Appendix D- Interactive Reach Prioritization Tool Methods Development

Interactive Reach Prioritization Tool Methods Development

Overview

This document outlines the GIS geoprocessing steps used to generate the stream and shoreline reach-scale impairment metrics (and supporting information) used within the Interactive Reach Prioritization Tool described in Chapter 4 of the Upper Klamath Basin Watershed Action Plan (UKBWAP). The intent of this document is to enable replication of the methods applied by GIS specialists and is written for a technical audience. Users interested in the general analytical approach and rationale behind the impairment metrics are encouraged to consult the UKBWAP.

The first section of this document describes analyses conducted by Trout Unlimited (TU) GIS staff in 2020 to update or generate new impairment metrics and supporting information for the UKBWAP. In many cases, those metrics rely on data generated for earlier versions of the UKBWAP by FlowWest staff in 2017. FlowWest methods are provided in Attachment A, in the second portion of this document.

2020 Impairment Metrics Methods

Trout Unlimited GIS staff developed stream and shoreline impairment metrics using a mix of FlowWest data from 2017, expert opinion, and new analyses. GIS methods for calculating the metrics are described below. Unless otherwise noted, TU used ArcGIS Pro software (version 2.6; ESRI, Redlands, California) to conduct the analyses and created Toolbox Models to facilitate repetition and update of the methods. A file geodatabase containing those Models is available for download here.

Channelization

TU used a shapefile representing known channel alignment modifications provided by FlowWest to generate the channelization metric. In late 2021, TU updated the Channelization metric in Brown Creek and Paradise Creek by digitizing channelized reaches from available 1956 aerial imagery. TU used the following general geoprocessing steps.

1. Buffer stream reaches by 100 meters on each side.
2. Sum the lengths of channel alignment modification features for each buffered reach in meters.
3. Divide the total length of alignment modifications by the total length of each reach.
4. Attribute reaches with this information.

These steps are additionally documented in the Toolbox Model “channelization”.

Channel Incision

TU used ArcGIS Pro and Lidar data to generate the channel incision metrics. TU used the following general geoprocessing steps.

1. Download individual Lidar datasets from State of Oregon Department of Geology and Mineral Industries Lidar viewer.
2. Import the individual datasets into a raster mosaic for 3 portions of the UKBWAP assessment area (Wood, Sycan, and Sprague rivers). Three separate datasets are required to accommodate the file size of the Lidar data and differences in acquisition characteristics, such as timing and horizontal/vertical value units (foot vs. meter). In late 2021, TU updated the Channel Incision metric and created a new mosaic for areas in the Upper Sprague and adjacent to Upper Klamath Lake where Lidar data was newly available.
3. Use the raster mosaic to generate a slope raster (percent rise).
4. Identify those portions of the slope raster with values greater than 35%, convert to polygons representing high slope areas, and calculate area of the polygons.
5. Select those high slope polygons with an area greater than 400 square meters and extract the elevational range within those polygons (i.e., the incision depth, or the maximum elevation minus minimum elevation) from the Lidar data.
6. Calculate the area within a variable width buffer of each stream reach that overlaps with a high slope polygon and the average incision depth within the portions of the high slope polygons that overlap the stream buffer. A standard 25 meter buffer was applied to all reaches except higher order portions of the Williamson, Sprague, and Wood rivers, where 50 meter buffers were applied (Fourmilecanal segments 3 - 6; sevenmilecanal segment 3; Sprague segments 33 - 78; sycan segments 3 - 6; Williamson segments 21 - 24) or 75 meter buffers were applied (Sprague segments 3 - 30; Williamson segments 3 – 18; Williamsonsidechannel segment 3).
7. Attribute reaches with this information.

These steps are additionally documented in the Toolbox Models "Area_incised_Sprague_Lidar_in_meters", Area_incised_Sycan_Lidar_in_feet", and Area_incised_Wood_Lidar_in_feet".

Levees and Berms

TU used a shapefile representing levees and berms, or 'flow obstructions' provided by FlowWest to generate the channelization metric. In late 2021, TU updated the Levees and Berms metric by digitizing features from newly available Lidar for areas in the Upper Sprague and adjacent to Upper Klamath Lake. TU used the following general geoprocessing steps.

1. Buffer stream reaches by 250 meters on each side.
2. Sum the length of levees and berms in meters within each buffered stream reach, for each side.
3. Divide total length of levees and berms on each side by total reach length in meters.

4. Calculate minimum distance in meters from levees and berms to stream channel on each side.
5. Calculate average distance in meters from stream channel to far edge of floodplain on each side.
6. Sum distance for each side from levees and berms to stream channel.
7. Sum distance for each side from stream channel to far edge of floodplain.
8. Divide summed distance from levees and berms to stream channel by summed distance from stream channel to far edge of floodplain.
9. Attribute reaches with this information.

These steps are additionally documented in the Toolbox Model "levees and berms".

Wetlands

TU applied expert opinion scores for UKL shoreline segments to generate the wetlands metric. A panel of four experts provided scores 1 (good) to 4 (poor) for each reach and those scores were averaged by reach.

Riparian and Floodplain Vegetation

TU used Google Earth Engine to calculate the vegetation type within floodplains. Floodplains were defined based on a variable width buffer of the stream reach centerline, with a standard 25 meter buffer applied to all reaches except higher order portions of the Williamson, Sprague, and Wood rivers, where 50 meter buffers were applied (Fourmilecanal segments 3 - 6; sevenmilecanal segment 3; Sprague segments 33 - 78; sycan segments 3 - 6; Williamson segments 21 - 24) or 75 meter buffers were applied (Sprague segments 3 - 30; Williamson segments 3 – 18; Williamsonsidechannel segment 3). TU originally evaluated a number of Landsat-derived land cover classification products, including the National Land Cover Dataset, Landfire, and Oregon's Statewide Habitat map, but determined that the spatial resolution of those products (30 x 30 meter pixels) was too coarse for identifying the conditions of interest in the riparian areas. To address the need for a higher spatial resolution, TU used USDA National Agricultural Imagery Program (NAIP) aerial photographs, which have a 1 x 1 meter spatial resolution (pixel size) in conjunction with the Google Earth Engine analytical platform. Google Earth Engine is a cloud-based remote sensing tool well suited for analyzing large datasets. At the time of analysis, the most recent NAIP imagery available in Google Earth Engine were from 2016.

Within Google Earth Engine, TU used the following JavaScript code to reclassify USDA NAIP imagery as mesic vegetation, xeric vegetation, bare ground, or open water based on NDVI or infrared band values. Output from this analysis was summarized within each buffer as the percentage of mesic vegetation within the terrestrial portions of the buffer (i.e., excluding open water from the calculation).

```
//Load buffered reaches
```

```
var fc = ee.FeatureCollection("users/kurtfesenmyer/KlamReal");

//Load NAIP imagery and select 2016
var collection = ee.ImageCollection('USDA/NAIP/DOQQ');
var collection_nrg = collection
  .filter(ee.Filter.listContains('system:band_names', 'N'));
var date = 2016

//Reduce NAIP collection to a single image with the max and add to map
var coll_nrg = collection_nrg.filterDate(date + '-01-01', date + '-12-31').max();
//Calculate NDVI
var naip_ndvi = coll_nrg.normalizedDifference(['N', 'R']);

//Classify:
//Mesic = 2 = NDVI > 0.3;
//Xeric = 0 = NDVI <= 0.3 and >= 0.05
//Bare = 10 = NDVI < 0.05
//Water = 11, 1 = IR (infrared) < 65
var ndvi_t = ee.Image(2).where(naip_ndvi.lte(0.30),0);
//NDVI threshold 0.05 both years
var bare_t = ee.Image(10).where(naip_ndvi.gte(0.05),0);
// IR water threshold for 2009: 100 ; for 2013: 65;
var ir = coll_nrg.select('N');
var water_t = ee.Image(1).where(ir.gte(65),0);
var output = (water_t.add(ndvi_t).add(bare_t));

// calculate count of pixels by type within each buffer
var count = fc.map(function(feature) {
  var cnt = output.reduceRegion(ee.Reducer.frequencyHistogram().unweighted(),
feature.geometry(),1);
  return feature.set ({'mean': cnt});
});

//export counts to a csv
print(ee.FeatureCollection(count)
 .getDownloadURL('csv', ['segmentID','mean'],'naip'));
```

Irrigation Practices

TU applied expert opinion scores for UKL shoreline segments to generate the irrigation practices metric. A panel of five experts provided scores 1 (good) to 4 (poor) for each reach and those scores were averaged by reach.

For stream reaches, this metric currently only accounts for the density of return points within each stream reach and does not include other information about irrigation practices. TU used a shapefile representing irrigation returns provided by FlowWest (covering the Williamson and Sprague sub-basins), supplemented by a shapefiles developed by TU representing irrigation returns in the Wood River valley to generate the irrigation practices metric for UKB stream reaches. TU used the following general geoprocessing steps.

1. Select only irrigation returns from the FlowWest shapefile, which also included diversions.
2. Merge FlowWest irrigation returns with TU Wood River valley irrigation returns.
3. Sum the count of irrigation returns by UKB stream reaches.
4. Divide the count of irrigation returns by total length in meters of each reach.
5. Attribute reaches with this information.

These steps are additionally documented in the Toolbox Model “irrigation practices”.

SPRINGS

TU applied expert opinion scores for UKB stream reaches to generate the springs metric. A panel of four experts provided scores 1 (good) to 4 (poor) for each reach and those scores were averaged by reach.

FISH PASSAGE

TU used a shapefile representing known fish passage barriers developed by TU staff to generate the fish passage metric. TU used the following general geoprocessing steps.

1. Sum count of fish passage barriers by stream reach.
2. Assign a multiplier to each stream reach based on National Hydrography Dataset Plus stream level to more heavily weight larger, more downstream reaches.
   a. Stream level 1 multiplier: 3
   b. Stream level 2 multiplier: 2
   c. Stream level 3+ multiplier: 1
3. Multiply count of fish passage barriers by stream level multiplier.
4. Divide weighted count of fish passage barriers by stream reach length in meters.
5. Attribute reaches with this information.

These steps are additionally documented in the Toolbox Model “fish passage”.

ROADS

TU used a geodatabase feature class representing roads provided by Oregon Department of Transportation to generate the roads metric. TU used the following general geoprocessing steps.

1. Buffer stream reaches by 100 meters on each side.
2. Select all roads except federal and state highways.
3. Sum length of selected roads in miles within 100-meter buffer by reach.
4. Divide summed length of roads within each buffered stream reach by the area in square miles of each buffered stream reach.
5. Attribute reaches with this information.

These steps are additionally documented in the Toolbox Model “roads”.

Fish Entrainment

TU used a shapefile of diversions in the Wood River valley developed by TU staff as well as a table of diversion locations in the remainder of the UKB developed by FlowWest to generate the fish entrainment metric. TU used the following general geoprocessing steps.

1. Merge TU and FlowWest diversion datasets.
2. Apply an entrainment score to each diversion according to the presence of a screen on the diversion.
    a. Screeened: 0
    b. Unknown: 1
    c. Unscreened: 2
3. Sum the scored screens by stream reach.
4. Divide the summed screen scores by reach length in meters.
5. Attribute reaches with this information.

These steps are additionally documented in the Toolbox Model “fish entrainment”.

Large Woody Debris

TU applied expert opinion scores for UKB stream reaches and UKL shoreline reaches to generate the large woody debris metric. Experts provided scores 1 (good) to 4 (poor) for each reach. The same three experts provided scores for UKB stream reaches and UKL shoreline segments. The UKL scores were averaged by shoreline segment.

Spawning substrate

TU applied expert opinion scores for UKB stream reaches and UKL shoreline reaches to generate the spawning substrate metric. Experts provided scores 1 (good) to 4 (poor) for each reach. Three experts provided scores for UKB stream reaches, and four experts provided scores for UKL shoreline segments. The UKL scores were averaged by segment.

2020 Beaver Dam Suitability Methods

TU created a beaver dam suitability layer for all National Hydrography Dataset Plus HR stream reaches in the UKB. This layer is not integrated into the impairment metrics scoring schema, rather is intended to serve as a reference layer to help inform restoration activities identified by the UKBWAP.

To create the beaver dam suitability layer, TU adapted the general modeling framework presented in Macfarlane et al. (2017), which predicts where and at what densities beaver dams can be built within riverscapes based on immutable factors (i.e., stream slope and stream power) and factors subject to land management (i.e., vegetation). For the UKB, TU focused solely on immutable factors for beaver dam suitability in acknowledgement of restoration approaches that do not require beaver to create stream habitat enhancements provided by beaver dams (e.g., beaver dam analogues [BDAs], post-assisted log structures [PALSs]).

TU characterized stream reaches based on the following rulesets:

- Stream slope as % (National Hydrography Dataset Plus HR attribute): 0 – 0.55 (Really flat); 0.5 – 15% (Can build dam); 15 – 23% (Probably can build dam); > 23% (Cannot build a dam)

- Drainage area in square kilometers (National Hydrography Dataset Plus HR attribute): 0 – 10000 (Can build a dam); > 10000 (Cannot build a dam)

- Baseflow stream power in watts/m: 0 – 175 (Can build a dam); 175 – 190 (Probably can build a dam); > 190 (Cannot build a dam). Baseflow stream power in watts/m is calculated based on this formula: (Reach drainage area/Gage drainage area) * Gage August 80% base flow. Gage drainage area and baseflow values are available via USGS StreamStats (https://streamstats.usgs.gov/ss/)

- Q2 (2-year interval flood) stream power in watts/m: 0 – 1000 (Dam persists); 1000 – 1200 (Occasional breach); 1200 – 2000 (Occasional blowout); > 2000 (Blowout). Q2 stream power in watts/m is calculated based on this formula: (Reach drainage area/Gage drainage area) * Gage Q2 flow. Gage drainage area and Q2 values are available via USGS StreamStats (https://streamstats.usgs.gov/ss/)

- Dam suitability:

Slope category	Drainage area category	Baseflow category	Q2 flow category	Beaver dam suitability
No dam	-	-	-	None
-	No dam	-	-	None

-	-	No dam	-	None
-	-	-	blowout	None
can build	can build	can build	dam persists	High
probably build	can build	can build	dam persists	Moderate
flat	can build	can build	dam persists	High
can build	can build	can build	occasional breach	Moderate
probably build	can build	can build	occasional breach	Low
flat	can build	can build	occasional breach	Moderate
can build	can build	can build	occasional blowout	Low
probably build	can build	can build	occasional blowout	Very low
flat	can build	can build	occasional blowout	Low
can build	can build	probably build	dam persists	Moderate
probably build	can build	probably build	dam persists	Low
flat	can build	probably build	dam persists	Moderate
can build	can build	probably build	occasional breach	Low
probably build	can build	probably build	occasional breach	Very low
flat	can build	probably build	occasional breach	Low
can build	can build	probably build	occasional blowout	Very low
probably build	can build	probably build	occasional blowout	Very low
flat	can build	probably build	occasional blowout	Very low

