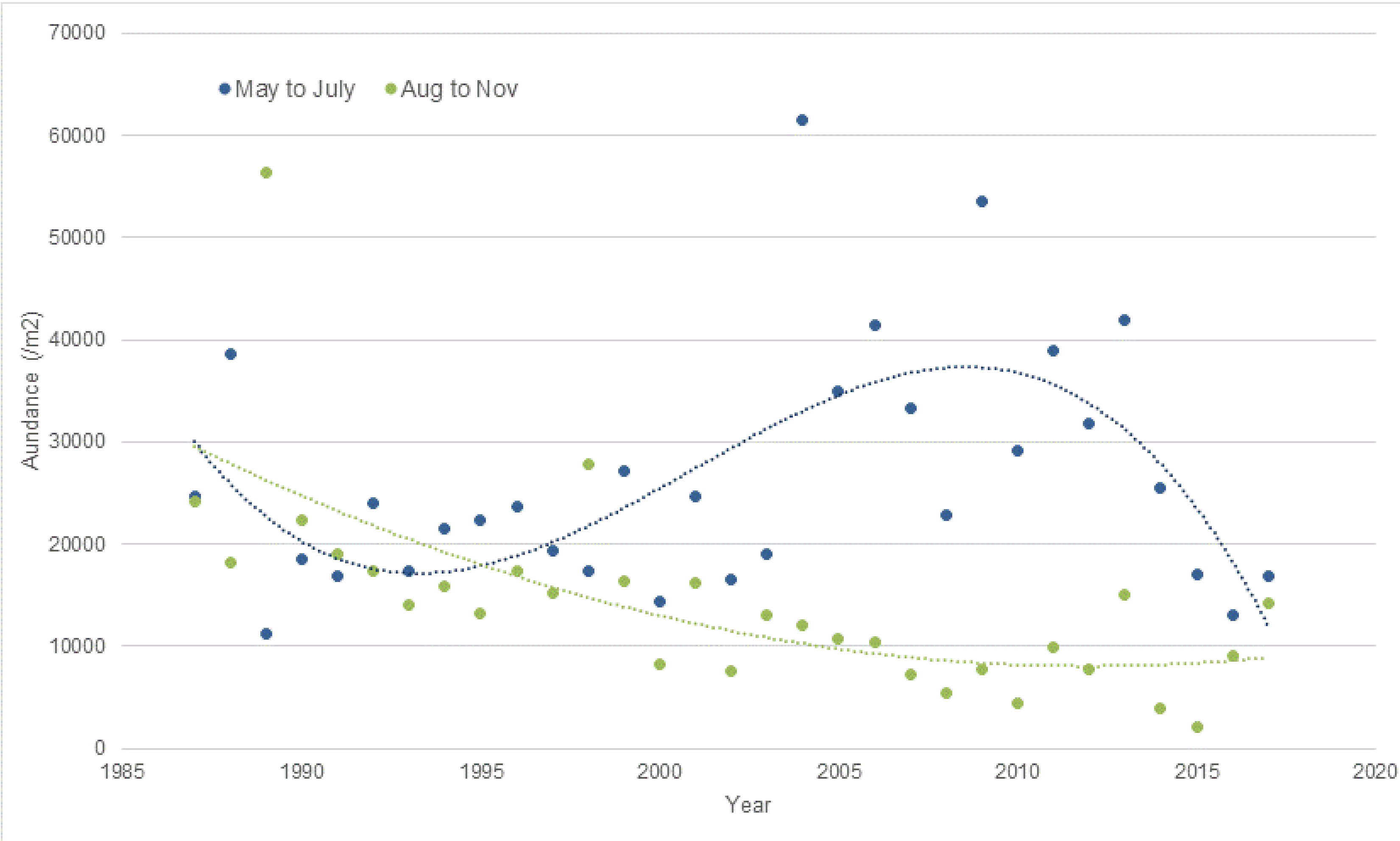


Figure 28. Comparison of Lakewide Adult *Artemia* Population Mean (per m^{-2}) Between Two Periods: May-June and November; 1979-2017

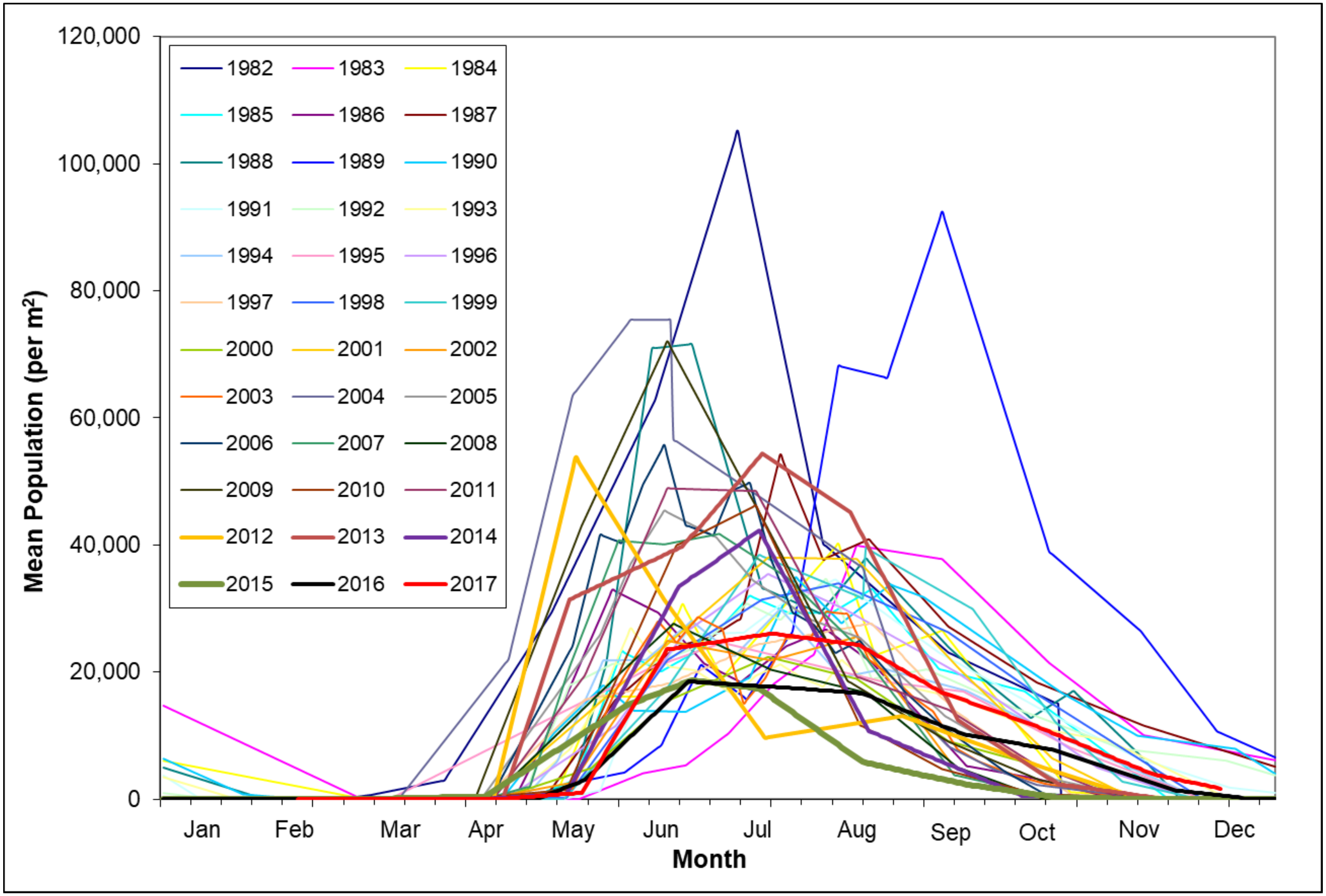


Figure 29. Lakewide Adult *Artemia* Population Mean (per m^{-2}); 1982 through 2017

The data period of monthly average *Artemia* biomass available to LADWP is much shorter than *Artemia* population as it starts in 2000. Between 2000 and 2002 the peak biomass was found in August and since 2002 the annual peak monthly biomass was found to occur in June or July except 2012 (Table 38). The peak in 2015 was observed during the month of June due to postponement of May monitoring. Higher than normal biomass in fall and winter (between September and December) was found in 2016 and again in 2017. Average biomass in November and December during 2017 monitoring season was the highest on record.

Table 38. Average Monthly *Artemia* Biomass; Stations 1-12 since 2000

Year	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000				8.1	18.4	**22.9**	**30.3**	**11.0**	**6.2**	0.4	0.1
2001				8.9	19.9	**31.1**	**32.5**	2.8	**8.3**	0.0	0.0
2002	0.0	0.1	0.3	2.4	15.2	14.6	17.1	7.3	0.1	0.0	
2003	0.0	0.0	0.2	8.0	**28.1**	17.1	**22.1**	**14.0**	**4.5**		0.0
2004	0.1	0.3	**13.9**	**28.5**	**33.0**	20.3	**26.2**	**12.0**	2.8	0.1	0.0
2005		0.2	0.6	**14.0**	**27.8**	**22.7**	**20.0**	**17.1**	3.9	0.1	0.0
2006	0.1	0.6	0.4	11.3	20.9	21.0	17.5	**13.1**	2.7	0.0	0.0
2007	0.0	0.0	1.0	10.9	15.2	**24.6**	**21.2**	5.9	1.1	0.0	0.0
2008		0.0	0.2	**16.1**	19.3	14.3	15.1	6.4	0.1		
2009	0.1	0.1	0.4	**17.3**	**37.2**	19.9	14.9	**12.2**	**4.7**	0.2	
2010		0.1	0.3	3.7	19.1	**22.4**	8.4	5.2	0.8	0.1	
2011		0.1	0.7	9.8	20.3	**24.8**	10.1	**9.7**	**5.7**	0.3	0.0
2012	0.0	0.1	0.2	**19.9**	17.7	19.6	**18.4**	**13.4**	**9.6**	0.4	**0.4**
2013	0.1	**1.8**	**17.2**	**13.8**	**23.2**	**28.6**	**23.8**	**15.0**	3.6	0.2	0.2
2014	**1.4**	**3.8**	**3.9**	**17.1**	**28.7**	**28.2**	7.7	5.1	0.9	**0.5**	0.2
2015	**0.8**	**1.7**	**10.1**	**32.3**	15.2	14.1	6.8	3.1	0.4	0.3	**0.3**
2016	**1.0**	**4.2**	3.2	7.5	17.0	17.4	14.8	**9.8**	**8.2**	**1.6**	**0.4**
2017	0.1	**2.1**	2.2	2.5	10.4	19.8	14.4	**10.8**	**9.6**	**3.3**	**1.6**
Average	0.3	1.0	3.4	12.9	21.5	21.3	17.8	9.7	4.1	0.5	0.2
Correlation	0.59	0.72	0.22	0.17	-0.24	-0.08	-0.70	-0.09	0.14	0.58	0.62

Analysis of Long Term Trends

Salinity and Mono Lake Elevation

The salinity of Mono Lake is tightly associated with lake elevation across all monitoring stations but one, and the relationships are much stronger for salinity measured at shallower depths (Table 39). The strength of the correlations was similar between two depth classes (0 to 10 m and 10 to 20 m) ranging from r=-0.84 to r=-0.92. Based on the best simple linear regression model for each station, salinity levels at the target elevation of 6,392 feet for three depth categories are presented in Table 40. Determinations of coefficient (r^2) ranged from 0.48 to 0.78, and salinity estimates ranged from 61 g/L to 76 g/L. For two depth classes (0 to 10 m and 10 to 20 m), the average salinity was estimated to be 66 g/L, which was approximately 10 g/L lower than the lowest observed salinity of 73.9 g/L in August 2008 and 77.2 g/L in July 1999 for 0 to 10 m and 10 to 20 m, respectively. For the depth class 20 to 40 m, the average salinity was estimated to be 72 g/L based on five stations whose depth exceeded at least 30 m; however, the average of r^2 among the five stations was 0.54, the lowest of all three depth categories. As a result, the estimated salinity below 20 m of depth may not be reliable.

Table 39. Relationships Between Salinity and Lake Elevation at Three Different Depths, Based on Monthly Values

	Depth		
Station	0 to 10m	10 to 20m	>20m
2	-0.89	-0.85	-0.72
3	-0.86	-0.87	-0.73
4	-0.87	-0.87	-0.69
5	-0.86	-0.88	-0.54
6	-0.89	-0.85	-0.66
7	-0.89	-0.84	-0.69
8	-0.45	-0.49	-0.78
10	-0.86	-0.87	-0.84
11	-0.92	NA	NA
12	-0.84	-0.86	-0.71

Table 40. Estimated Salinity Level at 6,392 feet Lake Level

Station	Depth	Estimated Salinity (µM)	r^2	Equation
2	0 to 10m	69	0.78	*y = -1.33 x (Elevation) + 8591*
	10 to 20m	71	0.73	*y = -1.27 x (Elevation Previous 6 Months) + 8245*
3	0 to 10m	67	0.75	*y = -1.62 x (Elevation) + 10463*
	10 to 20m	67	0.77	*y = -1.79 x (Elevation Previous 3 Months) + 11535*
	>20m	71	0.59	*y = -1.45 x (Elevation Previous 12 Months) + 9360*
4	0 to 10m	66	0.76	*y = -1.65 x (Elevation) + 10661*
	10 to 20m	67	0.77	*y = -1.77 x (Elevation Previous 3 Months) + 11420*
	>20m	72	0.54	*y = -1.4 x (Elevation Previous 10 Months) + 9027*
5	0 to 10m	66	0.74	*y = -1.7 x (Elevation) + 10976*
	10 to 20m	66	0.77	*y = -1.87 x (Elevation Previous 2 Months) + 12049*
6	0 to 10m	69	0.79	*y = -1.32 x (Elevation) + 8508*
	10 to 20m	71	0.73	*y = -1.26 x (Elevation Previous 6 Months) + 8157*
	>20m	76	0.48	*y = -0.94 x (Elevation Previous 12 Months) + 6114*
7	0 to 10m	69	0.78	*y = -1.32 x (Elevation) + 8547*
	10 to 20m	71	0.72	*y = -1.27 x (Elevation Previous 6 Months) + 8196*
	>20m	75	0.53	*y = -1.01 x (Elevation Previous 12 Months) + 6571*
8	0 to 10m	66	0.74	*y = -1.7 x (Elevation) + 10975*
	10 to 20m	66	0.78	*y = -1.87 x (Elevation Previous 2 Months) + 12023*
10	0 to 10m	65	0.75	*y = -1.84 x (Elevation Previous 2 Months) + 11885*
	10 to 20m	64	0.78	*y = -2.08 x (Elevation Previous 6 Months) + 13360*
12	0 to 10m	66	0.70	*y = -1.69 x (Elevation) + 10923*
	10 to 20m	66	0.76	*y = -1.88 x (Elevation Previous 3 Months) + 12081*
	>20m	71	0.55	*y = -1.5 x (Elevation Previous 10 Months) + 9706*
Average	0 to 10m	67	0.76	
	10 to 20m	68	0.76	
	>20m	74	0.54	

The relationship between salinity and lake elevation, with the highest r^2, is presented in Figure 30 through Figure 32 for each depth category. These figures show a very strong linear trend, but also deviations from the trend line which are colored orange in each figure. Further analysis revealed that these deviations points have mainly been occurring since 2009 and corresponded to spikes, both low and high, which tended to occur in summer (low) and winter (high) (Figure 33). In order to demonstrate a temporal trend of fluctuations within year, a range of salinity within each monitoring year was examined. The annual range of salinity widened considerably in recent years even compared to all other years where data were more complete (Figure 34). This trend was much more pronounced for the water depths shallower than 10 m, and was found consistently across the lake. In 2017 the range of salinity exceeded 15 g/L at all stations. At Station 6 salinity was initially 96.6 g/L in February, and reached the lowest level in September at 80.9 g/L, resulting in an interannual range of 15.7 g/L.

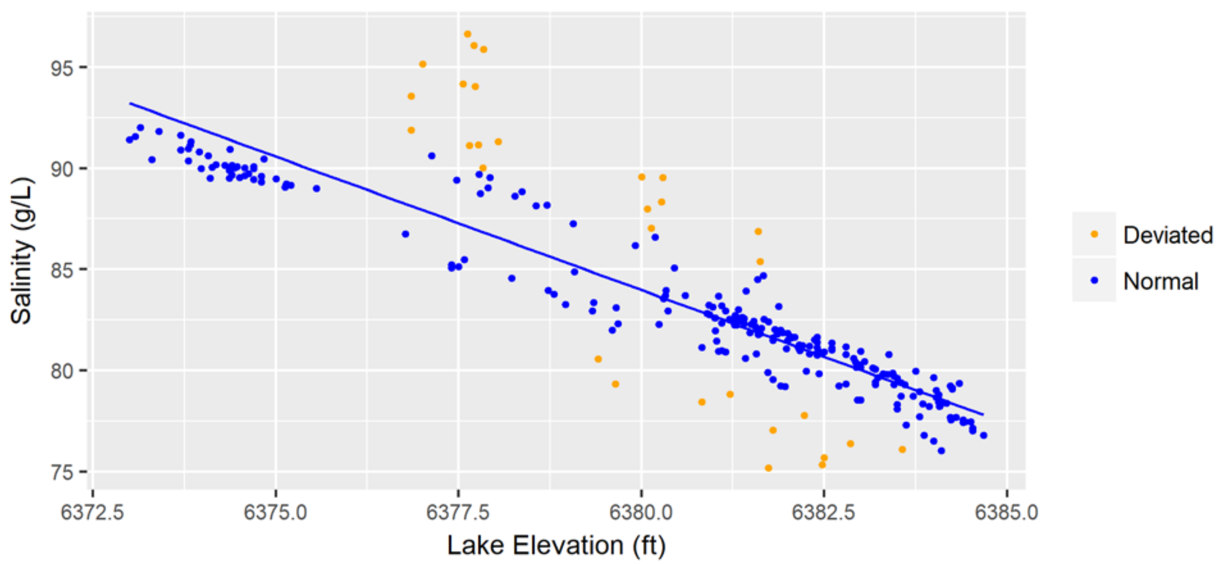


Figure 30. Relationship Between Salinity and Lake Elevation; 0-10 m

Salinity values were averaged for depths of between 0 and 10 m at Station 6. Blue line indicates a best fit line based on blue colored points only

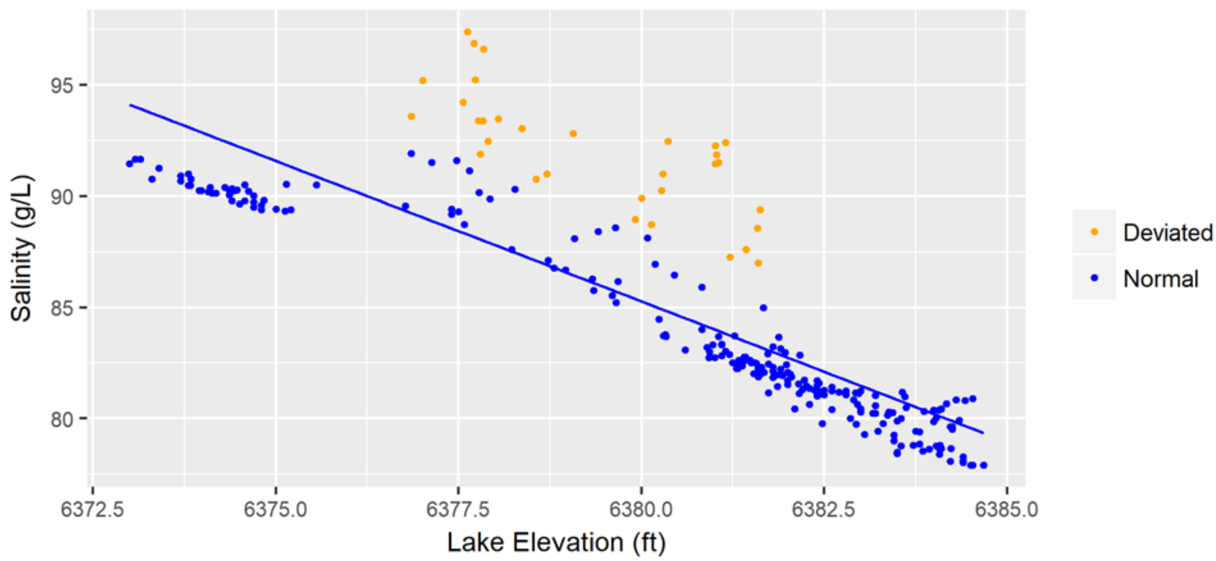


Figure 31. Relationship Between Salinity and Lake Elevation; 10-20m
Salinity values were averaged for depths of between 10 and 20 m at Station 6. Blue line indicates a best fit line based on blue colored points only

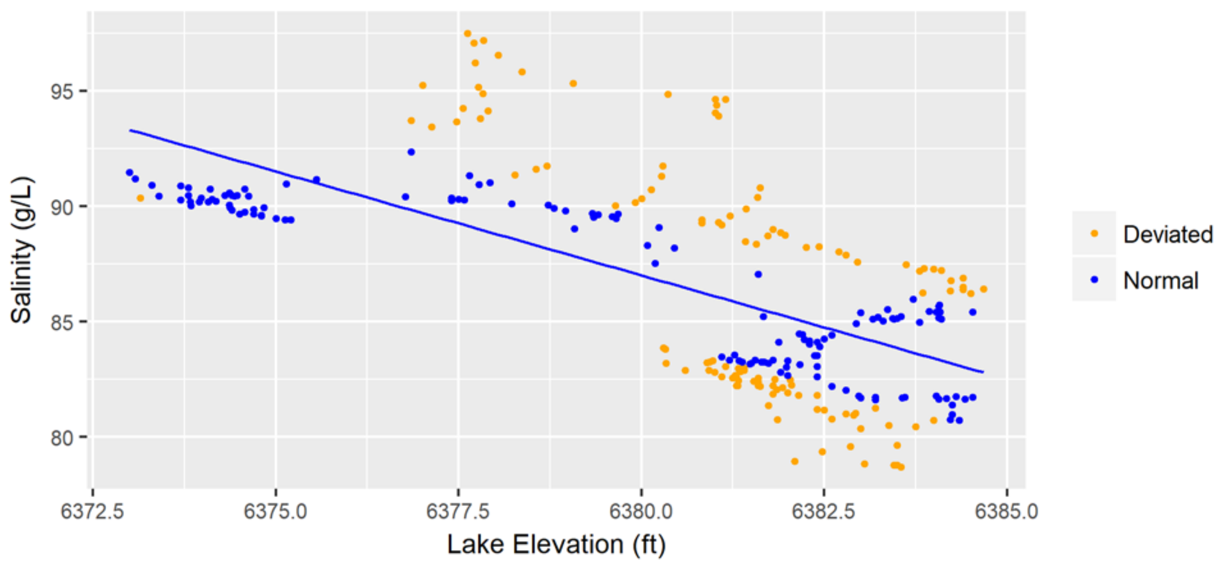


Figure 32. Relationship Between Salinity and Lake Elevation; 20-40 m
Salinity values were averaged for depths of between 20 and 40 m at Station 6. Blue line indicates a best fit line based on blue colored points only

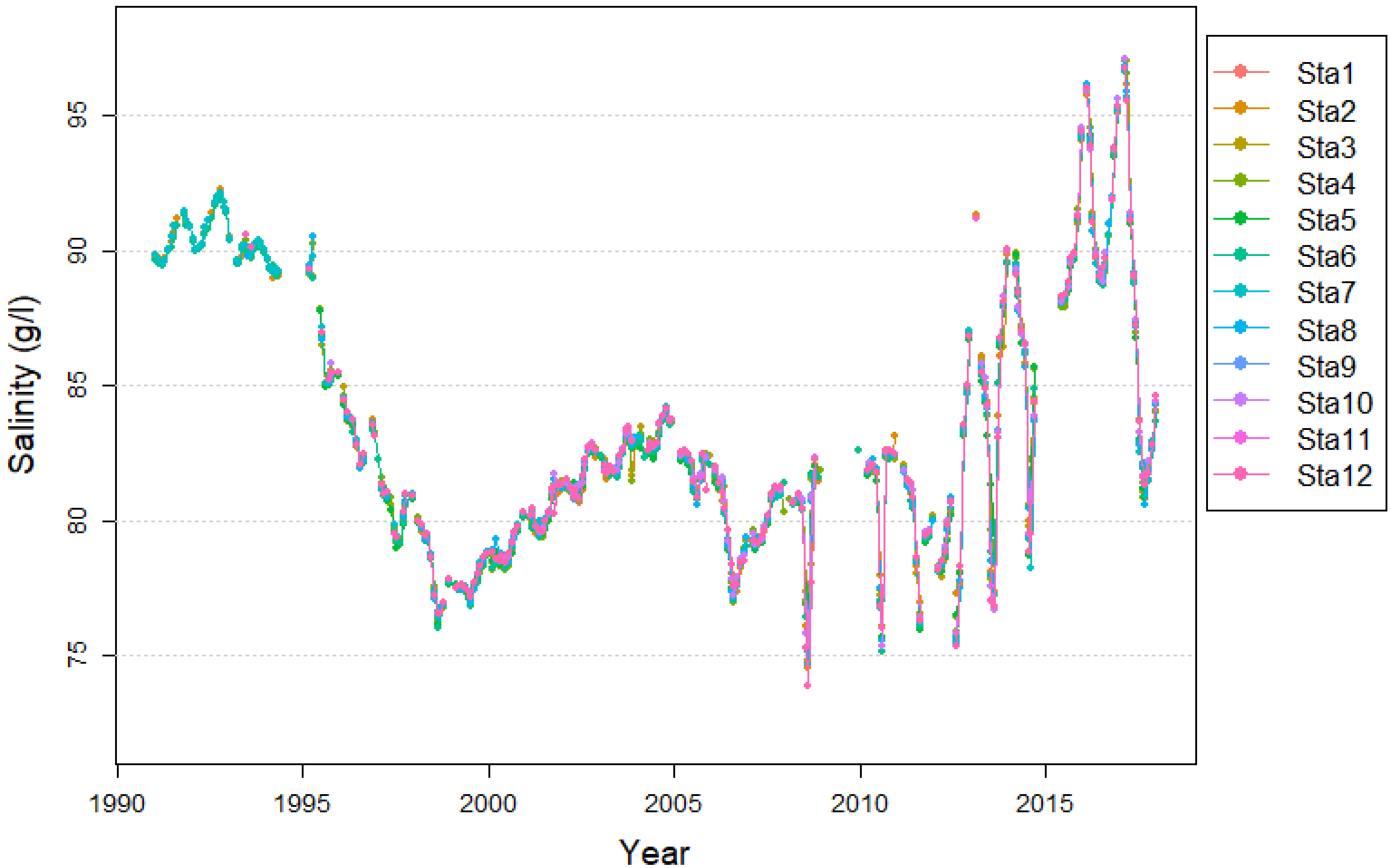


Figure 33. All Stations, Time Series Plot Based on Monthly Salinity Averaged Between 0 and 10m of Depth

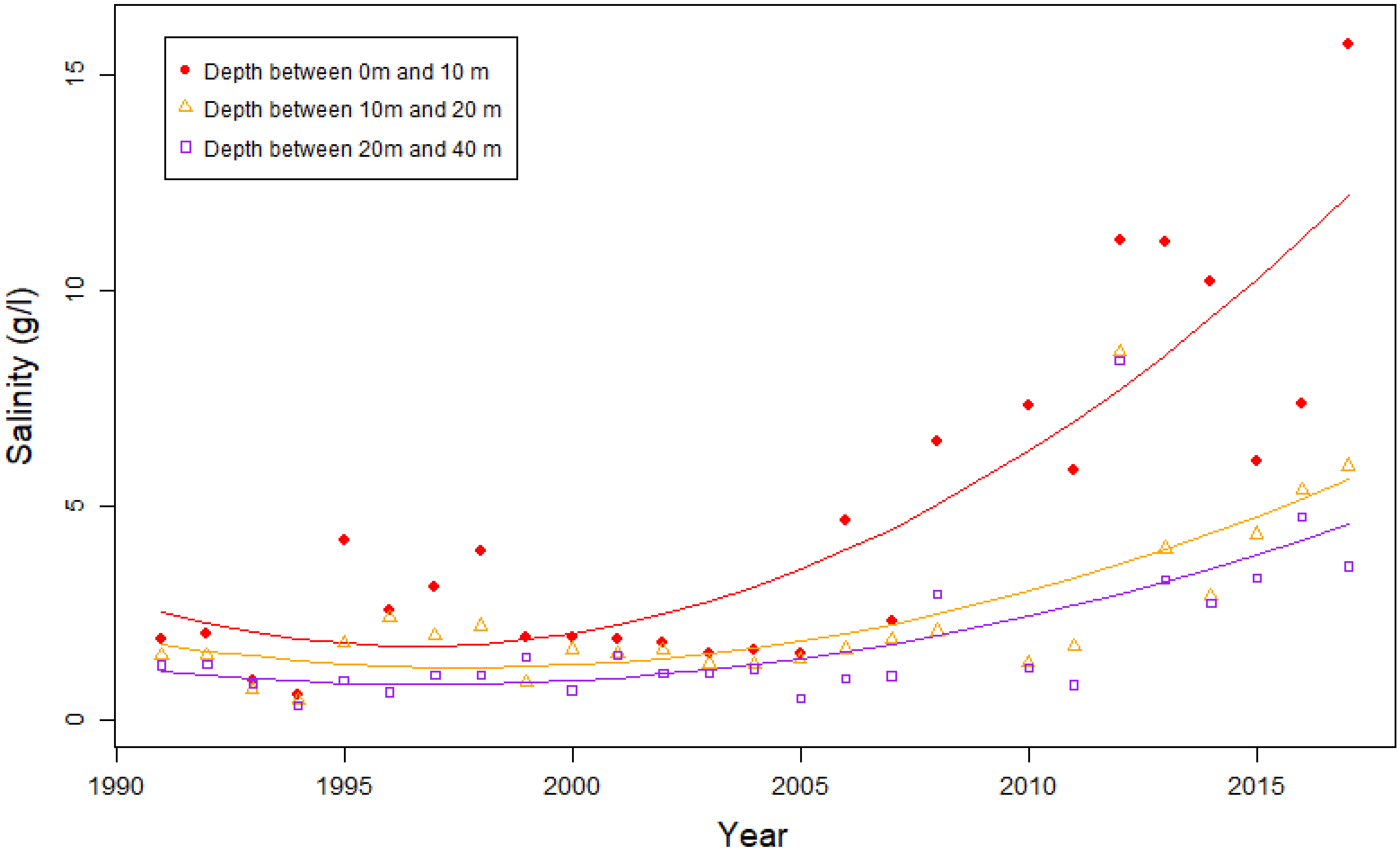


Figure 34. Station 6, Interannual Range of Monthly Salinity Reading at Station 6

When periods before and after 2009 are compared, the Later (2009-2017) shows a much steeper slope than the Earlier (1991-2008) for all stations; that is salinity increases at a much higher rate with given increase of lake elevation during the later period than the earlier period, and differences in the rate (slopes based on simple linear regression) are statistically different for all but one station (Table 41). Station 6 shows this trend clearly in Figure 35. The figure also shows deviating salinity readings for equivalent lake levels. For instance, at the lake level near 6,377.5 feet salinity levels are found around 85 g/L during the earlier period while salinity levels range between 88 g/L and 97 g/L during the later period. The same trend is also found at 6,380 feet as during the earlier period salinity readings cluster between 80 g/L and 85 g/L while salinity reading as high as 90 g/Lis found during the later period at the equivalent lake level. Not only is the salinity level higher during the later period, a range of salinity readings also increases for the later period for the lake level above 6,380 feet. Mono Lake appears to be saltier now than before, and much higher variability in salinity at a given lake level makes it difficult to predict future salinity levels. It also should be noted that the upper range of Mono Lake elevations used in the regression analysis only goes up to 6,384.7 feet; thus, any prediction beyond the value may not accurate.

Table 41. Statistical Difference in Simple Linear Regression Slope Between Two Time Periods

Station	Sloe Difference
2	<0.0001
3	0.0003
4	<0.0001
5	0.0001
6	<0.0001
7	<0.0001
8	0.0030
10	0.8078
12	0.0003

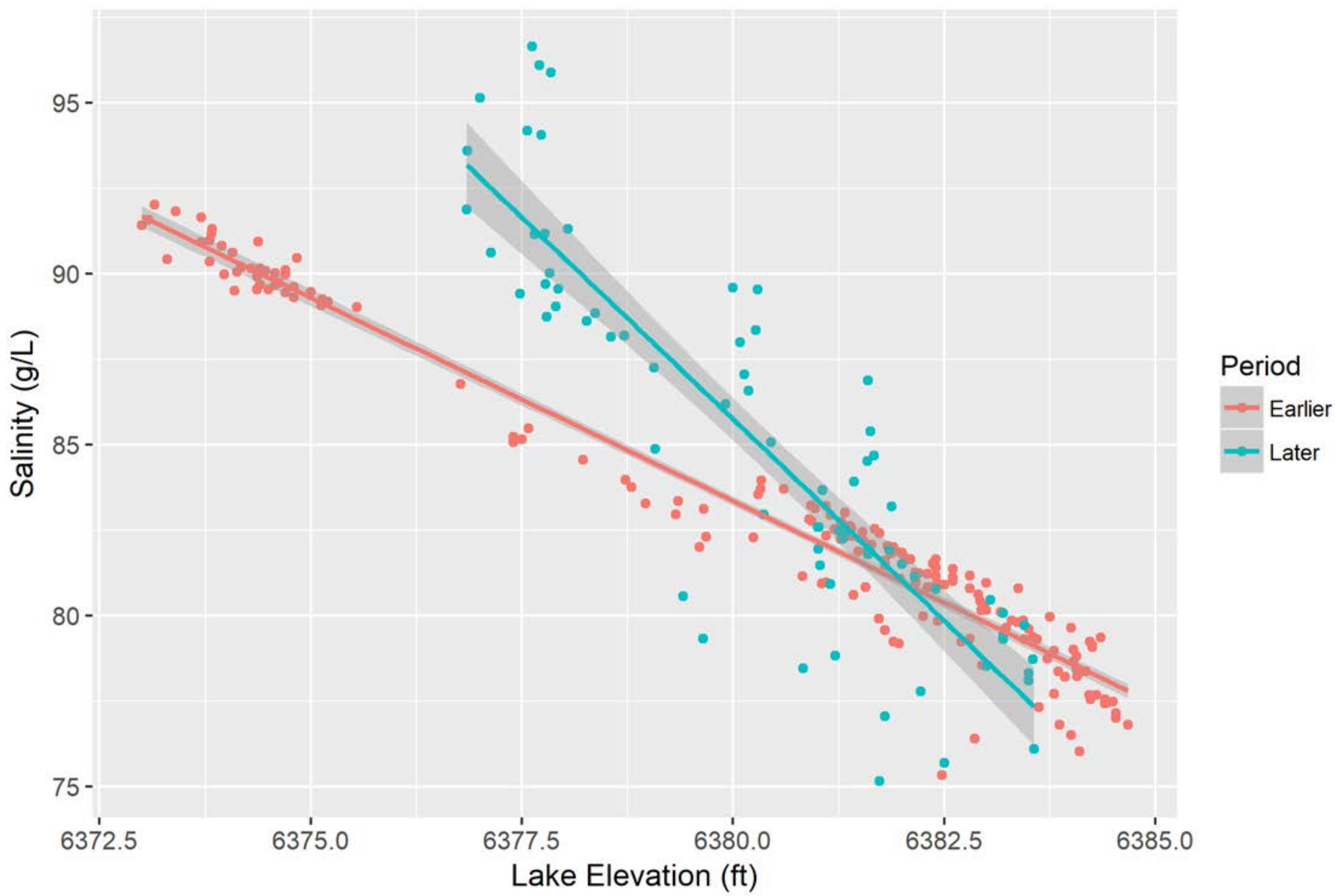


Figure 35. Difference in Slopes Between Two Periods of Monitoring Years: Earlier (1991-2008) and Later (2009-2017)

Artemia Population Peak

Lakewide mean *Artemia* population peaked in 1989, 2004, 2009, and 2013 and showed a declining trend with an average decline of approximately 500 m^{-2} per year (Figure 27). According to this relationship, the *Artemia* population would be approximately 23,133 m^{-2} if the current meromixis breaks in 2018 and approximately 22,676 m^{-2} if it breaks in 2019. A predicted peak would be indistinguishable from any other monomictic years which range from 7,676 m^{-2} to 27,639 m^{-2}. In spite of a declining trend of peaks, *Artemia* abundance during peak years was significantly different from that during non-peak years ($P = 0.0099$) as peak years averaged 30,102 m^{-2} compared to 17,206 m^{-2} during non-peak years (Table 42). This section examined the effect of meromixis on the Artemia population in Mono Lake.

Ammonium (NH4)

Ammonium recorded at the deepest monitoring depth (28 m) shows a similar trend as the *Artemia* population peaks. Peak monthly accumulation prior to the peak during the second meromixis was 1,173 µM in November 2001 (Table 42, Figure 36) with the average rate of accumulation being 124 µM/year, and for successive peaks ammonium accumulation dropped from 101 µM in 2007 to 45 µM in 2017, the latest meromixis. The hypolimnetic ammonium during the third and fourth meromictic events was more than twice as high as 2017 but much lower than that observed during the second meromixis indicating the importance of nutrient build up which appeared to be proportional to duration of meromixis.

When meromixis was broken, accumulated ammonium became available throughout the water column, and a nutrient boost at 2 m was apparent in 2004 but only slightly in 2009 and 2013 (Figure 37). Ammonium levels at 2 m in 2004 and 2009 were lower than what observed in 2016 which was a monomictic year. The similar trend was observed at the depth of 8 m (result not shown). A lower amount of epilimnetic ammonium availability during the third and fourth meromixis may explain reduced *Artemia* peaks following the meromixis, and low ammonium accumulation in 2017 may indicate yet smaller *Artemia* peak in 2019 or 2020.

Table 42. Artemia Population Summary During Meromixis and Monomixis

Meromixis	Duration	Peak Year	Peak *Artemia* abundance (m^3)	Average *Artemia* between peaks (m^3)	Reduction following a peak	NH_4 accumulation during meromixis (µM)*
1983~1987	5	1989	36,359		45%	NA
				16,576		
1995~2002	8	2004	32,044		44%	1,173
				17,514		
2005~2007	3	2009	25,970		43%	101
				17,529		
2011	1	2013	26,033		48%	89
				11,747		
2017~?						45
Average			30,102	17,206	45%	

** Maximum monthly hypolimnetic NH4 reading during a meromixis period recorded at depth of 28 m at Station 6*

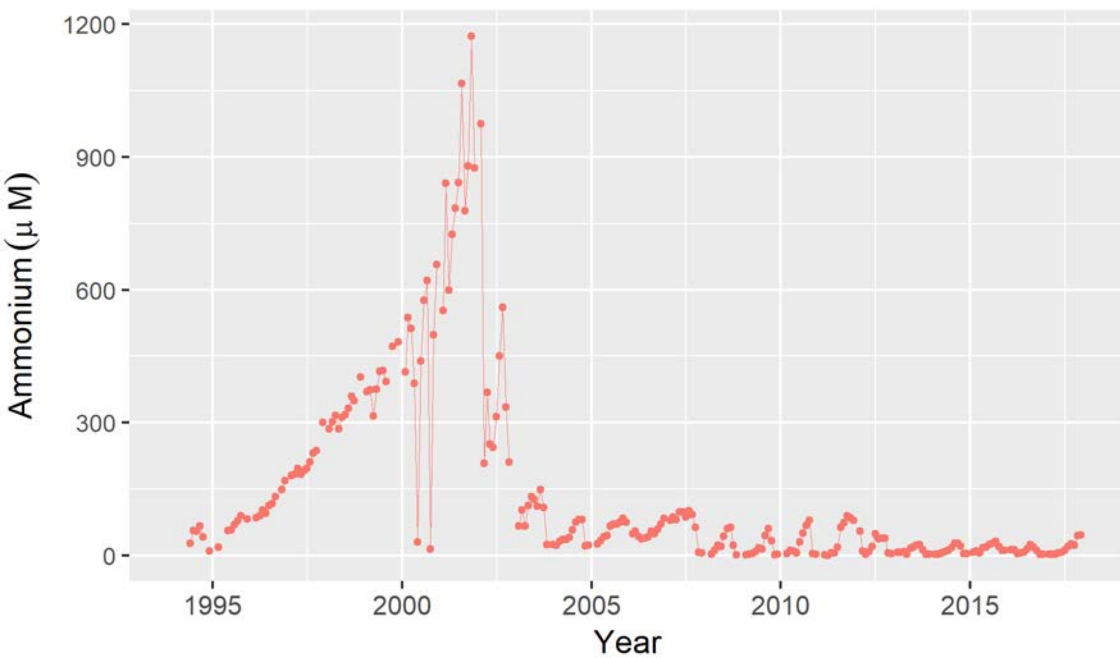


Figure 36. Station 6, Ammonium Accumulation at 28 m of Depth Recorded

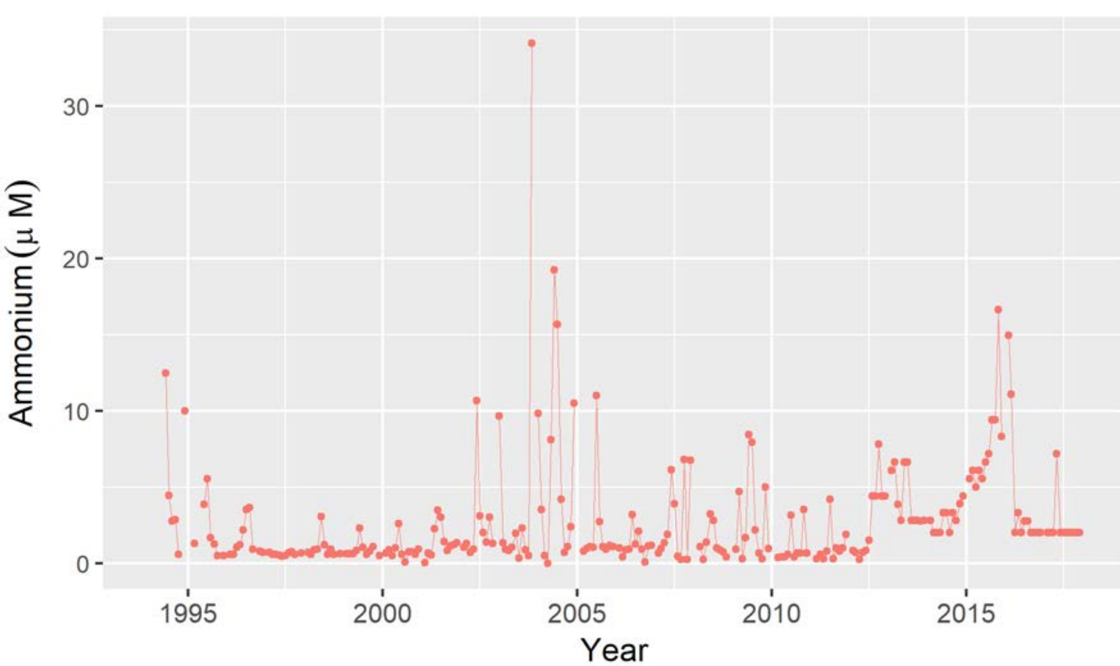


Figure 37. Station 6, Ammonium Accumulation at 2 m of Depth Recorded

Mono Lake Input

The second meromixis was by far the longest recorded meromixis lasting from 1995 to 2002. A majority of increased freshwater input occurred between 1995 and 1999 during which a total of 717,670 AF of water discharged into Mono Lake, the highest 5-year total on record (Table 43). Mono Basin runoff total during the first meromixis was higher than during the second meromixis (179,139 AF between 1982 and 1986 compared to 164,880 AF between 1995 and 1999); however, due to export from Mono Basin, inflow to Mono Lake was larger during the second meromixis than the first. As a result the lake level rose by 10.3 feet during the second meromixis compared to 6.2 feet during the first. Based solely on freshwater influx the second meromixis should have produced a much higher *Artemia* peak than the first meromixis.

The rise in the lake level in 2017 was comparable to what was observed during the third meromixis (2005 to 2007), 3.9 feet compared to 4.0 feet. Subsequently, the *Artemia* peak following the current meromixis may have a potential to achieve an *Artemia* peak closer to the third meromixis in terms of magnitude. However, a total amount of freshwater influx would be lower than during the third meromixis due to shorter duration of the current meromixis which may not allow sufficient accumulation of nutrients to boost an *Artemia* peak. A longer meromixis is achieved with higher sustained inflow to Mono Lake; the longer the period of sustained high flow, the longer the duration of meromixis. As mentioned previously, a longer meromixis results in a greater accumulation of ammonium, which in turn results in a higher *Artemia* population peak.

Table 43. Mono Lake Input During Meromixis and Monomixis

Meromixis	Total Input (10^3 AF)	Input responsible to form meromixis			Average Input (10^3 AF) for all other years	Lake Elevation Change (ft)
		Year	Total (10^3 AF)	Average (10^3 AF)		
1983~1987	535	1983~1986	510	128		6.2
					61	
1995~2002	971	1995~1999	718	144		10.3
					83	
2005~2007	375	2005~2006	313	156		4.0
					73	
2011	162	2011	162	162		1.9
					59	
2017~?	236	2017	236	236		3.9
Average				165	69	

Salinity

With a large influx of freshwater, epilimnetic salinity declines. During the second meromixis, the salinity gradient slowly developed with the onset of meromixis peaking at 13.2 g/L in August 1998 and disappearing in 2003, a year before the *Artemia* population peak (Figure 38 and Figure 39). During the third meromixis, however, the salinity gradient weakened at the end of 2005 and was re-established in 2006, resulting in a much weaker chemocline at the end of meromixis in 2007. The meromixis in 2011 fails to create a salinity gradient which is distinguishable from monomictic years, and a peak of gradient only reaches 7.4 g/L and quickly disappears. Chemocline during the second meromixis is much stronger and has lasted longer, which has resulted in greater accumulation of ammonium and subsequently a higher *Artemia* population peak in 2003.

Figure 38. Station 6, Maximum (red) and Minimum (blue) Salinity Recorded Through Water Column

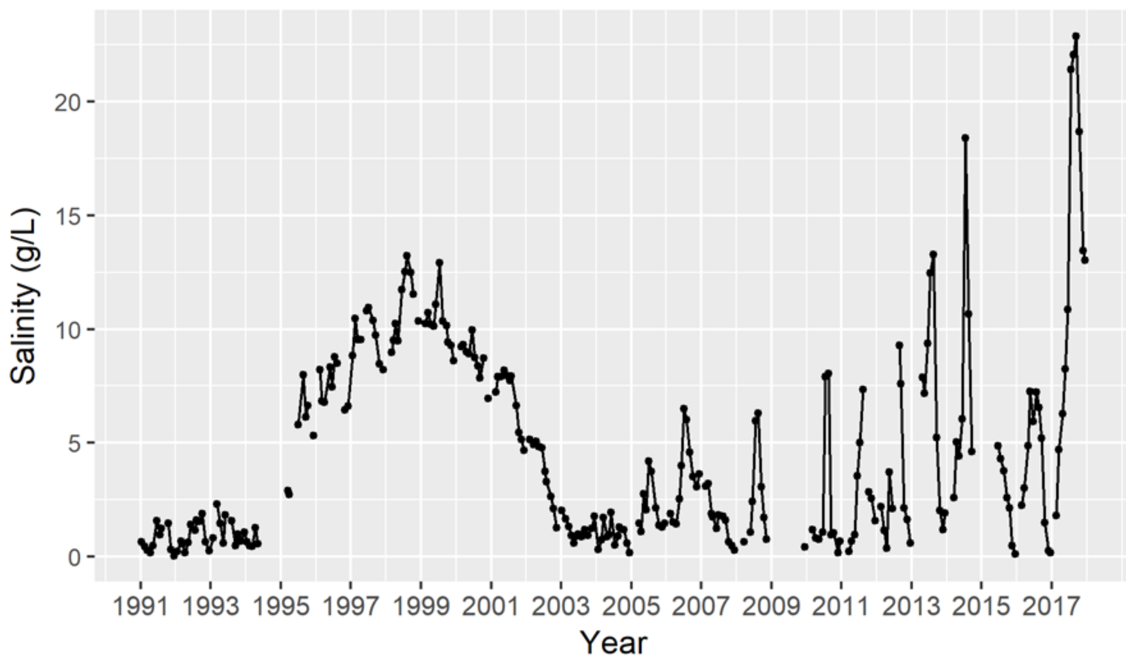


Figure 39. Station 6, Range of Salinity Through Water Column

A range of salinity through the water column has increased pronouncedly since 2008, exceeding 20 g/L in 2017. Due to holomixis at the end of 2016, the salinity gradient is near 0 at the beginning of 2017. Mono Lake has quickly stratified reaching the maximum gradient of 22.9 g/L in September and remains above 10 g/L at the end of the year thanks to the second largest inflow of freshwater on record. Chemocline in 2017 is much stronger than the previous 2 meromictic events, and may lead to higher *Artemia* population peak.

A Temporal Shift in Monthly Artemia Population

There has been a clear temporal shift in peak abundance of instars and adults as monthly peaks are occurring earlier in the year (Table 36 and Table 37), which are reflected on a strong linear negative trend of centroid days (calculated center of abundance of adults) in respect to monitoring years (Figure 26).

There appear to be three distinct periods of instar and adult abundance patterns:

1) later season occurrence between 1987 and 1994,
2) transition between 1995 and 2003, and
3) earlier season occurrence since 2004.

The first period coincides with the breakdown of the first recorded meromixis and subsequent monomixis, and monthly peaks tend to occur in June except 1987 and 1988 for instars and mostly in July or later for adults. High adult abundance is maintained into fall as over 100,000 m^{-2} is routinely recorded in October. The transition period coincides with the second meromixis which lasted from 1995 through 2003. During this period monthly peaks have shifted earlier for instars while monthly peaks remain in June for adults even though high abundance in fall is no longer recorded. The third period features two short-lived meromictic events and current meromictic event. Peak monthly instar abundance tends to occur mostly in April but as early as in March during some years while peak monthly adult abundance tends to occur in June and as early as in May. This trend; however, appears to be reversed slightly in recent years as a half of monitoring years show peak monthly abundance in July since 2010. In 2015 and 2016, a peak monthly abundance is observed in June; however, each peak is smaller but broader such that July monthly abundance is almost as high as that of June and July in the case of 2016.

Chlorophyll a

Spring chlorophyll a levels between 1995 and 2003 are more variable and tend to be lower than any time period since 2003 (Figure 40). A significantly positive trend exists between March chlorophyll *a* levels and monitoring years at 2 and 28 m of depth, and all depths but one (20 m) becomes significant when 1995 is removed from the analysis. Data prior to 1995 is not available for the analysis; thus, it is not possible to assess whether 1995 is atypical or not and to assume that a positive trend exists including data prior to 1995. It appears, however, that a shift in monthly *Artemia* instar abundance peaks coincide with the trend of spring chlorophyll *a* levels.

From April through June chlorophyll *a* levels have been increasing at the depths within 10 m of surface (Figure 41 through Figure 43). Abundance of food source could increase *Artemia* growth resulting in earlier monthly peaks; however, the recent slight reversal in the temporal shift in monthly adult population peaks does not conform to the increasing food source in recent years.

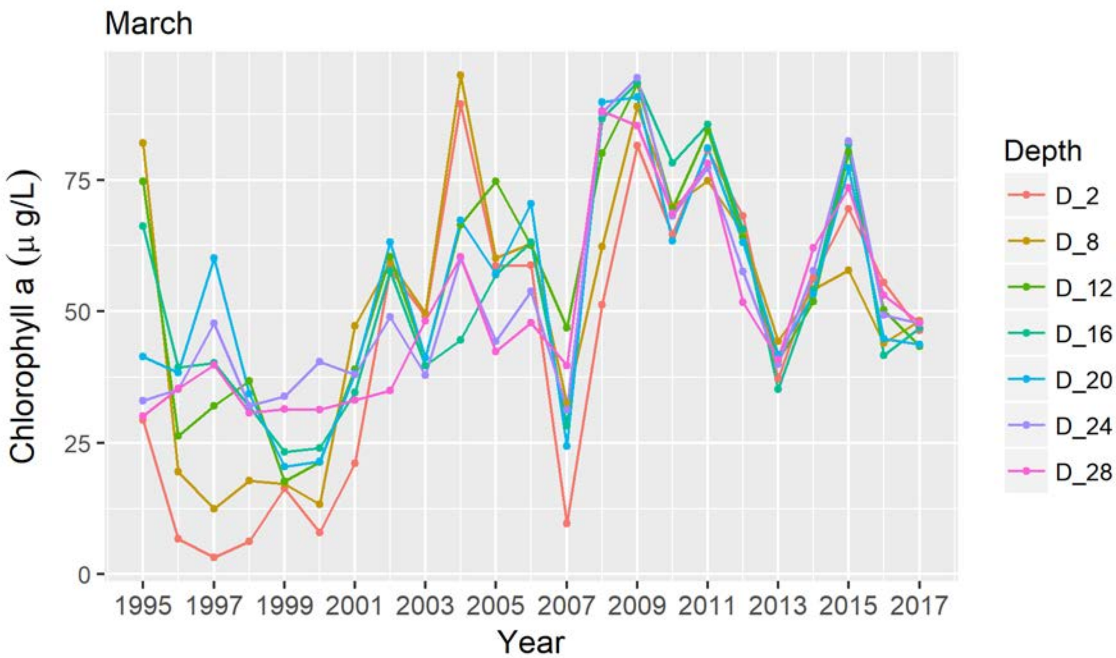


Figure 40. March Chlorophyll *a* Level Over Time for All Depths

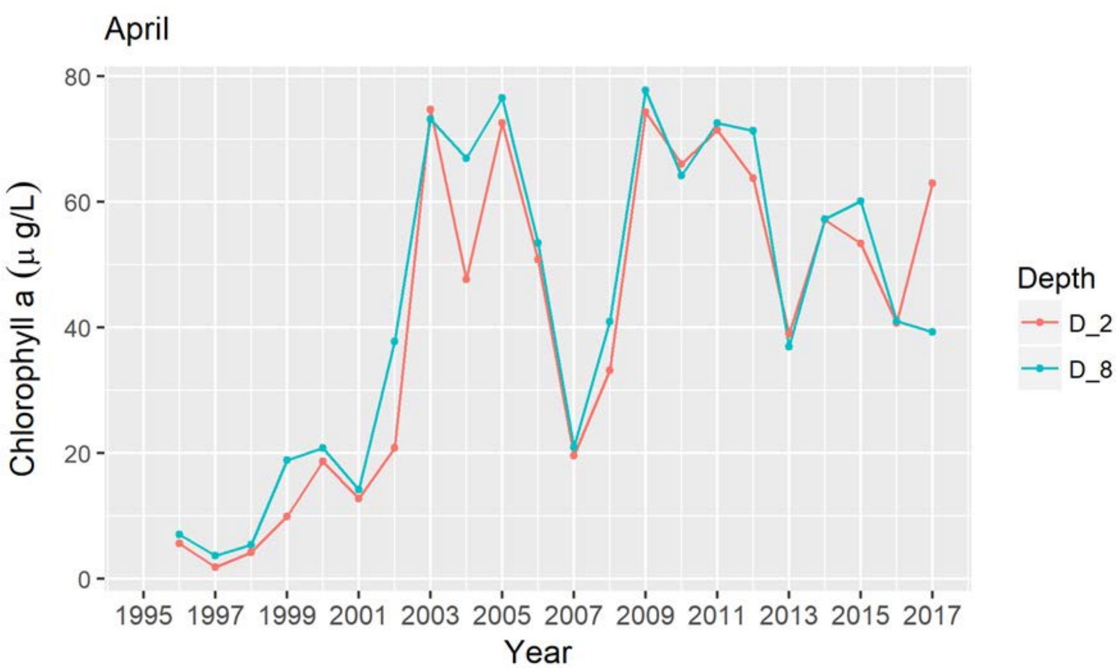


Figure 41. April Chlorophyll *a* Level Over Time for Depths at 2 m and 8 m

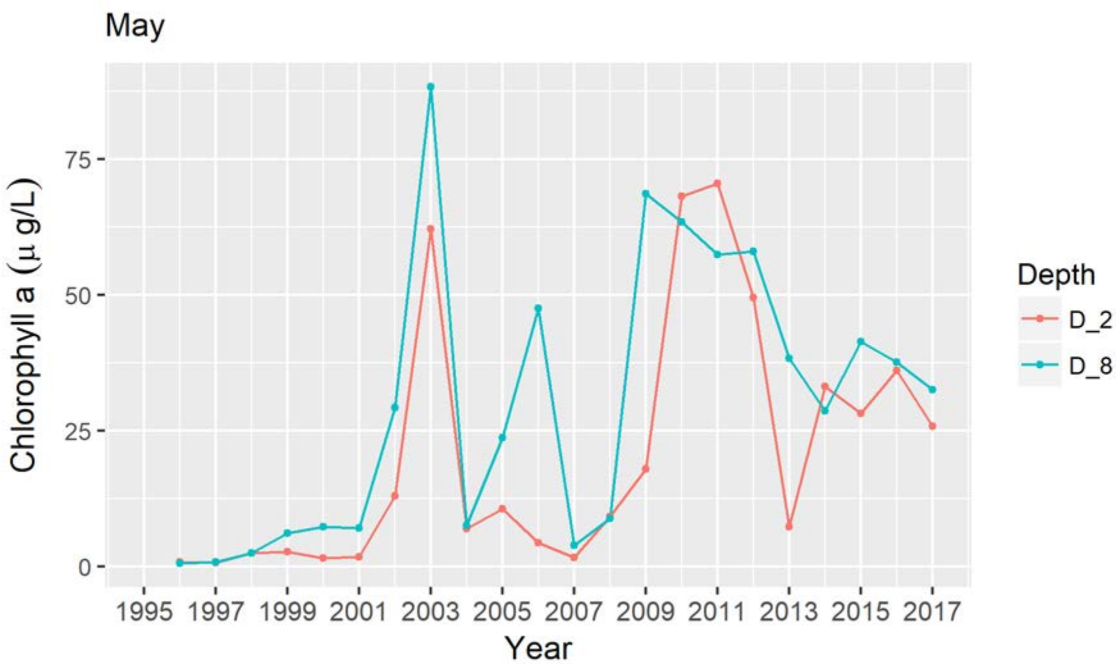


Figure 42. May Chlorophyll *a* Level Over Time for Depths at 2 m and 8 m

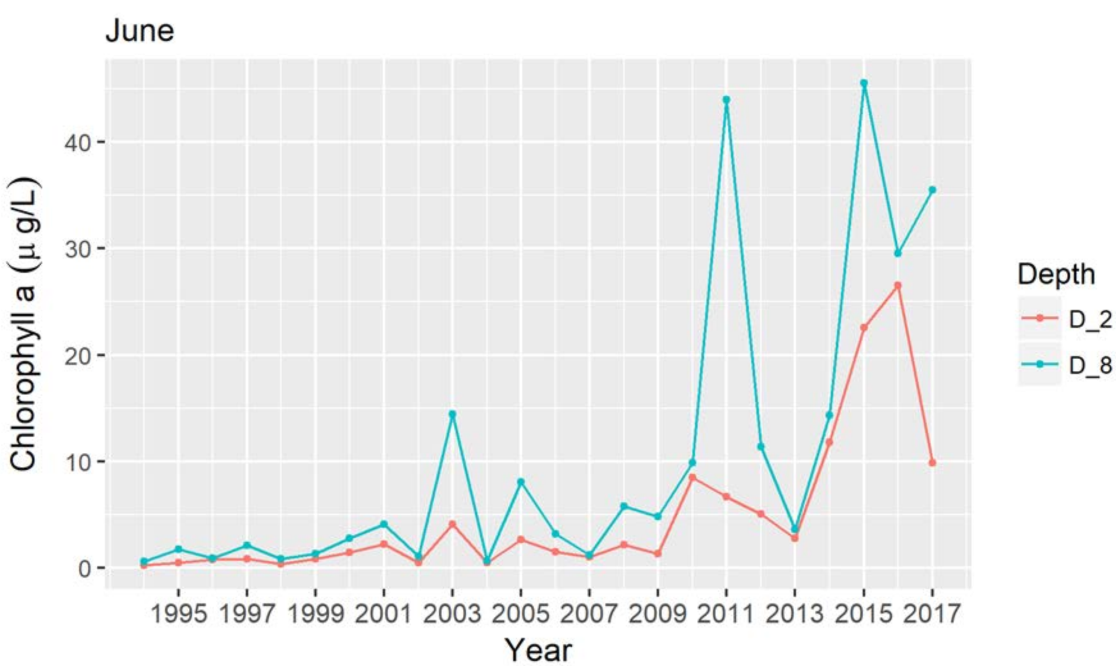


Figure 43. June Chlorophyll *a* Level Over Time for Depths at 2 m and 8 m

Temperature

Following this obligate period of dormancy, warmer water temperature is found to lead to shorter time required for hatching (Dana et al. 1988). Hypolimnetic water temperature remains relatively high during meromixis which reduces convection across the chemocline, resulting relatively warm and stable water temperature condition in hypolimnion. This is evident during the second meromixis (1995-2002) and somewhat during the third meromixis (2005-2007) (Figure 44). The trend becomes more apparent when hypolimnetic water temperature is averaged over February and March (Figure 45). The monomictic period between 1991 and 1995 (meromixis has not started in spring of 1995 yet) show lower spring hypolimnetic water temperature than the subsequent meromixis, averaging 2.4°C compared to 4.8°C during the meromixis. Spring hypolimnetic water temperature starts dropping as meromixis weakens, and this is evident between 2002 and 2005, in 2008, and somewhat between 2014 and 2016. The latest trend is hard to substantiate because of missing data in 2013 and 2015. In spite of temperature decline during meromixis, spring hypolimnetic water temperature since 2003 is higher than the monomictic period between 1991 and 1995, averaging 3.1°C compared to 2.4°C. The value may be inflated because it includes three years with spring hypolimnetic water temperature above 4°C during meromixis. During the last monomictic period (2013-2017), spring hypolimnetic water temperature also averages 3.1°C; thus, spring hypolimnetic water temperature appears warmer compared to earlier 90s, consistent with the trend found for *Artemia* instar monthly abundance. It appears that epilimnetic water temperature shows an upward trend since 2010 in April, but downward trend in June, and there is no clear trend in May (Figure 46 to Figure 48). Warmer hypolimnetic water appears to support earlier hatching of cysts, hence, earlier peak of instar abundance; however, the epilimnetic water temperature does not appear to explain the reversing of the peak monthly abundance.

