TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

This page intentionally blank.

2.3 STREAM CHANNEL MORPHOLOGY AND AQUATIC HABITAT STUDY (WTS 3)

2.3.1 Study Objectives

The objectives of the Stream Channel Morphology and Aquatic Habitat Study are to: (1) document existing aquatic habitat values in project-affected stream reaches; (2) assess how operation of the Lewis River Projects would affect stream morphology and aquatic habitat values during the period of the new license; and (3) provide information on the effects of potential management changes to water, wood, and sediment inputs in project-affected reaches.

2.3.2 Study Area

The study area for the Stream Channel Morphology and Aquatic Habitat Study is the Lewis River between Merwin Dam and Eagle Island, the Swift bypass reach, and Speelyai Creek.

2.3.3 Methods

To provide information on current aquatic habitat conditions and how these values may change over time under different river management scenarios, existing aquatic habitat, river geomorphology, and river changes through time have been evaluated. The primary reason for looking at changes in the river through time was to help predict how the river channel and corresponding aquatic habitat values may change in the future under the new licenses. Information on the amount of sediment supplied to the reach under current conditions and the location of these inputs was also collected.

The following sections describe the information collected and analyzed in each of the 3 study reaches. Similar information was collected in each reach, with some variations between reaches as noted below.

2.3.3.1. Lewis River Downstream of Merwin Dam

Pre-field Work

Sediment Input: A sediment input budget for the watershed area that currently contributes to Lewis River between Merwin Dam and Eagle Island was prepared (includes Colvin Creek, Johnson Creek, Cedar Creek, Ross Creek, and other un-named tributaries and side slopes to river). Sediment inputs considered include: (1) landslides; (2) soil creep and bank erosion; and (3) road surface erosion. Sediment input from each source was compiled and separated into fine-grained sediment (<0.1 inches - sand, silt, clay) and coarse-grained sediment (>0.1 inches - gravel, cobble, boulder) from each source based on dominant soil types and gradation information from the Cowlitz, Clark, and Skamania County soil surveys (USDA 1972, 1974, 1989).

Landslide input was estimated through a landslide inventory and volume calculation. The Landslide Inventory method is described in WDNR (1997, pages A-17 through

A-22). Landslides were mapped from the 1963, 1974, 1988, and 1993 historic aerial photographs. The volume of sediment supplied to streams from landslides was estimated based on the inventory. Volume from each slide was based on landslide dimensions (width and length measured on aerial photos, with average depths of 5 feet for shallow slides and debris torrents [USDA 1972, 1974] and 15 feet for small sporadic deep-seated failures). Delivery of debris from each landslide to a stream was noted based on proximity of the slide to a stream and observations of run-out zones. The total amount of sediment supplied during each photo period was summed and separated into fine- and coarse-grained inputs based on grain size data from county soil surveys (USDA 1972, 1974).

Soil creep and road surface erosion was calculated using the GIS-based SEDMODL program. This model delineates which road segments contribute sediment to streams and estimates surface erosion contributed from each segment based on road characteristics. Road surface erosion was considered fine-grained sediment. The model calculates soil creep based on average creep rates and soil depths along all stream channels. Soil creep was separated into fine/coarse grained inputs based on county soil surveys.

Areas with eroding banks were noted in the field, along with average bank heights and bank composition (gravel, cobble, etc.) The historic channel maps were overlaid to determine if rates of bank erosion could be measured on successive years. However, it was found that the channel was actually being straightened (as a result of gravel mining) so that meanders were not migrating. As a result, bank erosion rates could not be measured from the maps and bank erosion was not estimated.

Stream channel mapping: An initial map of the stream channel and habitat units was prepared on overlays to the 1996 aerial photographs of river (1:7,200 scale). Map units included: riffle, pool, glide, and cascade, as outlined in AFS (1985) and Bisson et al. (1981). Side channels were also delineated and mapped.

A map of the stream channel and side channels was also prepared on overlays to historic aerial photographs (1938, 1963, 1974, and 1988 – see Table 2.3-1 for photos selected based on events of geomorphic significance). The maps were digitized into GIS so successive years could be compared at the same scale to analyze channel changes through time. Large woody debris visible on historic photos was also counted on the 1938 photos to provide some indication of historic wood loading levels.

Channel Changes

Available stream gage rating tables/curves for the Lewis River at Ariel gage (14220500) were obtained from the U.S. Geological Survey (USGS). The only rating tables found were from the period 1982 to present and a table from 1975. Earlier records have been lost. The river stage was determined from each rating table at a flow of 1,000 cfs, 4,000 cfs, and 10,000 cfs. This information was plotted to determine if any systematic changes in river stage at a given flow are occurring that could be the result of channel aggradation or incision. It was hoped that longitudinal profiles of the river between the 1975 US Army Corps of Engineers profile and a more recent profile could be compared. However, no more recent profiles have been made, so this analysis could not be performed.

Table 2.3-1. Aerial photos used for stream mapping between Merwin Dam and Eagle Island and events of geomorphic significance.

Year	Figure	Aerial photograph date	Scale(inches:feet)	Discharge (cfs at Ariel gage)
1934	*Flood of record at Ariel Gage (129,000 cfs)*			
1932	*Merwin Dam begins operation*			
1937	*High flow (62,000 cfs) at Ariel Gage*			
1938	2.3-1a	3/10/38		4,320
1946	*High flow (67,000 cfs) at Ariel Gage*			
1953	*Yale Dam begins operation*			
1958/59	*Swift Dam begins operation*			
1962	*High flow (76,000 cfs) at Ariel Gage*			
1963	2.3-1b	5/29/63	1:12,000	3,180
1974	2.3-1c	6/13/74 (RM 9-16) 6/29/74 (RM 17-18) 5/5/74 (RM 19-20)	1:12,000	8,060 3,800 1,010
1975	*High flow (65,000 cfs) at Ariel Gage*			
1977	*High flow (72,000 cfs) at Ariel Gage*			
1988	2.3-1d	6/20/88 (RM 9-13) 6/24/88 (RM 13-20)	1:12,000	2,030 2,030
1993	2.3-1e	8/30/93 (RM 9-13) 9/3/93 (RM 13-20)	1:12,000	1,250 1,260
1996	*High flow (86,000 cfs) at Ariel Gage*			
1996	2.3-1f	10/7/96	1:7,200	2,470

Information from other studies of sediment transport and movement in bedrock channels was collected for comparison with the reach downstream of Merwin.

Fish spawning: Resource agency personnel who conduct spawning surveys in the Lewis River downstream of Merwin Dam were contacted to document where fish spawn, to get their impressions of where and how often gravel in the reach moves, and to discuss how this affects fish spawning areas. Information on the number of fall Chinook redds counted during the surveys was also obtained and graphed to determine if there have been any trends in fish use of the reach.

Large woody debris: Project operators responsible for collection and disposal of large woody debris in project reservoirs were contacted to help determine how much and what size wood is removed from the river system at project facilities.

<u>Field Surveys</u>

A field survey of the Lewis River between Merwin Dam and the downstream end of Eagle Island was made on September 11 and 12, 2000. The survey was conducted by boat. During the survey, the habitat map (1996 photo base) was field checked, habitat unit widths were measured, dominant/subdominant substrate was noted, and large woody debris were counted. Notes were made on acetate overlays on the 1996 aerial photographs.

During the field survey, back-eddies (areas where water flows upstream) were noted on the photo overlays as an indication of where eddies may also occur at higher flows. Anthropogenic constraints on the channel, such as riprap, boat ramps, or levees, were also marked.

Substrate was mapped on the overlays along with areas of suitable spawning-sized gravel. Substrate map units were based on dominant and sub-dominant particle sizes in the following categories:

- Silt
- Sand (<0.1 inch)
- Gravel (0.1–3 inches)
- Small Cobble (3–12 inches)
- Boulder (>12 inches)
- Bedrock

During the field survey, pebble counts and sub-armor samples were made at 12 locations, approximately every mile, between Merwin Dam and the downstream end of Eagle Island. A point count of 100 surface (armor) layer rocks was made at each pebble count location. The length of the median diameter of each rock was measured and assigned to one of the following size classes: less than 2 mm (0.08 in); 2 to 4 mm (0.08-0.16 in); 4 to 8 mm (0.16-0.3 in); 8 to 16 mm (0.3-0.6 in); 16 to 32 mm (0.6-1.3 in); 32 to 64 mm (1.3-2.5 in); 64 to 128 mm (2.5-5 in); and greater than 128 mm (5 in). A grab (shovel) sample of the sub-armor layer was also be taken for later dry sieving.

Samples of spawning gravel were also collected at 9 locations. At each site, 4 samples were taken along a riffle crest or gravel patch to help understand the variability of grain sizes and fine sediment content at that spawning area (Schuett-Hames et al. 1994).

Large woody debris within the bankfull width in each habitat unit was counted in the following size classes:

- Size Class 4 – over 36 inches in diameter, over 50 feet long
- Size Class 3 – over 24 inches in diameter, over 50 feet long
- Size Class 2 – over 12 inches in diameter, over 25 feet long
- Size Class 1 – over 6 inches in diameter, over 25 feet long (note: this size class was not counted in the Lewis River downstream of Merwin Dam but is included for consistency.)

Large woody debris with special attributes (i.e. rootwads, big root wads, jams) was noted. Potential large woody debris, defined for this survey as standing trees leaning over the bankfull channel, was counted separately in the Size Class 3 and 4.

Field Data Analysis

Spawning gravel samples were dry-sieved based on the method in Schuett-Hames et al. (1994) and particle size distribution, percent fines, median particle size, and Fredle Index were calculated. Sub-armor gravel grab samples were also dry-sieved. Pebble count data and sub-armor grab sample data were reduced to provide particle size distribution, mean particle size, D_{50}, D_{16} and D_{84}.

The geometric mean of the sample (D_g) is defined as D_g=(D_1W^1 x D_2W^2 x ….. D_nW^n) where D_n is the midpoint diameter of particles retained on the nth sieve and W_n is the decimal fraction of particles retained on the nth sieve.

The sorting coefficient is defined as D_{75} divided by D_{25} and is a dimensionless coefficient.

The Fredle Index is defined as D_g (in mm) divided by the sorting coefficient.

2.3.3.2. Swift Bypass Reach

Pre-field Work

Sediment Input: A sediment input budget for the watershed area that currently contributes to Swift bypass reach was prepared (including Rain and Ole creeks). Sediment inputs include: (1) landslides; (2) soil creep; and (3) road surface erosion. Sediment input from each source was computed based on the methods described in Section 2.3.3.1. The landslide inventory was based on the 1963, 1974, 1980, 1988, and 1993 aerial photographs.

Stream Channel Mapping: Stream channel maps of the Lewis River between Swift Dam and Yale Lake were prepared from the 1958, 1963, 1974, 1988, 1995, and 1998 aerial photographs. The maps show the extent of the wetted channel, side channels, and active bars on the dates flown (Table 2.3-2).

Channel Changes: Available stream gage rating tables/curves for the Lewis River at Cougar gage (14220500) were obtained from the USGS. The river stage was determined at a flow of 1,000 cfs, 4,000 cfs, and 10,000 cfs from each rating table. This information was plotted to determine if any systematic changes in river stage at a given flow are occurring that could be the result of channel aggradation or incision.

Field Surveys

A field survey of the Lewis River between Swift Dam and the Yale Lake was made on September 11 and 12, 1999. Methods of sampling were the same as described in Section 2.3.3.1.

Table 2.3-2. Aerial photos used for stream mapping in the Swift bypass reach and major spill events (over 20,000 cfs).

Year	Shown on Figure No.	Aerial Photograph Date	Scale (inches:inches)
1958	2.3-7a	9/5/58	
1958	*Operation of Swift No. 1 and No. 2 begins in December 1958*		
1962	*Spill of 20,500 cfs*		
1963	2.3-7b	7/6/63	1:12,000
1974	*Spill of 22,500 cfs*		
1974	2.3-7c	9/28/74	1:12,000
1975	*Spill of 41,100 cfs*		
1977	*Spills of 25,600 and 24,600 cfs*		
1980	*Spill of 31,600 cfs*		
1982	*Spill of 20,200 cfs*		
1988	2.3-7d	7/23/88	1:12,000
1990	*Spill of 22,800 cfs*		
1995	2.3-7e	7/15/95	1:7,920
1995	*Spill of 25,200 cfs*		
1996	*Spill of 44,700 cfs*		
1998	2.8-7f	6/28/98	1:7,200

Large woody debris was counted in size classes 1-4 (aquatic habitat mapping was completed previously in 1999). Substrate was also mapped on acetate overlays on the aerial photos along with areas of suitable spawning-sized gravel. During the field survey, pebble counts and sub-armor samples were made at 3 locations, approximately every mile. Samples of spawning gravel were also collected at 2 locations in the bypass reach and 1 location in Ole Creek, with 4 samples taken at each site. Sampling methods are described in Section 2.3.3.1.

Potential sources of sediment (terraces, landslides, tributaries) seen during the field survey were noted on the overlays. Estimates were made of dimensions (terrace height, landslide length, width, depth) as well as a visual estimate of particle sizes supplied by the source (estimated percent boulder, cobble, gravel, sand, etc.).

Painted Gravel Study: On May 11, 2000, painted rocks were placed at 4 locations within the Swift bypass reach of the Lewis River. The purpose was to monitor gravel movement during releases for the instream flow study, to help calibrate proposed bedload transport modeling. A patch of painted gravel was placed mid-channel just downstream from 3 of the instream flow study riffle transects (transects 45-1, 26-1, and 10-1) to simulate added spawning-sized gravel, and 43 painted rocks were placed 1 foot apart along the spawning transect (transect 6). The rocks to be painted were taken from bars on the lower Lewis River, and were a mix of particles between 0.5 and 6 inches (12.7-152 mm) in diameter. Flows of approximately 60, 140, and 300 cfs were released into the reach during the week of May 15, 2000 for the instream flow study. Painted rocks were visually inspected by the instream flow crew following each flow release. The rocks were also inspected during the September 13, 2000 gravel survey of the reach.

Data Analysis

Spawning gravel samples were dry-sieved based on the method in Schuett-Hames et al. (1994) and particle size distribution, percent fines, median particle size, and Fredle Index were calculated. Substrate samples were also dry-sieved, and particle size distribution and median particle size were calculated.

The WINXSPRO program was used to perform hydraulic and bedload transport modeling at 3 transects in the Swift bypass reach. The purpose of the modeling was to determine the flows that would transport spawning gravel-sized particles (median diameter 1.25 in/32 mm). Hydraulic information (cross-sections, water slope) was obtained from measurements taken during the instream flow study (AQU 2) at transects (Habitat Units) 6, 18, and 45. Hydraulic modeling was performed using the Nelson et al. (1991) or Thorne and Zevenbergen (1985) equations. Water surface elevations were obtained from the USGS topographic maps and by computing slope from difference in water surface elevations between the instream flow transects. Particle size information was obtained from the substrate sampling data. Bedload rating curves were calculated in the WINXSPRO program using the Meyer-Peter Müller (1948) and Parker et al. (1982) formulas.

2.3.3.3 Speelyai Creek

Pre-field Work

Sediment Input: A sediment input budget for the watershed area that contributes to Speelyai Creek was prepared. Sediment inputs considered included (1) landslides; (2) soil creep; and (3) road surface erosion. Sediment input from each source was computed based on the methods described in Section 2.3.3.1. The landslide inventory was based on the 1963, 1974, 1980, 1988, and 1993 aerial photographs.

Channel Changes: Available stream gage rating tables/curves for Speelyai Creek at Cougar gage (14219800) were obtained from the USGS. The river stage at a flow of 50 cfs, 100 cfs, and 500 cfs was determined from each rating table. This information was plotted to determine if any systematic changes in river stage at a given flow are occurring that could be the result of channel aggradation or incision.

Field Surveys

A field survey of Speelyai Creek between Merwin Lake and approximately 0.5 mile (0.8 km) upstream of the PacifiCorp diversion structure was made on September 25-28, 2000. The Speelyai Canal reach was also inventoried between Yale Lake and the PacifiCorp diversion. An aquatic habitat inventory was conducted. Habitat unit widths and lengths were measured, dominant/subdominant substrate and areas of spawning gravel were noted, and large woody debris was counted.

During the field survey, pebble counts and sub-armor samples were made at 10 locations, approximately every half mile to mile. Hydraulic information (cross section, water slope) was measured at each pebble count location using a hand level, survey rod, and tape.

Anthropogenic constraints on the channel, such as riprap, old bridge abutments, or levees, were noted as they were observed in the field. Houses/cabins located in close proximity to Speelyai Creek were also noted to help identify potential effects on structures if flows from upper Speelyai are altered.

Data Analysis

Hydraulic modeling using the WINXSPRO program was performed at 7 cross-sections in lower Speelyai Creek, 3 cross-sections in upper Speelyai Creek, and at 3 bridges in lower Speelyai Creek. The model was used to predict the change in water surface elevation at the 10 cross-sections under different flows, and to calculate the flow that could pass under the bridges without touching the underside of the bridge deck. The computations were used to assess the effects of different flow scenarios on water levels, bridges, and structures along lower Speelyai Canal.

2.3.4 Key Questions

The study is designed to address the following key questions in the 3 project-affected reaches (Lewis River downstream of Merwin Dam; Swift bypass reach; Speelyai Creek downstream of the canal diversion):

- What is the location, areal extent, and quality of salmonid spawning gravels downstream of Merwin?
- How does the quality of salmonid spawning gravels differ between areas?
- Where do side channel habitats occur downstream of Merwin?
- Have there been changes to the distribution and abundance of side channel habitat from historical conditions?
- How has the regulation of flows (especially peaking flows and ramping rates) affected salmonid spawning gravels downstream of the dams?
- How does the project affect the storage and downstream transport of LWD?
- What have been the effects of recent floods on fluvial geomorphic processes, channel morphology, and aquatic and riparian habitats and what might be the effects of future floods?
- Where might LWD placement increase the quality or quantity of habitat for aquatic species?
- At what seasons or flows would sediment augmentation be appropriate?

- How does the hydroelectric project affect the downstream passage of sediment and large woody debris?

The study is intended to partially address the following key questions (underlined portions addressed in this study):

- How have riparian conditions, sediment processes, LWD loading and characteristics, and hydrology changed from reference conditions and what are the current conditions for these watershed characteristics?
- Has the storage of fine sediments increased in streams due to flow regulation by the project? (focused on salmonid spawning gravels, not all portions of stream)
- How has the regulation of flows affected channel morphology, sediment transport, and riparian habitat?
- What is the effect of flood management on stream and floodplain ecosystems?
- What have been the effects of forest management practices on sediment supply, hydrology, instream large woody debris, riparian habitats, and channel morphology? (in selected reaches: downstream of Merwin, Swift bypass reach, and Speelyai Creek)
- How would restoration of instream flows to lower Speelyai Creek affect the stream channel and which species might benefit?

2.3.5 Results

2.3.5.1 Lewis River Downstream of Merwin Dam

Sediment Input

A sediment input budget was prepared for the Lewis River watershed between Merwin Dam and the downstream end of Eagle Island. Estimated average annual sediment input from soil creep, landslides, and road surface erosion was calculated. The average total sediment input to the lower Lewis River (excluding Cedar Creek) was 6,890 tons/year, primarily from management-related landslides along Colvin and Johnson creeks (Table 2.3-3). There are additional inputs of sediment from bank erosion along the Lewis River, but this input could not be quantified because the rate of bank erosion could not be determined from the aerial photograph record.

The average annual sediment input to the Cedar Creek watershed was 1,560 tons/year, with the majority coming from natural (background) landslides.

Table 2.3-3. Sediment inputs (average tons/year).

Source	Reach	
	Lewis River from Merwin Dam to Eagle Island (32 sq mi; excluding Cedar Creek)	Cedar Creek (55 sq mi)
Soil Creep	310	480
"Background" Landslides (clearcuts >50 years old)	500	630
Management-related landslides (road and recent clearcuts)	5,740	300
Road Surface Erosion	40	150
Total (tons)	**6,590**	**1,560**
Total tons/square mile/year	205	28

Based on the average grain size distribution of soils along streams (Table 2.3-4), the majority of the sediment inputs to Cedar Creek and the lower Lewis River are fine-grained (sand/silt/clay). Approximately 30 percent of the inputs to Cedar Creek are gravel and larger sized; only 8 percent of the inputs to the lower Lewis River are coarse-grained.

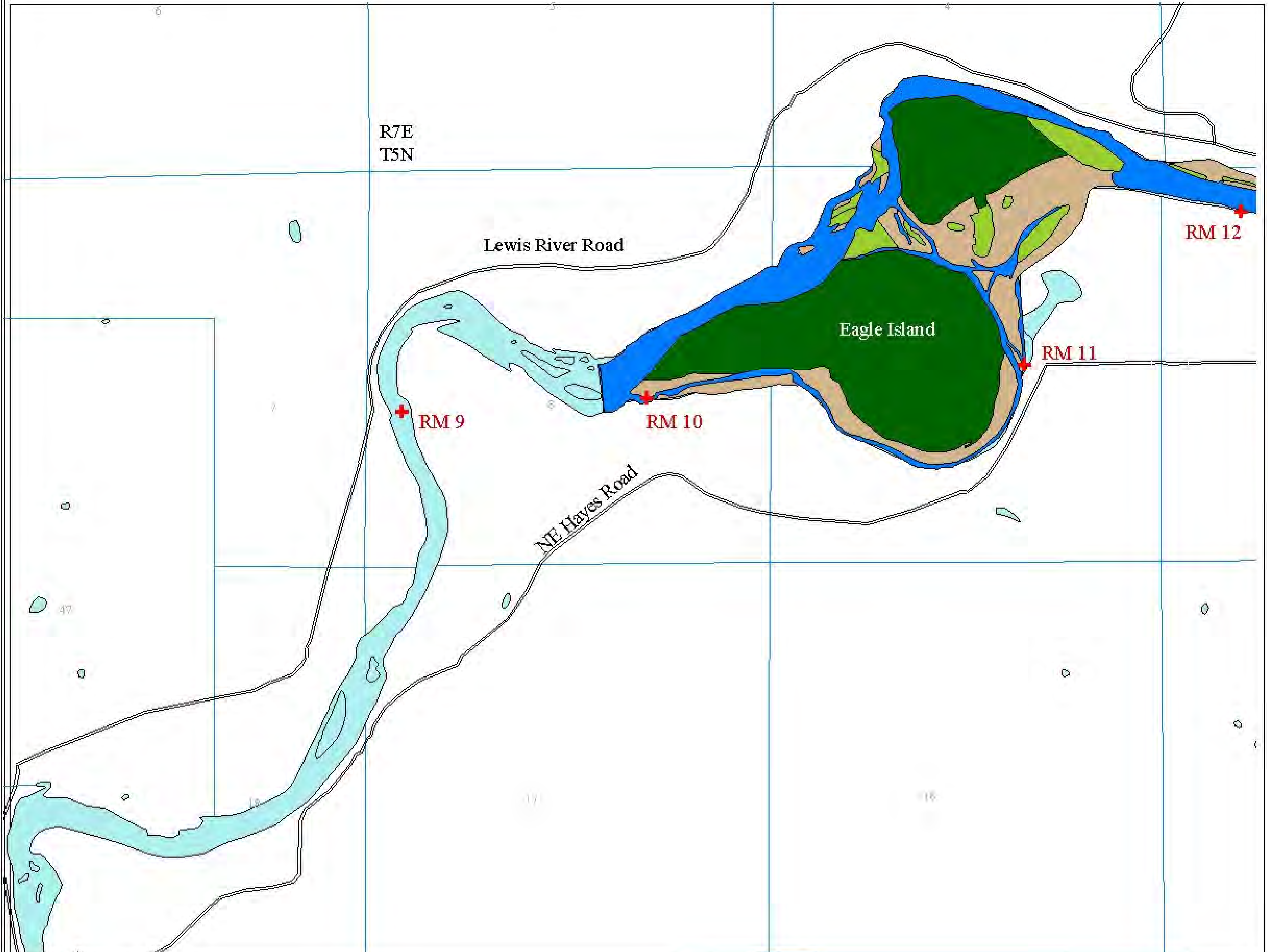
Table 2.3-4. Average grain size distribution of dominant soils in Lewis River sub-basins analyzed.

Sub-basin	Dominant Soil Series	Gravel (percent)	Sand (percent)	Silt/Clay (percent)
Lewis downstream of Merwin	Olympic silt loam	8	12	80
Cedar Creek	Cinnebar/Yacolt	30	10	60
Rain/Ole/Swift bypass	Swift	54	10	26
Upper Speelyai	Cinnebar	24	14	62
Lower Speelyai	Sifton gravelly loam	52	31	17

<u>Stream Channel Mapping</u>

Stream channel maps of the Lewis River between Merwin Dam and the downstream end of Eagle Island were prepared from the 1938, 1963, 1974, 1988, 1993, and 1996 aerial photographs (Figure 2.3-1 a through f) to compare channel position and changes in active bars and islands.

The Lewis River channel flows through a confined bedrock valley from Merwin Dam (River Mile (RM) 19.5) to just downstream of Cedar/Johnson creeks (RM 15). The river cannot migrate back and forth in this reach. Downstream of RM 15, the valley is 0.5 to 1 mile wide and the river can migrate back and forth between the valley walls. In this reach, the river contains mid-channel bars, numerous side channels, and Eagle Island, a large island that splits the channel between RM 10 and 11.7.