Below is the Python code TU used to map beaver dam suitability for National Hydrography Dataset Plus HR reaches.

```
#Purpose: Generate BRAT-like attributes rapidly using NHDPlus HR attributes

import arcpy
arcpy.env.overwriteOutput = True

# Variables - NHD Plus HR Flowline and FlowlineVAA table; reference basin drainage
#area in sqkm, Aug 80% low flow, Q2 flood flow from USGS StreamStats
BRAT_flowlines = r"C:\Users\kurt.fesenmyer\OneDrive - Trout Unlimited\Kurt_GIS\Else\Klamath_watershed_plan\Klamath_WAP.gdb\BRAT_flowlines"
NHDPlusFlowlineVAA =
r"H:\Reference_datasets\NHDPlus_HR\NHDPLUS_H_1801_HU4_GDB\NHDPLUS_H_1801_HU4_GDB.gdb\NHDPlusFlowlineVAA"

# Process: use Join Fields to add Drainage Area and Slope attributes from FlowlineVAA
table to NHD Plus HR Flowline
```

```
#BRAT_flowlines_3_ = arcpy.management.JoinField(in_data=BRAT_flowlines,
in_field="NHDPlusID", join_table=NHDPlusFlowlineVAA, join_field="NHDPlusID",
fields=["TotDASqKm", "DivDASqKm", "Slope"])[0]

# Process: add and calculate slope field with no 0 values
codeblock0 = """
def Reclass(Slope):
    if Slope < 0.001:
        return 0.001
    else:
        return float(Slope)"""

BRAT_flowlines_9_ = arcpy.management.CalculateField(in_table=BRAT_flowlines,
field="Geo_slope", expression="Reclass(!Slope!)", expression_type="PYTHON_9.3",
code_block=codeblock0)[0]

# Process: add and calculate low flow in CFS using reference basin drainage area in
sqkm, Aug 80% low flow from USGS StreamStats
BRAT_flowlines_8_ = arcpy.management.CalculateField(in_table=BRAT_flowlines_9_,
field="Hyd_QLow", expression="(!TotDASqKm!/157.471392)*6",
expression_type="PYTHON_9.3", code_block="")[0]

# Process: add and calculate Q2 flow in CFS using reference basin drainage area in sqkm,
Q2 flood flow from USGS StreamStats
BRAT_flowlines_4_ = arcpy.management.CalculateField(in_table=BRAT_flowlines_8_,
field="Hyd_Q2", expression="(!TotDASqKm!/157.471392)*183",
expression_type="PYTHON_9.3", code_block="")[0]

# Process: add and calculate low flow stream power in Watts/m
BRAT_flowlines_5_ = arcpy.management.CalculateField(in_table=BRAT_flowlines_4_,
field="Hyd_SPLow",
expression="(1000*9.80665)*!Geo_slope!*!Hyd_QLow!*0.028316846592",
expression_type="PYTHON_9.3", code_block="")[0]

# Process: add and calculate Q2 stream power in Watts/m
BRAT_flowlines_7_ = arcpy.management.CalculateField(in_table=BRAT_flowlines_5_,
field="Hyd_SPQ2",
expression="(1000*9.80665)*!Geo_slope!*!Hyd_Q2!*0.028316846592",
expression_type="PYTHON_9.3", code_block="")[0]

# Process: add and calculate slope categorical score
codeblock = """
def Reclass(Geo_slope):
    if Geo_slope < 0.05:
        return 'flat'
    elif (Geo_slope >=0.05 and Geo_slope <15):
```

```
        return 'can build'
    elif (Geo_slope >= 15 and Geo_slope <= 23):
        return 'probably build'
    elif Geo_slope > 23:
        return 'no dam'
    else:
        return 'missing'"""
BRAT_flowlines_10_ =
arcpy.management.CalculateField(in_table=BRAT_flowlines_7_, field="Cat_Slope",
expression="Reclass(!Geo_slope!)", expression_type="PYTHON_9.3", code_block =
codeblock)[0]

# Process: add and calculate drainage area categorical score
codeblock1 = """
def Reclass(TotDASqKm):
    if TotDASqKm <= 10000:
        return "can build"
    elif TotDASqKm > 10000:
        return 'no dam'
    else:
        return 'missing'"""
BRAT_flowlines_11_ =
arcpy.management.CalculateField(in_table=BRAT_flowlines_10_, field="Cat_DA",
expression="Reclass(!TotDASqKm!)", expression_type="PYTHON_9.3", code_block =
codeblock1)[0]

# Process: calculate low flow stream power score
codeblock2 = """
def Reclass(Hyd_SPLow):
    if Hyd_SPLow < 175:
        return 'can build'
    elif (Hyd_SPLow >= 175 and Hyd_SPLow < 190):
        return 'probably build'
    elif Hyd_SPLow >= 190:
        return 'no dam'
    else:
        return 'missing'"""
BRAT_flowlines_12_ =
arcpy.management.CalculateField(in_table=BRAT_flowlines_11_, field="Cat_QLow",
expression="Reclass(!Hyd_SPLow!)", expression_type="PYTHON_9.3", code_block =
codeblock2)[0]

# Process: add and calculate SP2 flow stream power score
codeblock3 = """
def Reclass(Hyd_SPQ2):
    if Hyd_SPQ2 < 1000:
```

```
        return 'dam persists'
    elif (Hyd_SPQ2 >= 1000 and Hyd_SPQ2 < 1200):
        return 'occasional breach'
    elif (Hyd_SPQ2 >= 1200 and Hyd_SPQ2 < 2000):
        return 'occasional blowout'
    elif Hyd_SPQ2 >= 2000:
        return 'blowout'
    else:
        return 'missing'"""
BRAT_flowlines_13_ =
arcpy.management.CalculateField(in_table=BRAT_flowlines_12_, field="Cat_Q2",
expression="Reclass(!Hyd_SPQ2!)", expression_type="PYTHON_9.3", code_block =
codeblock3)[0]

# Process: add and calculate combined final score but without consideration of vegetation
factors
codeblock8 = """
def Reclass(Cat_DA,Cat_Slope,Cat_QLow,Cat_Q2):
    if (Cat_QLow == 'no dam'):
        return "None"
    elif (Cat_Slope == 'no dam'):
        return "None"
    elif (Cat_DA == 'no dam'):
        return "None"
    elif (Cat_Q2 =='blowout'):
        return "None"
    elif (Cat_QLow =='can build' and Cat_Q2 =='dam persists' and Cat_Slope=='can
build'):
        return 'High'
    elif (Cat_QLow =='can build' and Cat_Q2 =='dam persists' and Cat_Slope=='probably
build'):
        return 'Moderate'
    elif (Cat_QLow =='can build' and Cat_Q2 =='dam persists' and Cat_Slope=='flat'):
        return 'High'
    elif (Cat_QLow =='can build' and Cat_Q2 =='occasional breach' and Cat_Slope=='can
build'):
        return 'Moderate'
    elif (Cat_QLow =='can build' and Cat_Q2 =='occasional breach' and
Cat_Slope=='probably build'):
        return 'Low'
    elif (Cat_QLow =='can build' and Cat_Q2 =='occasional breach' and
Cat_Slope=='flat'):
        return 'Moderate'
    elif (Cat_QLow =='can build' and Cat_Q2 =='occasional blowout' and
Cat_Slope=='can build'):
        return 'Low'
```

```
    elif (Cat_QLow =='can build' and Cat_Q2 =='occasional blowout' and
Cat_Slope=='probably build'):
        return 'Very low'
    elif (Cat_QLow =='can build' and Cat_Q2 =='occasional blowout' and
Cat_Slope=='flat'):
        return 'Low'
    elif (Cat_QLow =='probably build' and Cat_Q2 =='dam persists' and Cat_Slope=='can
build'):
        return 'Moderate'
    elif (Cat_QLow =='probably build' and Cat_Q2 =='dam persists' and
Cat_Slope=='probably build'):
        return 'Low'
    elif (Cat_QLow =='probably build' and Cat_Q2 =='dam persists' and
Cat_Slope=='flat'):
        return 'Moderate'
    elif (Cat_QLow =='probably build' and Cat_Q2 =='occasional breach' and
Cat_Slope=='can build'):
        return 'Low'
    elif (Cat_QLow =='probably build' and Cat_Q2 =='occasional breach' and
Cat_Slope=='probably build'):
        return 'Very Low'
    elif (Cat_QLow =='probably build' and Cat_Q2 =='occasional breach' and
Cat_Slope=='flat'):
        return 'Low'
    elif (Cat_QLow =='probably build' and Cat_Q2 =='occasional blowout' and
Cat_Slope=='can build'):
        return 'Very low'
    elif (Cat_QLow =='probably build' and Cat_Q2 =='occasional blowout' and
Cat_Slope=='probably build'):
        return 'Very low'
    elif (Cat_QLow =='probably build' and Cat_Q2 =='occasional blowout' and
Cat_Slope=='flat'):
        return 'Very low'
    else:
        return 'missing'"""
BRAT_flowlines_17_ =
arcpy.management.CalculateField(in_table=BRAT_flowlines_16_,
field="Cat_DamCapNV",
expression="Reclass(!Cat_DA!,!Cat_Slope!,!Cat_QLow!,!Cat_Q2!)",
expression_type="PYTHON_9.3", code_block = codeblock8)[0]
```

ATTACHMENT A – 2017 IMPAIRMENT METRICS METHODS

Restoration Opportunities Analysis (ROA): Task III

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DATE:	8/24/2017


THE SOUTH FORK SPRAGUE RIVER AT IVORY PINE ROAD.

CONTENTS

PURPOSE

The Restoration Opportunities Analysis (ROA) is the first step in identifying site-specific restoration actions and is part of concurrent planning efforts in the Upper Klamath Basin. The ROA is a component of the larger Sprague Basin Aquatic Adaptive Restoration Guide (AARG) and Upper Klamath Basin Watershed Action Plan, which are intended to inform restoration actions in the Upper Klamath Basin. ROAs will identify specific locations for restoration actions in the Upper Klamath Basin. These sites will provide significant opportunities to address key restoration goals in the watershed, specifically: improving instream water quality, restoring in-channel flow, increasing groundwater supply, and restoring plant diversity in riparian habitat. ROA Task I identified flow obstructions along the Sprague River where the channel is disconnected from the floodplain. ROA Task II built on the data collected for the flow obstructions analysis and identified restoration opportunities on the Sprague River, North Fork Sprague, South Fork Sprague, and Sycan River through (1) locating of irrigation diversion and return points, (2) identification of upland areas converted to juniper dominated communities, and (3) identification of stream reaches with straightened channels.

ROA Task III further builds on the geospatial analyses completed in Tasks I and II, and incorporates the following into GIS data layers:

- Canal and irrigation ditch networks in the Sprague River Tributaries and Williamson River basins;
- Location of direct irrigation returns to streams in the Sprague River tributaries (excluding the North and South Fork Sprague River and the Sycan River) and Williamson River basin;
- Location of water diversions in the Williamson River basin and Sprague River tributaries (excluding the North and South Fork Sprague River and the Sycan River), which would be candidates for screening designed to reduce fish entrainment;
- Location of berms, levees, and dikes that may be candidates for removal/set-back/breaching to facilitate floodplain reconnection in the Wood River Valley, Williamson River basin, and Sprague River tributaries (excluding the North and South Fork Sprague River and the Sycan River); and,
- Stream reaches with straightened channels that may be candidates for channel reconfiguration projects in the Wood River Valley, Williamson River basin, and Sprague River tributaries (excluding the North and South Fork Sprague River and the Sycan River).

Table 1 describes each water body within the spatial scope of the study, and the associated analyses completed for the water body. The ROA Task III spatial scope includes the additional rivers and creeks within the watersheds shown in Figure 1.

TABLE 1: MAPPING TASKS COMPLETED PER WATER BODY FOR ROA TASK III.

Watershed	Creek	Extent (from confluence to extent boundary in River Miles)	Canal and Irrigation Network Mapping	Direct Irrigation Returns Mapping	Water Diversion Mapping	Berm, Levee, and Dike Mapping	Historical Channel Change Mapping
Sprague	Blue Creek	0.9	ROA III	ROA III	ROA III	ROA III	ROA III
	Brown Creek	6.8	ROA III	ROA III	ROA III	ROA III	ROA III
	Brown Spring Creek	Entire reach (1.2)	ROA III	ROA III	ROA III	ROA III	ROA III
	Copperfield Creek	2.0	ROA III	ROA III	ROA III	ROA III	ROA III
	Deming Creek	2.1	ROA III	ROA III	ROA III	ROA III	ROA III
	Fishhole Creek	12.0	ROA III	ROA III	ROA III	ROA III	ROA III
	Fivemile Creek	9.0	ROA II/III	ROA II/III	ROA II/III	ROA I/II/III	ROA III
	Ish Tish Creek	0.9	ROA III	ROA III	ROA III	ROA III	ROA III
	Meryl Creek	3.7	ROA III	ROA III	ROA III	ROA III	ROA III
	North Fork Sprague	11.0	ROA I/II/III	ROA I/II/III	ROA I/II/III	ROA I/II/III	ROA I/II/III*
	Paradise Creek	4.7	ROA I/II/III	ROA I/II/III	ROA I/II/III	ROA I/II/III	ROA I/II/III
	Pole Creek	1.1	ROA III	ROA III	ROA III	ROA III	ROA III
	Snake Creek	1.9	ROA III	ROA III	ROA III	ROA III	ROA III
	South Fork Sprague	12.6	ROA I/II	ROA I/II	ROA I/II	ROA I/II	ROA I/II
	Sprague River	Entire reach (108.2)	ROA I/II	ROA I/II	ROA I/II	ROA I/II	ROA I/II
	Sycan River	12.9	ROA I/II	ROA I/II	ROA I/II	ROA I/II	ROA I/II*
	Trout Creek	12.0	ROA III	ROA III	ROA III	ROA III	ROA III
	Whisky Creek	9.2	ROA III	ROA III	ROA III	ROA III	ROA III
	Whitehorse Spring Creek	1.9	ROA I/II/III	ROA I/II/III	ROA I/II/III	ROA I/II/III	ROA I/II/III
Williamson	Larkin Creek	2.9	ROA III	ROA III	ROA III	ROA III	ROA III
	Williamson	46.7	ROA III	ROA III	ROA III	ROA III	ROA III
	Spring Creek	2.5	ROA III	ROA III	ROA III	ROA III	ROA III
	Sunnybrook Creek	0.6	ROA III	ROA III	ROA III	ROA III	ROA III

Watershed	Creek	Extent (from confluence to extent boundary in River Miles)	Canal and Irrigation Network Mapping	Direct Irrigation Returns Mapping	Water Diversion Mapping	Berm, Levee, and Dike Mapping	Historical Channel Change Mapping
	Upper Williamson	41.8	ROA III	ROA III	ROA III	ROA III	ROA III*
Wood River Valley	Agency Creek	0.8		**	**	ROA III	ROA III
	Annie Creek	6.7		**	**	ROA III	ROA III
	Crane Creek	4.3		**	**	ROA III	ROA III
	Crooked Creek	12.0		**	**	ROA III	ROA III
	Fort Creek	4.3		**	**	ROA III	ROA III
	Fourmile Creek	13.4		**	**	ROA III	ROA III
	Larkin Creek	2.9		**	**	ROA III	ROA III
	Sevenmile Creek	23.0		**	**	ROA III	ROA III
	Sun Creek	0.5		**	**	ROA III	ROA III
	Wood River	23.7		**	**	ROA III	ROA III*

Notes: * Analysis extends past project boundary; **Analysis completed by Trout Unlimited.