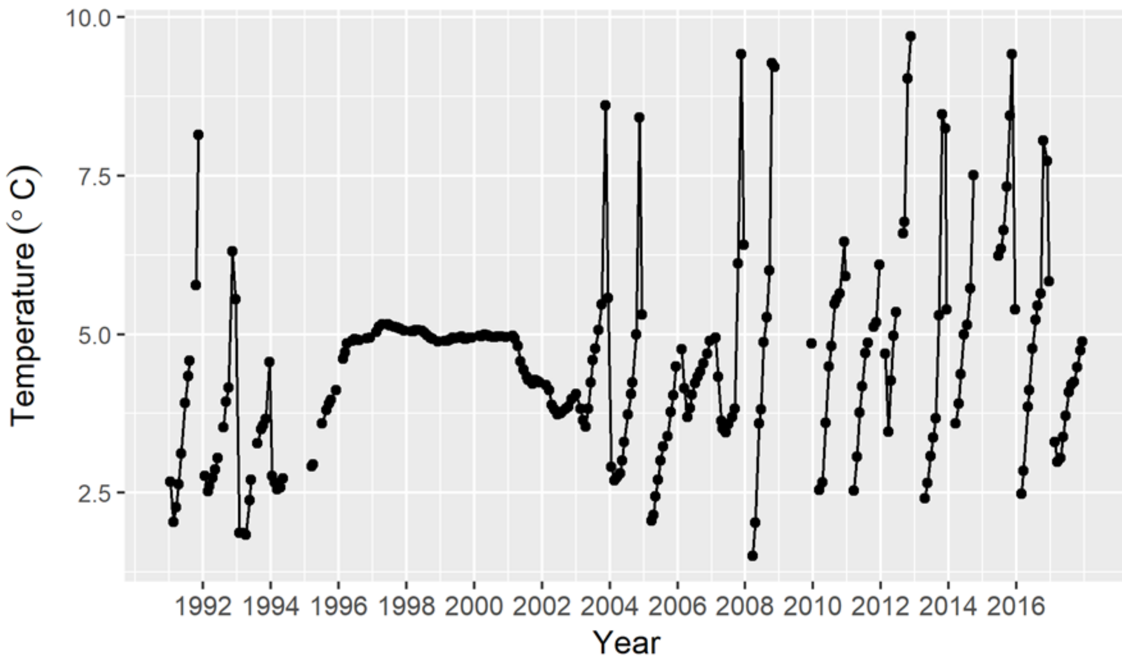


Figure 44. Station 6, Average Water Temperature Between 30 and 40 m of Depth

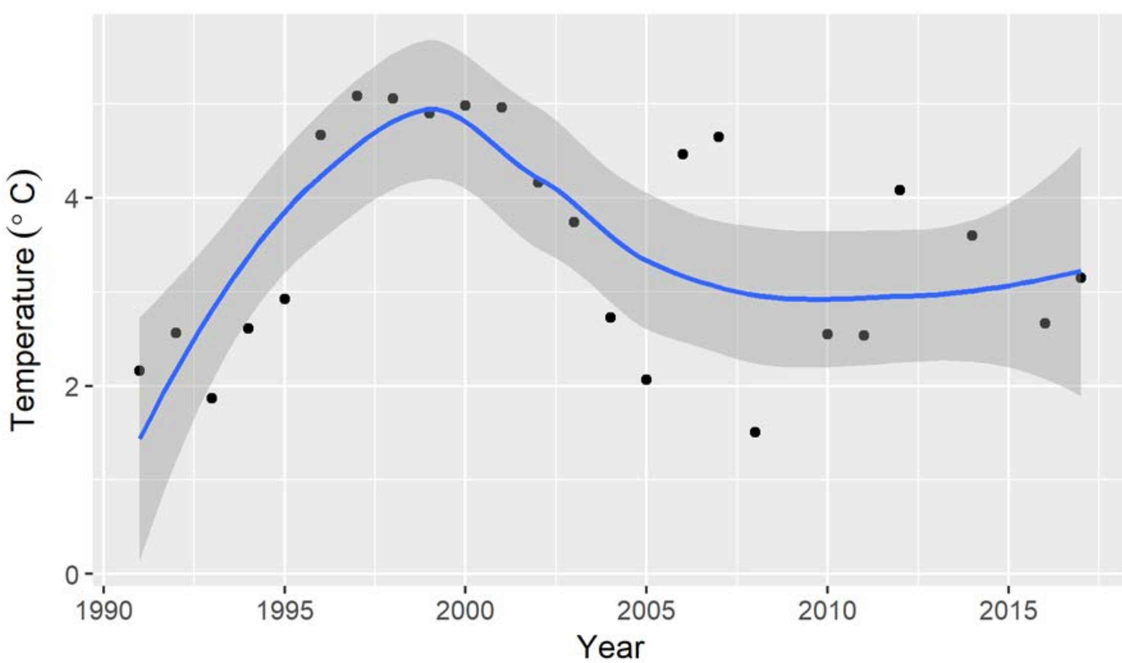


Figure 45. Station 6, Average Water Temperature Between 30 and 40 m of Depth During Spring

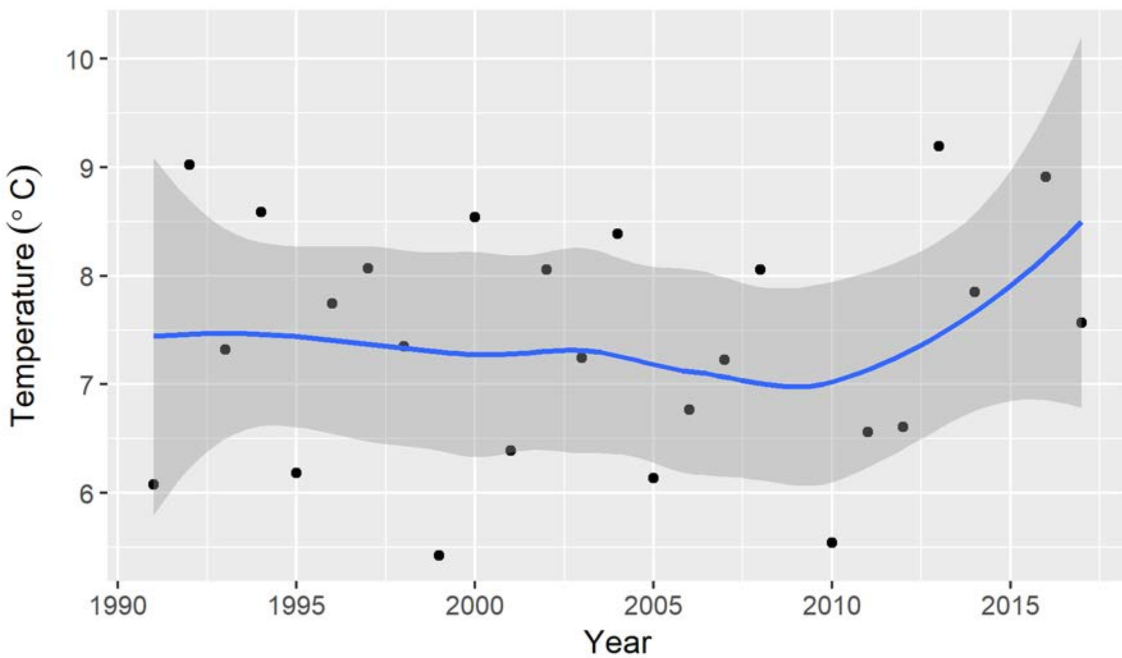


Figure 46. Station 6, Average Water Temperature Between 0 and 10 m of Depth in April

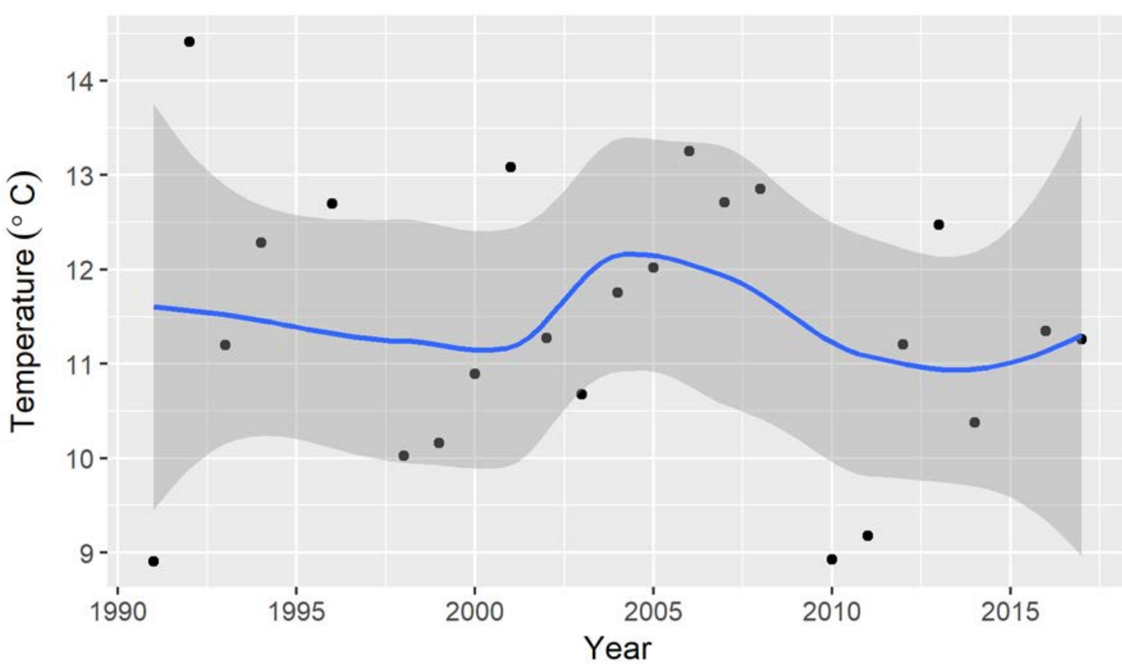


Figure 47. Station 6, Average Water Temperature Between 0 and 10 m of Depth in May

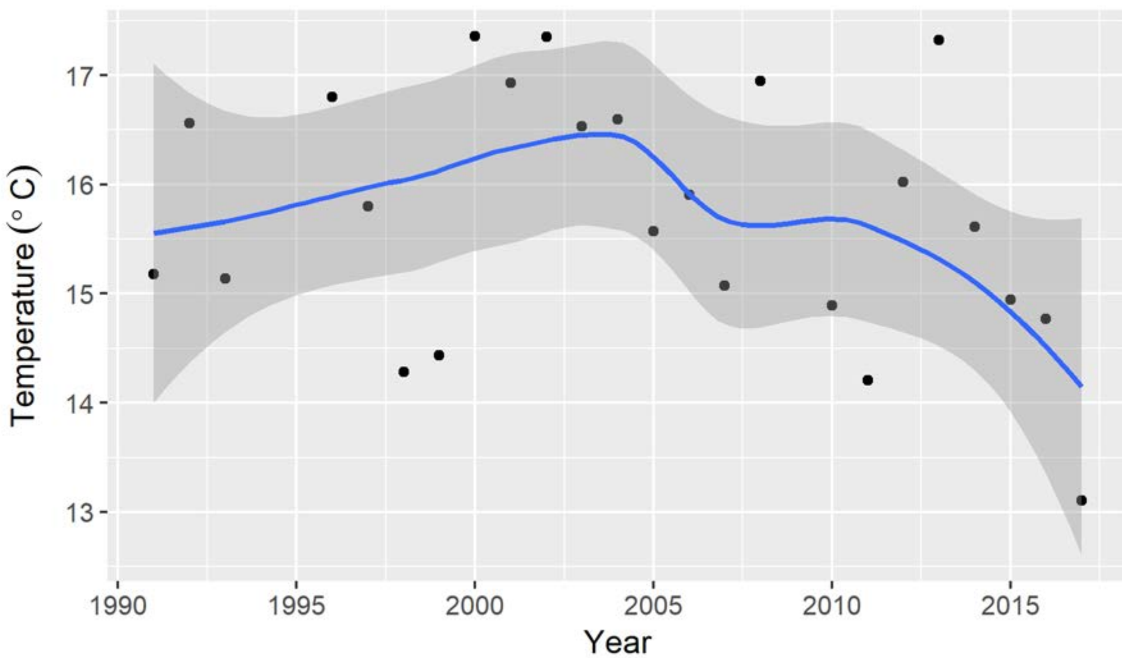


Figure 48. Station 6, Average Water Temperature Between 0 and 10 m of Depth in June

Ambient temperature greatly should affect water temperature especially at shallower depths. This relationship is very clear at shallower depths across the lake. For instance between 0 and 3 m of depth the relationship between water and air temperature yields a coefficient of determination of 0.89 (Figure 49). Hypolimnetic water it takes approximately 6 months to show any meaningful statistical relationship (Figure 50). Summer ambient temperature influences winter hypolimnetic water temperature or winter ambient temperature influences summer hypolimnetic water temperature. These relationships are much stronger only during monomixis when the lake becomes isothermal in winter. A combination of warmer summer and winter can lead to a gradual increase in hypolimnetic water temperature, which in turn can lead to earlier hatching.

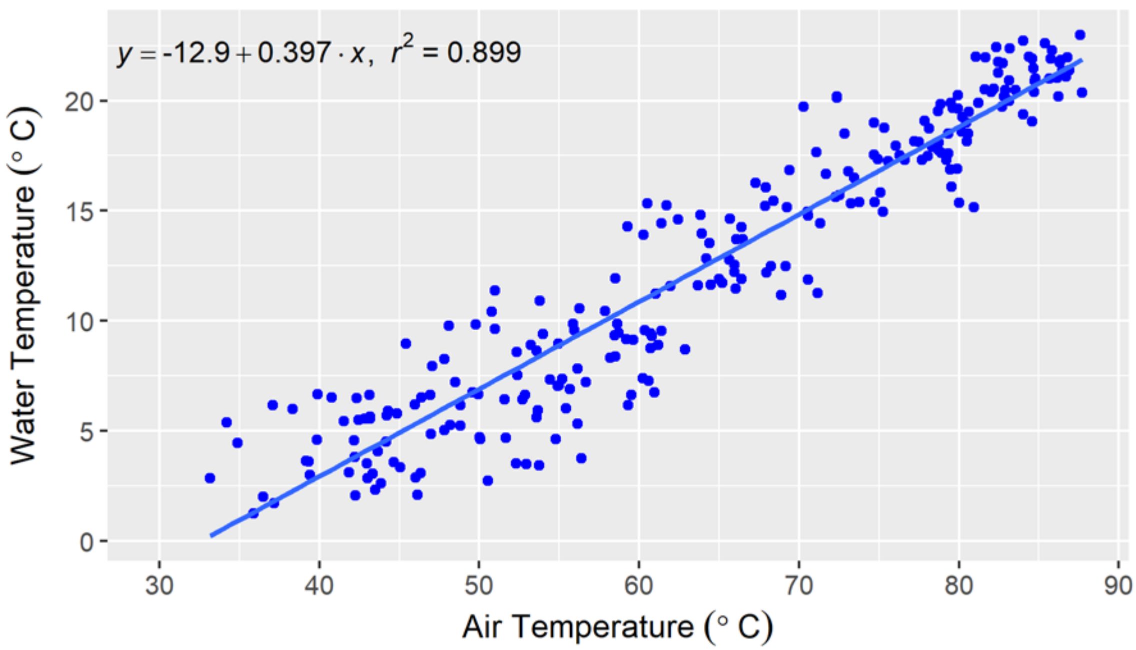


Figure 49. Station 6, Relationship Between Water and Air Temperature at Depth Between 0 and 3 m

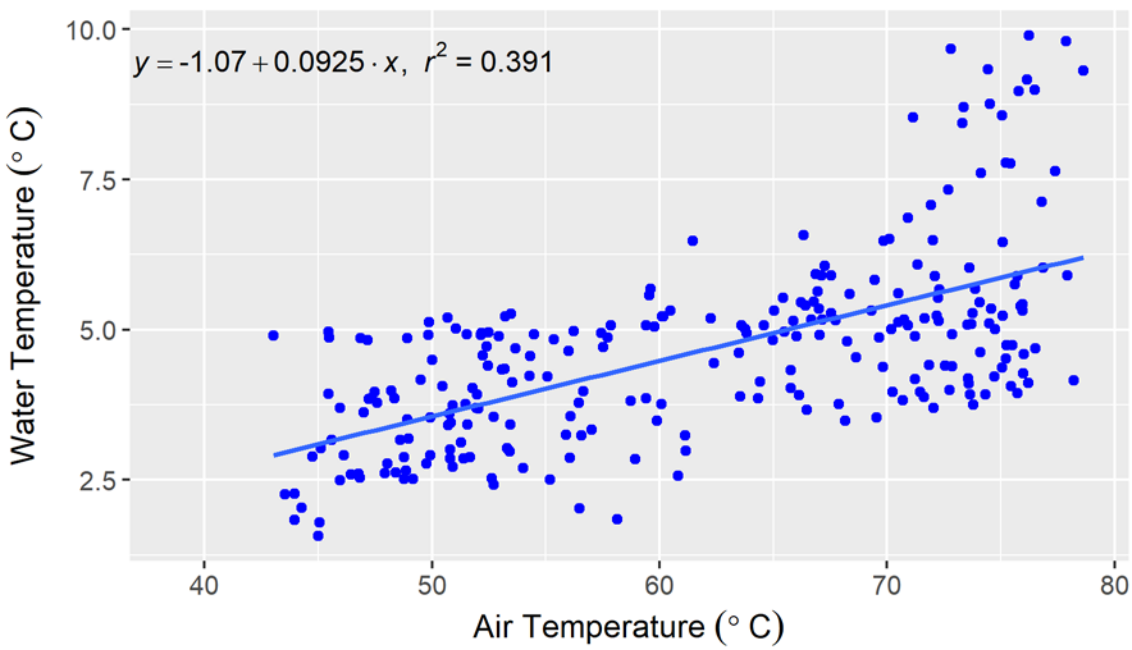


Figure 50. Station 6, Relationship Between Water and Air Temperature at Depth Between 20 and 40 m

4.2.4 Limnology Discussion

2017 Condition

The 2017 monitoring year marked the beginning of the fifth meromictic event since the beginning of the study. Mono Lake rose by 4.0 feet from 6,377.2 feet in January to 6,381.2 feet in September thanks to the second largest Mono Lake input on record. Chemocline established around 10m of depth with salinity gradient greater than 20 g/L between epilimnion and hypolimnion and weakened slightly but persisted throughout the year. As a result, the hypolimnion became suboxic to anoxic, and ammonium was deprived from the epilimnion and accumulated in the hypolimnion. The *Artemia* population continued to increase to reach 15,158 m^{-2} from the record low of 7,676 m^{-2} in 2015. Due to a continuous rebound of *Artemia* population and large influx of freshwater, clarity of the lake improved considerably from the past three years. In spite of this positive trend, the mean abundance remains below the long term average of 18.951 m^{-2}. For the second year in row a centroid (the calculated center of abundance of adults) remained above 220 days reversing the long term declining trend. Monthly instar abundance peaked in April and showed higher than the long term average in November and December.

The 2017 *Artemia* population falls within the value expected from the last population peak in 2013 (26,033 m^{-2}). The *Artemia* population tends to drop consistently during years following the population peak by the average of 45%, 30,102 m^{-2} during peaks compared to 16,570 m^{-2} for years immediately following the peak and tends to hover around this nonpeak average value during monomixis (Table 42). The *Artemia* population had declined in 2015 recording the lowest abundance on record; however, it has rebounded since then, showing resiliency of the *Artemia* population in Mono Lake. Historically the *Artemia* population also has demonstrated resiliency. The *Artemia* population has rebounded in spite of the lake level declining to the lowest level of the past century at 6,371.6 feet in December 1981 as Mono Lake input has started to increase. Salinity in the beginning of 2017 was the highest since 1991 despite of the lake level being almost 4 feet higher than during the early 1990s. Salinity has been demonstrated to affect survival, growth, reproduction, and cyst hatching of *Artemia* (Starrett and Perry 1985, Dana and Lenz 1986). Five years of drought between 2012 and 2016, the worst five year period on record, has resulted in the lake level declining from 6,383.6 feet in April 2012 to 6,376.8 feet in October 2016; consequently salinity between 0 and 10 m of depth increased from 75.7 g/L in August 2012 to 96.6 g/L in February 2017. Increasing salinity most likely contributed to lower *Artemia* abundance especially under the condition that salinity was higher than expected given lake levels during this period as discussed previously. With the second largest input into Mono Lake from tributaries salinity decreased 80.9 g/L in September and remained at 83.7 g/L in December. The *Artemia* population responded positively to declining salinity by increasing from 7,676 m^{-2} in 2015 to 15,158 m^{-2} in 2017. An amount of runoff determines lake level and salinity. Higher inputs helped the *Artemia* population to rebound in 2017.

Peak monthly instar and adult *Artemia* population abundance occurred in April and July, respectively, which is consistent with the long term trend for instar peak but not for adult peak. Hypolimnetic spring water temperature was above 3°C in 2017, higher than the average of 2.5°C found between 1991 and 1995. Chlorophyll *a* levels throughout water columns in spring also show an increasing trend since 1995. Warmer water temperature and increasing food sources in spring may have favored earlier instar peak in 2017. The adult peak, however, did not happen until July. Later monthly adult peak compared to previous years cannot be sufficiently explained by individual water parameters.

Future Condition

Future limnological condition of Mono Lake will largely depend on future runoff conditions. A lack of prolonged meromixis leads to smaller *Artemia* peaks and lower abundance during subsequent monomixis. Since the end of the third meromixis (1995-2002), the longest duration of wet period is 2 years (2005 to 2006) which resulted in three years of meromixis. Without a prolonged period of meromixis, ammonium accumulation remains magnitudes smaller than the accumulation level between 1995 and 2002.

A lack of sustained high freshwater input will also result in higher salinity. When the lake level dropped by 6.8ft salinity increased by 21 g/L to 96.6 g/L at the lake level of 6,377 feet. Not only Mono Lake becomes saltier with receding lake level, but evidence also suggests the lake has become saltier than before. Mono Lake is saltier now than at the equivalent lake levels between 1990s and 2010s. At 6,377 feet salinity was 96.6 g/L in 2017 while at equivalent lake elevation salinity was 85.1 g/L in August 1995. It is not clear what is causing the discrepancies in salinity; but lake level could further drop with drier and warmer climate forecasted for much of California in future (Ficklin et al. 2013). *Artemia* population appears to be survive and thrive in the salinity levels during monitoring years. However, further decline in the lake level could result in much higher salinity, which could approach the tolerance level (Dana and Lenz 1986).

The estimated salinity level at 6,392 feet ranges between 66 g/L and 72 g/L depending on the depth. It is not clear whether the *Artemia* population will increase beyond what has been recorded since 1987. As discussed, the *Artemia* population is strongly influenced by strength and duration of meromixis. Lower salinity certainly will result in a weaker salinity gradient or chemocline, such that Mono Lake could become holomictic much more easily than the current state. Without a strong and long lasting chemocline, ammonium accumulation would be lower, which would result in a lower *Artemia* population peak. A higher Mono Lake elevation, therefore, may have very limited impact on the lake's *Artemia* population; however, lower salinity associated with a higher Mono Lake level could lead to "invasions by predators or competitors of the brine shrimp, which could reduce productivity of the brine shrimp population" (Jones and Stokes Associates, Inc. 1994). At the same time more diverse invertebrate fauna could lead to increased food sources for shorebirds and waterfowl populations.

Summary

In 2017, Mono Lake began to stratify signaling the fifth recorded meromixis. As a result, epilimnetic nutrients were depleted while hypolimnetic nutrients started to increase, epilimnetic salinity started to decline while hypolimnetic salinity remained high, water temperature was lower than normal throughout the water column, and hypolimnetic DO remained suboxic to anoxic while epilimnetic DO was much higher in November and December. *Artemia* population abundance rebounded even though it remained below the long time average. *Artemia* daily population abundance shows a broader peak and higher than normal monthly abundance was observed for both adult and instar in later months.

Hatching of over-winter cysts would have been negatively affected by suboxic to anoxic condition and also higher salinity in the hypolimnion. In spite of very low hypolimnetic DO levels and a normal range of epilimnetic DO more instars were able to survive to become adults in 2017 than 2016. The *Artemia* population abundance mean was still below the long term average but higher than the previous 3 years. Higher adult population abundance also lead to more intense grazing resulting in much higher clarity than previous 3 years. With a large influx of freshwater, epilimnetic salinity started to decline resulting in higher epilimnetic DO levels which, in turn, have enhanced survivorship of both adults and instars and also hatching of nauplii in later months. A lack of holomixis in 2017 ensures further buildup of nutrients in the hypolimnion even though the hypolimnetic ammonium in December is still below the long term average. A duration of the current meromixis depends on snow accumulation and subsequent runoff in 2018. A longer meromixis results in a larger buildup of nutrients in the hypolimnion and a higherpeak of *Artemia* abundance during breakup of the meromixis.

Limnology Monitoring Program Evaluation

The current limnology monitoring program was started in 1998 as a part of the Plan although some limnological work on Mono Lake had been conducted since the late 1970s. *Artemia* adult population statistics date back to 1979 while 9-m integrated data for ammonium and chlorophyll *a* is available as far back as1987 and other water parameter data exist since either 1991 or 1994. It has been well-documented that the lake mixing regime greatly influences *Artemia* population dynamics and water parameters. A wealth of data has accumulated over the years and has led to a better understanding of Mono Lake limnological processes. The 2013 Settlement Agreement (SWRCB 2013) states that the Periodic Overview Report "shall evaluate trends and make recommendations for changes to the Waterfowl Program to increase effectiveness or reduce cost". An analysis was therefore conducted using all available data to evaluate the limnological program to determine if changes could be made to reduce cost, while maintaining the ability to assess the long term health of the waterfowl habitat on Mono Lake. The results of this analysis suggest that both temporal and spatial reductions in monitoring effort could be made, and thus a proposed modification to the limnological monitoring program is presented.

In 2011, Dr. Brian White, the Waterfowl Program Director at that time, evaluated available data and suggested that the monitoring program could be reduced. Dr. White presented a proposed reductions to the SWRCB, but these changes were met with opposition from the Parties and no changes were implemented.

For this report, an independent analysis of the program was conducted. The results of this analysis suggest that the current monitoring program can be scaled back by:

1. reducing a number of stations to monitor water parameters and *Artemia* population (spatial reduction) and/or
2. by reducing a number to visitations to the designated stations (temporal reduction).

Currently, conductivity and temperature are monitored at Stations 2 through 8, 10 and 12 (9 stations in total), 9-m integrated samples for ammonium and chlorophyll *a* are taken at Stations 1, 2, 5 through 8, and 11 (7 stations in total), and the *Artemia* population is sampled at all 12 stations. At Station 6 ammonium and chlorophyll *a* samples are taken from seven different depths (2, 8, 12, 16, 20, 24, and 28 m) and dissolved oxygen is recorded at every meter to the depth of around 38 m. Conductivity, temperature, 9-m integrated and *Artemia* population monitoring can be reduced in both time and space while dissolved oxygen and depth profiles of ammonium and chlorophyll *a* can be only reduced in time since these parameters are only monitored at one station.

All parameters of interest are currently sampled at Station 6, and this station will continue to be monitored in the future; thus, it is recognized that Station 6 should be used as the basis of spatial comparison. The adequacy of Station 6 to represent the entire lake was tested by correlating water parameters (temperature, conductivity, and 9-m integrated ammonium and chlorophyll *a*) to the remaining stations. For conductivity and temperature, the depth profiles for each monitoring month at Station 6 were correlated to the depth profiles for the corresponding months at the other eight stations. Monthly values based on 9-m integrated ammonium and chlorophyll at Station 6 were correlated to those recorded at the remaining six stations.

Annual statistics (mean, median, peak and centroid) are indices calculated based on the lakewide averages of adult *Artemia* population. Adult *Artemia* population counts at each station, thus, were correlated against each of the annual statistics in order to determine the representativeness of station. A series of correlations were performed between the lakewide annual statistics and monthly *Artemia* population counts which consisted not only the counts for all monitored months, but also summaries for various time periods, such as spring (sum of monthly counts between March and May) and summer (sum of monthly counts between June and August) (Table 44). Annual statistics were also calculated for each station and compared to the lakewide annual statistics.

Table 44. Descriptions of Monthly *Artemia* Population Count Variables used in Correlation Analysis

Variable Name	Description
Jan to Dec	Monthy count of the month
Total	Sum of monthly counts between January and December
Mean	Average of monthly counts between January and December
Peak	Peak monthly counts between January and December
Spring	Sum of monthly counts between April and May
Early.Summer	Sum of monthly counts between May and July
Summer	Sum of monthly counts between June and August
Peak.Summer	Sum of monthly counts between June and July
Late.Summer	Sum of monthly counts between July and September
Apr.to.Dec	Sum of monthly counts between April and December
Apr.to.Nov	Sum of monthly counts between April and November
Apr.to.Oct	Sum of monthly counts between April and October

Artemia population samples are further processed in the lab to estimate the population for each station. *Artemia* individuals are classified into instars, juvenile, female, and male. At 7 stations, instars are further classified into one of seven stages. The instar population count provides insight into how many cysts or/and nauplii have hatched but it appears to be poor predictor of the adult population statistics. Monthly *Artemia* instar population counts were first correlated against the lakewide annual statistics, and then to the adult population counts at each station in order to quantify the relationship between instar and adult numbers. The following variables for adult and instar were used to perform correlation analysis (Table 45). Instar variables mainly contain averages and peaks during the spring months, when instar monthly peaks tend to occur, while adult variables contain averages and peaks during summer months when the peak adult numbers tend to occur.

Table 45. Descriptions of Monthly Instar and Adult *Artemia* Population Count Variables used in Correlation Analysis

Variable Name	Description
Feb.Mar	Average or Peak between Febraury and March
Mar.Apr	Average or Peak between March and April
Spring	Average or Peak between March and May
May.Jun	Average or Peak between May and June
Jun.Jul	Average or Peak between June and July
Summer	Average or Peak between June and August
Late.Summer	Average or Peak between July and September
Fall	Average or Peak between September and November
Grow	Average or Peak between April and September
First	Average or Peak between February and June
Second	Average or Peak between July and December

Detailed Results of the Analysis

Table 46 shows the correlation coefficient calculated using the depth profiles of conductivity and temperature between Station 6 and the eight other stations. The depth profiles of conductivity and temperature at 8 stations (2, 3, 4, 5, 7, 8, 10, and 12) show very high degrees of similarity to those recorded at Station 6, indicating that Station 6 can be used as a representative of 8 stations. The majority, (over 75%) of the correlation coefficients were greater than 0.95, and 84% of the correlation coefficients were greater than 0.90. Similar results were found for 9-m integrated ammonium and chlorophyll *a* (Table 47). Not only was Station 6 extremely similar to other 5 stations, but all stations were similar to each other. Correlation coefficients for ammonium ranged from 0.90 to 0.95 for the comparisons between Station 6 and the other stations. For a comparison of all stations, correlation coefficients ranged from 0.86 to 0.97, averaging 0.93. Stations in closer proximity to one another show stronger correlations than stations located further apart. Correlations for chlorophyll *a* were stronger than those for ammonium ranging from 0.96 to 0.98 with the average of 0.97 for Station 6 and ranging from 0.94 to 0.98 with the average of 0.97 for all stations.

Table 46. Frequencies of Correlation Coefficients between Station 6 and 8 Other Stations for Conductivity and Temperature

				Conductivity					
Correaltion	Sta 2	Sta 3	Sta 4	Sta 5	Sta 7	Sta 8	Sta 10	Sta 12	All
>0.95	207	187	193	163	242	151	143	185	76%
0.9 to 0.95	25	17	17	25	15	23	16	15	8%
0.8 to 0.9	14	10	5	19	7	25	15	11	5%
0.5 to 0.8	10	7	6	17	5	16	3	10	4%
<0.5	27	7	7	24	19	27	10	4	6%
Total	283	228	228	248	288	242	187	225	
				Temperature					
Correaltion	Sta 2	Sta 3	Sta 4	Sta 5	Sta 7	Sta 8	Sta 10	Sta 12	All
>0.95	210	191	197	165	242	156	148	185	77%
0.9 to 0.95	24	13	10	23	14	23	15	16	7%
0.8 to 0.9	12	9	9	20	10	24	11	11	5%
0.5 to 0.8	14	11	4	22	7	16	2	7	4%
<0.5	23	6	8	18	15	24	11	6	6%
Total	283	230	228	248	288	243	187	225	

Table 47. Correlation Coefficients Among 7 Stations for 9 m Integrated Ammonium and Chlorophyll *a*

	Sta 1	Sta 2	Sta 5	Sta 6	Sta 7	Sta 8
			Ammonium			
Sta 2	0.97					
Sta 5	0.93	0.95				
Sta 6	***0.91***	***0.95***	***0.94***			
Sta 7	0.90	0.93	0.93	***0.96***		
Sta 8	0.88	0.92	0.94	***0.96***	0.98	
Sta 11	0.86	0.89	0.90	***0.92***	0.94	0.92
			Chlorophyll a			
	Sta.1	Sta.2	Sta.5	Sta.6	Sta.7	Sta.8
Sta.2	0.98					
Sta.5	0.98	0.98				
Sta.6	***0.97***	***0.97***	***0.98***			
Sta.7	0.96	0.97	0.97	***0.97***		
Sta.8	0.97	0.97	0.97	***0.98***	0.98	
Sta.11	0.94	0.96	0.96	***0.96***	0.98	0.98

Correlation coefficients between the lakewide annual statistics and monthly counts of *Artemia* population are presented in Table 48. For the lakewide mean, variables derived from monthly counts at Station 9 show very strong correlation followed by Stations 6 and 4 while monthly variables from the same 3 stations show strong correlations with the lakewide median even though correlations are weaker compared to the lakewide mean. The lakewide peaks show strong correlations with monthly variable derived from Station 10 followed by Stations 9 and 4. The lakewide centroid shows weaker correlations than the 3 other lakewide statistics as the strongest correlation was found to be 0.79 compared to 0.96 for the mean, 0.86 for the median, and 0.93 for the peak. Based on *Artemia* monthly counts, Stations 4, 6, 9 and 10 follow the lakewide annual statistics closely, especially the annual mean and peak.

Table 48. Correlation Coefficients calculated between Lakewide Annual Statistics and Monthly Counts of Adult *Artemia* Population

Lakewide annual statistics	Monthly Variable	Station	r	Lakewide annual statistics	Monthly Variable	Station	r
Mean	Apr.to.Oct	9	0.96	Peak	Apr.to.Oct	10	0.93
	Apr.to.Nov	9	0.96		Early.Summer	10	0.93
	Total	9	0.96		Apr.to.Nov	10	0.93
	Apr.to.Dec	9	0.96		Total	10	0.93
	Mean	9	0.94		Apr.to.Dec	10	0.93
	Early.Summer	9	0.93		Early.Summer	9	0.92
	Apr.to.Oct	6	0.92		Peak	4	0.92
	Apr.to.Nov	6	0.92		Mean	10	0.92
	Peak	4	0.91		Jun	10	0.89
	Total	7	0.91		Apr.to.Oct	9	0.89
Median	Total	9	0.86	Centroid	Sep	8	0.79
	Apr.to.Dec	9	0.86		Oct	2	0.78
	Apr.to.Oct	9	0.86		Sep	3	0.75
	Apr.to.Nov	9	0.86		Oct	8	0.74
	Mean	9	0.85		Sep	4	0.74
	Apr.to.Oct	4	0.83		Sep	6	0.74
	Apr.to.Nov	4	0.83		Oct	5	0.74
	Apr.to.Dec	4	0.83		Oct	3	0.74
	Total	4	0.83		Sep	5	0.72
	Apr.to.Oct	6	0.82		Oct	12	0.72

**Only 10 highest correlations are presented in Table 47.*

When annual statistics calculated at each station were compared to the lakewide annual statistics, Stations 6 and 9 were found to be strongly correlated to the lakewide mean with correlation coefficients of 0.95 and 0.91, respectively, while Stations 10, 6, and 4 were found to be strongly correlated to the lakewide centroid with correlation coefficients of 0.95, 0.94, and 0.90, respectively (Table 49). The medians and peaks did not show correlations as strong as the means and centroids. A combination of monthly counts and annual statistics at 4 Stations (4, 6, 9, and 10) appear to be able to predict the lakewide annual statics.

Table 49. Correlation Coefficients between the Lakewide Annual Statistics and Annual Statistic Calculated at Each Station

	Mean	Median	Peak	Centroid
Sta 1	0.33	0.45	0.30	0.86
Sta 2	0.84	0.78	0.73	0.84
Sta 3	0.71	0.62	0.62	0.81
Sta 4	0.87	0.80	0.80	0.92
Sta 5	0.77	0.76	0.53	0.90
Sta 6	0.91	0.71	0.82	0.94
Sta 7	0.89	0.83	0.73	0.88
Sta 8	0.85	0.76	0.87	0.86
Sta 9	0.95	0.87	0.86	0.88
Sta 10	0.83	0.83	0.85	0.95
Sta 11	0.63	0.67	0.56	0.80
Sta 12	0.86	0.78	0.71	0.86

Monthly instar *Artemia* population counts are poorer predictors of the lakewide annual statistics (Table 50). Stronger correlations were found for monthly variables taken during later months of the year after the peak adult population had already occurred, except in earlier years of the limnology monitoring. When the variables associated with monthly counts were tested, (Sep, Oct, Nov, and Dec), the strongest correlation was 0.57 (Centroid and Early Summer) which could only explain less than 36% of variation in changes associated with the lakewide annual statistic. Within each station, monthly instars *Artemia* population counts were also found very poor predictors of monthly adult *Artemia* population counts as most of correlations fell between -0.5 and 0.5 (Figure 51). The pattern did not change when only the selected monthly variables were used (Figure 52). The average correlation coefficients for all, and selected monthly variables were 0.05 and 0.10, respectively. These results indicate that higher abundance of instar does not necessary lead to higher abundance of adult or vice versa.

Table 50. Correlation Coefficients calculated between Lakewide Annual Statistics and Monthly Counts of Instar *Artemia* Population

Lakewide annual statistics	Monthly Variable	Station	r	Lakewide annual statistics	Monthly Variable	Station	r
Mean	Dec	12	0.62	Peak	Sep	9	0.68
	Sep	9	0.61		Dec	12	0.57
	Peak	11	0.44		Peak	4	0.46
	Peak	3	0.44		Total	4	0.42
	Total	3	0.43		Peak	11	0.42
	Total	4	0.43		Peak	3	0.42
	Peak	4	0.42		Oct	11	0.40
	Jun	3	0.42		Mean	4	0.39
	Jun	11	0.41		Jun	3	0.39
	Early.Summer	11	0.41		Apr.to.Oct	4	0.39
Median	Sep	9	0.54	Centroid	Nov	7	0.63
	Oct	12	0.36		Dec	12	0.60
	Dec	12	0.35		Nov	8	0.59
	Oct	11	0.35		Early.Summer	3	0.57
	Peak	11	0.29		Early.Summer	11	0.57
	Nov	12	0.29		Summer	11	0.56
	Jul	1	0.27		Peak.Summer	11	0.56
	Sep	7	0.27		Jun	11	0.55
	Total	3	0.27		Early.Summer	4	0.55
	Sep	12	0.26		Peak.Summer	3	0.53

*Only 10 highest correlations are presented in Table 47.

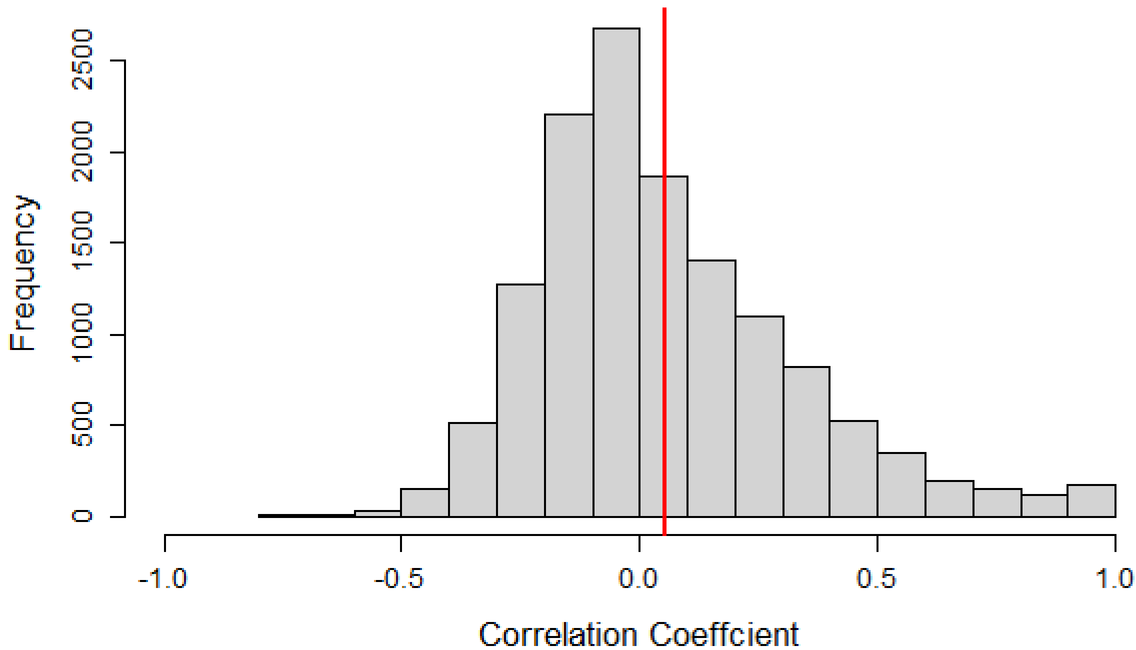
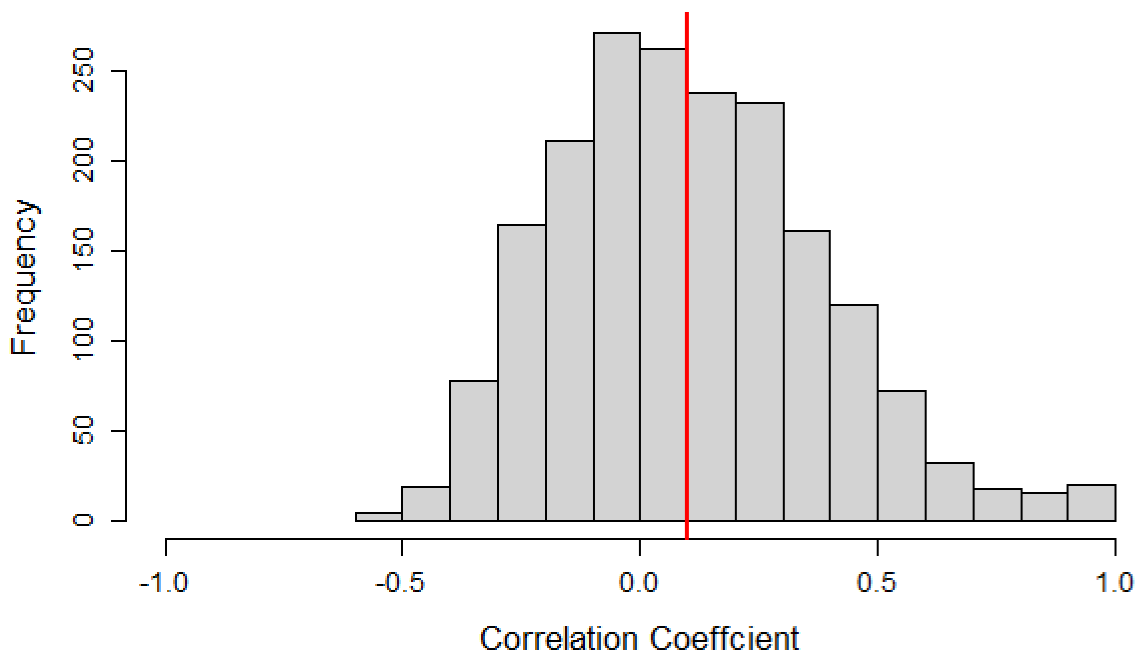


Figure 51. Histogram describing the Distribution of Correlation Coefficients between instar and adult *Artemia* population counts based on the selected



Monthly Variables

Figure 52. Histogram describing the Distribution of Correlation Coefficients Between Instar and Adult *Artemia* Population Counts based on the Monthly Variables

Recommendations and Justification

Station 6 is an adequate representation of the water parameters of Mono Lake when compared to all other stations where water parameters have been monitored. The water parameters at each of the monitoring stations have been remarkably similar over time. Station 6 is recommended as the station to continue to evaluate the depth profiles of dissolved oxygen, ammonium, and chlorophyll *a*. as the most consistent dataset exists for this station. Although temperature and conductivity profiles, and the 9 m integrated values for ammonium, chlorophyll a have also varied little between stations and Station 6 alone could be used as an index, it is recommended that this data also be collected at all four stations that are being proposed for long-term monitoring, in order to allow the ability to evaluate spatial patterns.

The *Artemia* annual statistics are based on *Artemia* population between May and November because very few to no adults are recorded between February and April. Both monthly counts and annual statistics at Stations 4, 6, 8, and 10 are strongly correlated to the lakewide annual statistics; thus, monthly counts only between May and November are adequate to estimate the lakewide annual statistics. Due to a seasonal shift of adult monthly peaks observed, April is added in order to detect this trend. In addition the relationships are much stronger when April is included into monthly variables; thus improving the estimation of the lakewide statistics.

Artemia instars are most abundant between February and May, peaking between March and April. Dropping February and March will result in a loss of instar abundance when they are hatching and growing. Correlations between instar and adult *Artemia* abundance are, however, very weak averaging 0.1, indicating that instar abundance during earlier months of the year is a very poor predictor of adult abundance later in the year. *Artemia* is considered as a food source for migrating waterfowl which utilizes Mono Lake most heavily from later summer through fall. It has been demonstrated that instar abundance is incapable of predicting the abundance during the peak season of waterfowl usages, there is very little basis for continuous monitoring in February and March.

Instar analysis has been performed at 7 stations. Instar or nauplii *Artemia* individuals are classified into 7 different stages (instar stages 1 through 7). Population estimates using the individual stages have been rarely used when *Artemia* population has been summarized in the past. *Artemia* development into adults is influenced by a combination of factors, including temperature and food sources. Due to this complex relationship, information regarding the instar stages does not provide any additional insight into adult *Artemia* abundance.

For the *Artemia* fecundity analysis, the only station among seven current stations which would continue to be monitored under this proposed modification is Station 6; thus, it is difficult to compare the new stations to the old stations. It is, however, recognized that variability in female lengths and numbers of eggs within each station is as great as or greater than variability among stations, such that a comparison of fecundity data among stations is meaningless, indicating that not enough samples are taken at each station. Only the average of 7 stations has been reported in the past. If a number of individual samples is increased from 12 to 20 at each station while reducing a number of stations from seven to four, a total number of samples per month will remain roughly the same as before, 80 samples from 4 stations compared 82 samples from 7 stations. The same objective will be achieved.

No analysis was performed regarding Secchi readings, but as the case for water parameters, Secchi readings across the lake are very similar. The seasonal pattern is almost identical each year except during summer months as *Artemia* grazing intensifies. Transparency during summer months shows a declining trend as described in this report. Monitoring Secchi readings at the proposed four stations in February and April through November will, therefore, adequately represent the entire lake and capture the long term trend of lake transparency.

As discussed previously, monitoring of the *Artemia* population between April and November would provide sufficient data to continue to calculate annual *Artemia* population statistics to evaluate long-term trends. Water parameter monitoring should also occur during the same months, April through November. *Artemia* starts emerging in mass in February and March; however, it has been demonstrated that instar abundance does not correlate strongly with adult abundance; thus, water parameters collected in February and March may be important for instar population but is less likely to be relevant for the adult population. Water parameters collected in December have very little impact on the *Artemia* population, whose peak generally occurs between May and August, and also on migrating waterfowl, whose peaks generally occur in September. The continued monitoring of the hypolimnetic water temperature in the winter, however, is recommended as there may be implications related to long term trends of Mono Lake. The data show a recent pattern of increasing hypolimnetic winter temperatures, and with a warming climatic trend, this trend may continue. The coldest hypolimnetic water temperature has been recorded in February; thus, in addition to April to November, hypolimnetic water temperature should be monitored at 4 stations in mid-February.

Summary of Specific Recommendations for Limnology Monitoring Program
Based on the analysis above, the following recommendations for future limnology monitoring are presented below:

1. Conduct *Artemia* sampling at Stations 4, 6, 9 and 10 monthly from April through November to estimate the lakewide annual statistics
2. Continue monitoring a depth profile of dissolved oxygen, ammonium, and chlorophyll *a* at Station 6 monthly from April through November
3. Conduct CTD (conductivity and temperature), Secchi depth, and 9-m integrated sampling for ammonium and chlorophyll *a* at Stations 4, 6, 9, and 10 from April through November
4. Conduct additional CTD monitoring at Stations 4, 6, 9, and 10 in February
5. Conduct Secchi disk reading at Stations 4, 6, 9, and 10 in February and April through November
6. Discontinue *Artemia* instar analysis in the future
7. Conduct *Artemia* fecundity analysis at Stations 4, 6, 9, and 10 from June through October
8. Continue all other monitoring not mentioned above e.g. Meteorological

4.3 Vegetation Status in Riparian and Lake-Fringing Wetlands

Vegetation and waterfowl habitats are being monitored at Mono Lake in order to evaluate the response to restoration. The re-establishment of perennial flow in the tributaries and increasing lake level were expected to have significant effects on the vegetation resources at Mono Lake (Drewien, Reid, and Ratcliff 1996). Three separate projects are being conducted to monitor the vegetation status in riparian and lake-fringing wetlands are:

1) vegetation transect monitoring at wetland and riparian sites,
2) mapping of the Mono Basin shoreline habitats, and
3) annual still photographs taken in association with waterfowl surveys.

The vegetation transect monitoring and mapping have been conducted by LADWP Watershed Resources staff. The annual still photographs were taken by Deborah House, LADWP Watershed Resources Specialist.

Riparian Wetlands

Riparian vegetation is found primarily along west shore sites where it is associated with perennial creeks. Within the areas influenced by the Plan, riparian wetlands are found primarily along Rush Creek, Lee Vining Creek, and Mill Creek. Creeks in the Mono Basin arise from glaciated valleys and are underlain primarily by deltaic gravels and young volcanic rocks (McBain and Trush, Inc. and R. Taylor and Associates 2010). Woody species including black cottonwood (*Populus balsamifera*), willows (i.e. *Salix lutea* and *S. exigua*), and Jeffrey Pine are common. Along the perennial creeks, wet meadow vegetation is restricted to the immediate stream banks, the deltas, and depressions in the floodplains.

Lake-Fringing Wetlands

Vegetation resources along the shoreline of Mono Lake are greatly influenced by the presence of streams and springs. In some shoreline areas, water table fluctuations influence annual changes in lake-fringing wetlands. Shoreline water resources are varied and include freshwater ponds, brackish ponds, hypersaline ponds, and mud flats. Wetland meadows occur in the vicinity of springs, ponds, and creeks. Alkali wet meadow, dominated by saltgrass (*Distichlis spicata*) and Baltic rush (*Juncus arcticus*), is abundant. This vegetation type typically provides near total canopy cover and may be seasonally flooded. In contrast, wet meadow areas are semi-permanently flooded areas that are more diverse than alkali wet meadow, supporting rushes (*Juncus* spp.), spikerushes (*Eleocharis* spp.), and sedges (*Carex* spp.). Marsh vegetation often occurs in association with both meadow types, and support species such as hard-stem bulrush

(*Schoenoplectus acutus*), cattail (*Typha latifolia*), and three square (*Schoenoplectus americanus*). Small isolated patches of the riparian shrub *Salix exigua* also occur at the freshwater springs around the lake.

Lake-fringing habitats also include areas where waters of lower salinity intercept the highly saline water of Mono Lake. This occurs at creek deltas, and where the flow of fresh water or brackish water springs enter the lake. These areas have been referred to as hypopycncal zones, and they occur where lower density, less saline water floats on top of higher density, more saline water. The extent, depth, and mere presence of a hypopycnal zone is expected to vary with velocity of spring or creek flow, as well as the degree of mixing that occurs due to wind and wave action. Hypopycnal zones were historically hypothesized as being highly valuable for waterfowl and that waterfowl using these hypopycnal areas are essentially in a freshwater environment (Stine 1995) and were able to use food resources (presumably *Artemia*) at or just below the fresh water lens.

4.3.1 Vegetation Monitoring Methodologies

Vegetation Transect Monitoring

Small scale vegetation monitoring is being conducted at riparian and lake-fringing wetland sites using the line-point intercept method to determine species composition and cover (LADWP 2015a). Vegetation monitoring has been conducted at permanently marked transects in wetland areas of DeChambeau Embayment, Warm Springs, and Simons Springs. In lower Rush Creek and lower Lee Vining Creek, monitoring is conducted in the riparian and delta areas, however transects are not physically marked. Vegetation transect monitoring was initiated in 1999, and has been conducted approximately every five years (1999, 2005, 2009, 2014) by LADWP Watershed Resources staff.

Lake-Fringing Wetlands

Landtype mapping is being conducted by LADWP to monitor changes in the extent of lake-fringing wetland as a basis for evaluating waterfowl habitat (LADWP 2015b). Aerial imagery has been used to map landtypes of the Mono Basin approximately every five years. Mapping areas have included the shoreline as well as upland areas up to the pre-diversion high water mark. The amount of acreage mapped each time has varied with lake elevation. The mapped acreage increases when the lake level drops, as the area mapped is then extended down to the new water line.

Landtype mapping has been conducted four times since implementation of the Plan, encompassing a maximum elevation difference of 4.8 feet. The lowest lake elevation at which mapping has been conducted was 6,379.6 feet in 2014, while the highest elevation was 6,384.4 feet in 1999. Between 1998 and 2017, however, the lake has experienced a broader range of elevation from a low of 6,377.1 feet in 2017 to a high of 6,385.1 feet in 1999 and 2006, or a total elevation range of 8.0 feet.

The fifteen mapped landtypes are based on those used to predict future waterfowl habitat (Chapin 2000) plus additional vegetation types present in the surrounding areas. Descriptions of mapped landtypes can be found in LADWP (2015b). Improved imagery, mapping software and techniques have likely resulted in enhanced accuracy and precision of landtype mapping in progressive years (LADWP 2015b).

Freshwater stream areas are water channels unobstructed by vegetation. The acreage of this habitat type has remained relatively consistent since 1999 (LADWP 2015b), and it is relatively straightforward to identify from aerial images. The remaining water resources categories are more difficult to map accurately from aerial images, as proper classification of ponded water types requires knowledge of the water source. For example, ephemeral brackish ponds and ephemeral hypersaline ponds were defined as differing from one another based on the presence or absence of vegetation. Shoreline ponds lacking vegetation have traditionally been mapped as hypersaline, although during periods of lake elevation change, brackish or freshwater ponds may develop and will often lack vegetation for up to two years due to a lag time for succession to occur (D. House, pers. obs.). Freshwater ponds may also be difficult to discern from other ponded habitat types without an understanding the of water resource types present.

Annual Aerial Photography

Annual aerial photographs are required by Order 98-05 in order to document annual shoreline vegetative conditions and provide more complete information to assess shoreline changes. The SWRCB determined that aerial imagery and subsequent mapping studies performed at five year intervals would not be sufficient to evaluate rapid shoreline changes that may occur, and would be of limited value for use in adaptive management of ongoing restoration activities (SWRCB 1998). Still photos were taken of lake-fringing habitats annually during fall between the months of September and November from a helicopter. Photographs were taken of all shoreline subareas at Mono Lake, Bridgeport Reservoir and Crowley Reservoir.

4.3.2 Vegetation Data Summary and Analysis

Vegetation Transects

The vegetation transect data as presented in *2014 Mono Lake Vegetation Monitoring Report* (LADWP 2015a) was reevaluated in terms of the waterfowl habitat quality for the purpose of this analysis. Plant species recognized as waterfowl food items based on Martin and Uhler (1939) were identified for each of the four monitoring sites: DeChambeau Embayment, Warm Springs, Simons Springs, Rush Creek and Lee Vining Creek. The mean total cover from all transects was calculated for each sampling year: 1999, 2004, 2009, and 2014.

Lake-Fringing Wetlands

An assessment of lake-fringing wetlands was conducted for all areas at or below 6,392 foot elevation. Almost all waterfowl activity has occurred within close proximity to shore, thus the average target lake elevation selected as the uppermost contour. This would include all lake elevations observed since implementation of the Plan, exclude large amounts of upland habitats, and allow for a focused assessment of lake-fringing waterfowl habitats.

LADWP (2015b) discussed the challenges associated with mapping habitats at Mono Lake. For analysis, the original mapped landtypes were collapsed into fewer categories based on whether they represented discrete habitat types and were easily discernible through landtype mapping. The landtypes used for further analysis will be referred to as "modeled landtypes" and the crosswalk provided in Table 44.

The acreages of mapped and modeled landtypes were summed for 1999, 2004, 2009, and 2014 for the entire shoreline for areas at or below 6,392 foot elevation. The resulting map file was further divided into 15 polygons, representing the shoreline subareas used to evaluate waterfowl spatial distribution (see Section 4.4 of this report). The mapped and modeled landtypes were then summed by shoreline subarea.

The effect of lake elevation on lake-fringing waterfowl habitats was evaluated. In order to estimate the habitat acreage in non-mapping years, various parameters of lake elevation were tabulated to be used as predictor variables. The lake elevation parameters used included monthly lake elevations, and 2, 3, 6, and 12 month running averages. For each segment and habitat type, a series of multiple linear regressions were performed, and the best model selected to describe the relationship between the various lake elevation parameters and habitat. These models were then used to predict the acreages of each habitat for years between sampling periods.

Pearson correlation was used to evaluate relationships between lake elevation and the modeled landtypes at the lake level, and by shoreline subarea. The results of the mapping by subarea were combined with the annual aerial photographs to describe the quantitative and qualitative changes in shoreline conditions in response to lake elevation changes.

Table 51. Cross-Walk of Mapped vs. Modeled Landtypes

Mapped Landtype	Modeled Landtype
Barren lake bed	Barren lake bed
Manmade	Manmade
Alkaline wet meadow	Meadow/Marsh
Dry meadow/forb	Meadow/Marsh
Marsh	Meadow/Marsh
Wet meadow	Meadow/Marsh
Ria	Ria
Riparian shrub	Riparian
Riparian woodland	Riparian
Great Basin scrub	Upland scrub
Ephemeral brackish pond	Water
Freshwater pond	Water
Hypersaline pond	Water
Freshwater stream	Water
Mudflat	Water

The digital bathymetric model of Mono Lake (Pelagos Corporation 1987, Raumann et al. 2002), was also used to evaluate near-shore waterfowl habitat. The raster-based digital elevation model (DEM) developed by Raunmann et al. (2002) served as the basis for generating one-foot contours that were clipped at the Mono Lake water surface evident on the 2017 imagery. Near-shore water depth was inferred from contour spacing.

Annual Aerial Photographs

The annual photographs of waterfowl habitats at Mono Lake, Bridgeport Reservoir and Crowley Reservoir were reviewed, compiled, and are included as appendices. Representative photos from each shoreline subarea were selected for each year, including photos of comparable views when possible. The annual photos, combined with field notes, were used to help evaluate and describe yearly changes in shoreline conditions. Annual photos of Mono Lake are provided as Appendices 2-18, Bridgeport Reservoir as Appendix 24, and Crowley Reservoir as Appendices 25-31.

4.3.3 Vegetation Status in Riparian and Lake-Fringing Wetlands Results

Vegetation Transects

Detailed vegetation monitoring transect data and information on transect locations can be found in the *2014 Mono Lake Vegetation Monitoring Report* (LADWP 2015a), and Appendix 23 provides a list of the scientific and common names as provided by the U.S. D. A. Natural Resources Conservation Service (https://plants.usda.gov/java/), of the plant species classified as waterfowl foods.

The mean cover of food plants has been highest at the DeChambeau Embayment site (Figure 51), and chairmaker's bulrush (*Schoenoplectus americanus*) has been the dominant species (Table 45). Warm Springs also supports very high cover of waterfowl food plants, although cover has decreased over the last two sample periods. Nevada bulrush (*Scirpus nevadensis*) and chairmaker's bulrush are the two most dominant species (Table 47). The decrease in live cover seen in 2009 and 2014 has been accompanied by an increase in dead wetland vegetation. The cover of waterfowl food plants at Simons Spring was similarly high during the 1999 sampling, but has since decreased significantly. As was seen at Warm Springs, dead plants (litter) increased significantly in 2009 and 2014. Sedges (*Carex* spp.) are most abundant at Simons Spring, with lesser amounts of bulrush (Table 46). The cover of waterfowl food plants in Rush Creek delta has increased from below 5% in 1999, to over 20% in 2014. Much of this increase has been due to the expansion of field horsetail (*Equisetum arvense*) (Table 48). Unlike the wetland sites, the amount of litter decreased, and notably, bare ground was not present in 2009 or 2014. The cover of water has decreased notably in along the Rush Creek delta transects. The cover of waterfowl foods has increased slightly in Lee Vining Creek also, from less than 2% cover to approximately 7% cover, but the cover of appropriate food items is still very low as compared to the other sites monitored. Lee Vining Creek supports very limited amounts of sedges and bulrush (Table 49). As was seen at Rush Creek, bare ground and litter have essentially disappeared from the Lee Vining Creek delta. Water has also been absent the last two sampling periods.

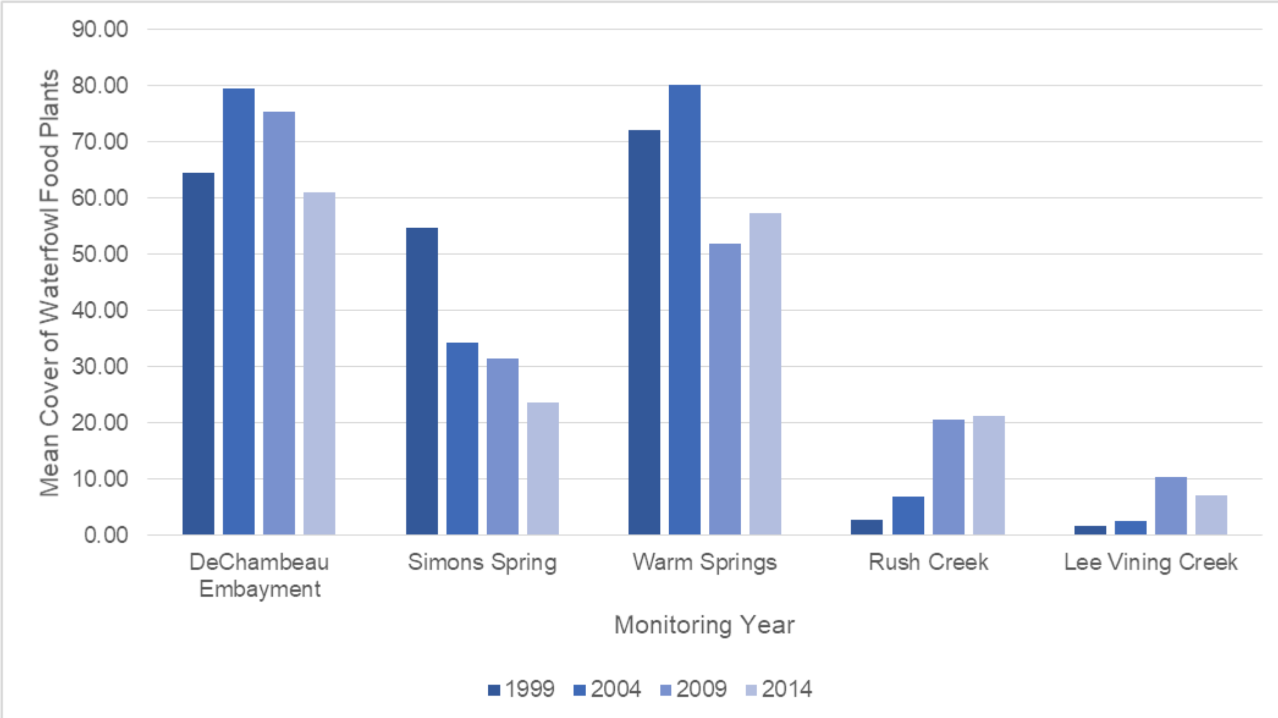


Figure 53. Waterfowl Food Plant Species Cover at the Wetland and Riparian Transect Sites

Table 52. Yearly Mean Percent Cover of Waterfowl Food Plant Species at DeChambeau Embayment, Averaged over the Three Transects

DeChambeau Embayment	**1999**	**2005**	**2009**	**2014**
Carex rostrata	0.2			
Chenepodaceae	2.7			3.1
Chenopodium album			3.0	3.3
Distichlis spicata	14.2	4.7	5.0	5.8
Hordeum jubatum	20.9	7.1	4.1	9.6
Rumex salicifolius			0.4	
Schoenoplectus acutus		0.2	3.1	1.6
Schoenoplectus americanus	24.8	63.6	55.2	37.1
Bolboschoenus maritimus			4.4	0.7
Scirpus nevadensis		1.8	0.2	
Triglochin concinna	1.6			
Triglochin maritima		2.2		
Mean Cover of Waterfowl Food Plants	**64.4**	**79.6**	**75.4**	**61.1**
Bare Ground	0.0	0.4	0.2	0.9
Litter/dead plants	6.9	4.0	11.3	16.9
Tufa	0.0	0.4	0.0	0.0
Water	3.1	2.0	0.0	0.0

Table 53. Yearly Mean Percent Cover of Waterfowl Food Plant Species at Simons Spring, Averaged over the Three Transects

Simons Spring	**1999**	**2005**	**2009**	**2014**
Carex nebrascensis			0.3	
Carex spp.		11.7	20.2	13.7
Distichlis spicata	6.9	3.6	3.3	1.7
Eleocharis macrostachya	13.0			
Hordeum jubatum	0.7		0.3	
Schoenoplectus acutus	9.3	7.0	5.0	4.7
Schoenoplectus americanus	15.3	4.4	1.1	2.0
Scirpus nevadensis	9.4	7.6	1.3	1.7
Mean Cover of Waterfowl Food Plants	**54.7**	**34.2**	**31.5**	**23.7**
Bare Ground	6.8	3.4	6.4	5.6
Litter/dead plants	5.1	5.4	32.1	31.4
Tufa	0.0	1.7	0.0	0.0
Water	0.7	0.0	0.4	0.0

Table 54. Yearly Mean Percent Cover of Waterfowl Food Plant Species at Warm Spring, Averaged over the Six Transects

Warm Springs	**1999**	**2005**	**2009**	**2014**
Cleomella plocasperma			0.1	0.3
Distichlis spicata	2.9	2.8	0.7	1.1
Schoenoplectus acutus	3.2	0.9	1.2	0.9
Schoenoplectus americanus	18.4	27.2	17.8	22.7
Scirpus nevadensis	47.6	49.1	32.0	32.3
Triglochin maritima		0.2		
Mean Cover of Waterfowl Food Plants	**72.1**	**80.2**	**51.8**	**57.3**
Bare Ground	7.4	2.8	4.7	5.1
Litter/dead plants	10.1	13.9	35.2	33.0
Rock	0.0	0.0	0.3	0.1
Tufa	0.0	0.2	0.0	0.0
Water	2.4	0.8	1.7	1.0

Table 55. Yearly Mean Percent Cover of Waterfowl Food Plant Species at Rush Creek, Averaged over the Seven Transects

Rush Creek	**1999**	**2005**	**2009**	**2014**
Carex aquatilis	0.2			
Carex douglasii		0.3		
Carex nebrascensis	1.1	1.8		3.0
Carex praegracilis	1.2			
Carex spp.		1.9		
Carex utriculata			1.3	
Distichlis spicata	0.4	0.7		
Eleocharis macrostachya				1.5
Eleocharis sp.		0.5		
Equisetum arvense		0.5	16.8	16.7
Rumex crispus		0.1		
Schoenoplectus americanus		0.9	1.3	
Scirpus microcarpus			1.3	
Scirpus nevadensis		0.3		
Triglochin maritima				
Mean Cover of Waterfowl Food Plants	**2.9**	**7.0**	**20.6**	**21.2**
Bare ground	16.1	4.7	0.0	0.0
Litter/dead plants	2.1	7.0	0.0	0.0
Rock	0.0	9.2	0.0	0.0
Water	20.8	19.5	2.4	6.7

Table 56. Yearly Mean Percent Cover of Waterfowl Food Plant Species at Lee Vining Creek, Averaged over the Six Transects

Lee Vining Creek	**1999**	**2005**	**2009**	**2014**
Carex spp.		1.8		2.8
Carex utriculata			7.2	
Cyperus sp.	0.3		2.1	1.5
Distichlis spicata	1.2			
Eleocharis sp.		0.1		
Rumex crispus	0.2	0.0		1.5
Schoenoplectus americanus		0.6	0.5	1.4
Trifolium longipes		0.2		
Trifolium sp.			0.6	
Mean Cover of Waterfowl Food Plants	**1.7**	**2.6**	**10.4**	**7.2**
Bare Ground	34.7	5.1	0.0	0.0
Litter/dead plants	9.9	12.3	0.0	0.0
Moss	0.0	0.1	0.0	0.0
Rock	0.0	36.7	0.0	0.0
Water	10.3	10.0	0.0	0.0
Salix exigua (dead)	3.2	0.2	0.0	0.0
Annual Forb	0.0	0.3	0.0	0.0

Lake-Fringing Wetlands

LADWP (2015b) provides detailed results of all mapped years, including the total acreage of each landtype both at the lakewide and shoreline subarea scale. The results presented here represent the acreages of landtypes found within (i.e., at or below) the 6,392-foot contour.