Lewis River
Hydroelectric Projects

Figure 2.3-1a
Stream Channel Changes in Lewis River Merwin Dam to Eagle Island

1938 Channel Position
Sheet 1 of 3

Channel Classifications

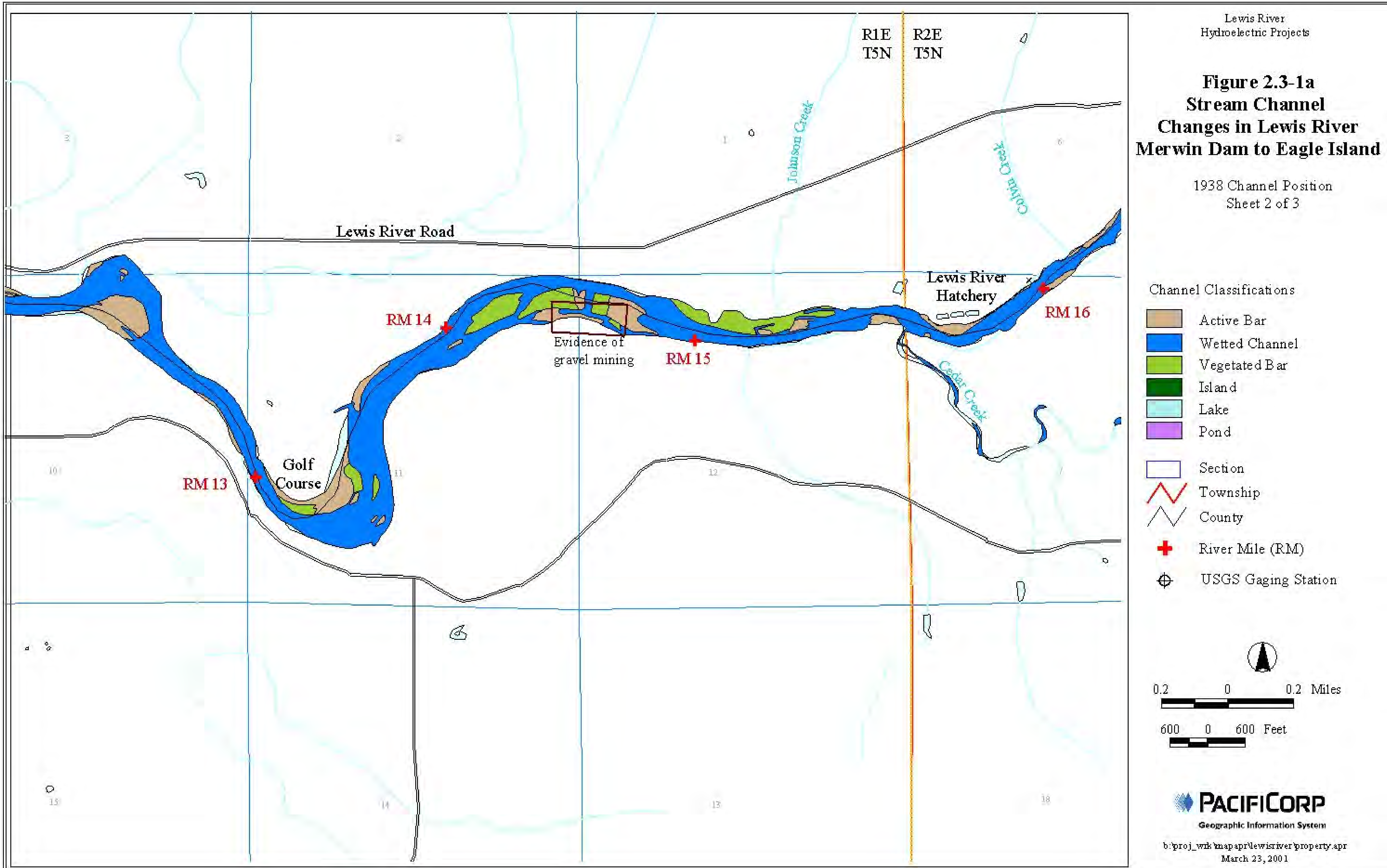
- Active Bar
- Wetted Channel
- Vegetated Bar
- Island
- Lake
- Pond
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

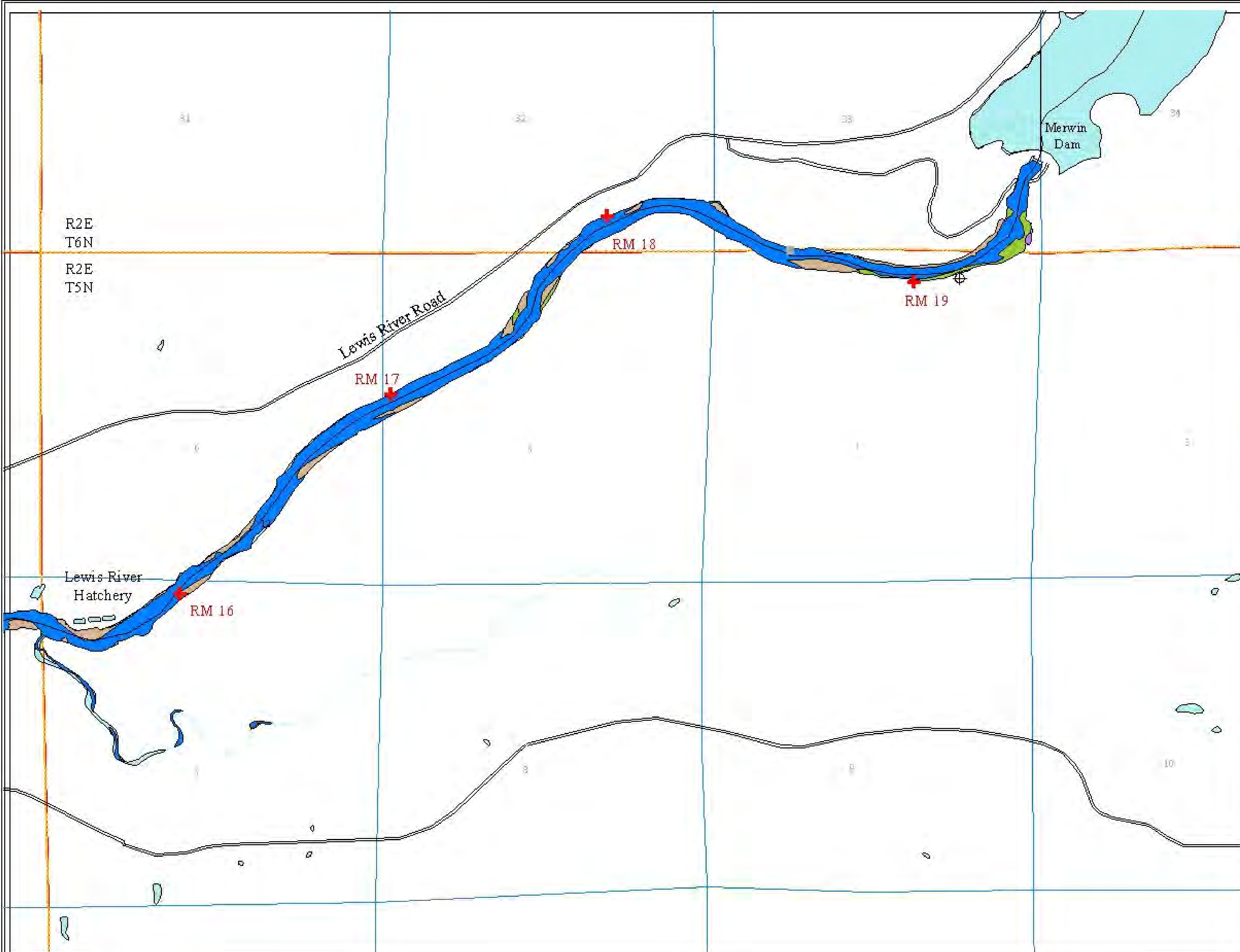
0.2 0 0.2 Miles

600 0 600 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001


Lewis River
Hydroelectric Projects
Figure 2.3-1a
Stream Channel
Changes in Lewis River
Merwin Dam to Eagle Island
1938 Channel Position
Sheet 2 of 3
R1E
T5N
R2E
T5N
Johnson Creek
Colvin Creek
Cedar Creek
Lewis River Road
Lewis River
Hatchery
RM 13
RM 14
RM 15
RM 16
Golf
Course
Evidence of
gravel mining
Channel Classifications
Active Bar
Wetted Channel
Vegetated Bar
Island
Lake
Pond
Section
Township
County
River Mile (RM)
USGS Gaging Station
0.2
0
0.2
Miles
600
0
600
Feet
PACIFICORP
Geographic Information System
b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects

Figure 2.3-1a
Stream Channel
Changes in Lewis River
Merwin Dam to Eagle Island

1938 Channel Position
Sheet 3 of 3

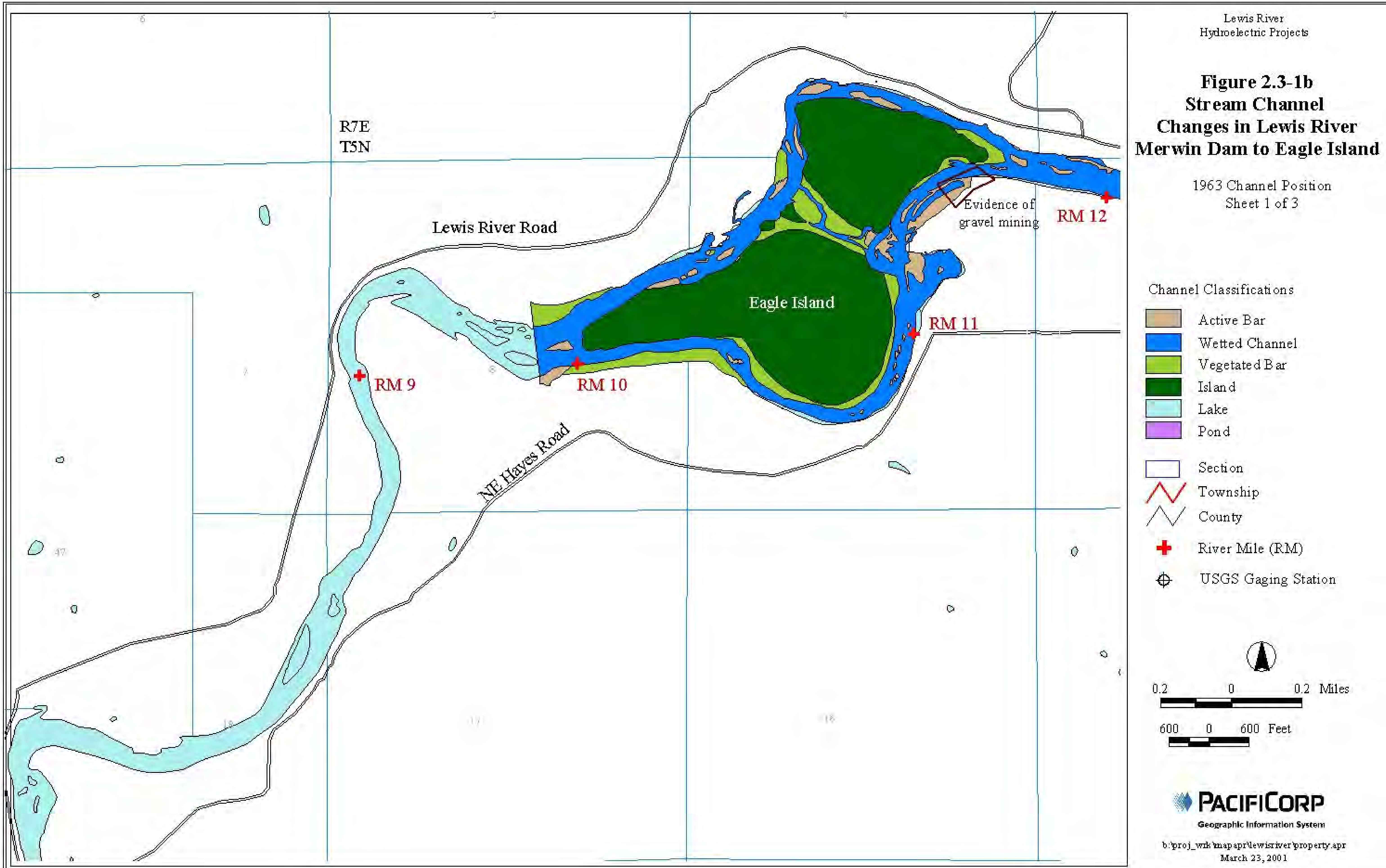
Channel Classifications

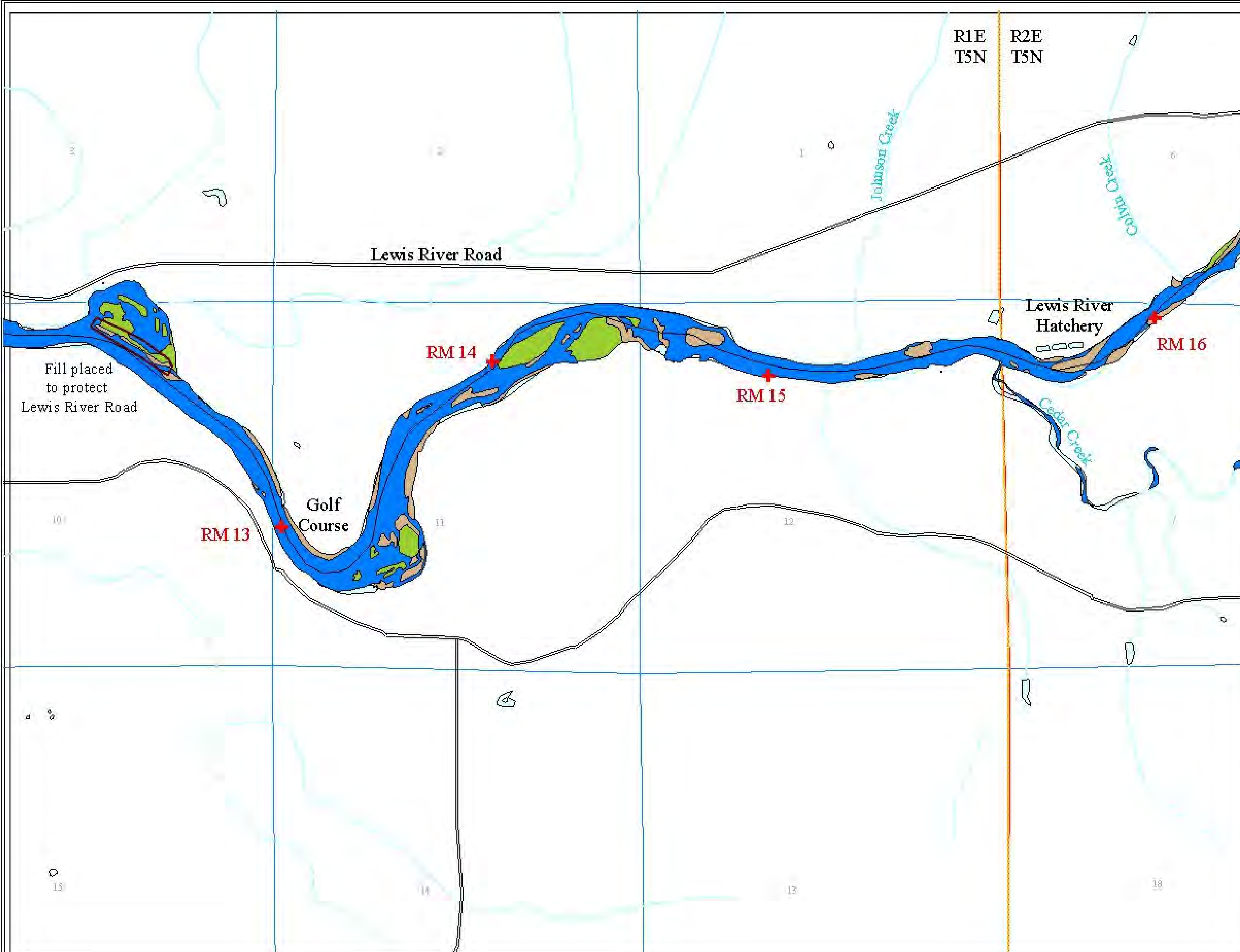
- Active Bar
- Wetted Channel
- Vegetated Bar
- Island
- Lake
- Pond
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles
700 0 700 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001


R7E
T5N
Lewis River Road
NE Hayes Road
Eagle Island
Evidence of
gravel mining
RM 9
RM 10
RM 11
RM 12
Lewis River
Hydroelectric Projects
Figure 2.3-1b
Stream Channel
Changes in Lewis River
Merwin Dam to Eagle Island
1963 Channel Position
Sheet 1 of 3
Channel Classifications
Active Bar
Wetted Channel
Vegetated Bar
Island
Lake
Pond
Section
Township
County
River Mile (RM)
USGS Gaging Station
0.2
0
0.2 Miles
600
0
600 Feet
PACIFICORP
Geographic Information System
b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects

Figure 2.3-1b
Stream Channel
Changes in Lewis River
Merwin Dam to Eagle Island

1963 Channel Position
Sheet 2 of 3

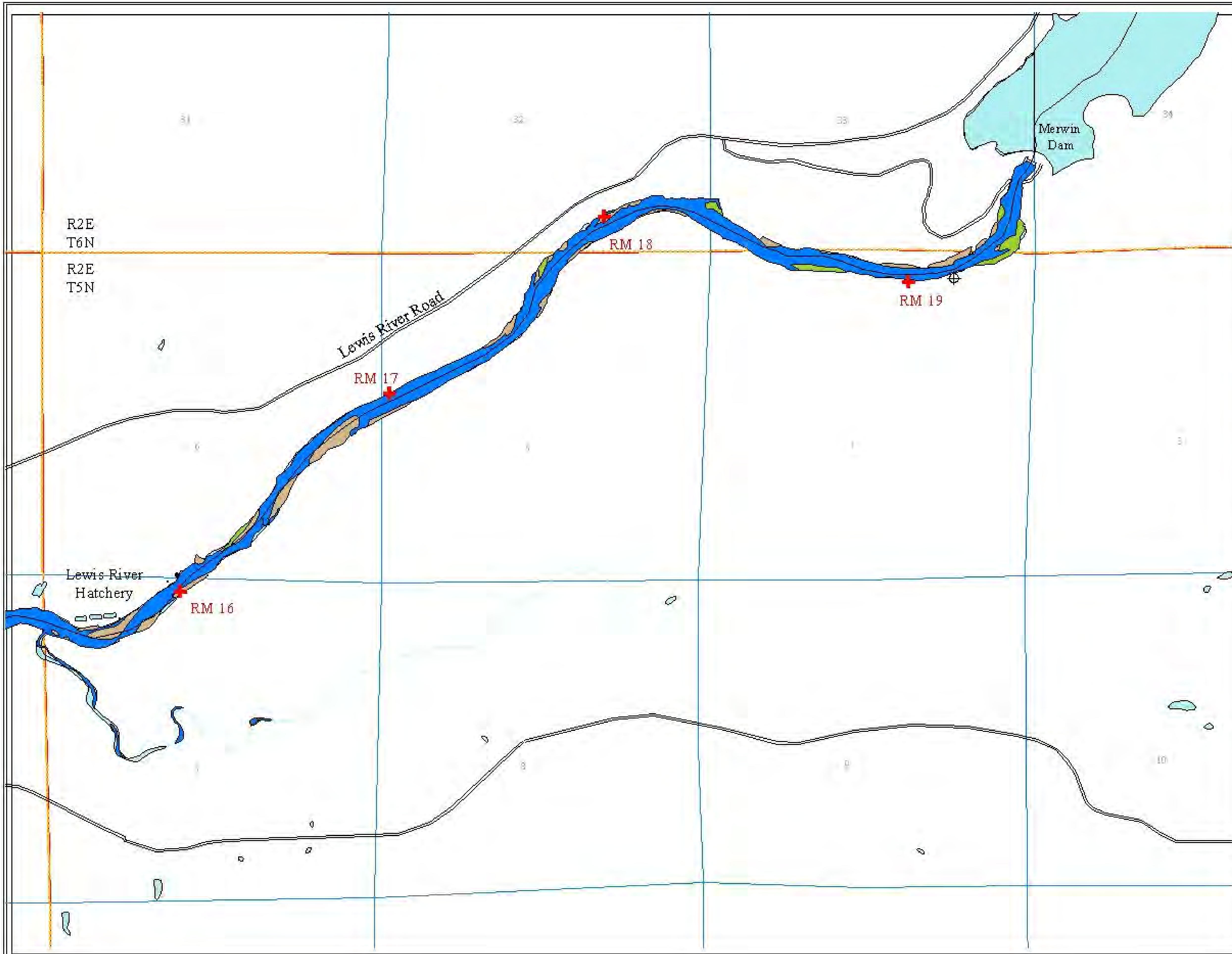
Channel Classifications
- Active Bar
- Wetted Channel
- Vegetated Bar
- Island
- Lake
- Pond
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

600 0 600 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects

Figure 2.3-1b
Stream Channel Changes in Lewis River Merwin Dam to Eagle Island

1963 Channel Position
Sheet 3 of 3

Channel Classifications

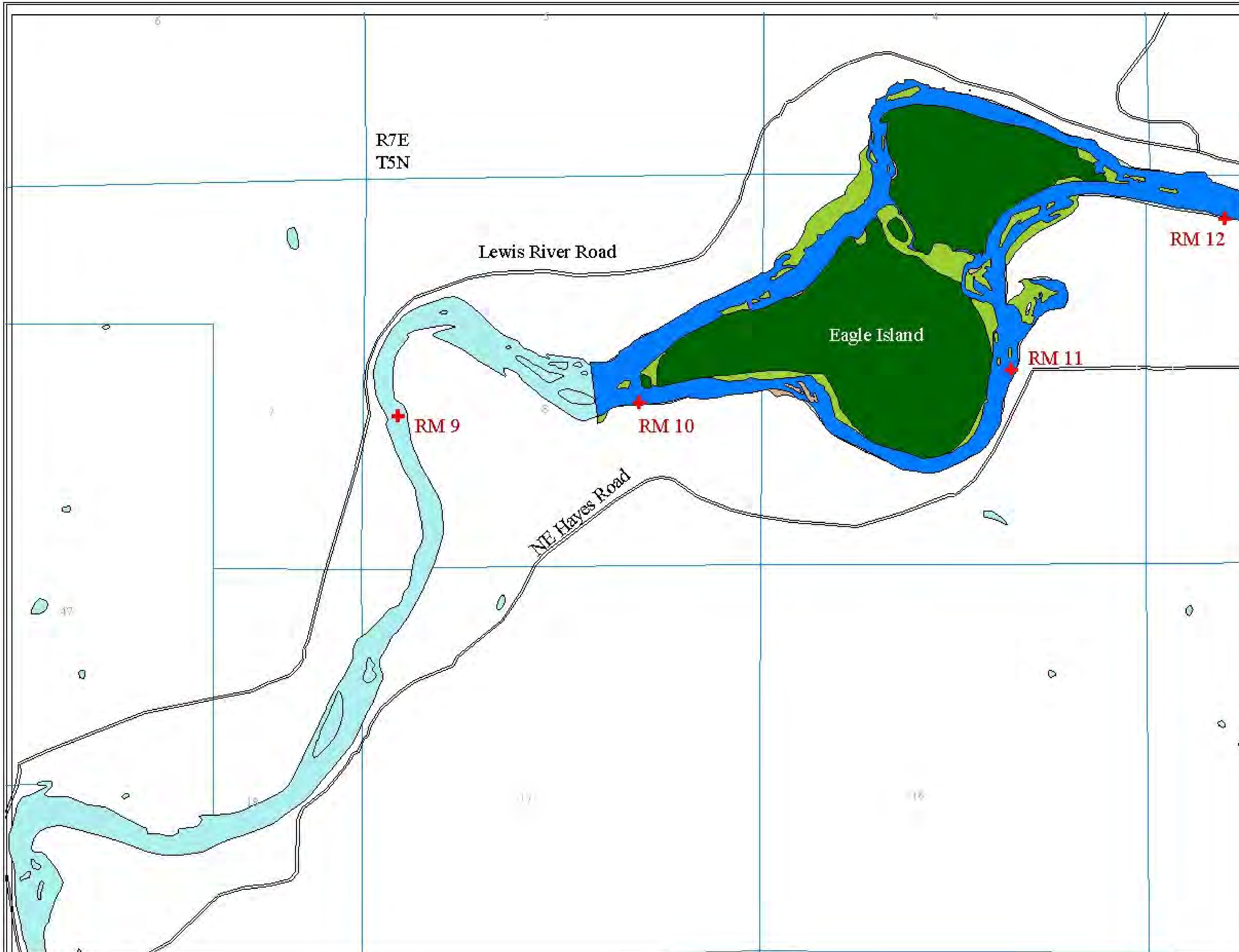
- Active Bar
- Wetted Channel
- Vegetated Bar
- Island
- Lake
- Pond
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

700 0 700 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects

Figure 2.3-1c Stream Channel Changes in Lewis River Merwin Dam to Eagle Island

1974 Channel Position
Sheet 1 of 3

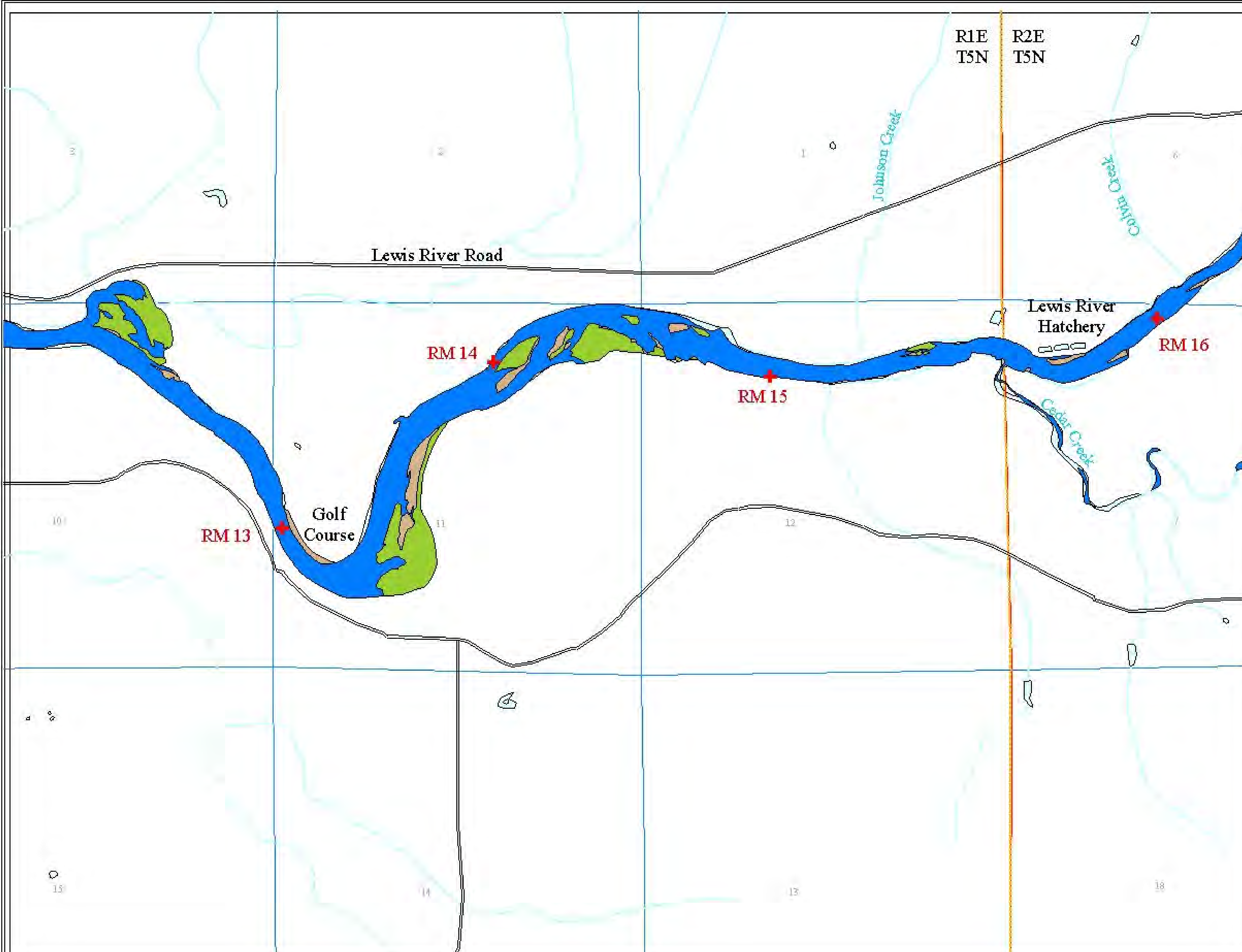
Channel Classifications
- Active Bar
- Wetted Channel
- Vegetated Bar
- Island
- Lake
- Pond
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

600 0 600 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects

Figure 2.3-1c
Stream Channel
Changes in Lewis River
Merwin Dam to Eagle Island

1974 Channel Position
Sheet 2 of 3

Channel Classifications

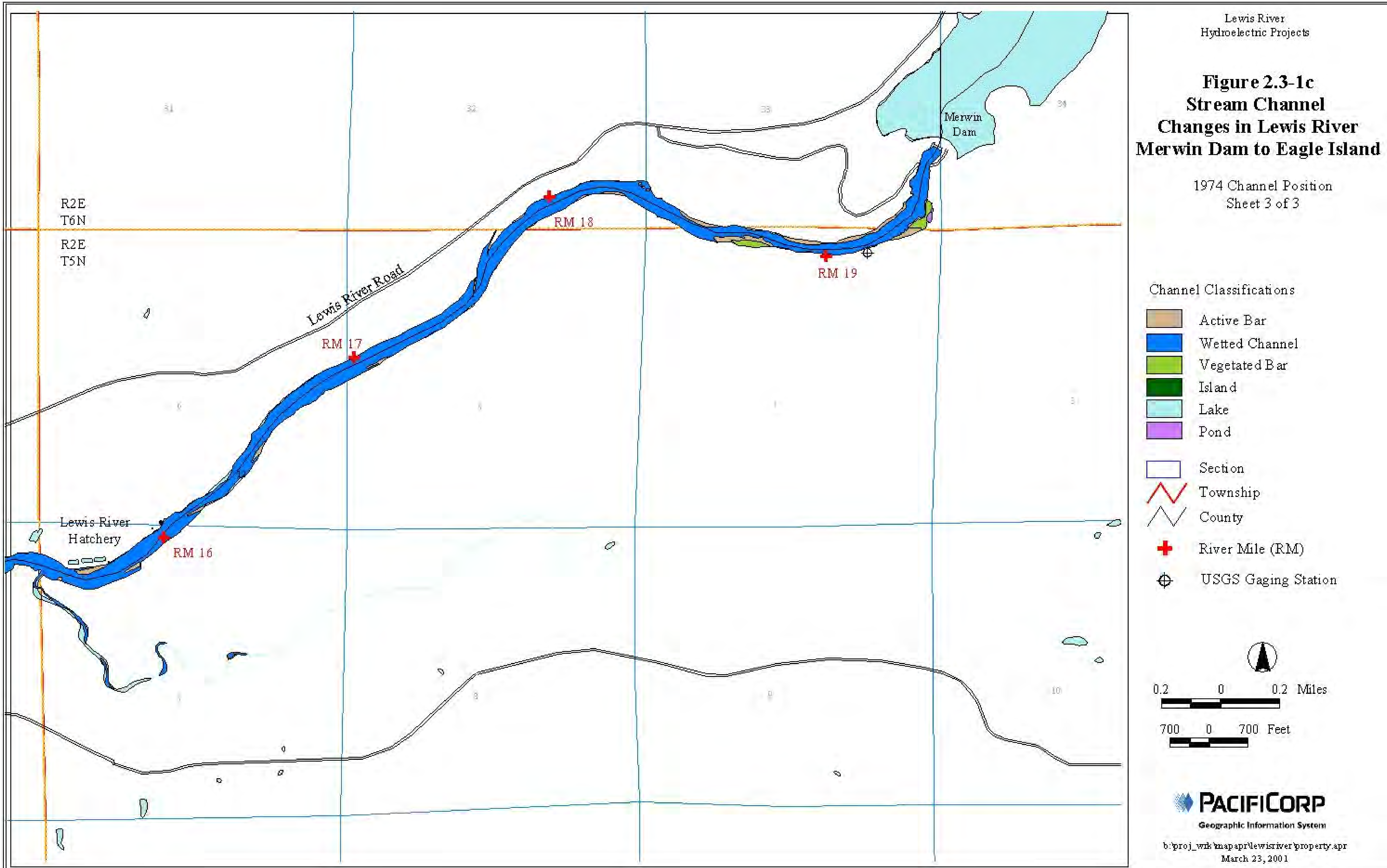
- Active Bar
- Wetted Channel
- Vegetated Bar
- Island
- Lake
- Pond
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