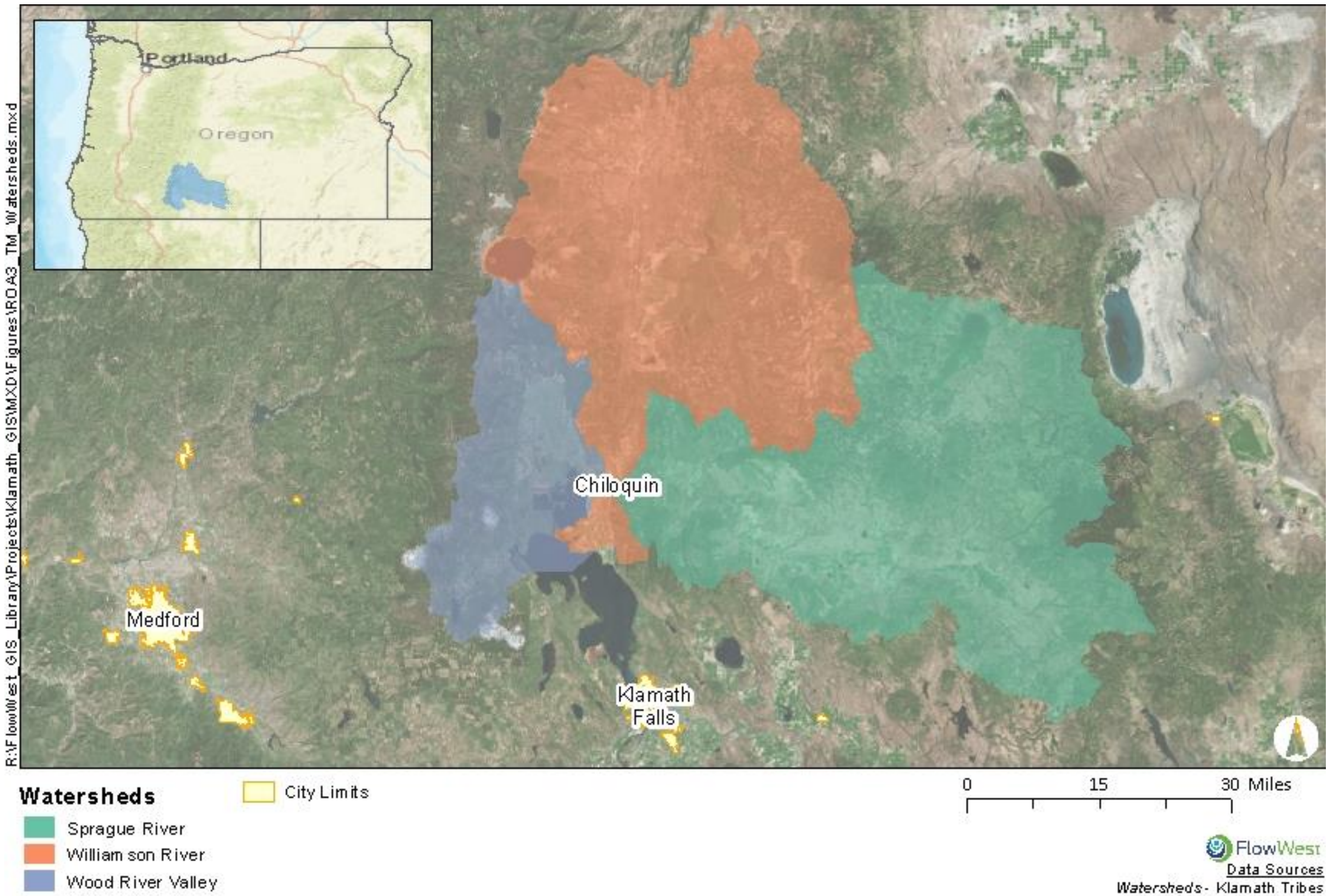

FIGURE 1: STUDY AREA WATERSHEDS.

As the Klamath Tribes assess and prioritize potential restoration actions in the Upper Klamath Basin, identifying locations where channel alignment has changed over time provides important context for future restoration actions. In our analysis we identified changes in alignment for flood control, irrigation, and agricultural production. These locations are high priority sites for restoration to restore geomorphic processes. We also identified many meander cutoffs that require additional analysis to determine why wide spread channel simplification has occurred. By understanding these changes, restoration mangers can design more sustainable restoration projects. Reduction of channel erosion and incision is important for both riparian and aquatic habitat for species of concern and to improve water quality. The soils in the Upper Klamath Basin are naturally rich in phosphorus and channel erosion contributes to the phosphorus load into Upper Klamath and Agency Lakes. This dataset of provides the first step in identification and prioritization of channel related restoration sites in the basin.

Flow obstructions were initially collected into a geospatial database in ROA Task I. These polyline features are defined as an artificial embankment or structure constructed in the floodplain or along the channel banks that prevents floodwaters from spreading out onto the floodplain. Initially, the focus of the flow obstruction identification was predominately levees, but our analysis shows that many other floodplain features direct, confine, and/or obstruct flow. These structures include levees, berms, canals, ditches, irrigation structures, paved and dirt roads (active and abandoned), railroad beds (active and abandoned), and residential or agricultural development. The geodatabase flow obstruction feature class identifies and geolocates each obstruction, and contains attribute information of the physical characteristics of each obstruction. This information can be used by restoration managers to identify areas to implement restoration projects, and the breadth of attribution within the database can be used to filter the obstructions in various ways to aid in prioritization of restoration activities.

The identification of irrigation diversion and return points has been a critical aspect of the ROA analysis, as many agricultural and ranching operations are located near the creeks of the Sprague, Upper and Lower Williamson River basins, in addition to the mainstems. These points are of interest for restoration purposes for several reasons. Untreated agricultural return flows increase the phosphorus and other nutrient loading into Upper Klamath Lake, and increase instream water temperatures—negatively impacting water quality for aquatic species. Unscreened diversions can result in juvenile and adult trout and sucker species entrainment in irrigation canals. Furthermore, these points are often associated with structures that interrupt and modify natural geomorphic and hydrologic processes by limiting overbank flow and floodplain deposition. The associated polyline structures are identified in the companion database of flow obstruction features. Irrigation diversion and return points in the Wood River Valley were excluded from this work, as the identification of those features was completed by a collaborator (Trout Unlimited). Identification of these features will aid in planning restoration actions targeting issues imposed by agricultural return flows and irrigation diversion infrastructure.

DATA ACQUISITION & INTEGRATION

Straightened Channel Identification

We used the USGS EarthExplorer website to identify and download single frame aerial photography for the Williamson River, Sprague River Tributaries, and Wood River Valley regions. We downloaded the oldest aerial imagery datasets available for the project reaches. In addition to the historical aerial images we also downloaded and rectified historical topographic maps from 1897 and 1965. We georeferenced the historical images using the ESRI Georeferencing tool in ArcMap 10.5. The fit of the control points is determined by observing changes in the residual for each point given the influence of the other control points, and by the root mean square (RMS) of all control points. Although the residuals were kept under 2.0 meters and the RMS was kept below 1.5 meters, the current channel centerline rarely fit the creeks in the historical images over the entire extent of each image. We were unable to completely correct the distortion of the historical images, but were able to use the georeferenced images to identify changes in channel alignment based on the pattern of the current channel centerline and the georeferenced images. In images where a project creek only covered a portion of the historical image, we georeferenced only the portion of the historical images near the project creek. This often resulted in the further distorting the historical image at the opposite side of the image. We used National Agriculture Imagery Program (NAIP) imagery from 2014 to georeference the historical images. We also used channel centerlines digitized by the Klamath Tribes from the NAIP (2014) imagery during the georeferencing process. A summary of the historical images used in this analysis and the spatial extent of each by river is shown in Table 2.

TABLE 2: SPATIAL EXTENT FOR HISTORIC CHANNEL DATA.

River/Creek	Format	Month	Year	Scale	Source	Extent
Western Wood River Valley	Map		1897	1:250,000	USGS TopoView	Entire area
	Map		1955	1:62,000	USGS TopoView	Entire area
	Aerial Photo	July	1953	1:37,400	USGS Earth Explorer	Western portion of Annie Creek, Seven and Four Mile Creek
Eastern Wood River Valley	Map		1897	1:250,000	USGS TopoView	Entire area
	Map		1955	1:62,000	USGS TopoView	Entire area
	Aerial Photo	July	1955	1:37,400	USGS Earth Explorer	Eastern portion of Seven and Four Mile Creek, Agency Creek, Annie Creek, Crane Creek, Crooked Creek, Fort Creek, and Sun Creek
Williamson River	Map		1889	1:250,000	USGS TopoView	Entire area
	Map		1957 & 1960	1:62,000	USGS TopoView	Entire area
	Aerial Photo	July	1955	1:37,400	USGS Earth Explorer	Klamath Marsh to confluence with Upper Klamath Lake
	Aerial Photo	Sept. & Oct.	1953	1:54,000	USGS Earth Explorer	Headwater to Klamath Marsh
Sprague River Tributaries	Map		1889	1:250,000	USGS TopoView	Entire area to just east of Bly
	Map		1957 & 1960	1:62,000	USGS TopoView	Entire area
	Aerial Photo	July	1955	1:37,400	USGS Earth Explorer	Sprague River Tributaries

We were unable to obtain historical aerial imagery prior to levee construction and channel straightening conducted on the South Fork Sprague in the late 1940s and early 1950s by the U.S. Army Corps of Engineers (USACE). The straightened channels in the South Fork are present in the aerial imagery from 1955. Unfortunately, the 1889 topographic map does not extend over the South Fork Reach past Bly and is of poor accuracy for comparison with the 1955 historical aerial photographs. However, the channel alignment clearly shows that channels near the South Fork Sprague River were straightened between the 1955 historical aerial photographs and the 1889 historical topographic map. Lastly, we were unable to obtain information on the levee construction in the South Fork; the projects were completed as an emergency flood protection effort and the USACE was not required to document these modifications (KBEF, 2007).

Flow Obstruction & Irrigation Diversion/Return point Identification

Numerous data sources were acquired and used during the ROA analysis to identify and map flow obstructions and irrigation diversion and return points in the study area, and are presented in Table 3. Data include: flow line features from the National Hydrography Dataset (NHD); aerial imagery, lidar-derived elevation data; a fish passage barrier database created by the Oregon Department of Fish and Wildlife (ODFW); a restoration project database from Oregon Watershed Restoration Inventory (OWRI); and an aerial thermal infrared (TIR) imagery analysis. Flow obstructions include both levee and berm features, as well as irrigation canal and ditch networks.

TABLE 3: DATA USED FOR FEATURE IDENTIFICATION.

Data Layer	Reference	Data Type	Attributes	Spatial Extent
Geomorphology and Flood-plain Vegetation of the Sprague and Lower Sycan Rivers	O'Connor et al 2013	Line	Built features (bridge, building, dam, irrigation ditch, levee, other built feature, railroad, road)	Mainstem Sprague River and lower reaches of major tributaries
Agency Lake, USGS 1:24k quad	USGS 1998	Raster	None	Quad. map
Chiloquin, USGS 1:24k quad	USGS 1998	Raster	None	Quad. map
Chiloquin, USGS 62,500 quad	USGS 1957	Raster	None	Quad. map
S'Ocholis Canyon, USGS 1:24k quad	USGS 1998	Raster	None	Quad. map
Buttes of the Gods, USGS 1:24k quad	USGS 1998	Raster	None	Quad. map
Sprague River West, USGS 1:24k quad	USGS 1998	Raster	None	Quad. map
Sprague River East, USGS 1:24k quad	USGS 1998	Raster	None	Quad. map
Beatty, USGS 1:24k quad	USGS 1998	Raster	None	Quad. map
Ferguson Mountain, USGS 1:24k quad	USGS 2004	Raster	None	Quad. map
Bly, USGS 1:24k quad	USGS 2004	Raster	None	Quad. map
Bly, USGS 62,500 quad	USGS 1960	Raster	None	Quad map
Campbell Reservoir, USGS 1:24k quad	USGS 2004	Raster	None	Quad. map
Yamsay Mountain, USGS 1:62,500 quad	USGS 1960	Raster	None	Quad map
Swan Lake, USGS 1:62,500 quad	USGS 1957	Raster	None	Quad map
Riverbed Butte, USGS 62,500 quad	USGS 1960	Raster	None	Quad map
Modoc Point, USGS 62,500 quad	USGS 1957	Raster	None	Quad map
Lenz, USGS 62,500 quad	USGS 1957	Raster	None	Quad map
Lake O Woods, USGS 62,500 quad	USGS 1955	Raster	None	Quad map
Klamath Marsh, USGS 62,500 quad	USGS 1957	Raster	None	Quad map
Fuego Mountain, USGS 62,500 quad	USGS 1960	Raster	None	Quad map
Fishhole Mountain, USGS 62,500 quad	USGS 1960	Raster	None	Quad map
Calimus Butte, USGS 62,500 quad	USGS 1956	Raster	None	Quad map
Beatty, USGS 62,500 quad	USGS 1960	Raster	None	Quad map
Pelican Butte, USGS 62,500 quad	USGS 1955	Raster	None	Quad map
Klamath, USGS 1:250k quad	USGS 1889	Raster	None	Quad map
Ashland, USGS 1:250k quad	USGS 1897	Raster	None	Quad map
National Hydrography Dataset	USGS 2007-2014	Vector	Name, feature type, ID, direction	National (clipped to the watershed)

Data Layer	Reference	Data Type	Attributes	Spatial Extent
The Sprague River Streambank Assessment Report	KWP 2010	Point	Name, feature type, description	River Mile (RM) 1 - 10 of the S. Fork Sprague River
2004 Sprague Lidar	Watershed Sciences 2004	Raster/ points	Bare earth elevations as 1 m grids and points	Mainstem Sprague and lower reaches of tributaries
2007 True Color Ortho-Photos: Sprague Watershed	Watershed Sciences 2008	Raster	Imagery	1,500 ft corridor centered on the mainstem Sprague and major tributaries
2010 0.3m	Microsoft 2010	Raster	Imagery	Watershed
NAIP 2012	USDA 2012	Raster	Imagery	Watershed
NAIP 2014	USDA 2014	Raster	Imagery	Watershed
National Elevation Dataset (NED)	USGS 2010	Raster	Elevation	Upper and Lower Williamson River
Oregon Department of Fish and Wildlife (ODFW) Fish Passage Database	ODFW 2015	Vector	Fish passage barriers	Watershed
Oregon Water Resources Department (OWRD) water rights point of diversion (POD) database	OWRD 2015	Vector	POD	Watershed
Aerial thermal infrared (TIR) imagery analysis data	Watershed Sciences 2008	Raster	Water temperature	Watershed

Klamath ROA III DEM Coverage

We used a combination of three DEMs to complete this analysis. No single DEM dataset with less than 10 meter resolution covers the entire study area. We used the following three DEM datasets with resolutions between 1 and 2.5 meters that cover the study extent:

- USGS 2010 DEM
- Klamath Tribes 2004 Sprague DEM
- Klamath Basin Rangeland Trust 2004 Wood DEM

The date of collection and resolution of each of the DEM data sets is listed in Table 4.