The dominant landtype at Mono Lake is barren lake bed. The acreage and dominance of this landtype has increased over the mapping periods, comprising 37% of the mapped acreage (702 acres) in 1999, increasing up to 62% of the mapped acreage (2,266 acres) in 2014. Meadow/marsh is the most abundant modeled vegetation type around Mono Lake, comprising up to 32% of the mapped area in 2014. Riparian vegetation, which comprises only small component of the lake-fringing wetlands (averaging <30 acres, or less than one percent of the total mapped acreage), has shown little change. Since 1999, most lakeshore water feature types have decreased with the most significant declines seen in brackish and hypersaline ponds.

Table 57. Modeled and Mapped Landtype Acreages Below 6,392-Foot

Landtype	*1999*	*2005*	*2009*	*2014*
Barren lake bed	**702.1**	**1226.5**	**1537.5**	**2266.2**
Man-made	**0.0**	**1.1**	**0.2**	
Meadow/Marsh	**892.8**	**1369.1**	**1162.5**	**1189.0**
Alkaline wet meadow	*216.1*	*1125.6*	*619.5*	*325.3*
Dry meadow/forb	*545.4*	*39.5*	*214.0*	*19.8*
Marsh	*110.4*	*173.5*	*301.8*	*152.4*
Wet meadow	*20.9*	*30.6*	*27.3*	*691.4*
Ria	**2.6**	**7.9**	**2.5**	**38.5**
Riparian	**31.1**	**21.1**	**25.9**	**37.3**
Riparian shrub	*31.1*	*18.4*	*25.5*	*35.5*
Riparian woodland		*2.6*	*0.4*	*1.8*
Upland scrub	**52.6**	**48.6**	**53.8**	**103.1**
Water	**226.4**	**151.0**	**30.5**	**41.9**
Ephemeral brackish pond	*104.5*	*144.8*	*21.2*	*15.0*
Freshwater pond	*11.2*	*1.2*	*1.7*	*6.7*
Freshwater stream	*0.7*	*2.0*	*4.3*	*4.4*
Hypersaline pond	*109.1*	*2.9*	*0.4*	*0.7*
Mudflat	*0.9*		*2.9*	*15.0*
Total Mapped Acreage	**1907.6**	**2825.3**	**2812.9**	**3676.0**

Because of the potential importance of the ria habitat to waterfowl, a review of previous mapping efforts was conducted and suggests that the acreage of ria has potentially been under mapped. This concern will be demonstrated by evaluating the mapping results from two sites: Wilson Creek and Rush Creek delta. The Wilson Creek subarea has substantial freshwater spring flow and, due to the shape of the shoreline, a few small protected bays. In 2000, the lake elevation was high, and the resulting mapped ria area, as compared to 2014, was less (see Figure 52 and compare to Figure 53). Although the spring flow into the bay and along the shoreline would undoubtedly have created ria, ria does not get mapped, as no features beyond the shoreline are included. In 2014, areas to the east of Tufa Mound spring were mapped as ria because of a difference in the spectral signature due to the shallow offshore slope and presence of pumice blocks. West of Tufa Mound spring, ria could not be picked up spectrally, and therefore was not mapped, although this bay is likely largely composed of ria habitat.

In 2000, at Rush Creek, ria was mapped upgradient of a littoral bar (Figure 54). Since mapping does not extend beyond the land surfaces, ria, which would be expected to fill the mouth of Rush Creek, is not mapped. In this situation, ria is also underestimated. In 2014 conditions (Figure 55), there were would not be ria in the mouth of the creek due to the lowered lake elevation, however a hypopycnal zone would extend beyond the mouth of Rush Creek and the mapped area.

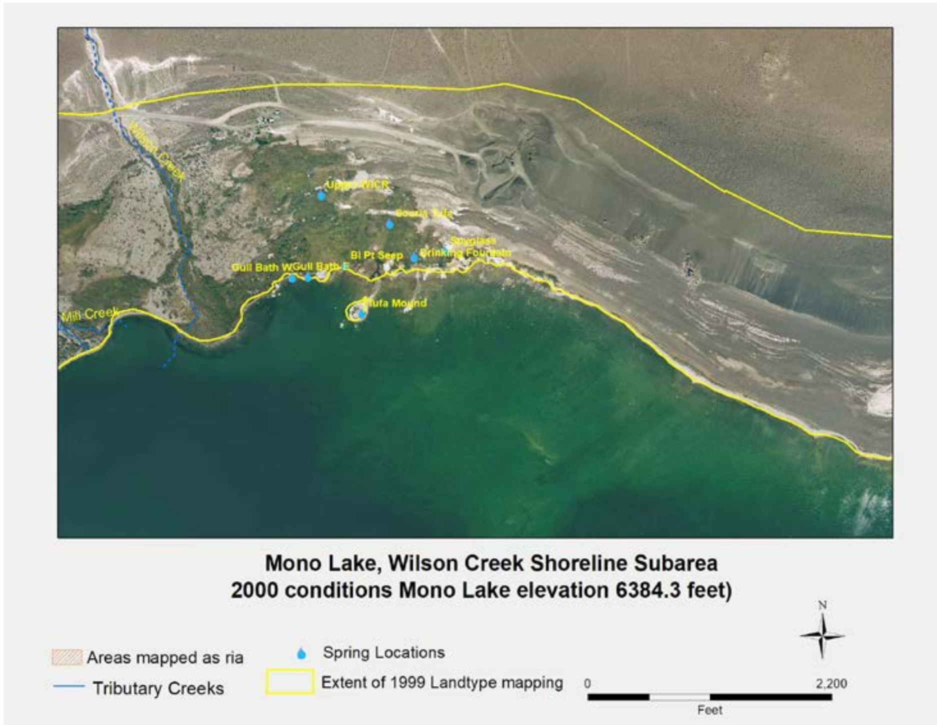


Figure 54. Wilson Creek, Mono Lake 2000 Conditions and Mapped ria

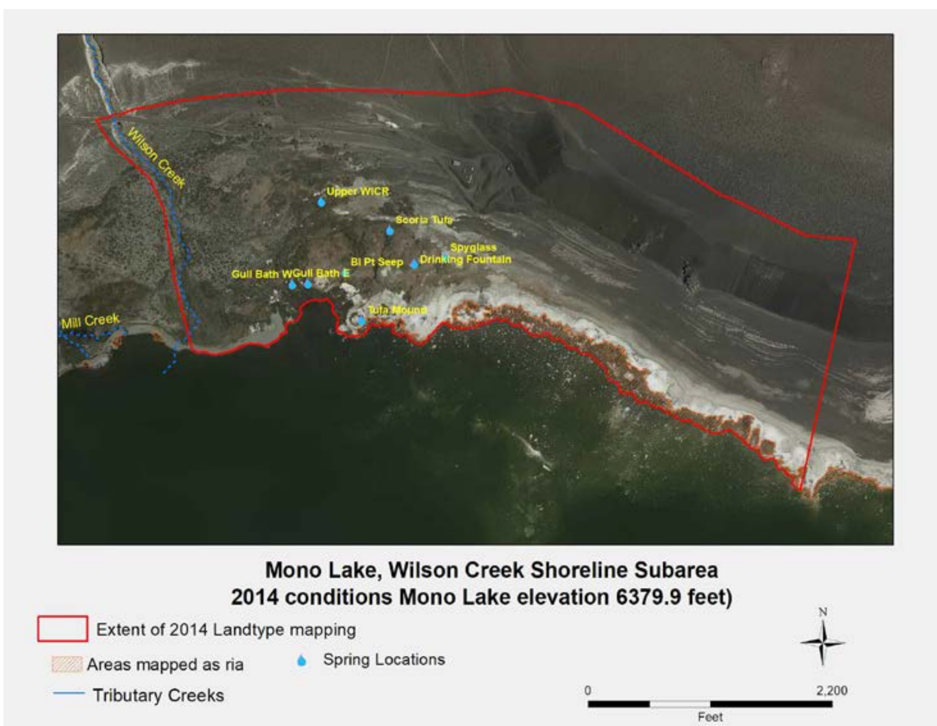


Figure 55. Wilson Creek, Mono Lake 2014 Conditions and Mapped ria

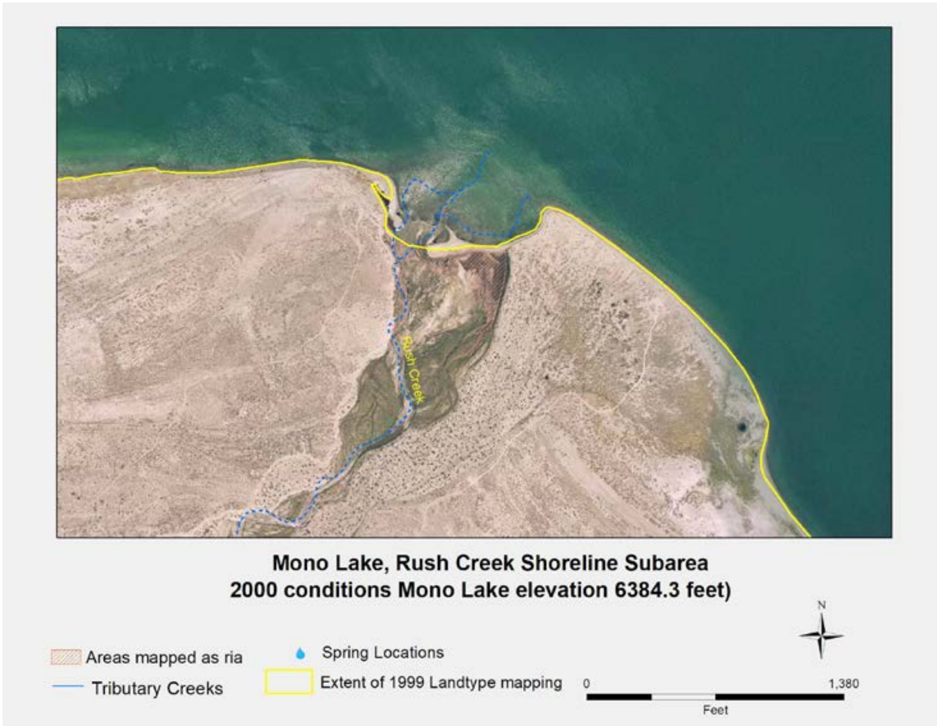


Figure 56. Rush Creek, Mono Lake 2000 Conditions and Mapped ria

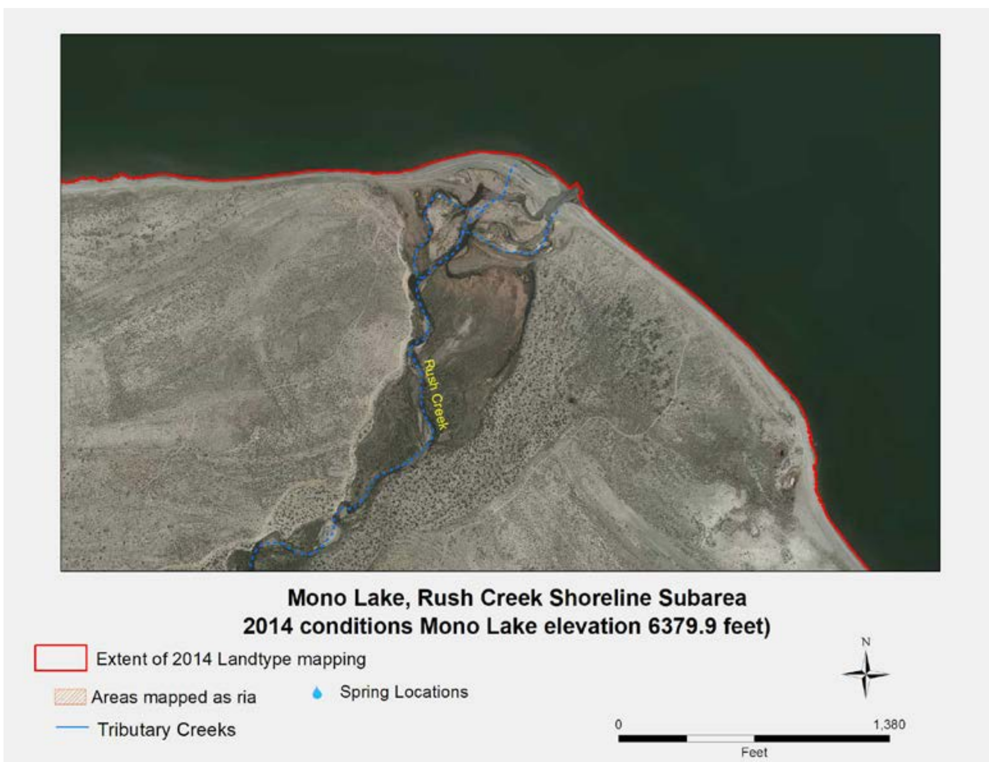


Figure 57. Rush Creek, Mono Lake 2014 Conditions and Mapped ria

Predicted Landtypes vs. Lake Elevation

The strongest response to lake elevation change is a decrease in barren lakebed with increasing lake elevation (Figure 56). With decreasing lake level, increases in meadow/marsh habitats are expected to occur one to two years after the decrease in lake level, as these habitat types expand on the exposed playa in some subareas. The overall acreage of riparian vegetation has not changed much, but slight decreases with increasing lake levels may occur as riparian vegetation becomes inundated, or dies due to salt water intrusion. Although ria has shown a tendency to decrease with increasing lake elevation, this may be an artifact created by the limitations of mapping. Lake-wide, changes in water features has not been significant. Water landtypes including freshwater streams and ponds, brackish ponds, hypersaline ponds, and mudflats show a pattern of increase in response to increases in lake elevation (Figure 56).

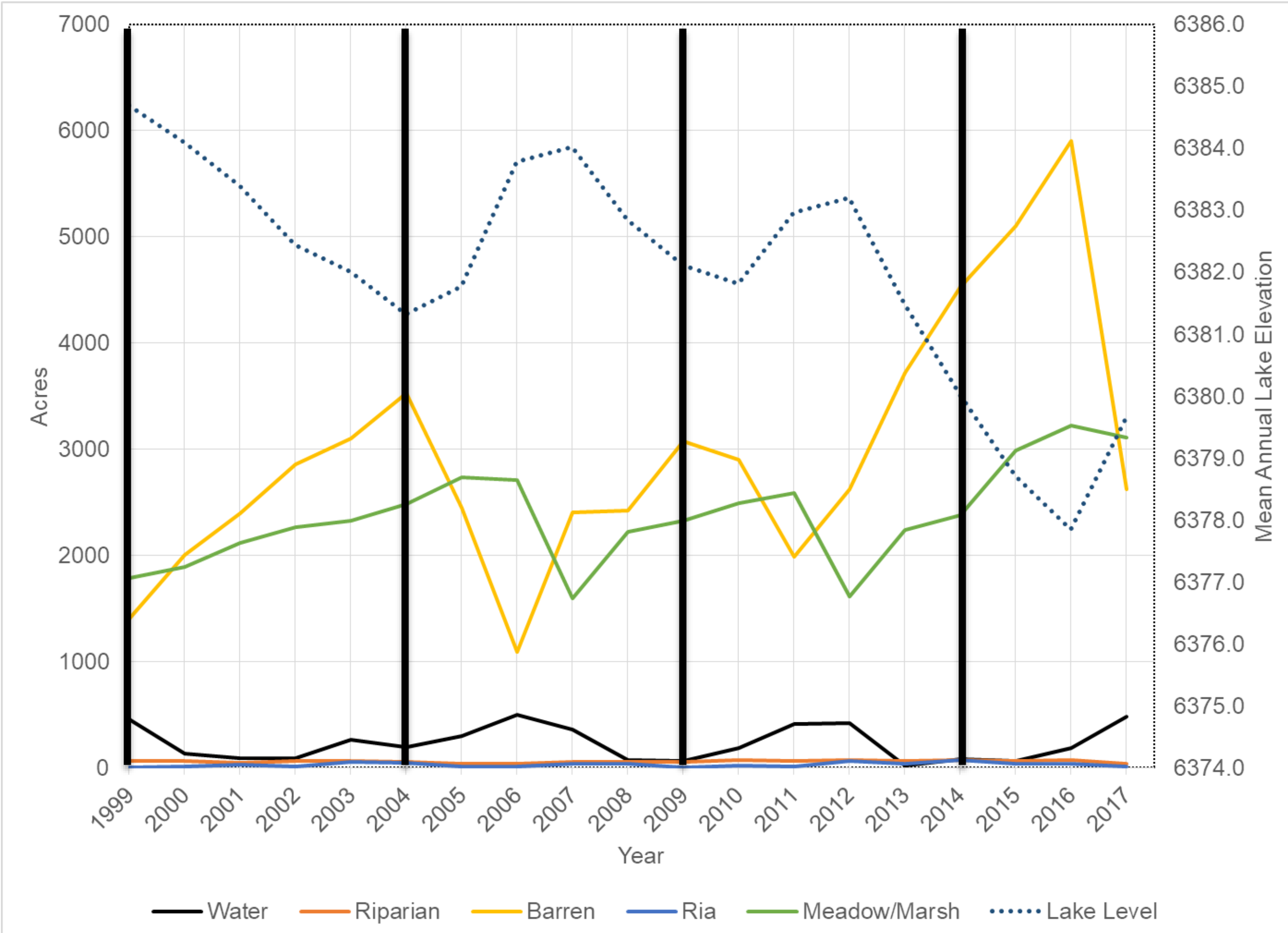


Figure 58. Predicted Acreages of Mono Lake Modeled Landtypes

Black vertical lines indicate landtype mapping years. Acreages for intervening years were predicted through multiple linear regression.

Lake-fringing Wetland Response to Lake Elevation Change by Subarea

Lake-wide, the only landtype showing a tendency to increase with increasing lake elevation was water habitats which include freshwater, brackish and hypersaline ponds, freshwater streams, and mudflats (Table 51). The tendency of water habitats to increase was statistically significant only in some subareas i.e. Black Point, Northeast Shore, and South Shore Lagoons. Water features have shown a decrease with increasing lake elevation at DeChambeau Creek. The amount of barren lake bed is very responsive to lake elevation showing significant increases with decreasing lake elevation at all sites except Northeast Shore, South Tufa and Wilson Creek. While meadow/marsh can become inundated during periods of increasing lake elevation, this was found to be significant at only a few sites including Mill Creek, Ranch Cove and Northeast Shore. Ria is projected to decrease with increasing lake elevation, however these results should be viewed skeptically for the reasons discussed previously. Riparian areas, particularly in Lee Vining Creek, may decrease as the lake level increases due to inundation. Upland areas are expected to decrease in several areas due to inundation.

Table 58. Relationship Between Lake Elevation and Landtypes by Shoreline Subarea

Values represent the correlation coefficient. Significance levels are indicated below.

Shoreline segment	Modeled Landtypes					
	Water	*Barren*	*Meadow/marsh*	*Ria*	*Riparian*	*Upland*
BLPO	** 0.628	** -0.645	-0.491	-0.367	-0.367	*** -0.866
BRCR	0.315	*** -0.754	-0.128	-0.367		-0.017
DECR	** -0.741	*** -0.819	-0.101	*** -0.821	-0.314	0.033
DEEM	-0.119	*** -0.815	-0.049	-0.367	-0.367	0.181
LVCR	* -0.594	** -0.725	-0.400	** -0.657	*** -0.754	** 0.663
MICR	0.068	*** -0.876	** -0.676	-0.378	0.105	0.424
NESH	* 0.615	-0.431	*** -0.899		-0.367	-0.449
RACO	0.411	*** -0.746	* -0.621		0.124	* -0.512
RUCR	0.036	** -0.656	-0.429	0.261	-0.151	** 0.685
SASP	0.474	*** -0.839	-0.453			*** -0.746
SOTU	0.327	-0.357	-0.357		-0.367	-0.239
SSLA	* 0.511	*** -0.988	-0.275			*** -0.772
WASP	0.182	*** -0.995	-0.146			0.001
WESH	-0.367	*** -0.969	-0.309	-0.367	-0.215	* -0.514
WICR	0.059	-0.394	-0.489	*** -0.757	-0.314	0.033
Total	0.461	*** -0.958	-0.484	* -0.588	* -0.572	** -0.712

Significance levels: *p<0.05, **p<0.01, ***p<0.001

Shoreline Subarea Vegetation and Detail Maps

Below are detailed descriptions of each shoreline subarea, and the corresponding vegetation data. Maps of each subarea are included, and show all of the mapped springs, their salinity class, and the nearshore bathymetry. The background image used is the 2017 color infrared image captured in July/August 2017 at a lake elevation of 6,381.2 feet. The annual photographs for each subarea have been compiled into appendices. The appendices where the reference photos for each subarea can be found as indicated in the header.

Black Point (BLPO)
(See Appendix 2 for annual photos)

Black Point is a volcanic hill on the northwest shore of Mono Lake. The shoreline here is composed of fairly dry, loose volcanic soils. Exposed shoreline comprises almost 60% of the area. Alkali and wet meadow vegetation occurs in scattered patches, primarily upgradient of the shoreline. At lower lake elevations, this shoreline area can be quite dry with notable increases in barren lake bed (see Appendix 2: 2009, 2012-2016) (Table 52). At the higher lake levels observed, brackish ponds developed along the shoreline, and the alkaline wet meadow became more lush (see Appendix 2: 2006, 2007, 2011). However, these ponds did not develop in 2017, a year in which the lake level rose four feet, up to a maximum elevation of 6,381.5 feet. Although there are no mapped springs in this subarea, the ponds that develop here during periods of higher lake elevation have been used by waterfowl. It is therefore suspected that the ponds are brackish and unmapped springs occur in this area as indicated by LADWP (1987). The bathymetry indicates a gradual offshore slope in this area (Figure 57).

Table 59. Acreages of Modeled and Mapped Landtypes Below the 6,392-foot Contour, Black Point Subarea

Landtype	*1999*	*2005*	*2009*	*2014*	*Mean % of mapped Area*
Barren lake bed	**36.0**	**33.1**	**81.0**	**121.1**	**51.7%**
Meadow/Marsh	**26.5**	**61.9**	**42.4**	**55.4**	**40.5%**
Alkaline wet meadow	*8.9*	*61.9*	*31.5*	*23.5*	*28.3%*
Dry meadow/forb	*17.6*		*10.9*	*2.1*	*8.6%*
Marsh			*0.1*	*1.1*	*0.1%*
Wet meadow				*28.8*	*3.5%*
Ria				**20.4**	**2.4%**
Riparian				**0.2**	**0.0%**
Riparian shrub				0.2	*0.0%*
Upland scrub			**3.3**	**11.0**	**2.0%**
Water	**7.9**	**0.6**	**1.8**	**0.2**	**3.3%**
Brackish pond	*7.9*	*0.6*	*1.8*		*3.3%*
Hypersaline pond	*0.0*			*0.2*	*0.0%*
Total mapped acreage	**70.5**	**95.6**	**129**	**208.23**	

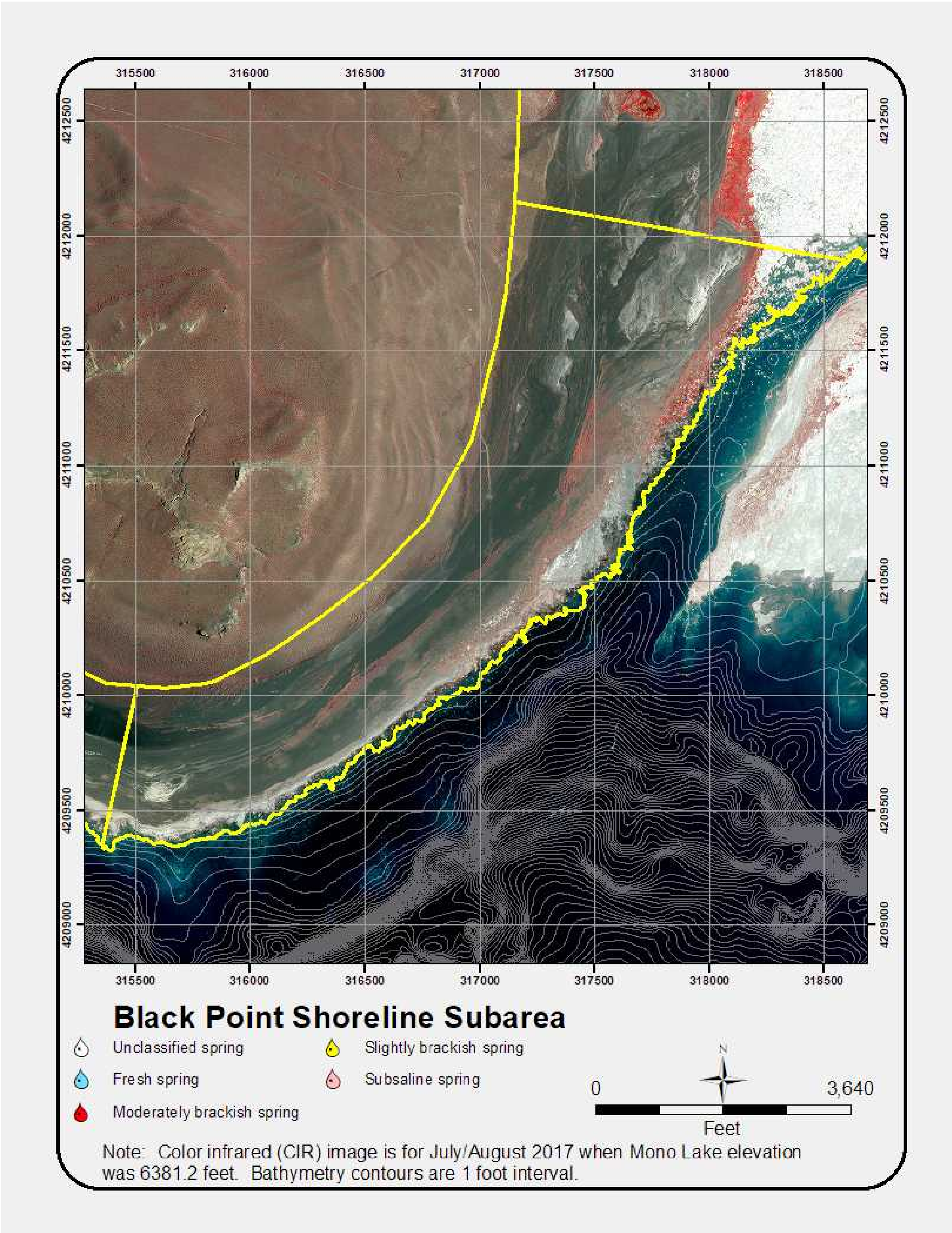


Figure 59. Black Point Subarea Springs and Nearshore Bathymetry

Bridgeport Creek – Bridgeport Creek (BRCR)

(See Appendix 3 for annual photos)

This shoreline area is at the terminus of the Bridgeport Creek drainage, however there is no surface flow of water in the creek near the lakeshore. There are several springs in this area, most of which are slightly brackish and support small brackish ponds (Figure 58). The other wetland resources in Bridgeport Creek are alkaline wet meadow, with small amounts of wet meadow and marsh (Table 53). Waterbird use is often most concentrated at the western end of this area, where spring flow has consistently reached the shoreline at all elevations observed. Ria is present at the outlet of each spring, and is likely to be more extensive than mapped. At higher lake elevations (see Appendix 3: 2006), brackish ponds developed along much of the length of this shoreline area. With decreasing lake elevations, barren lake bed has increased substantially without a subsequent expansion of vegetation, and brackish ponds have disappeared (see Appendix 3: 2014-2017). The bathymetry indicates a gradual offshore slope in this area, and there is a shallow shelf just offshore (visible in Figure 58).

Table 60. Acreages of Modeled and Mapped Landtypes Below the 6,392-foot Contour in the Bridgeport Creek Subarea

Landtype	*1999*	*2005*	*2009*	*2014*	*Mean % of mapped Area*
Barren lake bed	**37.0**	**64.4**	**91.4**	**177.2**	**38.3%**
Meadow/Marsh	**104.7**	**146.9**	**121.4**	**124.4**	**57.3%**
Alkaline wet meadow		*142.6*	*92.5*	*72.0*	*32.6%*
Dry meadow/forb	*104.6*	*4.1*	*16.7*		*19.0%*
Marsh	*0.1*	*0.2*	*12.1*	*1.9*	*1.6%*
Wet meadow				*50.4*	*4.2%*
Ria				**0.2**	**0.0%**
Upland scrub		**10.4**	**2.7**		**1.5%**
Water	**15.8**	**3.1**			**2.9%**
Brackish pond	*15.6*	*3.1*			*2.8%*
Freshwater pond	*0.0*				*0.0%*
Hypersaline pond	*0.2*				*0.0%*
Total mapped acreage	**157.6**	**224.8**	**215.5**	**301.8**	

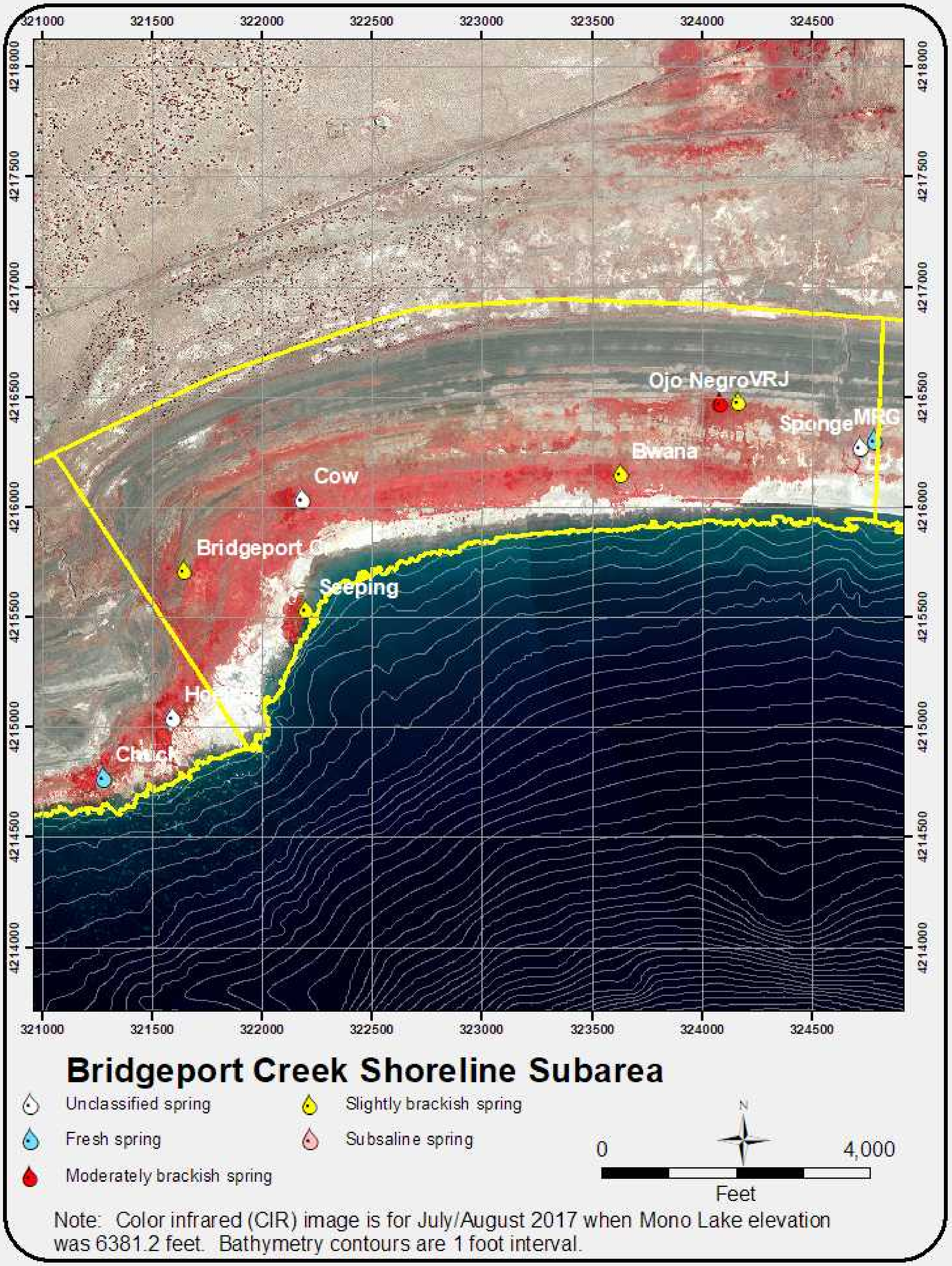


Figure 60. Bridgeport Creek Subarea Springs and Nearshore Bathymetry

DeChambeau Creek (DECR)
(See Appendix 4 for annual photos)

DeChambeau Creek lies along the northwest shore of Mono Lake. The flows in DeChambeau Creek are intermittent, and do not consistently reach the lakeshore. However, the DeChambeau Creek area has abundant nearshore freshwater resources due to the numerous springs (Figure 61).

The freshwater springs at DeChambeau Creek support wet meadow, mudflats, and riparian scrub. During periods of declining lake levels, wet meadow vegetation has been observed to expand in this area due to the abundance of freshwater spring flow which supports the expansion of wetland vegetation onto newly exposed mudflats. During periods of subsequent increasing lake elevations, the wet meadow vegetation, mudflats, and playa become inundated, leaving little exposed shoreline as occurred in 2010 and 2011 (see Appendix 4). The drop in lake elevation after 2011 resulted in erosional headcutting along several of the spring channels, and increased spring channel depths near the lake shore (Figure 59). Increases in barren lake bed area with declining lake elevation are much less substantial along west shore sites such as this than is seen in other areas of the lake. An area of ria is expected to occur at the outflow of each spring, although the extent of ria offshore is expected to vary with spring flow. Ria likely extends beyond the mapping boundaries for DeChambeau Creek, at least for some springs, thus ria as a resource in the DeChambeau Creek area is more prominent than is reflected by mapping. The bathymetry indicates a gradual offshore slope only near the shore in this area, and a moderately-rapid increase in water depth with increasing water depth from shore quickly follows (visible in Figure 60).

Figure 61. DeChambeau Creek Erosional Headcutting, 2015
Along a spring channel in response to the decrease in lake elevation.

Table 61. Acreages of Modeled and Mapped Landtypes Below the 6,392-foot Contour in the DeChambeau Creek Subarea

Landtype	*1999*	*2005*	*2009*	*2014*	*Mean % of mapped Area*
Barren lake bed	**7.7**	**10.3**	**15.0**	**24.0**	**37.4%**
Man-made		**0.0**			**0.0%**
Meadow/Marsh	**15.1**	**23.5**	**17.8**	**18.0**	**53.4%**
Alkaline wet meadow	*0.2*		*0.1*	*2.2*	*1.4%*
Dry meadow/forb	*3.6*	*5.1*	*4.0*		*10.1%*
Marsh		*0.9*	*0.4*	*3.9*	*2.8%*
Wet meadow	*11.3*	*17.5*	*13.3*	*11.9*	*39.1%*
Ria		***0.5***	***0.3***	***0.7***	***0.9%***
Riparian	***1.0***	***0.6***	***1.1***	***3.8***	***4.2%***
Riparian shrub	*1.0*	*0.5*	*1.1*	*3.8*	*4.0%*
Riparian woodland		*0.2*			*0.1%*
Upland scrub			**0.1**		**0.1%**
Water	**0.0**	**0.4**	**2.2**	**4.4**	4.0%
Freshwater pond		*0.4*		*0.0*	***0.3%***
Freshwater stream	*0.0*		*0.0*	*0.1*	*0.1%*
Mudflat			*2.1*	*4.3*	*3.6%*
Total mapped acreage	**23.9**	**35.3**	**36.5**	**50.9**	

Figure 62. Aerial of DeChambeau Creek Subarea

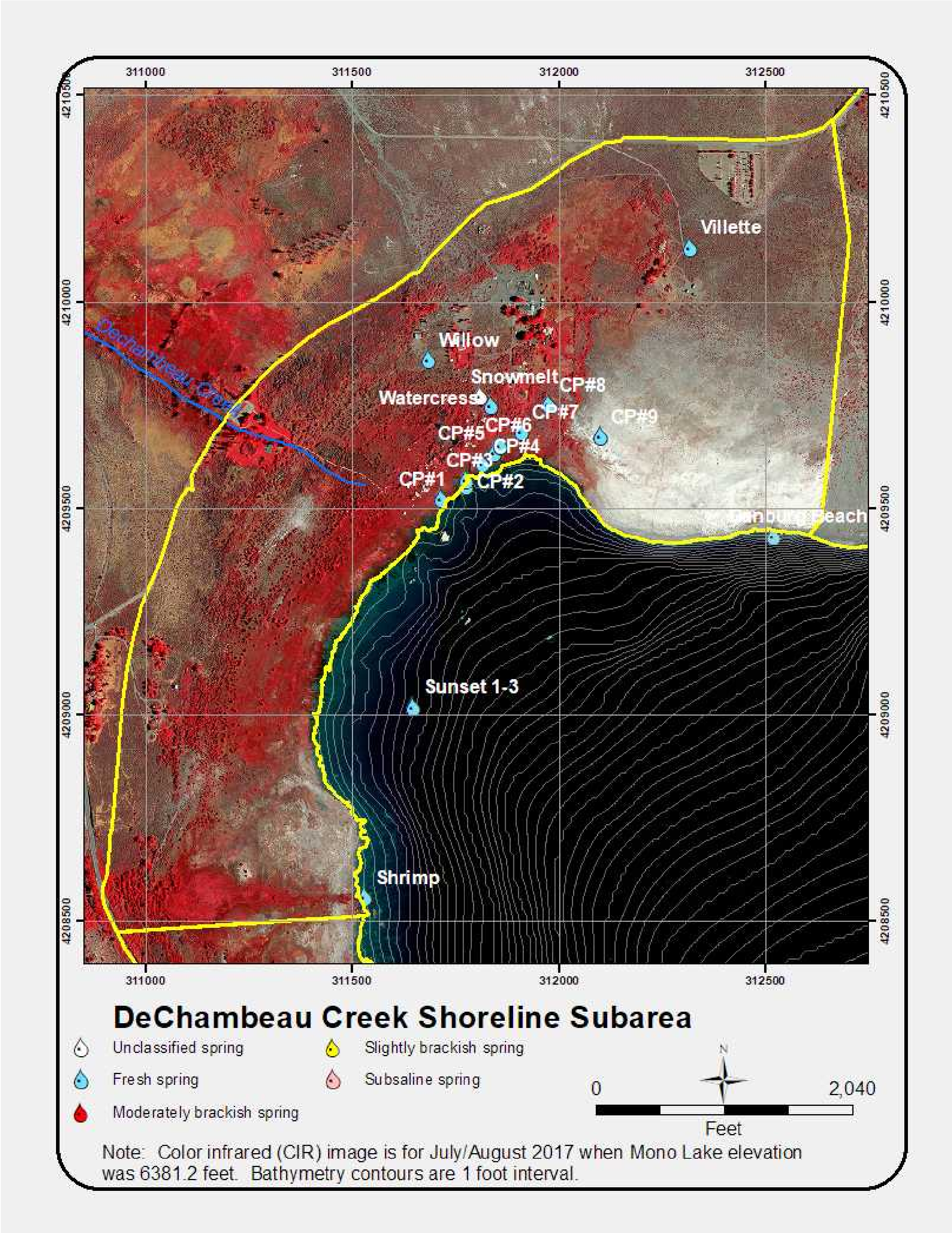


Figure 63. DeChambeau Creek Subarea Springs and Nearshore Bathymetry

DeChambeau Embayment (DEEM)
(See Appendix 5 for annual photos)

The DeChambeau Embayment area lies just east of the historic DeChambeau Ranch, and the DeChambeau and County Restoration ponds. Historically, Wilson Creek discharged into this area, and the area may have also been influenced by irrigation of the DeChambeau Ranch. Vegetation, dominated by alkali and wet meadow, is primarily confined to the inland portions of the embayment. There are fresh, slightly brackish and moderately brackish springs in this area, the largest of which is the slightly brackish Perseverance Spring. Spring flow has reached the lake at all elevations observed (Appendix 5: 2014 and 2015).

The wetland resources in DeChambeau embayment include alkaline wet meadow, small amounts of marsh, and several small brackish ponds. This portion of the lake is relatively shallow, and experiences rapid increases in the acreage of barren lake bed with decreasing lake levels.

The bathymetry map indicates a complex shoreline and offshore topography (Figure 63). Very shallow sloping topography exists nearshore in the southern portion of the subarea, with a deeper bay just offshore. Tufa blocks litter the entire subarea, and are most often visible in the southern portion of this area due to the topography. At the higher lake elevations observed (see Appendix 5: 2006), the tufa blocks have become partially to completely submerged and the shallow nearshore areas expand. A land bridge with an offshore island had formed by 2015 (see Appendix 5: 2015). At more extreme low lake levels, such as those observed in 2016, the geographic extent of the tufa blocks in the eastern portion of the subarea were revealed (Figure 62). The eastern portion of the shoreline in this subarea has a gradually sloping shoreline which extends offshore.

Table 62. Acreages of Modeled and Mapped landtypes below the 6,392-foot Contour in the DeChambeau Embayment Subarea

Landtype	*1999*	*2005*	*2009*	*2014*	*Mean % of mapped Area*
Barren lake bed	**29.6**	**161.0**	**245.1**	**387.8**	**44.7%**
Meadow/Marsh	**155.1**	**240.2**	**192.5**	**182.0**	**54.5%**
Alkaline wet meadow	*8.2*	*205.2*	*125.2*	*80.2*	*24.4%*
Dry meadow/forb	*144.5*		*27.8*	*1.6*	*21.0%*
Marsh	*2.5*	*35.1*	*39.6*	*26.1*	*5.9%*
Wet meadow				*74.2*	*3.2%*
Ria				**3.6**	**0.2%**
Riparian				**1.8**	**0.1%**
Riparian shrub				1.8	0.1%
Upland scrub	**0.4**	**0.1**	**1.3**	**0.0**	**0.1%**
Water	**1.3**	**2.0**	**0.2**	**0.8**	**0.3%**
Brackish pond	1.0	1.9	0.2	0.7	0.3%
Freshwater pond	0.4	0.1	0.0	0.0	0.1%
Hypersaline pond				0.1	0.0%
Total mapped acreage	**186.5**	**403.4**	**439.1**	**576.1**	

Figure 64. Formation of a Land Bridge with an Offshore Island, 2015 and Tufa Blocks in Eastern Portion of Subarea, 2016

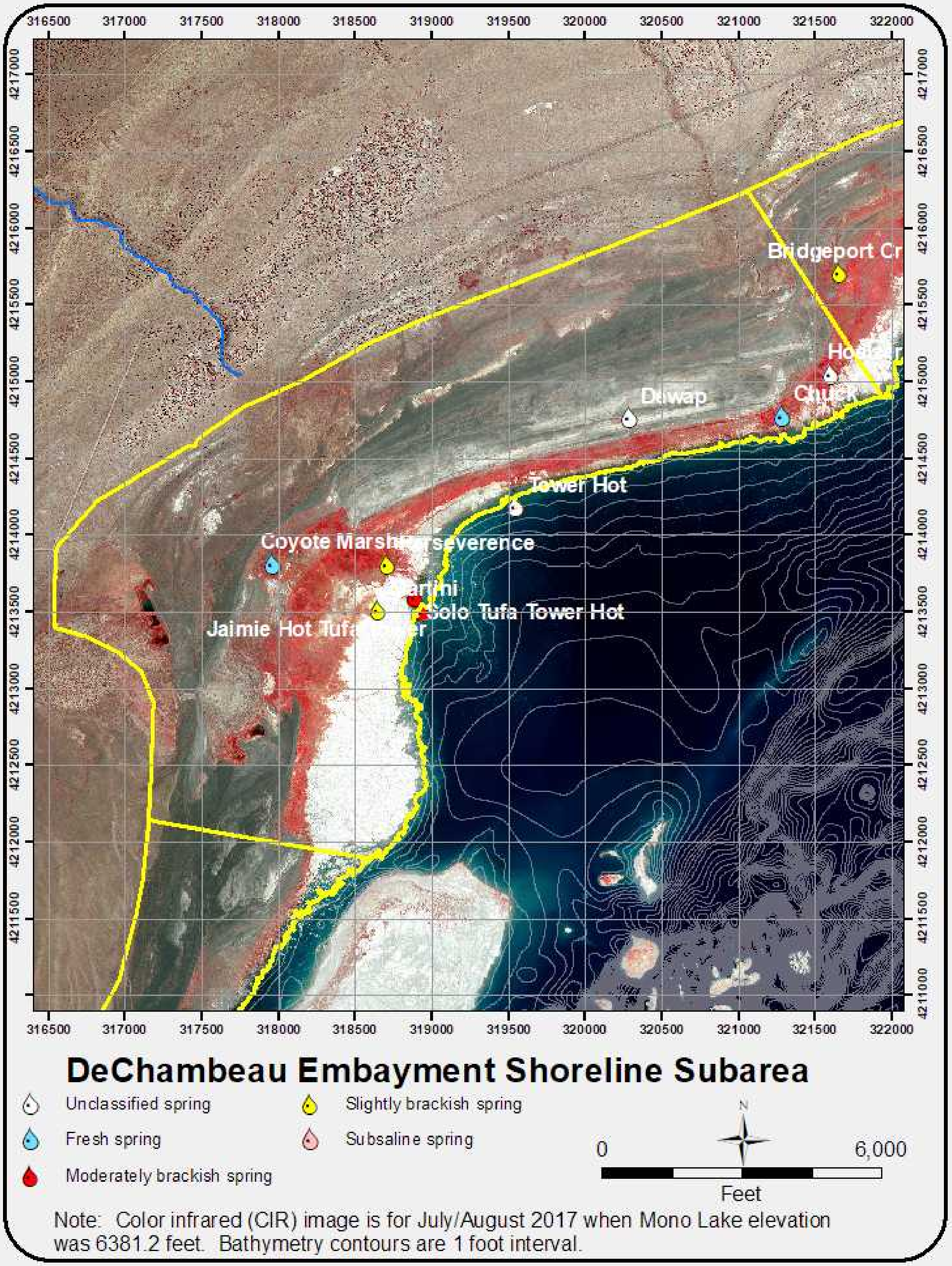


Figure 65. DeChambeau Embayment Subarea Springs and Nearshore Bathymetry

Lee Vining Creek (LVCR)
(See Appendix 6 for annual photos)

Lee Vining Creek, the second largest stream in the Mono Basin, has primarily a snowmelt-driven hydrologic regime, with peak stream flows occurring during the spring snowmelt season, and reduced flows during the remainder of the year. Peak flows typically occur in June or July in any given year, but may occur in April or May, particularly in dry years. Water diversion by LADWP began in 1941, resulting in a dry channel in the lower reaches of the creek in some years. Most of the impacts to the creek, as a result of LADWP diversions, occurred downstream of Highway 395 (SWRCB 1994). Under Decision 1631, LADWP was required to develop a stream restoration plan and undertake projects to rehabilitate Lee Vining Creek (LADWP 1996). Channel maintenance and flushing flows, referred to as “stream restoration flows” were established in order to mimic seasonal snowmelt runoff, with the magnitude of the flow based on the hydrological conditions for the year (SWRCB 1994).

Lee Vining Creek is a woody riparian system. The lower reaches of Lee Vining Creek and its delta support wet meadows. The creek supplies abundant freshwater year round, which remains confined to the main channel under low flow conditions, but inundates the lower floodplain under high flow conditions. At higher lake levels, the delta becomes flooded with lake water, inundating the willows and wet meadows close to shore, resulting in some dieback from salt water stress (Appendix 6: 2005, 2006). During periods of descending lake elevations, freshwater ponds form behind littoral bars (Appendix 6: 2007, 2008, and 2012, 2013) and the entire delta becomes flooded due to extensive channeling. At the extreme low lake elevation observed in 2016, extensive drying of the delta meadows occurred (Appendix 6: 2016). Ria extends offshore beyond the mapping boundary of Lee Vining Creek subarea, due to flows from Lee Vining Creek, however this waterfowl resource is not captured by landtype mapping.

Bathymetry of the area indicates limited shallow water areas near shore (Figure 64). Shallow sloping areas of water are limited to the delta and near the tufa grove, but depths rapidly increase lake-ward.

Table 63. Acreages of Modeled and Mapped Landtypes Below the 6,392-foot Contour, Lee Vining Creek Subarea

Landtype	*1999*	*2005*	*2009*	*2014*	*Mean % of mapped Area*
Barren lake bed	**3.3**	**2.9**	**8.2**	**12.7**	**28.2%**
Man-made		**0.2**			**0.2%**
Meadow/Marsh	**3.6**	**10.5**	**11.0**	**10.5**	**39.5%**
Alkaline wet meadow	*0.3*	*3.5*	*0.6*	*0.3*	*6.0%*
Dry meadow/forb	*1.3*	*2.9*	*5.7*	*1.0*	*12.3%*
Marsh	*2.0*	*4.1*	*0.9*		*9.9%*
Wet meadow			*3.8*	*9.2*	*11.3%*
Ria	**0.2**	**0.6**	**0.5**	**0.6**	**2.0%**
Riparian	**2.1**	**3.6**	**3.9**	**3.8**	**15.4%**
Riparian shrub	*2.1*	*1.5*	*3.9*	*2.1*	*11.1%*
Riparian woodland		*2.1*		*1.8*	*4.2%*
Upland scrub	**4.8**	**1.3**	**1.8**	**1.2**	**12.9%**
Water	**0.1**	**0.2**	**0.4**	**1.2**	**1.8%**
Freshwater stream	*0.1*	*0.2*	*0.4*	*1.1*	*1.8%*
Hypersaline pond				*0.0*	*0.0%*
Total mapped acreage	**14.0**	**19.2**	**25.8**	**30.0**	

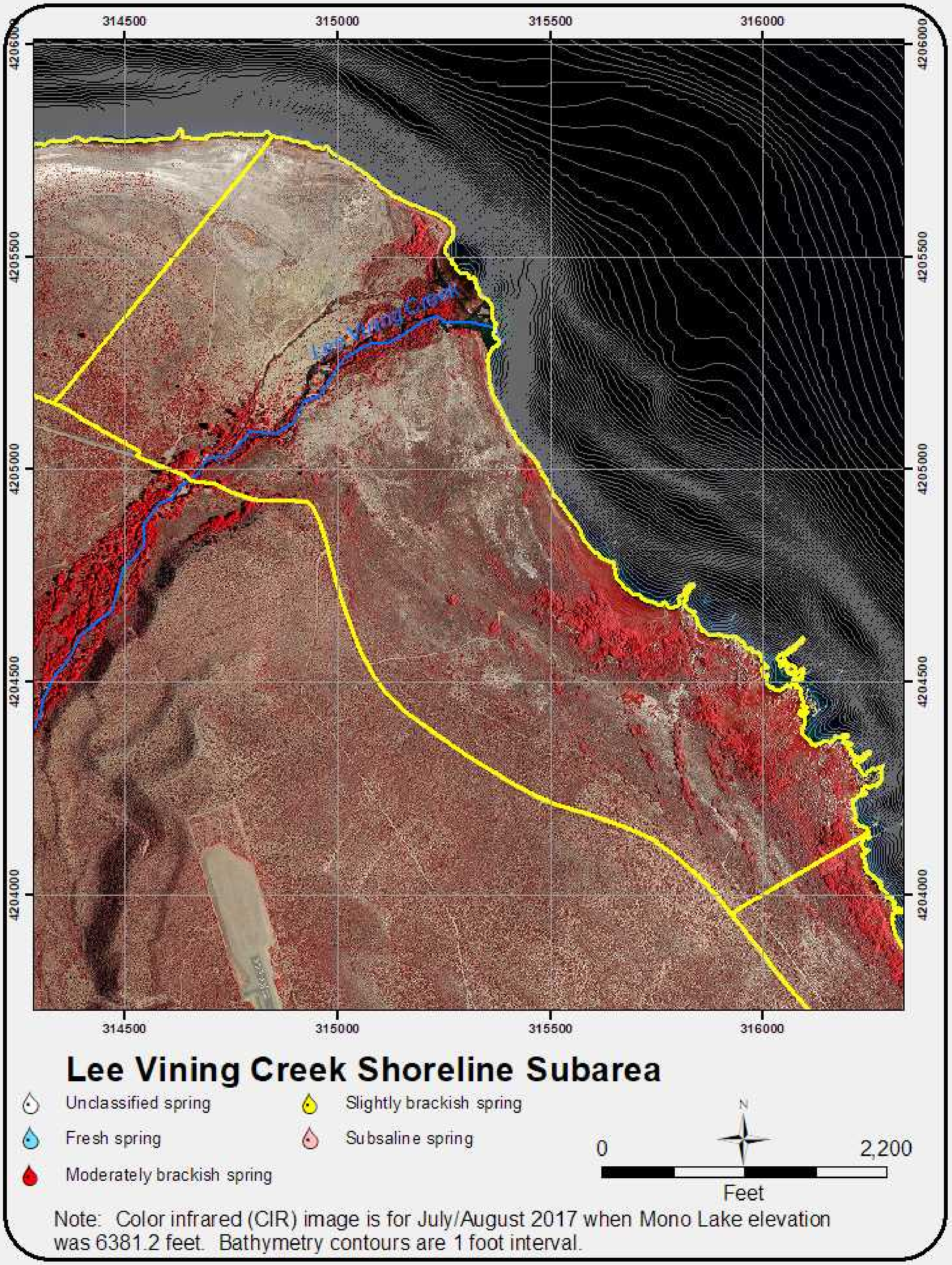


Figure 66. Lee Vining Creek Subarea Springs and Nearshore Bathymetry

Mill Creek (MICR)

(See Appendix 7 for annual photos)

Mill Creek, Mono Lake's third largest tributary originates in Lundy Canyon. Historically, water diversions for hydropower have affected Mill Creek riparian vegetation.

Freshwater ponds, streams, ria and riparian shrubs are the main waterfowl resources at Mill Creek. Both the flows from Mill Creek and Wilson Creek enter Mill Creek bay in this subarea, thus an area of ria is expected to extend well beyond the mapped boundary. While no springs have been identified in this area, freshwater often enters the lake at several points in the delta due to seepage through the loose volcanic soils (see Appendix 7: 2010-2016). There has also been a tendency for freshwater ponds to form on shore behind littoral bars (see Appendix 7: 2006, 2007, 2008, 2009, 2012). By 2012, beaver activity was noted in the delta, and over the years, several dams have been built amongst the willows leading to additional freshwater ponds just on shore. The thinning of the willow canopy from beaver activity is seen best in the 2012 photo (Appendix 7).

Bathymetry indicates the creek mouth constitutes the only shallow areas in the Mill Creek delta area (Figure 65). Lakeward, water depth increases rapidly.

Table 64. Acreages of Modeled and Mapped Landtypes Below the 6,392-foot Contour, Mill Creek Subarea

Landtype	*1999*	*2005*	*2009*	*2014*	*Mean % of mapped Area*
Barren lake bed	**4.9**	**6.0**	**7.0**	**9.5**	**59.2%**
Meadow/Marsh		**2.2**	**0.4**	**1.4**	**8.2%**
Alkaline wet meadow			*0.1*	*0.0*	*0.2%*
Dry meadow/forb			*0.2*		*0.4%*
Marsh		*2.0*			*4.6%*
Wet meadow		*0.1*	*0.2*	*1.4*	*3.1%*
Ria		**0.5**	**0.0**	**0.2**	**1.6%**
Riparian	**3.1**	**1.2**	**3.2**	**2.5**	**23.2%**
Riparian shrub	*3.1*	*1.2*	*3.2*	*2.5*	*23.2%*
Upland scrub		**1.1**	**1.0**		**4.6%**
Water	**0.4**	**0.2**	**0.3**	**0.3**	**3.1%**
Freshwater pond	*0.4*	*0.0*	*0.1*	*0.1*	*1.6%*
Freshwater stream	*0.0*	*0.2*	*0.2*	*0.3*	*1.5%*
Mudflat				*0.0*	*0.1%*
Total mapped acreage	**8.4**	**11.2**	**12.0**	**14.1**	

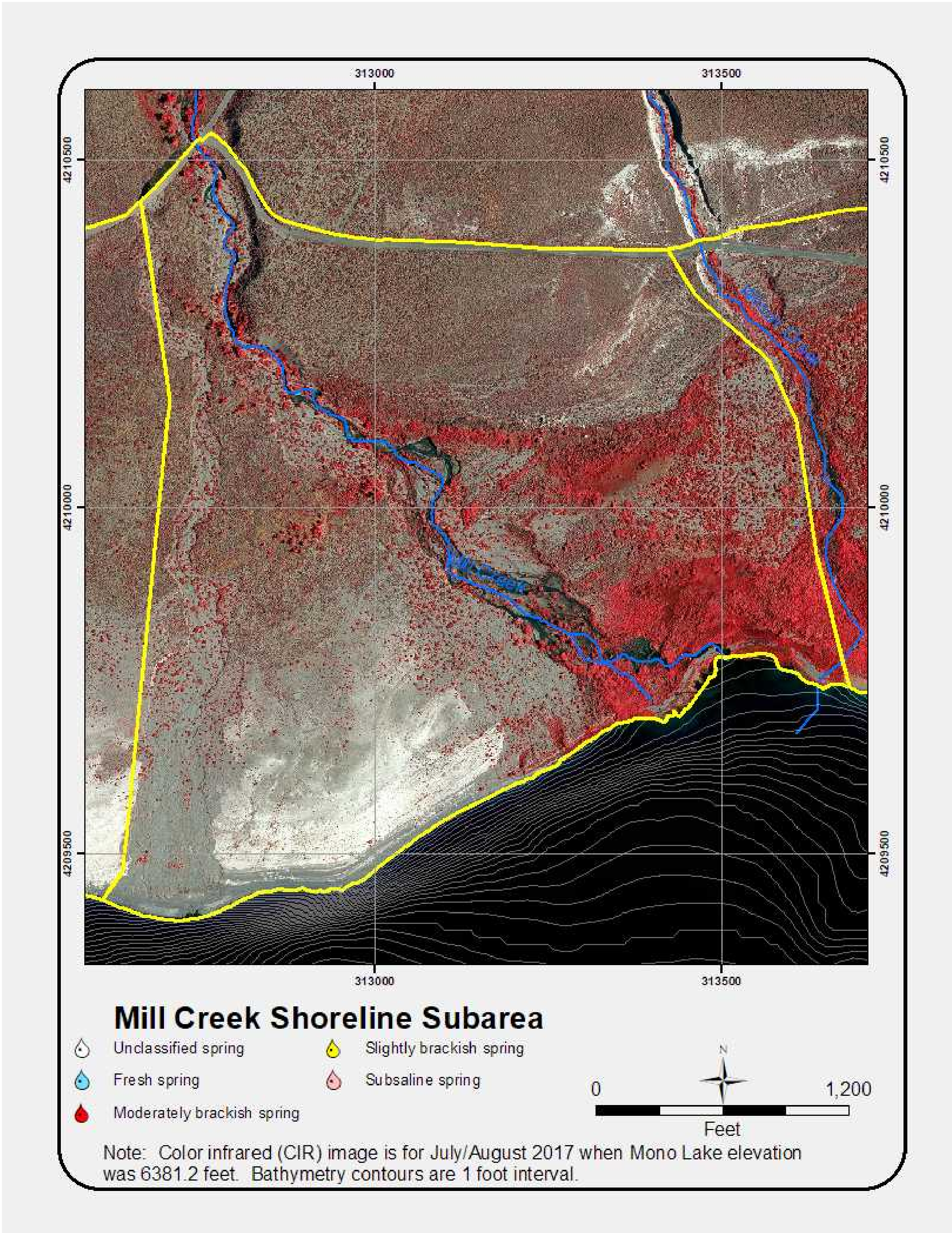


Figure 67. Mill Creek Subarea Springs and Nearshore Bathymetry

Northeast Shore (NESH)
(See Appendix 8 for annual photos)

In the Northeast Shore area, the groundwater is too saline to support vegetation, resulting in extensive areas of barren playa at most lake elevations. Barren playa currently comprises 99% of the Northeast Shore area, and only small amounts of alkali meadow are present.

At the higher lake elevations observed (see Appendix 8: 2006 and 2011) extensive ponds have formed along the length of the shoreline segment. Although there are no known mapped springs in this reach, some are evident (D. House, pers. obs.). The ephemeral ponds observed along Northeast Shore are presumed to be brackish as flow from springs in adjacent subareas are likely contributing to creation of these ponds. Salinity of these ephemeral ponds may also be influenced by groundwater input. Historically, large perennial brackish ponds were present along the northeast shore. These ponds persisted in depressional areas above the high water mark. In contrast to the perennial nature of these historic ponds, the ponds observed along the northeast shore have only persisted a single season.

The nearshore water present in 2016 may be the seepage of groundwater due to shoreline slumping in this year of low lake elevation. The bathymetry indicates a very gradual sloped shoreline in this subarea.

Table 65. Acreages of Modeled and Mapped Landtypes Below the 6,392-foot Contour, Northeast Shore Subarea

Landtype	*1999*	*2005*	*2009*	*2014*	*Mean % of mapped Area*
Barren lake bed	**316.4**	**370.9**	**364.2**	**381.2**	**96.3%**
Meadow/Marsh	**0.1**	**1.5**	**2.2**	**3.2**	**0.5%**
Alkaline wet meadow	*0.1*	*0.2*	*1.0*	*3.2*	*0.3%*
Dry meadow/forb		*1.3*	*1.1*		*0.2%*
Marsh			*0.1*		*0.0%*
Riparian				**0.2**	**0.0%**
Riparian shrub				*0.2*	*0.0%*
Upland scrub			**0.1**	**0.4**	**0.0%**
Water	**45.9**	**1.0**			**3.2%**
Brackish pond	*1.3*				*0.1%*
Hypersaline pond	*44.6*	*1.0*			*3.1%*
Total mapped acreage	**362.3**	**373.4**	**366.4**	**384.9**	

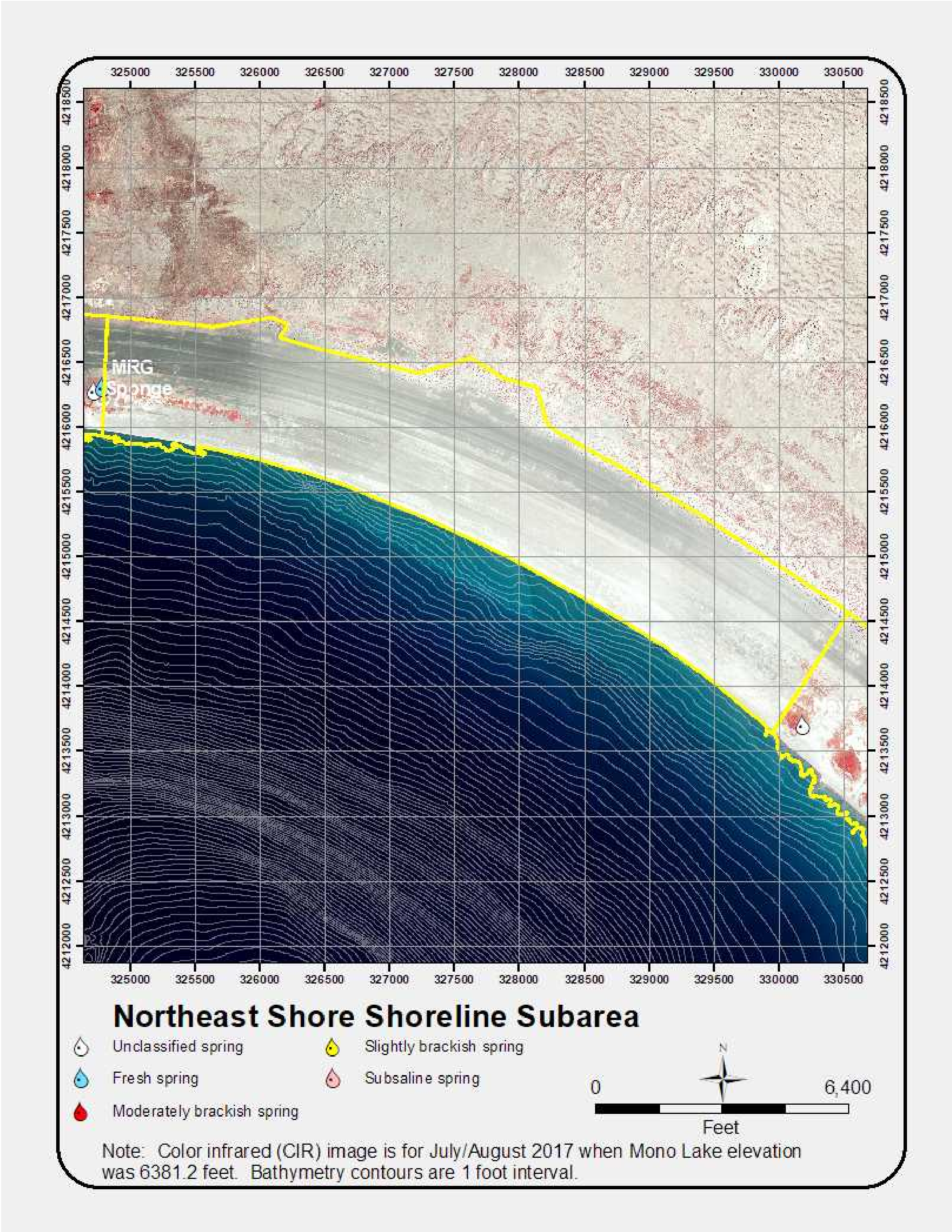


Figure 68. Northeast Shore Subarea Springs and Nearshore Bathymetry

Ranch Cove (RACO)
(See Appendix 9 for annual photos)

The Ranch Cove shoreline area is a relatively small area located between Rush Creek and Lee Vining Creek. The shoreline area is narrow and generally dry, supporting primarily coyote willow (*Salix exigua*), rabbitbrush, upland scrub, and barren playa (Table 59). The shoreline has not shown significant changes with lake elevation. Waterfowl resources are limited in this area, and there is no direct spring flow evident.