600 0 600 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001

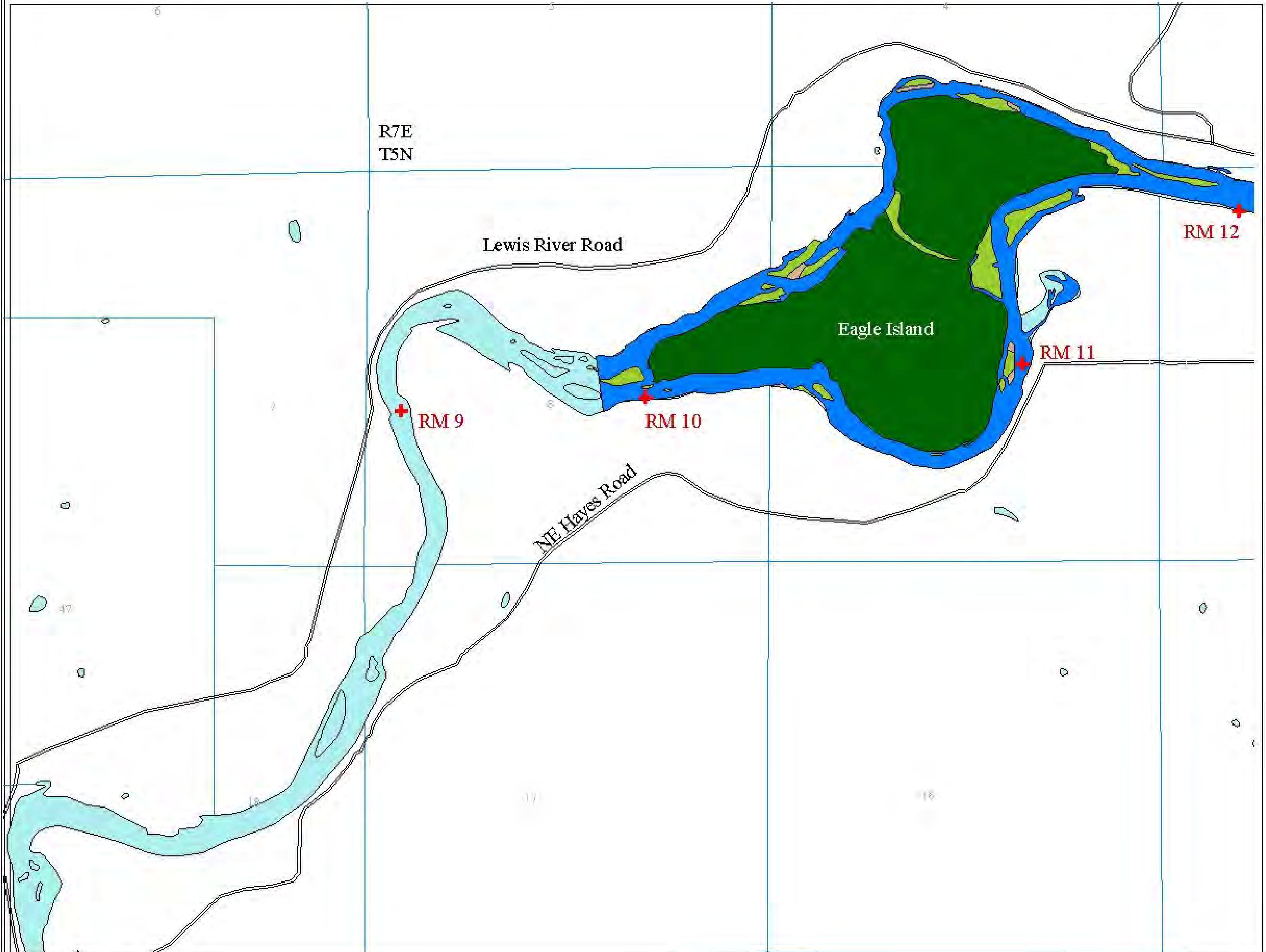


Lewis River
Hydroelectric Projects
Figure 2.3-1c
Stream Channel
Changes in Lewis River
Merwin Dam to Eagle Island
1974 Channel Position
Sheet 3 of 3
Channel Classifications
Active Bar
Wetted Channel
Vegetated Bar
Island
Lake
Pond
Section
Township
County
River Mile (RM)
USGS Gaging Station
0.2 0 0.2 Miles
700 0 700 Feet
Merwin Dam
R2E
T6N
R2E
T5N
Lewis River Road
RM 16
RM 17
RM 18
RM 19
Lewis River Hatchery
PACIFICORP
Geographic Information System
b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001

Lewis River
Hydroelectric Projects

Figure 2.3-1d
Stream Channel Changes in Lewis River Merwin Dam to Eagle Island

1988 Channel Position
Sheet 1 of 3



Channel Classifications

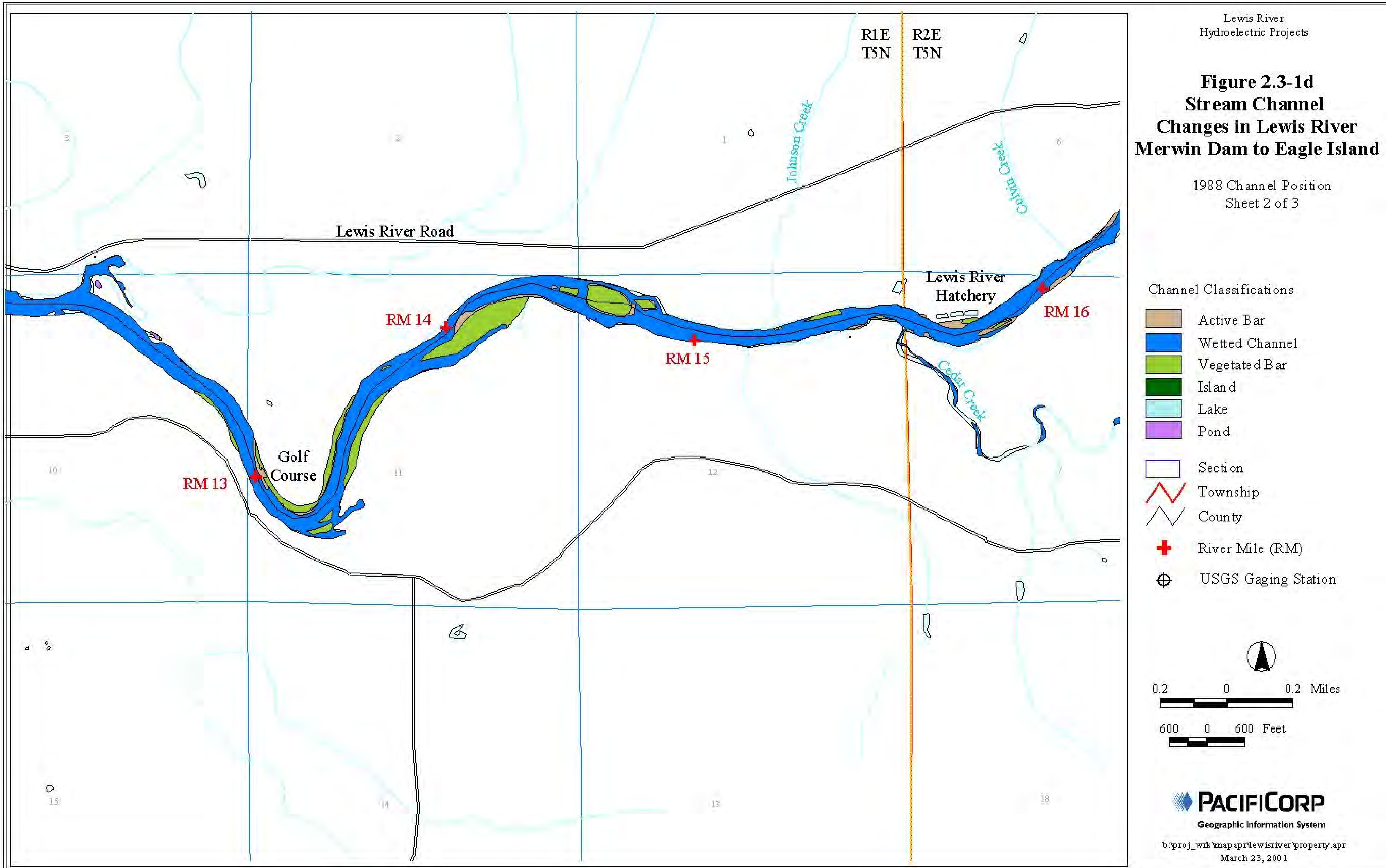
- Active Bar
- Wetted Channel
- Vegetated Bar
- Island
- Lake
- Pond
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

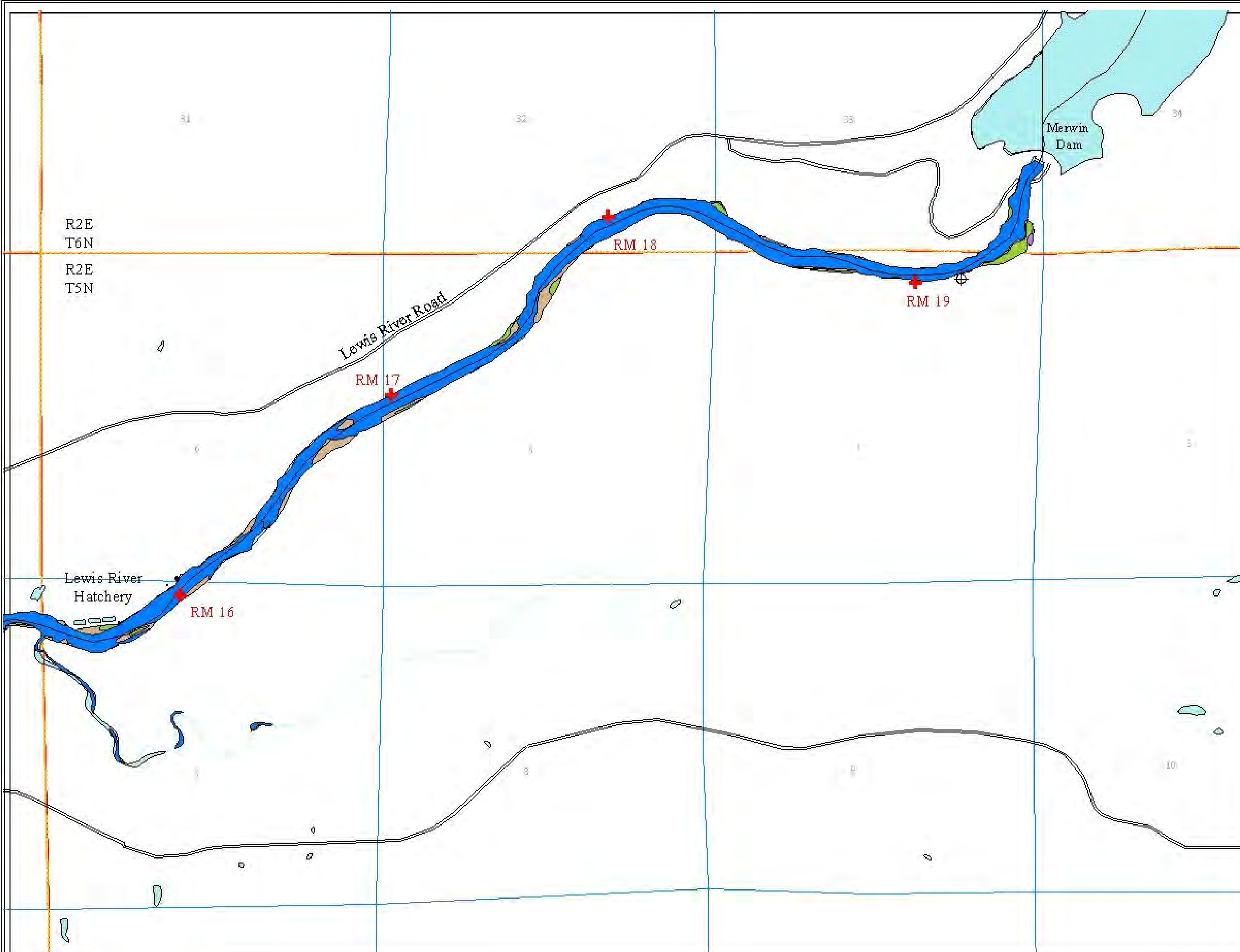
600 0 600 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects
Figure 2.3-1d
Stream Channel
Changes in Lewis River
Merwin Dam to Eagle Island
1988 Channel Position
Sheet 2 of 3
R1E
T5N
R2E
T5N
Johnson Creek
Colvin Creek
Cedar Creek
Lewis River Road
Lewis River
Hatchery
Golf
Course
RM 13
RM 14
RM 15
RM 16
Channel Classifications
Active Bar
Wetted Channel
Vegetated Bar
Island
Lake
Pond
Section
Township
County
River Mile (RM)
USGS Gaging Station
0.2 0 0.2 Miles
600 0 600 Feet
PACIFICORP
Geographic Information System
b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects

Figure 2.3-1d
Stream Channel
Changes in Lewis River
Merwin Dam to Eagle Island

1988 Channel Position
Sheet 3 of 3

Channel Classifications

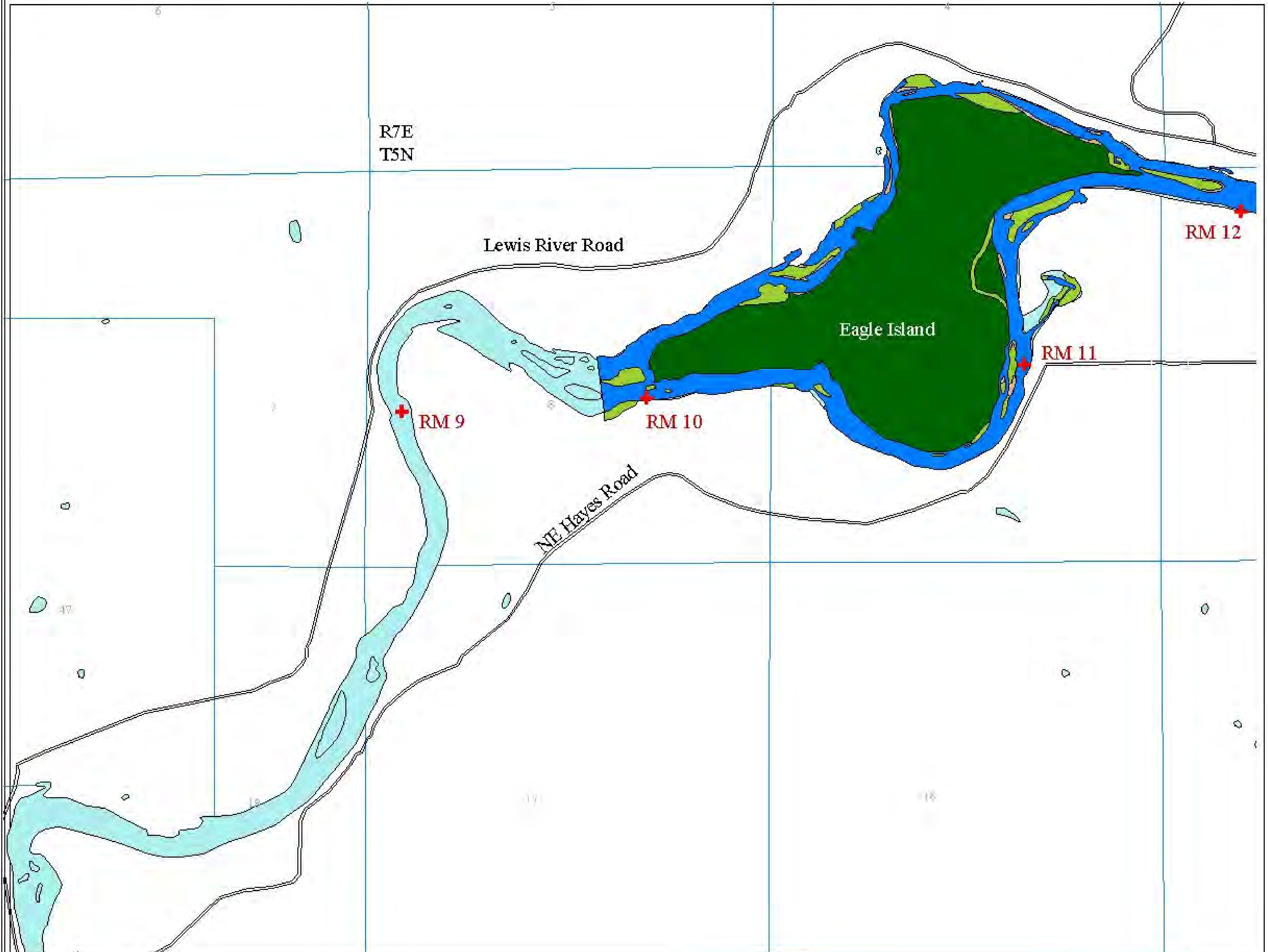
Active Bar
Wetted Channel
Vegetated Bar
Island
Lake
Pond

Section
Township
County
River Mile (RM)
USGS Gaging Station

0.2 0 0.2 Miles
700 0 700 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects

Figure 2.3-1e
Stream Channel Changes in Lewis River Merwin Dam to Eagle Island

1993 Channel Position
Sheet 1 of 3

Channel Classifications

- Active Bar
- Wetted Channel
- Vegetated Bar
- Island
- Lake
- Pond
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

600 0 600 Feet

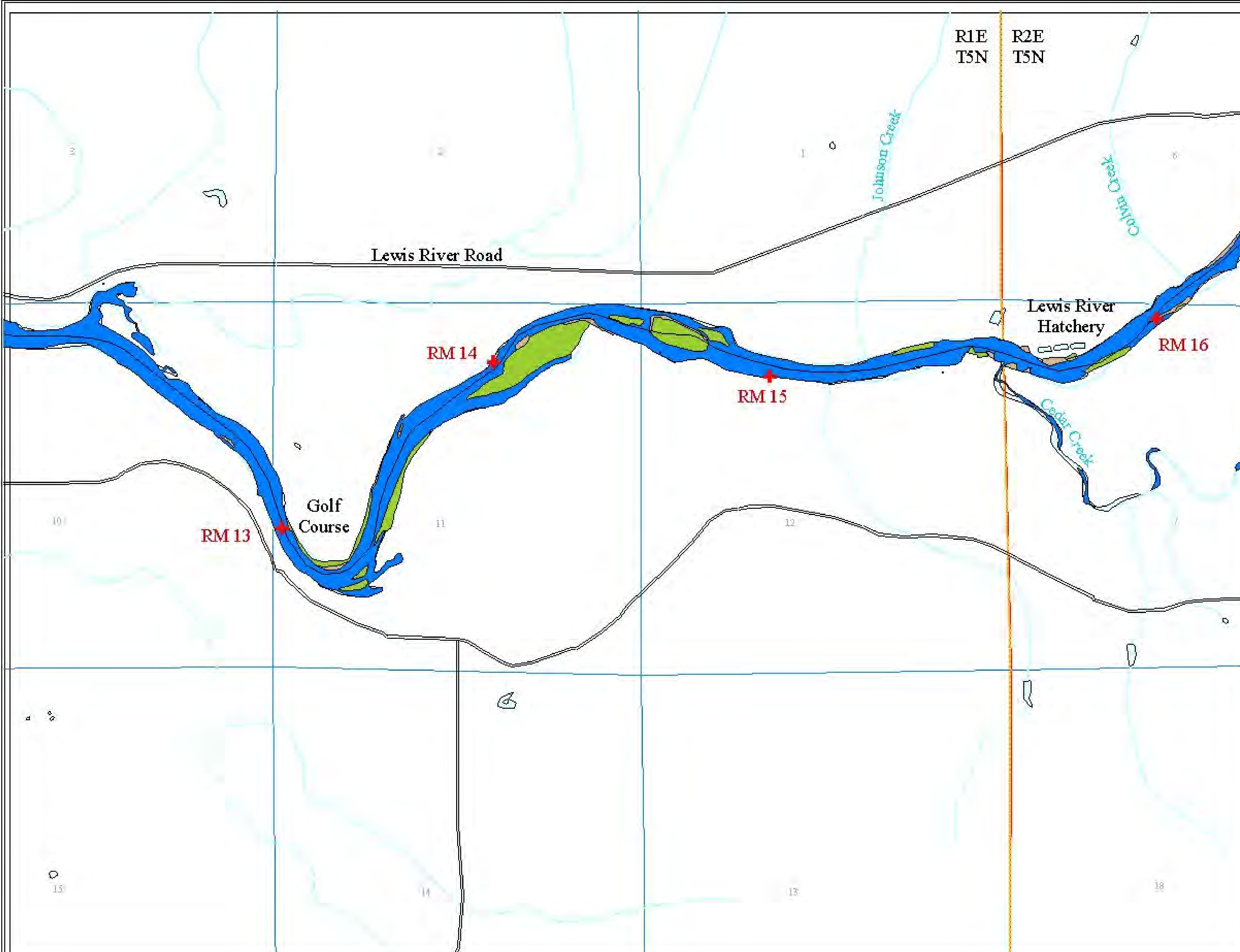
PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001

Lewis River
Hydroelectric Projects

Figure 2.3-1e
Stream Channel Changes in Lewis River Merwin Dam to Eagle Island

1993 Channel Position
Sheet 2 of 3



Channel Classifications

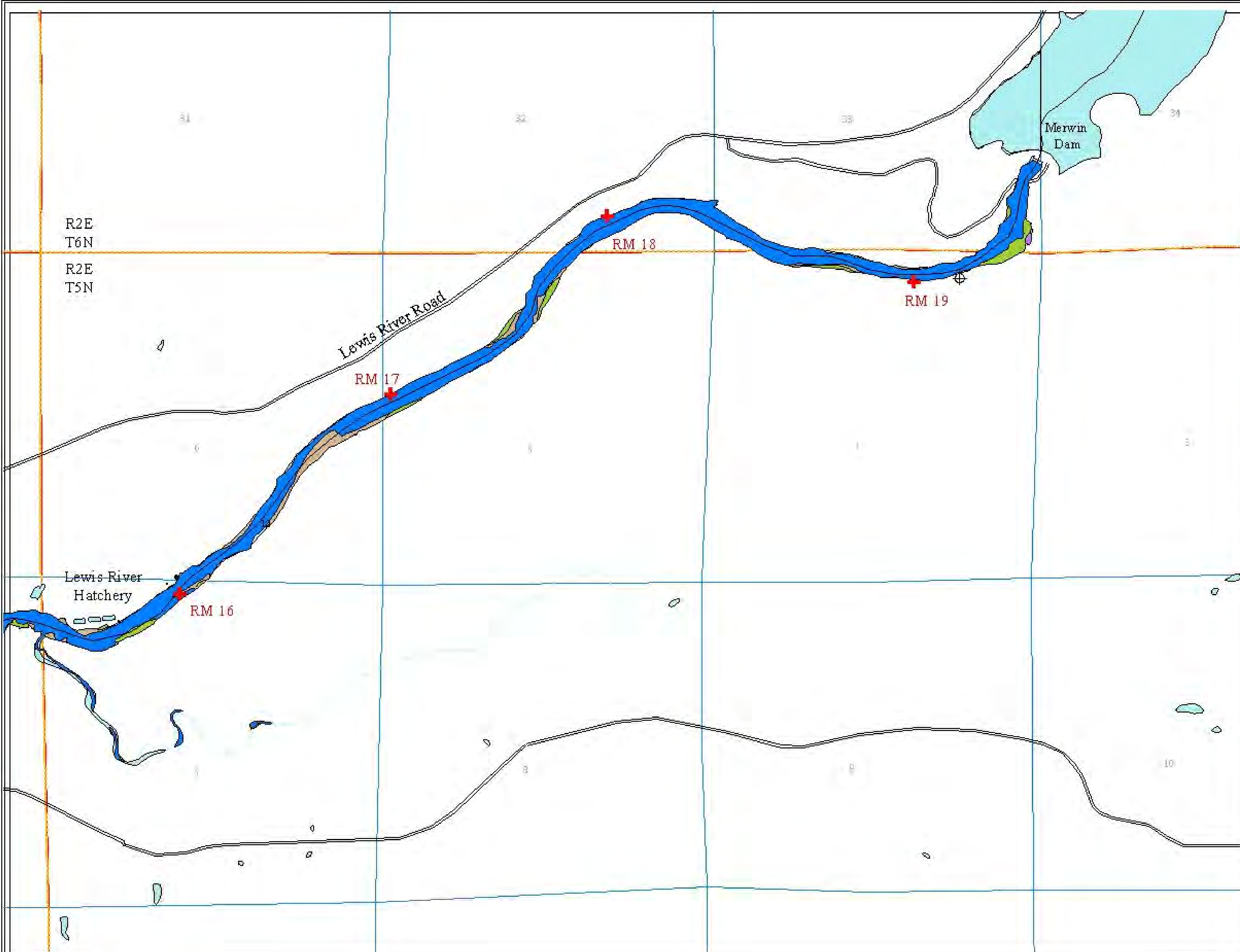
- Active Bar
- Wetted Channel
- Vegetated Bar
- Island
- Lake
- Pond
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

600 0 600 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects

Figure 2.3-1e
Stream Channel Changes in Lewis River Merwin Dam to Eagle Island

1993 Channel Position
Sheet 3 of 3

Channel Classifications

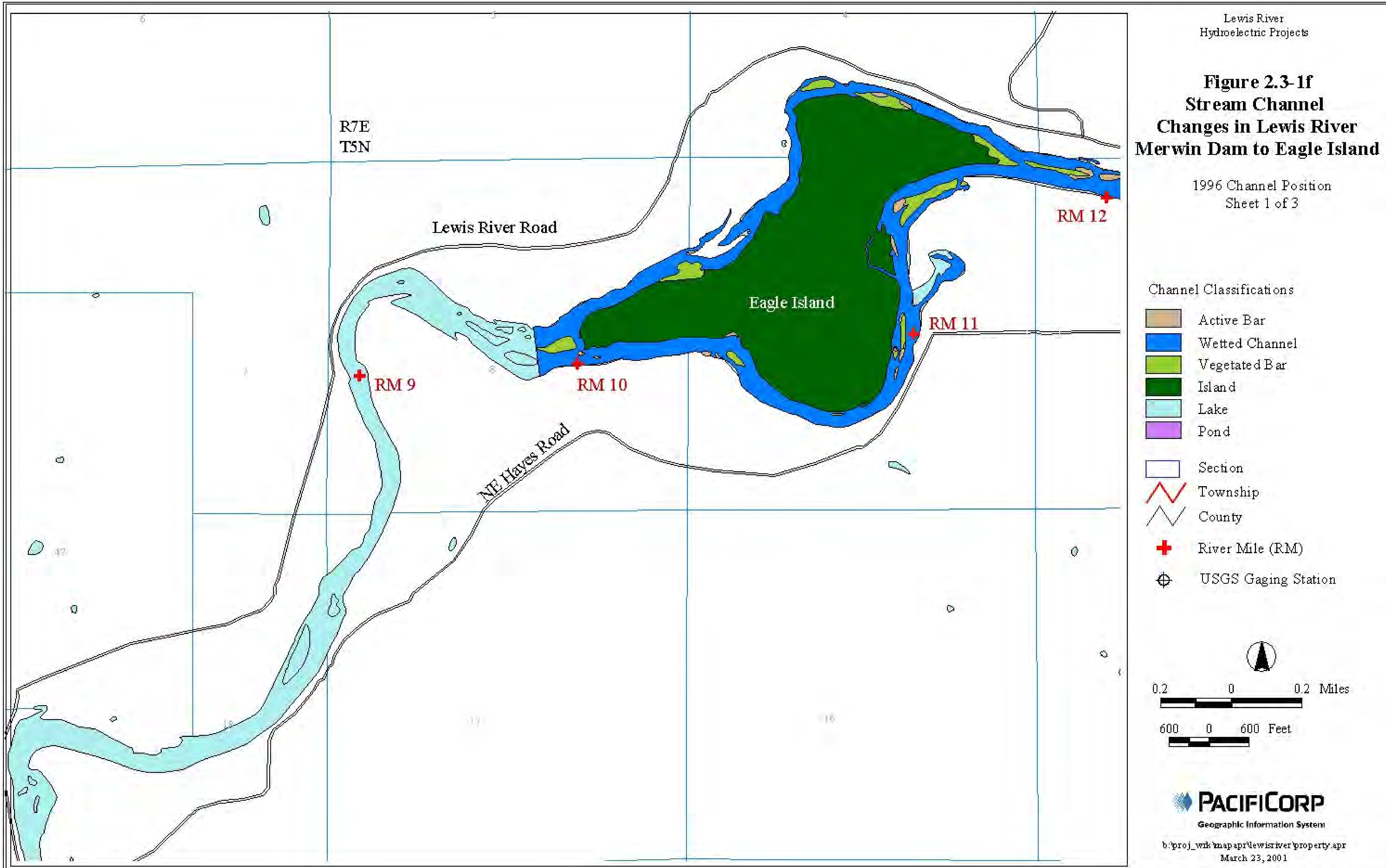
- Active Bar
- Wetted Channel
- Vegetated Bar
- Island
- Lake
- Pond
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