TABLE 4: DEM DATASETS, RESOLUTIONS, AND EXTENTS USED IN THIS ANALYSIS.

Name	Date	Resolution (meters)	Extent
USGS 2010 DEM	9/14/2010	2.5	Williamson Basin, Wood Basin (excluding Wood Valley)
Klamath Tribes 2004 Sprague DEM	November, 2004	1.0	Sprague River corridor
Klamath Basin Rangeland Trust 2004 Wood DEM	9/26-27, 2004	1.0	Wood Valley

The following three figures show the extents of the different DEM datasets and the Upper Klamath River basin ROA III project area (Figure 2). The USGS DEM covers the entire Williamson River basin, but does not cover the Sprague River basin. The USGS DEM also covers the forested portion of the Wood River basin outside of the area covered by the Klamath Basin Rangeland Trust DEM. The Klamath Tribes DEM covers the mainstem Sprague River corridor from the confluence with the Williamson River, and includes the non-forested portions of the Sprague River, South Fork Sprague River, North Fork Sprague River, and a portion of the Sycan River (Figure 3). Major tributaries to the Sprague are also included in this dataset. Lastly, the Klamath Basin Rangeland Trust DEM covers the irrigated portion of the Wood River Valley (Figure 4).

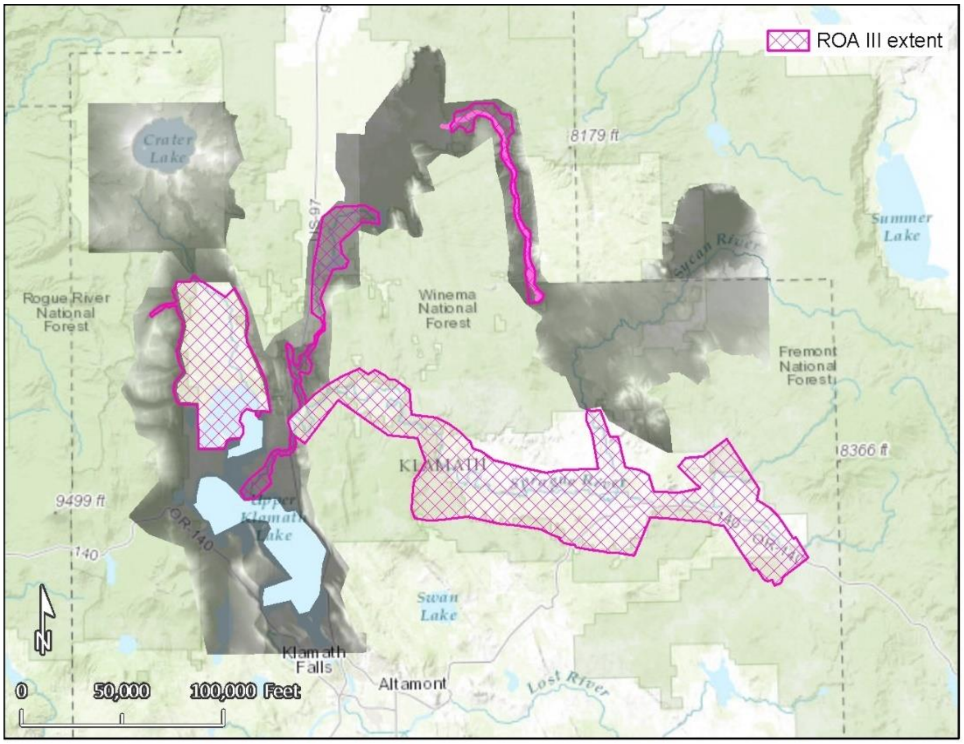

FIGURE 2: USGS 2010 DEM EXTENT.

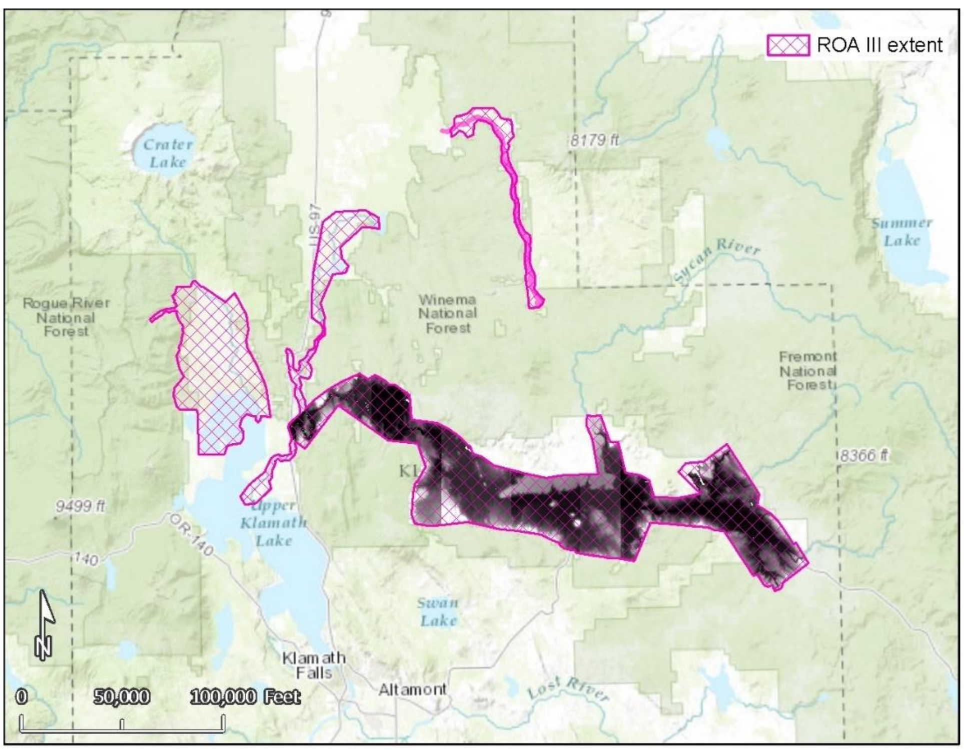

FIGURE 3: KLAMATH TRIBES 2004 SPRAGUE DEM EXTENT.

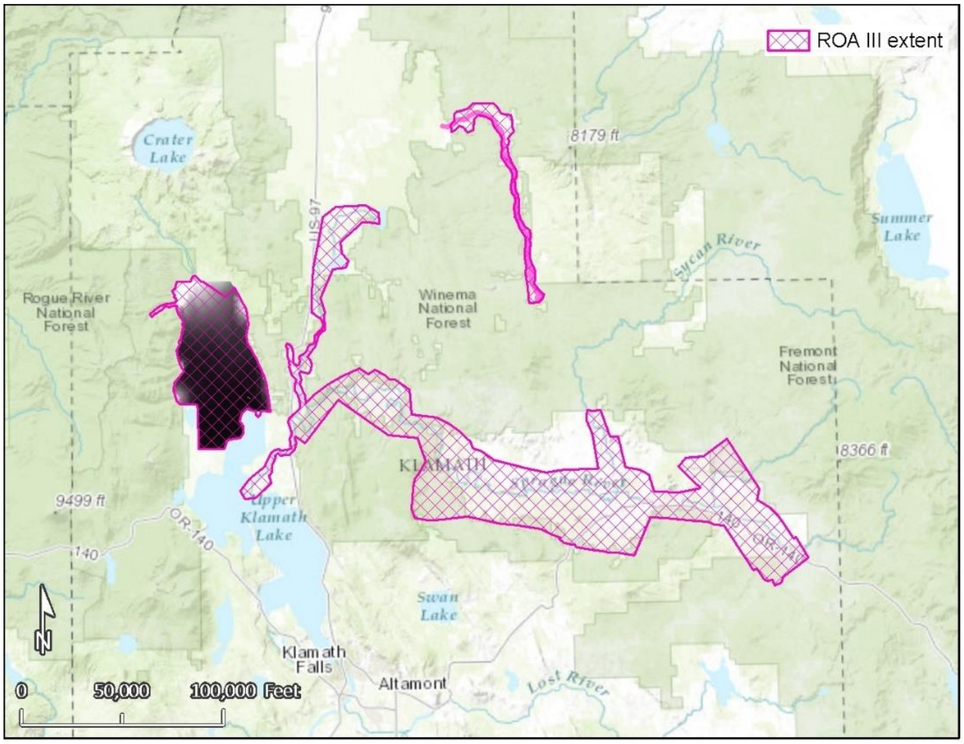

FIGURE 4: KLAMATH BASIN RANGELAND TRUST 2004 WOOD DEM EXTENT.

ANALYSIS

Straightened Channel Identification

We incorporated the 2014 centerline from the Klamath Tribes into the project GIS to compare with the geolocated historical aerial photographs and historical topographic maps. To ascertain whether channel planform changes had occurred, we reviewed the rivers from downstream to upstream, and created a point shapefile to delineate changes in channel alignment. At each identified channel change location, the change type was attributed as avulsion, meander cutoff, or channel straightening. Avulsions result from natural geomorphological changes, whereas channel straightening locations indicate anthropogenic influence on channel alignment. We attributed each point with the years in which the change had occurred based on the available datasets.

Next, this point shapefile of channel alignment changes was reviewed and cross-checked with two datasets: a polyline shapefile of infrastructure features that FlowWest mapped including levees, canals, dams, plugs, etc., and several point shapefiles denoting restoration project locations and information. Restorations projects cross-referenced included those managed by the US Fish and Wildlife (USFWS), OWEB, and the Bureau of Reclamation (BOR). The original point shapefile of channel alignment change locations was then expanded to attribute whether there was an existing restoration project near the channel change site and details about the restoration project if available. We included information on the infrastructure features near the channel alignment change in the attribute field *Structures*—particularly if they were likely to have influenced channel migration or confinement. Restoration projects near channel alignment change locations were documented in several attribute fields: project type, year, and funding source. Lastly, we created a polyline shapefile that delineates the length of the channel alignment change at each site.

We summarized the attributes for channel alignment changes documented as a point shapefile (Table 5). We placed a point near the center of each area of channel alignment change, i.e. at the center of a meander (Figure 5). In some cases if there were several channel path changes within a relatively short length of stream (e.g. < 0.5 miles), we added one point to indicate the changes in that location. We describe the attributes for our representation of channel alignment changes as a polyline shapefile in Table 6 below. The attributes for the polyline shapefile are the same as the point shapefile except for an additional attribute for the length of the channel segment.

TABLE 5: ATTRIBUTE TABLE FIELDS FOR CHANNEL ALIGNMENT CHANGE POINT SHAPEFILE.

Field	Description	Values	Field Type
FID	Object ID	0,1,2,3,…	Integer
ChangeType	Type of channel alignment change	Avulsion, straightened channel, meander cutoff, channel cutoff	Text
ChangeYear	Years over which change occurred	Typically between two years from available datasets (e.g. 1953 and 1968)	Text
Structures	Type/s of structures present near alignment change	Varies	Text
ExistingRP	Binary field indicating whether there is an existing restoration project reported near the channel alignment change	Y, N	Text
RP_Type	Restoration project type description, if available	Varies	Text
RP_Agency	Restoration project agency, if available	USFWS, OWEB, BOR	Text
RP_Year	Restoration project year	Varies	Text
Notes	Additional notes about channel alignment change	Varies	Text
Reach	Geomorphic reach from O'Conner et al., 2013	Reach, creek, or river name	Text
Geomorph	Geomorphic characteristics of each reach (for the Sprague River)	Sinuosity, secondary channels, channel cut off, anabranching, bedload sediment transport	Text
Multistem	Assessment of multistem channel form based on aerial photos from 1968, 2000, and 2014 and 1:24k topographic maps	Y, N	Text
Link_ID	ID to link the point and polyline shapefiles	1, 2, 3, …	Integer
Infrastructure	Was infrastructure a potential cause for channel change	Y, N	Text

TABLE 6: ATTRIBUTE TABLE FIELDS FOR CHANNEL ALIGNMENT CHANGE POLYLINE SHAPEFILE.

Field	Description	Values	Field Type
FID	Object ID	0,1,2,3,…	Integer
ChangeType	Type of channel alignment change	Avulsion, straightened channel, meander cutoff, channel cutoff	Text
ChangeYear	Years over which change occurred	Typically between two years from available datasets (e.g. 1953 and 1968)	Text
Structures	Type/s of structures present near alignment change	Varies	Text
ExistingRP	Binary field indicating whether there is an existing restoration project reported near the channel alignment change	Y, N	Text
RP_Type	Restoration project type description, if available	Varies	Text
RP_Agency	Restoration project agency, if available	USFWS, OWEB, BOR	Text
RP_Year	Restoration project year	Varies	Text
Notes	Additional notes about channel alignment change	Varies	Text
Reach	Geomorphic reach from O'Conner et al., 2013	Reach, creek, or river name	Text
Geomorph	Geomorphic characteristics of each reach (for the Sprague River)	Sinuosity, secondary channels, channel cut off, anabranching, bedload sediment transport	Text
Multistem	Assessment of multistem channel form based on aerial photos from 1968, 2000, and 2014 and 1:24k topographic maps	Y, N	Text
Infrastructure	Was infrastructure a potential cause for channel change	Y, N	Text
Link_ID	ID to link the point and polyline shapefiles	1, 2, 3, …	Integer
Length_ft	Length of channel where the alignment changed	Length (feet)	Integer