Bathymetry shows essentially no shallow area in this shoreline subarea, and a steeply sloped shoreline.

Table 66. Acreages of Modeled and Mapped Landtypes Below the 6,392-foot Contour, Ranch Cove Subarea

Landtype	*1999*	*2005*	*2009*	*2014*	*Mean % of mapped Area*
Barren lake bed	**4.6**	**6.1**	**11.6**	**17.6**	**35.5%**
Meadow/Marsh		**11.1**	**8.6**	**3.2**	**21.7%**
Alkaline wet meadow		*10.6*	*6.1*	*3.0*	*18.6%*
Dry meadow/forb		*0.5*	*2.5*		*2.9%*
Marsh		*0.0*	*0.0*		*0.0%*
Wet meadow			*0.0*	*0.2*	*0.2%*
Riparian	**10.7**	**4.3**	**2.8**	**7.9**	**25.7%**
Riparian shrub	*10.7*	*4.3*	*2.8*	*7.9*	*25.7%*
Upland scrub	**4.5**	**3.5**	**2.8**	**6.4**	**16.3%**
Water	**0.6**		**0.0**		**0.8%**
Brackish pond	*0.6*				*0.8%*
Freshwater stream			*0.0*		*0.0%*
Total mapped acreage	20.4	25.0	25.8	35.1	

Figure 69. Aerial View of Ranch Cove Subarea with Narrow Wetland Shoreline Habitats

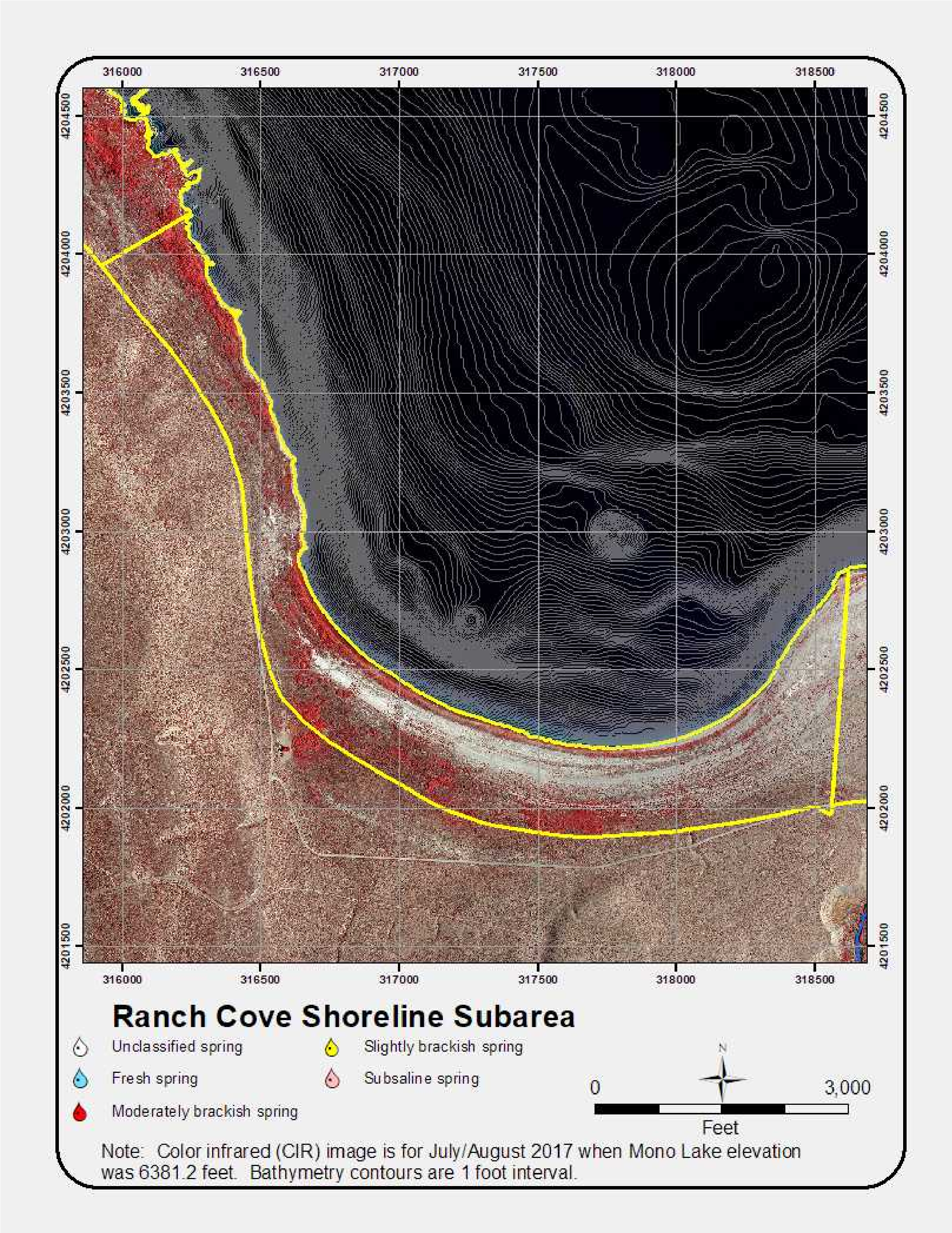


Figure 70. Ranch Cove Subarea Springs and Nearshore Bathymetry

Rush Creek (RUCR)

(See Appendix 10 for annual photos)

Rush Creek, the largest stream in the Mono Basin, has primarily a snowmelt-driven hydrologic regime with peak stream flows occurring during the spring snowmelt season, and reduced flows the remainder of the year. Peak flows typically occur in June or July in any one year, but may also occur in April or May, particularly in dry years (Beschta 1994). There is a long history of water diversion of Rush Creek waters for irrigation dating back to the 1860s. Water diversion by LADWP began in 1941, resulting in a dry channel in the lower reaches of the creek in some years. Notable large runoff events occurring in 1967, 1969, and the early 1980s, caused substantial incision and scouring due to an absence of riparian vegetation to protect the banks and stabilize the soils. Incision of floodplains drained shallow groundwater tables and left former side channels stranded above the newly incised main stream channel (SWRCB 1994). Under Decision 1631, LADWP was required to develop a stream restoration plan and undertake projects to rehabilitate Rush Creek (LADWP 1996). Channel maintenance and flushing flows, referred to as “stream restoration flows” were established in order to mimic seasonal snowmelt runoff, with the magnitude based on the hydrological conditions for the year (SWRCB 1994).

The wetland resources available at Rush Creek are primarily meadow and woody riparian vegetation (*Salix* spp.) (Table 60) and the creek supplies abundant freshwater year round. Just upstream of the delta, the floodplain is a broad meadow supporting scattered shrub willows. At higher lake levels or high creek flows, flooding has extended across the delta mouth (see Appendix 10: 2005, 2006, 2017). During periods of lake elevation recession, much channel braiding exists in the delta. From 2002 through 2014, side channels distributed water through the lower floodplain, creating saturated conditions, fresh water channels, and a stable fresh water pond along the eastern edge (see Appendix 10: 2002-2014). Headcutting along the mainstem resulted in channel erosion, and side channel abandonment. By the summer of 2015, the pond and channels used by breeding waterfowl disappeared as the lower floodplain experienced drying (see Appendix 10: 2015 and 2016). Rush Creek flows create an area of ria that is expected to extend well beyond the mapped boundary.

Bathymetry of the area indicates that shallow water area is confined to the immediate delta and does not extend beyond the mouth of the creek. Water depths rapidly increase once beyond the protective cove of the creek mouth.

Table 67. Acreages of Modeled and Mapped Landtypes Below the 6,392-foot Contour, Rush Creek Subarea

Landtype	*1999*	*2005*	*2009*	*2014*	*Mean % of mapped Area*
Barren lake bed	**9.0**	**9.9**	**20.8**	**32.3**	**32.3%**
Man-made		**0.1**			**0.1%**
Meadow/Marsh		**24.4**	**19.4**	**14.8**	**25.7%**
Alkaline wet meadow		*5.6*	*3.6*	*1.5*	*4.9%*
Dry meadow/forb		*9.9*	*13.5*	*3.3*	*11.6%*
Marsh		*8.9*	*1.9*	*3.7*	*6.6%*
Wet meadow			*0.4*	*6.3*	*2.6%*
Ria	**2.4**	**6.3**	**1.4**		**5.5%**
Riparian	**7.0**	**1.7**	**8.6**	**8.7**	**12.8%**
Riparian shrub	*7.0*	*1.7*	*8.6*	*8.7*	*12.8%*
Upland scrub	**15.2**	**6.2**	**7.5**	**7.1**	**20.0%**
Water	**0.5**	**1.4**	**4.1**	**2.7**	**3.7%**
Brackish pond	*0.2*	*0.3*		*0.1*	*0.3%*
Freshwater pond			*0.5*	*0.3*	*0.3%*
Freshwater stream	*0.3*	*1.1*	*3.6*	*2.3*	*3.1%*
Total mapped acreage	**34.0**	**50.0**	**61.7**	**65.6**	

Figure 71. Aerial View of the Rush Creek Delta, 2013

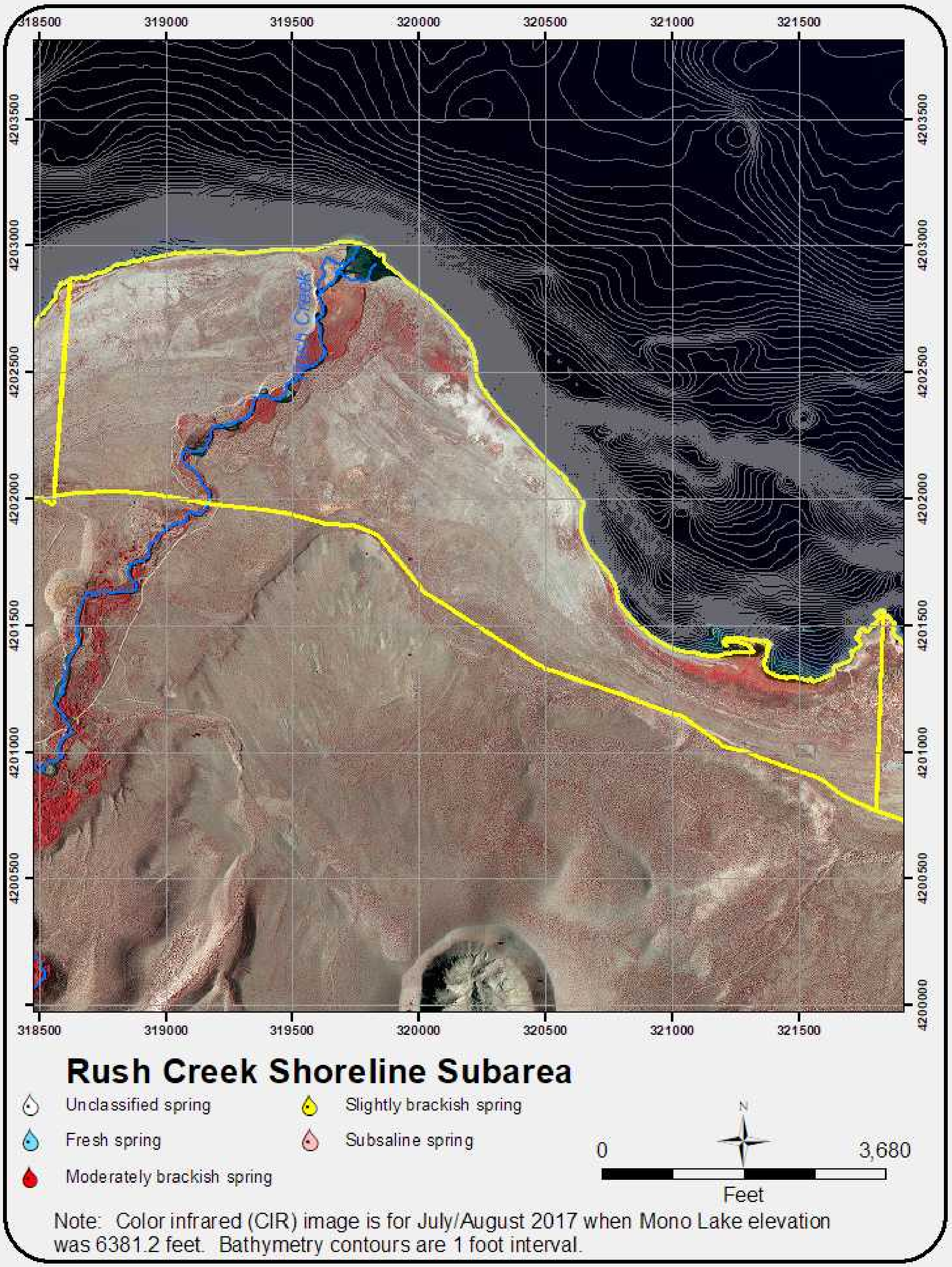


Figure 72. Rush Creek Subarea Springs and Nearshore Bathymetry

Simons Spring (SASP)
(See Appendices 11 and 12 for annual photos)

The Simons Spring subarea includes the southeastern portion of the lakeshore. Located centrally in the subarea is the Simons Spring faultline, a conspicuous feature on the landscape. Several large springs arise from the fault, conducting groundwater to the surface (Rogers et al. 1992). Being subject to the action of longshore currents, shoreline features of Simons Spring are dynamic, particularly west of Simons Spring faultline (Appendix 11). Due to the shoreline gradient, small changes in lake elevation result in large changes in the degree of shoreline flooding.

Open fresh water ponds are a prominent feature of the Simons Spring area, however their presence tends to be ephemeral, west of Simons Spring fault. Over the years, longshore currents have resulted in the development of several parallel littoral bars west of the Simons Springs faultline, most visible on the 2003 photos (Appendix 11). These littoral bars retain upgradient spring flow and support the creation of ponds, wet meadow, and marsh behind the sandbars. During periods of increasing lake level, lake water inundates areas supporting wetland vegetation upgradient of littoral bars (see Appendix 11: 2005, 2011). The vegetation dies back due to salt stress (see Figure 71, Appendix 11: 2007), opening up areas previously grown over with marsh or meadow (see Appendix 11: 2007). When the lake subsequently decreases, open fresh water ponds supported by up gradient springs develop. Many of the freshwater springs in this area reach the lakeshore through breaks in littoral bars, creating extensive mudflats on exposed playa (see Appendix 11: 2013). Although there may be a physical connection between the mudflats and lake water, the very shallow ponds formed on shore are fresh due to the high spring flow, and are colonized within 1-2 years by wet meadow vegetation (Figure 72). In summer of 2015, headcutting commenced along the westernmost spring channels with the continued decline in lake elevation. This resulted in a drying of the exposed playa in the westernmost part of this subarea. Terminal and Abalos spring at the faultline did not experience headcutting, and mudflats remained, supporting most of the bird activity in this area.

Just east of the Simons Spring faultline, permanent to semi-permanent brackish water pond are generally present through the year (Appendix 12: 2007, 2010). The remainder of the subarea to the east lacks spring flow to the lake and supports alkali wet meadow up gradient and barren playa on shore (Appendix 12: 2013)

Although not mapped as a landtype in this area, ria likely occurs due to the multiple areas of spring flow that reach the lake shore. The bathymetry indicates a more gradual offshore slope in the western half of the subarea, a steep offshore slope where the tufa towers of the faultline reach shore, and an increasing shallow slope to the east.

Table 68. Acreages of Modeled and Mapped Landtypes Below the 6,392-foot Contour in the Simons Spring Subarea

Landtype	*1999*	*2005*	*2009*	*2014*	*Mean % of mapped Area*
Barren lake bed	**33.2**	**109.7**	**173.0**	**324.0**	**28.9%**
Meadow/Marsh	**250.5**	**361.3**	**323.6**	**332.9**	**66.7%**
Alkaline wet meadow	*110.4*	*286.5*	*102.5*	*18.3*	*28.7%*
Dry meadow/forb	*68.4*	*5.7*	*19.8*		*6.8%*
Marsh	*71.6*	*69.1*	*201.3*	*42.6*	*20.9%*
Wet meadow				*272.0*	*10.3%*
Upland scrub		**1.0**	**0.5**	**1.5**	**0.1%**
Water	**24.4**	**41.1**	**2.8**	**4.1**	**4.3%**
Brackish pond	*11.1*	*41.1*	*1.5*	*2.2*	*3.1%*
Freshwater pond	*6.5*		*0.2*	*1.9*	*0.6%*
Hypersaline pond	*6.9*		*0.3*	*0.0*	*0.6%*
Mudflat			*0.7*		*0.0%*
Total mapped acreage	**308.1**	**513.1**	**499.8**	**662.6**	

Figure 73. Salt Intrusion into Freshwater Marsh at Simons Spring due to Rising Lake Levels

There is a large littoral bar down the center of the picture protecting the marsh to the left from the lake water. The salt stressed vegetation will die back, and if the lake retreats, open fresh water ponds will form.

Figure 74. Spring Channel Breaks Through a Littoral Bar at Simons Spring and Floods the Adjacent Playa

During this period in 2008 of receding lake elevation, the spring flow over the playa creates shallow fresh water areas adjacent to the lake. The abundant spring flow also creates a fresh water lens supporting the regrowth of wetland vegetation on the playa.

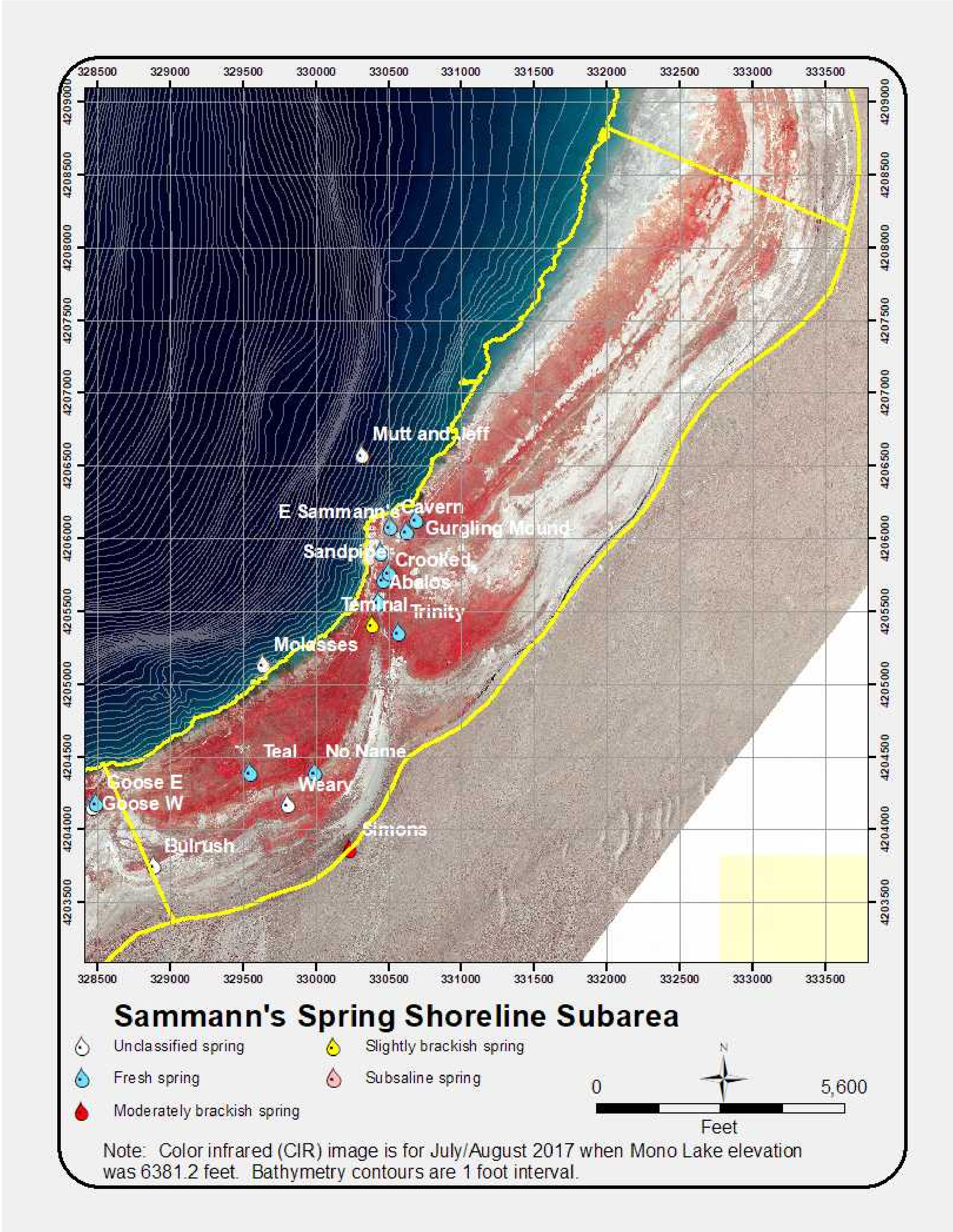


Figure 75. Simons Spring Subarea Springs and Nearshore Bathymetry

South Shore Lagoons (SSLA)
(See Appendix 13 and 14 for annual photos)

The South Shore Lagoons is a broad stretch of shoreline with scattered waterfowl habitat features. Waterfowl habitat features include permanent freshwater ponds supported by springs, and seasonal to semi-permanent ponds supported by groundwater, and ephemeral brackish ponds (Table 62). Like Simons Spring, the shoreline configuration in the South Shore Lagoons subarea is influenced by longshore currents.

At the western border of the subarea, a pond exists along a faultline (see Appendix 13: 2006). This pond has been ephemeral, and its presence a function of lake elevation. At the higher lake elevations observed (approximately 6,383 feet), the pond has been full (see Appendix 13: 2006, 2007, 2011). Below approximately 6282.5 feet, the pond experiences notable contraction in size (see Appendix 13: 2002, 2009) and as at elevations below 6,381.9 feet has been absent (Appendix 13: 2004, 2017-2017).

Sandflat Spring is an isolated freshwater spring supporting two small freshwater ponds, an upper pond, and a lower pond, surrounded by coyote willow. These were open water ponds until 2014, when water speedwell (*Veronica anagallis-aquatica*) and cattails (*Typha* sp.) encroached and enclosed the open water.

At the east end of the subarea is the Goose Springs complex (Appendix 14). Goose Springs is a large spring complex that forms a series of interconnected freshwater ponds surrounded by wet meadow and marsh (see Appendix 14: 2004). In some years, the development of a littoral bar downgradient has captured spring flow, creating large onshore ponds that can be either fresh or brackish (Appendix 14: 2005, 2007-2015).

Away from the immediate shoreline in this subarea, the terrain is sandy hummocks with numerous small, depressions supporting alkali meadow in most years. Groundwater levels in this area have been found to be responsive to lake elevation changes (Rodgers et al. 1992) due to the high topographic gradient and very permeable soils. In 2006 and 2007 when the lake elevation was at its highest observed (above 6,385 feet), these scattered wetlands filled with groundwater, creating a series of scattered fresh water ponds in the South Shore Lagoons subarea.

There exists only a narrow band of gradually sloping shoreline in the western portion of this subarea (Figure 76). In the vicinity of Goose Springs, the shoreline becomes more gradually sloped.

Table 69. Acreages of modeled and mapped landtypes below the 6,392-foot contour in the South Shore Lagoons subarea

Landtype	*1999*	*2005*	*2009*	*2014*	***Mean***
Barren lake bed	**36.7**	**57.0**	**63.5**	**88.8**	**32.1%**
Meadow/Marsh	**73.6**	**119.8**	**96.9**	**87.2**	**51.0%**
Alkaline wet meadow	*13.7*	*107.4*	*53.3*	*7.8*	*23.5%*
Dry meadow/forb	*60.0*	*0.8*	*37.9*	*0.0*	*16.7%*
Marsh		*11.6*	*5.7*	*12.6*	*3.5%*
Wet meadow				*66.8*	*7.3%*
Riparian	**0.9**	**0.4**	**0.2**	**0.4**	**0.3%**
Riparian shrub	*0.9*	*0.4*	*0.2*	*0.4*	*0.3%*
Upland scrub		**7.0**	**15.3**	**43.1**	**7.6%**
Water	**19.0**	**24.4**	**10.4**	**8.7**	**8.9%**
Brackish pond	*15.8*	*23.3*	*9.6*	*3.3*	*7.5%*
Freshwater pond	*3.3*	*0.4*	*0.7*	*4.4*	*1.3%*
Hypersaline pond		*0.6*	*0.0*	*0.1*	*0.1%*
Mudflat				*1.0*	*0.1%*
Total mapped acreage	**130.3**	**208.5**	**186.3**	**228.2**	

Figure 77. Goose Springs, South Shore Lagoons Subarea

The Goose Springs area has consistently attracted nesting waterfowl. The open water pond just on shore is fresh at the time of this photo. The nearshore area is most gradual in this subarea around Goose Springs.

Figure 76. Open Water Pond Formation

From 2007-2007, multiple open water ponds developed along the length of the South Shoreline subarea, creating nesting opportunities for waterfowl.

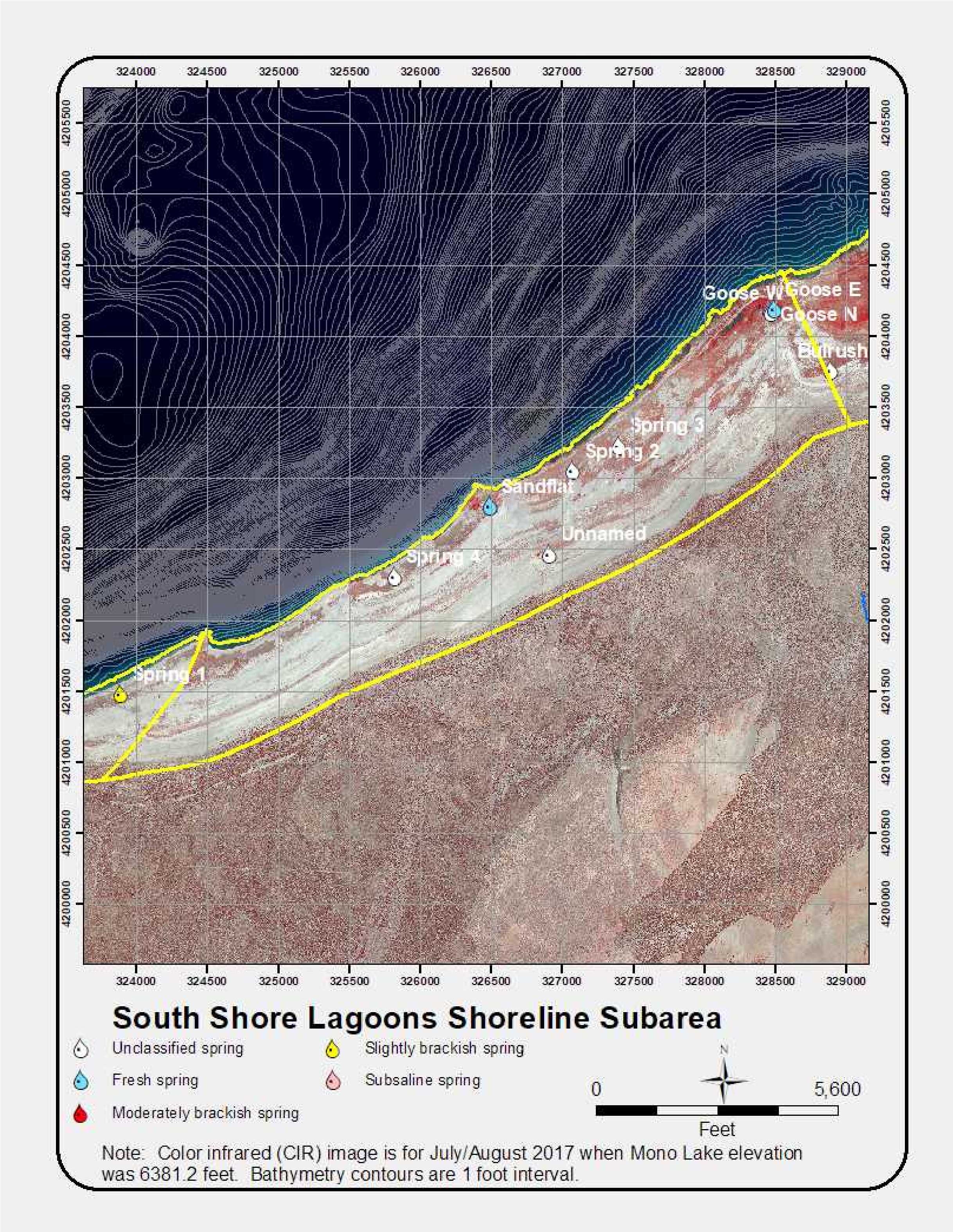


Figure 78. South Shore Lagoons Subarea Springs and Nearshore Bathymetry

South Tufa (SOTU)

(See Appendix 15 for annual photos)

The South Tufa area is the primary visitor access point to the Mono Lake shoreline and includes a large display of tufa towers. The western portion of the survey area, just east of the tufa towers differs notably in terms of waterbird habitat from the eastern portion, just east of a small tufa prominence onshore between the South Tufa access point and Navy Beach. In the western portion, the shoreline is narrow, the offshore topography steep, and the brackish springs creating wet mudflat conditions under most lake levels observed (Figure 77). East of the prominence the shoreline is very gradually sloped onshore as well as offshore. The eastern portion supports an ephemeral brackish pond whose presence has varied with lake elevation and seasonally. At somewhat intermediate lake elevations, the pond has persisted from summer through fall (see Appendix 15: 2005, 2011). In periods of lower lake elevation (Appendix 15: 2013-2016), the brackish pond was present in summer, but had dried by fall.

Table 70. Acreages of Modeled and Mapped Landtypes Below the 6,392-foot Contour in the South Tufa Lagoons Subarea

Landtype	*1999*	*2005*	*2009*	*2014*	***Mean***
Barren lake bed	**13.8**	**15.7**	**32.8**	**37.9**	**35.4%**
Man-made	**0.0**	**0.1**			**0.0%**
Meadow/Marsh	**1.8**	**39.9**	**18.2**	**23.3**	**27.1%**
Alkaline wet meadow	*0.1*	*38.9*	*8.8*	*12.4*	*19.2%*
Dry meadow/forb			*8.8*	*0.6*	*3.6%*
Marsh		*0.7*	*0.1*	*1.1*	*0.6%*
Wet meadow	*1.8*	*0.3*	*0.4*	*9.2*	*3.8%*
Riparian				**0.3**	**0.1%**
Riparian shrub				*0.3*	*0.1%*
Upland scrub	**27.3**	**14.6**	**14.1**	**28.2**	**32.3%**
Water	**4.3**	**8.7**	**0.1**	**0.3**	**5.2%**
Brackish pond	*4.3*	*8.7*		*0.2*	*5.1%*
Freshwater pond			*0.1*	*0.0*	*0.0%*
Hypersaline pond				*0.1*	*0.0%*
Total mapped acreage	**47.2**	**79.0**	**65.2**	**90.0**	

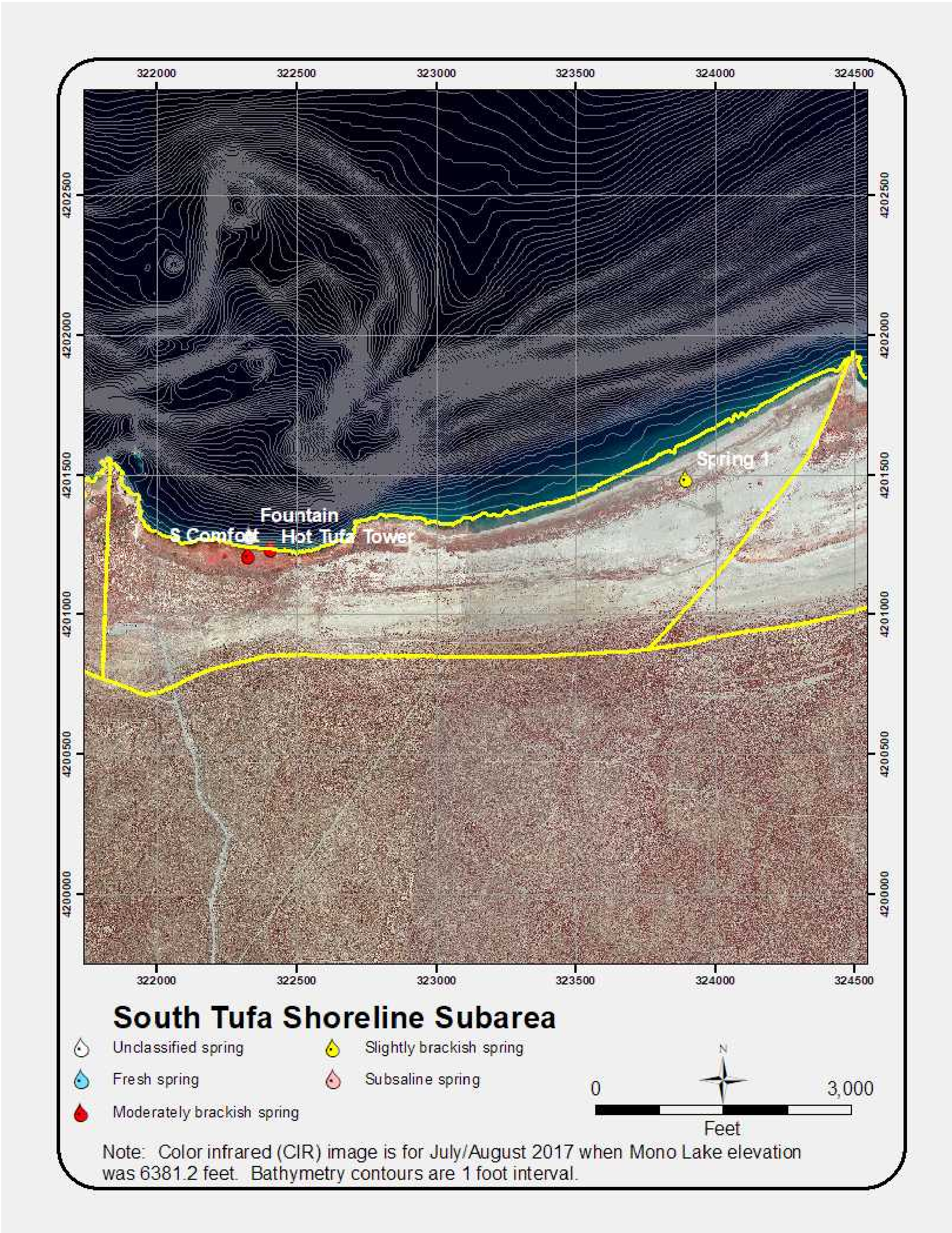


Figure 79. South Tufa Subarea Springs and Nearshore Bathymetry

Warm Springs (WASP)

(See Appendix 16 for annual photos)

The Warm Springs area is located on the eastern shore of Mono Lake. The main feature of the Warm Springs area is a permanent brackish pond that is fed by the outflow of Pebble and Twin Warm Springs (referred to as “north pond”). These and other springs in the area support extensive wet meadow, alkali meadow, and marsh vegetation (Table 64), primarily around the pond and springheads. The springs in the Warm Springs area are slightly to moderately brackish.

The north pond has been present at all lake elevations observed. Some expansion and contraction have occurred, with the pond at its largest extent in 2006 (see Appendix 16). This pond is the only place in the Warm Springs subarea where waterfowl are consistently encountered. Due to the very gradual sloping shoreline in this area (Figure 78), small changes in lake elevation result in large differences in the amount of exposed playa. Longshore action has also shaped this shoreline as evidenced by the prominent littoral bars (see Appendix 16: 2012) creating the north pond and ponds downgradient. During periods of declining lake elevation, seepage of water from the north pond through the loose sandy soil results in the development of ephemeral brackish ponds downgradient of the north pond as seen in 2010, 2012 (Appendix 16). Due in part to their ephemeral nature, vegetation development was not observed in these nearshore brackish ponds. In the summer of 2014, shoreline subsidence of approximately one foot was seen in the vicinity of the north pond. From 2014-2016, several new springs appeared in the expanse of exposed playa. Since 2014, some drying of the wetlands has been noted, possibly related to the reduced spring flow noted in Section 4.3.

Table 71. Acreages of Modeled and Mapped Landtypes Below the 6,392-foot Contour in the Warm Springs Subarea

Landtype	*1999*	*2005*	*2009*	*2014*	***Mean***
Barren lake bed	**146.3**	**340.8**	**358.7**	**567.8**	**51.8%**
Meadow/Marsh	*218.5*	*262.6*	*252.8*	*263.1*	*39.4%*
Alkaline wet meadow	*65.9*	*240.5*	*188.7*	*92.9*	*22.8%*
Dry meadow/forb	*118.4*	*3.7*	*37.5*		*8.0%*
Marsh	*34.2*	*18.3*	*26.5*	*56.2*	*5.2%*
Wet meadow				*114.0*	*3.4%*
Upland scrub			**1.7**	**1.2**	**0.1%**
Water	**103.3**	**67.4**	**8.2**	**8.7**	**8.6%**
Brackish pond	*45.8*	*65.9*	*8.1*	*8.6*	*5.5%*
Freshwater pond	*0.2*	*0.3*		*0.1*	*0.0%*
Freshwater stream				*0.0*	*0.0%*
Hypersaline pond	*57.3*	*1.2*	*0.1*	*0.0*	*3.1%*
Total mapped acreage	**468.1**	**670.8**	**621.4**	**840.9**	

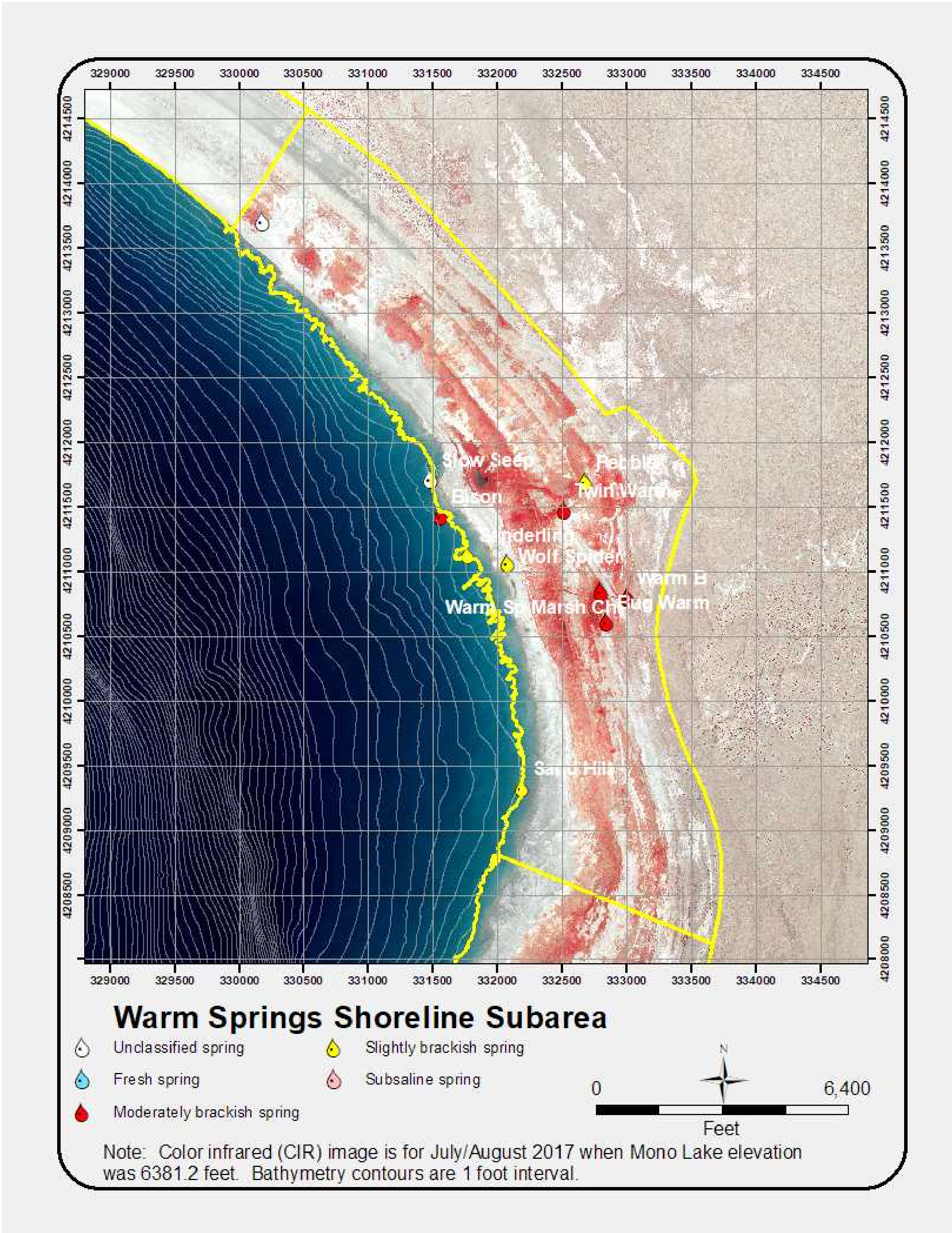


Figure 80. Warm Springs Subarea Springs and Nearshore Bathymetry

West Shore (WESH)
(See Appendix 17 for annual photos)

The majority of the West Shore subarea is located immediately east of Highway 395, along a steep fault scarp. While some shallow gradient areas exist along the southern boundary, the majority of the area is steeply sloping lakeward (Figure 79). Several fractured rock gravity springs (LADWP 1987) and two small drainages, Log Cabin Creek and Andy Thom Creek provide fresh water resources along the length of this shoreline subarea, although ponds are lacking. A very narrow beach exists along much of the length which becomes inundated at higher lake elevations (Appendix 17: 2006). Significant changes have not been noted in the configuration of this shoreline subarea with lake elevation changes.

Table 72. Acreages of Modeled and Mapped Landtypes Below the 6,392-foot Contour, West Shore Subarea

Landtype	*1999*	*2005*	*2009*	*2014*	***Mean***
Barren lake bed	**6.3**	**22.6**	**35.2**	**49.8**	**33.7%**
Man-made		**0.7**	**0.2**		**0.3%**
Meadow/Marsh	**36.6**	**34.4**	**37.7**	**46.4**	**54.2%**
Alkaline wet meadow	*7.2*	*8.8*	*2.0*	*2.1*	*8.1%*
Dry meadow/forb	*26.4*	*5.5*	*22.3*	*6.0*	*24.4%*
Marsh		*20.1*	*11.9*	*3.2*	*11.6%*
Wet meadow	*3.0*		*1.5*	*35.0*	*10.1%*
Ria				**1.0**	**0.2%**
Riparian	**3.3**	**9.1**	**6.1**	**4.8**	**8.0%**
Riparian shrub	*3.3*	*8.7*	*5.7*	*4.8*	*7.7%*
Riparian woodland		*0.4*	*0.4*		*0.3%*
Upland scrub	**0.5**	**3.5**	**0.7**	**3.1**	**2.5%**
Water				**4.9**	**1.1%**
Freshwater stream				*0.0*	*0.0%*
Hypersaline pond				*0.2*	*0.0%*
Mudflat				*4.6*	*1.1%*
Total mapped acreage	**46.7**	**70.3**	**80.0**	**109.9**	

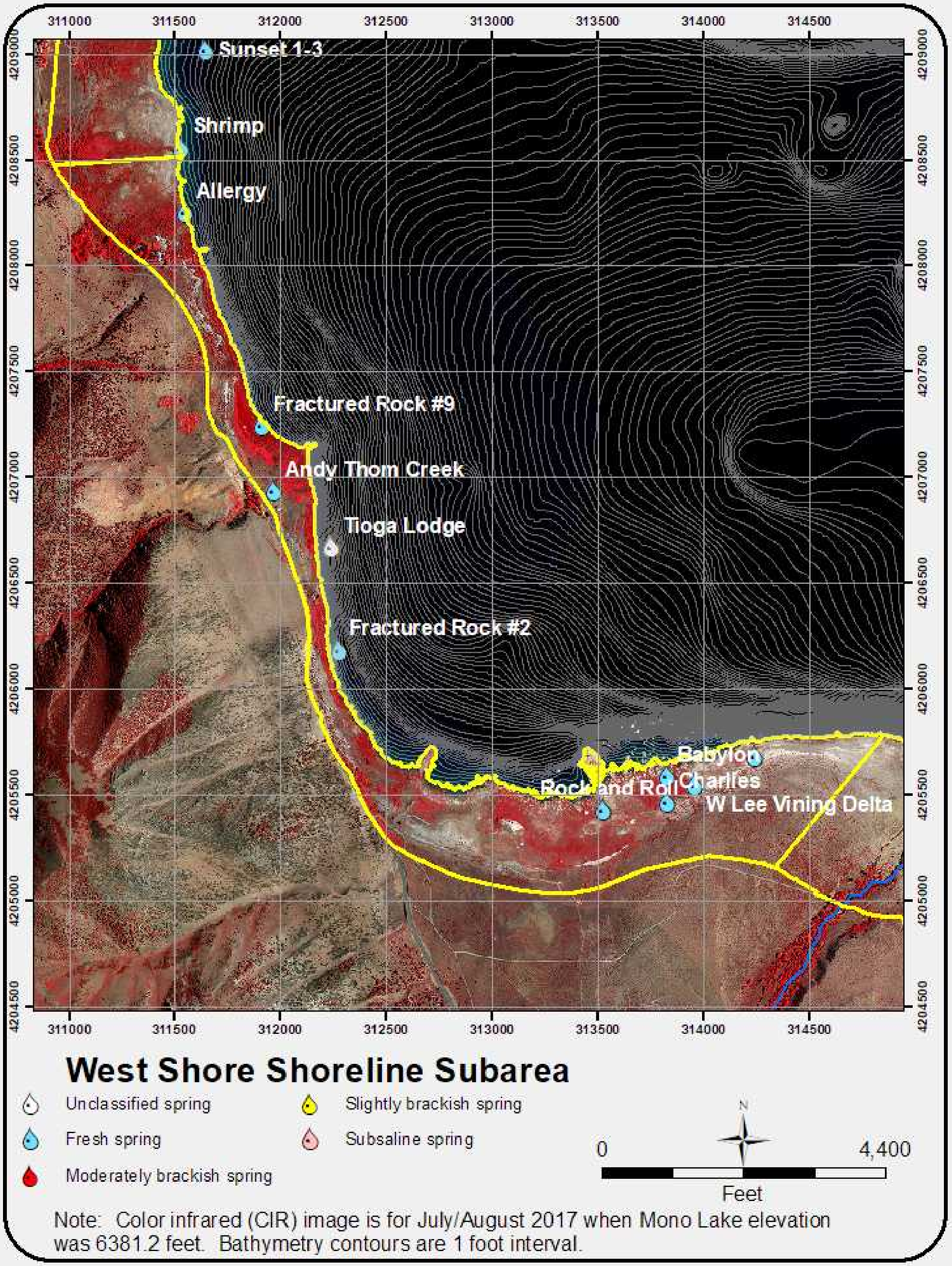


Figure 81. West Shore Subarea Springs and Nearshore Bathymetry

Wilson Creek (WICR)
(See Appendix 18 for annual photos)

Wilson Creek is along the northwest shore. Wilson Creek supports a large expanse of wet meadow, multiple fresh water springs, and mudflats (Table 66). The Wilson Creek subarea has the second highest median spring flow of the monitored springs. Due to the shoreline configuration and presence of large tufa towers, this subarea has two protected bays (see Appendix 18: 2011). Submerged pumice blocks are present throughout the shallows of the eastern portion of the subarea (see Appendix 18: 2016). The bathymetry indicates a very gentle sloping topography throughout the protected bays and all along the shoreline (Figure 80). Due to the shelter, spring flow, and shallow waters near shore, the hypopycnal layer may be extensive in this area. The spring flow and shallow waters also lend toward the formation of mudflats, which have been present at most lake elevations observed. At the lowest elevation observed (2016), the retreat of shoreline resulted in some loss of the protection of the bays, however, mudflats were still prominent due to the high spring flow. The extreme low lake elevation observed in 2016 allowed an opportunity to visualize the near shore topography and spring flow contribution in Wilson Creek bay (Figure 81). As seen in the photo, several significant fresh water springs contribute flow to the bay. The topography is very gently sloping throughout the entire bay, extending out beyond the mouth of the bay and east of Tufa Mound spring. The high spring flow in this area combined with the sheltered nature of the bay would support hypopycnal conditions. Even at higher lake elevations, such as in 2012 (Figure 82), hypopycnal conditions would likely occur across the bay except under windy conditions, due to the high spring flow and contribution from Wilson Creek to the west in 2012. The shallow areas in the bay would make food more accessible to waterfowl. The high spring flow conditions combined with the sheltering of the bay and shallow waters support ideal feeding and loafing conditions for waterfowl at Mono Lake.

Table 73. Acreages of Modeled and Mapped Landtypes Below the 6,392-foot Contour, Wilson Creek Subarea

Landtype	*1999*	*2005*	*2009*	*2014*	***Mean***
Barren lake bed	**17.2**	**16.1**	**29.9**	**34.4**	**49.8%**
Meadow/Marsh	**6.6**	**29.1**	**17.6**	**23.2**	**37.9%**
Alkaline wet meadow	*1.1*	*13.9*	*3.3*	*5.9*	*12.1%*
Dry meadow/forb	*0.6*	*0.0*	*5.4*	*5.3*	*5.0%*
Marsh		*2.4*	*1.2*	*0.0*	*2.0%*
Wet meadow	*4.8*	*12.8*	*7.6*	*12.0*	*18.8%*
Ria		**0.0**	**0.2**	**11.8**	**3.9%**
Riparian	**2.9**	**0.1**	**0.1**	**2.8**	**3.5%**
Riparian shrub	*2.9*	*0.1*	*0.1*	*2.8*	*3.5%*
Upland scrub			**0.8**		***0.4%***
Water	**2.6**	**0.7**	**0.1**	**5.6**	**4.4%**
Brackish pond	*1.0*	*0.1*			*0.9%*
Freshwater pond	*0.4*			*0.0*	*0.4%*
Freshwater stream	*0.2*	*0.6*	*0.1*	*0.6*	*0.7%*
Hypersaline pond	*0.1*				*0.1%*
Mudflat	*0.9*			*5.0*	*2.4%*
Total mapped acreage	29.3	45.9	48.7	77.9	

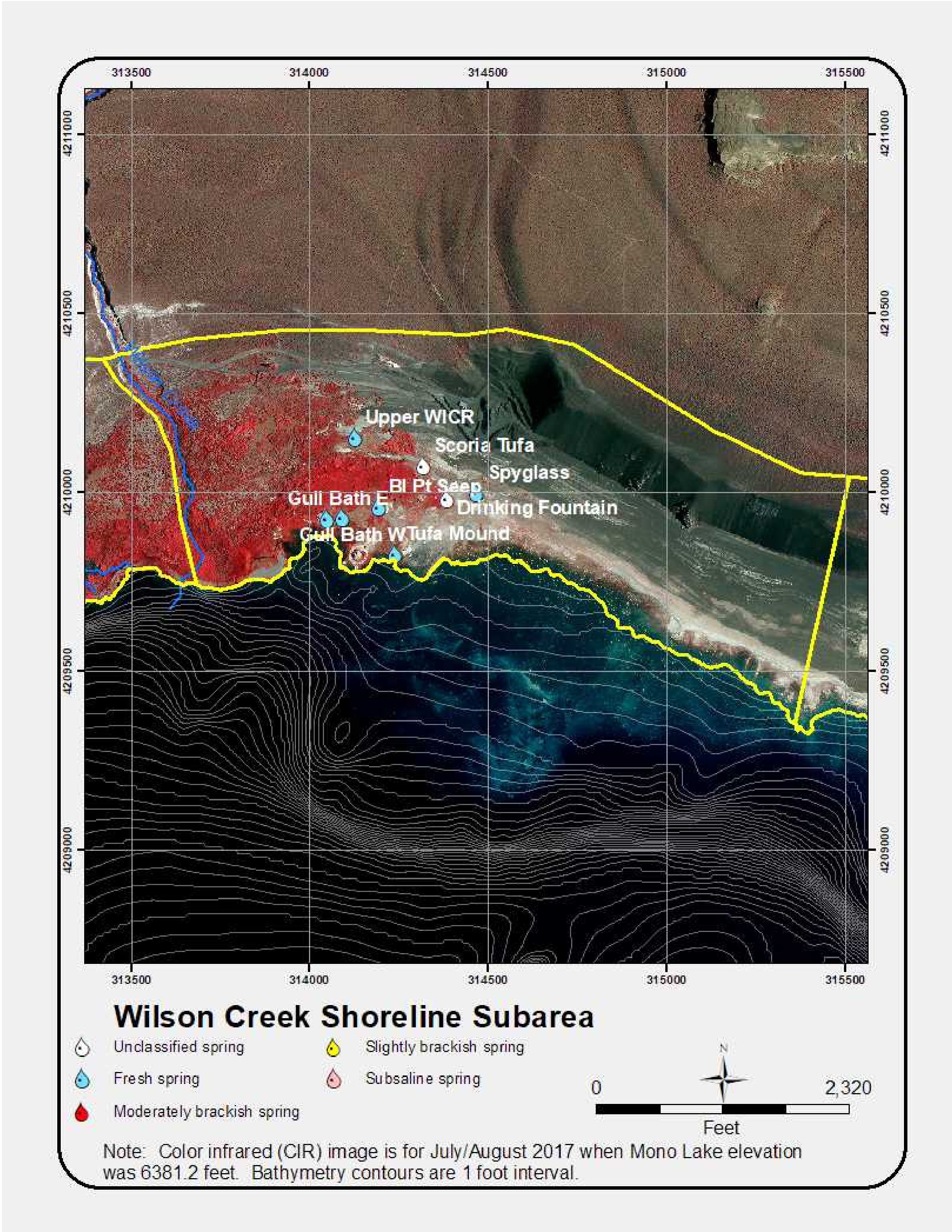


Figure 82. Wilson Creek Subarea Springs and Nearshore Bathymetry

Figure 83. Wilson Creek Bay, 2016.
At this extreme low lake elevation, the contribution of the spring flow to this area, and the extensive sloping shoreline can be seen.

Figure 84. Wilson Creek Bay, 2012.
The higher lake elevation results in the creation of sheltered bays. Spring flow into the bays would create hypopycnal conditions.

4.3.4 Vegetation Status in Riparian and Lake-Fringing Wetlands Discussion

Vegetation Transects

As expected, the wetland sites (DeChambeau Embayment, Simons Spring and Warm Springs) have supported overall higher cover of waterfowl food plants than either of the riparian sites (Rush Creek or Lee Vining Creek). The data for the wetland sites suggests a decrease in vigor, and increase in the decadence of the wetland vegetation. These changes may be a result of the decline in lake elevation, although decreased spring flow could be a contributing factor at Warm Springs. The riparian deltas have shown a response to the reestablishment of perennial flow, as bare ground and dead plant cover have declined substantially. The cover of waterfowl food plants, which are generally wetland plant species, has also increased over time in both Rush and Lee Vining Creek deltas.

Landtype Mapping

The contemporary shoreline of Mono Lake reflects the lowered lake elevation in that the predominant landtype is barren playa. Because landtype mapping extends from the historic high water mark down to the water's edge, the total mapped land acreage has increased since 1999 due to declines in lake elevation and shoreline retraction. This change is reflected primarily in the significant increase in the amount of barren lake bed acreage. Overall, the acreage of meadow/marsh has increased slightly since implementation of the Plan as the lake level has decreased. This is due to the perched water table above barren playa in some areas, resulting in the expansion of meadow/marsh habitats when the saline lake waters recede. The acreages of specific landtypes have varied over the years, however the large differences in acreage between mapping periods of specific meadow types may be due to inconsistencies in mapping (LADWP 2015b) and not entirely attributable to actual type conversion.

Ria has been defined as areas at the mouths of streams, or where spring flow or seepage from the adjacent shoreland that have some freshwater-saline water stratification (Stine 1995). It has been suggested that ria and hypopycnal areas are important to waterfowl in that they may provide a reduced salinity environment in which to feed. Mapping of ria has been somewhat subjective, lacking in effective techniques, and therefore has been subject to substantial error.

A review of previous mapping efforts suggests that the acreage of ria has potentially been under mapped. Although the acreage of mapped ria was highest in 2014, these results should be viewed skeptically. In 2014, there was increased effort to identify potential ria areas, and the increase in identified acreage is likely due to this additional effort.

In 2014, areas mapped as ria were identified by being:

1) spectrally distinct from the open water of Mono Lake (generally shallow areas near shore),

2) within the mapping polygon, and

3) judged to be hypopycnal areas due to known or suspected spring flow.

It is expected that under many situations where creeks or springs enter the lake, a hypopycnal zone will extend beyond the mapped boundary. Changes in the extent of hypopycnal areas, or ria in some area, will not be captured by landtype mapping. Woody riparian vegetation is limited in extent, as less than 40 acres has been identified during any single mapping. The extent of nearshore woody riparian vegetation has not shown much change over time. Riparian vegetation is found primarily in the deltas of all creeks tributary to Mono Lake, and around some fresh water springs. Upland scrub, dominated by Great Basin sagebrush (*Artemisia tridentata*) and Antelope bitterbrush (*Purshia tridentata*) occurs primarily on terraces upslope of shore.

Lakeshore water features include brackish ponds, freshwater ponds and streams, hypersaline ponds, and mudflats. Since 1999, most lakeshore water feature types have decreased with the overall decline in lake elevation. Lake-fringing ponds (whether brackish or hypersaline) have decreased more than any other type of lakeshore water feature. The acreage of mudflat has increased in a few particular areas (DeChambeau Creek, Simons Spring) in areas where there is sufficient spring flow to wet the areas of exposed playa. In periods of receding lake level, brackish ponds form in some shoreline areas. Landtype mapping has been unable to capture these more temporary changes as mapping has not been conducted during any year of receding lake elevation.

Mapping data and modeling predictions suggest that lakewide, Mono Lake landtypes may respond to changes in lake elevation in somewhat predictable ways, although not all shoreline subareas have responded similarly to changes in lake elevation. This model could be tested with future mapping data, and potentially be used to update landtype predictions for at the target lake elevation.

4.4 Waterfowl Population Surveys

Overview of Waterfowl Population Surveys

Waterfowl surveys have been conducted annually from 2002-2017 at Mono Lake, Bridgeport Reservoir and Crowley Reservoir (Figure) to track changes in population levels of waterfowl, and assess waterfowl use of the various wetland habitats. Surveys for waterfowl were ordered by the SWRCB as waterfowl populations are believed to have been affected by water diversions from the Mono Basin more so than other waterbird taxa. The monitoring of waterfowl populations was to continue through one complete wet/dry cycle after the targeted lake elevation of 6,392 foot elevation had been reached. At the time of development of the Plan, LADWP anticipated monitoring annually until 2014 (LADWP 1996).

From 1996 to 2001, waterfowl surveys were conducted under the Plan by Dr. Joe Jehl of Hubbs-Sea World Research Institute. Jehl performed primarily boat-based surveys of the Mono Lake shoreline. A few comparative aerial waterfowl counts of Bridgeport Reservoir and Crowley Reservoir were also conducted by Jehl, either by plane, boat, or from land.

In 2002, LADWP Watershed Resources Specialist Deborah House assumed responsibility for the project. House worked collaboratively with the Mono Lake Parties to develop a structured monitoring program involving ground counts for breeding waterfowl and aerial surveys for Mono Lake, and Bridgeport and Crowley Reservoirs. Any concerns regarding the proposed monitoring program were addressed prior to receiving final approval from the State Water Resources Control Board to implement the changes proposed. The waterfowl monitoring protocols developed by House and approved by the SWRCB in 2002, have been implemented for the entire 16-year period, 2002-2017.

Historical Waterfowl Information

The historical record is incomplete with regard to the use of Mono Lake by waterfowl during the pre-diversion period (Jones and Stokes Associates, Inc. 1994). However, written and verbal testimony by long-time residents and hunters, supplemented with minimal survey data, suggested that the waterfowl population of Mono Lake was once orders of magnitude larger. Declines in waterfowl use were noted as occurring by the early or mid-1960’s (Jones and Stokes Associates, Inc. 1994).

In the first half of the 20th century, impacts to waterfowl habitat were occurring throughout the Pacific Flyway, likely affecting waterfowl use at Intermountain West sites including Mono Lake. In California, the Central Valley Project Act, passed in 1933, resulted in significant alteration and destruction of wetlands throughout California’s Central Valley. Impacts to wetlands in the Central Valley have been extensive over time, and currently, only 13% of the 4 million acres of wetlands that existed in the mid-1800s still exists (Dahl and Allord 1997). The 1960s were a period in which significant declines in waterfowl numbers were noted at other locations along the Pacific Flyway as well, such as the Klamath Basin (Gilmer et al. 2004). Thus, although the ecological changes that occurred at Mono Lake in response to water diversions are believed to have contributed to declines in utilization by waterfowl, during the same time period, waterfowl and their habitats were experiencing impacts throughout the flyway.

In 1948, Walter Dombrowski, a duck club owner and seasonal aide with the California Department of Wildlife (then called Division of Fish and Game), conducted seven waterfowl surveys at the Rush Creek delta between September and November. These surveys provided semi-quantitative data including an estimate of the total number of waterfowl present and approximate proportion of the most abundant species. Based on these surveys and testimonies of residents, the SWRCB concluded that Mono Lake probably supported several hundred thousand waterfowl historically (SWRCB 2005). Dombrowski also provided a map indicating the spatial distribution of waterfowl around Mono Lake in that time period, reporting that 45% of waterfowl occurred in the Rush Creek delta. It is important to note that at the time of the surveys, Dombrowski was maintaining approximately 32 acres (B. Tillemans, pers. comm.) of artificial open-water duck ponds near the Rush Creek delta through water diversions. These ponds greatly enhanced the habitat available for waterfowl in the Rush Creek delta.

Waterfowl surveys were not conducted again at Mono Lake until 1998 when the California Department of Fish and Wildlife (then Department of Fish and Game) conducted a survey flight in October and another one in November of that year. The October 20 flight recorded 3,817 waterfowl, while the November 20 flight recorded 2,375 waterfowl.

No quantitative information regarding the historical size of the breeding population at Mono Lake is available, but it is believed that only a small breeding population was present in the Mono Basin during the prediversion period (Stine 1995).

Impacts to Waterfowl and Habitat From Diversions

The decline in lake elevation caused changes to the Mono Lake ecosystem, and was determined by the SWRCB to have impacted waterfowl and their habitat. Based on accounts from long-time residents, waterfowl declines in the Mono Basin were noted in the early to mid-1960s, coincident with the loss of open water habitat and fresh water input from Rush and Lee Vining Creeks (Jones and Stokes Associates, Inc. 1993). These ecological changes may have affected the food supply, habitat, or the ability of waterfowl to find shelter or cover.