700 0 700 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects

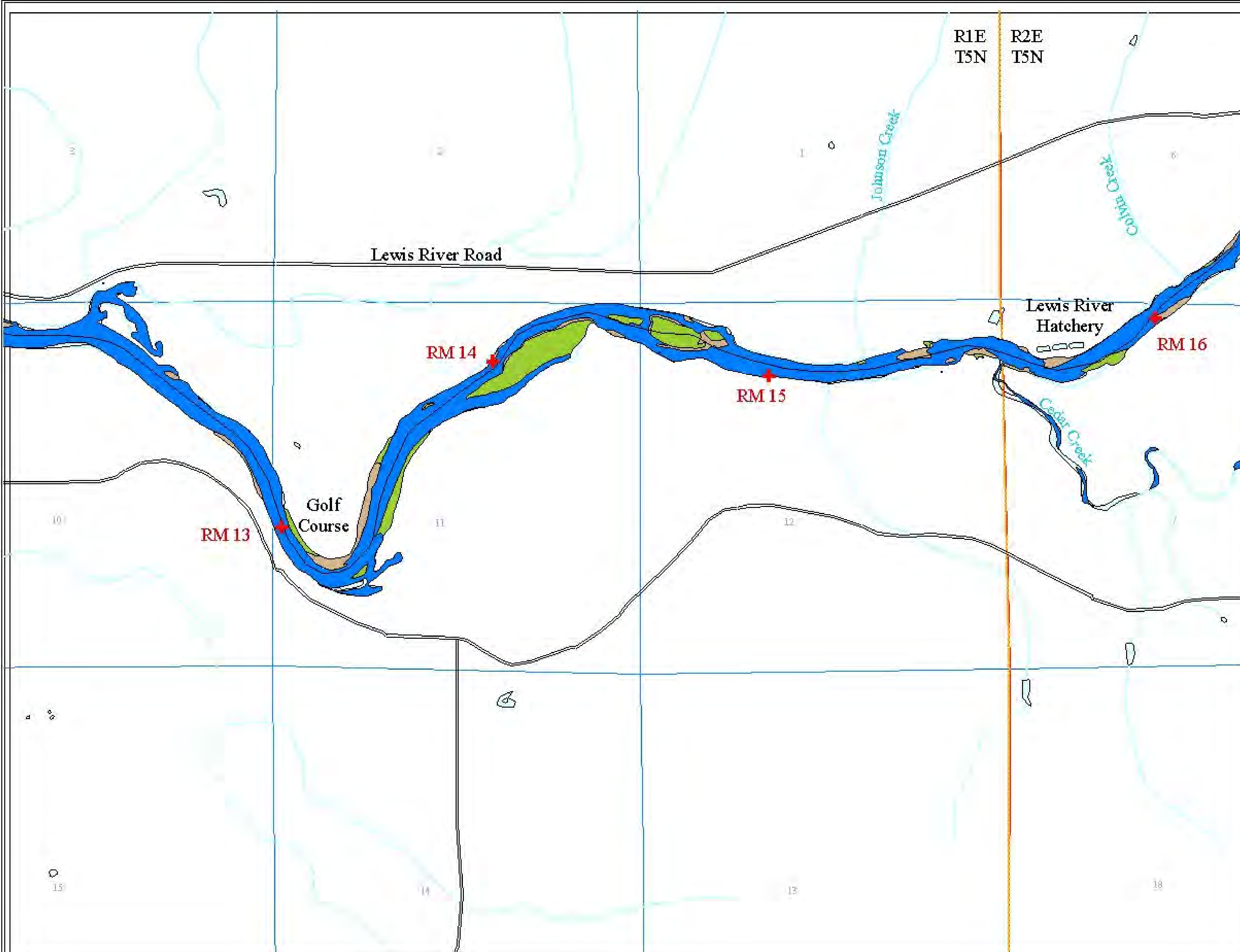
**Figure 2.3-1f
Stream Channel
Changes in Lewis River
Merwin Dam to Eagle Island**

1996 Channel Position
Sheet 1 of 3

Lewis River
Hydroelectric Projects

Figure 2.3-1f
Stream Channel Changes in Lewis River Merwin Dam to Eagle Island

1996 Channel Position
Sheet 2 of 3



Channel Classifications

- Active Bar
- Wetted Channel
- Vegetated Bar
- Island
- Lake
- Pond
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

600 0 600 Feet

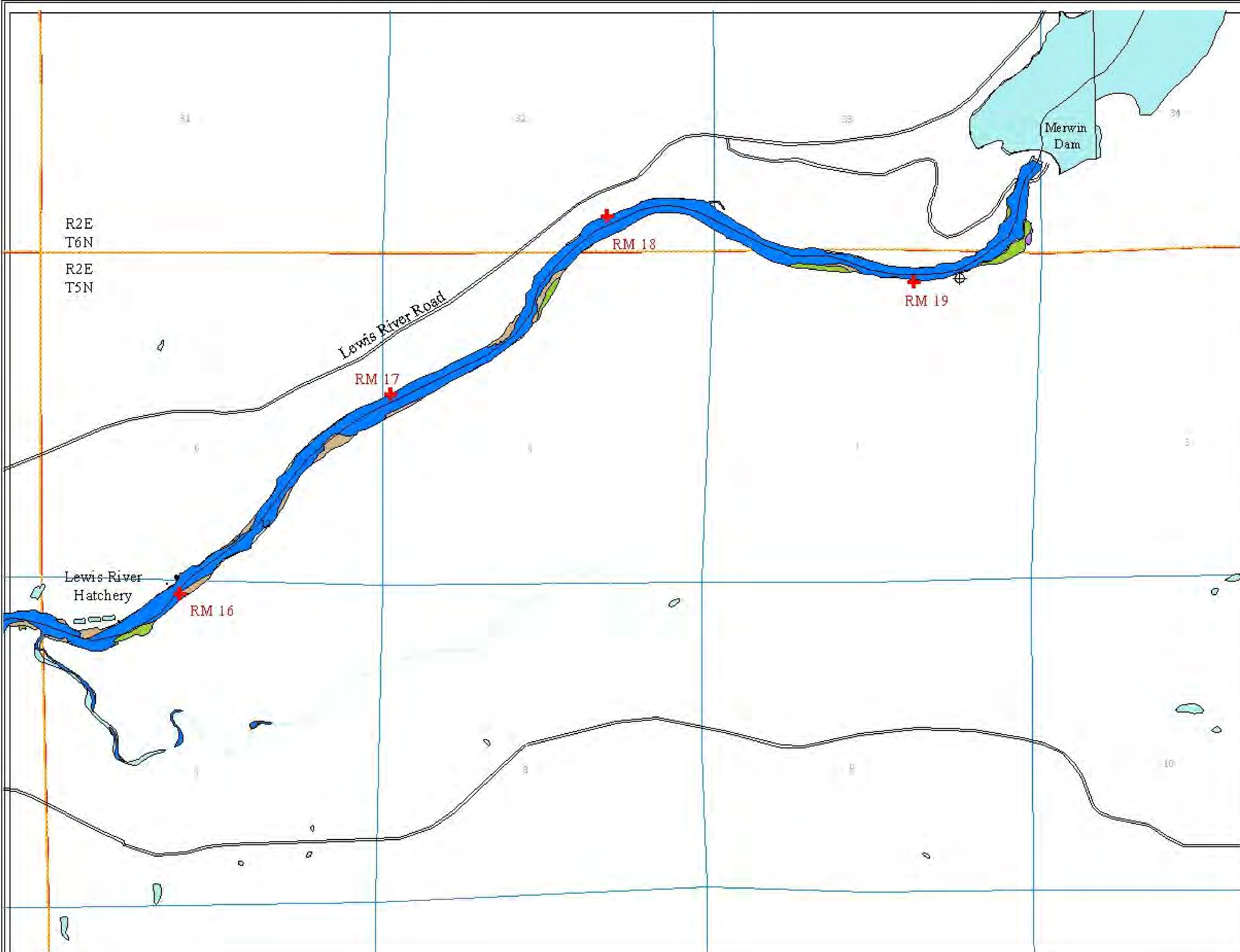
PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001

Lewis River
Hydroelectric Projects

Figure 2.3-1f
Stream Channel Changes in Lewis River Merwin Dam to Eagle Island

1996 Channel Position
Sheet 3 of 3



Channel Classifications

- Active Bar
- Wetted Channel
- Vegetated Bar
- Island
- Lake
- Pond
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

700 0 700 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001

Inspection of the aerial photos and an overlay of the mapped channel positions through time (Figure 2.3-2) shows that the position of the river has not changed in the confined reach between 1938 and the present. Bars in the river have changed slightly, but have remained in essentially the same location over time.

In the unconfined reach, the river has shifted in 3 locations. The first reach is associated with a long-term gravel mining operation. Gravel mining at the bar just downstream of RM 15 was evident in the 1938 photos. It has caused several changes to the channel configuration over time between RM 13.5 and 15. Gravel mining on the bar along the south side of the channel resulted in the main flow migrating to the south side of the river between the 1938 and 1963 photos and produced the mid-channel bar that is evident under current conditions. This caused the river to straighten between RM 14 and 15 as the main flow moved from the south to the north side of the channel at RM 14.5, and the meander at RM 13.5 straightened as “reverse migration” occurred. Normally, meanders migrate toward the outside of the bend, but this meander migrated northwest toward the inside of the bend, resulting in a straighter channel. Under current conditions, there is a backwater side channel over the location of the old meander.

The second straightened reach is at RM 12.5, just downstream from the Golf Course boat ramp. The 1938 photos show a large meander migrating toward the north, very close to the main highway. In the 1963 photos, it is evident that the river had continued its migration to the north (likely during the high flow of 1946) and threatened the roadway. A large pile of fill was piled across the upstream end of the meander (the location of the present Golf Course boat ramp) and extended downstream across the meander to ensure the river would not impinge on the road in the future. In 1963, the vegetation on the fill appeared to be approximately 15 years old, supporting the hypothesis that it had been placed following the 1946 high flow event. The current channel in this location follows the straightened course; the old meander is a backwater side channel with numerous beaver dams. It has been slowly filling with sediment based on the successive aerial photographs, as have the other cutoff meanders in the system.

The third location of channel change is in the Eagle Island area. In 1938, the main channel of the river was on the north side of Eagle Island, with a high flow channel splitting it into 2 islands at RM 11.3. The channel on the south side of Eagle Island only flowed during high water. A road across the south channel at the upstream end of the island provided access for farming and timber harvest. In the 1963 photos, the flow of the river was more equally divided in the north and south sides channels around Eagle Island. The road at the upstream end of the island was gone and dry land access was no longer possible. The channel between the 2 islands was narrower and becoming vegetated. A gravel mining operation near the upper end of the island, along the south side of the southern channel, was removing gravel from a near-channel bar and filling in another meander at the down-stream end of the bar. In the 1974 and subsequent photos, the gravel mining area had become a flowing side channel, and the partially filled-in meander was a backwater side channel. The channel between the islands has become progressively more vegetated (it is no longer a channel), and the flow of the river continues to shift to the southern channel.

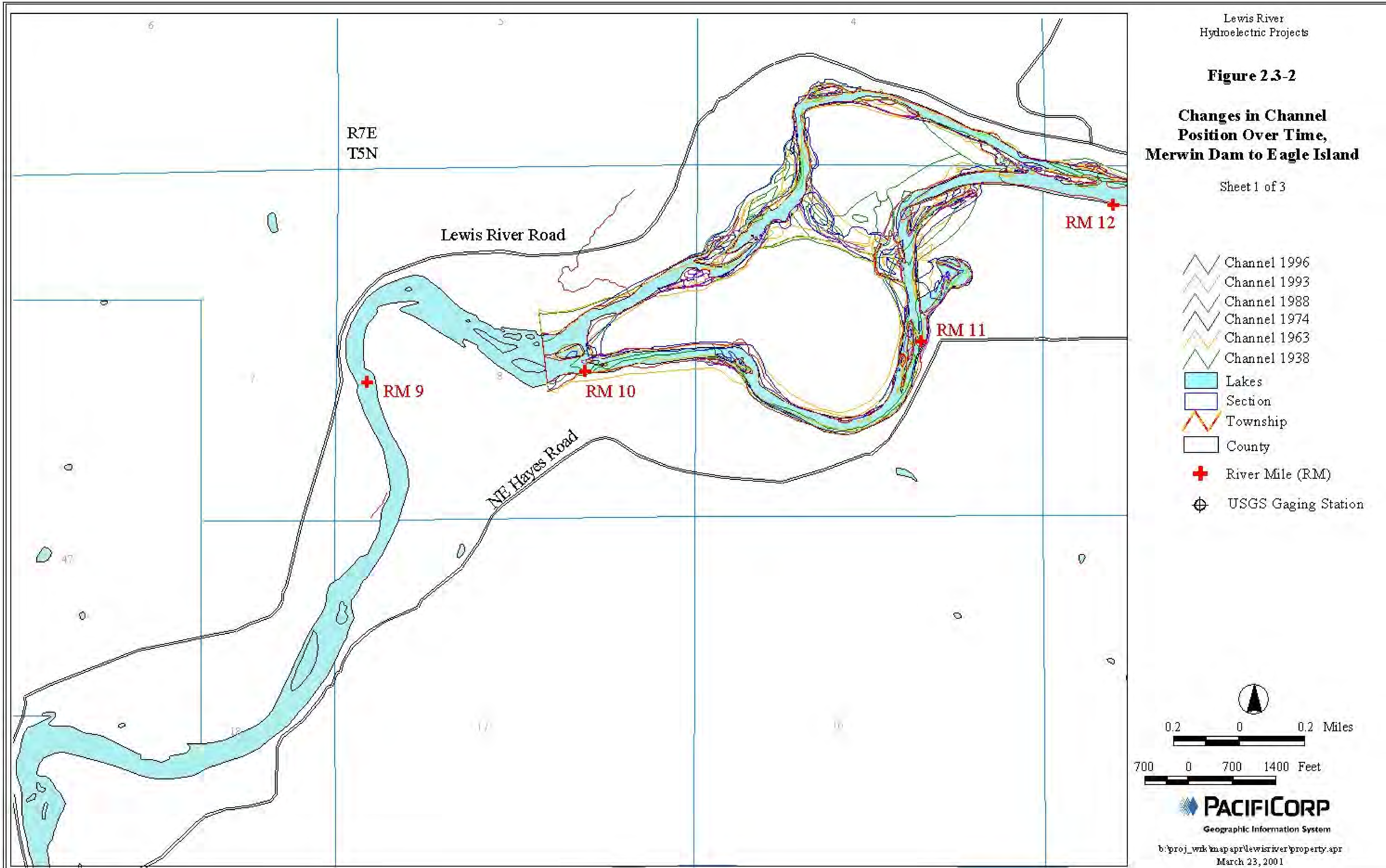
The channel changes described above appear to be primarily the result of non-project related changes in the river, associated with gravel mining operations and channel filling to protect the highway. Operation of the Lewis River projects has decreased the supply of sediment and large woody debris to the river downstream of Merwin Dam, and reduced the magnitude of high flows in the reach. These changes have undoubtedly also contributed to altering the river channel. Analysis of the progression of other channel changes through time can help us understand if major changes will continue over the period of the new license, or if the river had reached a new "equilibrium."

Decreasing sediment supply and the magnitude of peak flows often results in a river with more stable, vegetated bars and a less active channel as bedload supply and transport decreases. In order to investigate if this was happening downstream of Merwin Dam, the acreage of channel features (active bars, vegetated bars, islands, and wetted channel) was obtained from the GIS maps of the channel through time (Table 2.3-5 and Figure 2.3-3). The river was split into 3 reaches for this comparison: the confined reach (Merwin Dam to the hatchery); the unconfined reach (hatchery to the upstream end of Eagle Island); and Eagle Island (split channel).

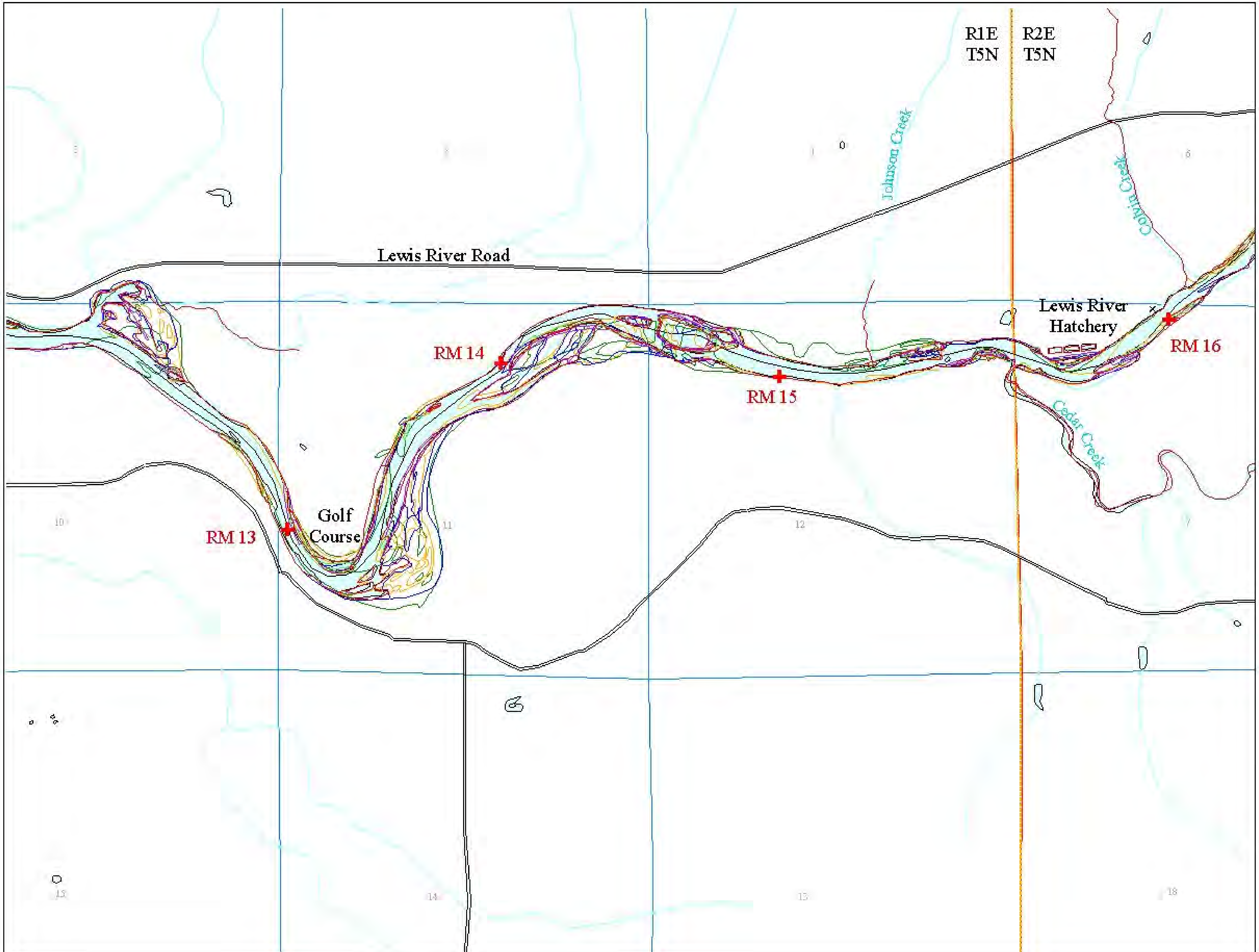
Note that the river discharge was not the same at the time the aerial photographs were taken during the 6 years studied. Flows varied between 1,250 cfs and 4,320 cfs except for the 1974 photos downstream of the Lewis River Hatchery which had much higher flow (8,000 cfs). The differences in flows result in some uncertainty regarding direct comparison of area of wetted channel and active bars. Assuming no other changes, photos taken during lower flows would have less wetted channel and more active bars than photos of the same channel at a higher flow. It is not possible to quantify this uncertainty since changes in wetted width depend upon both flow and channel cross section at each point along the river.

In the confined reach, the area of active bars decreased and the area of vegetated bars increased between 1938 and 1974. Between 1988 and present, the area of both has remained relatively constant. In the unconfined reach, there was a continual decrease in area of active bars between 1938 and 1993, with an increase in active bars between 1993 and 1996 (the photos were taken after the 1996 high flows). The area of vegetated bars increased between 1938 and 1974 and has remained relatively constant since then, with a slight decrease in 1996. The Eagle Island reach has shown the most marked changes through time. The area of active bars decreased dramatically around Eagle Island between 1938 and 1974 and has remained low, but stable. The area of vegetation (vegetated bars and island) has increased through time as the channel stabilized, and the channel that used to cut Eagle Island in half was abandoned.

The progression of channel changes shown on the aerial photographs indicates that the area of active channel bars decreased between 1938 and 1963, but has been relatively stable since 1974. Reduction in active bars and increases in vegetation on river channel features is consistent with the reduction in bedload sediment input and reduction in peak flows that occurred with the construction and operation of the Lewis River Projects. The relatively constant area of active bars in the channel since 1974 indicates that there has been little loss of active bars in the past 25 years of project operation.



R7E
T5N
Lewis River Road
NE Hayes Road
RM 9
RM 10
RM 11
RM 12
Lewis River
Hydroelectric Projects
Figure 2.3-2
Changes in Channel Position Over Time, Merwin Dam to Eagle Island
Sheet 1 of 3
Channel 1996
Channel 1993
Channel 1988
Channel 1974
Channel 1963
Channel 1938
Lakes
Section
Township
County
River Mile (RM)
USGS Gaging Station
0.2 0 0.2 Miles
700 0 700 1400 Feet
PacifiCorp
Geographic Information System
b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects

Figure 2.3-2

Changes in Channel Position Over Time, Merwin Dam to Eagle Island

Sheet 2 of 3

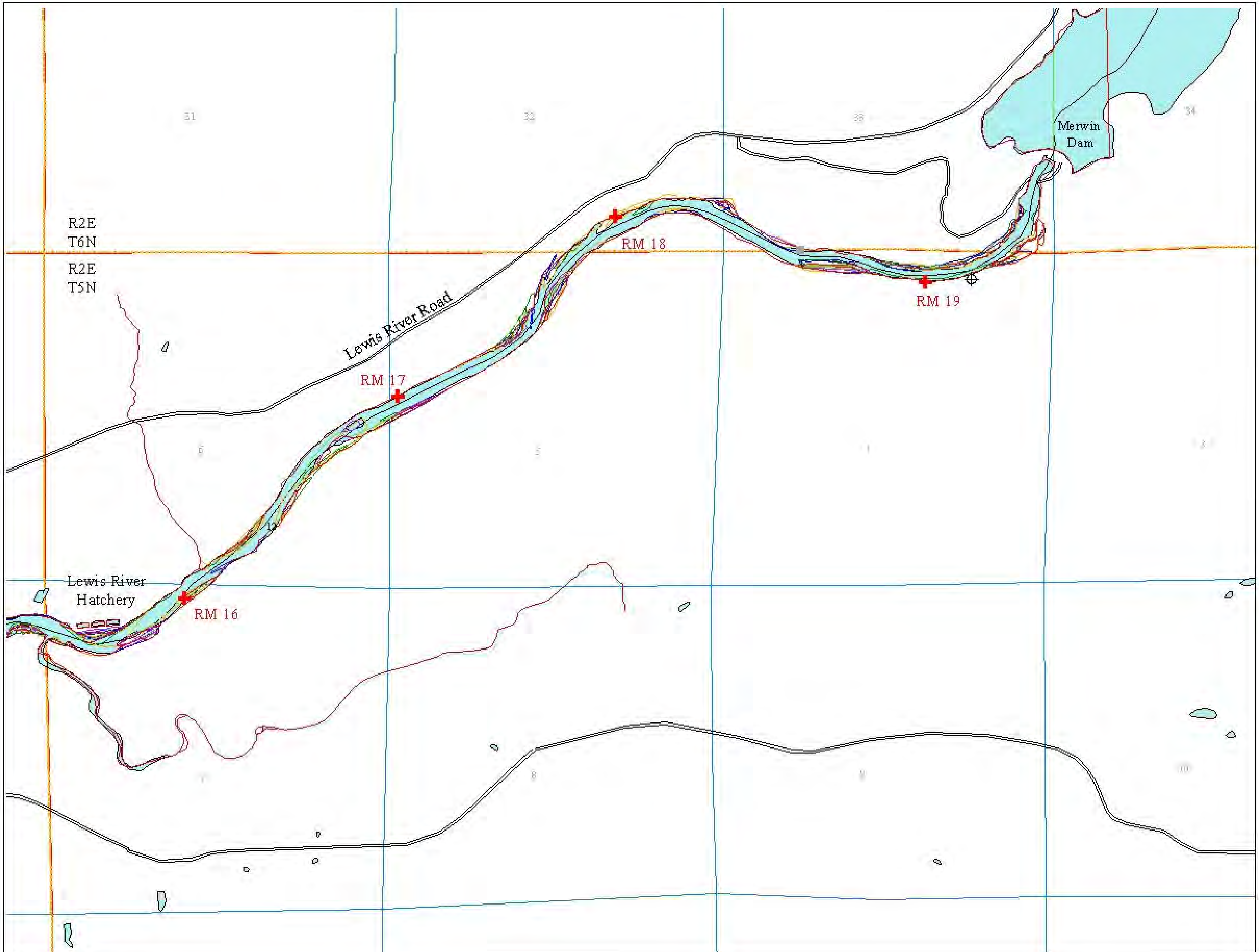
Channel 1996
Channel 1993
Channel 1988
Channel 1974
Channel 1963
Channel 1938
Lakes
Section
Township
County
River Mile (RM)
USGS Gaging Station

0.2 0 0.2 Miles

700 0 700 1400 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects

Figure 2.3-2

Changes in Channel Position Over Time, Merwin Dam to Eagle Island

Sheet 3 of 3

Channel 1996
Channel 1993
Channel 1988
Channel 1974
Channel 1963
Channel 1938
Lakes
Section
Township
County
River Mile (RM)
USGS Gaging Station

0.2 0 0.2 Miles

700 0 700 1400 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001

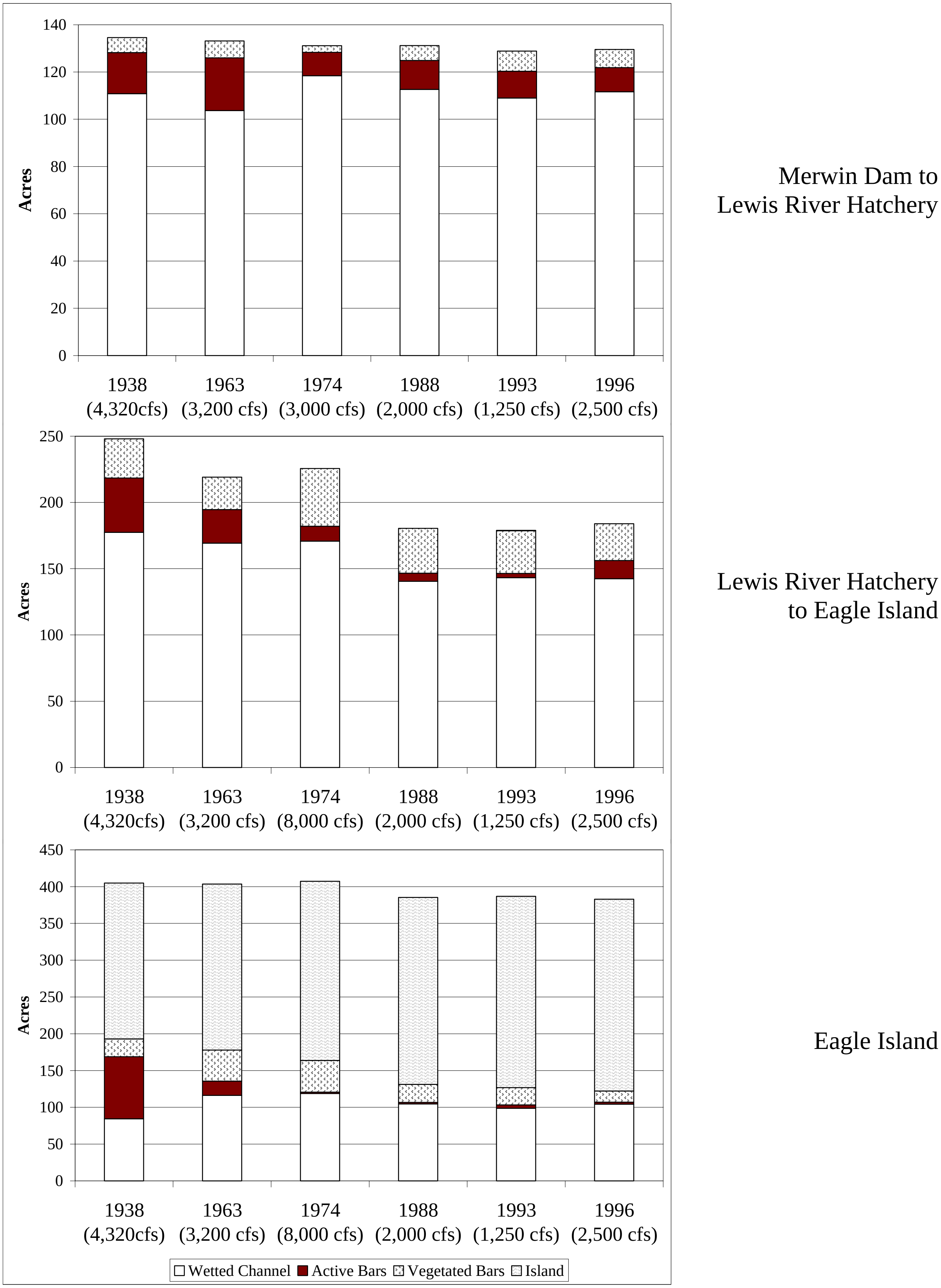


Figure 2.3-3. Changes in Lewis River, from Merwin Dam to Eagle Island.