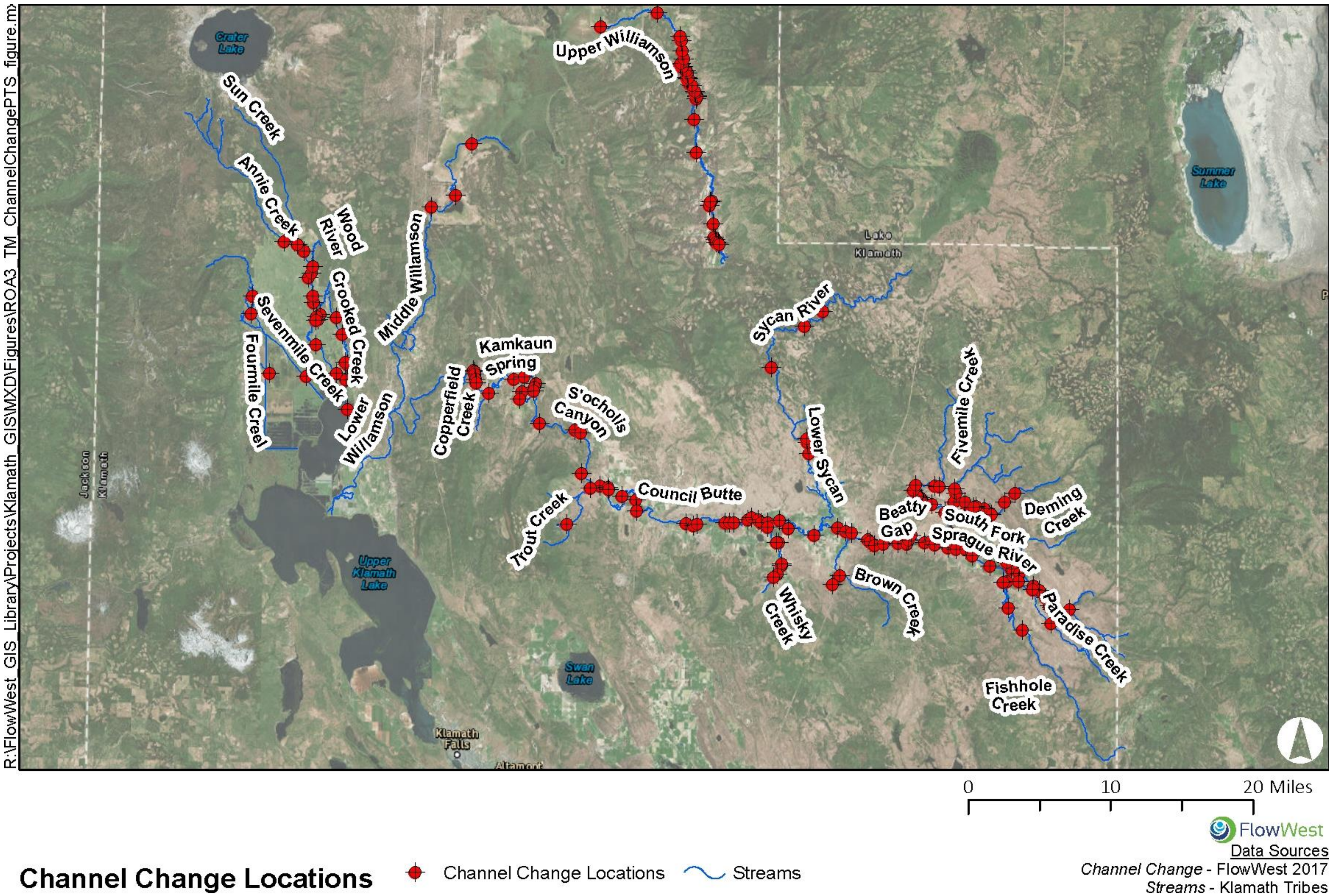

FIGURE 5: LOCATION OF CHANNEL CHANGE FEATURES.

Flow Obstruction Identification

When we first started this analysis we assumed that flow obstructions were predominately levees, but further investigation showed that many other floodplain features direct or confine flows in the Sprague and Williamson River watersheds. In addition to levees, other flow obstructions include: paved and dirt roads (active and abandoned), railroad beds (active and abandoned), canals, drainage ditches, irrigation structures, and residential or agricultural development. We defined flow obstruction as an artificial embankment or structure constructed in the floodplain or along the channel banks that prevents floodwaters from spreading out onto the floodplain. Obstructions were not necessary constructed with the purpose of diverting floodwater flow paths, but nonetheless, these obstructions do confine or direct unimpeded flow. In ROA Task II, irrigation canals and ditches were mapped within an approximately 1000-ft buffer of streams; in this analysis that spatial extent was expanded and all identifiable components of the irrigation networks were mapped within the study extent (see pink ROA III boundaries in Figure 2-Figure 4). Flow obstructions were categorized into classes and types (Table 7) and attributed as such in the accompanying shapefile. A discussion of each flow obstruction follows.

Flow Obstruction Classes and Types

TABLE 7: FLOW OBSTRUCTION CLASSES AND TYPES.

Class	Type
Berm	Berm
Development	Building pad
	Grading
Irrigation	Canal
	Canal bermed
	Dam
	Ditch
	Ditch bermed
	Weir
Levee	Levee
Restoration	Berm
	Plug
	Wetland
Transportation	Railroad
	Road
	Road / bridge

Berm

We defined a berm as a small (in comparison to levees) artificial ridge or bank used to confine or direct flow (Figure 6). Berms are defined here as having less than two feet of relief from the surrounding ground surface. We tried to distinguish berms from natural levees, which we excluded from our analysis.

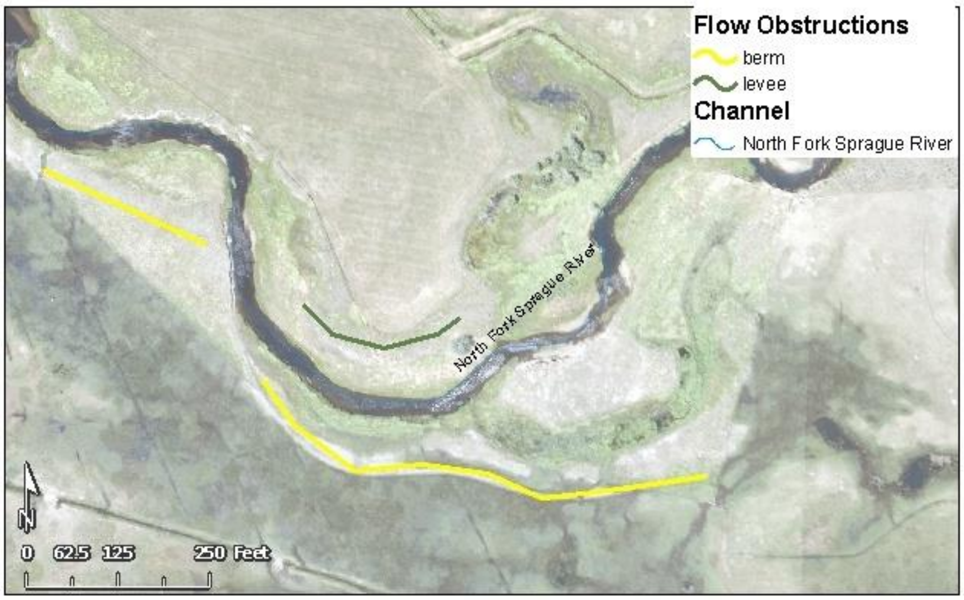

FIGURE 6: EXAMPLE OF BERM AND LEVEE FEATURES DELINEATED ALONG THE NORTH FORK SPRAGUE RIVER.

Development

The development classification includes modified bank or floodplain topography related to residential, agricultural, and/or commercial land use. We identified grading areas where fill has been placed on the floodplain and building pads where structures have been built in the floodplain (Figure 7).

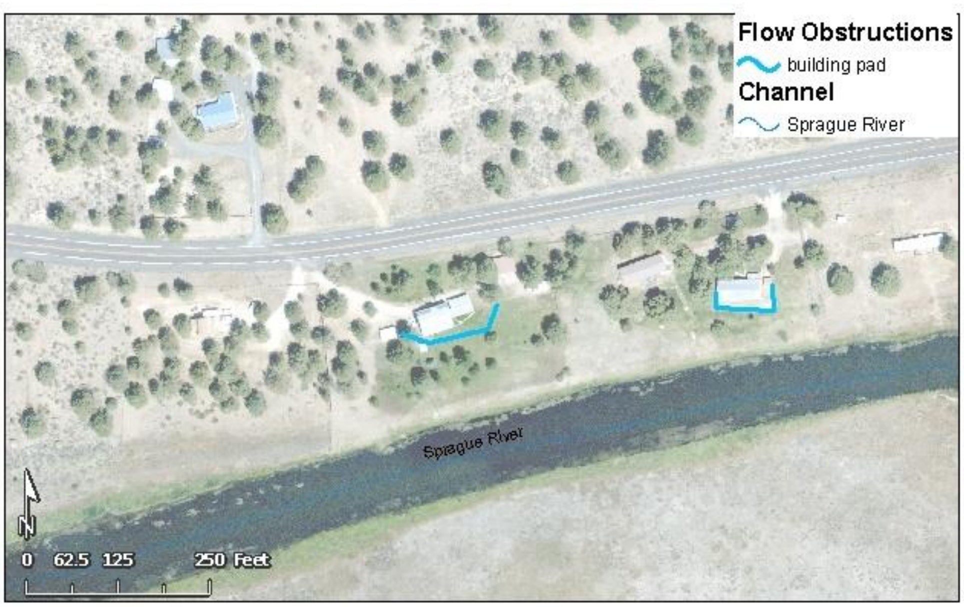

FIGURE 7: EXAMPLE OF BUILDING PAD FEATURES DELINEATED ALONG THE SPRAGUE RIVER.

Irrigation

The irrigation classification has the most sub-types of the features that we identified. In general, irrigation features include structures that convey irrigation or return flow (Figure 8). Irrigation structures include dams and weirs. Canals and ditches are features dug into the ground surface and flush with the surround topography. We used the labels from existing data sources for canals and ditches and when we were able to identify a flow direction from aerial photographs, we associated canals with diversions and ditches with drainage or return flow. Canals and ditches with material mounded next to them were classified as "bermed." We included canals and ditches without a berm in our analysis as they can direct floodplain flows through the existing channel network. Many levees also have barrow trenches directly in front or behind them that makes the delineation between levee and canal/ditch difficult, and is one potential source of error in our analysis.

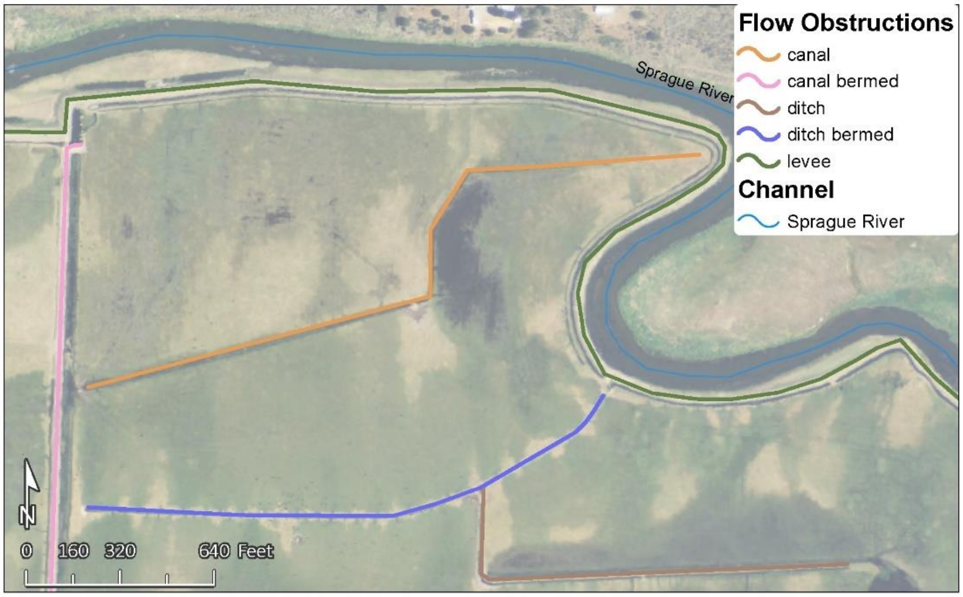

FIGURE 8: EXAMPLE OF CANAL, CANAL BERMED, DITCH, DITCH BERMED, AND LEVEE FEATURES DELINEATED ALONG THE SPRAGUE RIVER.

Levee

For this analysis we defined levees as artificial embankments two feet higher than the surrounding surface along a stream to protect land from flooding or to direct flood flows (Figure 9). Levees often have an adjacent canal or ditch, and in the case of numerous flow obstructions we mapped the dominate feature (based on height or proximity to the channel). Natural levees are geomorphic features found on floodplains and are formed when flood waters spread out onto the floodplain and overbank flows deposit sediment at the top of the bank. We used the two-feet height threshold based on the 2004 lidar data to differentiate artificial levees from berms, natural levees, and natural topographic features. Levee features were characterized as parallel, offset, or perpendicular. A parallel levee follows the top of bank of the channel, an offset levee is set back from the top of bank and typically confines the river corridor from meander bend to meander bend. Lastly, perpendicular levees concentrate floodplain flows into the channel and extend from the top of bank across the floodplain. We define the front of the levee as the side facing floodwaters (typically towards the channel or facing upstream for floodplain levees perpendicular to the channel).

FIGURE 9: EXAMPLE OF THE LEVEE FEATURES DELINEATED ALONG THE SOUTH FORK SPRAGUE RIVER.

Restoration

We identified restoration features that impact flood flows at identified restoration sites (Figure 10). We classified restoration features as built structures intended to restore the riparian zone. We identified plugs, constructed wetlands, and berms. Our analysis may have missed restoration projects or additional restoration features that have limited impacts on flow concentration or direction.

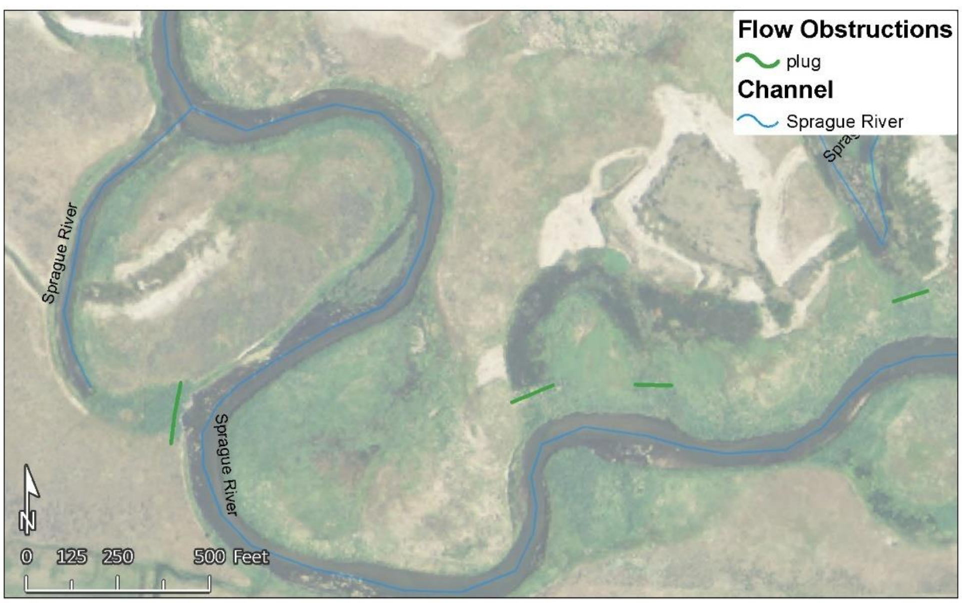

FIGURE 10: EXAMPLE OF PLUG FEATURES DELINEATED AT A RESTORATION SITE ALONG THE SPRAGUE RIVER.

Transportation

We delineated transportation features related to recreational, rail, and vehicular traffic networks. We classified transportation features as road, railroad, and road / bridge (Figure 11). The road category includes dirt roads, paved roads, and highways that are active or abandoned. The railroad category includes both active rail lines and the Oregon, California and Eastern (OC&E) Woods Line State Trail.

Lastly, the road / bridge category includes both bridges and elevated road segments on the approach or abutment for the bridge and includes both active and abandoned features.