The decline in lake elevation and subsequent increased salinity may have affected food resources for waterfowl. Although even at prediversion levels, Mono Lake was considered saline, the salinity was much lower. Based on modeling data (Vorster 1985), the salinity of Mono Lake in the early 1940's was approximately 48 gm/L. By the mid-1960s, salinity had increased to over 70 gm/L, and was close to 100 g/L by 1982.

The increase in salinity experienced by Mono Lake may have had effects on the invertebrate community, thereby providing a mechanism to affect waterfowl populations. Although data on the prediversion invertebrate community is not available, the relationships between salinity and invertebrate communities is well-studied. Salinity is a dominant factor regulating aquatic invertebrate community structure, especially in hydrologically closed lakes (Verschuren et al. 2000). Aquatic invertebrate community species richness tends to be highest in fresh water systems, decreasing with increasing salinity (Waterkeyn et al. 2008) as few species are tolerant of highly saline conditions. Biomass is often highest however, at intermediate levels of salinity. Even those species tolerant of saline and hypersaline waters, including brine shrimp (*Artemia*) and alkali flies (*Ephydra* spp.), experience increased mortality and reduced reproduction as salinity increases (Browne and Wanigasekera 2000, Herbst and Dana 1977).

The increase in salinity that Mono Lake experienced due to diversions is believed to have affected the invertebrate community structure. For example, a previously abundant rotifer, *Hexarthra jenkinae*, essentially disappeared at the highest salinities, only to be recently found in numbers in shoreline habitats of reduced salinity (Jellison et al. 2001). Aquatic invertebrate communities inhabiting saline lakes are sensitive to fluctuations in salinity.

Diversions also altered the shoreline waterfowl habitats. Although marsh and meadow habitat expanded as the lake level dropped, open water ponds associated with these habitats were lost. The lowering of the lake resulted in the exposure of significant acreage of barren lake bed. While meadow and marsh habitats can provide cover and nesting opportunities for waterfowl, the overall value of these habitats was considered reduced as the wetland vegetation was of dense, dead mats lacking open water and new growth (Drewien, Reid and Ratcliff 1996). In addition, the meadow and marsh habitats were no longer adjacent to the lake's edge, where spring flow would have created a hypopycnal layer of water in areas close to cover. The loss of freshwater marshes and ponds linked with areas of hypopycnal layers is believed to have significantly impacted waterfowl (SWRCB 1996).

The decline in lake elevation is believed to have resulted in a loss of sheltered areas for waterfowl through changes in the configuration of the shoreline. According some early accounts, waterfowl spent a considerable amount of time on the open water of Mono Lake while feeding although others reported waterfowl congregating in the deltas and nearshore areas to feed and drink (Jones and Stokes Associates, Inc. 1993). Waterfowl would retreat to the shore and bays during periods of inclement weather and high winds, seeking shelter and refuge (Stine 1995). One area where waterfowl habitat was believed to have been affected was the Simons Spring shoreline, where a bight existed east of the Simons Spring faultline prediversion. Due to the numerous springs in this area, the bight would have provided shelter during high winds, and also served as a favorable environment for foraging. The decline in lake elevation is believed to have resulted in a simplification of the lake shoreline configuration in this area and reduced sheltered bay habitat.

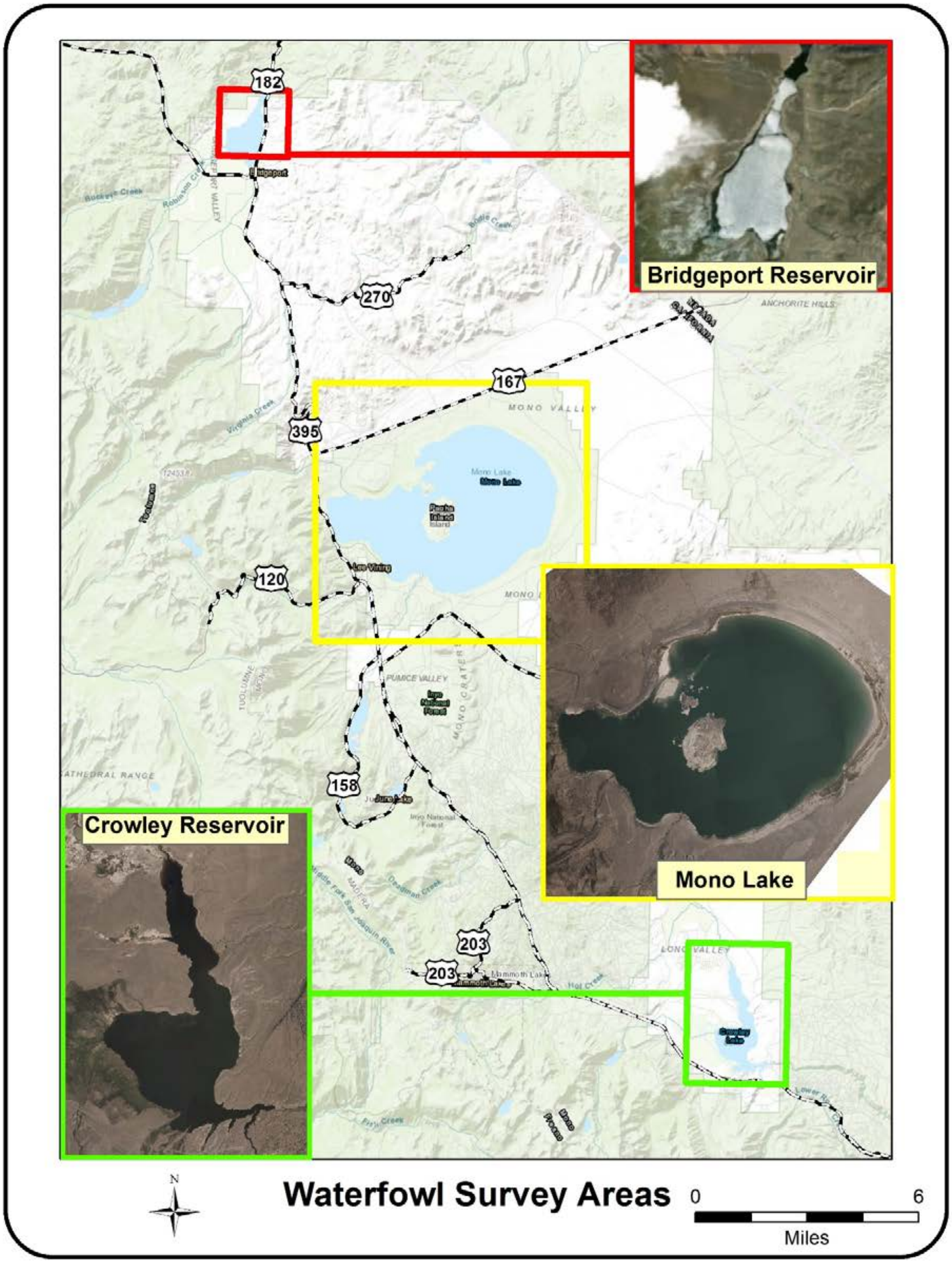


Figure 85. Overview of Waterfowl Survey Areas

Summer Ground Surveys

Summer ground surveys were conducted only in the Mono Basin along shoreline of Mono Lake and at the DeChambeau and County Pond complexes. Although summer use was believed to be small as compared to the fall migratory population, limited information has been available regarding summer waterfowl populations at Mono Lake. Summer ground surveys of Mono Lake were conducted at sites as specified in the Plan. The Plan provided no specific guidance regarding the objectives of summer monitoring, however Drewien et al. (1996) recommended summer counts to record numbers and species composition of waterfowl and other waterbirds. The implied intent of summer surveys was to fill in gaps in knowledge regarding summer use by waterfowl.

Fall Aerial Surveys

Fall waterfowl surveys were conducted at Mono Lake and two nearby lakes - Bridgeport Reservoir and Crowley Reservoir also in Mono County, California (Figure 83). Situated just east of the town of Lee Vining, Mono Lake is almost centrally located in Mono County. Bridgeport Reservoir is approximately 22 miles northwest of Mono Lake near the town of Bridgeport. Crowley Reservoir is approximately 31 miles southeast of Mono Lake, and 12 miles southeast of the town of Mammoth Lakes.

The primary value of Mono Lakes to waterbirds is as a migratory stopover, and use by waterfowl is expected to be highest during the fall migratory period. In order to evaluate whether population changes observed at Mono Lake are mirrored at other Eastern Sierra water bodies or are specific to Mono Lake, comparison counts have been done annually at Bridgeport and Crowley Reservoirs.

4.4.1 Waterfowl Population Monitoring Methodologies

Summer Ground Surveys

Mono Lake Shoreline Surveys

Each year, from 2002 to 2017, summer ground counts were conducted along the shoreline of Mono Lake to record summer waterfowl use, assess the breeding population, document the number of broods, and record habitat use. The following is a summary of the ground count methodology detailed in Mono Lake Waterfowl Population Monitoring 2016 Annual Report (LADWP 2017). All surveys were conducted by Deborah House.

Nine shoreline subareas and approximately 14 miles of shoreline was surveyed annually (Figure 84). The following shoreline subareas were surveyed: South Tufa, South Shore Lagoons, Simons Spring, Warm Springs, Wilson Creek, Mill Creek, DeChambeau Creek Delta, lower Rush Creek and Rush Creek Delta, and lower Lee Vining Creek and delta.

Three summer ground-count surveys were conducted annually at each of the shoreline subareas. Surveys were conducted at three-week intervals beginning in early June. The summer ground count survey dates for each year are provided as Appendix 19. Surveys were conducted by walking at an average rate of approximately 1 mile/hr, depending on conditions, and recording waterfowl species as they were encountered. Surveys started within one hour of sunrise, and all shoreline areas were surveyed over a 3-5 day period. The order in which the various sites were visited was varied in order to minimize the effect of time-of-day on survey results. For each waterfowl observation, the following was recorded: time of the observation; the habitat type being used; and an activity code indicating how the bird, or birds were using the habitat. Examples of activities recorded include resting, foraging, flying over, nesting, brooding, sleeping, swimming, or calling.

While conducting these summer ground counts at Mono Lake, emphasis was placed on finding and recording all waterfowl broods. Because waterfowl are easily flushed, and females with broods are especially wary, the shoreline was frequently scanned well ahead of the observer in order to increase the probability of detecting broods. Information recorded for broods included species, size, GPS coordinates (UTM, NAD 83, Zone 11, CONUS), habitat use, and age. Broods were aged based on plumage and body size (Gollop and Marshall 1954).

Since 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 an age class to broods allowed for a determination of the minimum number of “unique broods” using the Mono Lake wetland and shoreline habitats.

Habitat use was recorded in order to document habitat use by waterfowl at Mono Lake. Habitat use was recorded using the mapped landtype categories. 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.

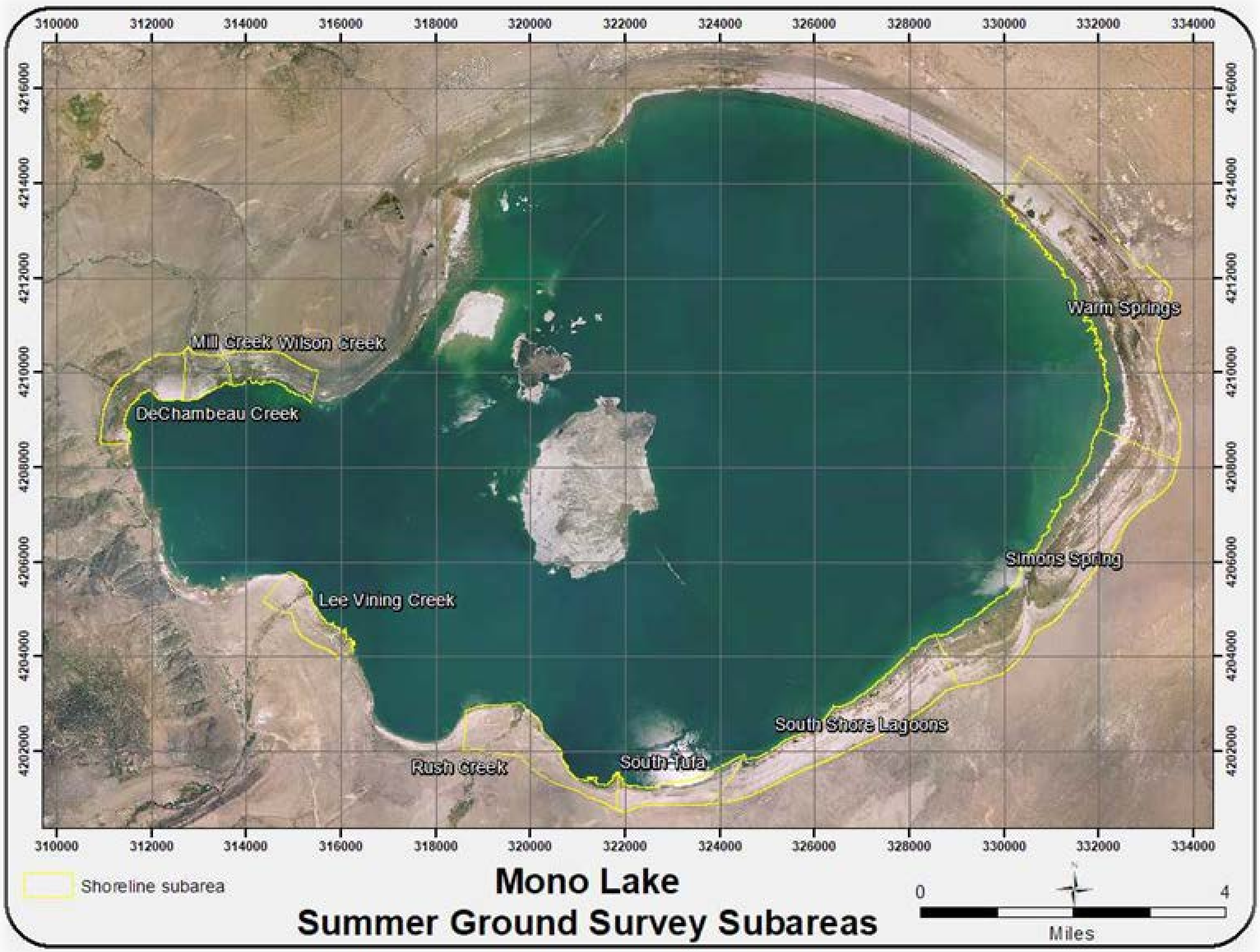


Figure 86. Shoreline Subareas Where Summer Ground Count Surveys were Conducted from 2002-2017

Salinity measurements of lake-fringing ponds were taken using an Extech EC400 Conductivity/TDS/Salinity probe in order to aid in the classification of fresh versus brackish ponds when recording habitat use. Ponds with a salinity of less than 500 ppm were classified as fresh. Ponds with vegetation present and a salinity of greater than 500 ppm were classified as brackish. Ponds with a measured salinity greater than 10 ppt (the maximum range of the probe) lacking vegetation and subsurface or surface freshwater inflow were classified as hypersaline.

Restoration Ponds

From 2002-2017, summer ground counts were also conducted at the DeChambeau and County Pond complexes north of the lake.

The DeChambeau Ponds are a complex of five artificial ponds of varying size. There are two water sources currently supplying water to the DeChambeau Ponds. Most of the water is from Wilson Creek and is delivered to the DeChambeau ponds via an underground pipe and has averaged 1-2 cfs recently (N. Carle, pers. com.). The underground piping flows water from pond 1 to pond 5. The second source is water from a hot spring adjacent to DeChambeau_04. The hot spring water was formerly delivered to each of the five ponds through piping. A leak developed around 2008 or 2009 in the pipe supplying the ponds (N. Carle, pers. com.). Since the development of the leak, hot spring water has only been capable of being delivered to DEPO_04. Although a propane powered well to supply groundwater was installed, this is no longer being used due to cost.

The County Pond complex consists of two ponds – County Pond East (COPOE) and County Pond West (COPOW). Water is delivered to the County Ponds via a pipe from the DeChambeau Ponds. A diverter box exists at the County Ponds to allow some control over water releases to the individual ponds. According to the U.S. Forest Service, County Pond West has been difficult to dry out, thus has been subject to cattail overgrowth.

Figure 87. Aerial Map of DeChambeau Ponds

Figure 88. Aerial Map of County Ponds

Fall Aerial Surveys

From 2002-2017, aerial surveys were conducted annually during the fall waterfowl migratory period at three lakes in Mono County: Mono Lake, Bridgeport Reservoir, and Crowley Reservoir. Each year, six surveys were conducted biweekly, with the first survey conducted the first week of September, and the final survey occurring in the mid-November. In all cases, surveys of all three waterbodies were completed in a single flight by 1200 hours (local time) on the day of the survey. Survey dates for each year are provided as Appendix 20. Each of the three study sites were divided into shoreline and/or open-water segment areas in order to document the spatial distribution of waterfowl.

Aerial surveys were conducted using a high-winged four-passenger aircraft at a speed of approximately 130 kilometers per hour, and at a height of approximately 60 meters above ground. Two observers other than the pilot were present on all six flights. There have been consistent observers over the length of the project. The principal observer, Deborah House, was present on all but two surveys during the study period. Although there was some personnel turn-over early in the project, Chris Allen, LADWP Watershed Resources Specialist, has been the second observer since 2009.

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

Mono Lake Shoreline

Fall aerial surveys were conducted at Mono Lake in order to effectively survey both the shoreline and open water areas and be able to complete the surveys in less than two hours. Most dabbling ducks and geese can be found in close proximity to the shoreline. Ruddy Duck, which is one of the two most abundant species, however, can occur in large numbers well offshore. Completing the surveys within this short of a time period limits the chance of double-counting birds due to local movements, and effectively records the total birds present on a single day.

The areas surveyed at Mono Lake were the shoreline and off-shore open water areas of Mono Lake. All areas were surveyed during each flight. The shoreline was divided into 15 shoreline segments (Appendix 21). Shoreline segment boundaries for Mono Lake followed those established in Jehl (2002), except for minor adjustments made in order to provide the observer with obvious landmarks that are easily seen during aerial surveys. A sampling grid was established in 2002 to survey open-water areas of Mono Lake during aerial flights. The grid consisted of eight parallel transects spaced at one-minute (1/60th of a degree, approximately one nautical mile) intervals that were further divided into a total of 25 sub-segments of approximately equal length (Figure 5, Appendix 22).

Perimeter surveys were conducted over water while maintaining a distance of approximately 500-800 feet from the shoreline. When conducting aerial surveys, the perimeter flight was conducted first, and 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. When conducting cross-lake transect counts, observers sat on opposite sides of the plane and counted Ruddy Ducks, other waterfowl, and phalaropes occurring on the open water. In order to increase detection of waterfowl on the open water, observers sat on opposite sides of the aircraft during cross-lake transect surveys. Although 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 opposite headings 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.

During aerial surveys, the beginning and ending points for each subsection were determined using landscape features, or, when over open water, by using a stopwatch, since the survey aircraft's airspeed was carefully controlled and uniform, and the approximate length of each subsection was known.

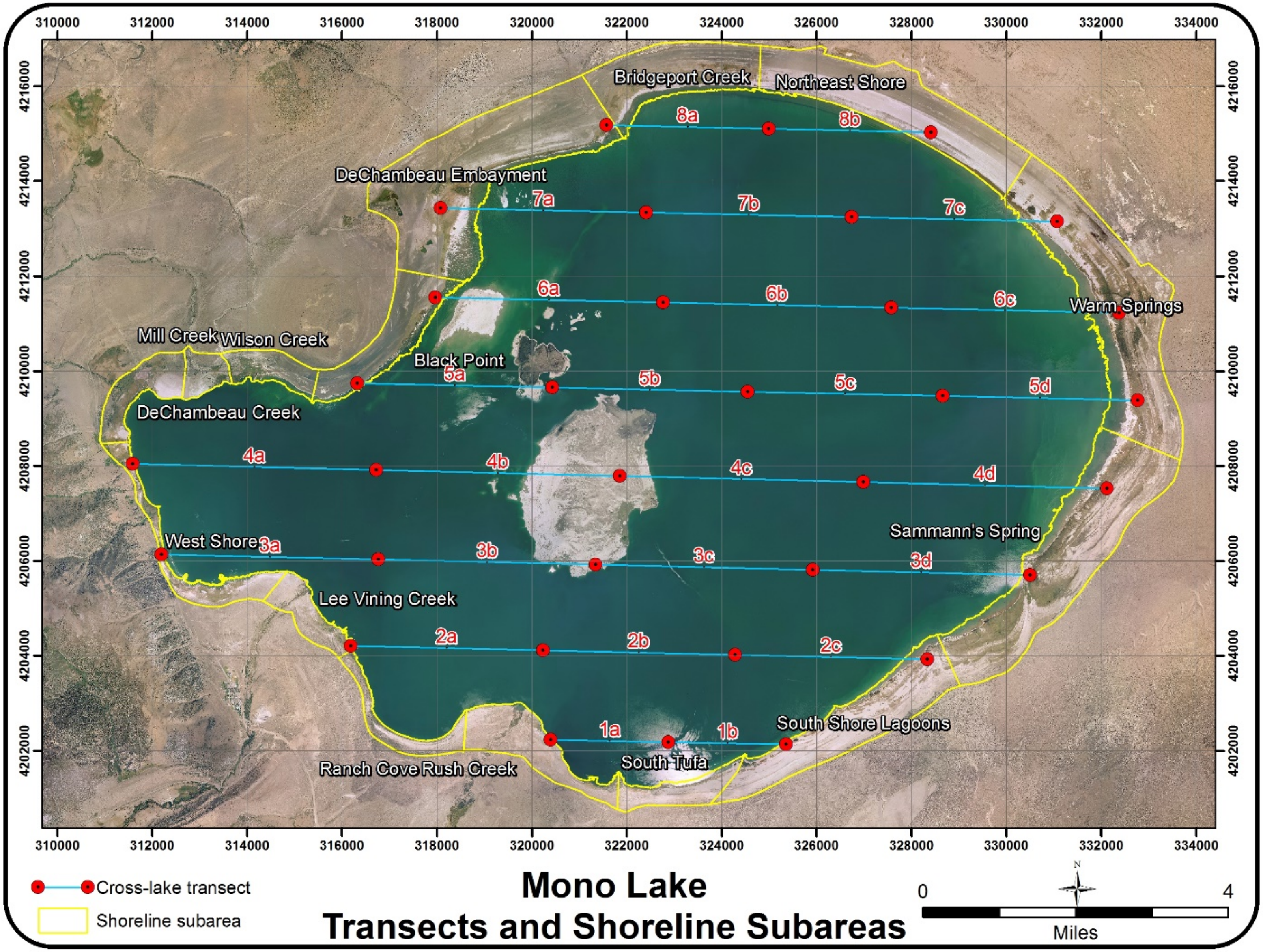


Figure 89. Mono Lake Shoreline Subareas and Cross-lake Transects

Restoration Ponds

DeChambeau and County Restoration Pond complexes were also surveyed during the aerial flights. Waterfowl observations were recorded by pond.

Bridgeport Reservoir

Bridgeport Reservoir is located in Bridgeport Valley, at an elevation of 6,460 feet. Bridgeport Reservoir is a small reservoir with a surface area of approximately 7.4 square miles and a storage capacity of 42,600 acre-feet. The reservoir is rather shallow with a mean depth of 15 feet and a maximum depth of 43 feet (Horne 2003). Bridgeport Reservoir captures flows from Buckeye Creek, Robinson Creek, and the East Walker River to be used for agricultural purposes in Nevada. Irrigated pastures border the south and southwestern portion of the reservoir, while Great Basin scrub is dominant along the north arm and east shore.

Bridgeport Reservoir is eutrophic and experiences summer blooms of blue-green algae. Four colonial forms of cyanobacteria have been found to be common: *Aphanizomenon*, *Anabaena*, *Microcystis*, and *Gloeotrichia* (Horne 2003). In shallow areas near the deltas, submergent aquatic vegetation is abundant.

Although Bridgeport is a small reservoir, ground access to areas where waterfowl concentrate is limited. Three shoreline segments were established at Bridgeport Reservoir: North Arm, West Bay, and East Shore (Figure 6). The North Arm includes primarily sandy beaches bordered by upland vegetation. The West Bay receives fresh water inflows from Buckeye and Robinson Creeks and the East Walker River, creating extensive mudflat areas adjacent to these creek inflow areas, especially when the water level in the reservoir is higher. The West Bay also receives extensive seepage and runoff from the adjacent irrigated pastures. The East Shore includes some mudflat and meadow areas in the vicinity of the East Walker River, but the majority of the East Shore area is bordered by Great Basin scrub or exposed reservoir bottom. At Bridgeport Reservoir, all shoreline areas were surveyed during aerial flights, with additional passes over open water areas as needed, based on waterfowl distribution.

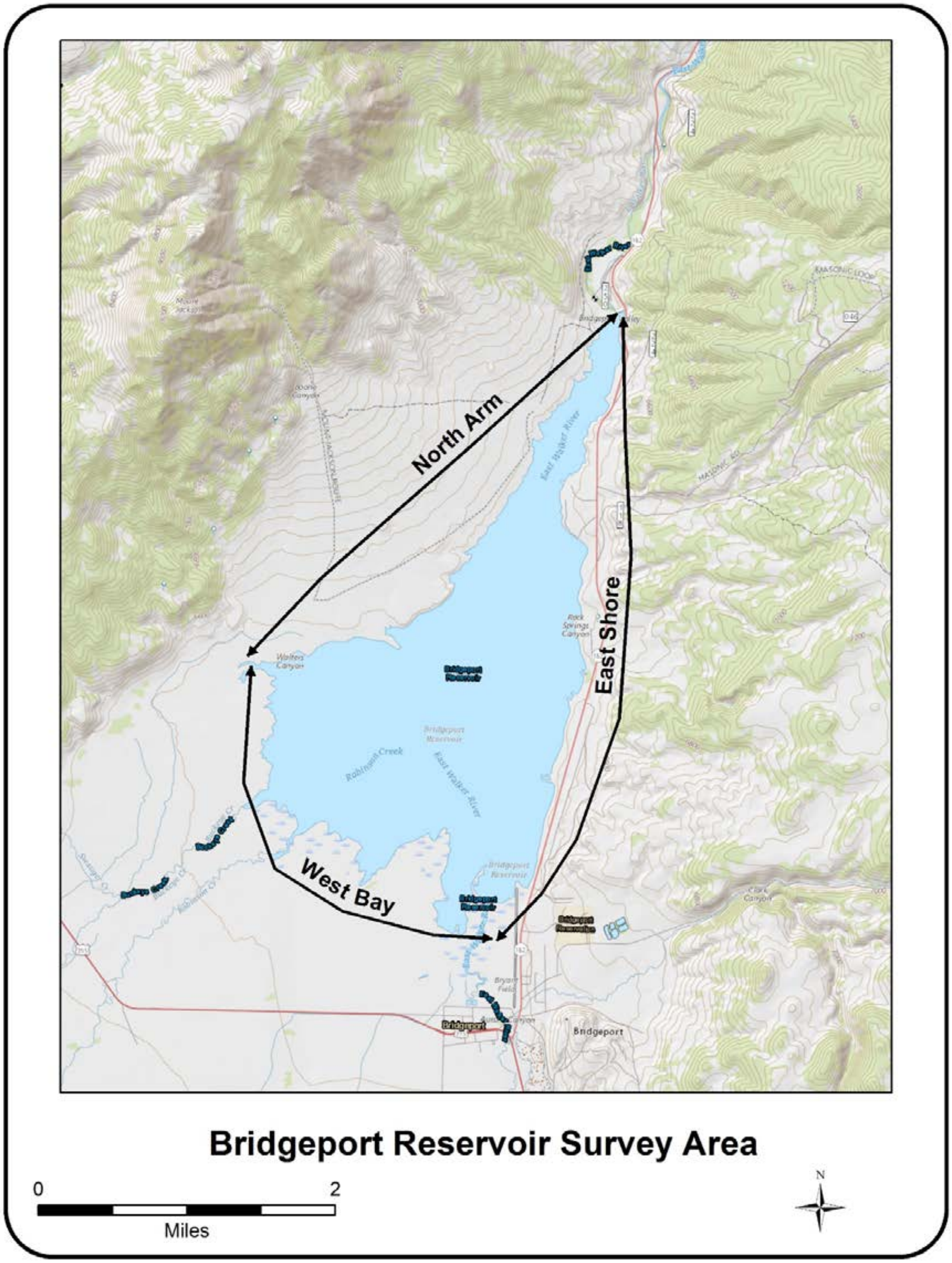


Figure 90. Bridgeport Reservoir Survey Area and Subareas

Crowley Reservoir

Crowley Reservoir is located in Long Valley, at an elevation of 6,780 feet. Created by the construction of the Long Valley Dam in 1941, Crowley Reservoir is the second largest lake in Mono County, and the largest reservoir in the county, averaging 13.2 square miles in area. The development of Crowley Reservoir in 1941 to store exports from the Mono Basin may have helped mitigate the loss of waterfowl habitat at Mono Lake as diversions were initiated (B. Tillemans, testimony to the SWRCB, November 15, 1993). Crowley is much deeper than Bridgeport Reservoir, with a mean depth of 35 feet and a maximum depth of 125 feet (Corvallis Environmental Research Laboratory and Environmental Monitoring Support Laboratory 1978). The storage capacity of Crowley Reservoir is 183,465 acre-feet. The major source of fresh water input to Crowley Reservoir is the Owens River. Other fresh water input includes flows from McGee and Convict Creeks, Layton Springs, and subsurface flow from other springs along the west shore. Vegetation communities immediately surrounding Crowley Reservoir include irrigated pasture, wet meadow, Great Basin scrub, alkali meadow, and mudflats.

Crowley Reservoir is eutrophic and experiences summer blooms of the nitrogen fixing cyanobacteria *Gloeotrichia* in summer, and late-summer and fall season blooms of the cynaobacteria *Aphanizomenon* (Jellison et al. 2003). In shallow areas near the deltas, submergent aquatic vegetation is abundant. Crowley Reservoir is known for supporting a healthy population of midges (Chironomidae).

Ground access is good at most locations of Crowley, but limited in the area of highest waterfowl use in the McGee Bay area.

At Crowley Reservoir, seven shoreline segment areas were established (Figure 7). All shoreline areas were surveyed during each flight with additional passes over open water areas as needed, based on waterfowl distribution.

Crowley Shoreline Subareas

Upper Owens - The Upper Owens area includes large areas of exposed mudflats and reservoir bottom, and receives direct inflow from the Owens River.

Sandy Point - Most of the length of Sandy Point area is bordered by cliffs or upland vegetation. Small areas of meadow habitat occur in this area, and limited freshwater input occurs at Green Banks Bay.

North Landing - The North Landing area is influenced by subsurface flows and supports meadow and wet meadow habitat, particularly near the western border.

McGee Bay - The McGee Bay shoreline area supports vast mudflat areas immediately adjacent to wet meadow habitats. McGee Creek and Convict Creek are tributaries to Crowley Reservoir in this shoreline area. Other sources of water with the McGee Bay include spring flow and subsurface flow from up-gradient irrigation.

Hilton Bay - The Hilton Bay area includes Big Hilton Bay to the north and Little Hilton Bay to the south. The Hilton Bay area, surrounded by meadow and sagebrush habitat, receives small amounts of fresh water input from Hilton Creek, Whiskey Creek, and spring flow.

Chalk Cliffs - The Chalk Cliffs area lacks fresh water inflow areas and wetland habitats, and is dominated by sandy beaches adjacent to steep, sagebrush-covered slopes.

Layton Springs - The Layton Springs shoreline area is bordered by upland vegetation and a large area of sandy beach. Layton Springs provides fresh water input at the southern border of this lakeshore segment.

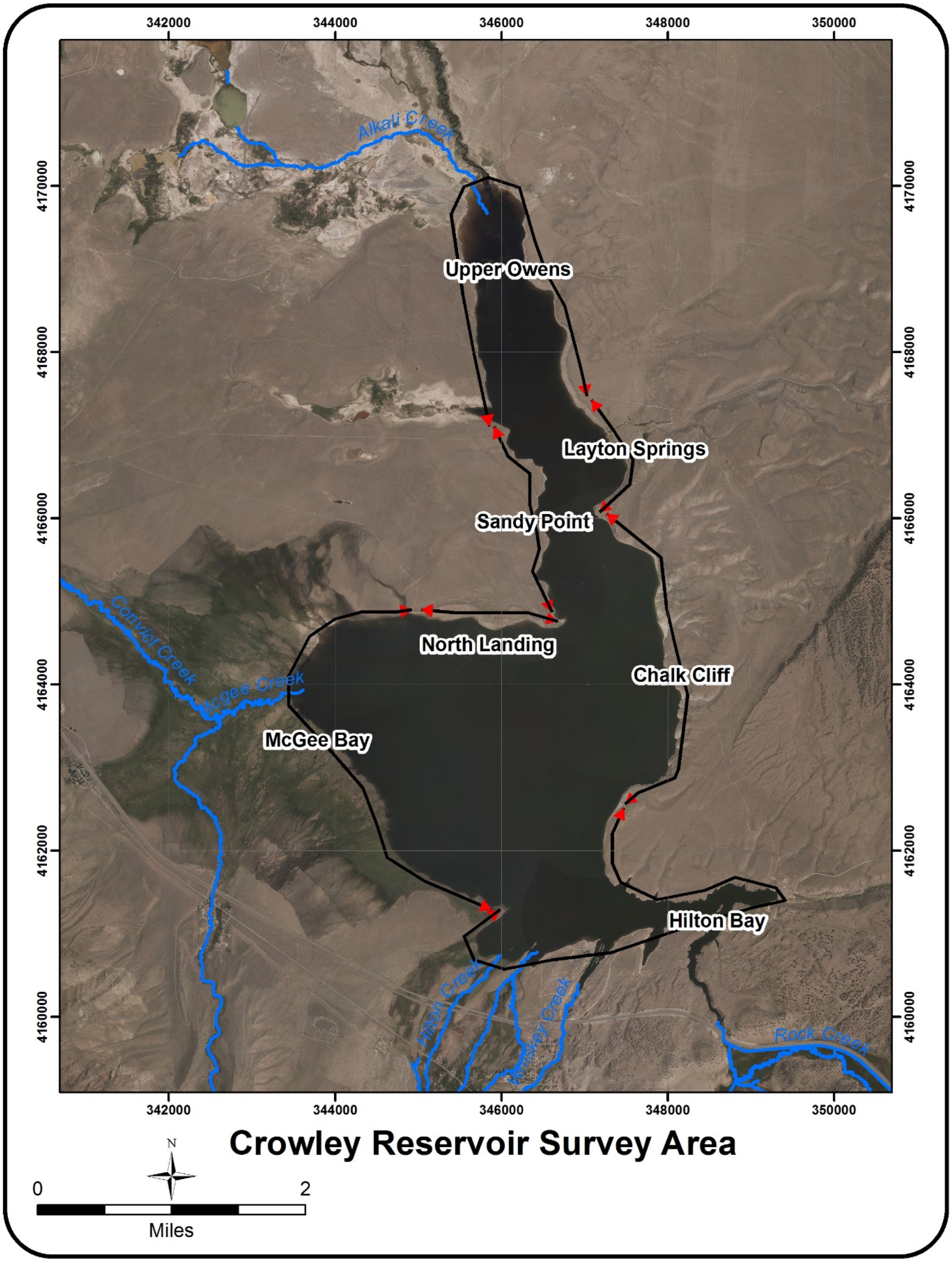


Figure 91. Crowley Reservoir survey area and subareas

4.4.2 Waterfowl Data Summary and Analysis

Summer Ground Surveys

Summer Waterfowl Community

Summer waterfowl numbers were totaled over the three surveys for all species. Waterfowl species were classified as breeding or nonbreeding based on whether a territorial pair, nest, or brood had been observed over the length of the study. The annual mean was calculated for breeding waterfowl species only.

Breeding Population Size and Composition

The annual breeding population size was estimated using two methods. In developing the estimate of population size, the mean number of each species was compared to twice the number present on the third survey. Waterfowl numbers during the first survey, conducted the first week of June have always been highest, as late migrants and males of breeding pairs are present. Waterfowl numbers decline through the summer to their lowest value by the third survey as males depart after breeding. The third survey has been composed largely of females with their broods of various ages, small numbers of juveniles, and occasional small groups of transient males. The results of the two methods of population size estimation were found to be fairly comparable, with the species mean over the three surveys judged to be slightly more accurate. Trends in total breeding waterfowl community size were evaluated using simple linear regression (Sigma Plot 13.0).

The breeding waterfowl community composition was evaluated by calculating the 2002-2017 mean plus standard error for each breeding species. The long-term trend in the size of the breeding population was evaluated using simple linear regression.

Variables influencing breeding waterfowl populations
The hydrologic, limnologic, weather and modeled landtype parameters were examined to determine their influence on waterfowl breeding population size.

Waterfowl Brood Parameters

The parameters of total annual broods and mean brood size were calculated as an index of waterfowl productivity at Mono Lake. The calculation of brood parameters included all nesting species except Canada Goose. Canada Goose initiates nesting earlier than the other waterfowl species and family groups can be difficult to approach closely on foot except in areas where they have become habituated to humans. These factors combined with the tendency of this species to be highly mobile has made ageing broods accurately and determining the minimum number of broods difficult.

Mean brood size was calculated for each species and compared to records of clutch size found in the literature.

The hydrologic, limnologic, weather and modeled landtype parameters were examined to determine their influence on total annual broods or mean brood size. The effect of creek flow on waterfowl use were examined for Rush Creek and Lee Vining Creek. Simple linear regression was used to evaluate the relationship between daily measured creek flow (cfs) and waterfowl use.

Evaluation of the Effectiveness of Summer Surveys

Summer waterfowl survey data was evaluated to determine the effectiveness of the surveys in terms of the timing. The number of broods and the age classes of broods seen during each survey were used for this evaluation.

Correlations between the breeding waterfowl indices were evaluated in order to determine if any one survey could serve as a long-term indicator of the response of waterfowl to restoration.

Breeding Waterfowl Spatial Distribution

The spatial distribution of breeding waterfowl was evaluated by calculating mean waterfowl use by shoreline subarea. The productivity of each shoreline subarea was evaluated by comparing the proportion of the total waterfowl population using a shoreline subarea to the proportion of total broods found in the same subarea.

Restoration Ponds

Waterfowl numbers for each pond were summed and averaged over the three surveys. Descriptive statistics were calculated for each pond and for all ponds combined. The trend in use of the Restoration Ponds by waterfowl in summer was evaluated using simple linear regression.

Fall Surveys

Population Indices

Three indices were developed to evaluate the fall use: total waterfowl counts, peak counts, and an estimate of population size or the number of waterfowl using Mono Lake each fall. Total waterfowl counts involved summing waterfowl totals over the six surveys for a year to provide a yearly total. The total waterfowl counts can be interpreted as an index of the number of waterfowl using Mono Lake in the fall, assuming a short turnover time, and that new individuals are encountered during each survey. This method is likely to overestimate use, but is a simple index in the absence of information regarding stopover periods. The peak counts within any one year was also compiled to represent the maximum number of waterfowl that might be expected on any one day at Mono Lake and to allow for comparison to early waterfowl data. Thirdly, a population estimator was used to estimate the total number of waterfowl using Mono Lake each fall.

An estimate of the fall waterfowl population size was calculated for each survey area following Hicklin (1987). An example of how the calculation was done is provided in Table 74. The calculation of the fall population estimate is based new arrivals, or count increases over the preceding survey. This estimate assumes a stopover duration period of at least the period between surveys, which has been on average, 14 days. If the stopover duration is less than 14 days, the fall population may be underestimated.

Table 74. Sample calculation to determine annual fall waterfowl populations

Date	Total Waterfowl	Days Bet Survey	New Arrivals	Stayovers	Departures
9/4/2008	9613	–	9613	0	
9/18/2008	9510	14	0	9510	103
10/1/2008	13914	13	4404	9510	0
10/15/2008	2619	14	0	2619	11295
10/29/2008	1748	14	0	1748	871
11/17/2008	848	19	0	848	900
	Estimate of Fall Population for 2008		**14017**		

Species Composition

Waterfowl were placed into species groups based on genera for summarization. The species groups were Geese and Swans (genera *Anser*, *Branta* and *Cygnus*), dabbling ducks (genera *Aix*, *Spatula*, *Mareca*, and *Anas*, and diving ducks (genera *Aythya*, *Melanitta*, *Bucephala*, *Lophodytes*, *Mergus*, and *Oxyura*).

Spatial distribution

The number of waterfowl detected during the shoreline perimeter flights and the cross-lake transects were summed. The annual and total mean proportion of waterfowl detected in each of the shoreline subareas was calculated. In order to evaluate whether changes in the spatial distribution of waterfowl indicate a response to changes in lake elevation, the Simpson's E evenness index was calculated yearly for each subarea and year. Pearson correlation was used to evaluate the relationship between the distribution of waterfowl among the difference shoreline subareas (evenness) and lake elevation.

Ruddy Duck distribution was evaluated visually using ArcGis spatial analysis. The mean number of Ruddy Duck per shoreline segment seen during shoreline surveys and the number per cross-lake transect was calculated for the time period 2002-2017. Mean Ruddy Duck values were spatially associated with the midpoints of each shoreline subarea and cross-lake transect. The spline spatial analyst tool was used to create a map representing the average spatial distribution of Ruddy Ducks.

Trend

The trend in total fall counts of waterfowl, of Northern Shoveler, and of Ruddy Duck were evaluated by linear regression of the $\log_{10}$ of waterfowl counts over time. Waterfowl counts were log transformed prior to analysis.

Comparison with Reference Data

Waterfowl data from Mono Lake, Bridgeport Reservoir and Crowley Reservoir were evaluated to determine if correlations existed between annual peak waterfowl numbers, total waterfowl encountered per survey, and annual totals.

Trends in the total number of Northern Shoveler and Ruddy Duck at the three survey areas were compared using Analysis of Covariance (ANCOVA). The resulting interaction term was evaluated to determine differences in the slopes of the regression lines, i.e. do the species trends differ between sites?

Waterfowl data from these surveys were also compared with available regional waterfowl data to further evaluate trends and patterns of use of the survey areas. The available data sources were the North American Waterfowl Breeding and Population Habitat Survey (Olson 2017, U.S. Fish and Wildlife Service 2017), California State

Waterfowl Breeding Population Surveys (Olson 2017, Skalos and Weaver 2017), Sacramento National Wildlife Refuge waterfowl surveys (https://www.fws.gov/refuge/Sacramento/surveys.html), and Owens Lake lakewide waterbird surveys by LADWP. LADWP has been conducting lakewide waterbird surveys of the Owens Lake dust control project area since 2008. In 2012, the survey schedule was expanded to include surveys in September and October. For this comparison, fall survey data from late August, late September and late October 2012-2017 were evaluated.

Restoration Ponds

Table 1- summed species for all three surveys, then divided by three for yearly average. Use Sigma stat Descriptive stats for 2002-2016 mean. Average calculated for each year, then SD calculated for the 15 samples (based on the mean). Range for all (not the mean).

Integration with 1996-2001 Waterfowl Monitoring Data

The early data collection was done on a somewhat irregular schedule, which limits the statistical inference possible. These data were reviewed and the comparable data incorporated to extend the period of record in which to evaluate waterfowl response to restoration. An estimate of the number of broods observed was available for 2000 and 2001 and these data were compared with 2002-2017 brood parameters. Peak lakewide fall waterfowl numbers from 1996-2001 were compared with those from 2002-2017 as an index to the overall trend in use from the early years of restoration to later years.

WATERFOWL SURVEY RESULTS

4.4.3 Waterfowl Population Survey Results

Summer Ground Counts - Mono Lake Shoreline

Summer waterfowl community

Summer shoreline surveys detected 17 waterfowl species, including 7 breeding and 10 nonbreeding species (Table 19). Annually, an average of 929 +/- 70.6 waterfowl (range 440-1683) have been recorded on all three summer surveys including breeding and nonbreeding individuals. For reference, the English and scientific name of all waterfowl species encountered are provided in Appendix 23.

Breeding population size and composition

Mono Lake has supported a breeding waterfowl population averaging approximately 300 waterfowl per year, or 150 pairs. This number has ranged from a low of 145 (73 pairs) in 2017 to a high of 555 (277 pairs) in 2007. Ducks have comprised 85% of the population and Canada Geese 15%.

Table 75. Results of Summer Ground Surveys

Species breeding along Mono Lake shoreline are in bold type.

Species	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*Species Total*
Brant		1						1	2					2	3		**9**
Canada Goose	**23**	**79**	**75**	**182**	**152**	**183**	**55**	**141**	**129**	**233**	**152**	**201**	**186**	**160**	**152**	**145**	**2248**
Wood Duck						8										2	**10**
Blue-winged Teal	9	3						3		1				2	3		**21**
Cinnamon Teal	**50**	**38**	**53**	**44**	**55**	**163**	**18**	**15**	**13**	**27**	**49**	**14**	**8**	**39**	**10**	**13**	**609**
Northern Shoveler	4		2	3	1	4							2				**16**
Gadwall	**560**	**656**	**605**	**617**	**627**	**839**	**415**	**803**	**494**	**383**	**604**	**622**	**424**	**426**	**224**	**168**	**8467**
American Wigeon			1												1		**2**
Mallard	**134**	**172**	**145**	**119**	**163**	**330**	**160**	**118**	**65**	**112**	**192**	**167**	**86**	**109**	**71**	**83**	**2226**
Northern Pintail	**33**	**30**	**30**	**9**	**17**	**101**	**7**		**4**	**3**	**16**		**1**	**7**		**5**	**263**
Green-winged Teal	**19**	**24**	**25**	**10**	**20**	**42**	**13**	**25**	**23**	**44**	**52**	**34**	**102**	**94**	**44**	**18**	**589**
Unidentified teal	90		57	2				2		1			1				**153**
Redhead	20		4	9	7	5	12	4			1	9		2	1		**74**
Bufflehead														1			**1**
Hooded Merganser														1			**1**
Common Merganser												1				1	**2**
Red-breasted Merganser							4			2	1					3	**10**
Ruddy Duck	**26**	**5**	**17**	**7**	**2**	**8**	**22**	**11**	**15**		**8**	**4**	**5**	**19**	**12**	**2**	**163**
Total summer waterfowl	**968**	**1008**	**1014**	**1002**	**1044**	**1683**	**706**	**1123**	**745**	**806**	**1075**	**1052**	**815**	**862**	**521**	**440**	**14864**
Total mean breeding waterfowl	**311.7**	**334.7**	**335.7**	**330.0**	**345.3**	**555.3**	**230.0**	**371.7**	**247.7**	**267.7**	**357.7**	**347.3**	**271.0**	**284.7**	**171.0**	**144.7**	

The waterfowl species breeding at Mono Lake include: Canada Goose, Cinnamon Teal, Gadwall, Mallard, Northern Pintail, Green-winged Teal, and Ruddy Duck. All of these except Northern Pintail and Ruddy Duck have been seen at Mono Lake in all years Table 75, however evidence of breeding has not been observed in all years for all species. Canada Goose have comprised approximately 15% of the breeding waterfowl population or an average of 46 (Table 75, Figure 92) individuals, however the population size may be inflated due to the tendency of this species to nest early. The most abundant breeding species has been Gadwall with an annual population size of 176 (range 168-839) or 58% of the breeding waterfowl community. Cinnamon Teal have been few in number with an average of 12.7 (range 8-163, 4%). Few breeding pairs of Cinnamon Teal have been encountered, and the majority of birds seen on the summer surveys are believed to be early fall migrants. Mallard have been detected in all years and comprise 15% of the breeding population, with an average of 46 and numbers ranging from 71-330. Northern Pintail have been a small component of the breeding population averaging 5.5 birds/year (range 0-101), or 2% or the population. Green-winged Teal have been a regular breeding species, although small in numbers, averaging 12.3 birds/year (range 13-102) or 4% overall. Non-breeding Ruddy Duck oversummer in small numbers at Mono Lake, however this species is considered a breeding species as it has bred along in shoreline habitats, and is a regular breeding species at the Restoration Ponds. Numbers seen during summer shoreline surveys have ranged from 0-26, averaging 3.4 birds or 1% overall.

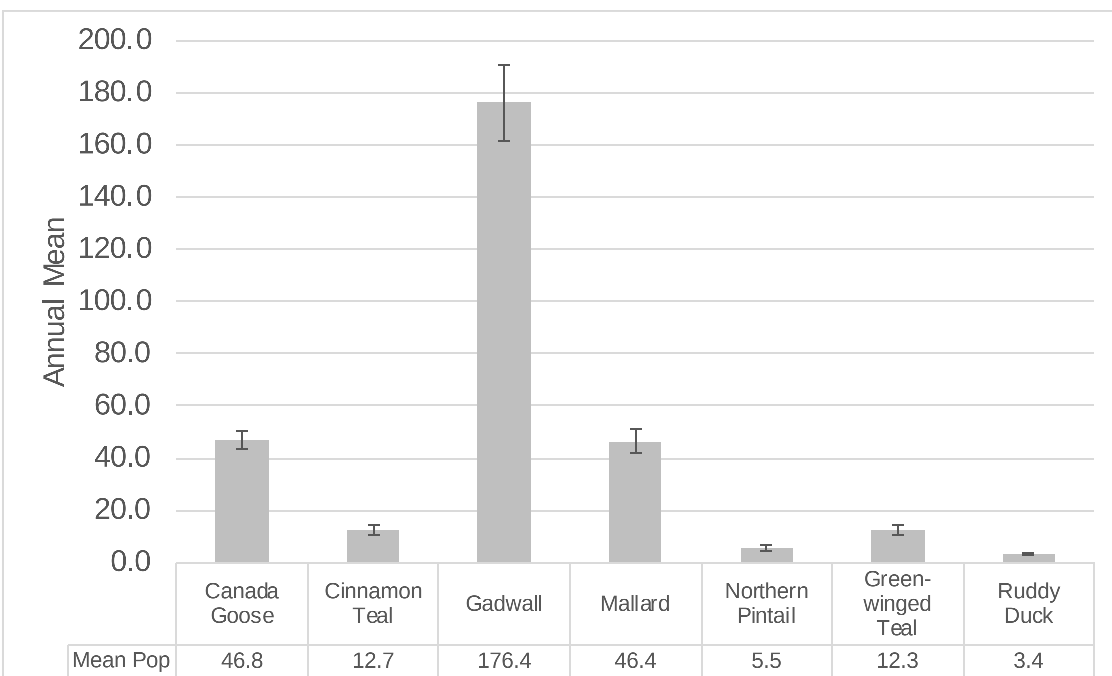


Figure 92. Annual Mean Population Size of Breeding Waterfowl Species at Mono Lake, 2002-2017

Variables Influencing Breeding Waterfowl Populations

There has been an overall downward trend in the size of the breeding population (r^2 = 0.33, p=0.20) (Figure 93). The largest breeding population (555 total) was seen in 2007 when the lake was also at the highest elevation observed of 6,384.5 feet. Breeding populations were at their lowest in 2016 and 2017 when totals were 171 and 145 respectively.

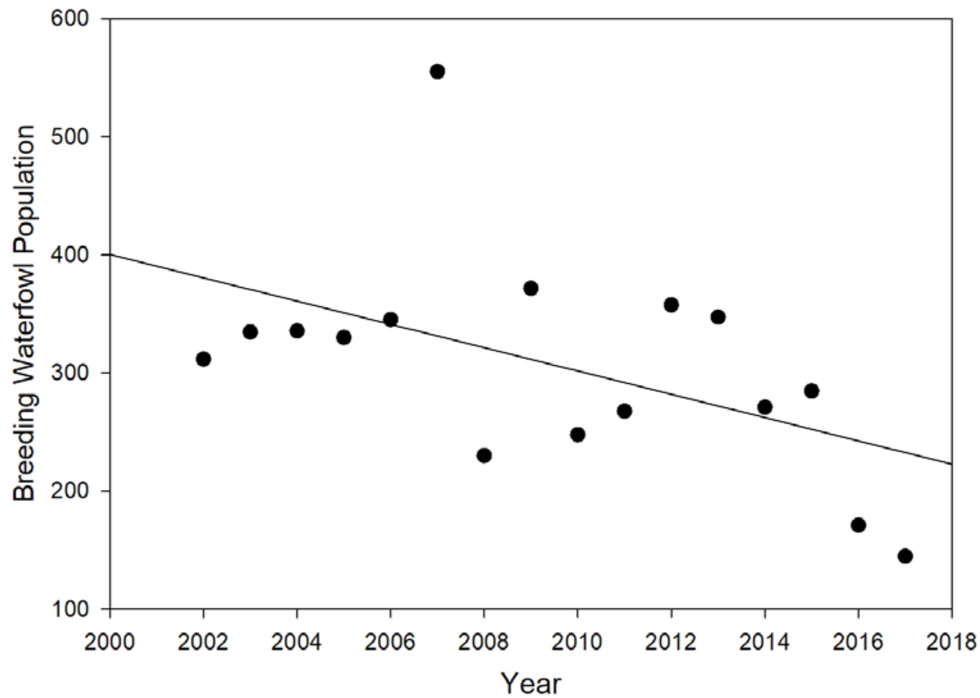


Figure 93. Long-term Trend in breeding waterfowl populations from 2002-2017

The annual size of the breeding waterfowl population was found to be influenced by three factors: lake elevation, spring *Artemia* population levels, and spring precipitation. These three factors explained approximately 68% of the variation in the total annual breeding waterfowl population size at Mono Lake. The model results indicate little evidence of multicollinearity between the variables (VIF < 5).

Table 76. Best-Fit Model for Total Breeding Waterfowl

Model R^2 = 0.6871, VIF = 3.99

Variable	*r*	*p value*
Lake Elevation (June)	0.75	0.0184
Monthly Total *Artemia* - May and June	0.53	0.0199
Spring Precipitation	-0.40	0.0393

The elevation of Mono Lake in June has been the strongest predictor of the total breeding waterfowl population size (r^2 = 0.75, p = 0.0183) (Table 76), and increased lake levels in June have corresponded to larger breeding populations (Figure 94). At lake elevations below 6,381 feet, the breeding waterfowl population has dropped below the long-term average. When the lake was at its highest elevation of 6384.5 feet in June of 2007, the breeding population was at the highest observed.

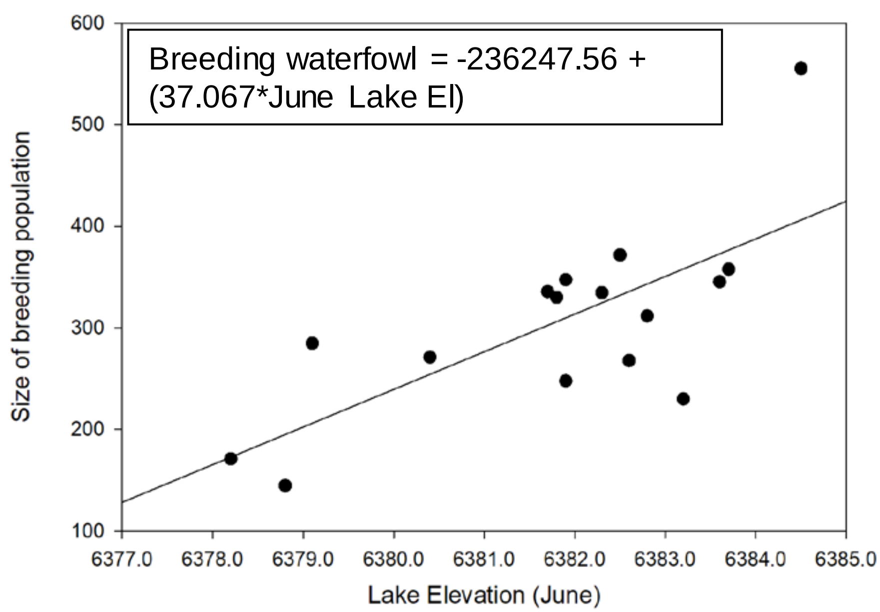


Figure 94. Relationship Between Mono Lake Elevation and the Size of the Waterfowl breeding population, in June.
Waterfowl breeding population size has been positively correlated with lake elevation.

The spring *Artemia* population (May through June) was also positively correlated with the breeding population size ($R^2 = 0.53$, $p = 0.01986$). Spring precipitation (March-May) also contributed to explaining variability in the breeding population, with higher spring precipitation associated with a reductions in the size of the breeding population.

Waterfowl Use vs. Creek flow

There has been no relationship between waterfowl use and creek flows at Rush Creek or Lee Vining Creek (Figures 95 and 96)

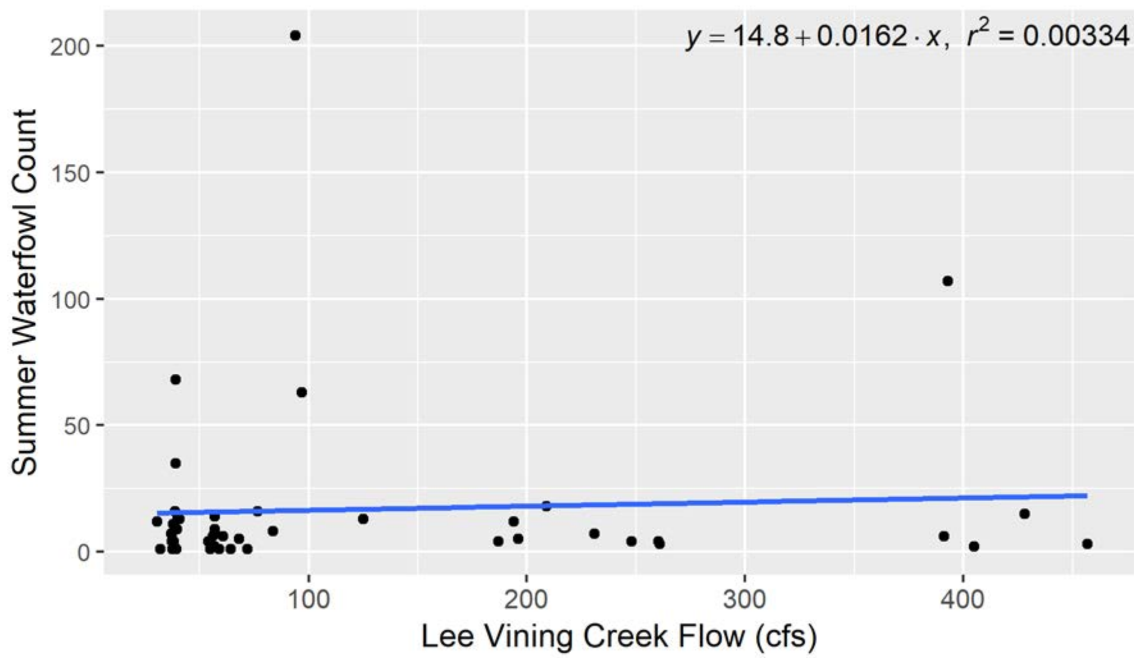


Figure 95. Lee Vining Creek Flows vs. Summer Waterfowl Counts

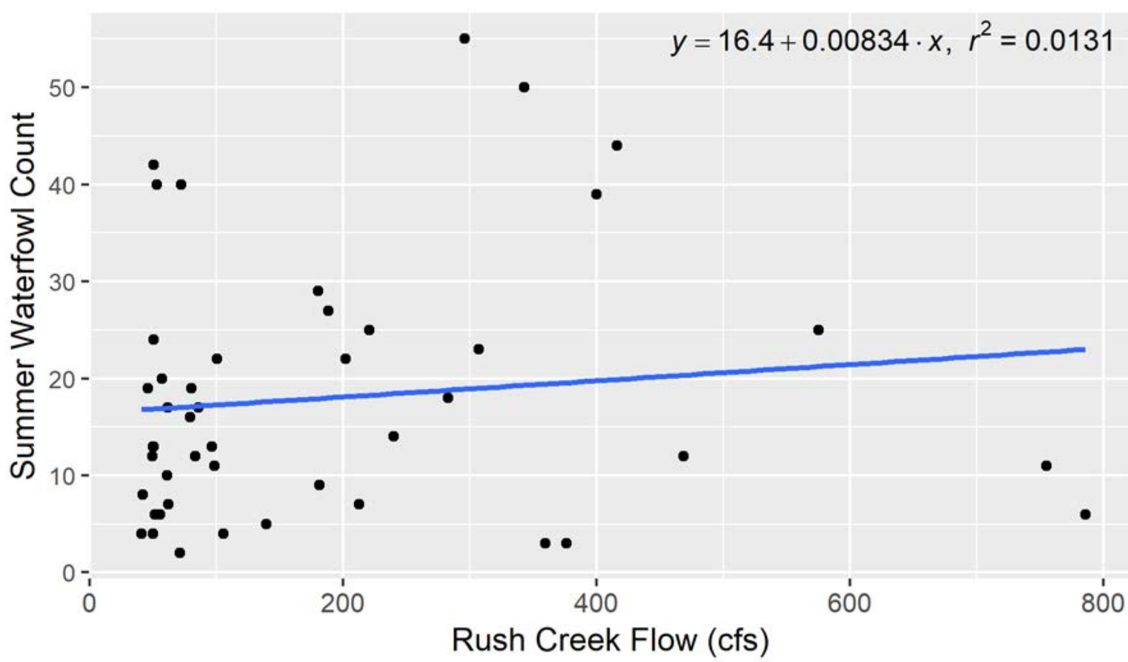


Figure 96. Rush Creek Flows vs. Summer Waterfowl Counts

Waterfowl Brood Parameters

The total number of broods along the shoreline of Mono Lake has averaged 45.3 (range 26-73), exclusive of Canada Goose (Figure 9, Table 77). The highest number of broods were found in 2006 and 2007 when 72 and 73 broods were found, respectively. Numbers were also elevated in 2011-2012, and slightly above the average in 2002-2003, and 2008-2009. Low numbers have been observed since 2013. Over the entire study period, there has been no long term trend in brood numbers.

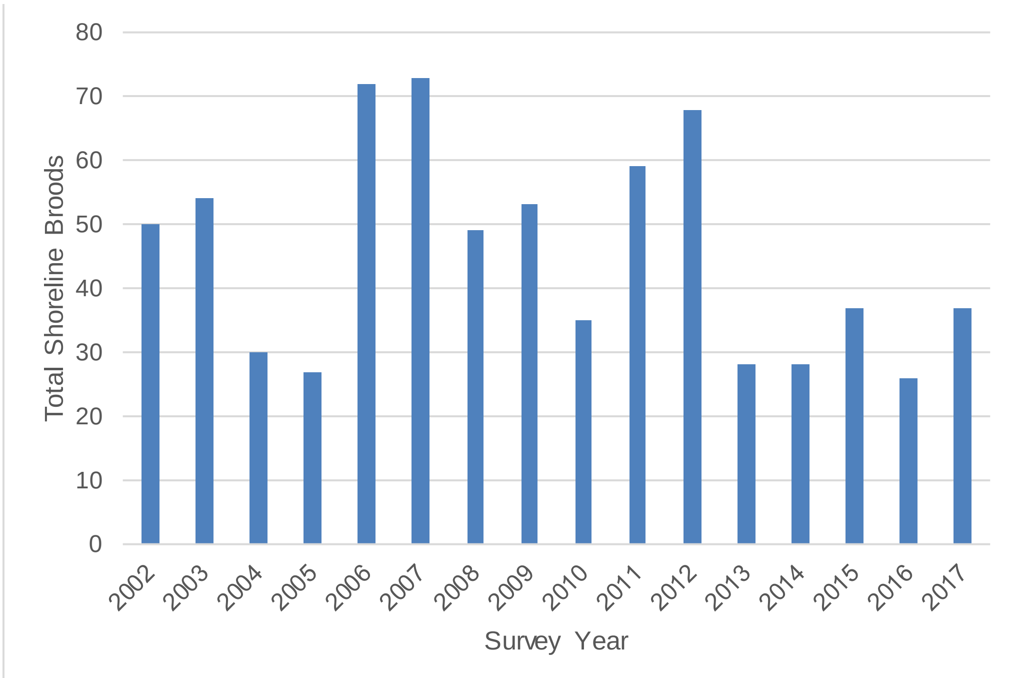


Figure 97. Total Number of Waterfowl Broods Found, all Mono Lake Shoreline Subareas

The species for which the highest number of broods have been found has been Gadwall, averaging 34.6 broods a year (range 19-61) (Table 77). Mallard have also been a regular breeding species at Mono Lake, with broods detected annually. The number of Mallard broods has been quite variable, averaging 6.6, and ranging from one up to 21. Green-winged Teal broods have been seen in most years, averaging 2.8 annually (range 0-11). Northern Pintail and Cinnamon Teal have nested infrequently in shoreline habitats, and in most years, broods of these species have not been observed. Ruddy Duck broods were found only in 2008 – both in a cattail-lined freshwater pond along the south shore. Canada Goose has also nested annually at Mono Lake, most often on tufa in the open water. Canada Goose initiates nesting earlier than the other waterfowl species and family groups can be difficult to approach closely on foot except in areas where they have become habituated to humans. These factors combined with the tendency of this species to be highly mobile around the lake has made defining and ageing broods difficult, and reducing the confidence in the annual brood count for this species. It is estimated that there has been an average of 5-6 Canada Goose broods annually.