Table 2.3-5. Area of different channel features downstream of Merwin Dam (area in acres).

Reach	Year	Active Bars	Vegetated Bars	Island	Wetted Channel
Merwin Dam to Lewis River Hatchery (confined reach)	1938 (4,320 cfs)	17.4	6.4	0	111
	1963 (3,200 cfs)	22.3	7.1	0	104
	1974 (3,000 cfs)	9.9	2.8	0	118
	1988 (2,000 cfs)	12.3	6.2	0	113
	1993 (1,250 cfs)	11.3	8.6	0	109
	1996 (2,500 cfs)	10.3	7.7	0	112
Lewis River Hatchery to Eagle Island (unconfined reach)	1938 (4,320 cfs)	41.1	29.6	0	177
	1963 (3,200 cfs)	25.3	24.4	0	169
	1974 (8,000 cfs)	11.2	43.5	0	171
	1988 (2,000 cfs)	6.2	33.8	0	141
	1993 (1,250 cfs)	3.1	32.4	0	143
	1996 (2,500 cfs)	13.6	27.8	0	142
Eagle Island (split channel)	1938 (4,320 cfs)	84.4	24.2	212	84
	1963 (3,200 cfs)	19.3	42.3	226	116
	1974 (8,000 cfs)	1.7	43.1	244	119
	1988 (2,000 cfs)	2.0	24.6	254	105
	1993 (1,250 cfs)	4.4	23.6	260	99
	1996 (2,500 cfs)	2.6	15.3	261	104

NA = not available

Channel Aggradation/Incision

An analysis of the rating curves for the Lewis River near Ariel gage was also completed to help determine if there was any systematic aggradation or incision of the channel bed. The stage (water surface elevation) at 1,000, 4,000 and 10,000 cfs was plotted through time to determine if it was changing (Figure 2.3-4). Data from 1975 and 1982 to present was analyzed (earlier data was missing). No systematic increase or decrease in stage at any of the 3 flows was found. This indicates that the river at the gage location (just downstream from Merwin Dam) has not been aggrading or incising since 1975. Gravel deposits used for spawning by anadromous fish are located at the gage site.

Aquatic Habitat and Substrate

Aquatic habitat was mapped between Merwin Dam and Eagle Island during the 2000 field survey (Figure 2.3-5). Details of the data collected in habitat units is included in WTS 3 Appendix 1. Habitat unit numbers shown on Figure 2.3-5 correspond to unit numbers in WTS 3 Appendix 1.

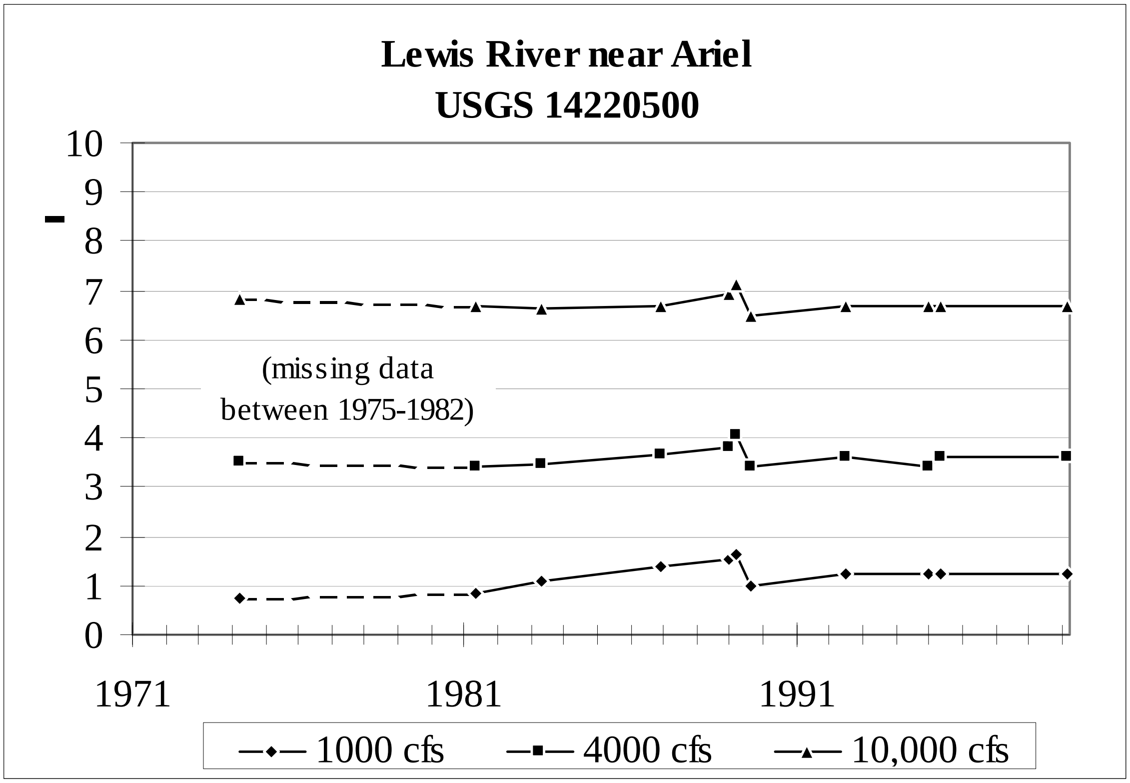


Figure 2.3-4. Gage height versus given flow for the Lewis River at Ariel gage.

The reach between Merwin Dam and just downstream of the Lewis River Hatchery (Habitat Unit 18) is confined in a bedrock channel. Aquatic habitat in this reach is characterized by glides (56 percent), riffles (22 percent), and pools (22 percent; Table 2.3-6). No side channels were mapped. Average wetted widths during the field survey were 224-269 feet; average bankfull widths were 305-350 feet. Dominant/subdominant substrate was cobble/gravel in the glides and riffles, and boulder/bedrock/cobble in the pools. A total of 1,042,000 square feet of spawning-sized gravel deposits were mapped during the field survey in this reach.

Downstream of the confined reach, the Lewis River valley widens from 0.5 to 1 mile wide. In this unconfined reach, historically the river has been able to migrate across its valley. As mentioned previously, human intervention has prevented migration of several meanders in this reach in the past 70 years. Aquatic habitat in the unconfined reach is dominated by glide habitat (60 percent), with close to 1,000 feet each of side channels (23 percent) and riffles (17 percent). No pools were mapped in this reach. Average wetted widths were 210-232 feet for riffles and glides, respectively, and 87 feet for the side channels. Bankfull widths were 256-296 feet for riffles and glides and 108 feet for side channels. Dominant/subdominant substrate was cobble/gravel in the riffles and glides and gravel/silt/sand in the side channels.

Table 2.3-6. Summary of aquatic habitat in the Lewis River between Merwin Dam and Eagle Island.

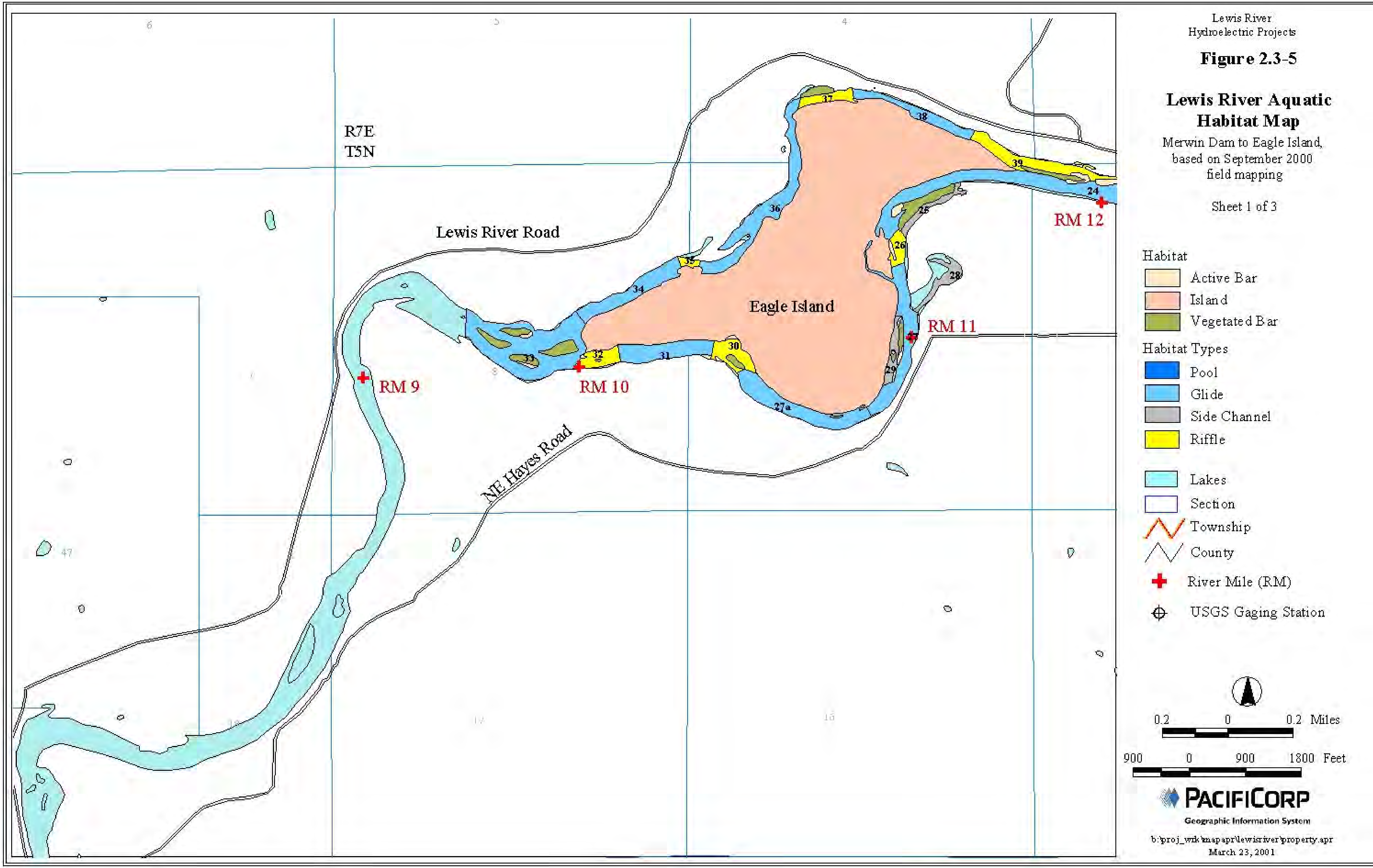
Confined Reach	**Riffle**	**Glide**	**Pool**	**Side Channel**
Average length (ft)	871 (22 %)	2,267 (56%)	854 (22%)	none
Average wetted width (ft)	224	252	269	none
Average bankfull width (ft)	350	305	313	none
Total wetted area (sq ft)	1,222,085	3,440,601	1,408,551	none
Dominant substrate	CO	CO	BO/BR/CO	none
Subdominant substrate	CO/GR	GR	CO	none
Spawning gravel area (sq ft)	429,500	491,000	121,600	none
Unconfined Reach	**Riffle**	**Glide**	**Pool**	**Side Channel**
Average length (ft)	922 (17%)	3,080 (60%)	none	1,175 (23%)
Average wetted width (ft)	210	232	none	87
Average bankfull width (ft)	256	296	none	108
Total wetted area (sq ft)	1,416,530	7,329,776	none	413,750
Dominant substrate	CO/GR	CO	none	GR/SI
Subdominant substrate	GR	GR	none	SA
Spawning gravel area (sq ft)	419,500	678 ,400	none	72,200

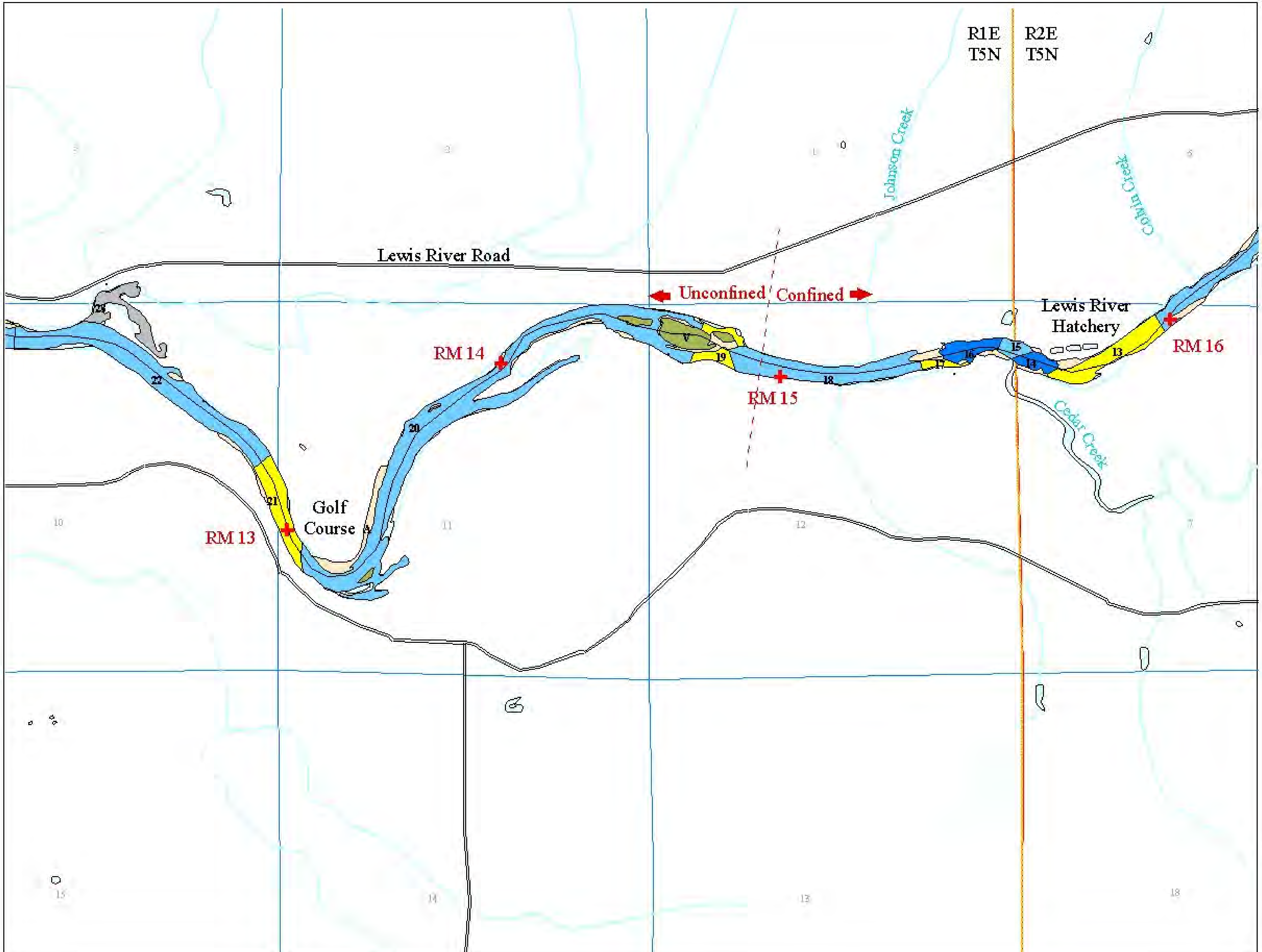
BO = boulder CO = cobble SA = sand
BR = bedrock GR = gravel SI = silt

Large woody debris was also counted in the Lewis River downstream of Merwin during the 2000 field survey (Table 2.3-7). An average of 9.6 pieces of large woody debris/mile were located in the confined reach; more large woody debris (20.4 pieces/mile) were found in the downstream unconfined reach. No beaver dams or log jams were found.

Pieces of large woody debris were also counted on the 1938 and 1996 aerial photos for comparison with the field evidence. A total of 52 pieces of large wood were counted on the 1938 photos; 159 pieces were counted on the 1996 photos. While it is possible that some pieces of wood were missed on the older photos, it is clear that there was little wood in the lower Lewis River in the mid-1930s. Merwin Dam had only been in operation 7 years at the time of the photo. At that time, all flows that exceeded the single unit capacity of about 4,000 cfs were spilled. Large woody debris was not contained during very large events (e.g., the 1934 flood), but was passed downstream during high flow events. Most likely, a great deal of wood had been removed in the late 1800s and early 1900s as part of stream cleaning operations.

Substrate Mapping and Sampling: Channel substrate was mapped during the 2000 field survey (Figure 2.3-6). In addition, pebble counts and sub-armor layer samples were taken at 12 sites between Merwin Dam and Eagle Island. Substrate sample locations are shown on Figure 2.3-6. Detailed results of the substrate sampling and photos of the sample sites are included in WTS 3 Appendix 2.


Lewis River
Hydroelectric Projects
Figure 2.3-5
Lewis River Aquatic Habitat Map
Merwin Dam to Eagle Island, based on September 2000 field mapping
Sheet 1 of 3
Habitat
Active Bar
Island
Vegetated Bar
Habitat Types
Pool
Glide
Side Channel
Riffle
Lakes
Section
Township
County
River Mile (RM)
USGS Gaging Station
0.2 0 0.2 Miles
900 0 900 1800 Feet
PACIFICORP
Geographic Information System
b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001
R7E
T5N
Lewis River Road
NE Hayes Road
Eagle Island
RM 9
RM 10
RM 11
RM 12



Lewis River
Hydroelectric Projects

Figure 2.3-5

Lewis River Aquatic Habitat Map

Merwin Dam to Eagle Island, based on September 2000 field mapping

Sheet 2 of 3

Habitat
- Active Bar
- Island
- Vegetated Bar

Habitat Types
- Pool
- Glide
- Side Channel
- Riffle

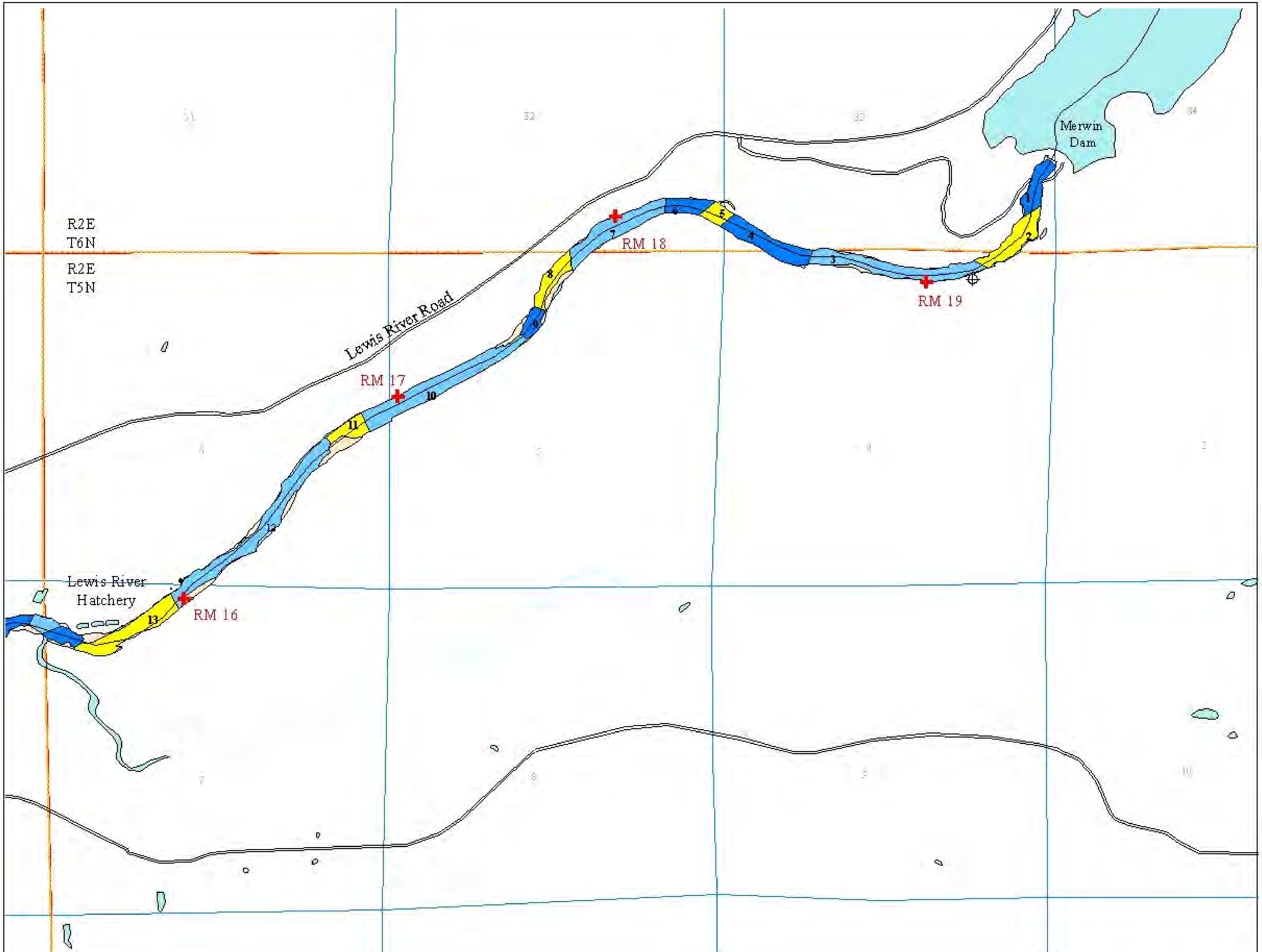
- Lakes
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

900 0 900 1800 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects

Figure 2.3-5

Lewis River Aquatic Habitat Map

Merwin Dam to Eagle Island, based on September 2000 field mapping

Sheet 3 of 3

Habitat
- Active Bar
- Island
- Vegetated Bar

Habitat Types
- Pool
- Glide
- Side Channel
- Riffle

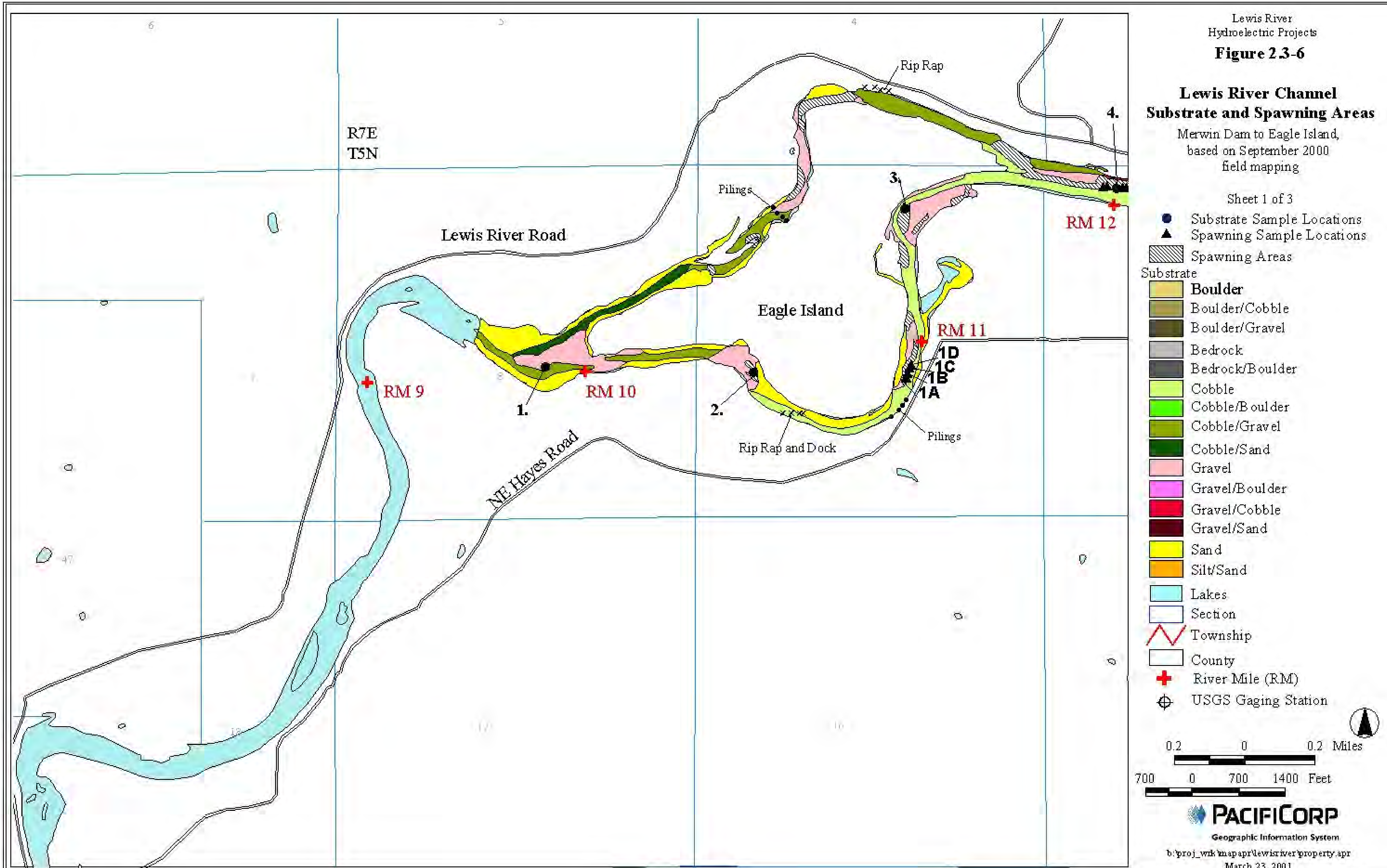
- Lakes
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

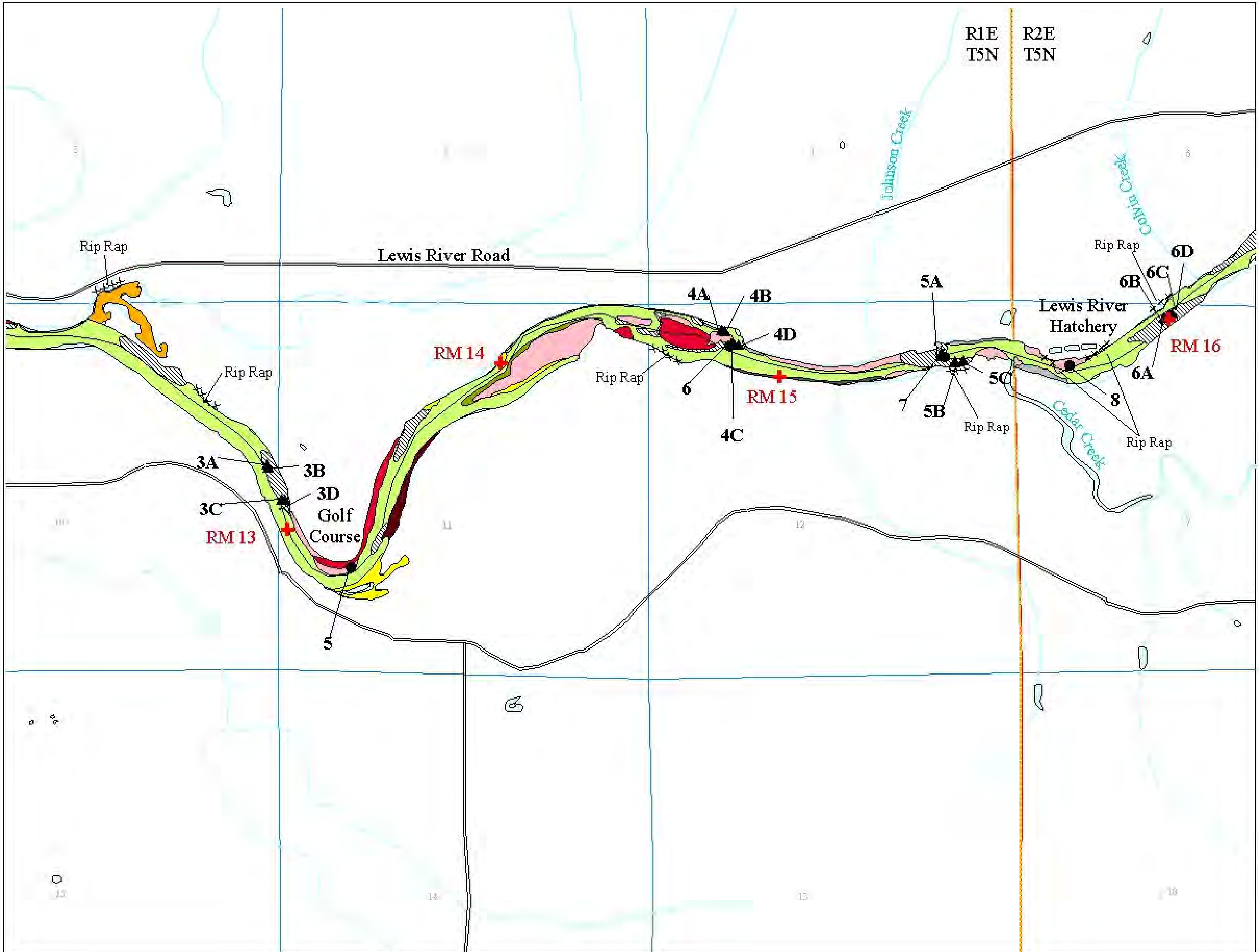
0.2 0 0.2 Miles

900 0 900 1800 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001


Lewis River
Hydroelectric Projects
Figure 2.3-6
Lewis River Channel
Substrate and Spawning Areas
Merwin Dam to Eagle Island,
based on September 2000
field mapping
Sheet 1 of 3
Substrate Sample Locations
Spawning Sample Locations
Spawning Areas
Substrate
Boulder
Boulder/Cobble
Boulder/Gravel
Bedrock
Bedrock/Boulder
Cobble
Cobble/Boulder
Cobble/Gravel
Cobble/Sand
Gravel
Gravel/Boulder
Gravel/Cobble
Gravel/Sand
Sand
Silt/Sand
Lakes
Section
Township
County
River Mile (RM)
USGS Gaging Station
0.2 0 0.2 Miles
700 0 700 1400 Feet
PACIFICORP
Geographic Information System
b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001
R7E
T5N
Lewis River Road
NE Hayes Road
Eagle Island
Rip Rap
Pilings
Rip Rap and Dock
Pilings
RM 9
RM 10
RM 11
RM 12
1.
2.
3.
4.
1A
1B
1C
1D