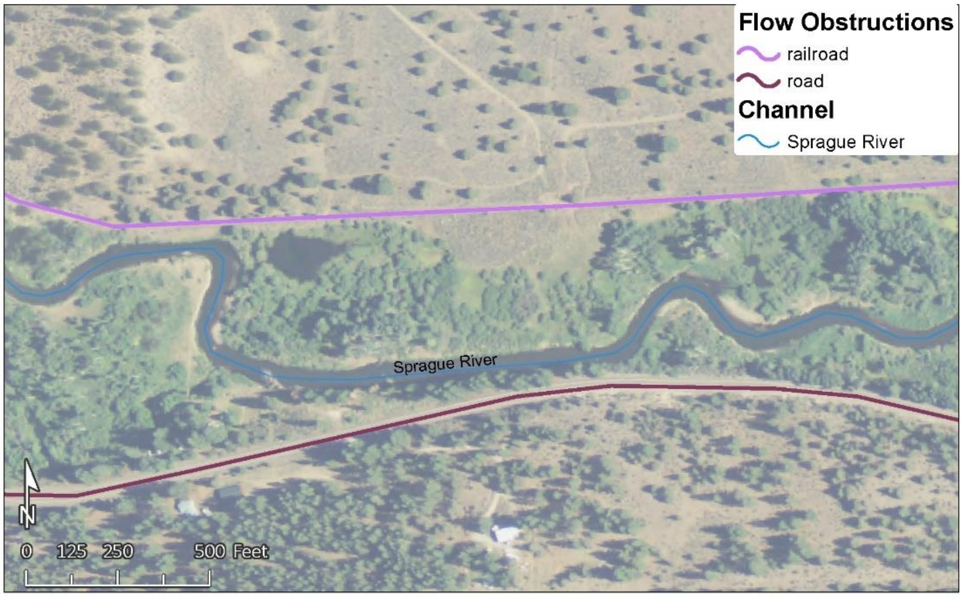

FIGURE 11: EXAMPLE OF RAILROAD AND ROAD FEATURES DELINEATED ALONG SPRAGUE RIVER.

Mapping

We conducted flow obstruction mapping in two phases. In the first phase, we incorporated the existing data layers and delineated levees from maps and aerial photographs. In the second phase we created a slope map, hillshade map, and generated contours from the 2004 lidar data. Next we systematically reviewed the Sprague River and major tributaries to identify flow obstruction features from the slope map, hillshade map, contours, and aerial photographs. Lastly, we attributed mapped features and added attribute data.

Existing Data

First, we integrated the levees delineated in Geomorphology and Flood-plain Vegetation of the Sprague and Lower Sycan Rivers (O'Connor et al 2013) and used this layer as our base shapefile that we modified as we added features. Each digitized feature was attributed with the primary source. Next, we digitized levees delineated on USGS 1:24,000 topographic maps and reviewed the National Hydrography Dataset (USGS 2007-2014) for levees. We did not find any levees in the National Hydrography Dataset (USGS 2007-2014) in the Sprague Watershed, but we utilized the flow network and canals and ditches during our systematic review in the second phase of the levee mapping. Point data from The Sprague River Streambank Assessment Report (KWP 2010) was added to the associated levees digitized from aerial photographs. Lastly, we digitized features that we interpreted as levees or flow obstructions on aerial imagery from 2007 (Watershed Science 2008), 2010 (Microsoft 2010), and 2012 (USDA 2012).

Lidar-based Identification of Flow Obstructions

In the second phase of the flow obstruction mapping, we incorporated the 2004 lidar (Watershed Sciences 2004) raster data processed as 1 meter grids and generated a slope map and 2 foot contours. The 2 foot contours were created to give us a general understanding of the floodplain and channel geometry above the water surface and to verify the areas highlighted in the slope map. Using the 3D Analyst Extension in ArcMap 10.2, we created a slope map and symbolized the resulting slope map by categories. We used yellow for slopes of 16-22 degrees for approximately 3:1 slope, orange for 22-34 degrees for approximately 2:1 slope, and red for greater than 34 for 1:1 slopes. This method allowed us to identify high slope areas that are likely from manmade structures compared to the natural terrain. For each orange to red area (slopes greater than 16 degrees), we reviewed the contours and then looked at the 2007, 2010, and 2012 imagery to help identify flow obstruction features. We also created a hillshade layer using 3D Analyst to help identify flow obstruction features. We cut cross sections from the 2004 lidar derived grids to identify flow obstructions. We also used the cross sections to differentiate between steep channel banks and levees.

Flow Obstruction Attributes

For each flow obstruction feature delineated we compiled attributes for the source of the data used to delineate the feature, the type of flow obstruction, the distance from the channel, alignment, confinement on one or both sides of the channel, the length of the obstruction, the class of obstruction, stream, reach, and elevation and height attributes for the an example cross section of the flow obstruction (Table 8). The attributes allow users of the shapefile to prioritize and categorize flow obstructions within the Upper Klamath Basin.

TABLE 8: FLOW OBSTRUCTION SHAPEFILE FIELD AND ATTRIBUTES.

Field	Description	Values	Field
Id	Unique feature identifier	Numeric	Integer
Type	Type of levee or flow obstruction	berm, building pad, canal, canal bermed, dam, ditch, ditch bermed, grading, levee, OCE trail, plug, pond, pond bermed, road, road / bridge, weir, wetland	Text
Align	Alignment of the flow obstruction to the channel	parallel, perpendicular, parallel / perpendicular	Text
Banks	Obstructions on one or both banks	1, 2	Number
Length_ft	Length of the obstruction	Distance calculated in GIS in meters and converted to feet	Number (ft)
LevType*	Levee or berm location with respect to the channel	Channel, channel / setback, floodplain, offset, perpendicular, setback	Text
Source1	Primary data layer used to identify feature	2004 lidar, 2007 aerial imagery, 2010 lidar, 2014 aerial imagery	Text
hWSE04_ft*	Height from the 2004 lidar Water Surface Elevation to the crest of the levee	Height	Number (ft)
h_BANK_ft*	Height from the base of the levee facing flow to the Water Surface Elevation	Height	Number (ft)
h_LEVft_ft*	Height of the levee facing the floodwaters from the toe to the crest	Height	Number (ft)
h_LEVbk_ft*	Height of the opposite side of the levee to floodwaters from the toe to the crest	Height	Number (ft)
SUB_ft*	Subsidence- difference between the front point and back point elevation	Height	Number (ft)
OFFSET_ft*	Distance from the 2012 NAIP edge of water to the toe of the levee/obstruction	Distance	Number (ft)
NOTE	Notes about features and/or how they were measured		Text
Channel	Name of main channel obstruction is nearest to	Creek or river name	Text
Reach	Name of reach obstruction is nearest to	Reach, creek, or river name	Text
TypeClass	Flow obstruction class	Berm, Development, Irrigation, Levee, Restoration, Transportation	Text
WSEpt_ft*	Water Surface Elevation at levee cross section	Elevation	Number (ft)
Front_pt*	Elevation at the base of the levee facing flow	Elevation	Number (ft)
Back_pt*	Elevation at the base of the levee facing floodplain (backside of levee)	Elevation	Number (ft)
Crest_pt*	Elevation at top of levee	Elevation	Number (ft)
Status	Feature status		Text
Notes_1	Notes from Klamath Tribes staff		Text

**Attributed to levee and berm features only.*

Irrigation Diversion and Agricultural Return Flow Identification

We cross-referenced several datasets to identify return and diversion features. The flow obstructions feature class layer was used to examine the canal network per agricultural operations, and locate areas where flow was likely to be diverted or returned to the rivers and creeks via canals and/or ditches. We also used an analysis of terrain slope from elevation data, and cut cross sections over larger swaths of topography to examine the general direction of gradient. This helped us ascertain whether features were likely to be inflow or outflow canals. We also used satellite imagery to cross-check whether features were diversions or returns, specifically we looked for pumps, piping, and irrigation structures. These features were recorded in a shapefile and relevant descriptions were included in the attribute table.

We reviewed this first cut dataset of return and diversion features, and amended it to include information from several relevant databases. First, we incorporated the flow line directionality of the NHD data into the diversion and return feature data. When a feature overlaid a flow line, we recorded the directionality to help identify whether the diversion feature was likely diverting river flow or returning agricultural discharge into the river channel. The NHD data was also helpful in understanding the general flow directions in canals and ditches near the Sprague River; often if a flowline did not overlay a feature we were able to estimate the likely flow direction based on nearby canals in the same irrigation system. However, the NHD data was not complete in the Sprague Basin and many channels were not included in the NHD dataset and errors were discovered in the dataset. Next, we compared the fish passage barrier database (ODFW) and the restoration project database (OWRI) with the diversion and return flow features we mapped. Any barriers or restoration projects we found in proximity to or overlapping the diversions were used to add to the diversion feature attribution. These datasets helped to identify some diversion features that have been screened and we eliminated these from our diversion feature shapefile.

Finally, we incorporated the 2007 TIR report information (Watershed Sciences 2008a); this report was produced to identify springs and thermal refugia throughout the Sprague watershed. The report also documented diversion and irrigation return canals throughout the Sprague River mainstem, North Fork, South Fork, and Sycan Rivers, as well as several tributaries including Meryl Creek and Fivemile Creek. The irrigation diversion and agricultural return flow canals reported in this document were cross-referenced with the diversion and return features we mapped. We added attributes to indicate whether the 2007 TIR report (Watershed Sciences 2008a) had shown the features to be for return or diversion flows, and also added any features the TIR reported that were not already in our shapefile. Finally, we cross-referenced our identified diversion and return flow features with the NHD data, terrain slope, aerial imagery, and the 2007 TIR report (Watershed Sciences 2008a) and assigned a final category for each feature.

Table 9 describes the attribute fields for the irrigation diversion and return feature point class shapefiles.

TABLE 9: ATTRIBUTE TABLE FIELDS FOR AGRICULTURAL RETURN AND DIVERSION POINT SHAPEFILES.

Field	Description	Values	Field Type
OBJECTID	Object ID	0,1,2,3,…	Integer
Type	Feature type	Canal, canal bermed, pump	Text
Location	Diversion or return feature location in reference to the river channel	Channel, floodplain, setback	Text
Source	Data source from which feature was identified	2004 lidar, 2014 aerial imagery, 2016 aerial imagery 2007 TIR report, NHD, flow obstruction shapefile, ORWD, June 2017 field work	Text
Channel	Name of main channel feature is nearest to	Creek or river name	Text
Reach	Name of reach feature is within	Reach, creek, or river name	Text
OFPBDS	Description of fish barrier present if reported in Oregon Fish Passage Barriers 2015 database	Varies	Text
TIR_report	If reported, classification as return or diversion by TIR report	Return or diversion	Text
Final_Desi	Final classification of feature as diversion or return made by FlowWest based on slope from lidar data, aerial imagery, NHD flow direction, and the TIR report	Return or diversion	Text
Notes	Additional notes about diversion or return feature	Varies	Text
Year		Notes from Klamath Tribes staff	Text
Scrn_stat	Screen status		Text
Pass_bar		Notes from Klamath Tribes staff	Text
Notes_1		Notes from Klamath Tribes staff	Text
Status	Return status		Text

Field Verification

In June 2017, we examined several locations within the study area to validate flow obstruction and irrigation return and diversion point features mapped using remotely-sensed data. We were able to confirm a number of diversion points, return points, canals, levees and berms along the Upper and Lower Williamson River, Spring Creek, the Sprague River mainstem, and Whisky Creek. We also recorded features in the field that were not identifiable in the various datasets used in the ROA analysis, and made revisions and edits to features that were misidentified or not currently present on the landscape. Unfortunately, several areas in the Upper Williamson River and along Fishhole Creek we hoped to evaluate were inaccessible via public property.

The following series of figures highlights several findings from the June 2017 fieldwork. Figures 13 and 14, 15 through 18, and 19 through 21 refer to the Williamson River, Sprague River, and Spring Creek, respectively.

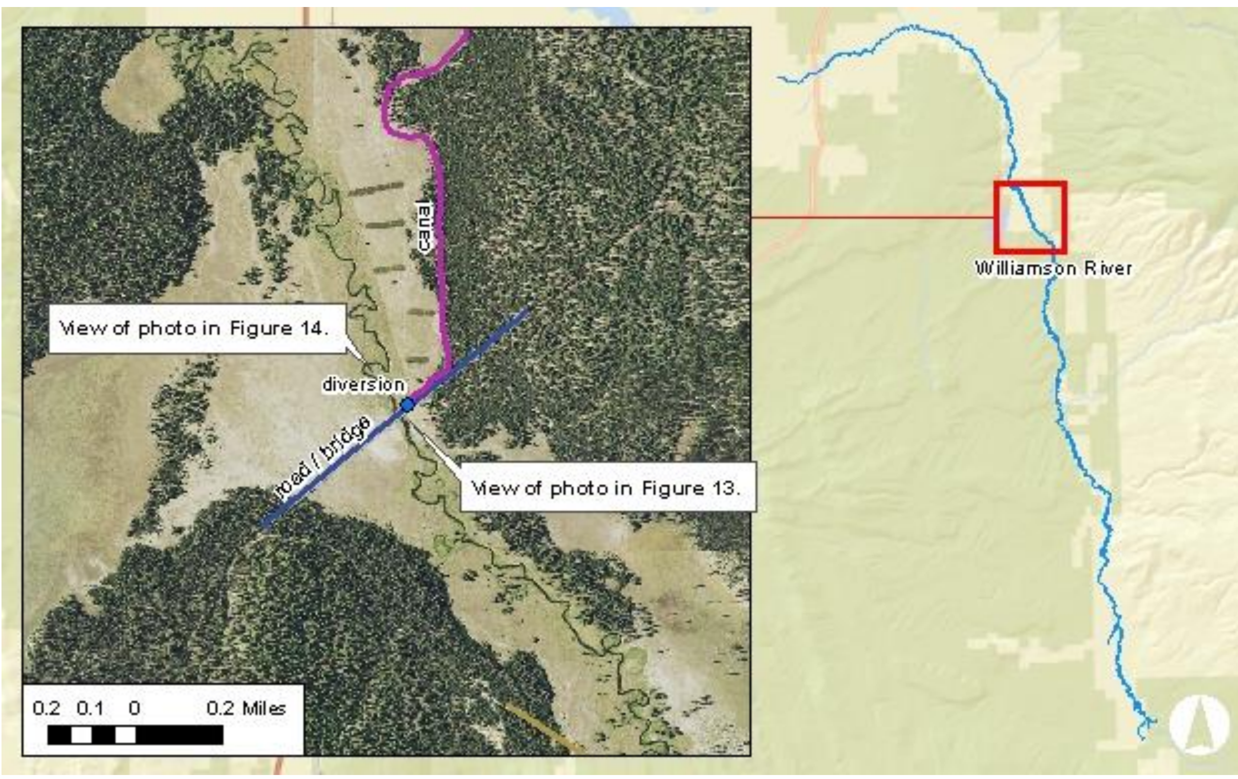

FIGURE 12: REFERENCE MAP FOR FIGURES 13 AND 14

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FIGURE 13: UPSTREAM OF BRIDGE ON THE UPPER WILLIAMSON RIVER. NOTE FENCING ADJACENT TO CHANNEL EDGE AND THE ACCESSIBILITY OF THE RIPARIAN AREA FOR CATTLE.