Table 77. Total Yearly Broods and 2002-2017 Mean for Shoreline Breeding Species

Year	*Cinnamon Teal*	*Gadwall*	*Mallard*	*Northern Pintail*	*Green-winged Teal*	*Ruddy Duck*	*Total*
2002	0	40	8	2	0	0	**50**
2003	1	39	7	5	2	0	**54**
2004	1	21	5	2	1	0	**30**
2005	0	21	5	0	1	0	**27**
2006	1	61	7	2	1	0	**72**
2007	1	46	21	3	2	0	**73**
2008	0	41	5	1	0	2	**49**
2009	0	40	9	0	4	0	**53**
2010	0	30	4	0	1	0	**35**
2011	0	50	5	0	3	0	**59**
2012	0	46	11	0	11	0	**68**
2013	0	25	1	0	2	0	**28**
2014	0	22	1	0	5	0	**28**
2015	0	25	6	0	6	0	**37**
2016	0	19	3	0	4	0	**26**
2017	0	28	8	0	1	0	**37**
Mean	**0.3**	**34.6**	**6.6**	**0.9**	**2.8**	**0.1**	**45.4**
Std Error	**0.1**	**3.1**	**1.2**	**0.4**	**0.7**	**0.1**	**4.2**

Mean brood size at Mono Lake has been similar among the breeding species (Table 78), with an overall average of 5.3 young. The lowest mean brood size has been 4.6 for Mallard and the highest has been 6.2 for Northern Pintail. Brood size was used to evaluate waterfowl productivity at Mono Lake by comparing observed brood sizes to published clutch sizes. Clutch size refers to the number of eggs, while brood size is the number of ducklings. Twelve Gadwall broods larger than 13 young, or the maximum brood size reported in the literature, were seen over the entire study period, with up to four in one year (2007).

Most broods were detected when they were still very young as the majority of broods (84%) were Class I broods, or less than 18 days old (Table 80). Of the Class I broods, almost half were Class IA, or no more than one week old. A small percentage of Class I broods were not able to be aged to subclass due to distance, limited viewing time or other factors. Approximately 15% of all broods recorded were Class II or approximately 19 up to 45 days old. A higher percentage of Class II broods could not be aged to subclass due in part to their greater mobility and the greater difficulty in precise aging in this class. Only Class I broods, or Class II that were known to not have been recorded during a previous visit were used to calculated brood parameters.

Table 78. Mean Brood Size

Breeding Species	*Cinnamon Teal*	*Gad wall*	*Green-winged Teal*	*Mallard*	*Northern Pintail*	*Ruddy Duck*
Mean Brood Size	5.0	5.6	5.1	4.6	6.2	5.0
Std error	1.5	0.3	0.8	0.5	0.9	-
Min	1	1	1	1	1	2
Max	8	33	13	15	13	8
Total Broods	4	554	44	106	15	2

Table 79. Age of Broods when Detected

The majority of broods detected were less than one week old (IA).

Brood Age	*Number Detected*
IA	337
IB	229
IC	118
Class I (A, B or C), undetermined	33
IIA	18
IIB	23
IIC	18
Class II (A, B or C), undetermined	67
III	2

Evaluation of the Effectiveness of Summer Surveys

The first surveys completed the first week of June have only detected 6% of all broods (45/726) (Table 23). Of the broods found in the first week of June, most all of these were Class I. The one Class III brood found was a Mallard, which tend to be an earlier nesting species than Gadwall or Green-winged Teal. The majority broods (60%) have been found on Survey 3, the third week of July. During this third survey, most of the waterfowl present are hens with broods. Some males on molt migration or older juveniles are also seen. In some years during the third survey, one or two females without broods have been seen that were suspected to be still nesting.

Variables Influencing Brood Parameters

The hydrologic, limnologic, weather and modeled landtype parameters were examined to determine their influence on the number of broods or brood size. Of the variables examined, only lake elevation and conductivity were found to be correlated with brood parameters.

At Mono Lake, the total number of broods and brood size were both positively correlated with lake elevation, and negatively correlated with conductivity (salinity). There was less scatter in the data for brood numbers than for brood size suggesting other factors may be affecting brood size. The number of broods was most closely associated with lake elevation in June. At elevations below 6,382 feet, brood numbers and brood sizes were reduced. Brood numbers were highest as the lake approached 6,384 feet. Conductivity in May has been negatively correlated with both brood number and brood size. No correlations were found between any of the habitat parameters and the brood parameters.

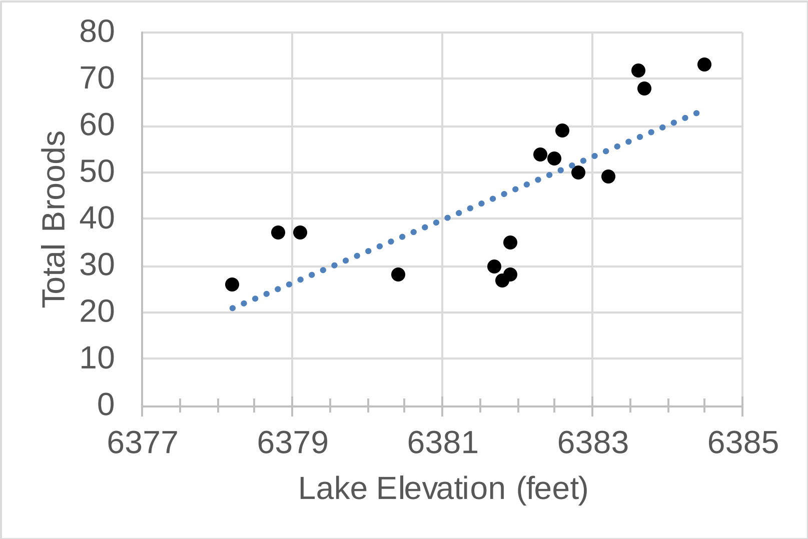


Figure 98. Total Broods vs. Lake Elevation (June)

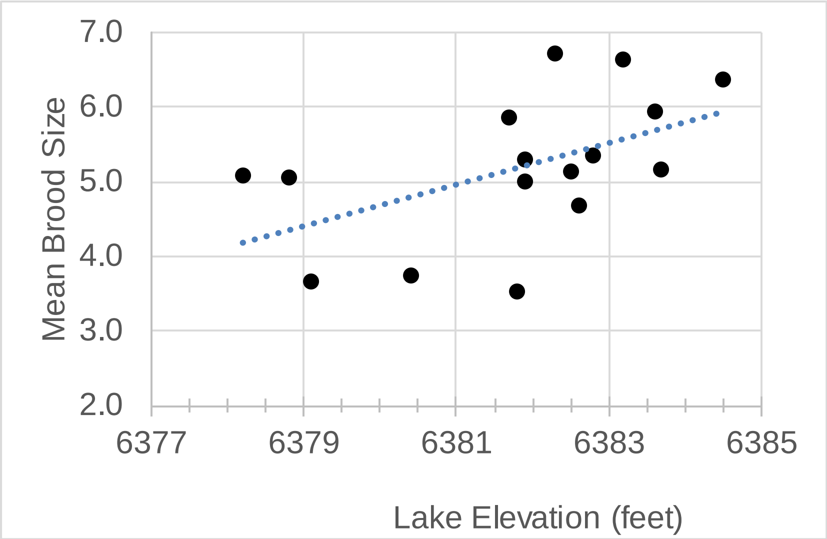


Figure 99. Mean Brood Size vs. Lake Elevation (June)

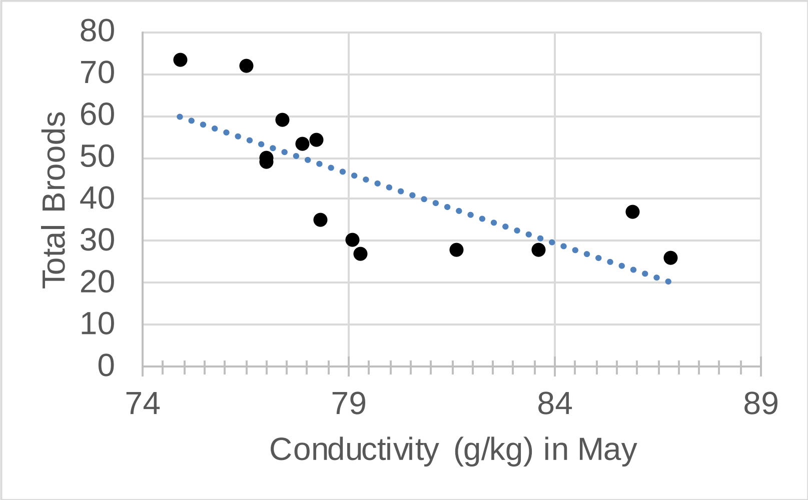


Figure 100 Total Broods vs. Conductivity

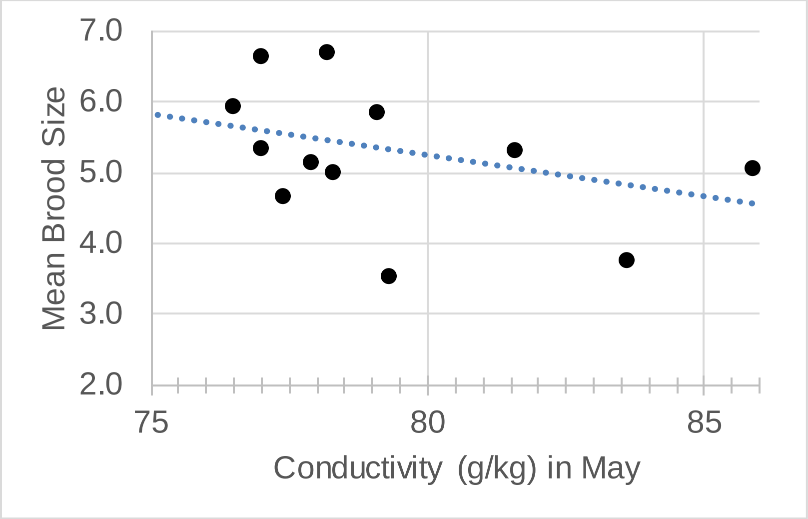


Figure 101. Mean Brood Size vs. Conductivity

Table 80. Broods Detected on each Summer Survey, Brood Age.
Only 6% of broods were seen on Survey 1.

Brood Age	*Survey 1*	*Survey 2*	*Survey 3*
I	2	7	21
IA	19	127	149
IB	14	56	122
IB	0	1	0
IC	6	17	78
II	2	19	32
IIA	1	6	9
IIB	0	9	13
IIC	0	3	11
III	1	1	0
Total broods per Survey	45	246	435

Breeding Waterfowl Spatial Distribution

Breeding waterfowl species have been observed at all shoreline subareas surveyed in the summer. Wilson Creek, Mill Creek, and South Shore Lagoons have been the main areas of breeding waterfowl use (Table 81). Use of South Tufa has been the lowest and lower than all other sites. DeChambeau Creek, Lee Vining Creek, Rush Creek, and Warm Springs have each supported similar numbers of waterfowl, but approximately 1/3 that was observed at Wilson, Mill and South Shore Lagoons. Simons Spring use has been intermediate between these areas and the high use sites.

The breeding species have shown differential preferences for areas around the lake (Table). Cinnamon Teal have been most common along the south shore at South Shore Lagoons and Simons Spring where fresh water and brackish ponds are most numerous. Wilson and Mill Creek have been the main areas of use by Gadwall, but this species has also been abundant at South Shore Lagoons. Gadwall have been the most abundant breeding waterfowl species observed at all sites except DeChambeau Creek and South Tufa where they have been outnumbered only by Canada Goose. Mallard have been seen mostly along the south (South Shore Lagoons and Simons Spring) and east shore at Warm Springs. They have been as common as Gadwall at Simons and Warm Springs. Northern Pintail have occurred in low abundances in all years, and have had a distribution similar to Mallard. Green-winged Teal have been observed at all sites, being most abundant in the Goose Springs area of South Shore Lagoons and Rush Creek. Ruddy Duck are generally only found along the northwest shore sites where over summering birds are typically seen. In 2008 when Ruddy Ducks bred along the shoreline of Mono Lake, they were found in a fresh water pond in the South Shore Lagoons area.

Table 81. Spatial Distribution of Breeding Waterfowl Species at Mono Lake.
Mean number by species and total mean waterfowl, 2002-2017

	Shoreline Segment								
Breeding Species	*DECR*	*LVCR*	*MICR*	*RUCR*	*SASP*	*SOTU*	*SSLA*	*WASP*	*WICR*
Cinnamon Teal	0.9	0.2	0.5	1.7	10.3	0.3	12.2	8.4	3.6
Gadwall	43.5	35.1	120.8	27.8	42.2	9.7	95.5	23.0	131.7
Mallard	5.4	5.9	8.1	9.1	34.9	0.6	38.0	23.3	13.9
Northern Pintail	0.1	0.3	0.9	0.3	3.9	1.1	5.7	3.1	1.1
Green-winged Teal	2.1	1.1	5.8	8.1	4.3	0.4	10.0	1.4	3.6
Ruddy Duck	0.8	0.0	5.5	0.0	0.6	0.0	0.6	0.2	2.5
Total mean	**52.7**	**42.6**	**141.6**	**46.8**	**96.3**	**12.1**	**162.0**	**59.3**	**156.3**
Canada Goose*	60.9	0.7	8.0	4.3	18.4	15.3	12.5	0.0	20.4

*Number likely inflated by older broods

Overall, more broods have been found at South Shore Lagoons than any other subarea. The next most productive site has been Wilson Creek. A few sites have supported either more or less than the expected proportion of broods, based on waterfowl population numbers for these areas. On average, more broods than expected have been seen at both Rush Creek and South Shore Lagoons. Areas where the number of broods has been less than expected have been South Tufa and Warm Springs.

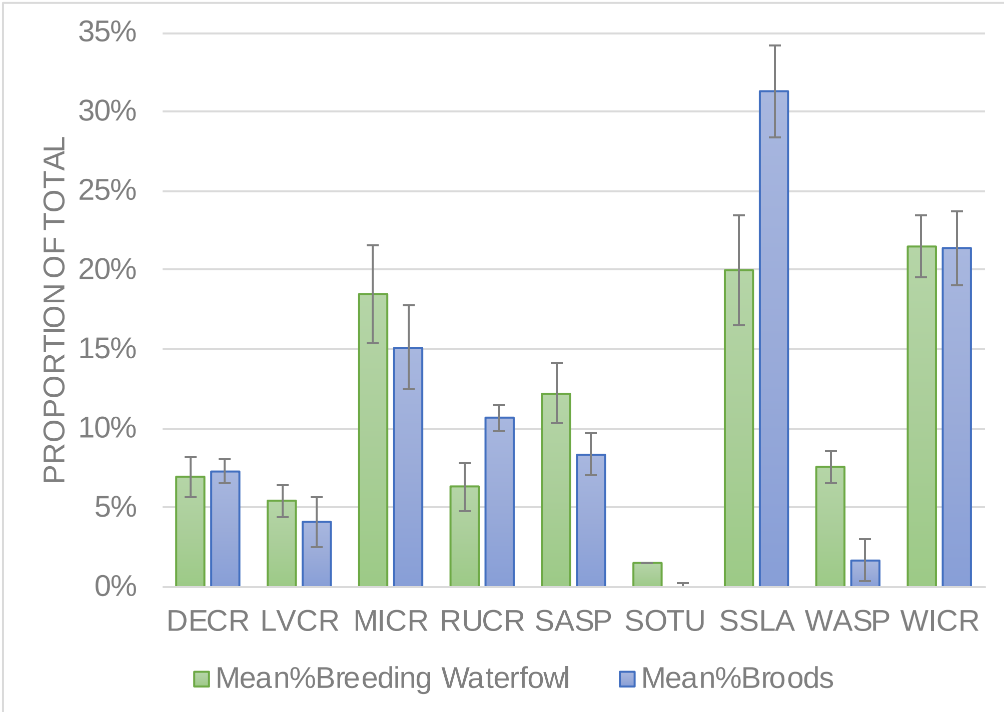


Figure 102. Proportion of Breeding Waterfowl Observations relative to the Percent of Total Broods

Subareas with higher proportion of breeding waterfowl relative to the percent of broods are not favored breeding areas, but may be used for foraging.

Habitat Use

Canada Goose was the only species that regularly used meadow/marsh habitat (Table 82). Canada Goose were more frequently seen in wet meadow habitats than all other meadow/marsh landtypes, and rarely used marsh or dry meadow/forb. On-shore water features were the landtype most heavily used by dabbling ducks, with freshwater and brackish ponds receiving the most use. Gadwall showed the lowest proportional use of on-shore water features, and the highest proportional use of ria. Green-winged Teal were more heavily associated with freshwater habitats than other species, with most observations in freshwater streams and freshwater ponds. The species most associated with mudflats and barren lakebed was Canada Goose. Ruddy Ducks were observed primarily on the open water, except in the single year (2008) when nesting occurred in a freshwater pond in the South Shore Lagoons area.

Table 82. Proportional Habitat use by Breeding Waterfowl Species

Landtypes		*Breeding Waterfowl Species*						
Modeled	*Mapped*	*Canada Goose*	*Cinnamon Teal*	*Gadwall*	*Green-winged Teal*	*Mallard*	*Northern Pintail*	*Ruddy Duck*
Meadow/Marsh		39%	2%	2%	2%	4%	2%	0%
	Marsh	*1%*	*1%*	*0%*	*0%*	*1%*	*0%*	*0%*
	Wet Meadow	*21%*	*0%*	*1%*	*1%*	*1%*	*1%*	*0%*
	Alkaline Wet Meadow	*15%*	*0%*	*0%*	*0%*	*2%*	*2%*	*0%*
	Dry Meadow/Forb	*2%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Water		10%	82%	34%	66%	69%	69%	12%
	Freshwater Stream	*0%*	*1%*	*2%*	*11%*	*5%*	*1%*	*0%*
	Freshwater Pond	*0%*	*29%*	*13%*	*44%*	*20%*	*12%*	*2%*
	Brackish Pond	*3%*	*49%*	*17%*	*11%*	*41%*	*51%*	*10%*
	Hypersaline Pond	*0%*	*3%*	*2%*	*0%*	*3%*	*5%*	*0%*
	Mudflat	*7%*	*0%*	*0%*	*0%*	*1%*	*0%*	*0%*
Upland		0%	0%	0%	0%	0%	0%	0%
Ria		10%	6%	33%	22%	12%	5%	0%
Riparian		0%	0%	0%	1%	0%	1%	0%
Barren Lake Bed		23%	5%	15%	5%	11%	11%	0%
Open water		18%	5%	15%	4%	4%	11%	88%

Summer Ground Counts - Restoration Ponds

Summer Waterfowl Use

A total of 944 waterfowl have been observed at the Restoration Ponds from 2002-2017 (Table 83). Although variable, total waterfowl use has generally been highest at COPOE and DEPO_4, with higher counts at COPOE. Waterfowl use of COPOW has been highly variable, with high numbers in some years, but low in most. Although DEPO_01 has been dry since 2012, this pond but has been generally been productive when active, with a median use similar to DEPO_2 and DEPO_3, both of which have been continuously inundated through the period of study, however use has been somewhat variable. DEPO_03 is a small pond that has been continuously active and has received fairly consistent low-level use. DEPO_05 was only active from 2002-2006, but was moderately productive in those years.

Table 83. Total Waterfowl by Pond and Year Summed Over the Three Summer

	Year																
Restoration Pond	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
COPOE	14	5	12	8	21	24	4	17	28	12	24	32	36	34	18	1	290
COPOW	24	7	7	7	9	39	19	2	4	1							119
DEPO_1	2	8	12	1	9	14	14	14	21	10							105
DEPO_2		2	22	7	7	8	5	11	10	15		1	7	17		2	114
DEPO_3	11	1	7	1	2	2	2	1		6	3	7	7	2	3	7	62
DEPO_4	7	15	11	25	9	9	7	10	11	17	8	6	7	12	26	19	199
DEPO_5	15	22	6	9	3												55
All Ponds	73	60	77	58	60	96	51	55	74	61	35	46	57	65	47	29	944

Surveys

The average number of waterfowl at the Restoration Ponds per survey was 20.3 +/- 4.9 sd (range 6-40). COPOE has consistently attracted more waterfowl than any other pond with an average of 6.4 waterfowl per visit. The second most attractive pond has been DEPO_4, averaging 4.0 waterfowl per visit, although use has been significantly higher only than DEPO_3 and DEPO_5.

Waterfowl use of the restoration ponds has been declining (Figure 103) (r^2=0.32, p = 0.21). Although COPOW has remained flooded, no waterfowl were detected after 2011. Use of DEPO_3, which has been continuously flooded, has also declined since 2011, and in some years, no waterfowl were seen on surveys. DEPO_1 has been dry in summer since 2012, and DEPO_5 dry since 2007.

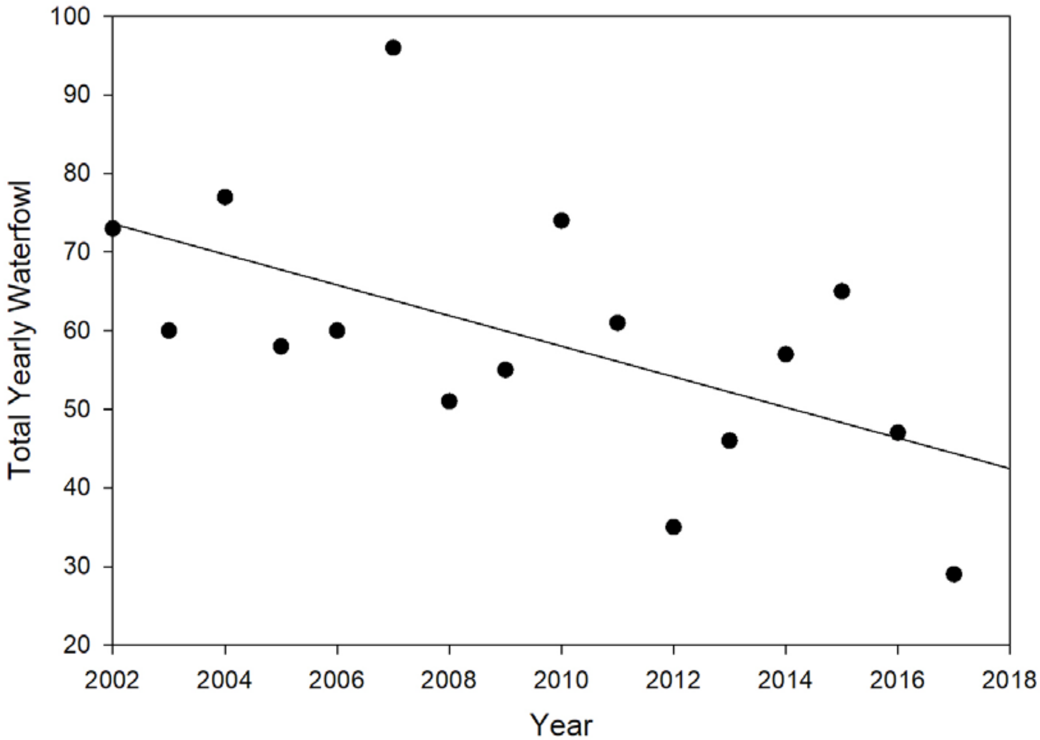


Figure 103. Trend in Total Waterfowl Use of the Restoration Ponds, 2002-2017
There has been a significant trend of decrease in use (r^2=0.32, p = 0.21).

The Restoration Ponds have attracted at least twelve waterfowl species in summer, and of these, breeding evidence has been observed for Gadwall, Cinnamon Teal, Northern Pintail, Green-winged Teal and Ruddy Duck (Table). The other seven species recorded included non-breeding transients, or species known to breed locally (e.g. Mallard), but for which no broods have been observed. COPOE has had the highest overall species richness, while the fewest number of species have been observed at DEPO_5. Three species have accounted for 85% of all summer waterfowl: Gadwall (374/915, 40%), Cinnamon Teal (203/915, 22.2%), Ruddy Duck (202/915, 22.1%). Gadwall and Cinnamon Teal have been seen annually at the Restoration Ponds, averaging 8.3 birds per survey (range 4.7-11.3) and 4.5 birds per survey (range 0-14) respectively. Ruddy Ducks have been observed in all years except 2004, averaging 4.49 birds per survey (range 0-11.0).

Restoration Pond Broods

From 2002-2016, a total of 137 waterfowl broods have been seen at the Restoration Ponds and an annual average of 9.1 +/-3.7 broods. Gadwall have bred annually and accounted for 80% (110/137) of all broods (Table). Ruddy Duck, first noted breeding in 2007 has accounted for 15% of all broods (20/137). Ruddy Duck has bred fairly consistently since 2007, however broods have not been detected in all years. Although Cinnamon Teal has been one of the more abundant species, single broods have been observed in only four of the 15 years. Green-winged Teal and Northern Pintail are infrequent breeding species at the ponds as only one brood of each species has been observed.

The County Ponds and the DeChambeau pond complex have supported similar numbers of waterfowl broods. Use of individual ponds, however has differed such that two ponds (COPOE and DEPO_04) have accounted for more broods than all other ponds combined (42% and 25% of total broods respectively).

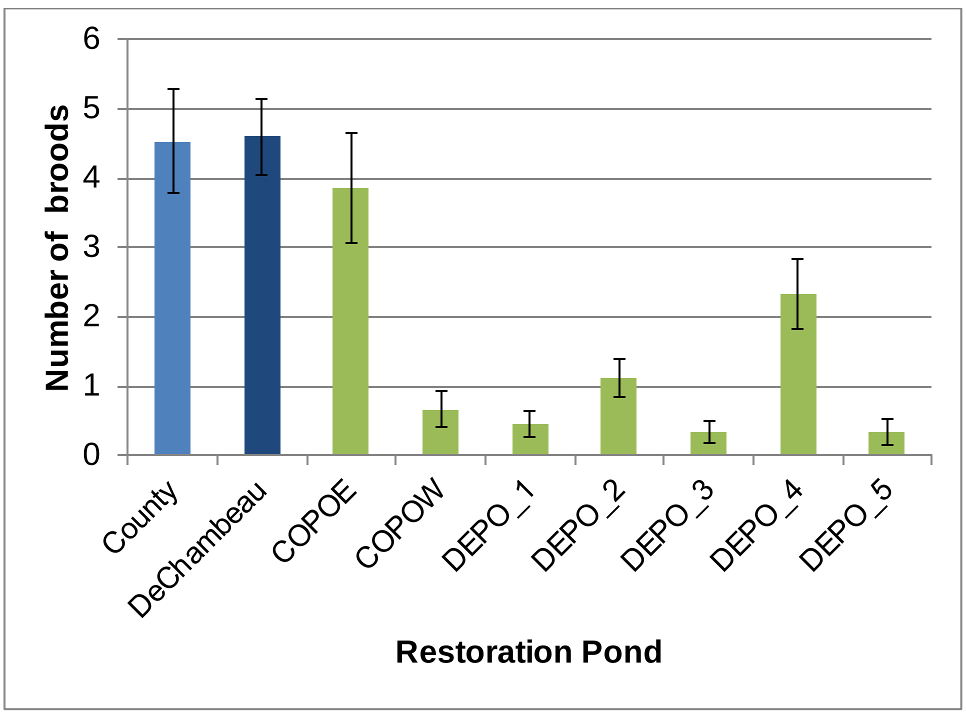


Figure 104. Mean Number of Broods Detected at each Restoration plus SE; 2002-2017

There has been no trend in the number of broods observed at the Restoration Ponds (r=0.22), however the data suggest some relationship to lake elevation and possibly shoreline condition. The number of broods at the Restoration ponds has been negatively correlated with the number of broods around the lake shore and positively influenced by increases in May precipitation. Although lake elevation has had a strong influence on the number of broods along the lakeshore, lake elevation has not had a direct impact on brood number at the ponds.

Table 84. Number of Broods per Species and Year at the Restoration Ponds

Species	Year															Broods per Species
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
Cinnamon Teal			1	1									1		1	**4**
Gadwall	5	6	7	14	8	7	5	9	6	5	5	6	8	17	2	**110**
Green-winged Teal												1				**1**
Northern Pintail	1															**1**
Ruddy Duck						1	1	1	6	3		1	5		2	**20**
Unidentified Teal		1														**1**
Broods per Year	**6**	**7**	**8**	**15**	**8**	**8**	**6**	**10**	**12**	**8**	**5**	**8**	**14**	**17**	**5**	**137**

Mono Lake Fall Aerial Surveys

Fall Waterfowl Population Size and Species Composition

The 96 fall aerial surveys at Mono Lake from 2002-2017 have recorded at total of 423,656 waterfowl. The yearly total number of waterfowl has averaged 26,479 +/-2,872 SE (Table 85). The lowest total count of 11,856 was in 2010, and the highest total count of 51,377 in 2004. Peak numbers have averaged 8,764, ranging from a low of 3,293 in 2010 to the highest single day count of 17,844 at the end of September in 2004. The estimated annual fall waterfowl population of Mono Lake, is 9,651 +/- 1,086 SE. Population estimates have ranged from a low of 3,460 in 2017 to a high of 18,590 in 2004.

Table 85. Mono Lake Yearly Waterfowl Population Indices

Year	Total	Peak	Population Estimate
2002	25,410	7,751	7,571
2003	43,240	9,920	12,868
2004	51,377	17,844	18,590
2005	22,189	7,942	8,263
2006	22,157	6,605	6,943
2007	23,668	9,926	10,080
2008	38,252	13,914	14,017
2009	27,861	7,920	10,906
2010	11,856	3,293	4,760
2011	21,897	5,248	5,635
2012	43,108	17,400	17,400
2013	23,712	8,213	8,557
2014	21,898	8,171	11,075
2015	16,882	8,437	8,654
2016	15,275	4,297	5,644
2017	14,874	3,350	3,460
Mean	**26,479**	**8,764**	**9,651**
Std Err	**2,872**	**1,090**	**1,086**

Total waterfowl numbers have been highest from mid-September through the end of September. After the end of September, waterfowl numbers at Mono Lake usually decline substantially. Early fall numbers have been most variable, while reduced variability has been associated with counts conducted from mid-October through mid-November. (Table 86).

Table 86. 2003-2017 Waterfowl Statistics for Each of the fall Surveys at Mono Lake

Survey	*Mean*	*Std. Error*	*Minimum*	*Maximum*
Early Sept	5452.8	668.5	860	9613
Mid-Sept	6431.2	955.3	1887	17400
End Sept	6524.9	1139.6	1487	17844
Mid-Oct	3386.8	545.7	846	9239
End Oct	2606.0	472.8	692	7134
Mid-Nov	2076.8	464.1	596	7862

Dabbling ducks have accounted for a majority of the waterfowl totals, averaging 16,493 (Table 87). The dabbling duck Northern Shoveler has accounted for over 80% of dabbling ducks and 50% of all waterfowl recorded. Annual total Northern Shoveler counts have averaged 13,451 (range 4,733-27,400). Divers, comprised of almost exclusively Ruddy Duck, accounted for 36% of all waterfowl. Annual total Ruddy Duck counts have averaged 9,739 (range 2,507-27,357). Geese and swans have comprised <1% of all waterfowl at Mono Lake, with Canada Goose the only regularly occurring species. Annual Canada Goose numbers have ranged from 51 up to 376.

Table 87. Summary of Fall Waterfowl Species Composition - Mono Lake; 2002-2017 Compiled Data

Species Group	***Species***	**Lakewide Mean**	**Std Err**	***Min***	***Max***
Geese and swans	Greater White-fronted Goose	3.4	2.2	-	34
	Snow Goose	3.8	1.2	-	15
	Ross's Goose	0.1	0.1	-	1
	Cackling Goose	3.4	2.1	-	33
	Canada Goose	215.6	24.6	51	376
	Tundra Swan	0.1	0.1	-	2
	Total Geese and swans	226			
Dabbling Ducks	Gadwall	228.8	48.2	20	709
	American Wigeon	9.3	3.0	-	40
	Mallard	720.5	162.2	219	2,613
	Blue-winged Teal	0.1	0.1	-	2
	Cinnamon Teal	60.8	23.9	-	318
	Northern Shoveler	13,451.4	1,718.3	4,733	27,400
	Northern Pintail	713.2	253.3	8	3,870
	Green-winged Teal	559.2	109.5	58	1,569
	Unidentified Teal	749.9	197.5	25	2,646
	Total Dabbling Ducks	16,493			
Divers	Redhead	4.1	2.0	-	32
	Ring-necked Duck	1.1	0.6	-	8
	Lesser Scaup	7.8	2.9	-	40
	Surf Scoter	0.1	0.1	-	2
	White-winged Scoter	0.1	0.1	-	1
	Bufflehead	4.5	2.1	-	35
	Common Merganser	0.2	0.1	-	1
	Ruddy Duck	9,739.9	1,714.6	2,507	27,357
	Unidentified Diving Duck	1.4	0.8	-	12
	Total Divers	9,759			
	Total Waterfowl	**26,479**		**11,856**	**51,377**

Spatial Distribution

Trend evaluation

There has been a downward trend in total fall waterfowl use at Mono Lake over the 2002-2017 period (r = -0.524, p=0.037) (Figure 105). Northern Shoveler use has been highly variable, with distinct peaks and troughs (Figure 106) but no overall trend (r= -0.126, p=0.642).

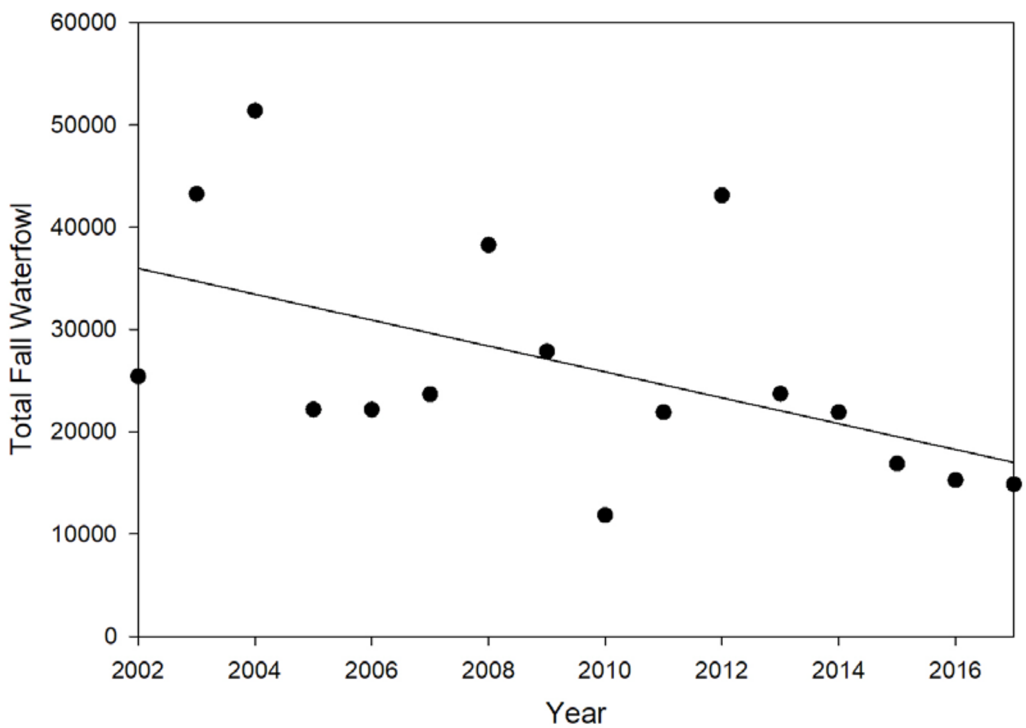


Figure 105. The Trend in Total Fall Waterfowl Populations at Mono Lake, 2002-2017

There has been a significant downward trend in total fall waterfowl over the 2002-2017 period (r = -0.524, p=0.037).

Use of Mono Lake by Northern Shoveler has not shown any direct relationship to lake elevation. There has been a tendency for the number of Northern Shovelers to be higher in years of declining lake elevation (average of 14,000) than in years of increasing lake elevation where numbers have averaged 9,300.

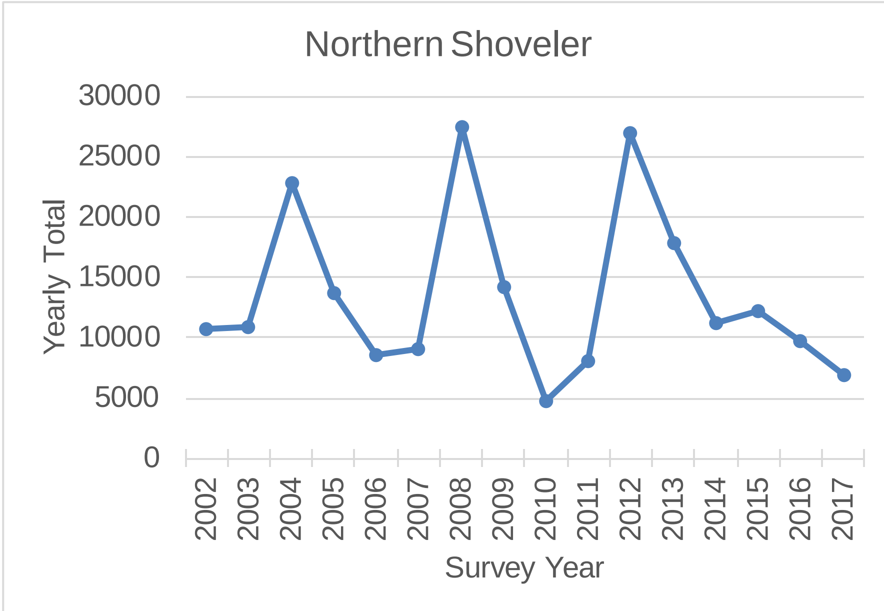


Figure 106. Total Annual Northern Shoveler Numbers at Mono Lake

Use by Northern Shoveler has been variable, and there has been no long-term trend.

Ruddy Duck numbers at Mono Lake have declined significantly over time (-0.665. p =0.000496). Ruddy Ducks numbered over 20,000 in 2003 and 2004, declined to around 10,000 annually after 2004, and showed further declines from 2013 on. Lake elevation has explained 57% of the variation in the number of Ruddy Ducks at Mono Lake. Ruddy Duck numbers have been highest when the lake elevation has been above approximately 6,382.0 feet (Figure). Numbers have declined substantially at lake elevations below approximately 6380 feet.

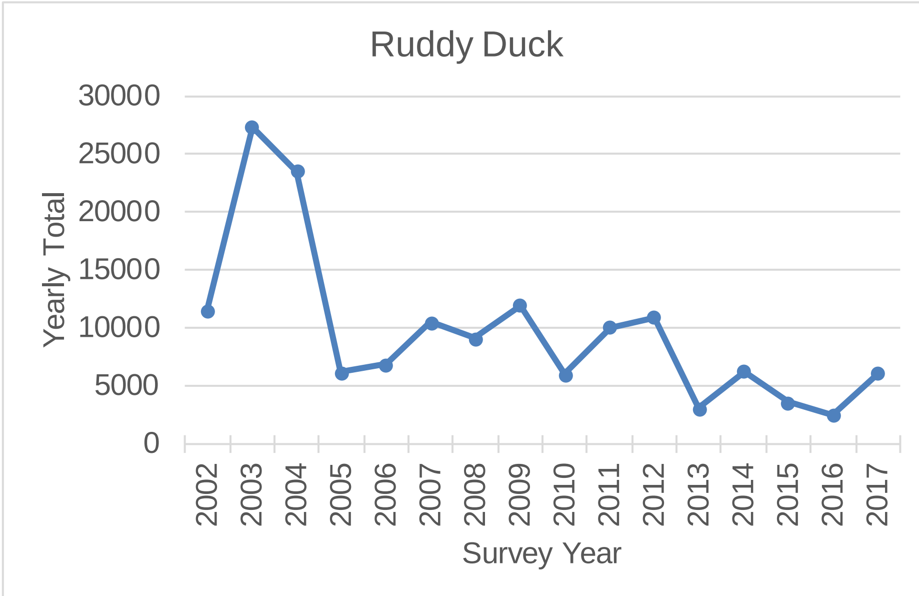


Figure 107. Total Annual Ruddy Duck Numbers at Mono Lake

There has been a significant decline in use by Ruddy Duck.

Model Outputs

Fall waterfowl use at Mono Lake has shown a cyclical pattern and a conceptual model was developed to elucidate potential relationships between the ecological variables being monitored and fall waterfowl use. The variables included in this model were Mono Lake landtypes, lake elevation, food supply (*Artemia*), and water quality parameters. Linear regression models indicate that fall waterfowl use may be influenced by changes in lake elevation, the food supply in early fall, and climate.

Table 88. Variables Explaining the Abundance of Waterfowl at Mono Lake During Fall

Parameter	*Variable*	*r*
Lake elevation	Elevation the previous September	0.5700
Artemia	*Artemia* biomass - August	0.6409
	Artemia biomass - August/September	0.5701
	Artemia fecundity - September	0.6550
Water Temperature	Summer Water Temperature (May-October)	0.6975

Unlike use by breeding waterfowl, total fall waterfowl use has not been directly correlated with lake elevation (r = 0.2970). At lowered lake elevations, total fall waterfowl numbers have not been significantly lower. Higher counts have occurred at elevations between 6,381 feet and 6,383 feet but lake levels above 6,383 feet have not resulted in higher numbers of waterfowl. Most observations have been within a narrow two-foot elevation range of 6,381-6,383 feet.

Changes in lake elevation have influenced waterfowl use. Decreases in lake elevation from the previous September have resulted in increased use by waterfowl (r=0.570).

Waterfowl use has been correlated with the biomass and fecundity of *Artemia* in fall (Table 88). Lakewide mean biomass in August and the mean of August/September were both positively correlated with total waterfowl use. Shrimp fecundity, or the mean number of cysts produced in September has been correlated with the waterfowl numbers in that month.

Waterfowl numbers were also found to be rather strongly positively correlated with Mono Lake water temperatures in the epilimnion (r = 0.6975)

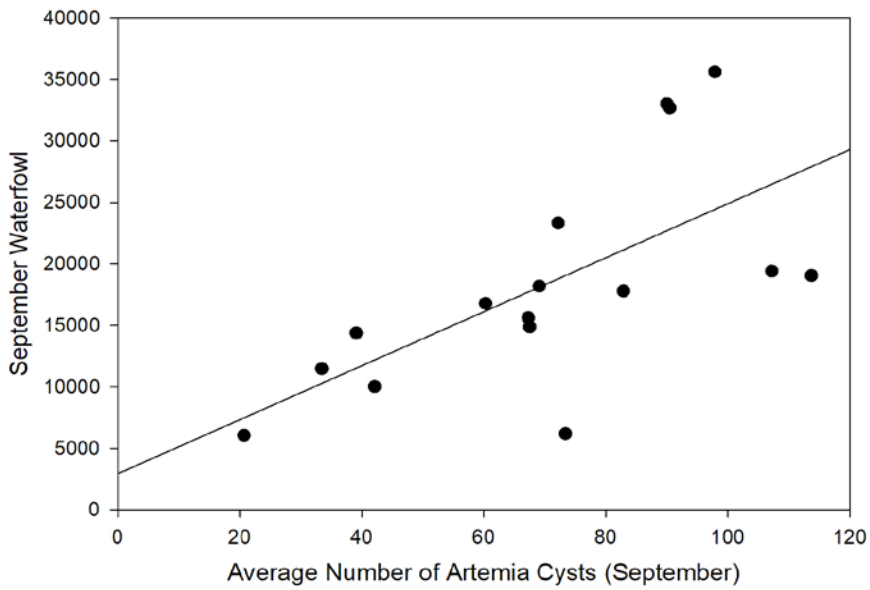


Figure 108. Relationship Between Total Waterfowl in September and the Average Number of *Artemia* Cysts

Some waterfowl species, including Northern Shoveler and Green-winged Teal are known to feed on Artemia cysts. Annual variations in Artemia fecundity may influence the food supply for waterfowl.

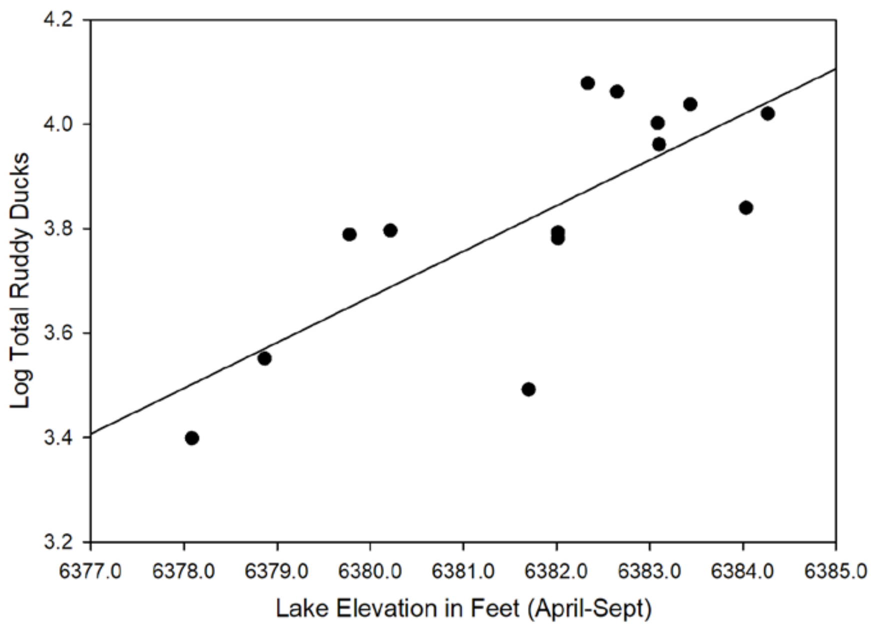


Figure 109. Relationship between lake elevation and Ruddy Duck numbers at Mono Lake

Ruddy Duck numbers have been positively correlated with lake elevation and have been highest when the lake elevation has been above approximately 6,382 feet.

Bridgeport Reservoir

Fall Waterfowl Population Size and Species Composition

Fall aerial surveys of Bridgeport Reservoir have recorded at total of 519,389 waterfowl of 22 species (Table 89). Annual waterfowl use at Bridgeport has been more variable than at either Crowley Reservoir or Mono Lake. Total waterfowl numbers have generally been highest in mid-September through the end of September. Numbers typically decline substantially by mid-October although high counts have occurred through mid-October. Bridgeport Reservoir has supported an average of 34,244 +/- 4,523 waterfowl annually (range 13,119-83,186). Geese and swans have comprised approximately 4%

of waterfowl, with Canada Goose the only regularly occurring species. Annual Canada Goose numbers have ranged from 468 up to 3,257. Dabbling ducks have accounted for 90% of waterfowl and have varied from an annual low count of 7,600 to a high of 82,657. The dabbling duck community is much more diverse than that found at Mono Lake, with high use by Northern Shoveler, Gadwall, Mallard, Northern Pintail and Green-winged Teal. Divers account for 6% of all waterfowl, and as is the case for dabblers, the diving duck community is more diverse than is found at Mono Lake. Although Ruddy Duck is the most abundant diver, as is also the case at Mono Lake, the number of Ruddy Ducks at Bridgeport are typically much lower. Other diving duck species, such as Bufflehead, Ring-necked Duck, and Common Merganser are regularly occurring and occur in higher numbers than are seen at Mono Lake.

Table 89. 2003-2017 Waterfowl Statistics for Each of the Fall Surveys at Bridgeport Reservoir

Survey	*Mean*	*Std. Error*	*Minimum*	*Maximum*
Early Sept	7157.3	966.1	2024	12160
Mid-Sept	8699.4	1224.7	1142	17955
End Sept	7249.1	1673.5	1531	23150
Mid-Oct	4228.4	1028.4	847	17355
End Oct	3296.3	633.1	826	10117
Mid-Nov	2937.6	482.6	356	6141

Table 90. Summary of Fall Waterfowl Species Composition – Bridgeport Reservoir; 2003-2017 Compiled Data

Species Group	Species	Mean	StdError	Max	Min
Geese and swans	Snow Goose	2.8	2.1	31	0
	Greater White-fronted Goose	2.5	1.7	20	0
	Cackling Goose	0.5	0.5	8	0
	Canada Goose	1331.9	213.4	3257	468
	Tundra Swan	12.0	5.6	85	0
	Total Geese and swans	1349.8		3401	468
Dabbling Ducks	Cinnamon Teal	246.9	74.8	805	0
	Northern Shoveler	8228.2	1053.8	17159	3553
	Gadwall	6561.8	1005.1	14042	969
	American Wigeon	74.3	27.6	406	0
	Mallard	4462.5	966.1	15459	1320
	Northern Pintail	4339.7	783.2	11171	1003
	Green-winged Teal	3473.1	754.4	10367	730
	Unidentified Teal	3629.1	902.9	13248	25
	Total Dabbling Ducks	31015.6		82657.0	7600.0
Divers	Canvasback	3.7	1.8	25	0
	Redhead	74.4	22.3	301	0
	Ring-necked Duck	117.1	85.6	1300	0
	Lesser Scaup	45.7	11.9	167	0
	White-winged Scoter	0.1	0.1	1	0
	Bufflehead	136.8	16.8	294	63
	Common Goldeneye	0.7	0.4	6	0
	Common Merganser	84.4	17.0	260	10
	Red-breasted Merganser	0.1	0.1	1	0
	Ruddy Duck	1413.9	245.2	2991	92
	Unidentifed Diving Duck	2.0	2.0	30	0
	Total Divers	1878.9		5376.0	165.0

Spatial distribution

Of the three subareas at Bridgeport Reservoir, an overwhelming majority of the waterfowl have been found in the West Bay. Waterfowl are found throughout the West Bay and among the several deltas and inlets created where Buckeye Creek, Robinson Creek, and the East Walker River enter the West Bay. Geese are often found out on the meadows away from the water's edge.

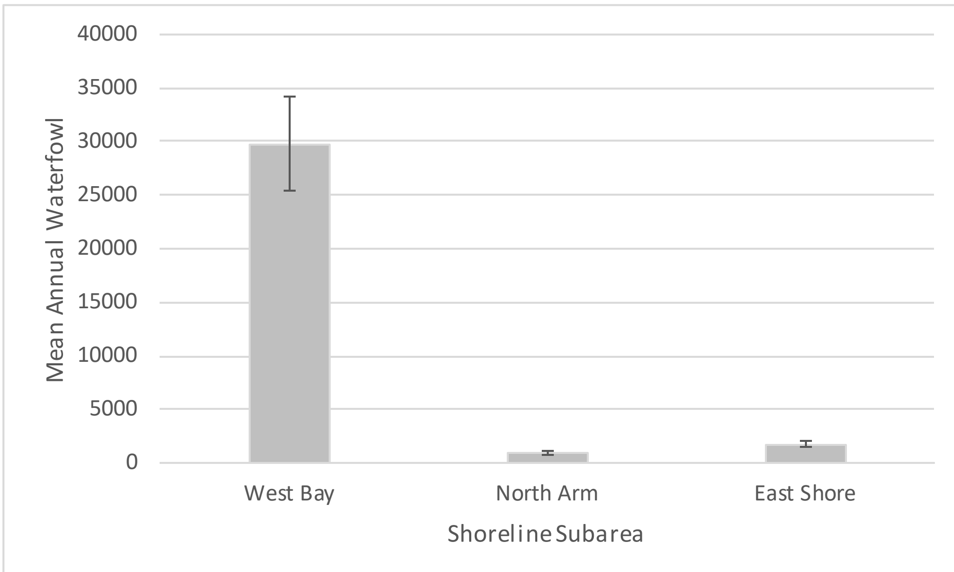


Figure 110. Spatial Distribution of Waterfowl at Bridgeport Reservoir

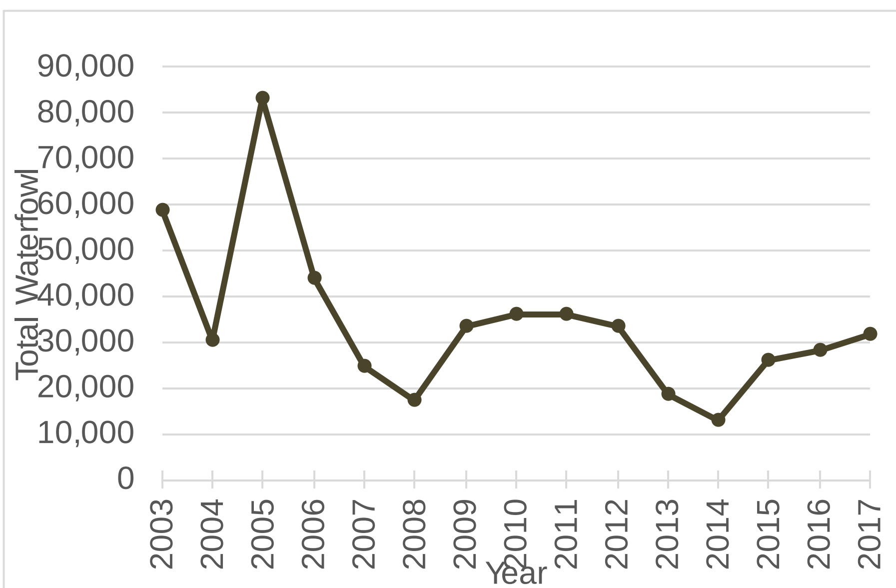


Figure 111. Total fall Waterfowl at Bridgeport Reservoir.

Waterfowl use of Bridgeport Reservoir has been responsive, in part to how full the reservoir is (Figure 112). Waterfowl use has generally declined and been at its lowest when the reservoir has also been at its lowest level. Conversely, waterfowl use has generally increased with increasing reservoir elevations.

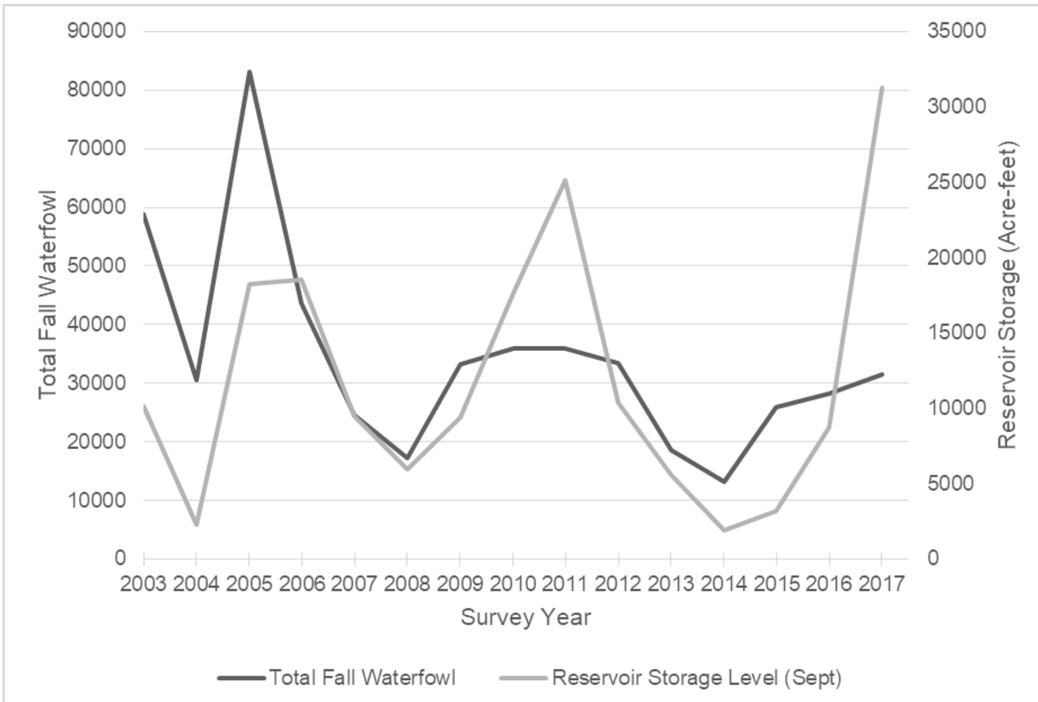


Figure 112. Fall Waterfowl Numbers at Bridgeport Reservoir as a Function of Reservoir level

Crowley Reservoir

Fall Waterfowl Population Size and Species Composition

Fall aerial surveys of Crowley Reservoir have recorded a total of 744,148 waterfowl of 27 species. Total waterfowl numbers have generally been highest from mid-September through mid-October and numbers have not declined as much late in the season as the other two survey areas. Crowley Reservoir has supported an average of 48,325 +/- 5,199 waterfowl annually (range 17,955-82,006).

Geese have been less abundant at Crowley than at Bridgeport Reservoir. Geese and swans have comprised <2% of waterfowl. Annual Canada Goose numbers have ranged from 98 up to 2,432 (Table 92). Dabbling ducks have accounted for 76% of waterfowl and numbers have varied from an annual low count of 5,525 to over 84,000. As with Bridgeport Reservoir, the dabbling duck community is much more diverse than that found at Mono Lake, with high use by Northern Shoveler, Gadwall, Mallard, Northern Pintail and Green-winged Teal. Divers are more abundant here than at the other two sites, accounting for 22% of all waterfowl. As is the case at Bridgeport Reservoir, the diving duck community is much more diverse than that found at Mono Lake. Very high numbers of Ruddy Duck and Bufflehead have been encountered at Crowley.

Table 91. 2003-2017 Waterfowl Statistics for each of the fall surveys at Mono Lake

Survey	*Mean*	*Std. Error*	*Minimum*	*Maximum*
Early Sept	9651.3	1126.2	2745	18108
Mid-Sept	14716.9	1767.4	5118	32001
End Sept	14508.9	2143.8	3502	29329
Mid-Oct	14178.9	1977.9	1656	28395
End Oct	11660.0	1611.5	3023	28104
Mid-Nov	9746.7	1340.6	3101	20387

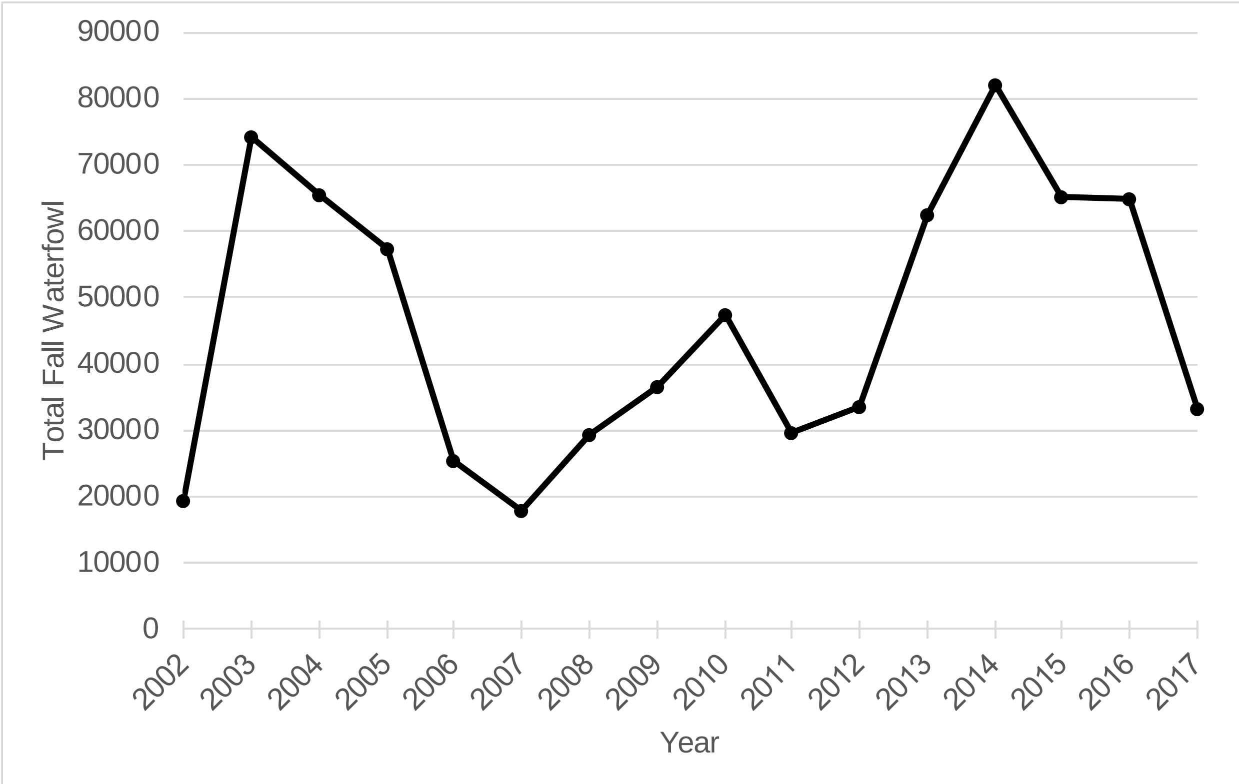


Figure 113. Total fall Waterfowl at Crowley Reservoir

Table 92. Summary of Fall Waterfowl Species Composition – Crowley Reservoir; 2003-2017 Compiled Data

Species Group	Species	Mean	Standard Error	Max	Min
Geese and Swans	Snow Goose	3.6	2.1	30	0
	Ross's Goose	0.1	0.1	1	0
	Greater White-fronted Goose	17.7	8.2	121	0
	Cackling Goose	0.1	0.1	1	0
	Canada Goose	739.0	161.1	2,219	98
	Tundra Swan	16.6	4.6	60	0
	Total Geese and Swans	777.1		2,432	98
Dabbling Ducks	Blue-winged Teal	0.9	0.4	5	0
	Cinnamon Teal	353.7	150.4	1,925	19
	Northern Shoveler	7,894.5	1,384.0	17,205	713
	Gadwall	4,748.3	598.5	8,099	541
	American Wigeon	386.1	104.6	1,327	12
	Mallard	7,509.0	1,231.6	15,925	911
	Northern Pintail	6,589.2	714.3	11,030	1,640
	Green-winged Teal	5,758.7	1,149.6	16,920	1,689
	Unidentified Teal	3,665.0	1,033.3	12,219	0
	Total Dabbling Ducks	36,905.3		84,655	5,525
Divers	Canvasback	54.3	26.7	310	0
	Redhead	112.9	28.7	338	0
	Ring-necked Duck	77.5	21.9	327	0
	Lesser Scaup	129.9	31.2	424	8
	Surf Scoter	0.1	0.1	1	0
	White-winged Scoter	0.1	0.1	2	0
	Bufflehead	600.3	94.1	1,256	190
	Common Goldeneye	1.1	0.6	8	0
	Hooded Merganser	0.7	0.4	5	0
	Common Merganser	16.9	5.5	75	0
	Red-breasted Merganser	0.1	0.1	1	0
	Ruddy Duck	9,649.6	2,023.2	24,406	1,450
	Total Divers	10,643.5		27,153	1,648

Spatial Distribution

Waterfowl at Crowley Reservoir have been concentrated in two main areas – McGee Bay and the Upper Owens River delta. The overwhelming number of waterfowl have been found in McGee Bay where they occur in large numbers all along the length of this shoreline subarea. This shoreline subarea receives inflow from Convict and McGee Creeks, and spring flow and subsurface flows from irrigation upgradient. Wetland vegetation often extends to the shoreline, with small areas of mudflats present at all except the highest reservoir levels. During the later fall surveys in October, diving ducks can be numerous with large flocks of Ruddy Ducks and other diving duck species just off shore and on the open water. The other area of concentration is the Upper Owens River delta where flows from the Owens River enter the reservoir. Except at very high reservoir levels, this area has extensive mudflats for loafing, shallow feeding areas, and quiet backwater bays. During most surveys, few waterfowl are encountered at Chalk Cliffs. Flocks of waterfowl have only been observed in this area after the start of waterfowl hunting season when birds are then consistently seen offshore or loafing along the narrow, dry beach. Hilton Bay has good waterfowl habitat with adjacent meadows and some fresh water inflow, but due to its small size, has supported small numbers of primarily dabbling ducks. Waterfowl use of the Layton Spring subarea is usually concentrated near the spring inflow. Birds may also be scattered in smaller numbers along the mudflats or nearshore throughout the remainder of the subarea which is primarily sandy beach. North Landing is another shoreline area with no direct fresh water inflow. Springs and subsurface flow nearshore attract waterfowl at various reservoir elevations. Few waterfowl have been seen along the Sandy Point subarea as this area has no freshwater input, and supports sagebrush up gradient.

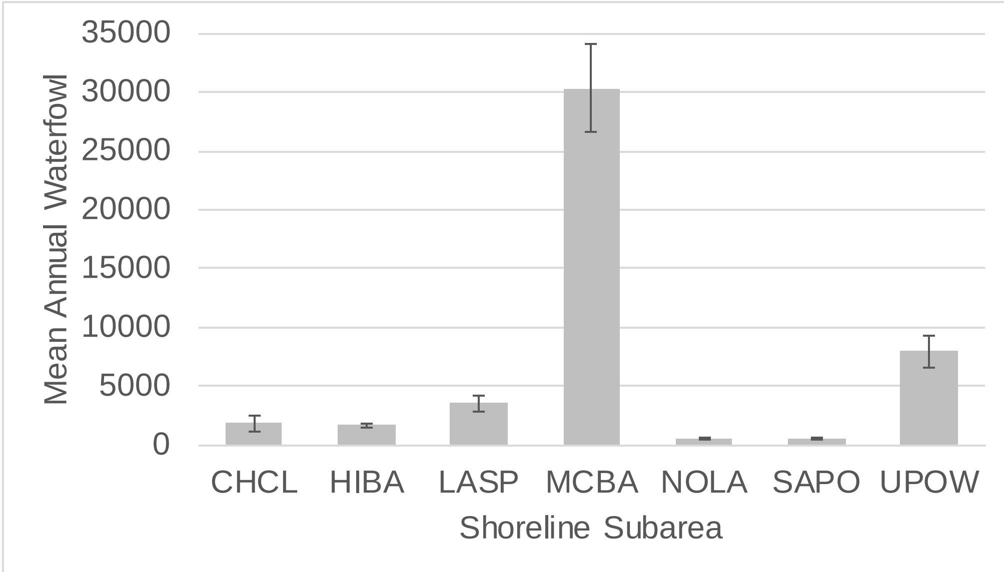


Figure 114. Spatial Distribution of Waterfowl at Crowley Reservoir

Bars are 2003-2017 means plus SE.