Lewis River
Hydroelectric Projects

Figure 2.3-6

Lewis River Channel Substrate and Spawning Areas

Merwin Dam to Eagle Island, based on September 2000 field mapping

Sheet 2 of 3

- Substrate Sample Locations
- Spawning Sample Locations
- Spawning Areas

Substrate

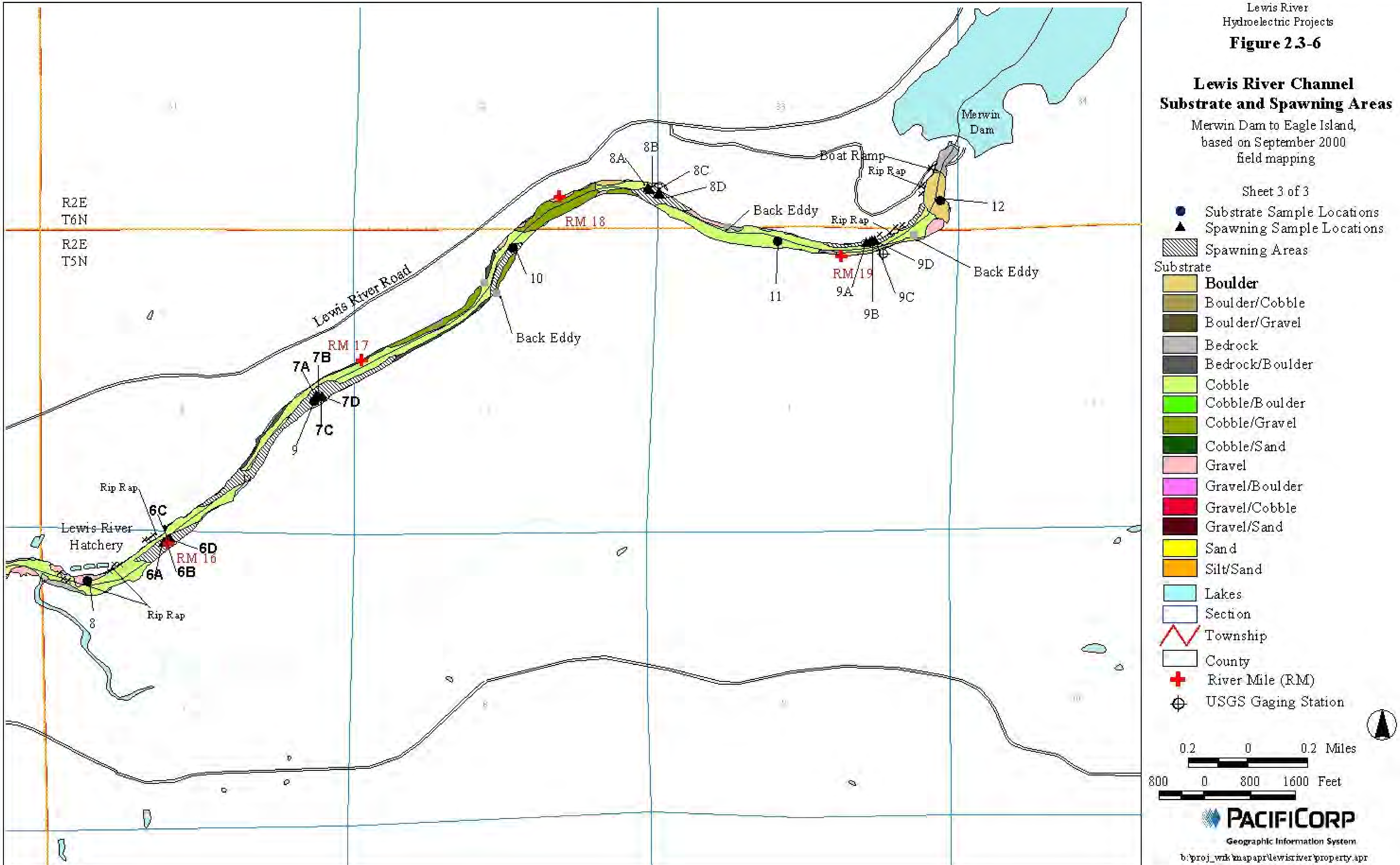
- Boulder
- Boulder/Cobble
- Boulder/Gravel
- Bedrock
- Bedrock/Boulder
- Cobble
- Cobble/Boulder
- Cobble/Gravel
- Cobble/Sand
- Gravel
- Gravel/Boulder
- Gravel/Cobble
- Gravel/Sand
- Sand
- Silt/Sand
- Lakes
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

700 0 700 1400 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects

Figure 2.3-6

Lewis River Channel Substrate and Spawning Areas

Merwin Dam to Eagle Island,
based on September 2000
field mapping

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001

Table 2.3-7. Summary of large woody debris in the Lewis River downstream of Merwin.

	Class 4			Class 3			Class 2		Class 1		Instream	Root wad	Beaver
Reach	Wet	Bnk	Pot	Wet	Bnk	Pot	Wet	Bnk	Wet	Bnk	LWD/mi*	or jams	Dams
Confined	0	0	4	2	1	41	28	12	nc	nc	9.6	10 RW	none
Unconfined	0	0	0	11	0	21	95	0	nc	nc	20.4	26 RW	none
Total	**0**	**0**	**4**	**13**	**1**	**62**	**123**	**12**	**nc**	**nc**	**15.4**	**36 RW**	**none**

Class 4 = >36"diam, >50' long
Class 3 = >24"diam, >50' long
Class 2 = >12" diam, >25' long
Class 1 = >6" diam, >25' long
Wet = within wetted channel
Bnk = within bankfull channel (exclusive of those counted in wetted channel)
Pot = potential; standing but leaning over bankfull channel
nc = not counted
* Instream LWD/mile includes wetted and bankfull

The changes in median substrate size along the Lewis River between Merwin Dam and Eagle Island are shown in Figure 2.3-7. The substrate samples were taken at comparable locations within the channel (the upstream end of point bars) so that they would show variations in grain size along the channel. A general fining downstream trend is shown, with a jump in median grain size in Sample 7, at the bar just downstream from the confluence with Cedar Creek (RM 15.7). This jump is likely a result of sediment input from Cedar Creek, with the largest Cedar Creek particles deposited just downstream from the confluence.

Figure 2.3-8 shows the changes in armor layer grain size distribution along the same reach of the Lewis River. A similar downstream-fining pattern is shown.

Spawning Gravel

Areas of spawning-sized gravel were mapped during the 2000 field survey, and samples of the gravel were taken to analyze the grain size distribution. The spawning areas are shown in a hatched pattern on Figure 2.3-6, along with the sample locations (triangles). Detailed results of the spawning gravel sampling and photos of sample locations are included in WTS 3 Appendix 3.

Spawning Gravel

Areas of spawning-sized gravel were mapped during the 2000 field survey, and samples of the gravel were taken to analyze the grain size distribution. The spawning areas are shown in a hatched pattern on Figure 2.3-6, along with the sample locations (triangles). Detailed results of the spawning gravel sampling and photos of sample locations are included in WTS 3 Appendix 3.

The area of spawning-sized gravel along the length of the channel is shown in Figure 2.3-9. Habitat unit numbers refer to the designations on Figure 2.3-5. Spawning-sized gravel is distributed throughout the reach, with the largest deposit upstream of the hatchery.

A summary of grain size and gravel quality indices for the spawning gravel samples is shown in Table 2.3-8. Median grain size of the samples ranged from 13 to 30 mm, Fredle Indices ranged from 7 to 28, and percent finer than 2 mm ranged from 0 to 13 percent. These values indicate good quality spawning gravel, with a low percent fines and a grain size distribution suitable for use by anadromous fish.

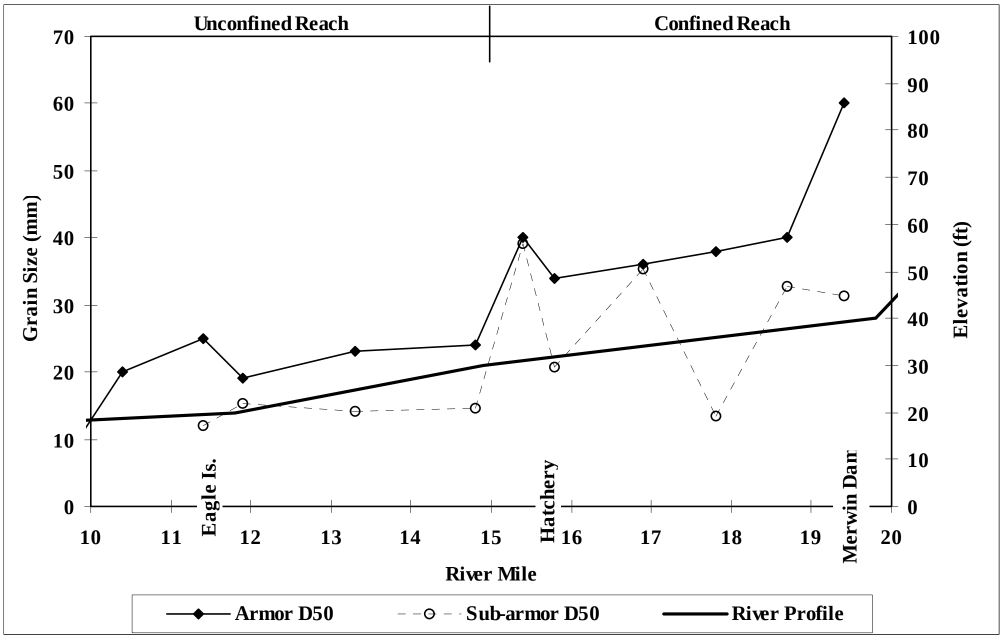


Figure 2.3-7. Change in median (D_{50}) surface armor and sub-armor gravel samples in the Lewis River downstream of Merwin Dam.

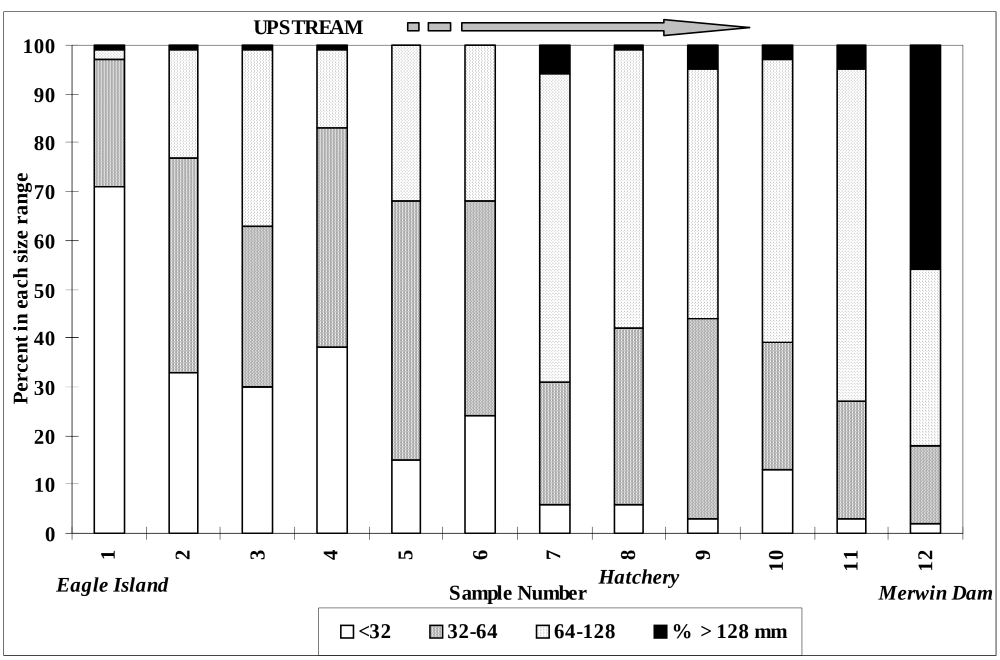


Figure 2.3-8. Change in grain size distribution of surface (armor) gravel samples in the Lewis River downstream of Merwin Dam.

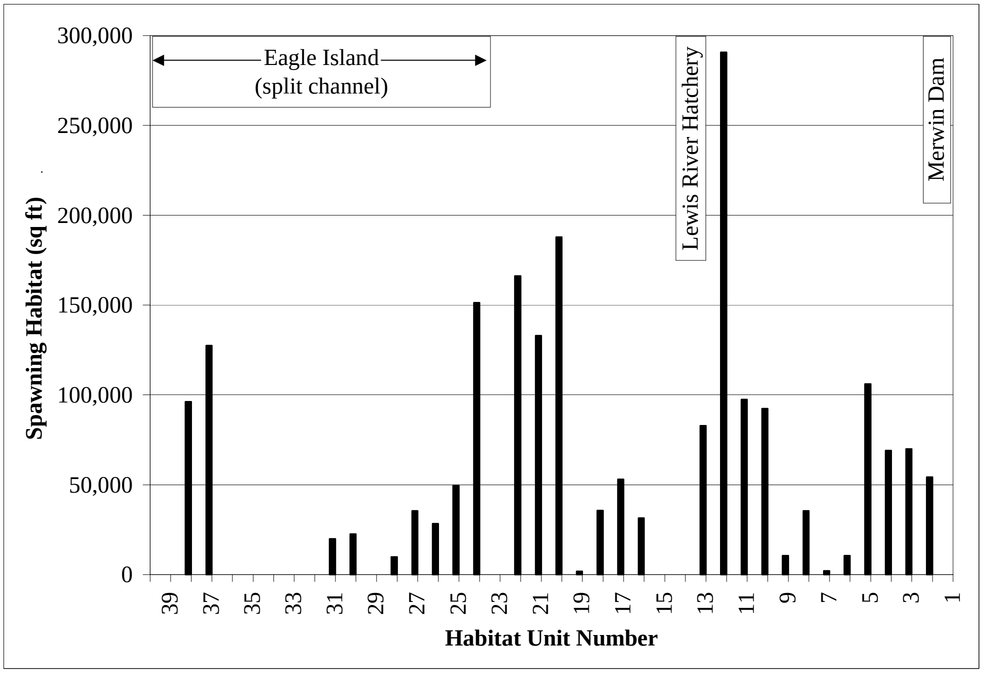


Figure 2.3-9. Area of spawning-sized gravel in each habitat unit in the Lewis River downstream of Merwin Dam.

Table 2.3-8. Summary of spawning gravel samples, Lewis River downstream of Merwin Dam.

Sample	D_{84}[a] (mm)	D_{75} (mm)	D_{65} (mm)	D_{50} (mm)	D_{25} (mm)	D_{16} (mm)	Dg[b] (mm)	Sorting Coeffi-cient[c]	Fredle Index[d]	% finer than 2 mm	% finer than 1 mm
1A	22.7	17.8	14.8	12.2	5.8	0.8	14.4	3.1	4.7	14.8%	10.2%
1B	25.3	21.8	17.9	13.6	6.3	2.3	16.8	3.4	4.9	12.0%	9.2%
1C	25.6	22.2	18.5	14.2	7.8	3.2	17.9	2.8	6.3	11.6%	9.1%
1D	23.8	19.5	15.5	12.8	6.5	1.3	15.1	3.0	5.1	15.6%	11.3%
Average 1	**24**	**20**	**17**	**13**	**7**	**2**	**16**	**3**	**5**	**13%**	**10%**
2A	40.7	30.8	28.3	24.4	18.0	15.4	46.5	1.7	27.1	0.7%	0.3%
2B	28.3	25.8	23.0	18.8	11.2	6.6	27.0	2.3	11.7	4.3%	1.9%
2C	33.9	28.5	24.6	18.8	10.7	6.5	28.5	2.7	10.7	4.9%	2.5%
2D	25.7	22.4	18.8	13.3	7.7	4.6	20.8	2.9	7.1	5.5%	2.5%
Average 2	**32**	**27**	**24**	**19**	**12**	**8**	**31**	**2**	**14**	**4%**	**2%**
3A	14.5	13.1	11.6	9.3	4.6	2.8	12.9	2.9	4.5	5.9%	4.2%
3B	39.1	29.6	25.0	18.0	10.8	7.2	30.3	2.8	11.0	3.3%	2.0%
3C	30.3	27.3	24.1	19.3	12.2	9.8	33.5	2.2	14.9	0.7%	0.5%
3D	27.1	24.6	21.9	17.7	11.4	9.2	27.6	2.2	12.8	3.1%	2.1%
Average 3	**28**	**24**	**21**	**16**	**10**	**7**	**26**	**3**	**11**	**3%**	**2%**
4A	44.1	32.9	28.4	23.3	13.2	6.0	33.2	2.5	13.4	5.1%	2.0%

Table 2.3-8. Summary of spawning gravel samples, Lewis River downstream of Merwin Dam (cont.).

Sample	D_{84}[a] (mm)	D_{75} (mm)	D_{65} (mm)	D_{50} (mm)	D_{25} (mm)	D_{16} (mm)	Dg[b] (mm)	Sorting Coeffi-cient[c]	Fredle Index[d]	% finer than 2 mm	% finer than 1 mm
4B	38.6	29.7	25.7	19.7	7.7	3.1	25.5	3.9	6.6	7.6%	3.5%
4C	30.7	27.6	23.5	17.4	9.8	5.3	24.3	2.8	8.6	8.9%	7.1%
4D	28.4	24.8	20.9	15.3	7.2	2.6	19.8	3.4	5.8	10.8%	7.1%
Average 4	**35**	**29**	**25**	**19**	**10**	**4**	**26**	**3**	**9**	**8%**	**5%**
5A	39.6	30.6	28.2	24.7	18.8	16.6	49.5	1.6	30.3	0.2%	0.2%
5B	27.4	25.1	22.5	18.6	13.4	11.9	35.7	1.9	19.2	0.0%	0.0%
5C	23.5	19.0	14.0	12.3	6.5	4.1	19.2	2.9	6.6	2.9%	2.3%
5D	30.8	26.8	22.4	15.8	5.8	2.3	20.6	4.6	4.4	10.3%	6.9%
Average 5	**30**	**25**	**22**	**18**	**11**	**9**	**31**	**3**	**15**	**3%**	**2%**
6A	51.8	44.9	37.3	28.3	17.4	12.6	47.2	2.6	18.3	1.4%	0.7%
6B	51.9	45.1	37.5	29.3	21.8	19.0	61.7	2.1	29.8	0.0%	0.0%
6C	32.6	29.8	27.7	24.6	19.5	17.6	50.5	1.5	33.0	0.0%	0.0%
6D	64.0	56.9	49.0	37.1	24.3	20.6	76.9	2.3	32.8	0.0%	0.0%
Average 6	**50**	**44**	**38**	**30**	**21**	**17**	**59**	**2**	**28**	**0%**	**0%**
7A	47.3	37.8	27.4	23.9	13.6	9.7	37.7	2.8	13.5	3.1%	1.6%
7B	36.7	29.9	27.1	23.0	16.2	12.3	39.0	1.8	21.1	2.5%	2.0%
7C	50.7	43.2	34.9	28.5	21.6	19.1	60.4	2.0	30.2	0.1%	0.0%
7D	43.8	32.5	29.1	25.3	18.9	16.7	49.2	1.7	28.7	0.3%	0.1%
Average 7	**45**	**36**	**30**	**25**	**18**	**14**	**47**	**2**	**23**	**2%**	**1%**
8A	15.2	26.3	22.7	17.4	5.1	2.2	21.1	5.1	4.1	8.4%	4.4%
8B	37.9	30.4	26.0	19.5	9.0	4.2	43.2	3.4	12.7	6.3%	3.6%
8C	31.4	28.0	24.1	18.4	9.7	5.3	28.1	2.9	9.7	3.2%	1.9%
8D	37.7	29.0	24.1	16.9	9.5	4.5	24.8	3.0	8.2	8.2%	5.7%
Average 8	**31**	**28**	**24**	**18**	**8**	**4**	**29**	**4**	**9**	**6%**	**4%**
9A	29.9	26.6	23.0	17.5	10.2	6.4	28.0	2.6	10.7	2.8%	0.9%
9B	29.5	26.5	23.2	18.3	10.4	4.4	24.1	2.5	9.5	9.2%	5.3%
9C	29.6	25.0	19.9	13.9	5.0	1.4	18.5	5.0	3.7	12.0%	5.3%
9D	34.7	27.4	21.8	14.6	5.1	1.9	20.8	5.4	3.9	9.1%	3.6%
Average 9	**31**	**26**	**22**	**16**	**8**	**4**	**23**	**4**	**7**	**8%**	**4%**

[a] D_{84} through D_{16} indicate the grain size (in mm) of the 84th through 16th percentile. In other words, a D_{84} of 27 mm indicates that 84% of the sample was smaller than 27 mm and 15% of the sample was coarser than 27 mm.

[b] Dg is the geometric mean of the sample and is defined as $Dg=(D_1^{W1} \times D_2^{W2} \times \ldots\ldots D_n^{Wn})$ where D_n is the midpoint diameter of particles retained on the nth sieve and W_n is the decimal fraction of particles retained on the nth sieve.

[c] The sorting coefficient is defined as D_{75} divided by D_{25} and is a dimensionless coefficient.

[d] The Fredle Index is defined as Dg (in mm) divided by the sorting coefficient.

In addition to physical measurements of spawning gravel quantity and quality, information on the use of the habitat by spawning anadromous fish was plotted. The WDFW have conducted fall Chinook redd counts in the river between Merwin Dam and the hatchery every year since 1971 (WDFW 2001 and Shane Hawkins, pers. comm.). Total annual redds counted in the 4 sections of the river are shown in Figure 2.3-10. The 4 sections are as follows:

- Section 1 – Merwin Dam (RM 19.5) to RM 18.5
- Section 2 – RM 18.5 to RM 17.8
- Section 3 – RM 17.8 to RM 16.7
- Section 4 – Lewis River Hatchery (RM 15.7) to RM 16.7

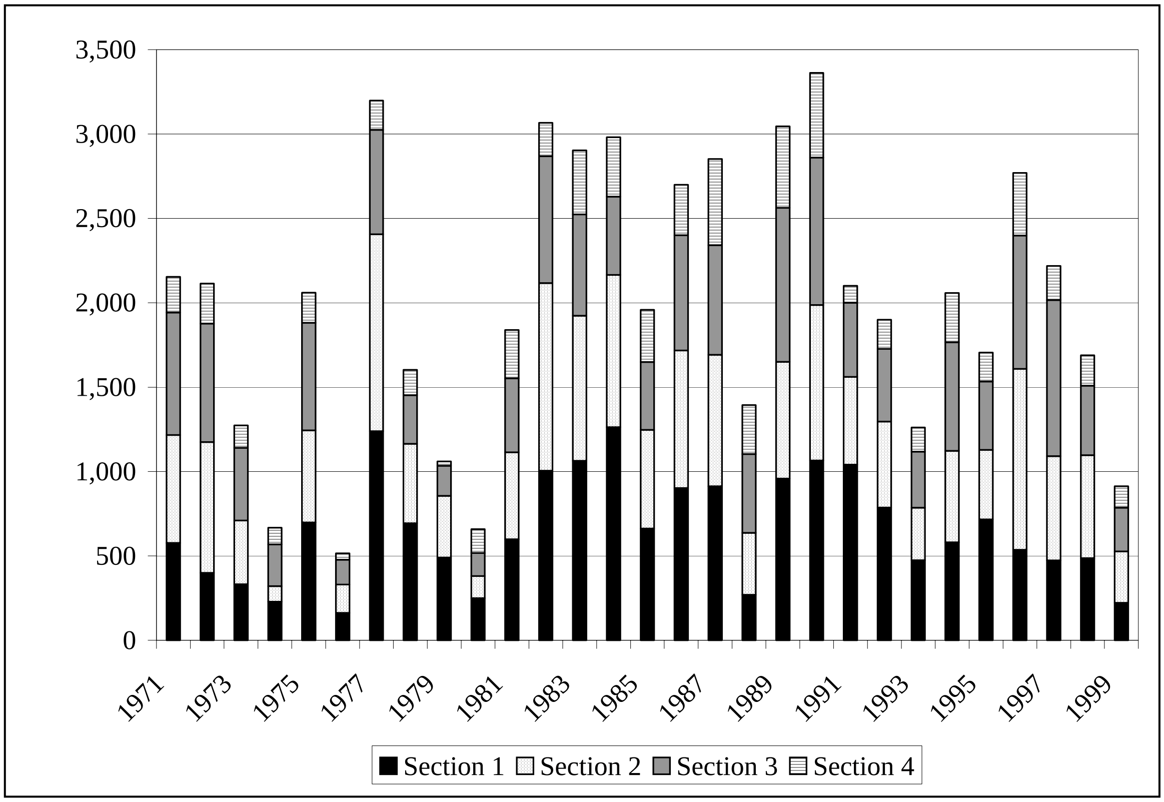


Figure 2.3-10. Fall Chinook redd counts in the Lewis River downstream of Merwin Dam.

Total redd counts, and the number of redds in each survey reach, vary through time. Redd counts are obviously dependent upon a number of variables besides availability of spawning gravel, including number of returning adults, ocean conditions, harvest, floods, etc. However, there does not seem to be any systematic decrease in total number of redds through the years, which could indicate a reduction in the total amount of spawning gravel (among other factors).

The distribution of redds in different sections of the river are shown in Figure 2.3-11. If spawning gravel was being flushed downstream, a shift in spawning from upstream (Section 1) to downstream sections would be expected. The highest flows downstream of Merwin Dam in this period occurred in 1975 (65,000 cfs), 1977 (72,000 cfs) and 1996 (86,000 cfs). There does not appear to be any systematic decrease in redds in Section 1 through time or following the 1975 or 1977 events. There has been a lower percentage of redds in Section 1 following the 1996 event than the period just prior to 1996, but the distribution is still within the range experienced in earlier years. Continued monitoring of redd counts and distribution between sections may help indicate if this shift persists.

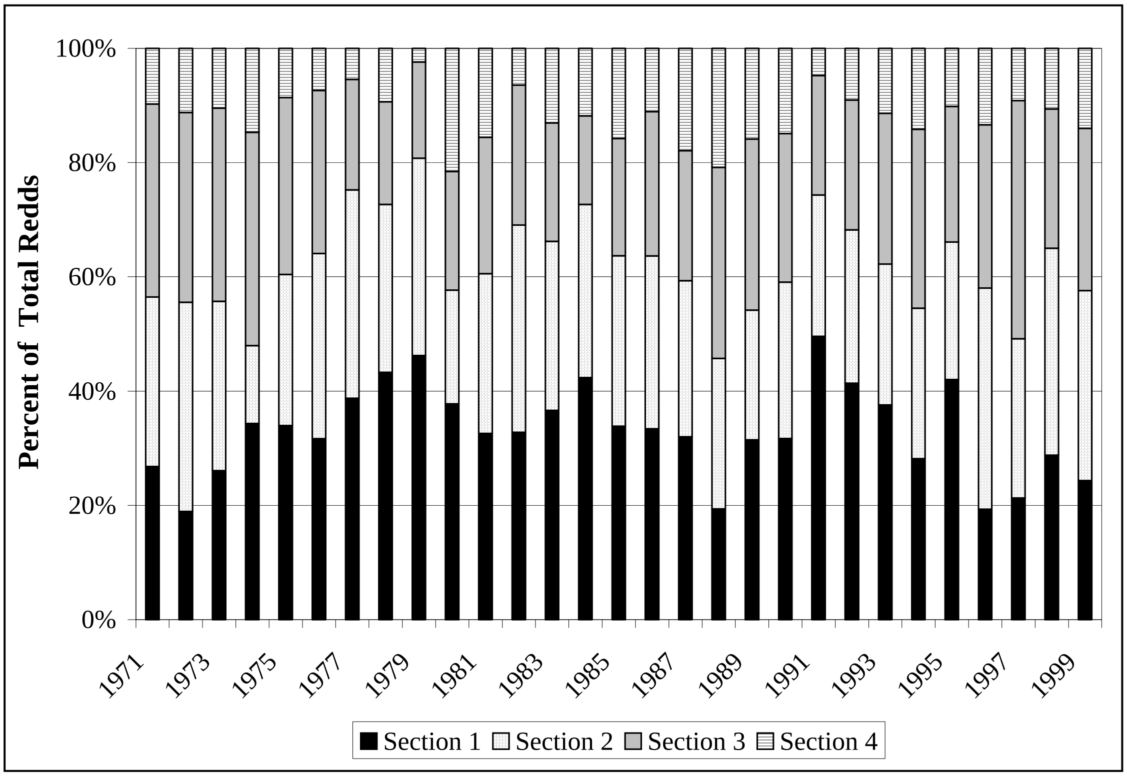


Figure 2.3-11. Distribution of redds downstream of Merwin Dam, expressed as percent of total redds counted each year.