FIGURE 14: DOWNSTREAM OF BRIDGE ON THE UPPER WILLIAMSON RIVER. NOTE RIPARIAN AREA IS FENCED OFF.

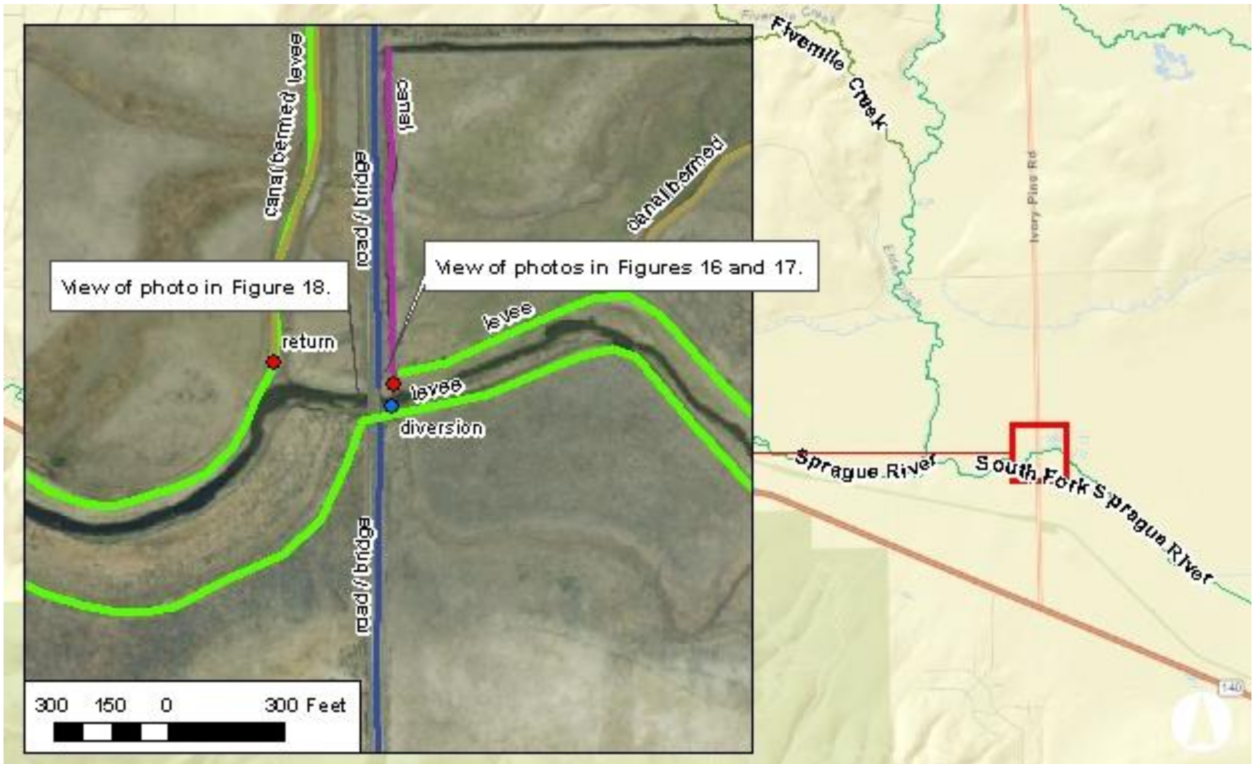

FIGURE 15: REFERENCE MAP FOR FIGURES 16, 17, AND 18.


FIGURE 16: CATTLE NEAR IRRIGATION RETURN CANAL ADJACENT TO IVORY PINE ROAD.

FIGURE 17: RETURN FROM CATTLE AREA INTO SPRAGUE RIVER JUST UPSTREAM OF IVORY PINE ROAD BRIDGE.


FIGURE 18: RETURN AGRICULTURAL FLOW MIXED INTO RIVER DOWNSTREAM OF IVORY PINE ROAD BRIDGE.

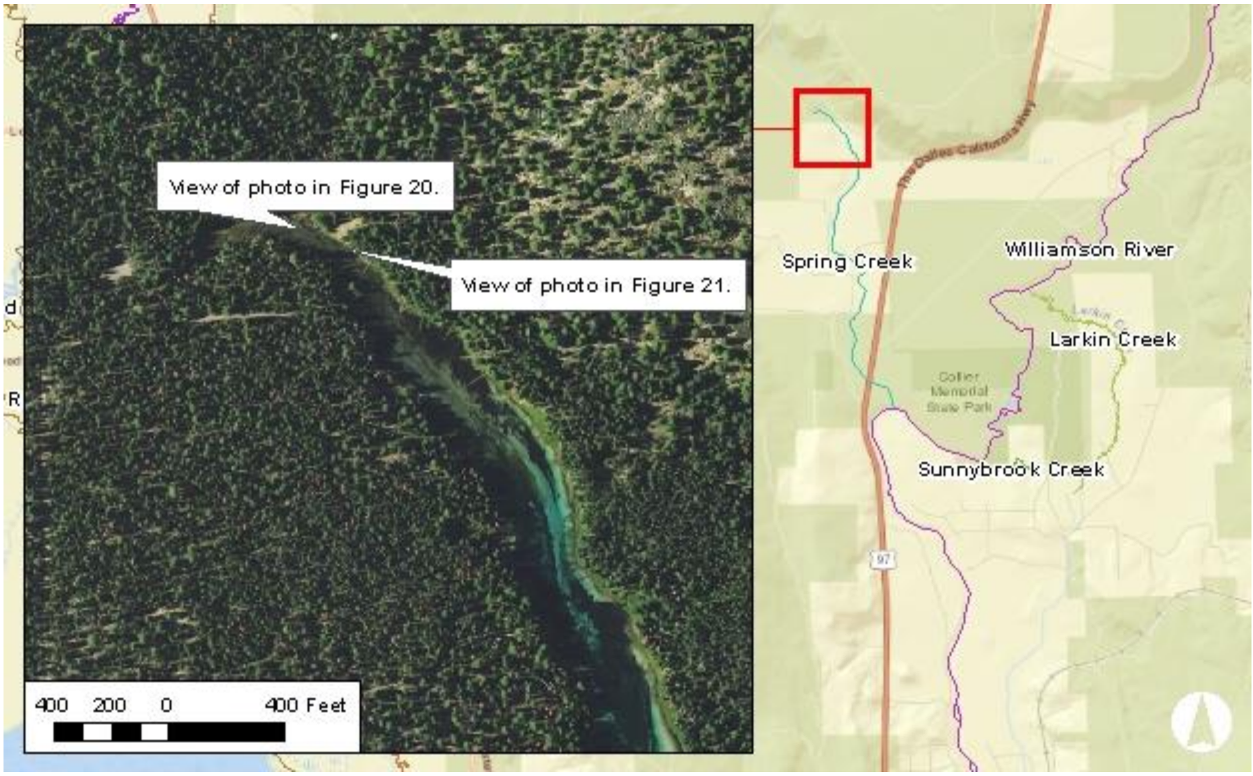

FIGURE 19: REFERENCE MAP FOR FIGURES 20 AND 21.

FIGURE 20: SPRING CREEK (LOOKING UPSTREAM) AT LOCATION WHERE A SMALL DIRT ROAD WAS MISIDENTIFIED AS A CANAL FROM ELEVATION DATA.

FIGURE 21: SPRING CREEK (LOOKING DOWNSTREAM) AT LOCATION WHERE A SMALL DIRT ROAD WAS MISIDENTIFIED AS A CANAL FROM ELEVATION DATA.

RESULTS

Straightened Channel Identification

The following tables and maps summarize the extent of mapped channel change features expanded and refined during the ROA III study. Of the three watersheds investigated in this study, we identified the highest number of channel change location in the Sprague Watershed (Table 10; Table 11). In terms of the cumulative length of features, the Wood River Valley was very close to the Sprague, but the number of features was much smaller. In the Wood River Valley, Fourmile Creek and Sevenmile Creek account for the majority of the length of the mapped features.

TABLE 10: SUMMARY OF CHANNEL CHANGE FEATURES BY WATERSHED.

Watershed	Number of Mapped Features	Length of Mapped Features (mi)
Sprague	118	36.0
Williamson	36	12.4
Wood River Valley	24	28.1

To quickly identify reaches that have experience the most channel change (by length of features) we developed Figure 22. The reaches with the highest length of mapped features are clearly identified as the Upper Williamson, Sevenmile Creek, and Fourmile Creek. The channelized portions of South Fork Sprague River and Fishhole Creek also have long sections of altered channels.

TABLE 11: DETAILED SUMMARY OF CHANNEL CHANGE FEATURES BY WATERSHED, CHANNEL, AND REACH.

Watershed	Channel	Reach	Number of Mapped Features	Length of Mapped Features (mi)
Sprague	Brown Creek	Brown Creek	2	2.2
	Copperfield Creek	Copperfield Creek	1	0.2
	Deming Creek	Deming Creek	2	1.4
	Fishhole Creek	Fishhole Creek	4	5.1
	Fivemile Crek	Fivemile Crek	10	1.3
	Meryl Creek	Meryl Creek	2	1.0
	North Fork Sprague	North Fork Sprague	12	2.6
		Upper Valley	1	0.1
	Paradise Creek	Paradise Creek	3	3.0
	South Fork Sprague	South Fork Sprague	15	7.4
	Sprague	Beatty Gap	8	1.1
		Beatty-Sycan	3	1.5
		Buttes of the Gods	6	0.7
		Council Butte	14	2.2
		KamKaun Spring	12	2.4
		S'choholis Canyon	4	0.6
		Upper Valley	4	0.6
	Sycan River	Lower Sycan	3	0.4
		Sycan River	3	0.3
	Trout Creek	Trout Creek	2	0.2
	Whisky Creek	Whisky Creek	7	1.8
Williamson	Middle Williamson	Middle Williamson	3	1.8
	Upper Williamson	Upper Williamson	33	10.6
Wood River Valley	Agency Creek	Agency Creek	1	0.1
	Annie Creek	Annie Creek	2	0.2
	Crooked Creek	Crooked Creek	5	3.0
	Fourmile Creek	Fourmile Creek	1	12.4
	Sevenmile Creek	Sevenmile Creek	3	10.0
	Sun Creek	Sun Creek	1	0.1
	Wood River	Wood River	12	2.4

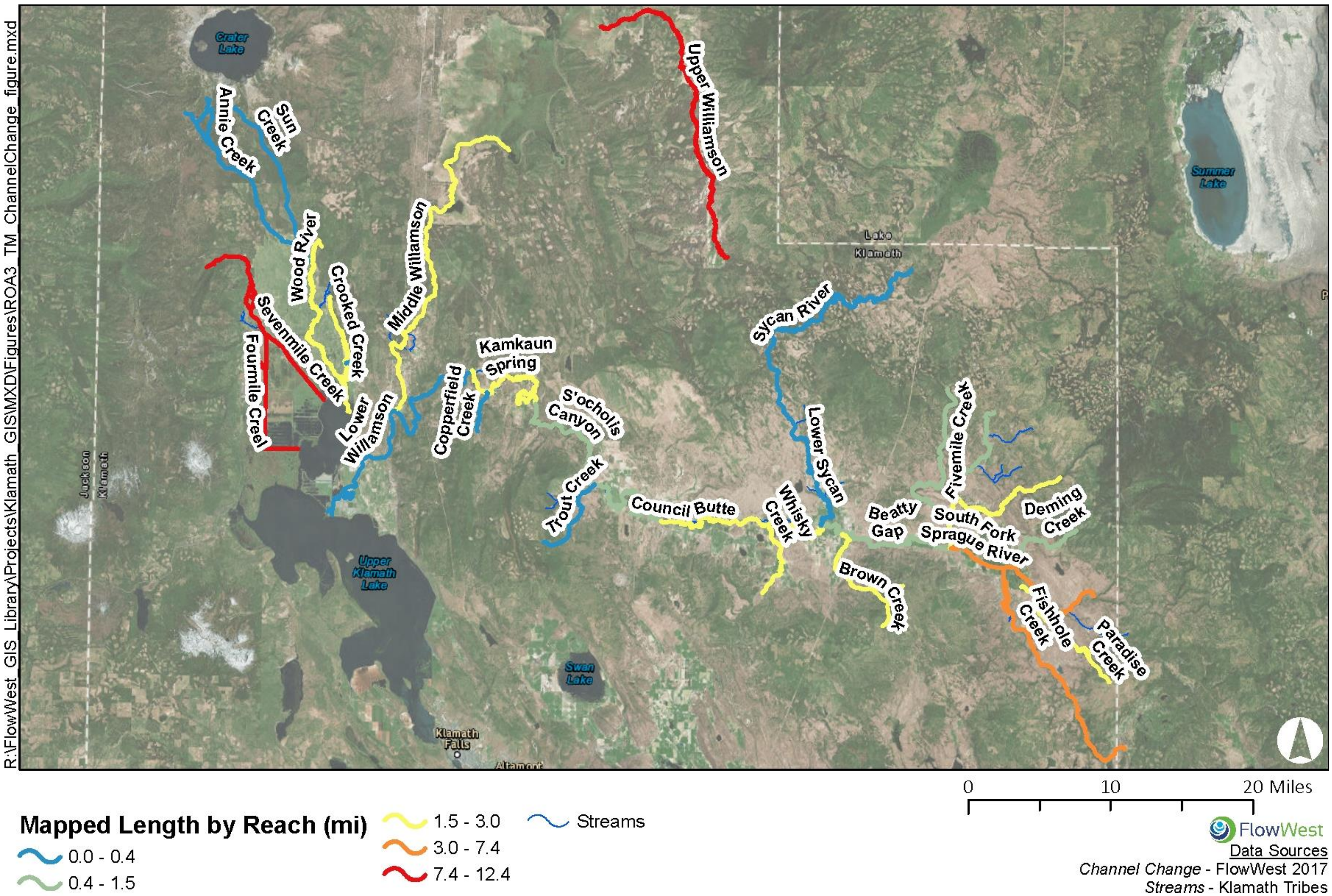

FIGURE 22: CUMMULATIVE LENGTH OF MAPPED CHANNEL CHANGE FEATURES PER REACH IN THE SPRAGUE, WILLIAMSON, AND WOOD RIVER VALLEY WATERSHEDS. THE "STREAMS" LAYER DEPICTS WATER BODIES THAT EITHER HAD NO IDENTIFIABLE CHANNEL CHANGE OR WERE NOT INCLUDED IN THE STUDY SCOPE.

Flow Obstruction & Irrigation Diversion and Return Point Identification

The following tables and maps summarize the extent of the flow obstructions and irrigation and diversion point locations datasets expanded and refined during the ROA III study.

TABLE 12: COUNTS OF FLOW OBSTRUCTIONS FOR THE WILLIAMSON AND WOOD RIVER VALLEYS.