Comparison of Reference Data to Evaluate Trends

Bridgeport/Crowley

The comparison surveys have shown that Mono Lake attracts a disproportionally small number of waterfowl, despite its large size (Figure 115). The long-term mean annual waterfowl use at Mono Lake has been the lowest of the three surveys areas, although there has been some slight overlap in the overall mean with Bridgeport Reservoir. The waterfowl community at Mono Lake also differs notably from the other two survey areas in that it is composed primarily of the few species typically associated with saline lakes. In contrast, the waterfowl communities of Bridgeport and Crowley Reservoirs are more diverse as is typical of fresh water systems.

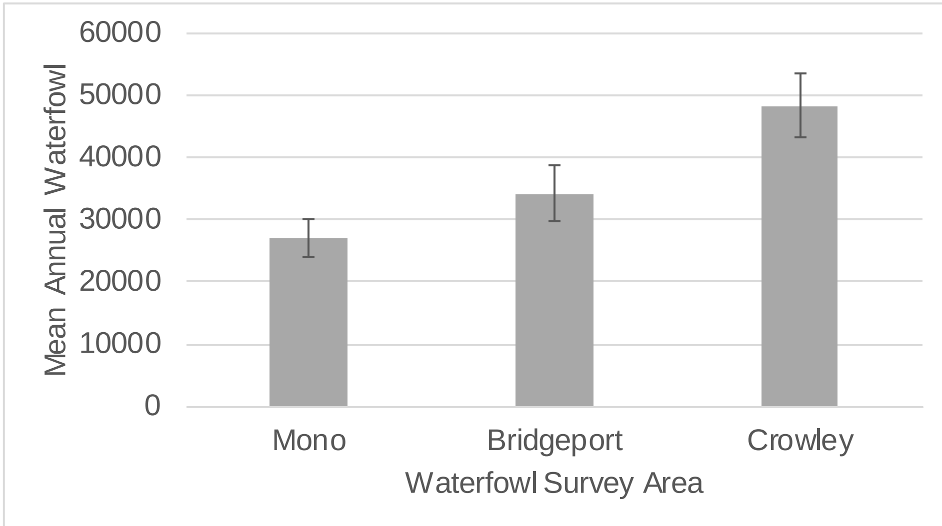


Figure 115. Comparison of Mean Fall Waterfowl at each of the Three Surveys Areas, 2003-2017

On an annual basis, waterfowl use of Bridgeport and Mono Lake appear to be more associated with each other than Mono Lake is with Crowley Reservoir (Table 115). There has been a negative correlation between peak waterfowl numbers observed at Mono Lake and Bridgeport Reservoir. Higher peak counts within a year at Bridgeport Reservoir have been associated with lower peak counts at Mono Lake. In years of reduced peak counts at Bridgeport, the peak count at Mono Lake has been elevated. No such relationship in the peak count of waterfowl at Mono Lake and Crowley Reservoir has been observed.

The total waterfowl numbers observed during each survey of Mono Lake and Bridgeport have been positively correlated with each other as both survey areas have demonstrated a similar seasonal decay in total numbers (Table 116). No such relationship was observed seasonally with Crowley Reservoir as waterfowl numbers often remain elevated at Crowley through at least the end of October.

The following correlation table compares annual peak waterfowl number, total waterfowl by survey, and annual total waterfowl at Mono Lake to Bridgeport and Crowley Reservoirs.

Table 93. Correlations Between the Waterfowl Population Indices of Mono Lake, Bridgeport Reservoir and Crowley Reservoir

	COMPARISON WATERFOWL SURVEY AREA			
	Bridgeport		Crowley	
MONO LAKE VARIABLE	***r***	***p value***	***r***	***p value***
Annual Peak Numbers	**-0.6997**	**0.0025**	**0.0298**	**0.9126**
Survey Total	**0.3825**	**0.0002**	**0.0197**	**0.8514**
Annual Total	**-0.0399**	**0.8835**	**-0.0260**	**0.9239**

Northern Shoveler has shown differing patterns of use and long-term trends among the three survey areas (Table 93). While no long-term trend in Northern Shoveler numbers has been observed at Mono Lake, slight trends have been observed at the other two survey areas. Since 2007, Northern Shoveler use has shown a slight declining trend in total use at Bridgeport Reservoir while use has been increasing slightly at Crowley during this same time period.

Ruddy Duck have shown differing patterns of use and long-term trends among the three survey areas (Table 94). The Ruddy Duck survey data indicate a significant decline in use over time of Mono Lake. Numbers were initially high (yearly totals over 20,000) to annual totals below 10,000 since 2005. The population of Ruddy Duck at Crowley Reservoir has subsequently been increasing over this time period, and since 2013, more Ruddy Ducks have been observed at Crowley Reservoir than at Mono Lake.

Table 94. Correlations Between Total Annual Northern Shoveler and Ruddy Ducks at the Three Survey Areas

Comparison	**Test result**	**Species**	
		Northern Shoveler	**Ruddy Duck**
Mono Lake vs. Bridgeport	r	0.0339	-0.4223
	p value	0.9046	0.1169
	interaction	0.6499	***0.0005**
Mono Lake vs. Crowley	r	-0.0984	-0.5800
	p value	0.7271	***0.0234**
	interaction	***0.0438**	***0.0000**
Bridgeport vs. Crowley	r	-0.3477	0.5266
	p value	0.2041	***0.0437**
	interaction	***0.0007**	***0.0023**

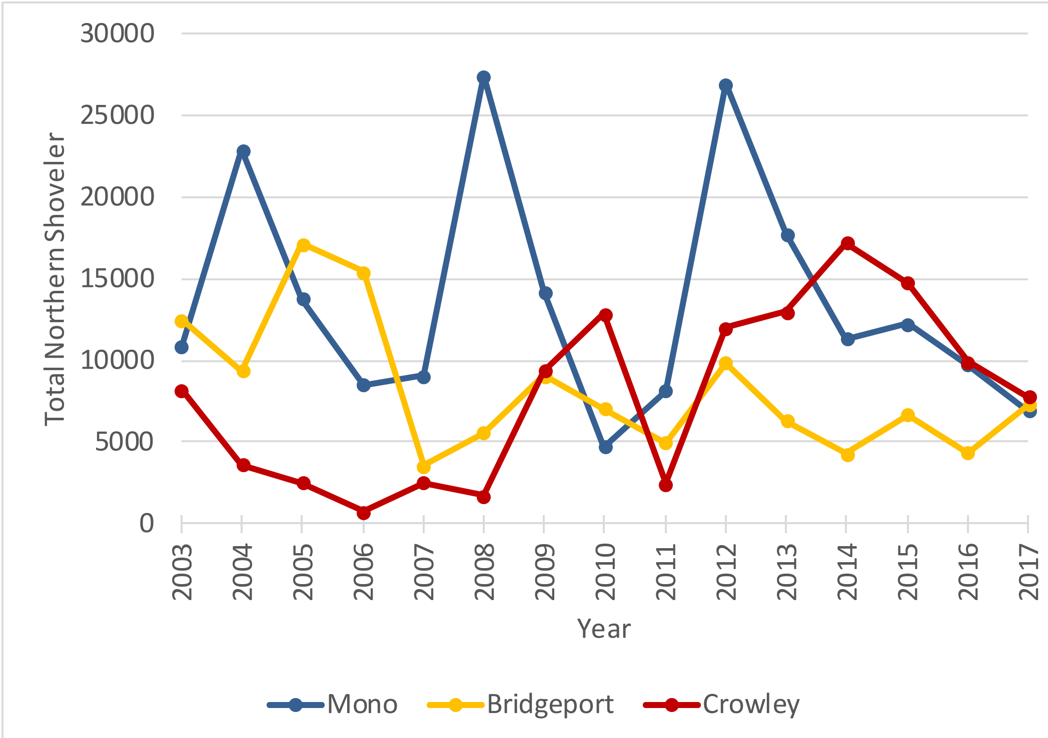


Figure 116. Comparison of Total fall Northern Shoveler at the Three Survey areas

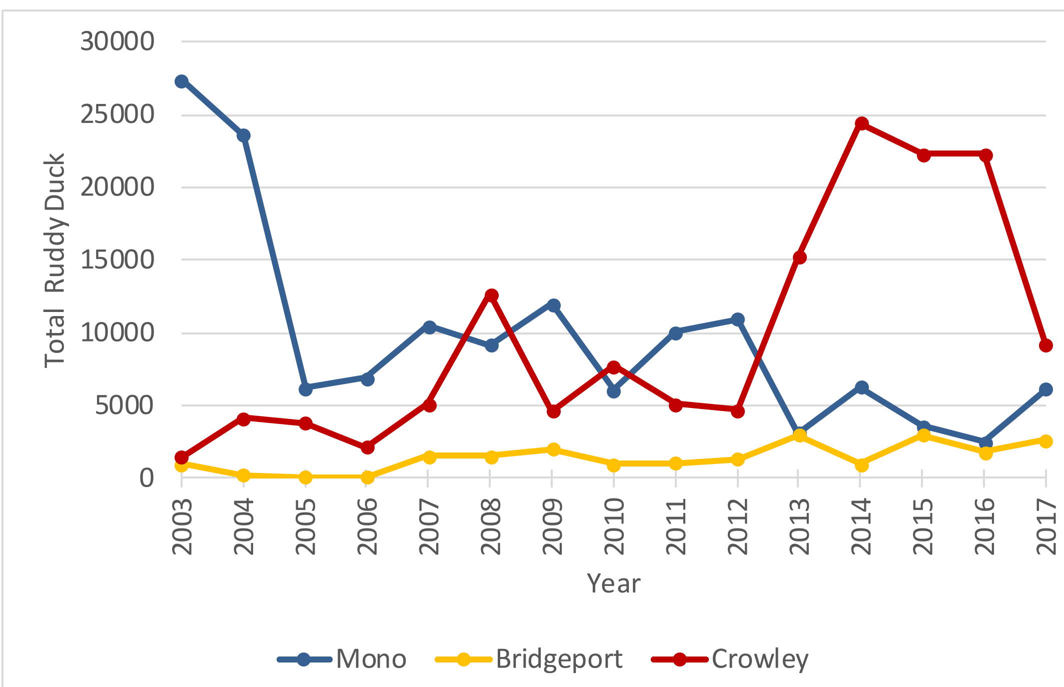


Figure 117. Comparison of Total fall Ruddy Duck at the Three Survey Areas

Comparisons with Regional Data

Annual waterfowl numbers at each of the survey areas was compared with data from the Pacific Flyway Breeding Waterfowl Surveys, Breeding Waterfowl Surveys for the Western States (California, Nevada, Utah, and Washington), California Breeding Waterfowl Surveys, Sacramento National Wildlife Survey Fall counts, and Owens Lake fall waterfowl surveys.

Of all the regional data evaluated, the annual patterns of total fall waterfowl use of Mono Lake was most closely aligned with those observed at Owens Lake (Table, Figure). Since fall waterfowl counts were initiated at Owens Lake in 2012, there has been an annual decline observed, with a slight increase in numbers in fall of 2017. It is during this time period that the most significant drop in use of Mono Lake was also seen. This time period coincides with an extended multi-year drought, and saline lakes systems can be quite responsive to environmental change. It is unknown if waterfowl that stopover at Mono Lake in fall also stop at Owens Lake. Waterfowl numbers at Mono Lake were not found to be correlated with

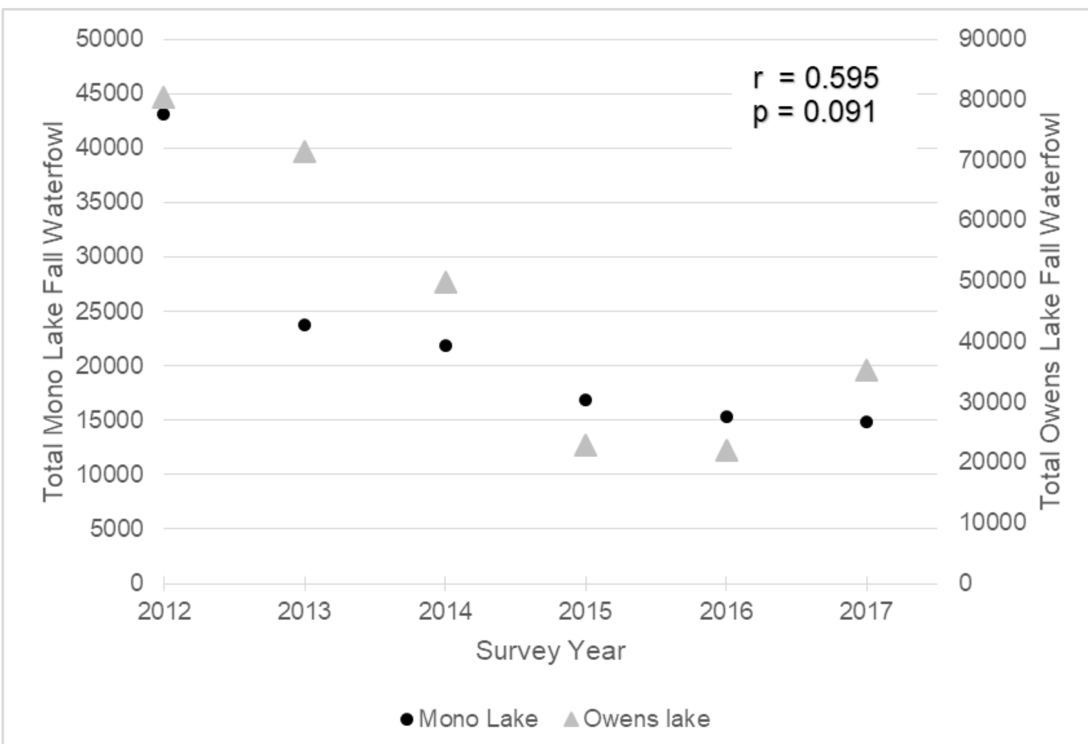


Figure 118. A comparison of Fall Waterfowl Populations at Mono Lake and Owens Lake, 2012-2017.

Fall survey numbers at Bridgeport showed a negative correlation with the Pacific Flyway Breeding surveys and Sacramento National Wildlife Refuge fall numbers (Table).

The pattern of use at Crowley Reservoir differs from that observed at either Mono Lake or Bridgeport Reservoir. The annual pattern of use at Crowley Reservoir suggests that this site may see increased use during periods of drought. The years of lowest fall waterfowl numbers (2006-2008, 2011, 2017) correspond to wet periods. Higher fall numbers have occurred during dry periods as seen in 2003-2004, 2013-2016.

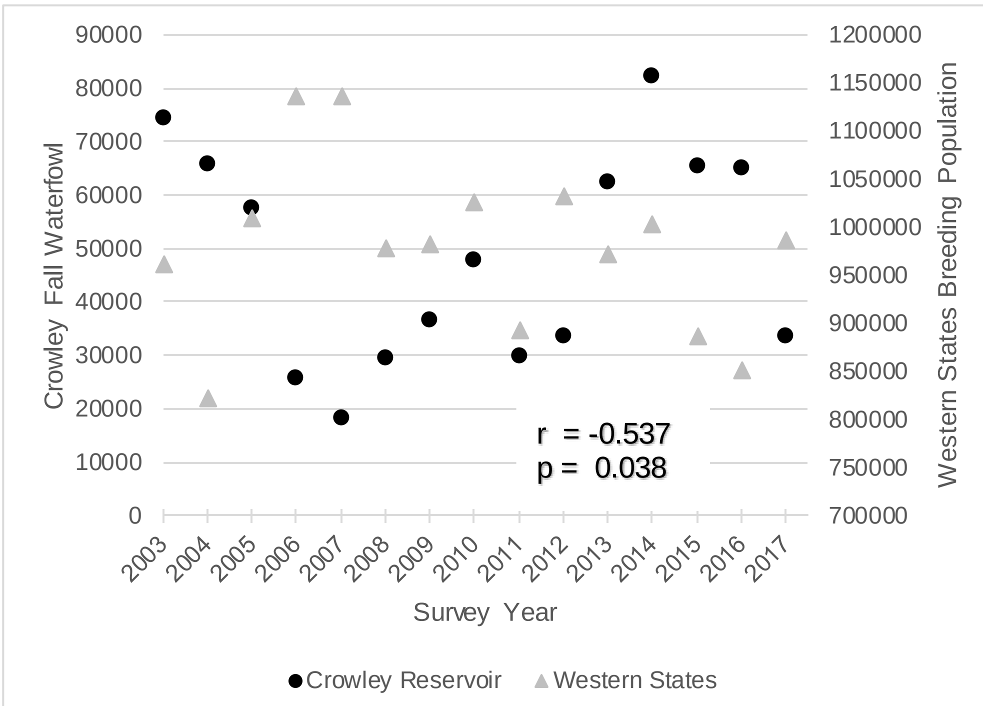


Figure 119. Fall Waterfowl counts at Crowley Reservoir vs. the Breeding Waterfowl Population in the Western States

California, Nevada, Washington and Utah

This inverse relationship was also observed when comparing the annual waterfowl numbers at Crowley with the breeding populations in the Pacific Flyway states of Washington, Utah, Nevada, and California ("western states"). Increases in the western breeding population during the same wet periods discussed above generally were negatively correlated with counts at Crowley Reservoir ($r = -0.537$, $p = 0.038$).

Table 95. Correlations between fall waterfowl numbers at Mono Lake, Bridgeport Reservoir, and Crowley Reservoir and other regional data.

Waterfowl Survey Area	Test statistic	Pacific Flyway Breeding Waterfowl	Western States	California Breeding Waterfowl	Sacramento NWR - Fall Waterfowl	Owens Lake Total Fall Waterfowl
Mono Lake	**r**	**-0.399**	**-0.16**	**0.0805**	**-0.0241**	**0.595**
	p value	*0.126*	*0.553*	*0.767*	0.935	*0.0909*
Bridgeport	**r**	***-0.592**	**0.118**	**0.443**	***-0.618**	**-0.353**
	p value	*0.0202*	*0.676*	*0.0981*	0.0184	*0.352*
Crowley	**r**	**0.0671**	***-0.537**	***-0.561**	**-0.424**	**-0.0626**
	p value	*0.812*	*0.0388*	*0.0297*	0.131	*0.873*
Bridgeport and Crowley	**r**	**-0.329**	**-0.319**	**-0.129**	***-0.711**	**-0.252**
	p value	*0.232*	*0.246*	*0.648*	*0.00438*	*0.514*

Integration with Prior Waterfowl Monitoring

Although summer waterfowl monitoring was initiated in 1996, brood data is only available for 2000 and 2001. Jehl reported a total of 16-20 broods in 2000, which is well below the 2002-2017 average. In 2001, Jehl reported 50-53 broods which is within the range observed with this study. Taking into account the 2000-2001 brood data does not alter the conclusion that there has been no long-term trend in the number of broods produced at Mono Lake.

Data on fall peak waterfowl numbers for the initial years after implementation of the Plan were compared to the 2002-2017 time period. The data suggests an overall increase in peak fall waterfowl numbers may have increased since implementation of the Plan. Peak waterfowl numbers in the first six years after implementation of the Plan ranged from 1,000 to 5,000 averaging 2,580. Since 2002, peak waterfowl numbers have ranged from a low of 1,300 to a high of 11,000, averaging 4,230.

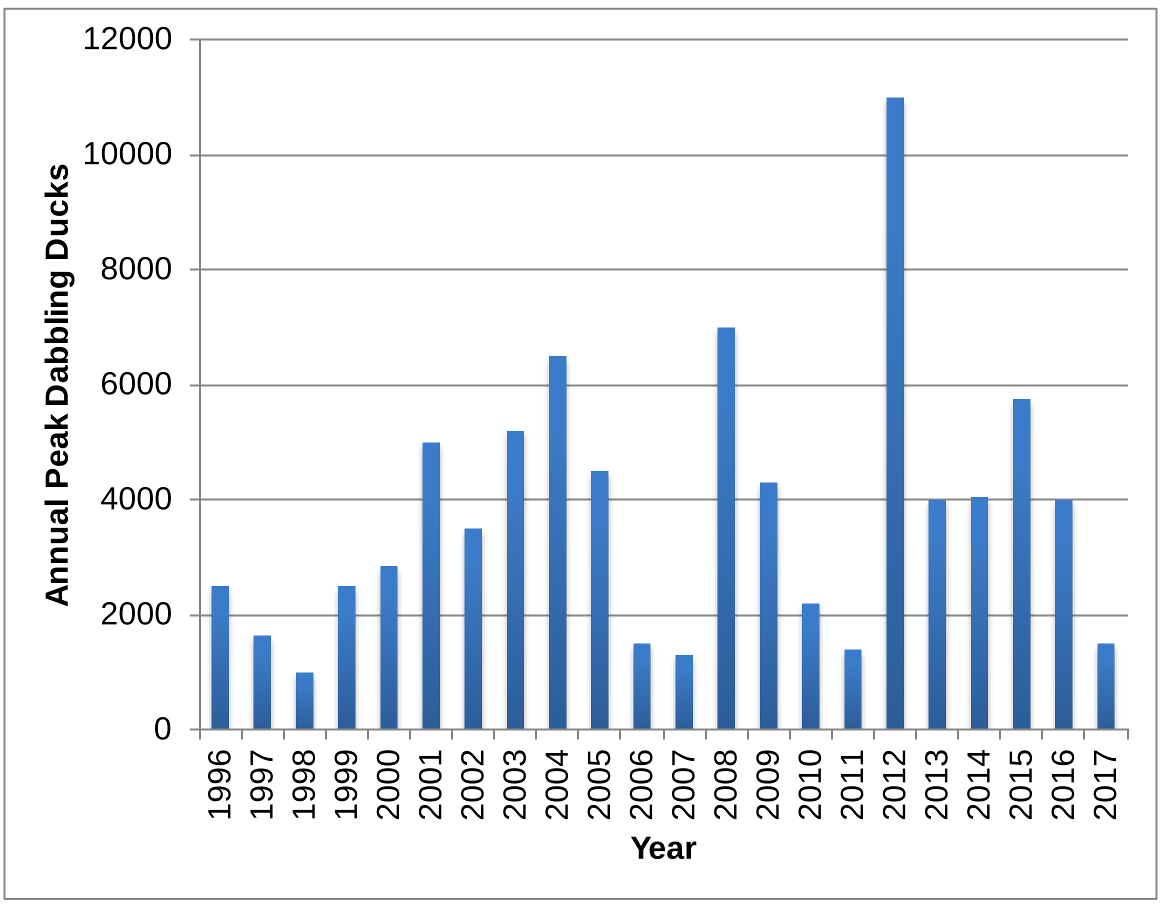


Figure 120. Peak waterfowl counts at Mono Lake since Implementation of the Plan

Waterfowl Population Monitoring Program Evaluation

The waterfowl survey data were evaluated to determine if the monitoring program could be streamlined, yet provide indices to the response of the waterfowl population to restoration. This was conducted for the summer breeding waterfowl population data, brood data, and total fall waterfowl counts.

Correlations exist among the various breeding waterfowl parameters (Table 96). The number of broods and breeding waterfowl observed on survey 3 have shown the most interrelatedness with other breeding waterfowl parameters. Fewer relationships exist with the other two surveys. The number of broods seen on survey 3 was positively correlated with total broods and the number of breeding waterfowl present during the survey. The number of breeding waterfowl seen on survey 3 was positively correlated with total broods and the mean breeding waterfowl population. Thus, under a reduced monitoring schedule, the most important summer survey to conduct is survey 3. Data from survey 3 could provide reasonable indices as to total broods and the breeding waterfowl population. The least important survey to conduct is survey 1.

Table 96. Correlation Coefficients Between the Breeding Waterfowl Parameters and Survey Numbers

Breeding Waterfowl Parameter	Brood Survey 2	Broods Survey 3	Breeding Waterfowl-Survey 1	Breeding Waterfowl-Survey 2	Breeding Waterfowl-Survey 3	Total Broods	Mean Breeding Population
Broods-Survey 1	0.171	*0.538	0.295	0.349	0.496	*0.499	0.403
Brood Survey 2		*0.699	0.095	0.301	*0.501	*0.721	0.305
Broods Survey 3			0.247	0.443	*0.562	*0.925	0.452
Breeding Waterfowl-Survey 1				*0.716	0.311	0.326	*.874
Breeding Waterfowl-Survey 2					*0.753	*0.547	*.951
Breeding Waterfowl-Survey 3						*0.647	*.694
Total Broods							*0.555

*Significant at $p<0.05$

Correlations between the total lakewide waterfowl, exclusive of Ruddy Duck, and the number of waterfowl observed on each survey, and at each shoreline subarea were examined. The total number of waterfowl on Surveys 1-4 were positively correlated with total annual waterfowl, but the relationship did not hold for Surveys 5 and 6. Mill Creek, Wilson Creek and Simons Spring were the only shoreline subareas whose waterfowl use was correlated with lakewide annual waterfowl numbers. Data from Surveys 1-4 at Mill Creek, Wilson Creek and Simons Spring provided the strongest correlation with total annual waterfowl numbers at Mono Lake. The strength of the correlation is similar to Surveys 1-4 of all subareas (r=0.91 vs r=0.97). Under a reduced monitoring schedule, surveys 5 and 6 could be discontinued. In addition, based on the 2002-2017 data, Mill Creek, Wilson Creek and Simons Spring would be the most important sites to survey to provide an index to waterfowl populations at Mono Lake.

Table 97. Correlations Between total, annual lakewide waterfowl at Mono Lake and Survey number, shoreline subarea, and the combined totals from Mill, Wilson and Simons Spring. *=significant at p<0.05.

Survey or Shoreline Subarea	Total Waterfowl
Survey 1 All subareas	*0.7470
Survey 2 All subareas	*0.7970
Survey 3 All subareas	*0.7410
Survey 4 All subareas	0.4830
Survey 5 All subareas	0.1070
Survey 6 All subareas	-0.6470
Black Point	-0.1310
Bridgeport Creek	0.1110
DeChambeau Creek	0.2010
DeChambeau Embayment	0.0589
Lee Vining Creek	-0.0562
Mill Creek	*0.5550
Northeast Shore	-0.0899
Ranch Cove	-0.1590
Rush Creek	0.0844
Simons Spring	*0.5850
South Tufa	-0.2470
South Shore Lagoons	0.3960
Warm Springs	0.0752
West Shore	-0.1660
Wilson Creek	*0.7520
Survey 1_Mill, Wilson, Simons	*0.6170
Survey 2_Mill, Wilson, Simons	*0.5880
Survey 3_Mill, Wilson, Simons	*0.7570
Survey 4_Mill, Wilson, Simons	*0.6060
Survey 1-4_Mill, Wilson, Simons	*0.9130
Survey 1-4_All subareas	*0.9700

Waterfowl Survey Discussion

Summer ground surveys – Mono Lake shoreline

Breeding Population Size and Composition

While from a local standpoint, Mono Lake can be considered important as a breeding waterfowl site, at a regional scale, Mono Lake supports a relatively small breeding population. The breeding population of Mono Lake was compared to other sites within the intermountain west (Table). Within Mono County, the only other site supporting a breeding waterfowl community of similar size is Crowley Reservoir. Surveys conducted in the 1990's indicated that Crowley Reservoir supported an estimated 200-300 pairs of nesting waterfowl (Mono Basin Hearing Transcripts 1993, Shuford and Metropolos 1996).

Honey Lake in Lassen County is a large shallow endorheic sink in northeastern California, also at the western edge of the Great Basin region. Fed by the Susan River, Honey Lake is shallow, and undergoes substantial seasonal and annual variation in size. The wildlife area was originally acquired to provide nesting waterfowl habitat. The breeding population recorded in the early 1950's was significantly higher than that observed in 2002-2003. The 2002-2003 population was comparable to that which has been observed at Mono Lake. The Fish Springs National Wildlife Refuge is an area of spring-fed marshes and managed wetland habitats in the Great Salt Lake desert. Although less than half the size of Mono Lake, early studies in the 1960's showed this area supported a breeding population six times as large as Mono Lake. Summer Lake in Oregon is a shallow saline lake fed by the Ana River. The Ana River flows through a series of impoundments and wetland habitats before emptying into Summer Lake. Although equivalent in size to Mono Lake, waterfowl productivity at Summer Lake is significantly greater. Malheur National Wildlife Refuge includes Malheur and Mud Lakes, one of the largest inland marshes in the United States and managed areas supporting a variety of other wetland habitat types. The shallow lakes and impoundments are highly productive waterfowl breeding areas. Tule and Lower Klamath Lakes include large areas of shallow freshwater habitats supporting highly productive waterfowl habitats.

Table 98. Productivity of Mono Lake for breeding waterfowl as compared to other regional sites

Source	*Approximate Acres of Region*	*Study Years*	*Average Breeding Population*	*Number of Ducklings*
Mono Lake, Mono Co, CA	44,160	2002-2017	300 (145-555)	270 (88-507)
Crowley Lake, Mono Co, CA	8,500	1990's	200-300	
Honey Lake, Lassen County, CA (Matchett and Sedinger 2008)	13,000	2002-2003	190	
Fish Springs NWR, Utah (McKnight 1969)	18,000	1967-1968	1,800	3,687
Honey Lake Valley, Lassen Co, CA (Hunt and Naylor 2017)	20,000	1951-1953	4,909 (4,212-5,354)	
Summer Lake, OR (Bellrose 1976)	48,000	not stated		10,000
Malheur NWR, OR (Cornely 1982)	181,967	1971-1980		33,000
Tule and Lower Klamath Lakes, CA (Bellrose 1976)	25,000	not stated		50,000

Although the number of species breeding at Mono Lake is not high, the breeding community is more diverse than previously reported. In contrast to that reported by Jehl (2002), Gadwall was not the only nesting species at Mono Lake. Whether this reflects colonization of additional species or survey methodology is not clear. Gadwall was the most visible species at Mono Lake as they were the species most frequently feeding in freshwater outflow areas nearshore, and showed no hesitation to take their broods of any size out into the open water when disturbed. Other species were much more difficult to detect, remaining in the onshore wetlands or along freshwater streams. Boat-based surveys, as were conducted from 1996-2001, would have easily detected Gadwall, but may have missed the other nesting species such as Cinnamon Teal, Mallard, and Green-winged Teal due to their tendency to seek cover on shore, and their hesitancy to take broods out on the open waters of Mono Lake. Ground based surveys, while more time intensive, allowed more detailed information and for the detection of species more closely associated with shoreline habitats.

The total waterfowl breeding population has been declining along with a decline in average brood size. Lake elevations below 6,382 feet appear to be detrimental to the breeding population. Breeding populations have been higher with larger brood sizes at lake elevations above 6,382 feet, with the highest number of breeding waterfowl and broods at the highest elevation observed (6,385 feet). The effect of further increases in lake elevation above 6,385 feet is unknown. Whether further increases in lake elevations will provide additional benefits or be detrimental to breeding waterfowl populations is uncertain.

Waterfowl Brood parameters

The mean brood size of the breeding species suggests that waterfowl productivity may be low at Mono Lake. Most broods were detected when they were still very young which may improve the ability to assess the differences between reported clutch and brood size. For all species, the mean clutch size reported in the literature is higher than size of broods observed at Mono Lake. The mean brood size for the two most abundant breeding is below the average reported clutch size. The average clutch size in Gadwall is 8-12 (Leschack et al. 1997), while average brood size at Mono Lake has been 5.6. The mean clutch size of Mallard is 8.7, while that observed at Mono Lake has been 4.6.

Clutch size and brood size are not directly comparable because brood size may be reduced due to duckling mortality. The first two weeks after hatching are the most critical in terms of duckling survival when mortality can be most severe (Ball et al. 1975, Cox et al. 1998, Street 1977). Duckling survival can be affected by various factors including the overland travel distance of young broods (Ball et al. 1975), wetland availability (Amundson and Arnold 2001), predation, or inadequate nutrition (Street 1977). Young ducklings could perish, leading to a decreased brood size irrespective of clutch size. Clutch size can also be affected by female condition. Within species variations in clutch size has been found to be related to female condition and nutrients acquired on the breeding grounds (Ankney and Afton 1988, Choinière and Gauthier 1995).

Some very large broods exceeding the maximum known clutch size for a species have also been seen, most frequently in Gadwall, but also possibly in Mallard. These large broods could be the result of conspecific brood parasitism, or post-hatching brood amalgamation. Conspecific brood-parasitism occurs when a hen lays her eggs into the nest of another female. Post-hatching brood amalgamation occurs when a female abandons her young or otherwise loses her young to another hen (Eadie et al. 1988).

While the salinity of Mono Lake is closely tied to lake elevation, these two variables may be independently affecting brood numbers and brood size to some extent. In general, when the surface level of Mono Lake was higher, there were more open water ponds. At elevations above 6,385 feet, many more temporary wetlands developed along the south shoreline, and breeding waterfowl and brood numbers were at their highest. At elevations below 6,382 feet, brood numbers and brood sizes were reduced. In addition to increasing the available wetlands, increases in lake elevation have also placed potential breeding ponds closer to favorable feeding areas at the outflow of creeks and springs where densities of *Artemia* may be higher (Dana and Herbst 1977). Thus, lake elevation may not only provide additional areas of high food abundance in temporary wetlands, but decrease exposure of ducklings or adults as they feed on shore. Salinity may influence productivity at Mono Lake by affecting food supply. Although clutch size data are not available, the average brood size for waterfowl at Mono Lake is below that reported in the literature.

Spatial distribution

Breeding waterfowl species have been found at all summer survey sites, but the results suggest that not only do some sites consistently support more breeding waterfowl, but sites may differ in productivity or how water use the shoreline subareas. Waterfowl breeding populations are concentrated into highly localized areas around the shoreline of Mono Lake, where fresh water resources occur for young ducklings. While breeding waterfowl have been observed in all subareas, use has been concentrated in three subareas: Wilson Creek, Mill Creek and South Shore Lagoons. Even within those subareas, breeding waterfowl use has been concentrated in areas of appropriate nesting or feeding habitat. South Shore Lagoons and Wilson Creek and Mill Creek have supported a similar proportion of the overall breeding waterfowl community. The South Shore Lagoons has produced more broods, with most breeding activity in the Goose Springs area. Although good brooding and breeding habitat, the South Shore Lagoons may not be ideal foraging habitat as indicated by the disparity between adult waterfowl use and the number of broods seen. Waterfowl have been observed to move widely between scattered foraging areas all along the south shore. Although breeding waterfowl use is high in the Goose Springs area, waterfowl may need to forage elsewhere along the south shore to meet their energy needs. Waterfowl breeding bird use and brood production are similar at Wilson Creek, indicating this site provides both excellent breeding and foraging habitat. The expansive meadow habitat in the Wilson Creek provides suitable nesting habitat for the species common at Mono Lake. The Wilson Creek delta also provides excellent foraging opportunities due to the presence of multiple fresh water springs combined with a broad shallow gradient offshore area, and protected bay. Drift studies showed the biomass of invertebrates at Gull Bath spring in the Wilson Creek delta to be produce well over an order of magnitude above the next most productive site (Herbst 1977). Breeding waterfowl may use sites such as South Tufa and Warm Springs for feeding, but generally avoid these areas for nesting and brood-rearing.

Habitat Use

During development of the Plan, it was noted that there was little information on how waterfowl use Mono Lake habitats. Ground surveys allowed an opportunity to record specific habitat types waterfowl used, below the level of detail used for modeling. On shore water features including freshwater streams, freshwater ponds, brackish ponds, hypersaline ponds, and mudflats have been heavily used by all dabbling duck species. The exception to this was Gadwall which used these habitats proportionally less. Gadwall was the most visible breeding species and the most likely to be seen feeding, resting or brooding in areas of ria, or resting on shore in open areas, or taking their broods away from shore out on the open water. The only other species that regularly escorted their broods offshore was Canada Goose, while the other species retreated to hide within the wetland vegetation surrounding ponds or just offshore. Canada Goose were rarely seen in lake-fringing ponds, and more typically seen on mudflats, wet meadow, or alkaline meadow sites where they frequently fed on the new growth of sedges (*Carex* sp.) and rushes (*Juncus* sp.). Cinnamon Teal demonstrated the highest association with onshore water features including brackish ponds and freshwater ponds and was infrequently seen at the shoreline. Green-winged Teal were encountered more frequently in association with freshwater streams such as Rush Creek and Mill Creek, where freshwater ponds and riparian scrub habitat were available. Although Mallard used a variety of habitats including alkaline wet meadow, marsh, brackish and freshwater ponds, when with broods they were typically seen in ponds away from the immediate shoreline. Northern Pintail were observed primarily in alkaline wet meadow and brackish ponds and, as was the case with Mallard, rarely came to shore with broods. The majority of Ruddy Ducks observed in summer were were observed on the open water likely nonbreeders. When nesting in shoreline areas, as in 2008, Ruddy Ducks were found in a freshwater pond along the South Shore.

Response of the Breeding Waterfowl Population to Restoration

The breeding waterfowl community has demonstrated a positive response to the primary restoration objective of increasing the level of Mono Lake. Larger breeding populations, more broods and larger brood sizes have been seen with increases in lake elevation. Decreases in lake levels have been associated with reductions in the size of breeding population, fewer broods, and smaller brood sizes. These responses suggest that waterfowl breeding productivity at Mono Lake is influenced by lake elevation. There may be a lower threshold of lake elevation below which changes in the breeding habitat become more significant. This lower threshold appears to be around 6,382 feet as below that elevation, all waterfowl breeding parameters have shown a decline.

The range of elevations over which observations have occurred has been fairly limited as the majority of the observations have taken place at lake elevations between approximately 6,382 and 6,383.5 feet. Whether further increases in lake elevations beyond 6,385 feet will provide additional benefits or be detrimental to breeding waterfowl populations is uncertain. Applying an assumption of a continued linear positive response to further increases in lake elevation, the projected breeding waterfowl population at the target lake elevation of 6,392 feet is a little over twice the average waterfowl breeding population, or 684 birds (342 pairs). A population of double the current breeding size is still small from a regional scale, and insignificant at the level of individual waterfowl species population.

Lake elevation affects waterfowl breeding populations through direct and indirect effects. At higher lake elevations, waterfowl breeding habitat quantity and quality have been increased. This effect is seen primarily along the south shore, where the number and size of fresh water ponds is greater when the lake has been higher. As lake level drops, ponds along the south shore dry up or become encroached with emergent vegetation. Many studies have shown that waterfowl breeding productivity is linked to the abundance and quality of open water wetlands and ponds supporting high densities of aquatic invertebrates (Cox et al. 1998, Pietz et al. 2003, Kaminski and Prince 1981, Krapu et al. 1983). The abundance and availability of aquatic invertebrates limits the number of breeding waterfowl and waterfowl brood survival (Sjoberg et al. 2000). The increased number of open water fresh or brackish ponds along the south shoreline associated with higher lake elevations creates additional foraging areas for breeding waterfowl and their broods.

Lake elevation may also be affecting breeding populations indirectly by affecting brood survival. One process by which this may occur is increased predation exposure and risk. As the lake level decreases, the distance between nesting areas with vegetation and high quality feeding areas, such as spring outflow sites, increases. This will result in an increased distance of overland travel by broods often on exposed barren lakebed between areas of cover and feeding sites. This effect is especially evident along the south shoreline where small changes in lake elevation result in more dramatic changes in degree of shoreline flooding. Not only might this increased distance increase their energy expenditure, but also increase the exposure of young broods to predation. Ducklings are flightless for approximately the first seven weeks of life, and suffer the highest mortality in the first two weeks of life (Ball et al. 1975, Cox et al. 1998). Predation and adverse weather have been cited as major causes of duckling mortality (Cox et al. 1998). Predators of young ducks include coyote (*Canis latrans*), California Gull (Gates 1962), raccoon (*Procyon lotor*) and mink. Reduced energy expenditures will support higher growth rates of ducklings, providing some protection against adverse weather and predation (Cox et al. 1998). Factors affecting brood survival may ultimately influence the breeding population because of the tendency of waterfowl to return to their natal area to breed (Doherty et al. 2002).

The abundance of one of the main food resources at Mono Lake has also influenced breeding waterfowl populations. Modeling indicates the *Artemia* population in May and June explain part of the variability in breeding waterfowl numbers. Compared to other avian species, the energetic demands of nesting waterfowl are high, as egg and yolk size are disproportionally large relative to body size (Lack 1968). The availability of invertebrates has been found to be a major proximate factor determining the initiation of egg laying in ducks and waterfowl obtain the protein needed for egg formation through dietary intake on the breeding grounds (Krapu 1974, Choinière and Gauthier 1995). Waterfowl were frequently seen feeding in near shore, often in the outflow of springs or creeks where *Artemia* is expected to be an abundant prey item. *Artemia* numbers may influence the breeding population by affecting female condition.

Modeling also indicated that spring precipitation has a negative influence on the breeding waterfowl population. A mechanism that may account for this is regional habitat availability. In wetter years, habitat conditions at sites other than Mono Lake may improve, resulting more dispersed breeders. Alternatively, very wet springs could result in nest failure or inundation of favored nesting locations. The mechanism by which spring precipitation has influenced waterfowl breeding populations at Mono Lake is not well understood.

Summer Ground Surveys - Restoration Ponds

The Restoration Ponds have attracted small numbers of breeding waterfowl in the summer. Over 60% of all waterfowl have been observed in two of the five ponds (DEPO_4 and COPOE) that have been wet in most, if not all years. The apparent lower productivity of other ponds could be related to pond size, condition, or other factors.

The data suggests a changes in waterfowl use of some of the ponds, especially over the last six years. At COPOW, a heavy growth of emergent vegetation (e.g. cattails) has resulted in limited open water habitat. The area of open water has appeared to continue to contract over the last several years. COPOW appears to be susceptible to cattail encroachment, and this pond has experienced a few short periods when open water was available, and waterfowl use was generally high, followed by longer periods of dense cattail growth and low waterfowl use, especially since 2011. Although continuously wetted and still dominated by open water, use of DEPO_2 has dropped off over the last six years. The reasons for this are not known, however, the change in water source as a result of the break in the pipe that occurred circa 2008/2009 should be considered as a factor that may be influencing pond conditions. In 2017, problems with infrastructure also affected COPOE. In spring, U.S. Forest Service staff noted the diverter box at the junction of COPOW and COPOE was broken, and water could not be delivered to COPOE. This problem was not resolved until mid-summer, resulting in very low waterfowl use.

Fall Aerial Counts

Mono Lake - Population size and species composition

The regular schedule of fall surveys conducted from 2002-2017 have allowed for the calculation of waterfowl population indices for Mono Lake not previously available. Three different indices were used to assess the population of Mono Lake waterfowl. At the high end, up to 51,000 waterfowl have been found to use Mono Lake in a single year, but this is likely an overestimate of the number using the lake. A more conservative estimate of the annual population size at Mono Lake is the calculated population index of 9,651, ranging from 3,460 to 18,590. On any one day, over 17,000 waterfowl have been present at Mono Lake.

The two key waterfowl species at Mono Lake are the dabbling duck Northern Shoveler and the diver Ruddy Duck, which combined accounted for 88% of all waterfowl. The species composition recorded by these surveys does not differ from those of historic accounts. Northern Shoveler and Ruddy Duck are waterfowl species that can form significant proportions of waterfowl communities at saline lake systems. Other saline lakes in the western states where Northern Shoveler and/or Ruddy Ducks are abundant components of the waterfowl community include Lake Abert (Senner et al 2018), Owens Lake (LADWP 2014), and the Salton Sea (Shuford et al. 2000 Patten et al. 2003).

The differences in the characteristics between individual saline lakes with regard to parameters such as salinity, fresh water inputs, and water depth, can influence the quality of the habitat for waterfowl and therefore species composition and abundance. Salinity and water depth influence not only the types and abundance of food items, but also accessibility. Mono Lake is deep, highly saline, with limited shallow shoreline areas. These features limit the habitat quality for waterfowl and may ultimately limit recovery of waterfowl populations. In order for waterfowl to meet their energetic demands, food resources need to be accessible, abundant, and of sufficient quality.

The food resources at individual saline lakes can vary widely, depending on salinity and fresh water inputs. Closed lake systems can vary from brackish (1-3 gm/L) to highly saline (e.g. Mono Lake 80-90 gm/L). At moderate salinity levels aquatic invertebrate communities are more diverse than at higher salinities. Few invertebrate species are tolerant of high salinities, thus highly saline lakes such as Mono Lake have low invertebrate diversity, however, can support large number of some species. Depending on salinity, the invertebrate community of closed lake systems may include *Artemia*, Dipterans (alkali fly, midges), Corixids, water fleas (Daphnia), beetles (Coleptera). The highly saline water of Mono Lake currently only support *Artemia* and *Ephydra*, however other species may have occurred historically when the lake was no more than 50 gm/L salinity. For example, experimental studies have shown that at the prediversion salinity of 50 gm/L, twice the diatom diversity would have been supported and greater biomass and diversity of benthic algae (Herbst and Blinn 1998). The highly saline waters also limits the availability of vegetable food sources to isolated fresh water and brackish ponds as the salinity of the lake is above the tolerance of wetland plants.

Birds inhabiting saline environments encounter additional energetic costs associated with osmoregulation. Osmoregulation in waterbirds occurs through physiological, behavioral, or mechanistic adaptations. In some species, ingesting salts while feeding and drinking in saline environments cause large changes in the organs responsible for osmotic regulation including the kidneys, small intestine, and hindgut. Salt glands are the most efficient organ by which waterbirds cope with excess salt. Birds in marine environments have more well-developed salt glands than non-marine species (Gutiérrez 2014). In high salinity environments, the intestines of some birds increase in mass, so that the salt holding capacity, increases and more salt can be routed to the salt glands (Gutiérrez 2014). Salt glands hypertrophy when birds switch from fresh to saline habitats in order to maintain water and electrolyte balance (El-Gohary et al. 2013, Gutiérrez 2014). Maintaining large, functioning salt glands is physiologically demanding. Birds may also osmoregulate through behavioral or mechanistic actions. Behaviorally, birds may avoid saline habitats, or by feeding on prey with lower salt loads, or visit fresh water sources near feeding grounds. Other birds may use mechanical means of decreasing the intake of saline water such as using surface tension to deliver prey to the mouth or using the tongue to compress water off of prey (Rubega 1997, Mahoney and Jehl 1985).

Waterfowl using Mono Lake must balance the energetic costs of migration and molt and with food intake. The two most abundant and widespread secondary producers are brine shrimp and alkali flies. Other food resources are available at lake-fringing brackish and freshwater ponds, however these are localized at particular shoreline areas, and their presence and availability ephemeral.

Waterfowl diets vary according to the feeding environment and available food resources. Food items reported as being important to Northern Shovelers feeding in saline habitats include water boatmen (Corixidae) (Euliss and Jarvis 1991), copepods and rotifers (Euliss 1989), brine shrimp cysts (Roberts 2013, Boula 1986, Vest 2013) and alkali fly larvae (Roberts 2013. Boula 1986) and pupae (Boula 1986). Brine shimp adults are not as digestible and have lower caloric density as compared to other food sources, and may not be selected for when other food is available. The diet of Northern Shovelers at Mono Lake has not been studied; therefore the extent to which they use the various life stages of brine shrimp or alkali fly at Mono Lake is unknown. Although many dabbling duck species consume both vegetable and animal foods, many studies have found a preponderance of animal matter in the diet of Northern Shoveler. In saline lakes that lack aquatic vegetation and have limited vegetative food resources such as Mono Lake, waterfowl species whose diet is composed largely of animal manner can still find resources. Northern Shoveler also has a specialized bill morphology including very closely spaced lamellae, allowing for the effective filtering of small aquatic invertebrates (Gurd 2007). Northern Shoveler may be able to feed more efficiently at Mono Lake than other species, despite saline conditions because of their bill structure.

Although Northern Shoveler may be abundant at saline lakes, they do not have the physiological adaptation of well-developed salt glands for osmoregulation (Roberts 2013). Like most nonmarine waterfowl, Northern Shoveler need access to fresh water daily. Northern Shoveler can forage efficiently at saline sites however supporting only small aquatic invertebrates such as those found at Mono Lake, and osmoregulate through behavioral means by visiting fresh water resources.

Despite the productivity of Mono Lake, access of these food resources to dabbling duck species like Northern Shoveler is somewhat limited. The topography and bathymetry is such that shallow-water feeding areas, especially those near springs, are widespread and not extensive. The range of water depths for optimal foraging by dabbling ducks is 2-10 inches. Prey will generally be less accessible in water depths greater than about 10 inches, and thus foraging efficiency will decrease. At Mono Lake, dabbling ducks have been observed to feed almost exclusively near shore, and more specifically, where the bathymetry data suggests a greater extent of shallow water than areas where waterfowl use is lower or absent. In contrast to anecdotal historic reports, I saw no evidence that waterfowl fed on the open water of Mono Lake, in areas that would presumably have a hypopycnal layer of water, i.e. off-shore of Rush Creek and Lee Vining Creek.

Mono Lake appears to support fewer Northern Shoveler and perhaps other dabbling duck species than expected, based on the size of the lake, likely due to a combination of topography, salinity, and fresh water inputs. Lake Abert a waterfowl community also dominated by Northern Shoveler (Senner et al 2018), has supported peak counts higher than that observed at Mono Lake, at over 22,000. Lake Abert is of comparable size, yet it a shallow lake, averaging 5 feet deep. The Owens Lake dust control project area with a flooded area half the size of Mono Lake, has supported single day counts of over 60,000 Northern Shovelers (LADWP 2014b). Ponds at Owens Lake that support these numbers are typically shallow (<10 inches) and brackish (<30 ms/cm). The species composition of the waterfowl community of the Salton Sea is similar in that Ruddy Ducks have comprised the overwhelming majority (83%) or the diving ducks, and Northern Shovelers (25,000 wintering birds) have been 50% of the dabblers (Shuford et al. 2000). The dabbling duck community has been more diverse than has been observed at Mono Lake as Northern Pintail, American Wigeon, and Green-winged Teal are also fairly abundant (Shuford et al. 2000 Patten et al. 2003). The Salton Sea is considered shallow, although with an average water depth of 30 feet, is deep enough to support diving birds. Although historically the Salton Sea was brackish (~3,500 ppm salinity), in recent years the salinity has been rising, and is now approximately 52,000 ppm (Bellini et al. no date).

The spatial distribution of waterfowl at shoreline sites in fall suggests that waterfowl habitat at Mono Lake is highly localized. Although the Wilson Creek area makes up <2% of the entire shoreline area, it has supported 45% of all dabbling ducks. The combination of abundant spring flow, extensive wet meadow habitat upgradient, and shallow offshore gradient in the Wilson Creek bay likely contribute to creating a favorable shallow water feeding and loafing area. Increases in lake elevation create local improvements in waterfowl habitat and waterfowl use becomes more dispersed.

As a diving species that remains offshore, Ruddy Ducks are not expected to be directly affected by shoreline changes. Only 30% of Ruddy Ducks were seen during perimeter flights – in other words within approximately 800 feet of the shoreline. Most Ruddy Ducks were seen off-shore of Bridgeport Creek and DeChambeau Embayment where the lake is not only shallow, but has many brackish springs, and an unusual amount of hard surface substrates in the form of pumice blocks.

The Ruddy Duck diet is composed of primarily aquatic invertebrates. In fresh and brackish water lakes, midge larvae have been found to be the main food item consumed by Ruddy Ducks, but other food items have been common including Corixids, Cladocera, and *Ephydra* (Euliss and Jarvis 1991, Hohman et al. 1992). In hypersaline lakes were brine shrimp and alkali flies are the main food source, alkali flies are preferred by all but a few waterbird species because of their higher nutritional value (Warnock 2005).

The distribution of Ruddy Ducks at Mono Lake overlaps high productivity areas for alkali fly. Although no diet study of Ruddy Ducks at Mono Lake has been conducted, Johnson and Jehl (2002) noted alkali fly larvae in the stomachs of three Ruddy Duck carcasses collected at Mono Lake. Herbst found that the north shoreline area had the highest productivity of alkali fly larvae and pupae are highest on hard surfaces such as tufa, tufa covered pumice blocks, and mudstone, than soft surfaces such a mud or sand (Herbst 1990, Herbst 1993). Low ammonium concentrations limits the production of planktonic algae and may also limit the production of benthic algae (Herbst 1993, Herbst and Bradley 1989). Declining lake elevations result in a decrease of submerged tufa habitat (Herbst 1990) and reduced flooding of the tufa covered pumice blocks. Herbst and Bradley 1990 found that the density and biomass of alkali fly larvae and pupae were greatest at depths of 0.5 meter and 1 meter, but reduced in deeper water. Modeling predicted that alkali fly abundance would be maximized at 6,380 feet, as this was the elevation where the area of hard substrate larval and pupae attachment in shallow waters would be highest (Herbst and Bradley 1990). Ruddy Duck numbers were at their highest in 2003 and 2004 just following a period of rapid rise in lake elevation. In other periods of rapid increase in lake elevation, such as occurred in 1982-1988, a shift in the diet of California Gull suggests an increase in the availability or quality of prey at Mono Lake. During a period of low lake elevation from 1976-1982 (elevation below 6,380 feet), alkali fly comprised less than 5% of the gulls diets. As the lake was rising, from 1982-1988, the proportion of the diet of comprised of alkali flies increased to 20-50% (in Herbst and Bradley 1990). The spatial distribution of Ruddy Ducks supports the hypothesis that alkali flies may be an important food item of this species at Mono Lake. If so, Ruddy Ducks congregate in areas where alkali fly production should be higher than other areas of the lake, and prey would be accessible. If Ruddy Ducks are relying primarily on alkali flies at Mono Lake, then significant changes to the fly population, or to the accessibility of this food resource may influence use of Mono Lake.

Ruddy Ducks may engage in behavioral and mechanistic osmoregulation. Ruddy Ducks feed by drawing water and or benthic material into their bill, then filtering the material by forcing the water and material out (Tome and Wrubleski 1988). This straining as well as a diet of brine fly larvae, which possess physiological adaptations which allow them to maintain a water balance similar to freshwater invertebrates (Herbst et al. 1988), may limit salt intake by Ruddy Ducks at Mono Lake. Access to fresh water would allow further reductions in salt loading.

Although a dominant species of the Mono Lake waterfowl community, the population of Ruddy Ducks at Mono Lake is only moderately-sized, as compared to other regional sites. Ruddy Duck numbers in the Owens Lake dust control project area are fairly similar to those at Mono Lake, with peak counts averaging 5,000. Although the flooded areas of Owens Lake total approximately 35 square miles, the majority of birds have been found in three ponds totaling approximately 3 square miles. The Ruddy Duck is the most abundant waterfowl species at the Salton Sea where a very large wintering population of 75,000 Ruddy Ducks occurs (Shuford et al. 2000). The Salton Sea is not only much larger than Mono Lake, but less saline.

The causative factors determining annual fall waterfowl numbers have not been clearly identified. Correlations were found between waterfowl and lake elevation, fall *Artemia* populations, the average fall cyst production of *Artemia,* and summer water temperatures, however how these factors may interact remains unclear. Higher total fall numbers of waterfowl have occurred at elevations between 6,381 feet and 6,383 feet, mainly due to the response of Ruddy Ducks. Further increases above 6,383 feet have not resulted in higher numbers of waterfowl.

It is important to note that most observations have been within a narrow two-foot elevation range of 6,381-6,383 feet. Thus, these results should be viewed cautiously and the response to further increases in lake elevation above 6,385 cannot be predicted at this time.

It is uncertain the underlying mechanism behind the response of Northern Shoveler to decreases in lake elevation from the previous September. One possible explanation for this is that in some shoreline subareas, shoreline ponds develop during the receding limb after periods of elevated lake levels. Northern Shoveler may also be responding to dry conditions or drought effecting waterfowl habitat at Bridgeport Reservoir, or other Intermountain West sites, as declines in lake elevation usually follow winters of below normal precipitation.

Artemia biomass production and cyst production appear to partly explain the annual variation in waterfowl populations at Mono Lake. In open saline waters of Great Salt Lake, Northern Shoveler and Green-winged Teal were found to consume largely *Artemia* cysts and adults. In that study, cysts comprised a larger component of the diet than adult brine shrimp, making up 52% of the biomass of the diet of the shoveler, and 80% of Green-winged Teal diets (Roberts 2013). While some waterfowl species, such as Mallard and geese are typically seen in shoreline ponds or mudflats, other fall migrants including Northern Shoveler, Green-winged Teal and Northern Pintail, congregate near shore at creek deltas. *Artemia* are likely to be an abundant prey item in these areas, however other potential dietary items may be present. A time budget study has not been conducted of waterfowl use of shoreline areas during fall migration, thus the importance of the different subareas for feeding, drinking, roosting, or bathing is not known.

The comparisons of yearly waterfowl use of the survey areas with other sites suggests that the factors influencing waterfowl use of each survey area may differ. Annual waterfowl use patterns were most similar to those observed at a nearby saline lake system, while the comparison of waterfowl use of Bridgeport and Crowley to regional data showed similarities to other fresh water systems.

5.0 SUMMARY OF THE MONO BASIN WATERFOWL RESTORATION PROGRAM

The Mono Basin Waterfowl Habitat Restoration Program was developed to evaluate the effect of changes in the Mono Lake area relative to the restoration objectives, and to provide information to guide future restoration activities. The program has included a number of restoration projects, objectives, and monitoring projects. Restoration has included establishing a target lake elevation, reestablishing perennial flow in tributaries, channel openings, providing financial assistance for the restoration of waterfowl habitat, and exotic species control.

The progress made toward the target lake elevation has been slow. Although it has been 24 years since Decision 1631, the elevation of Mono Lake is still well below the target lake level. Despite the four periods of lake level rise, in which the lake rose 3 to 4 feet each time, there has been an overall trend of decreasing lake elevation. The ecological changes associated with this decrease have also affected lake-shore fringing waterfowl habitats, at least temporarily.

Restoration in the Mono Basin along the tributaries to Mono Lake has included the establishment of perennial flows in Rush Creek and Lee Vining Creek, and the reopening of side-channels in Rush Creek to restore waterfowl and riparian habitat in the Rush Creek bottomlands. The rewatering of Rush and Lee Vining Creek has undoubtedly provided significant ecological benefits to the wildlife and ecosystem of the Mono Basin. The benefits of the recovery of riparian resources along Rush and Lee Vining Creek have been described for songbird populations (Heath 2003). Restoration has improved nesting habitat for waterfowl species that nest in riparian areas in the Mono Basin, including Green-winged Teal and Mallard, due to the increase in availability of perennial water for feeding and escape by broods, and by supporting the growth of meadow and wetland vegetation for nesting. In wet years, wetlands of the Rush Creek bottomlands become inundated, creating small open water ponds that are attractive to nesting and migrating waterfowl. However, the actual number of waterfowl that use the riparian corridor is small (House 2013), especially as compared to the lake-fringing habitats, and the channel-opening restoration projects have likely had more direct conservation value for riparian-dependent species in the Mono Basin than for its waterfowl populations. Additional benefits may be realized for waterfowl as the system matures.

The establishment of perennial flow in Rush and Lee Vining Creek has resulted in the reestablishment of deltas and presumed hypopycnal areas along the perimeter of Mono Lake near these outflow areas. These delta areas are very important wildlife areas, and are used by many waterbirds for feeding, resting, bathing, and drinking. Although waterfowl use of the deltas has been higher than that observed along the riparian corridors, the use of the restored Rush and Lee Vining Creeks by fall migratory waterfowl has accounted for less than 5% of all waterfowl use. In the delta areas, waterfowl have been observed close to shore during summer ground counts and fall aerial surveys. Extensive use by waterfowl of areas presumed to be hypopycnal areas, such as those offshore of Rush and Lee Vining Creeks, has not been evident. The extent of these hypopycnal areas, and how they benefit waterfowl, has not been demonstrated conclusively.

There has been no evidence that waterfowl use of shoreline areas has been directly responsive to the magnitude of creek flow. Creek flows influence upstream waterfowl habitat indirectly by supporting the growth of wetland vegetation for nesting and cover. The influence of creek or spring flow on food supply or accessibility is not known.

No correlations were found between waterfowl use and the lake-fringing wetland monitoring data. Several reasons are possible for this including 1) waterfowl are selecting habitats at a finer scale than is being mapped, or 2) near shore parameters of habitats such as spring flow rate, spring flow type, invertebrate drift, or the bathymetry of near shore areas hold some importance with regard to waterfowl habitat, and should be integrated into the waterfowl habitat monitoring or assessment.

Order 98-05 provided for funds to be set aside for waterfowl habitat restoration in the Mono Basin. The Restoration Ponds represent a potential location in the Mono Basin for waterfowl habitat enhancement. Waterfowl habitat at the Restoration Ponds might benefit from upgrades to the existing water delivery system, to allow for more flexibility in water delivery to individual ponds. The system is also in need of repair, as recent failures in the water delivery infrastructure have affected water deliveries to individual ponds.

Tamarisk is having little impact in the Mono Basin and is being effectively controlled.

Although the Plan includes a rather exhaustive monitoring program, the Waterfowl Habitat Restoration monitoring program suffers from a lack of coordination between the various monitoring components. This may limit the ability to interpret patterns in waterfowl use of Mono Lake in response to restoration, should they exist. The Waterfowl Restoration Program might also benefit from coordinated monitoring schedules for some tasks, and a more focused monitoring or additional short-term studies to address currently unanswered questions. These changes might not only be beneficial in terms of understanding waterfowl habitat and use, but would also add to our understanding of the ecological factors that may influence use of Mono Lake by other important waterbird groups.

6.0 RECOMMENDATIONS

The time period for restoration of waterfowl habitat has been greatly extended due primarily to the protracted time period that has been required for lake elevation recovery. The Plan states that monitoring will focus on waterfowl habitats rather than a projected number of waterfowl. The Plan also states that monitoring should consider the duration required for restoration to occur, the goals and objectives of the particular project, and the level of effort needed to collect the data (Drewien, Reid, and Ratcliff 1996). Decision 1631 recognized that raising the elevation of Mono Lake could take roughly 29 to 44 years depending upon the assumptions made regarding future hydrology. However, the original monitoring Plan was developed under the assumption that the lake elevation would recover and reach its target level within approximately 20 years after Decision 1631.

The Plan had proposed schedules for a discontinuation of the monitoring programs, most sun-setting after the lake had reached its target elevation, and had demonstrated ecosystem stability. Decision 1631 required LADWP to prepare a restoration plan with reasonable, financially feasible restoration measures. LADWP has complied with the Decision 1631 and Order 98-05, and in some cases, has conducted monitoring in excess of that originally proposed. Waterfowl habitat restoration is not complete, however, since the target lake level has not been achieved, and some required monitoring also has yet to be completed. In light of the extended time period required for restoration, and the level of monitoring that has been conducted to date, less-frequent but more focused approach for long-term monitoring of waterfowl habitat in the Mono Basin is proposed.

Lake-fringing ponds, springs, deltas, and nearshore habitats of spring outflow areas, are the habitats most used by waterfowl and many other waterbird species that use Mono Lake. Changes in these areas are not being adequately assessed by the current monitoring program. Future monitoring should focus on changes to these habitats as a function of lake level changes, as well as long-term changes in these habitats. This data may be useful to evaluate the response of waterfowl and other waterbird species to lake level changes at Mono Lake.

Specific recommendations are presented below for each component and Table 99 provides a comparison of the current required monitoring, and the proposed changes to the monitoring program. Although performing particular monitoring tasks at certain lake elevations might be ideal in order to insure data at various lake elevations, this is often difficult in practice. Data collection on 5-year intervals, as has been done for vegetation monitoring, will continue to provide data on long-term trends, and at various lake elevations over time.

The following are my specific recommendations for the waterfowl monitoring program:

1) **Lake elevation** – No change to current monitoring; continue to monitor lake elevation on a biweekly basis

2) **Stream Flows** - No change to current monitoring; continue to monitor daily stream flow

3) **Spring Surveys** – Continue to monitor at five-year intervals

4) **Limnological monitoring** – Continue the annual limnological monitoring program, but incorporate spatial and temporal reductions. Reduce the monitoring of water parameters and Artemia populations to April-November at four stations (4, 6, 9 and 10). Conduct conductivity, water temperature profiles, Secchi depth, and 9-m integrated sampling at each of these four stations during each visit April-November. Conduct conductivity and water temperature profiles at each of these four station in February to monitor changes in mid-winter conditions, and the long-term trend in winter minimum temperatures of the hypolimnium. Continue *Artemia* fecundity sampling June-October but increase the sample size to 20 at each of the four sampled stations. Discontinue the instar analysis

5) **Vegetation transects** – the vegetation transect sampling was required at five-year intervals until 2014, at which point LADWP could evaluate the need to continue the program. As the monitoring data indicate the establishment of relatively stable, late seral vegetation communities, I recommend suspending the vegetation transect study at this time. Once the target lake elevation is reached, conducting a final year of vegetation transect monitoring could be instructive.