2.3.5.2 Swift Bypass Reach

<u>Sediment Input</u>

A sediment input budget was prepared for the Swift bypass reach watershed. The reach was separated into 3 sub-basins: Rain Creek, Ole Creek, and the remaining parts of the watershed that drain to the bypass reach. Average total sediment input to Rain Creek was 9,855 tons/year, primarily from natural (not management-related) sources (Table 2.3-9). Average annual sediment input to Ole Creek was 1,590 tons/year, with 65 percent of the sediment coming from management-related landslides (originating in roads and recent clearcuts). Average annual sediment input to the remainder of the Swift bypass reach was 20 tons/year, primarily from natural sources.

Several ancient large, deep-seated landslides were included in the landslide inventory in Rain and Ole creeks. These features likely have not contributed much sediment to the streams recently, but did in the past. The streams are probably continuing to process this sediment and transport it downstream during high flows. The abundant boulders, cobbles, and gravel are transported from the upper, higher gradient portions of the Rain and Ole creek watersheds during high flows and deposited as the creeks flow onto the lower gradient alluvium.

Table 2.3-9. Sediment inputs in the Swift Bypass Reach (average tons/year).

Source	Rain Creek (2.4 sq mi)	Ole Creek (5 sq mi)	Swift bypass (2 sq mi; w/o Rain or Ole creeks)
Ancient landslides (large, persistent deep seated; probably not contributing much currently)	6,400*	135,000*	0
Soil creep	20	46	20
“Background” landslides (forests >50 years old)	9,740	540	0
Management-related landslides (road and recent harvest units)	95	1,000	0
Road surface erosion	<1	2	<1
Total recent inputs (not including ancient slides)	9,855	1,590	20
Total tons/square mile/yr	4,100	320	10

* Ancient slides are large, persistent, deep-seated features that probably have not contributed much sediment in the past 50 years. However, the streams are likely still transporting stored sediment from these features through the watershed during peak flow events.

Under current conditions, there is little input of sediment into the Swift bypass reach upstream of Ole Creek. No major upslope sediment sources exist in the reach. The only sediment comes from gravel and cobble stored in the bars along the reach. During large spill events, some of the stored sediment is moved into the active channel. This occurred during the 1996 spill event (peak flow was approximately 40,000 cfs) and resulted in some small gravel deposits on the downstream side of boulders in the reach. These gravel deposits were absent during the 1994 river survey conducted as part of the Yale relicensing studies. It is likely that the gravel deposits will slowly be flushed downstream and out of the reach during moderate spill events in the future.

The soils and sediment in the Swift bypass watershed are derived from volcanic rock and have a large fraction of gravel and cobble particles. Soils are composed of an average of 54 percent gravel (20 percent >3 inches), 10 percent sand, and 26 percent silt and clay (Table 2.3-4). This is the source of the large amount of cobble and gravel found in the lower reaches of Rain and Ole creeks that is routed to the lower bypass reach during high flow events.

Stream Channel Mapping

Stream channel maps of the Lewis River between Swift Dam and Yale Lake were prepared from the 1958, 1963, 1974, 1988, 1995, and 1998 aerial photographs (Figure 2.3-12). The maps show the extent of the wetted channel on the dates flown and side channels and active bars are noted.

The maps show that the active river channel has decreased in width following closure of Swift Dam. Vegetation has encroached on the former active channel. However, during extremely large spill events that occur every decade or so (see Figure 2.4-5 in WTS 4, the Swift Bypass Synthesis Report), the vegetation is uprooted, widening the active channel. Vegetation encroaches again following the spill, and the cycle repeats. There has not been appreciable shifting of the channel position through the years.

Channel Aggradation/Incision

The stage at given flows for the Lewis River at Cougar gage (located approximately 3/4 mile downstream of Swift Dam) was plotted to determine if any systematic changes in river stage at a given flow are occurring that could be the result of channel aggradation or incision (Figure 2.3-13). The gage is no longer active, but rating curves were available from 1924 through 1975. The rating curve was fairly stable through 1957, indicating no aggradation or incision was occurring at the gage site. From 1957 through 1967, the stage gradually increased approximately 1.5 feet for a given flow. Construction of Swift Dam began in 1956 and was completed in 1958. The gage is located in a large, deep pool and a cobble/boulder riffle with mid-channel bar provides the control point. It is unlikely that the entire channel in the Swift bypass reach has aggraded since the current channel is dominated by cobble and boulder; it likely had a finer substrate in the past. The aggradation at the gage site could be the result of downstream movement of sediment associated with dam construction, or with the flushing of substrate from the channel between Swift Dam and the gage site. The large increases in 1957 and 1967 are not associated with any known large spill events. It is possible that the aggradation was a localized phenomenon, and may have been transitory in nature; records have not been kept for this site in the past 25 years.

Aquatic Habitat and Substrate

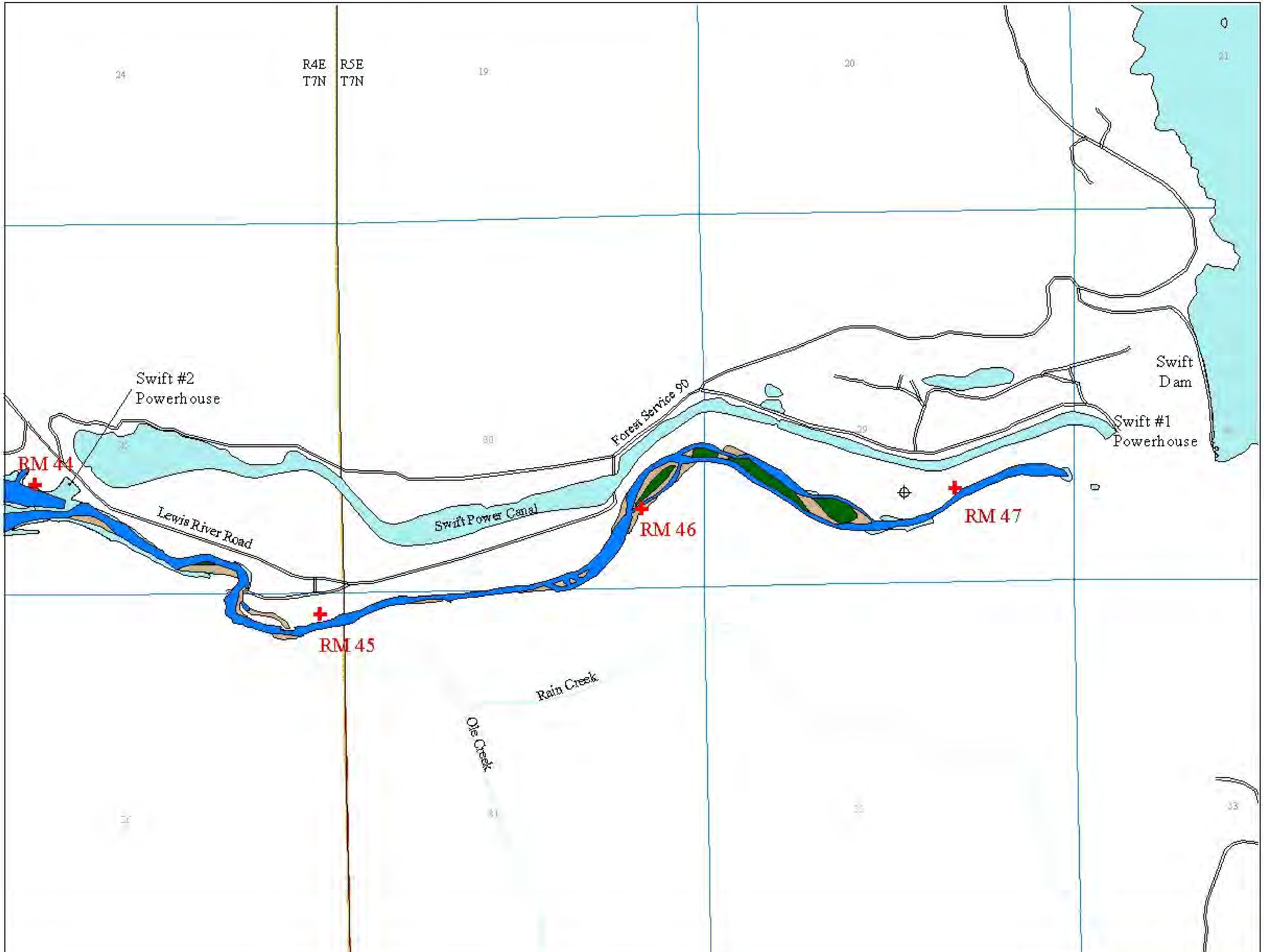
The Swift bypass reach is dominated by riffle (37 percent) and glide (28 percent) habitat (Table 2.3-10). Approximately 19 percent of the reach is pool habitat; 12 percent is classified as side channels. Substrate is dominantly cobble and small boulder. Details of the aquatic habitat and large woody debris sampling are included in WTS 3 Appendix 1.

Large woody debris was counted in each habitat unit in four size classes. The location of the woody debris was also noted (within wetted channel or within bankfull channel). A total of 10 small wood pieces (defined as over 12 inches in diameter and over 25 feet long) and 44 pieces of brush (defined as over 6 inches in diameter and over 25 feet long), were located within the bankfull channel. Only 7 of these pieces (3 small and 4 brush) were within the wetted channel. This is an average of 21.2 pieces per mile of small and brush-sized wood. The majority of wood was in the downstream end of the reach, in a log jam located at the sharp bend downstream from the confluence with Ole Creek.

Lewis River
Hydroelectric Projects

Figure 2.3-12a Stream Channel Changes in Swift Bypass Reach

1958 Channel Position



Channel Classifications

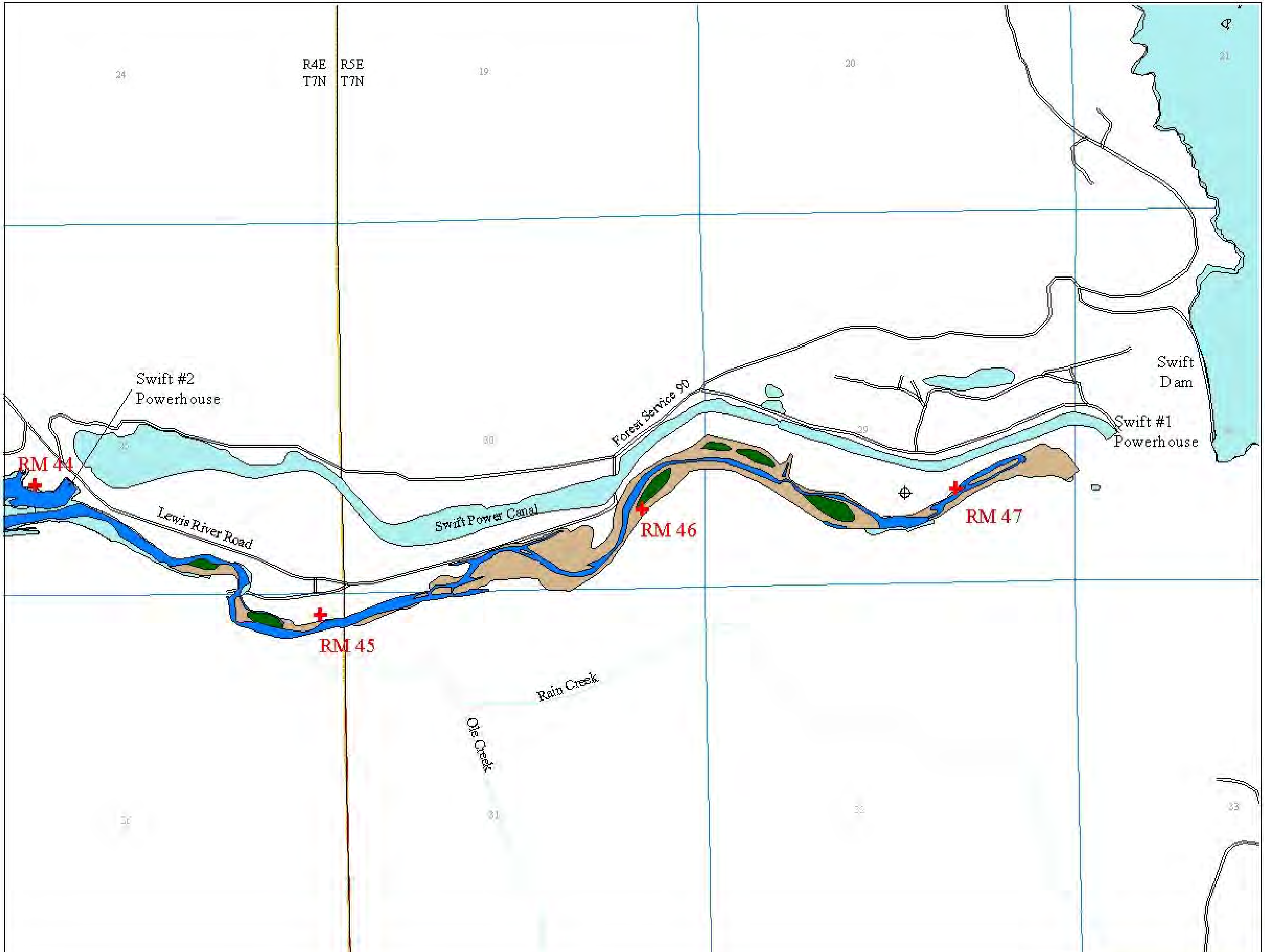
- Active Bar
- Wetted Channel
- Vegetated Bar
- Island
- Lake
- Pond
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

1000 0 1000 2000 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



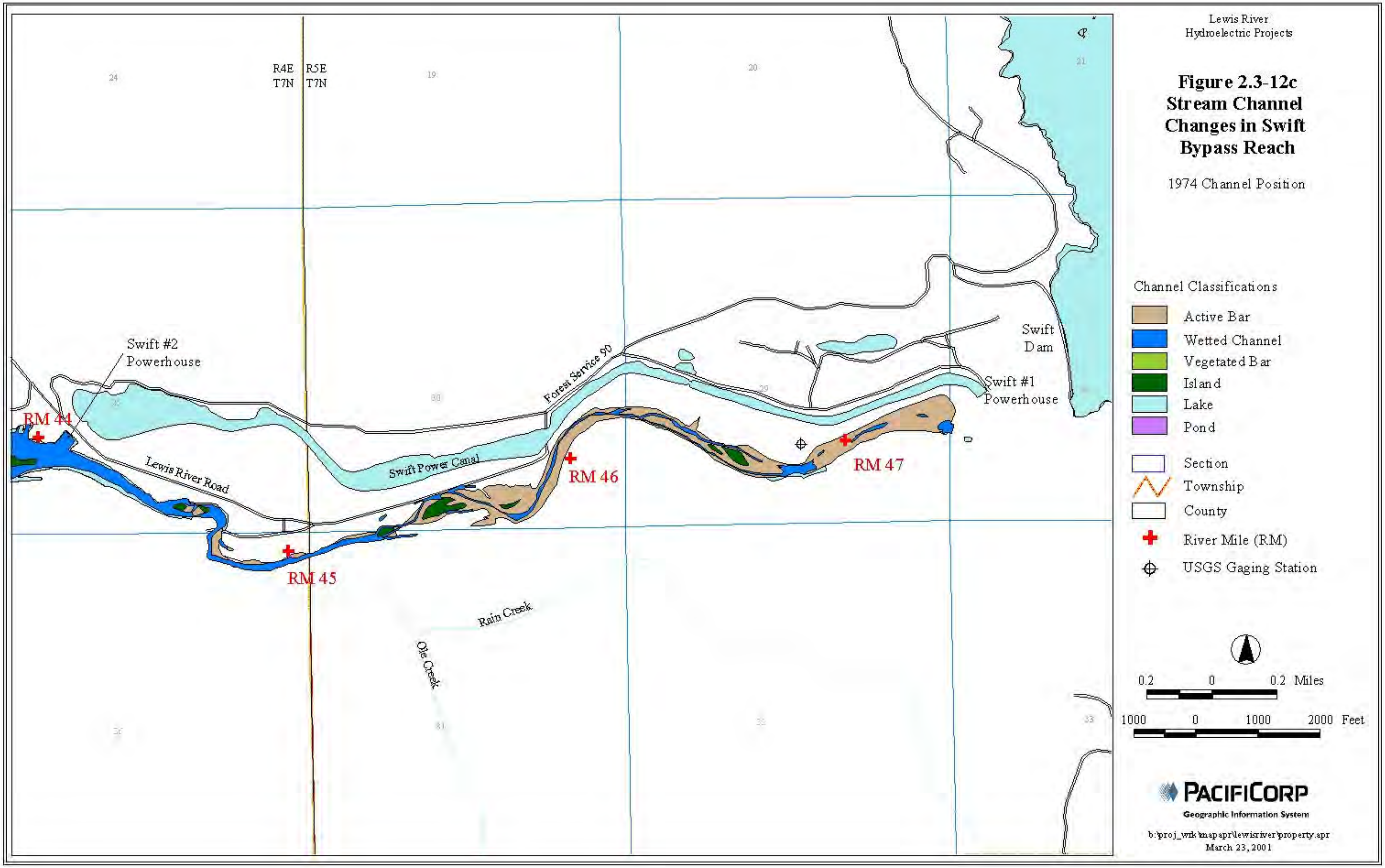
Lewis River Hydroelectric Projects

Figure 2.3-12b Stream Channel Changes in Swift Bypass Reach

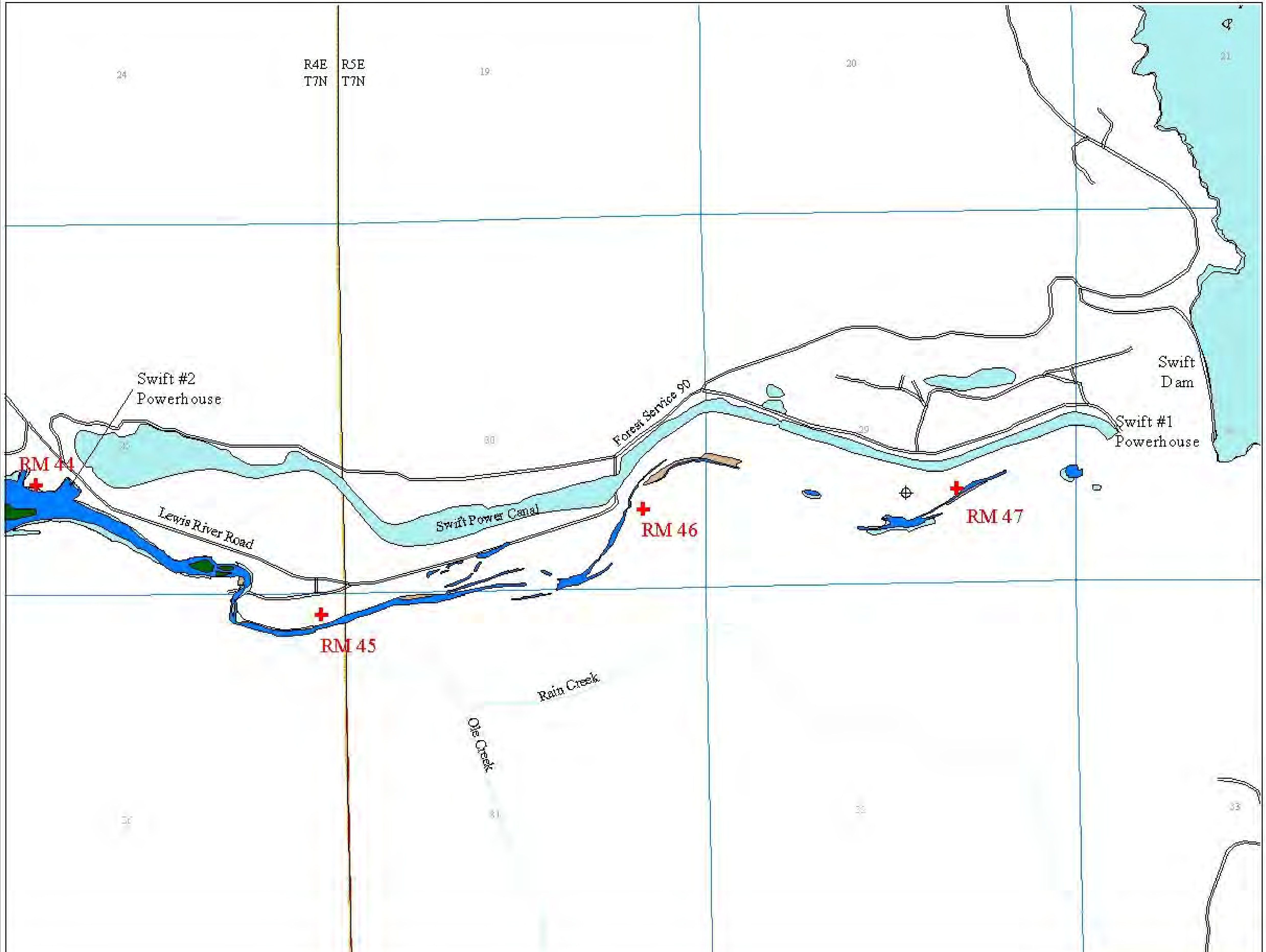
1963 Channel Position

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects
Figure 2.3-12c
Stream Channel
Changes in Swift
Bypass Reach
1974 Channel Position
Channel Classifications
Active Bar
Wetted Channel
Vegetated Bar
Island
Lake
Pond
Section
Township
County
River Mile (RM)
USGS Gaging Station
0.2 0 0.2 Miles
1000 0 1000 2000 Feet
R4E T7N
R5E T7N
Swift #2
Powerhouse
Swift #1
Powerhouse
Swift
Dam
Forest Service 90
Swift Power Canal
Lewis River Road
Rain Creek
Ole Creek
RM 44
RM 45
RM 46
RM 47
PACIFICORP
Geographic Information System
b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects

Figure 2.3-12d Stream Channel Changes in Swift Bypass Reach

1988 Channel Position

Channel Classifications

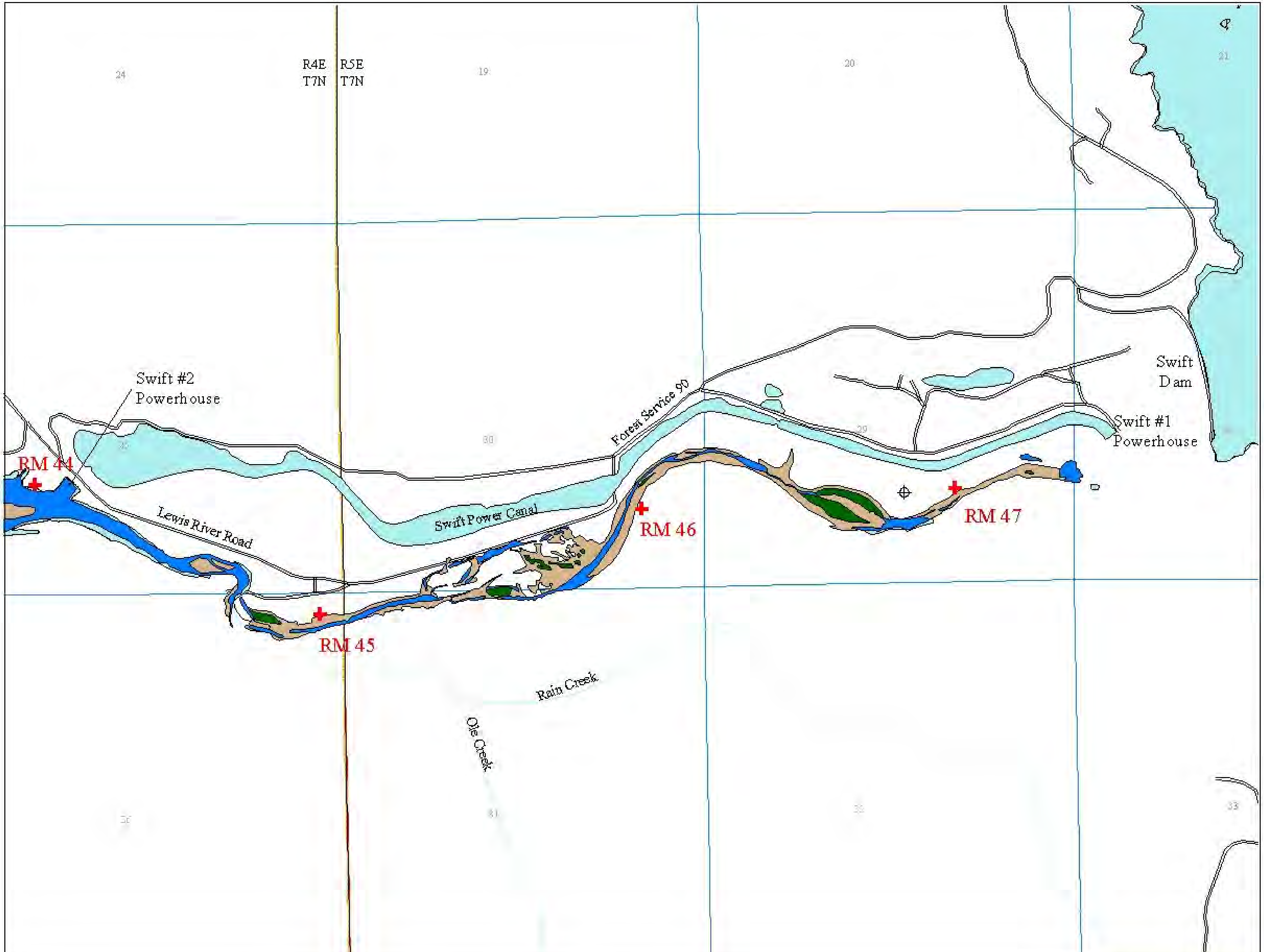
- Active Bar
- Wetted Channel
- Vegetated Bar
- Island
- Lake
- Pond
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

1000 0 1000 2000 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects

Figure 2.3-12e
Stream Channel Changes in Swift Bypass Reach

1995 Channel Position

Channel Classifications

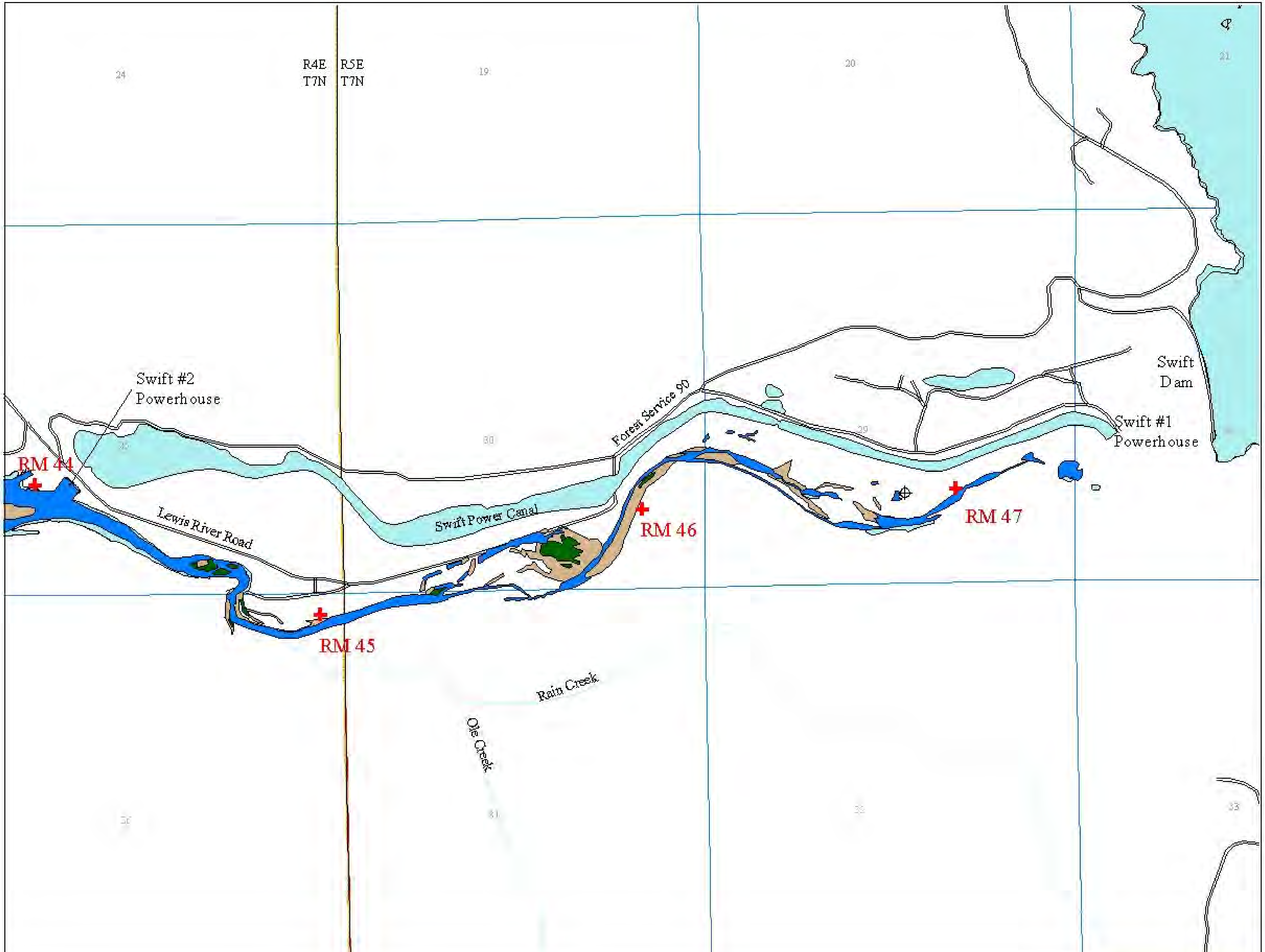
- Active Bar
- Wetted Channel
- Vegetated Bar
- Island
- Lake
- Pond
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

1000 0 1000 2000 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001



Lewis River
Hydroelectric Projects

Figure 2.3-12f
Stream Channel Changes in Swift Bypass Reach

1998 Channel Position

Channel Classifications

- Active Bar
- Wetted Channel
- Vegetated Bar
- Island
- Lake
- Pond
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

1000 0 1000 2000 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001

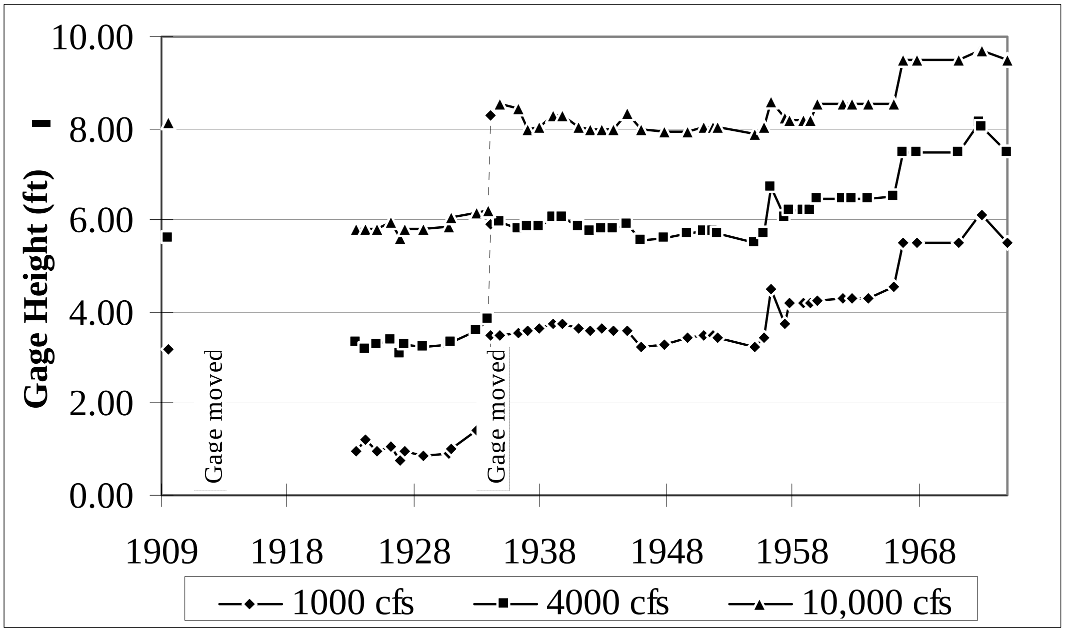


Figure 2.3-13. Gage height versus given flow for the Lewis River at Cougar gage.