Channel	Reach	Flow Obstruction Category	Number of Mapped Features	Total
Williamson River	Upper Williamson	Berm	39	**220**
		Irrigation	176	
		Levee	2	
		Transportation	3	
	Middle Williamson	Berm	1	**35**
		Development	1	
		Irrigation	27	
		Levee	2	
		Transportation	4	
	Lower Williamson	Berm	2	**14**
		Irrigation	5	
		Levee	4	
		Transportation	3	
Spring Creek	Spring Creek	Transportation	1	**1**
Wood River	Wood River	Berm	2	**7**
		Levee	5	
Fourmile Creek	Fourmile Creek	Levee	1	**1**
Sevenmile Creek	Sevenmile Creek	Levee	2	**2**
Crooked Creek	Crooked Creek	Berm	1	**2**
		Levee	1	

TABLE 13: COUNTS OF FLOW OBSTRUCTION FEATURES BY REACH FOR THE SPRAGUE RIVER.

Channel	Reach	Flow Obstruction Category	Number of Mapped Features	Total
Sprague River	Beatty-Sycan	Irrigation	9	**15**
		Transportation	6	
	Beatty Gap	Irrigation	5	**12**
		Levee	2	
		Transportation	5	
	Braymill	Irrigation	1	**9**
		Transportation	8	
	Buttes Of The Gods	Berm	4	**74**
		Irrigation	58	
		Levee	8	
		Restoration	2	
		Transportation	2	
	Chiloquin Canyon	Development	5	**20**
		Irrigation	1	
		Transportation	14	
	Council Butte	Berm	2	**104**
		Development	2	
		Irrigation	67	
		Levee	21	
		Restoration	6	
		Transportation	6	
	Kamkaun Spring	Berm	6	**106**
		Irrigation	64	
		Levee	26	
		Restoration	7	
		Transportation	3	
	S'ocholis Canyon	Irrigation	3	**19**
		Transportation	16	
	Upper Valley	Irrigation	7	**8**
		Levee	1	
North Fork Sprague River	North Fork	Berm	5	**49**
		Irrigation	26	
		Levee	10	
		Transportation	8	
	Upper Valley	Irrigation	1	**1**
South Fork Sprague River	South Fork	Irrigation	41	**75**
		Levee	23	
		Transportation	11	

TABLE 14: COUNTS OF FLOW OBSTRUCTIONS FOR CREEKS.

Channel	Flow Obstruction Category	Number of Mapped Features	Total
Brown Creek	Berm	5	**22**
	Irrigation	7	
	Levee	5	
	Transportation	5	
Brown Spring Creek	Irrigation	3	**3**
Copperfield Creek	Berm	4	**17**
	Irrigation	8	
	Levee	4	
	Transportation	1	
Crane Creek	Transportation	1	**1**
Deming Creek	Irrigation	7	**7**
Fishhole Creek	Berm	15	**40**
	Irrigation	9	
	Levee	15	
	Transportation	1	
Five Mile Creek	Irrigation	6	**7**
	Transportation	1	
Meryl Creek	Irrigation	3	**4**
	Levee	1	
Paradise Creek	Irrigation	5	**5**
Sycan River	Irrigation	11	**15**
	Restoration	1	
	Transportation	3	
Trout Creek	Irrigation	3	**4**
	Transportation	1	
Whisky Creek	Berm	9	**69**
	Irrigation	45	
	Levee	8	
	Transportation	7	
Whitehorse Spring Creek	Berm	1	**19**
	Irrigation	17	
	Transportation	1	

TABLE 15: COUNTS OF IRRIGATION DIVERSIONS AND RETURNS BY STREAM AND REACH.

Channel	Reach	Category	Number of Mapped Features
Brown Creek	Brown Creek	**diversion**	**3**
		return	1
Deming Creek	Deming Creek	**diversion**	**1**
Fishhole Creek	Fishhole Creek	**diversion**	**5**
		return	1
Fivemile Creek	Fivemile Creek	**diversion**	**3**
Meryl Creek	Meryl Creek	**diversion**	**3**
		return	1
North Fork Sprague River	North Fork	diversion	5
		return	2
Paradise Creek	Paradise Creek	**diversion**	**2**
South Fork Sprague River	South Fork	**diversion**	**10**
		return	12
Sprague River	Beatty-Sycan	**diversion**	**1**
	Beatty Gap	**diversion**	**2**
		return	3
	Buttes of the Gods	**diversion**	**10**
		return	4
	Chiloquin Canyon	**diversion**	**1**
		return	1
	Council Butte	**diversion**	**10**
		return	19
	Kamkaun Spring	**diversion**	**6**
		return	4
	S'ocholis Canyon	**diversion**	**1**
	Upper Valley	**diversion**	**1**
		return	3
	Council Butte	return	1
Sycan River	Beatty-Sycan	**diversion**	**1**
	Lower Sycan	**diversion**	**7**
		return	5
Trout Creek	Trout Creek	**diversion**	**2**
Whisky Creek	Whisky Creek	**diversion**	**8**
		return	2
Whitehorse Spring Creek	Whitehorse Spring Creek	**diversion**	**5**
		return	1
Williamson River	Upper Williamson	**diversion**	**14**
		return	6
	Middle Williamson	**diversion**	**6**
		return	2

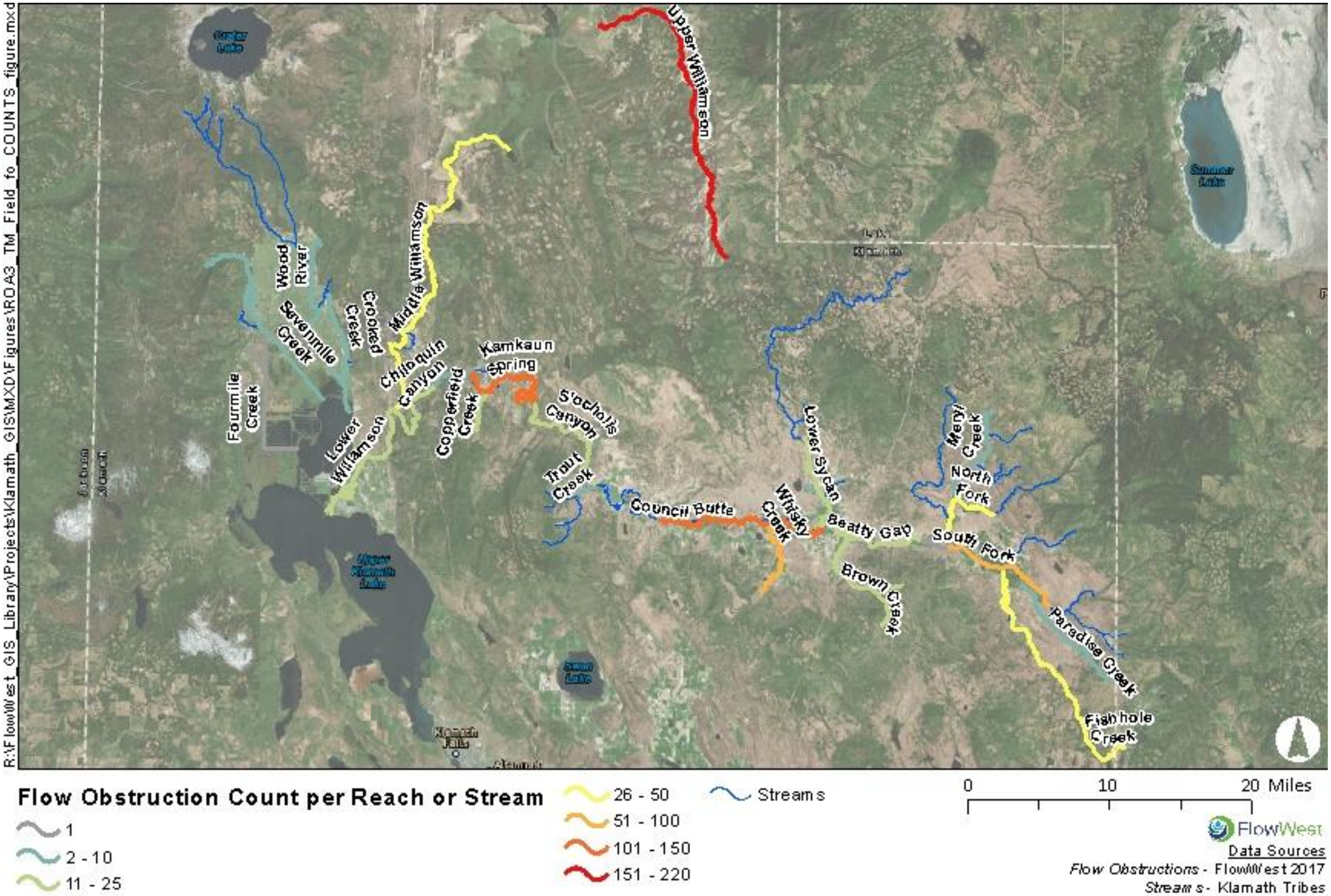

FIGURE 23: FLOW OBSTRUCTIONS PER REACH OR STREAM IN THE SPRAGUE AND WILLIAMSON RIVER WATERSHEDS. THE "STREAMS" LAYER DEPICTS WATER BODIES THAT EITHER HAD NO IDENTIFIABLE FLOW OBSTRUCTIONS OR WERE NOT INCLUDED IN THE STUDY SCOPE.

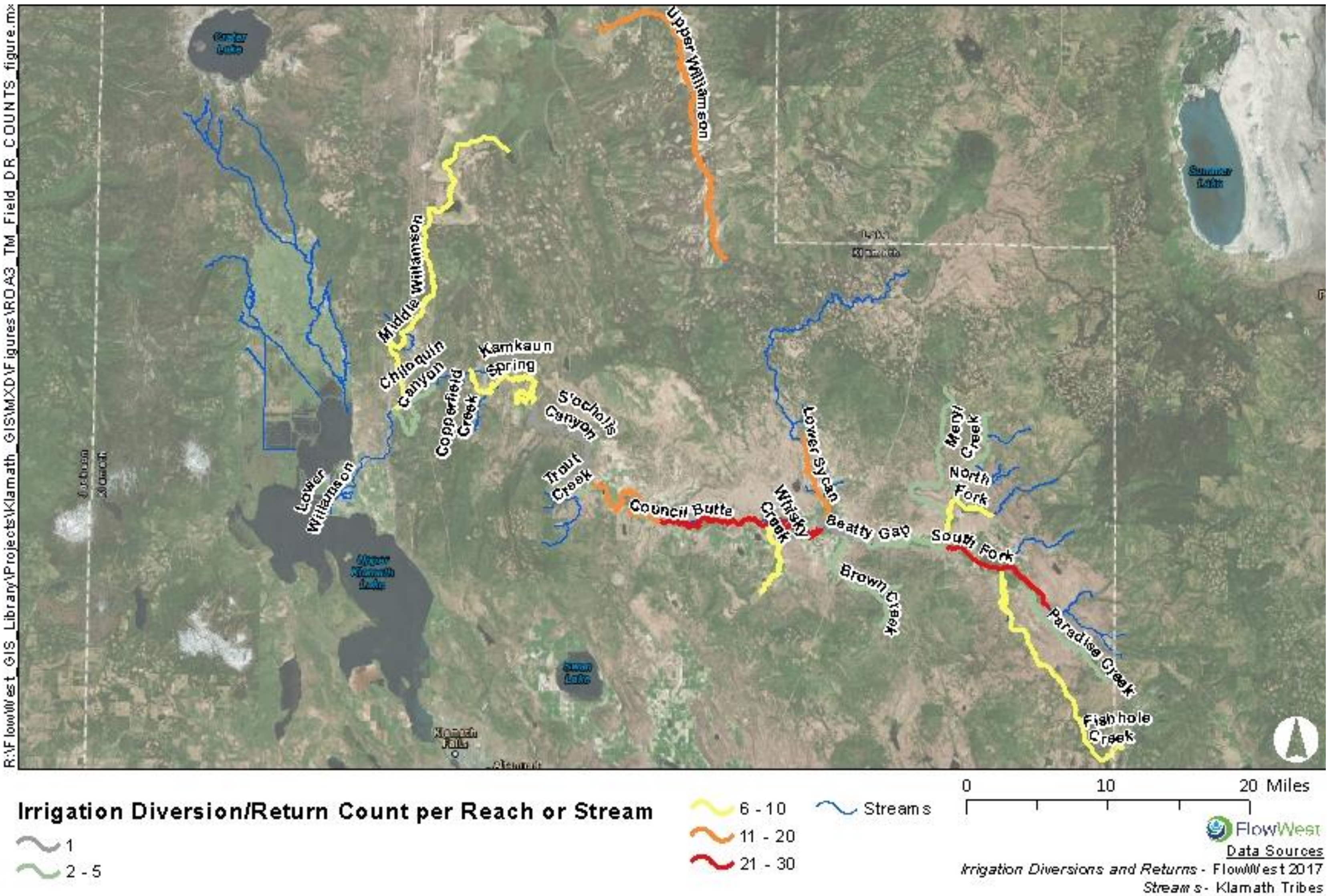

FIGURE 24: IRRIGATION DIVERSION AND RETURN POINTS PER REACH OR STREAM IN THE SPRAGUE AND WILLIAMSON RIVER WATERSHEDS. THE "STREAMS" LAYER DEPICTS WATER BODIES THAT EITHER HAD NO IDENTIFIABLE IRRIGATION DIVERSIONS OR RETURNS, OR WERE NOT INCLUDED IN THE STUDY SCOPE.

Discussion of Results

Reconnaissance-level field verification was very useful in this analysis, and implementing a systematic field verification process in collaboration with landowners would improve the quality of the data derived from aerial photographs and topography.

To further prioritize channel realignment restoration sites, the provided shapefile can be queried to refine the number of sites. For example, channel change sites related to restoration projects could be queried out of the shapefile. This would reduce 26 potential restoration sites from consideration. Further, channel changes that likely resulted from infrastructure (79 sites) could be selected and prioritized. A detailed study of flood control opportunities in the leveed reach of the South Fork Sprague River should be considered where there is a high concentration of historical channel realignment. There has been significant channel manipulation in the Upper Williamson reach that should be investigated further. Our analysis did not include the Klamath Marsh, but major channel alignment changes are evident from a brief review of the historical aerial images.

The results of the flow obstruction analysis identify several reaches and creeks with high densities of structures (50 or greater) impeding natural flow and morphology: the Upper Williamson, the Kamkaun Spring and Council Butte reaches of the Sprague River, the North Fork Sprague River, the South Fork Sprague River, and Whisky Creek, as shown in Figure 23. Flow obstructions related to irrigation uses (i.e. canals and ditches) are the most predominant in all of these reaches and creeks. The count per reach or creek index provides a summary breakdown of all of the results, however the flow obstruction database can further queried and analyzed to prioritize restoration activities.

Irrigation diversions and returns points are predominant in several reaches and creeks in the study area, consistent with the predominance of flow obstructions related to agricultural irrigation activities. The Council Butte reach of the Sprague River has the most identified diversion and return points at 29. This section of the Sprague River has concentrated agricultural use. The South Fork Sprague River has the second-highest number of these points at 22, while the Upper Williamson—also an area of significant agricultural activity—has 20. The results of this study should be integrated with current efforts undertaken by other stakeholders to map irrigation diversion and returns points in the Wood River Valley to maximize the effectiveness of restoration planning and implementation.

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