6) **Landtype mapping** – continue at 5-year intervals; conduct ground-truthing to ensure proper classification of shore-fringing water features such as freshwater, brackish and hypersaline ponds. Consider documenting community composition by shoreline subarea, at least for areas at or below the 6,392 foot contour.

7) **Fall waterfowl counts** – Every five years, conduct six aerial counts at two-week intervals at Mono Lake, as was conducted from 2002-2017, until the lake reaches the target elevation of 6,392 feet and goes through one complete wet/dry cycle.

These aerial counts will include the shoreline and cross-lake transects. In intervening years, conduct four fall grounds counts two-week intervals at Mill Creek, Wilson Creek and Simons Spring, starting the first week of September. As discussed in section 4, the four surveys at the three sites will provide an index to the total waterfowl population at Mono Lake. Lakewide surveys conducted every 5 years can be used to reevaluate the use of the indices, and determine long-term trends in populations and spatial distribution.

8) **Fall comparison counts** - The Plan recognized that the importance of comparison data might justify the need to continue the counts on an annual basis. The data suggest that waterfowl populations at Mono Lake are responding more to conditions at the lake itself, and have poor correlation to numbers and trends at the nearby freshwater lakes used as comparison sites. Although the comparison data has been instructive, and has helped substantiate conclusions regarding waterfowl response to local conditions at Mono Lake, annual counts at these nearby freshwater reservoirs are not necessary to evaluate the response of waterfowl to restoration at Mono Lake. Comparison counts at Bridgeport and Crowley Reservoirs can be reduced to every five years to continue to provide an index to long-term trends in Mono County that may influence use of Mono Lake. Supporting the continuation of comparison counts at nearby saline lake systems such as Owens Lake would also be useful.

9) **Summer ground counts** Reduce the number of counts per year to one (conduct survey 3 only). This single survey will not only continue to provide an index to the response of breeding waterfowl to restoration (brood number, breeding waterfowl population size), but is useful for the documentation and evaluation of on-the-ground conditions. At the target lake elevation, conduct all three surveys.

10) **Waterfowl time budget study**. Order 98-05 required a time budget study to be conducted during each of the first two fall migration periods after the plan was approved, and again when Mono Lake reaches its target lake elevation. A single time budget study was completed in fall of 2000 on Ruddy Ducks. LADWP should complete the second time budget study focusing on shoreline use by waterfowl. A time budget study allows for the determination of the relative importance of different shoreline sites for migratory waterfowl, and would provide insight into the importance of hypopycnal areas for feeding, resting, or drinking.

11) **Conduct a hypopycnal area investigation**. It was hypothesized in the Decision 1631 that "Near the mouths of the tributary streams, a phenomena called "hypopycnal stratification" occurs in which the lighter fresh water flowing into the

lake floats on the top of the denser saline water already in the lake." Furthermore, Section 6.4 of Order 98-05 states that the lake level of 6,392 feet will restore a significant amount of waterfowl habitat by restoring large hypopycnal areas near the mouths of Rush and Lee Vining Creek. If hypopycnal areas do not occur, or if waterfowl are not using them to the extent proposed, then expectations regarding the response to restoration may need to be reevaluated. The current limnological monitoring method is not designed to accurately test this hypothesis because stations are too far spread from each other and also, most importantly, are far from the deltas. Relating limnological monitoring to waterfowl monitoring is crucial to understand waterfowl use of Mono Lake. LADWP recommends initiating an investigation into theexistence and spatial/temporal extent of hypopycnal stratification, and and relating the findings to waterfowl use.

This would be a short-term focused study intended to demonstrate the presence and extent of hypopycnal areas at specified locations, including Rush Creek, Lee Vining Creek, and Wilson Creek, and possibly others. This study would be conducted during peak runoff periods (June/July) and again in fall (September) during peak waterfowl migration. The study would preferably be conducted the same year as the time budget study. The study would include limnological sampling along a transect perpendicular to the shoreline to document salinity profiles and invertebrate abundances.

12) **Conduct an invertebrate inventory at the Mono Lake springs.** It is recommended that this be conducted in conjunction with the next spring survey. Productivity may be related to water quality, surrounding vegetation, or substrate. The differences between springs and the food resources they support may help explain the spatial distribution patterns of waterfowl at Mono Lake. The results of this study will be evaluated, and further recommendations made.

13) **Develop techniques to improve the documentation of annual changes in shoreline habitats.** Annual monitoring of shoreline habitat is still recommended, however methods of documenting the conditions should be improved. The current method of taking photographs annually from a helicopter provides only a qualitative visual assessment of the response of important waterbird habitat features to lake elevation changes. In order to focus on changes to important habitat features, an improved method of documenting the availability of shoreline ponds that is both feasible and efficient should be developed. One method that could be explored involves the use of an unmanned aerial vehicle to conduct the annual photography of shoreline habitats. The use of a UAV would likely

improve the quality and usefulness of the images obtained by being able to more precisely control the location, angle, elevation and height above ground from which the images are taken. This monitoring could focus on specific areas which are of interest due to waterfowl use or the anticipated changes in shoreline habitat.

14) **Explore the option of conducting waterfowl counts using an unmanned aerial vehicle**. The reliability of results from aerial surveys of waterfowl depends on the experience and training of the observer, lighting conditions, and detectability of the species present. Aerial surveys of Mono Lake also require a highly trained pilot with experience in low level, low speed, high altitude flying, which comes with inherent risk. Use of a UAV may allow improved documentation of fall waterfowl surveys, and some studies indicate that the accuracy of counts may be improved.

15) **Consider repairs or upgrades to the infrastructure of the Restoration Ponds for the purpose of waterfowl habitat improvement in the Mono Basin.** Currently, the infrastructure of the ponds is in a state of disrepair. Only a portion of the $275,000 originally earmarked for waterfowl restoration projects in the Mono Basin has been used as the other potential waterfowl habitat improvement projects including prescribed fire and the development of scrapes were determined by the Parties to be either not feasible, impractical, or insufficient benefit to justify. Habitat at the ponds might be enhanced by rotational or seasonal flooding of ponds as opposed to permanent inundation of just a few ponds.

16) **Improve the sharing of information between LADWP and California State Parks regarding tamarisk locations and treatment efforts so that efforts are not duplicated.** Although an interagency program has not been established to control saltcedar or other non-native vegetation, LADWP has been opportunistically treating salt cedar along the creeks and California State Parks is also conducting surveillance and treatment. The sharing of information between agencies would assist in assessing the progress toward eradication efforts.

17) **Reevaluate the Mono Basin Waterfowl Habitat Restoration Monitoring Program in another five years.**

Table 99. Summary of the Current and Recommended Changes to the Waterfowl Habitat Monitoring Program

Mono Basin Habitat Restoration Monitoring Program; Current Program and Recommended Changes			
Monitoring Component/ Recommended Measure	**Description**	**Required Frequency per Order 98-05 and 1996 Plan**	**Recommendation per 2018 Mono Basin Waterfowl Periodic Overview Report**
Hydrology	Lake Elevation	Weekly through one complete wet/dry cycle after the lake level has stabilized.	No change
	Stream Flows	Daily through one complete wet/dry cycle after the lake level has stabilized.	No change
	Spring Surveys	5-year intervals (August) through one complete wet/dry cycle after the lake level has stabilized.	No change; continue to monitor at 5-year intervals
Lake Limnology and Secondary Producers	Meteorological data, data on physical and chemical environment of the lake, phytoplankton, and brine shrimp population levels.	Annually (monthly February-December) until the lake reaches a relatively stable level. LADWP will evaluate monitoring at that time and make a recommendation to the SWRCB whether or not to continue. • Conductivity and water temperature profiles at 9 stations February-December • 9-m integrated sampling for ammonium and chlorophyll at 7 stations February-December • DO, Ammonium, Chlorophyll *a* depth profile at Station 6 February-December • *Artemia* population sampling at 12 stations February-December • *Artemia* fecundity at seven stations	Continue annual monitoring with temporal and spatial reductions. • Conductivity and water temperature profiles, and Secchi depths at Stations 4, 6, 9 and 10 in February and April-November • 9-m integrated sampling for ammonium and chlorophyll a Stations 4, 6, 9, 10 April-November • DO, Ammonium, Chlorophyll *a* depth profile Station 6 April-November • *Artemia* population sampling at Stations 4, 6, 9, and 10 April-November • *Artemia* fecundity at Stations 4, 6, 9, and 10 June-October; collect 20 samples at each of the four stations • Discontinue instar analysis

Table 99. Cont. Summary of the Current and Recommended Changes to the Waterfowl Habitat Monitoring Program

Mono Basin Habitat Restoration Monitoring Program; Current Program and Recommended Changes			
Monitoring Component/ Recommended Measure	**Description**	**Required Frequency per Order 98-05 and 1996 Plan**	**Recommendation per 2018 Mono Basin Waterfowl Periodic Overview Report**
Vegetation Status in Riparian and Lake Fringing Wetland Habitats	Establishment and monitoring of vegetation transects and permanent photopoints in lake fringing wetlands	Five-year intervals or after extremely wet year events (whichever comes first) until 2014. LADWP will evaluate the need to continue this program in 2014 and present findings to SWRCB.	Suspend the vegetation transect monitoring at this time. Once the target lake elevation is reached, conduct a final year of vegetation transect monitoring.
	Aerial photographs of lake-fringing wetlands and Mono Lake tributaries	Five-year intervals until target lake elevation of 6,392 feet is achieved.	Continue at five-year intervals; conduct ground-truthing to ensure proper classification of shore-fringing water features coincident with this mapping.
Waterfowl Population Surveys and Studies	Fall aerial counts	Two counts conducted every other year October 15- November 15. All waterfowl population survey work will continue through one complete wet/dry cycle after the target lake elevation of 6,392 feet is achieved. From 2002-2017, six aerial counts have been conducted at Mono Lake, Bridgeport Reservoir, and Crowley Reservoir	Conduct six aerial counts at two-week intervals once every five years at Mono Lake, as was conducted from 2002-2017, until the lake reaches the target elevation of 6,392 feet and goes through one complete wet/dry cycle. In intervening years, conduct four fall grounds counts two-week intervals at Mill Creek, Wilson Creek and Simons Spring, starting the first week of September. Reduce frequency of fall comparison counts at Bridgeport and Crowley Reservoirs to every five yrs. Explore the use of an unmanned aerial vehicle (UAV) in conducting future waterfowl counts at Mono Lake.
	Aerial photography of waterfowl habitats	Conducted during or following one fall aerial count. All waterfowl population survey work will continue through one complete wet/dry cycle after the target lake elevation of 6,392 feet is achieved.	Explore the use of an unmanned aerial vehicle (UAV) or other techniques for this annual monitoring activity.

Mono Basin Habitat Restoration Monitoring Program; Current Program and Recommended Changes			
Monitoring Component/ Recommended Measure	**Description**	**Required Frequency per Order 98-05 and 1996 Plan**	**Recommendation per 2018 Mono Basin Waterfowl Periodic Overview Report**
Waterfowl Population Surveys and Studies, continued	Ground counts	Total of eight ground counts annually (two in summer, six in fall). All waterfowl population survey work will continue through one complete wet/dry cycle after the target lake elevation of 6,392 feet is achieved. From 2002-2017, three summer ground counts were conducted; fall counts were done via aerial surveys	Reduce the number of summer counts per year to one (conduct survey, (3) only). Upon reaching target elevation, conduct all three surveys to document population at 6,392 feet. Four fall ground counts will be conducted, replacing the aerial counts.
	Waterfowl time activity budget study	To be conducted during each of the first two fall migration periods after restoration plans are approved, and then again when the lake is at or near the target elevation.	A time budget study was completed in fall 2000 on Ruddy Ducks. It is recommended that LADWP complete the second time budget study focusing on shoreline use by waterfowl.

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8.0 APPENDICES

Appendix 1. Waterfowl Food Plants Species Found on Mono Lake Wetland and Riparian Transects

Family	**Scientific Name**	**Common name**
Capparaceae	*Cleomella plocasperma*	twisted cleomella
Chenopodaceae	*Chenopodaceae*	goosefoot family
	Chenopodium album	lambsquarter
Cyperaceae	*Bolboschoenus maritimus*	cosmopolitan bulrush
	Carex aquatilis	water sedge
	Carex douglasii	Douglas' sedge
	Carex nebrascensis	Nebraska sedge
	Carex praegracilis	clustered field sedge
	Carex rostrata	beaked sedge
	Carex spp.	sedge species
	Carex utriculata	Northwest Territory sedge
	Cyperus sp.	flatsedge
	Eleocharis macrostachya	pale spikerush
	Eleocharis sp.	spikerush species
	Schoenoplectus acutus	hardstem bulrush
	Schoenoplectus americanus	chairmaker's bulrush
	Scirpus microcarpus	panicled bulrush
	Scirpus nevadensis	Nevada bulrush
Equisetaceae	*Equisetum arvense*	field horsetail
Fabaceae	*Trifolium longipes*	longstalk clover
	Trifolium sp.	clover species
Juncaginaceae	*Triglochin concinna*	slender arrowgrass
	Triglochin maritima	seaside arrowgrass
Poaceae	*Distichlis spicata*	salt grass
	Hordeum jubatum	foxtail barley
Polygonaceae	*Rumex crispus*	curly dock
	Rumex salicifolius	willow dock

APPENDIX 2. BLACK POINT SUBAREA

AERIAL PHOTOS, 2002-2017

Black Point

2002

2003

Photo not available

2004

Photo not available

2005

Black Point

2006

2007

2008

Photo not available

2009

Black Point

2010

2011

2012

2013

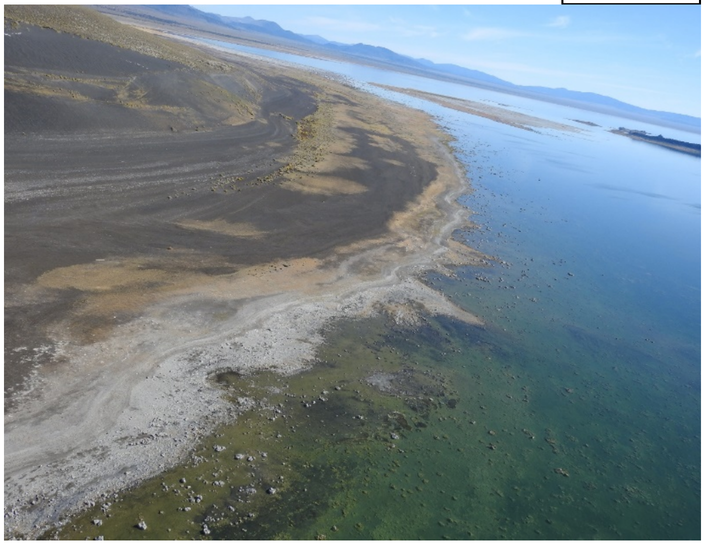
Black Point

2014

2015

2016

2017



APPENDIX 3. BRIDGEPORT CREEK SUBAREA

AERIAL PHOTOS, 2002-2017

Bridgeport Creek

2002

2003

2004

2005

Bridgeport Creek

2006

2007

2008

2009

Bridgeport Creek

2010

2011

2012

2013

Bridgeport Creek

2014

2015

2016

2017

APPENDIX 4. DECHAMBEAU CREEK SUBAREA

AERIAL PHOTOS, 2002-2017

DeChambeau Creek

2002

2003

2004

2005

DeChambeau Creek

2006

2007

2008

2009

DeChambeau Creek

2010

2011

2012

2013

DeChambeau Creek

2014

2015

2016

2017

APPENDIX 5. DECHAMBEAU EMBAYMENT SUBAREA

AERIAL PHOTOS, 2002-2017

DeChambeau Embayment

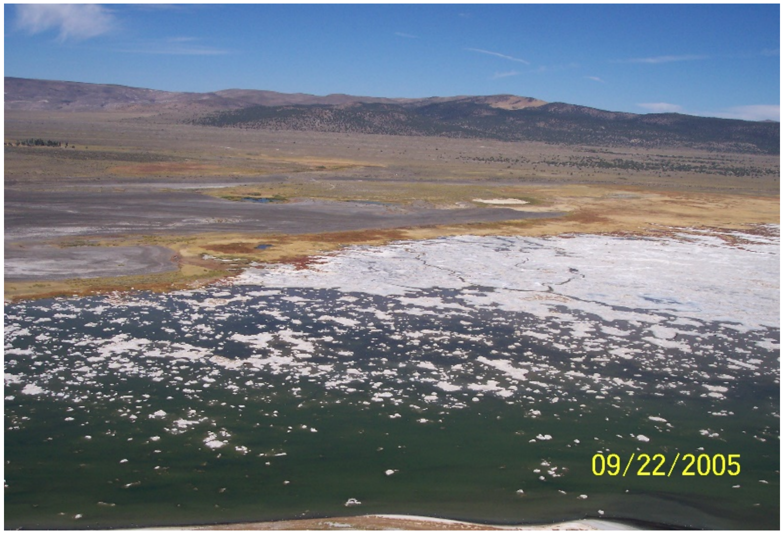
2002

2003

Photo not available

2004

2005



DeChambeau Embayment

2006

2007

2008

2009

DeChambeau Embayment

2010

2011

2012

2013

DeChambeau Embayment

2014

2015

2016

2017

APPENDIX 6. LEE VINING CREEK SUBAREA

AERIAL PHOTOS, 2002-2017

Lee Vining Creek

2002

2003

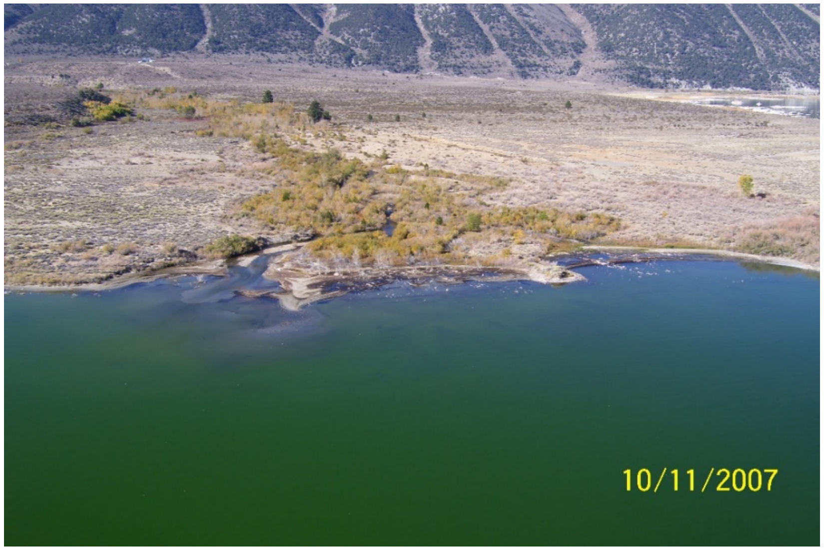
2004

2005

Lee Vining Creek

2006

2007



2008

2009

Lee Vining Creek

2010

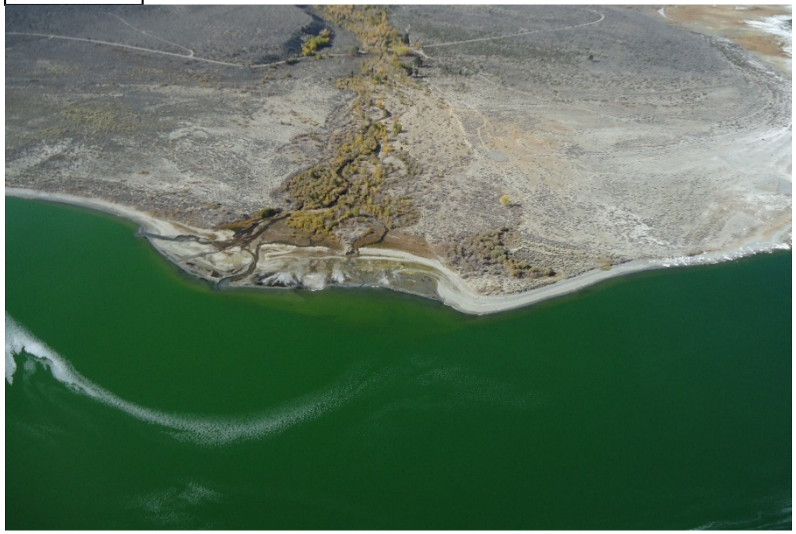
2011

2012

2013

Lee Vining Creek

2014



2015

2016

2017

APPENDIX 7. MILL CREEK SUBAREA

AERIAL PHOTOS, 2002-2017

Mill Creek

2002

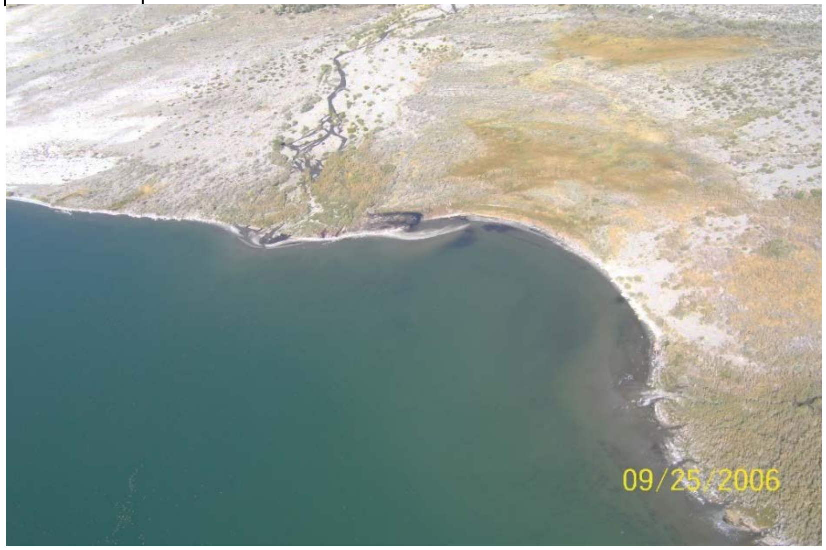
2003

2004

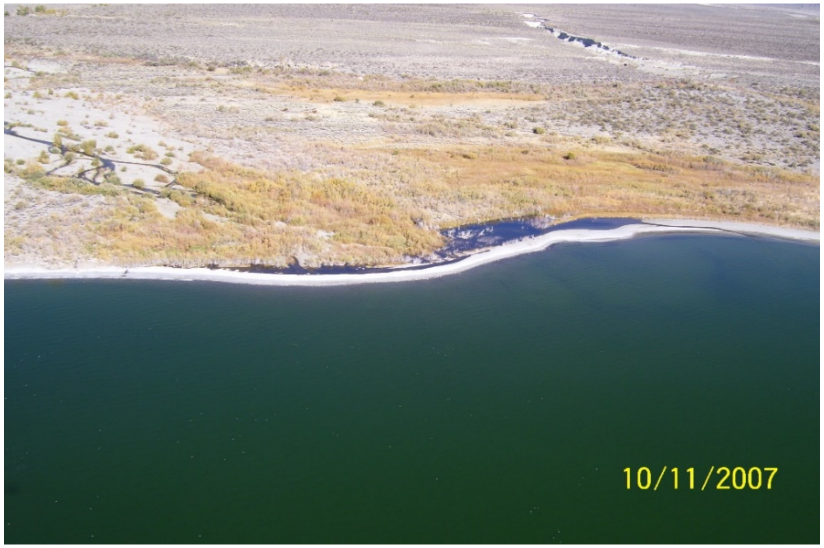
2005

Mill Creek

2006



2007



2008

2009

Mill Creek

2010

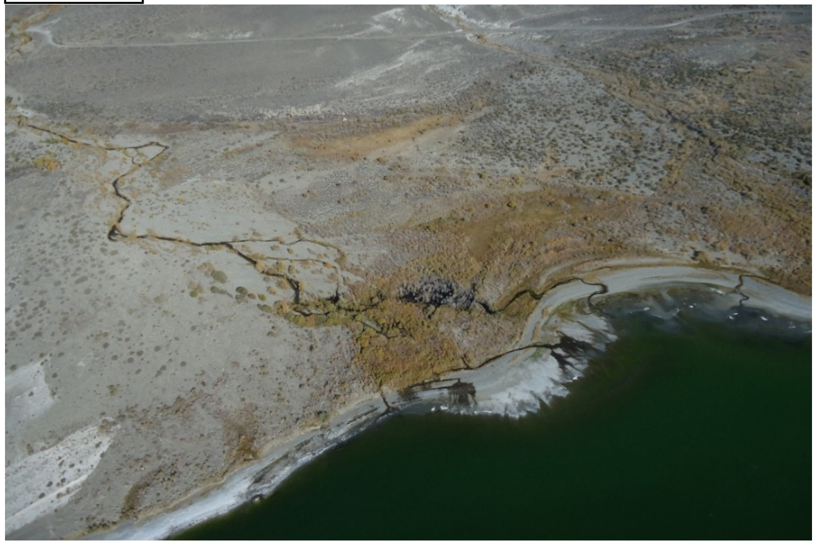
2011

2012

2013

Mill Creek

2014



2015

2016

2017

APPENDIX 8. NORTHEAST SHORE SUBAREA

AERIAL PHOTOS, 2002-2017

Northeast Shore

2002

2003

Photo not available

2004

Photo not available

2005

Northeast Shore

2006

2007

2008

2009

Northeast Shore

2010

2011

2012

2013

Northeast Shore

2014

2015

2016

2017

APPENDIX 9. RANCH COVE SUBAREA

AERIAL PHOTOS, 2002-2017

Ranch Cove

2002

2003

Photo not available

2004

Photo not available

2005

Ranch Cove

2006

2007

2008

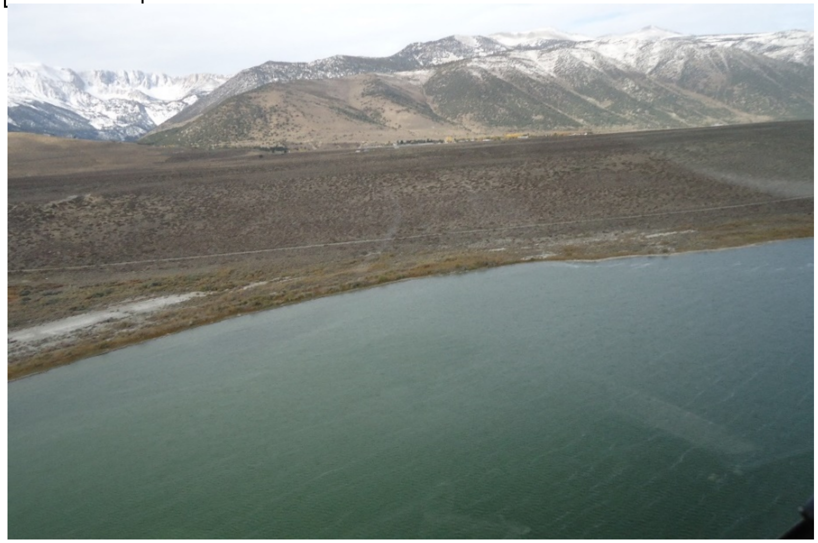
2009

Ranch Cove

2010

2011

2012



2013

Ranch Cove

2014

2015

2016

2017

APPENDIX 10. RUSH CREEK SUBAREA

AERIAL PHOTOS, 2002-2017

Rush Creek

2002

2003

2004

2005

Rush Creek

2006

2007

2008

2009

Rush Creek

2010

2011

2012

2013

Rush Creek

2014

2015

2016

2017

APPENDIX 11. SIMONS SPRING SUBAREA (WEST)

AERIAL PHOTOS, 2002-2017

Simons Spring West

2002

2003

2004

2005

Simons Spring West

2006

2007

2008

2009

Simons Spring West

2010

2011

2012

2013

Simons Spring West

2014

2015

2016

2017

APPENDIX 12. SIMONS SPRING SUBAREA (EAST)

AERIAL PHOTOS, 2002-2017

Simons Spring East of Faultline

2002

Photo not available

2003

Photo not available

2004

2005

Simons Spring East of Faultline

2006

2007

2008

2009

Simons Spring East of Faultline

2010

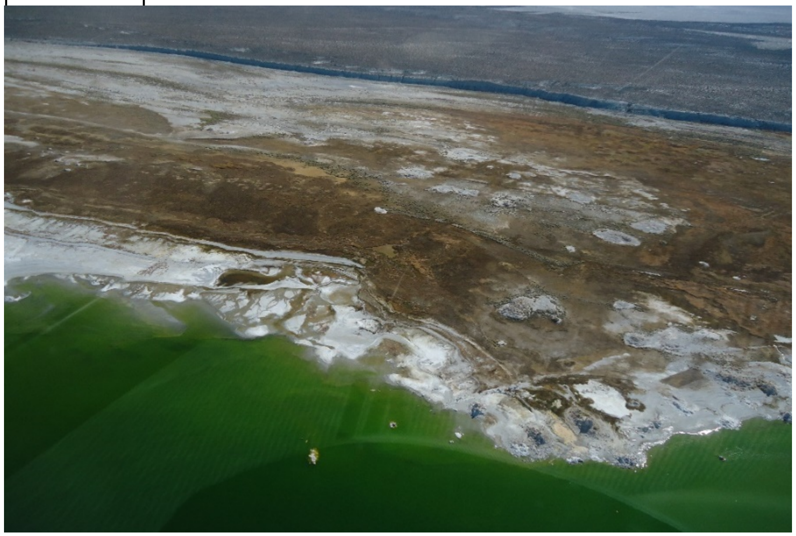
2011

2012

2013

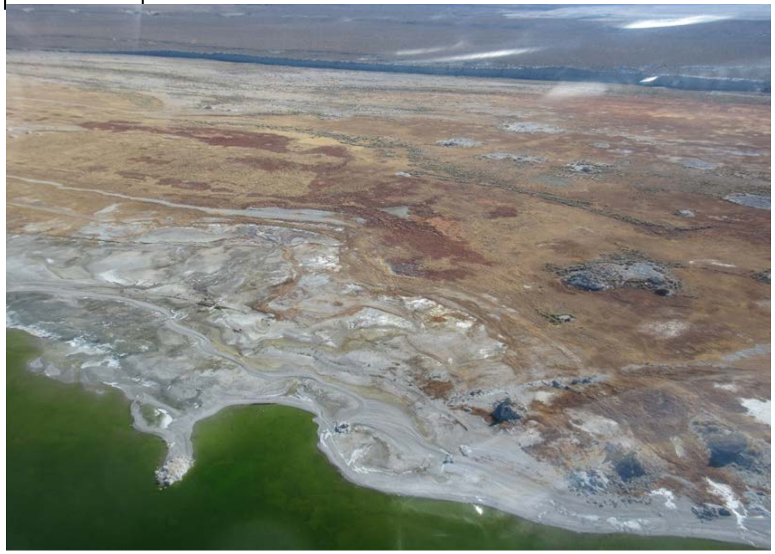
Simons Spring East of Faultline

2014



2015

2016



2017

APPENDIX 13. SOUTH SHORE LAGOONS SUBAREA

(FIRST POND)

AERIAL PHOTOS, 2002-2017

South Shore Lagoons – First Pond

2002

2003

2004

2005

South Shore Lagoons – First Pond

2006

2007

2008

2009

South Shore Lagoons – First Pond

2010

2011

2012

2013

South Shore Lagoons – First Pond

2014

2015

2016

2017

APPENDIX 14. SOUTH SHORE LAGOONS SUBAREA

(GOOSE SPRINGS)

AERIAL PHOTOS, 2002-2017

South Shore Lagoons – Goose Springs

2002

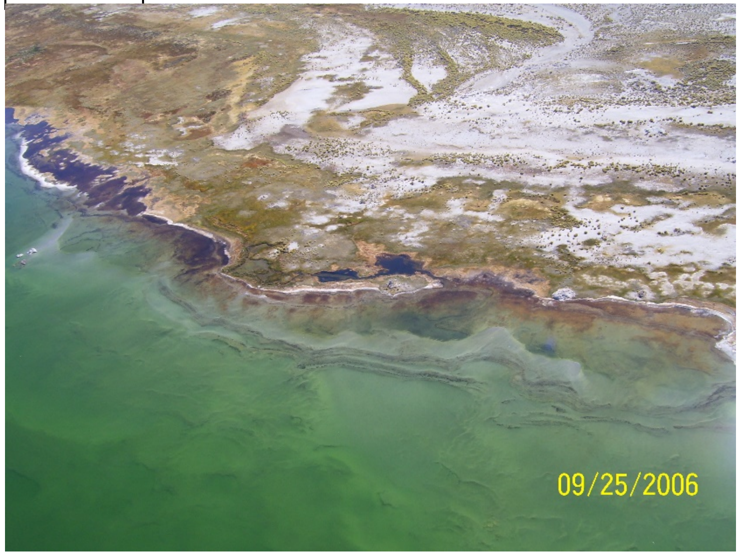
2003

2004

2005

South Shore Lagoons – Goose Springs

2006



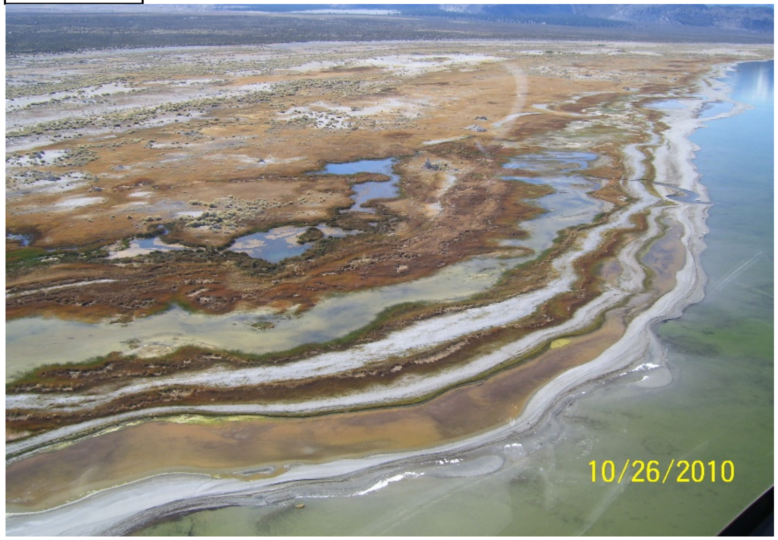
2007

2008

2009

South Shore Lagoons – Goose Springs

2010



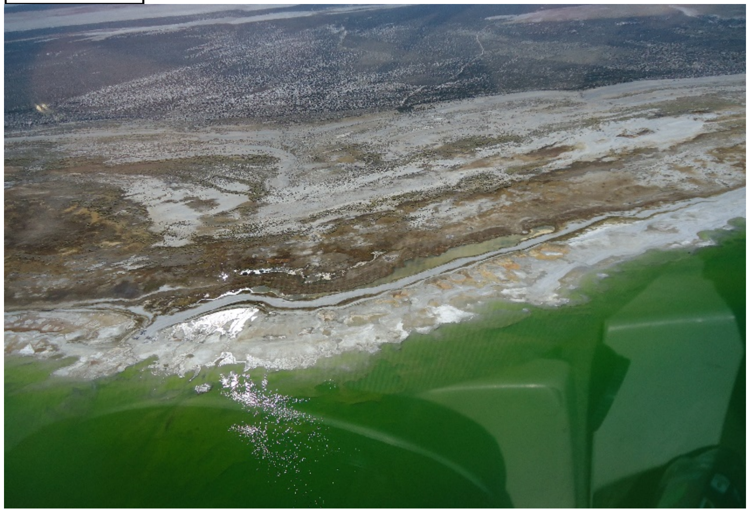
2011

2012

2013

South Shore Lagoons – Goose Springs

2014



2015

2016

2017

APPENDIX 15. SOUTH TUFA SUBAREA
AERIAL PHOTOS, 2002-2017

South Tufa

2002

2003

Photo not available

2004

Photo not available

2005

South Tufa

2006

2007

2008

2009

South Tufa

2010

2011

2012

2013

South Tufa

2014

2015

2016

2017

APPENDIX 16. WARM SPRINGS SUBAREA

AERIAL PHOTOS, 2002-2017

Warm Springs

2002

2003

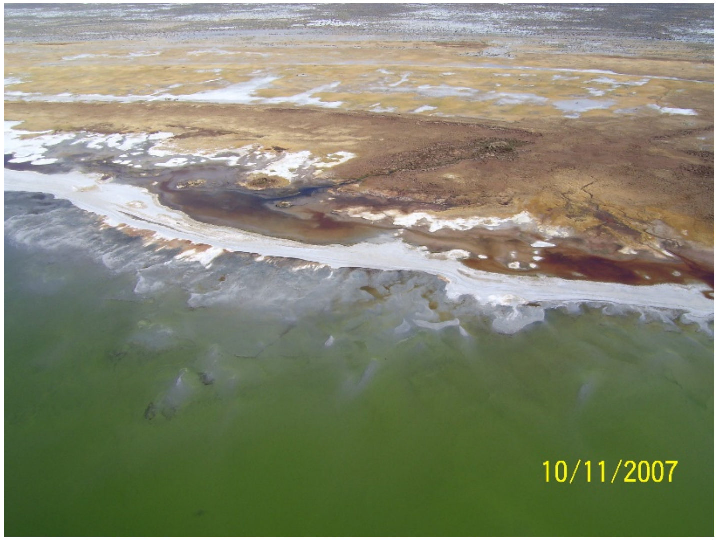
2004

2005

Warm Springs

2006

2007



2008

2009

Warm Springs

2010

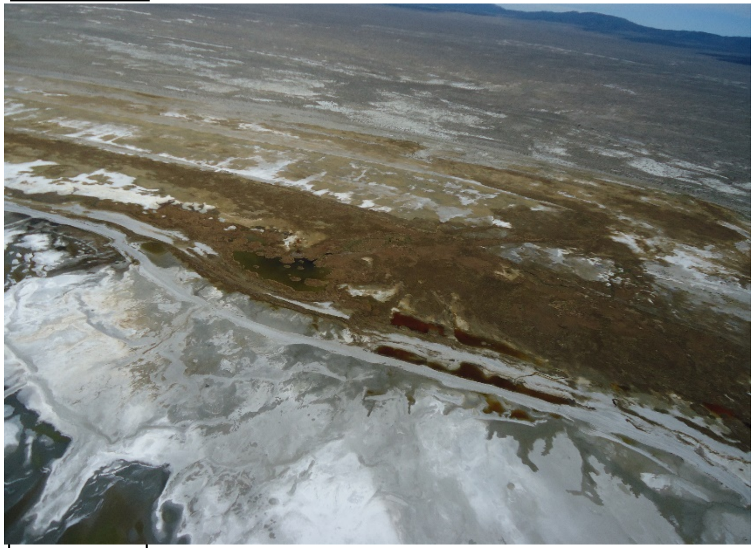
2011

2012

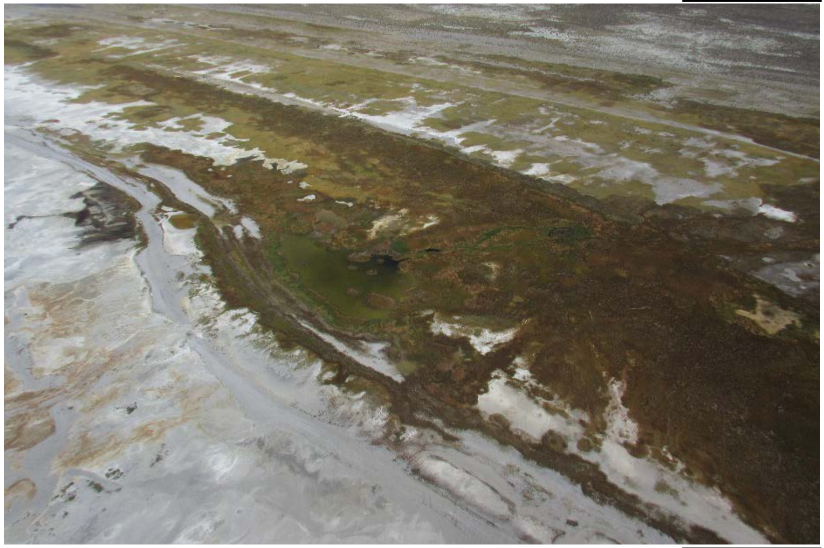
2013

Warm Springs

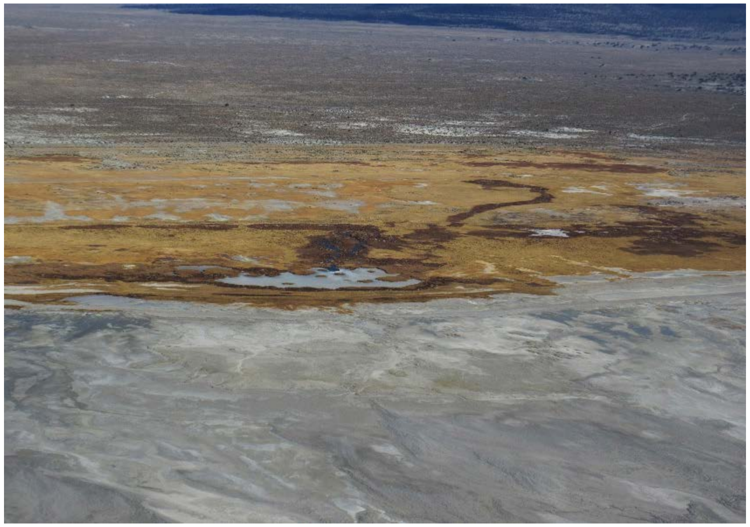
2014



2015



2016



2017

APPENDIX 17. WEST SHORE SUBAREA

AERIAL PHOTOS, 2002-2017

West Shore

2002

Photo not available

2003

Photo not available

2004

2005

Photo not available

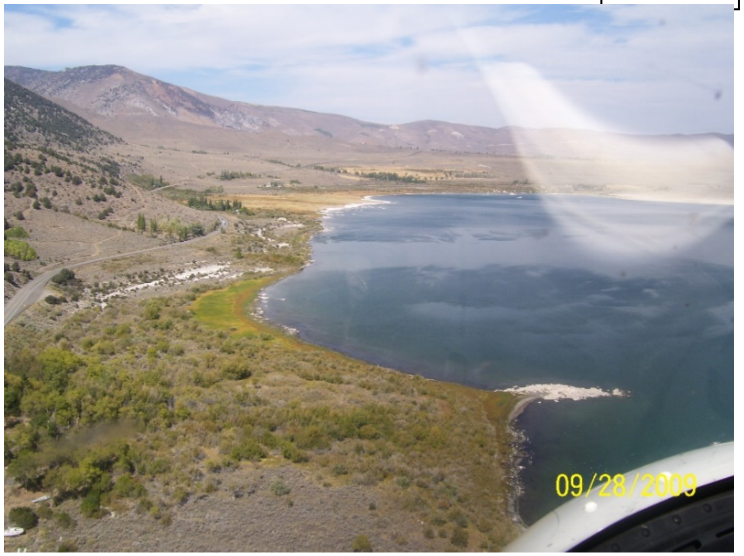
West Shore

2006

2007

2008

2009



West Shore

2010

2011

2012

2013

West Shore

2014

2015

2016

2017

APPENDIX 18. WILSON CREEK SUBAREA

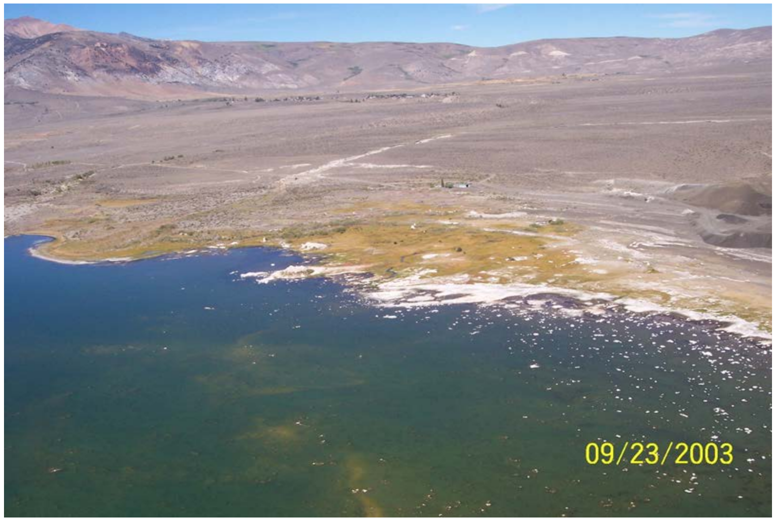
AERIAL PHOTOS, 2002-2017

Wilson Creek

2002

2003

2004



2005

Wilson Creek

2006

2007

2008

2009

Wilson Creek

2010

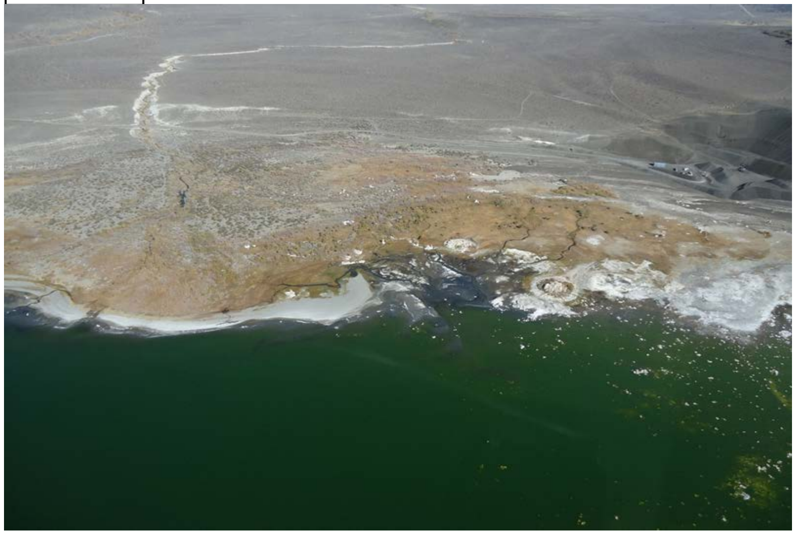
2011

2012

2013

Wilson Creek

2014



2015

2016

2017

Appendix 19. Summer Waterfowl Ground Survey Dates

Year	Survey 1	Survey 2	Survey 3
2002	June 5-7	July 1-3	July 22-24
2003	June 9-11	June 30-July 2	July 21-23
2004	June 7-9	June 28-30	July 19-21
2005	June 6-8	June 27-29	July 18-20
2006	June 5-7	June 26-28	July 17-20
2007	June 4-7	June 25-29	July 16-19
2008	June 9-11	July 1-3	July 21-23
2009	June 9-11	June 29-July 2	July 20-23
2010	June 8-10	June 27-July 1	July 19-21
2011	June 6-8	July 1-3	July 22-24
2012	June 4-7	June 27-29	July 17-23
2013	June 3-6	June 24-27	July 15-18
2014	June 2-4	June 23-26	July 14-17
2015	June 8-11	June 29-July 2	July 20-24
2016	June 6-9	June 27-30	July 18-21
2017	June 6-9	June 27-30	July 18-21

Appendix 20. Fall Waterfowl Aerial Survey Dates

Year	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5	Survey 6
2002	5-Sep	19-Sep	3-Oct	17-Oct	31-Oct	14-Nov
2003	4-Sep	18-Sep	2-Oct	14-Oct	4-Nov	14-Nov
2004	7-Sep	16-Sep	30-Sep	12-Oct	28-Oct	10-Nov
2005	1-Sep	16-Sep	27-Sep	13-Oct	27-Oct	9-Nov
2006	6-Sep	21-Sep	3-Oct	17-Oct	31-Oct	15-Nov
2007	6-Sep	18-Sep	2-Oct	23-Oct	30-Oct	13-Nov
2008	4-Sep	18-Sep	1-Oct	15-Oct	29-Oct	17-Nov
2009	3-Sep	17-Sep	1-Oct	15-Oct	2-Nov	16-Nov
2010	1-Sep	16-Sep	29-Sep	14-Oct	27-Oct	16-Nov
2011	1-Sep	14-Sep	28-Sep	11-Oct	25-Oct	9-Nov
2012	4-Sep	18-Sep	2-Oct	16-Oct	29-Oct	13-Nov
2013	3-Sep	19-Sep	1-Oct	15-Oct	29-Oct	12-Nov
2014	3-Sep	16-Sep	1-Oct	16-Oct	29-Oct	12-Nov
2015	2-Sep	17-Sep	2-Oct	13-Oct	30-Oct	12-Nov
2016	6-Sep	23-Sep	6-Oct	19-Oct	1-Nov	10-Nov
2017	1-Sep	13-Sep	28-Sep	12-Oct	27-Oct	7-Nov

Appendix 21. Start and End Points for Mono Lake Shoreline Subareas (UTM NAD 83)

Shoreline Subarea	**Code**	**Easting**	**Northing**
South Tufa	SOTU	321827	4201363
South Shore Lagoons	SSLA	324470	4201876
Simons Spring	SASP	328552	4204369
Warm Springs	WASP	332240	4208707
Northeast Shore	NESH	330050	4213640
Bridgeport Creek	BRCR	324787	4216042
DeChambeau Embayment	DEEM	321835	4215037
Black Point	BLPO	318172	4211968
Wilson Creek	WICR	315378	4209451
Mill Creek	MICR	313690	4209742
DeChambeau Creek	DECR	312630	4209468
West Shore	WESH	311454	4208509
Lee Vining Creek	LVCR	314833	4205764
Ranch Cove	RACO	316216	4204134
Rush Creek	RUCR	318624	4202827

Appendix 22. Start and End Points for Mono Lake Cross-Lake Transects (UTM NAD 83)

Transect	Start		End	
	Easting	Northing	Easting	Northing
1a	320401	4202229	322879	4202184
1b	322879	4202184	325358	4202139
2a	316184	4204211	320233	4204118
2b	320233	4204118	324282	4204024
2c	324282	4204024	328332	4203930
3a	312190	4206140	316767	4206031
3b	316767	4206031	321344	4205923
3c	321344	4205923	325920	4205815
3d	325920	4205815	330497	4205706
4a	311591	4208046	316724	4207917
4b	316724	4207917	321856	4207788
4c	321856	4207788	326989	4207659
4d	326989	4207659	332122	4207530
5a	316319	4209745	320432	4209656
5b	320432	4209656	324545	4209567
5c	324545	4209567	328658	4209478
5d	328658	4209478	332771	4209389
6a	317962	4211556	322768	4211446
6b	322768	4211446	327572	4211335
6c	327572	4211335	332378	4211225
7a	318074	4213434	322406	4213341
7b	322406	4213341	326738	4213248
7c	326738	4213248	331071	4213155
8a	321576	4215185	324994	4215107
8b	324994	4215107	328412	4215029

Appendix 23. Waterfowl Species List

English Name	Scientific Name
Snow Goose	*Anser caerulescens*
Ross's Goose	*Anser rossii*
Greater White-fronted Goose	*Anser albifrons*
Brant	*Branta bernicla*
Cackling Goose	*Branta hutchinsii*
Canada Goose	*Branta canadensis*
Tundra Swan	*Cygnus columbianus*
Wood Duck	*Aix sponsa*
Blue-winged Teal	*Spatula discors*
Cinnamon Teal	*Spatula cyanoptera*
Northern Shoveler	*Spatula clypeata*
Gadwall	*Mareca strepera*
American Wigeon	*Mareca americana*
Mallard	*Anas platyrhynchos*
Northern Pintail	*Anas acuta*
Green-winged Teal	*Anas crecca*
Unidentified Teal	*Anas (sp)*
Canvasback	*Aythya valisineria*
Redhead	*Aythya americana*
Ring-necked Duck	*Aythya collaris*
Lesser Scaup	*Aythya affinis*
Surf Scoter	*Melanitta perspicillata*
White-winged Scoter	*Melanitta fusca*
Bufflehead	*Bucephala albeola*
Common Goldeneye	*Bucephala clangula*
Hooded Merganser	*Lophodytes cucullatus*
Common Merganser	*Mergus merganser*
Red-breasted Merganser	*Mergus serrator*
Ruddy Duck	*Oxyura jamaicensis*
Unidentified Diving Duck	*Anatinae* (gen, sp)

APPENDIX 24. BRIDGEPORT RESERVOIR

AERIAL PHOTOS, 2002-2017

Bridgeport Reservoir

2002

Photo not available

2003

Photo not available

2004

2005

Bridgeport Reservoir

2006

2007

2008

2009

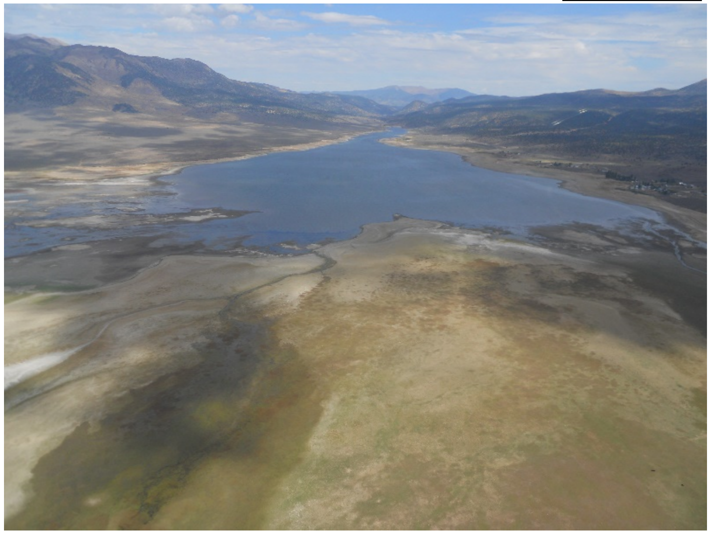
Bridgeport Reservoir

2010

2011

2012

2013



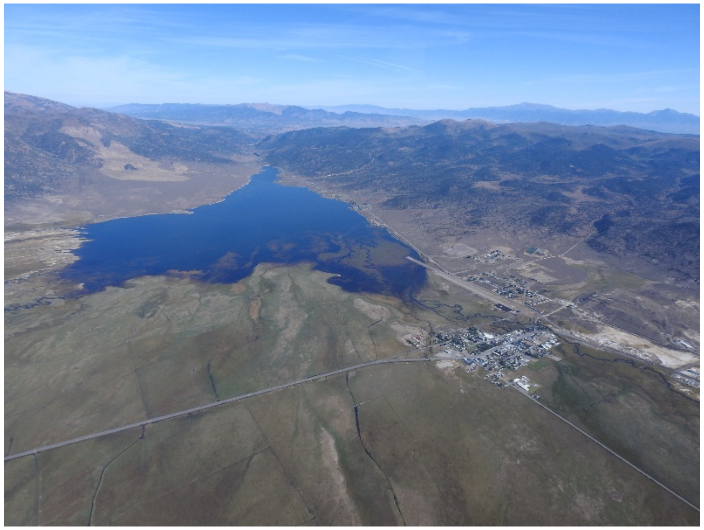
Bridgeport Creek

2014

2015

2016

2017



APPENDIX 25. CHALK CLIFFS SUBAREA

AERIAL PHOTOS, 2002-2017

Chalk Cliffs

2002

Photo not available

2003

Photo not available

2004

2005

Chalk Cliffs

2006

2007

2008

2009

Chalk Cliffs

2010

2011

2012

2013

Chalk Cliffs

2014

2015

2016

2017

APPENDIX 26. HILTON BAY SUBAREA

AERIAL PHOTOS, 2002-2017

Hilton Bay

2002

Photo not available

2003

Photo not available

2004

2005

Hilton Bay

2006

2007

2008

2009

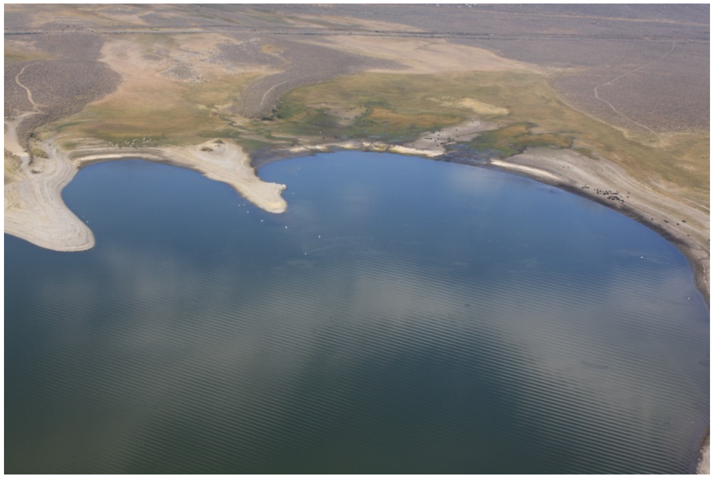
Hilton Bay

2010

2011

2012

2013



Hilton Bay

2014

2015

2016

2017

Photo not available

APPENDIX 27. LAYTON SPRINGS SUBAREA

AERIAL PHOTOS, 2002-2017

Layton Springs

2002

Photo not available

2003

2004

2005

Layton Springs

2006

2007

2008

2009

Layton Springs

2010

Photo not available

2011

2012

2013

Layton Springs

2014

2015

2016

2017

APPENDIX 28. McGee Bay SUBAREA

AERIAL PHOTOS, 2002-2017

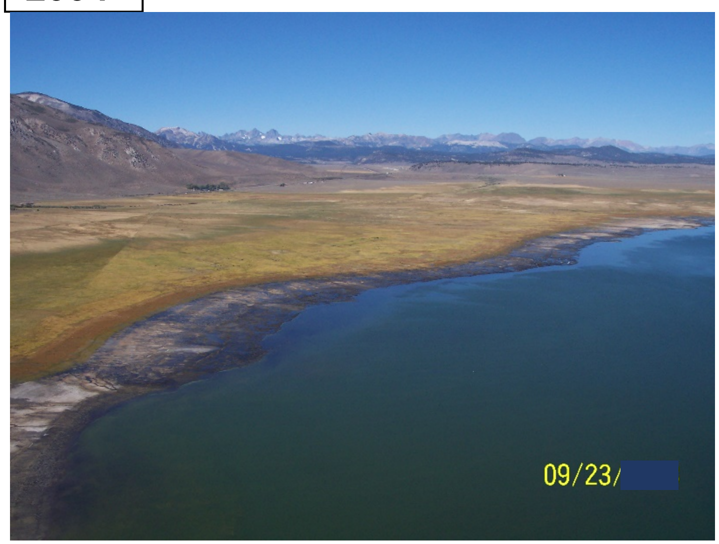
McGee Bay

2002

Photo not available

2003

2004



2005

McGee Bay

2006

2007

2008

2009

McGee Bay

2010

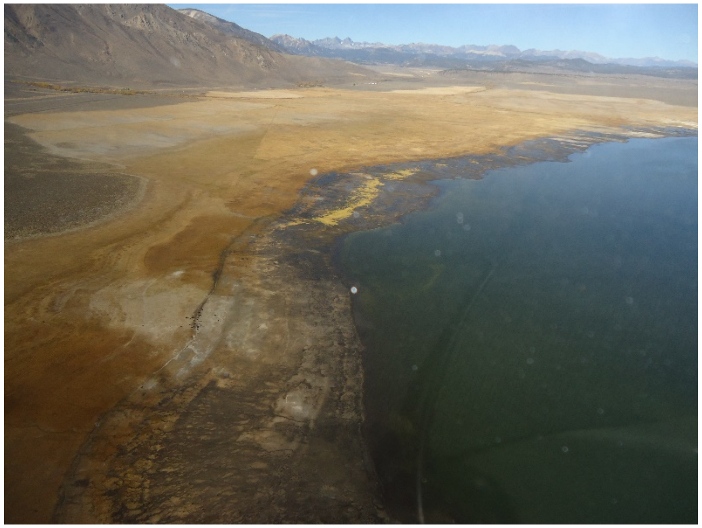
2011

2012

2013

McGee Bay

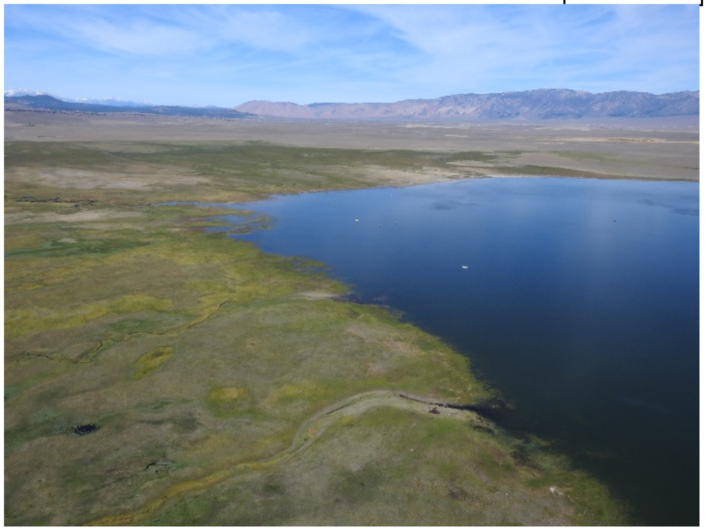
2014



2015

2016

2017



APPENDIX 29. NORTH LANDING SUBAREA

AERIAL PHOTOS, 2002-2017

North Landing

2002

Photo not available

2003

Photo not available

2004

Photo not available

2005

Photo not available

North Landing

2006

2007

2008

Photo not available

2009

North Landing

2010

Photo not available

2011

2012

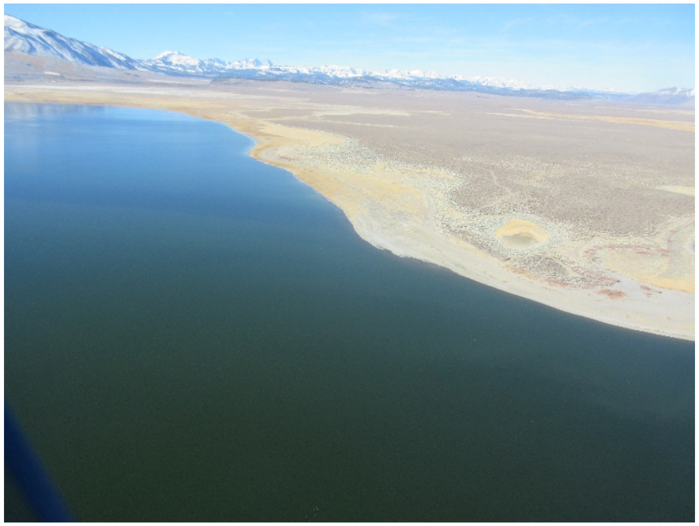
2013

North Landing

2014

2015

2016



2017

APPENDIX 30. SANDY POINT SUBAREA

AERIAL PHOTOS, 2002-2017

Sandy Point

2002

Photo not available

2003

Photo not available

2004

Photo not available

2005

Sandy Point

2006

2007

2008

2009

Sandy Point

2010

2011

2012

2013

Sandy Point

2014

2015

2016

2017

APPENDIX 31. UPPER OWENS SUBAREA

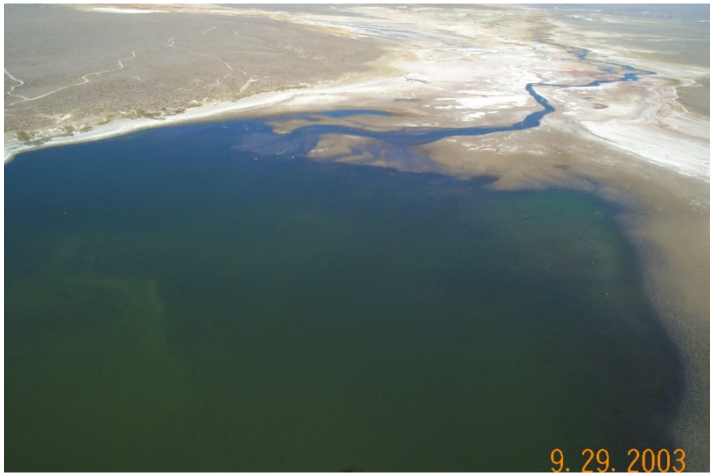
AERIAL PHOTOS, 2002-2017

Upper Owens

2002

Photo not available

2003



2004

2005

Upper Owens

2006

2007

2008

2009

Upper Owens

2010

2011

2012

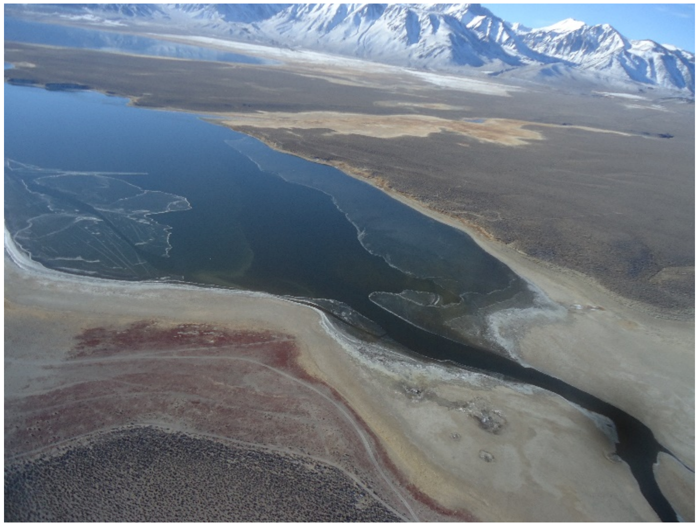
2013

Upper Owens

2014

2015

2016



2017