The riparian zone closest to the active channel in the Swift bypass reach is dominated by alder, with some large cottonwoods. There are few large coniferous trees in the riparian zone. As a result, recruitment potential of large woody debris from the riparian forests in the bypass reach is low. The riparian areas in lower Ole Creek contain larger trees, with overstory trees estimated between 10-24 inches dbf based on aerial photograph interpretation. The Ole Creek riparian stands are a mix of black cottonwood, Douglas-fir, and mixed hardwood/conifer stands. Observations of lower Ole Creek show more abundant large woody debris loading in the creek than in the upper Swift bypass reach, indicating Ole Creek is a source of large woody debris as well as gravel.

Substrate Mapping and Sampling

Channel substrate was mapped during the 2000 field survey (Figure 2.3-14). In addition, pebble counts and sub-armor layer samples were taken at 3 sites. Substrate sample locations are shown on Figure 2.3-14. Detailed results of the substrate sampling and photos of the sample sites are included in WTS 3 Appendix 2.

The changes in median substrate size along the Lewis River in the Swift bypass reach are shown in Figure 2.3-15. The substrate samples were taken at comparable locations within the channel (the upstream end of point bars) so that they would show variations in grain size along the channel. The substrate samples upstream of Ole Creek were primarily large particles (over 64 mm median diameter); those downstream of Ole Creek were much finer with a median diameter closer to 32 mm.

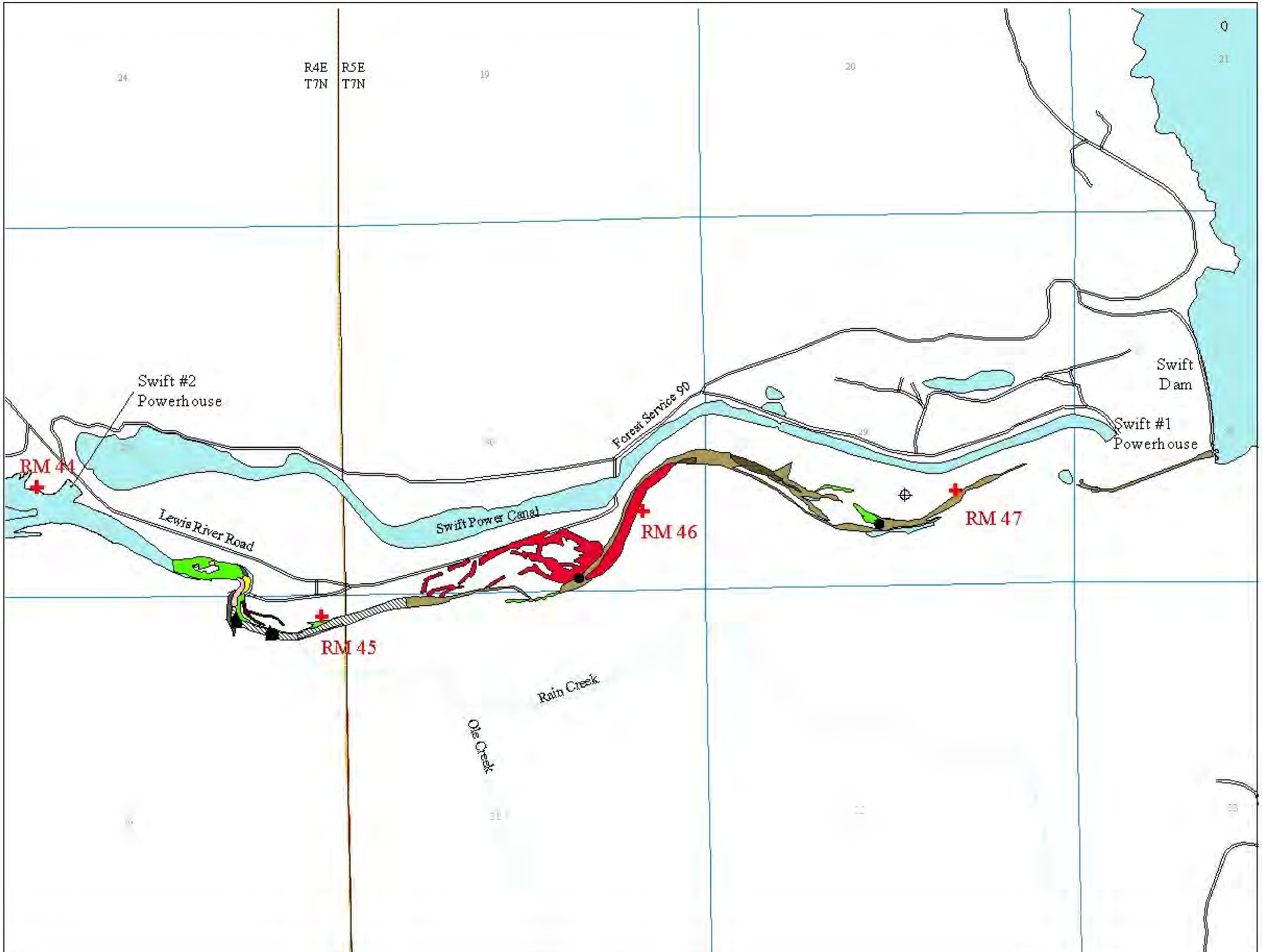
Table 2.3-10. Summary of aquatic habitat in the Swift bypass reach.

Lower Confined Reach	**Riffle**	**Glide**	**Pool**	**Side Channel**	**Cascade**
Average length (ft)	224	161	510	none	69
Average wetted width (ft)	79	80	80	none	100
Total wetted area (sq ft)	154,018	96,668	40,800	none	6900
Dominant Substrate	SB	CO/SB	CO	none	SB
Subdominant substrate	CO/SB	SB	GR	none	CO
Spawning Gravel Area (sq ft)	120,000			none	0
Mod confined Reach	**Riffle**	**Glide**	**Pool**	**Side Channel**	**Cascade**
Average length (ft)	294	208	187	2,450	91
Average wetted width (ft)	35	53	50	15	20
Total wetted area (sq ft)	44,629	52,149	19,245	36,750	3,525
Dominant Substrate	SB	CO/SB	CO/GR	not noted	SB
Subdominant substrate	CO	CO/SB	SA	not noted	LB
Spawning Gravel Area (sq ft)	126,000 in patches and pockets			0	0
Unconfined Reach	**Riffle**	**Glide**	**Pool**	**Side Channel**	**Cascade**
Average length (ft)	260	264	171	3,048	150
Average wetted width (ft)	53	58	55	26	54
Total wetted area (sq ft)	100,447	133,781	41,779	79,248	15,720
Dominant Substrate	SB	CO	CO/GR	not noted	BO
Subdominant substrate	CO	SB	CO/SB	not noted	CO
Spawning Gravel Area (sq ft)	0	0	0	0	0
Upper confined Reach	**Riffle**	**Glide**	**Pool**	**Side Channel**	**Cascade**
Average length (ft)	256	317	439	none	140
Average wetted width (ft)	53	57	113	none	38
Total wetted area (sq ft)	54,845	59,950	77,100	none	5,320
Dominant Substrate	SB	SB	SB	none	LB
Subdominant substrate	LB	CO/LB/SB	LB	none	SB
Spawning Gravel Area (sq ft)	0e	0	0	0	0

BO = boulder CO = cobble SA = sand
BR = bedrock GR = gravel SI = silt

Spawning Gravel

Samples of spawning gravel were also collected at 2 locations in the bypass reach downstream of Ole Creek, and 1 location in Ole Creek. No substantial accumulations of spawning gravel were found upstream of the Ole Creek confluence. Results of the spawning gravel sampling are summarized in Table 2.3-11. The sampled spawning gravel had a median diameter of 13-17 mm (0.5-0.7 inches), 4-9 percent particles finer than 2 mm, and a Fredle Index of 5-7. These metrics indicate the available spawning gravel is good quality. There is a lack of suitably-sized spawning gravel for most resident salmonids and anadromous salmonid species upstream of Ole Creek.



Lewis River
Hydroelectric Projects

Figure 2.3-14

Lewis River Channel
Substrate and Spawning Areas

Swift Bypass Reach,
based on September 2000
field mapping

- Substrate Sample Locations
- Spawning Sample Locations
- Spawning Areas

Substrate
- **Boulder**
- Boulder/Cobble
- Boulder/Gravel
- Bedrock
- Bedrock/Boulder
- Cobble
- Cobble/Boulder
- Cobble/Gravel
- Cobble/Sand
- Gravel
- Gravel/Boulder
- Gravel/Cobble
- Gravel/Sand
- Sand
- Silt/Sand
- Lakes
- Section
- Township
- County
- River Mile (RM)
- USGS Gaging Station

0.2 0 0.2 Miles

1000 0 1000 2000 Feet

PACIFICORP
Geographic Information System

b:\proj_wrk\mapapr\lewisriver\property.apr
March 23, 2001

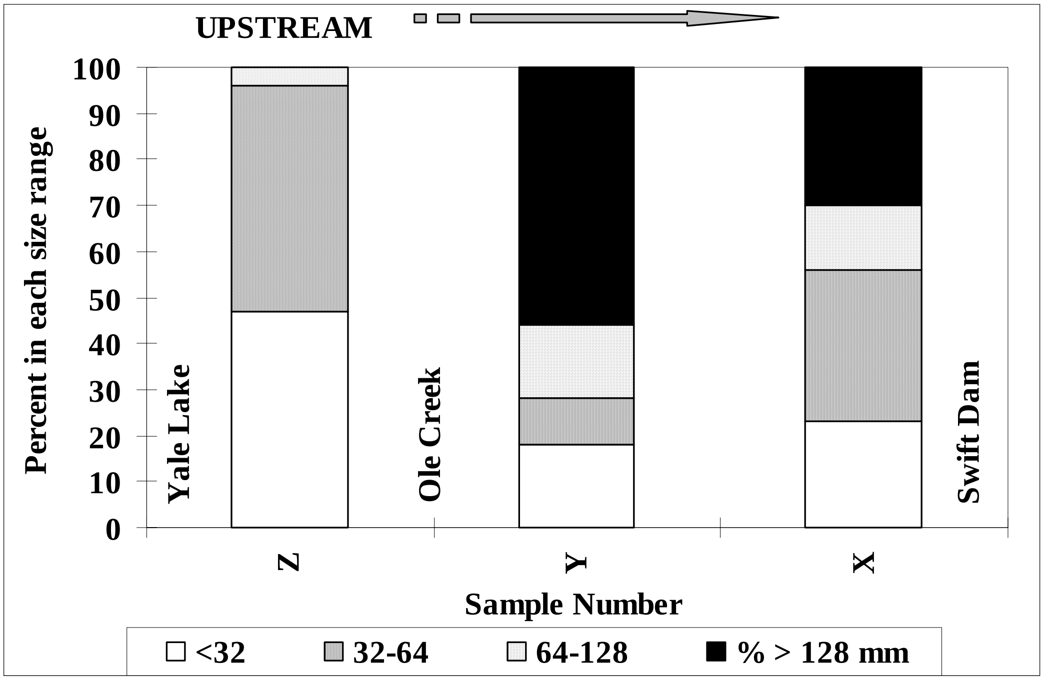


Figure 2.3-15. Change in grain size distribution of surface (armor) gravel samples in the Swift bypass reach.

Painted Rock Study

In order to determine the flow at which gravel-sized particles were mobile in the Swift bypass reach, painted gravel was placed at 4 locations prior to the instream flow study. The movement of the painted rocks was monitored after each flow release. The following sections summarize the findings at each location.

Transect 45-1R, Riffle – A cluster of bright yellow gravel, 0.5-6.0 inches (12.7-152 mm) in diameter, was placed 13-14 feet downstream of Station 67 in the middle of the channel. Table 2.3-12 shows the water depth, velocity, calculated discharge, and any rock movement noted during the 3 flow releases.

Transect 26-1R, Riffle – A cluster of bright orange gravel, 0.5-6.0 inches (12.7-152 mm) in diameter, was placed 11-12 feet downstream of Station 59.5 in the middle of the channel. Table 2.3-13 shows the water depth, velocity, calculated discharge, and any rock movement noted during the 3 flow releases.

Transect 10-1R, Riffle – A cluster of bright blue gravel, 0.5-6.0 inches (12.7-152 mm) in diameter, was placed 12-13 feet downstream of riffle Transect 10, in the middle of the channel. Table 2.3-14 shows the water depth, velocity, calculated discharge, and any rock movement noted during the 3 flow releases.

Table 2.3-11. Summary of spawning gravel samples, Swift bypass reach and Ole Creek.

Sample	D_{84}[a] (mm)	D_{75} (mm)	D_{65} (mm)	D_{50} (mm)	D_{25} (mm)	D_{16} (mm)	Dg[b] (mm)	Sorting Coeffi-cient[c]	Fredle Index[d]	% finer than 2 mm	% finer than 1 mm
Swift Bypass 1A	19.7	14.8	11.9	7.4	1.7	1.0	10.1	8.5	1.2	16.1%	6.9%
Swift Bypass 1B	23.5	19.0	15.2	12.3	6.0	3.3	18.3	3.2	5.8	4.7%	1.6%
Swift Bypass 1C	35.6	28.6	24.3	17.9	10.0	5.3	26.4	2.9	9.2	7.0%	4.1%
Swift Bypass 1D	25.4	21.9	18.1	13.6	6.1	2.7	17.7	3.6	4.9	10.0%	5.8%
Average Swift Bypass 1	**26**	**21**	**17**	**13**	**6**	**3**	**18**	**5**	**5**	**9%**	**5%**
Swift Bypass 2A	19.2	12.2	13.5	11.0	5.0	3.3	16.7	2.4	6.9	2.2%	0.9%
Swift Bypass 2B	24.1	19.9	15.7	12.7	6.3	3.5	19.2	3.2	6.1	3.2%	1.0%
Swift Bypass 2C	24.9	21.2	17.1	13.7	8.2	4.7	21.4	2.6	8.2	3.1%	1.2%
Swift Bypass 2D	25.7	22.4	18.8	14.2	7.7	4.6	20.8	2.9	7.1	5.5%	2.5%
Average Swift Bypass 2	**23**	**19**	**16**	**13**	**7**	**4**	**20**	**3**	**7**	**4%**	**1%**
Ole A	23.2	18.5	15.2	12.7	8.2	5.7	18.5	2.3	8.2	6.0%	5.8%
Ole B	21.6	16.1	13.8	10.4	3.1	1.6	13.0	5.1	2.5	9.9%	5.2%
Ole C	25.1	21.5	17.4	12.4	3.6	1.7	15.8	6.0	2.7	8.6%	3.6%
Ole D	29.5	25.9	21.8	15.8	6.7	2.4	20.5	3.9	5.3	9.4%	6.1%
Average Ole	**25**	**20**	**17**	**13**	**5**	**3**	**17**	**4**	**5**	**8%**	**5%**

[a] D_{84} through D_{16} indicate the grain size (in mm) of the 84th through 16th percentile. In other words, a D_{84} of 27 mm indicates that 84% of the sample was smaller than 27 mm and 15% of the sample was coarser than 27 mm.

[b] Dg is the geometric mean of the sample and is defined as $Dg=(D_1^{W1} \times D_2^{W2} \times \ldots\ldots D_n^{Wn})$ where D_n is the midpoint diameter of particles retained on the nth sieve and W_n is the decimal fraction of particles retained on the nth sieve.

[c] The sorting coefficient is defined as D_{75} divided by D_{25} and is a dimensionless coefficient.

[d] The Fredle Index is defined as Dg (in mm) divided by the sorting coefficient.

Table 2.3-12. Transect 45-1 summary of painted rock movement.

Measured discharge (cfs)	Water depth above rock cluster (ft)	Water velocity above rock cluster (ft/sec)	Movement noted
51	2.0	1.04	None
134	2.9	1.96	None
280	3.4	4.0	None

No movement of the rocks was noted during the September gravel survey.

Table 2.3-13. Transect 26-1 summary of painted rock movement.

Measured discharge (cfs)	Water depth above rock cluster (ft)	Water velocity above rock cluster (ft/sec)	Movement noted
70	3.0	1.00	None
151	3.4	1.63	None
263	3.9	1.6	None

No movement of the rocks was noted during the September gravel survey.

Table 2.3-14. Transect 10-1 summary of painted rock movement.

Measured discharge (cfs)	Water depth above rock cluster (ft)	Water velocity above rock cluster (ft/sec)	Movement noted
87	1.2	2.44	None
142	1.4	2.26	Slight movement of rocks on right and left downstream edges of pile (moved 2-5 inches)
362	2.0	2.36	Some movement, especially at downstream edges of pile (moved 6-12 inches downstream). Most rocks in original position.

Movement of rocks was noted during the September field survey; the rocks were spread between 12 and 23 feet downstream of the transect line, indicating movement of up to 13 feet. The smallest particles (0.5 to 1.5 inch diameter) moved the farthest downstream.

Transect 6SPAWN, Spawning Riffle – A row of bright orange gravel, 0.5-6.0 inches in diameter, was placed along a transect 17 feet downstream of the Spawning Transect (transect 6). Table 2.3-15 shows the location, water depth and size of rocks placed on May 11, 2000 as well as any movement of particles noted during the September 13, 2000 field survey (no movement was noted during any of the instream flow study releases). Between the instream flow study in May and the September field survey, there evidently was a higher flow at this transect, likely a result of inflow from the Rain/Ole Creek system that is upstream of this transect. The mid-channel gravel bar at this transect migrated downstream and covered some of the painted rocks in the middle of the transect. Some of the smaller rocks (2-3 inches in diameter) had moved a few feet downstream or were missing, and at the left end of the transect, a few rocks had actually moved upstream under a large boulder, likely a result of back-eddies in that location.

Table 2.3-16 shows the velocities and depths measured at the instream flow study transect during the 3 measured flows. Note that the instream flow transect is 17 feet upstream from the painted rock transect. No movement of rocks was observed during these flows.

Sediment Transport Modeling

Sediment transport modeling using the WINXSPRO program was performed at 3 cross-sections in the Swift bypass reach The model was used to predict the transport of any added gravel in the Swift bypass reach. Details of the modeling are provided in WTS 3 Appendix 4.

Table 2.3-15. Location, water depth, and size of painted rocks placed at Transect 6 in May 2000.

Distance from Left Bank Headpin (ft)	Water Depth	Rock Size (inches median diameter)	Movement noted on 9/13/00 field check
145	1	3	
144	1	4	
143	1	3.5	
142	0.9	2.5	
141	0.9	2.5	4 feet downstream
140	1	2	Missing, not found
139	1.1	3.5	
138	1.4	3.5	
137	1.5	2.5	
136	1.6	3	
135	1.8	4	3 feet downstream
134	1.7	3	3 feet downstream
133	1.6	2.5	Missing, not found
132	1.1	3.5	
131	1	4	
130	0.8	3	Missing, not found
129	0.8	2	1 foot downstream
128	1	2	Buried 1"
127	0.8	4	0.5 foot downstream
126	0.6	3	
125	0.5	2.5	
124	0.4	3.5	
123	0.6	2.5	Buried 1"
122	0.6	2	Buried 2"
121	0.7	3	Buried 3"
120	0.9	4	Buried 4"
119	1	2.5	Buried 6"
118	0.9	3	Buried 6"
117	1.1	2.5	Buried 2"
116	1.3	4.5	Missing, not found
115	1.4	3	Missing, not found
114	1.6	2.5	
113	2	2.5	0.5 foot downstream
112	2.2	2	
111	2.4	2	
110	2.5	2.5	Buried 1"
109	2.6	3	
108	2.6	2.5	2.5 feet downstream
107	2.6	2.5	Buried 1"
106	2.5	3	
105	2.4	2.5	
104	2.4	2	
103	2.3	5	Moved 2 feet upstream under boulder

Table 2.3-16. Water velocities and depths measured at Transect 6 during instream flow study.

Distance from Left Headpin (ft)	120 cfs Measured Discharge		207 cfs Measured Discharge		316 cfs Measured Discharge	
	Depth (ft)	Velocity (ft/sec)	Depth (ft)	Velocity (ft/sec)	Depth (ft)	Velocity (ft/sec)
53					LWE	
56			LWE		0.5	0.68
58			0.1		0.6	1.41
61			0.1		0.6	0.41
65	LWE		0.4	0.62	0.7	0.51
68	0.6	0.88	0.8	1.04	1.5	2.59
71	0.8	0.26	1.2	1.91	1.5	0.89
74	1.0	1.90	1.6	1.88	1.7	3.07
76	0.8	0.27	1.3	2.29	1.4	0.93
79	0.1		0.7	2.58	0.9	2.21
82	0.1		0.5	1.56	0.9	1.57
85	0.9	0.21	1.3	0.84	1.5	1.18
88	1.8	0.51	2.3	0.82	2.5	1.12,1.42
91	2.3	1.29	2.5	1.4,1.4	2.9	2.16,2.19
94	2.3	1.69	2.6	1.68,2.08	3.1	2.20,2.68
97	2.7	1.55,1.81	3.0	1.92,2.42	3.2	2.10,2.48
100	3.0	1.27,1.74	3.4	1.7,1.97	3.7	1.95,2.70
103	3.0	1.21,1.72	3.2	1.69,1.92	3.5	2.35,2.61
106	2.3	1.80	2.7	1.78,2.32	3.1	2.13,2.70
109	1.8	1.48	2.0	1.90	2.5	1.50,3.17
112	1.1	0.84	1.4	1.39	2.2	2.41
115	0.8	0.97	1.2	0.90	1.5	2.06
118	0.9	0.15	1.5	0.14	1.5	1.85
121	0.5	0.08	0.8	0.14	1.0	0.41
124	0.1		0.1		0.5	0.76
127	0.2	0	0.4	0.67	0.9	1.60
130	0.7	0.29	1.0	1.34	1.3	1.50
133	0.5	0.39	1.0	1.48	1.2	0.93
136	1.6	0.05	2.0	0.08	2.2	0.14
139	2.3	0.82	2.6	1.42,1.7	2.8	1.62,1.83
142	2.7	0.55,1.33	3.1	.98,1.32	3.4	0.88,1.42
145	2.5	0.25,0.48	2.6	.47,.65	3.3	0.56,1.48
148	2.2	0.74	2.4	1.15	2.7	0.67,1.42
151	1.4	0	1.7	0.22	2.0	0.65
154	0.5	0.11	0.7	0	1.3	0.07
157	0.0		0.7	0	0.5	0.48
160	RWE		RWE		0.1	
163					RWE	

LWE: Left water's edge
RWE: Right water's edge

Modeling at the 3 riffle transects indicate that transport of gravel-sized particles (size distribution suitable for use by spawning anadromous fish) would be initiated at flows of approximately 500 cfs. Transport rates increase rapidly with flows, and if the bed was composed of solely gravel-sized particles, the model predicts very high transport rates at flows over 3,000 cfs. Larger boulder or cobble-sized clasts in the substrate, or placement of gravel in holding structures would help to hold the gravel under moderately high flows. However, at flows over 5,000 cfs it is unlikely that spawning-sized gravel would be retained in locations accessible by fish.

2.3.5.3 Speelyai Creek

Speelyai Creek was divided into 3 reaches for analysis purposes: upper Speelyai Creek (upstream of the PacifiCorp diversion); the canal reach (the canal dug between the PacifiCorp diversion and Yale Lake); and lower Speelyai Creek (between the PacifiCorp diversion and Lake Merwin).

Sediment Input

A sediment input budget was prepared for the Speelyai Creek watershed. Estimated average annual sediment input from soil creep, landslides, and road surface erosion were calculated. Average total sediment input to lower Speelyai Creek (downstream of the PacifiCorp diversion) was 242 tons/year, primarily from natural sources (Table 2.3-17). Average annual sediment input to upper Speelyai Creek was 9,800 tons/year, with 95 percent of the sediment coming from management-related landslides (originating in roads and recent clearcuts).

Table 2.3-17. Sediment inputs (average tons/year).

Source	Upper Speelyai Creek (13 sq mi)	Lower Speelyai Creek (4 sq mi)
Soil Creep	145	20
“Background” Landslides (clearcuts >50 years old)	370	220
Management-related landslides (road and recent clearcuts)	9,250	0
Road Surface Erosion	35	2
Total	**9,800**	**242**
Total tons/square mile/year	750	60

Soils in the upper Speelyai watershed are fine grained, with an average of 24 percent gravel, 14 percent sand, and 62 percent silt and clay (Table 2.3-4). Soils in the lower Speelyai watershed are coarser-grained, with an average of 52 percent gravel, 31 percent sand, and only 17 percent silt and clay. The grain size of sediment inputs in the 2 watersheds are likely similar to the soils in each watershed.

Channel Aggradation/Incision

Speelyai Creek is too small to be seen on aerial photographs of the area, so no maps of channel changes could be made.

Information from USGS rating curves for the Speelyai Creek at Cougar gage (14219800) was plotted to determine if any systematic changes in river stage at a given flow are occurring that could be the result of channel aggradation or incision (Figure 2.3-16). The gage is in upper Speelyai Creek and was located just upstream of the highway bridge until the 1996 flood. Following the flood, it was moved downstream of the highway bridge to a location just downstream of the PacifiCorp diversion at the head of the canal leading to Yale Lake. Prior to the 1996 high flow, the gage appeared stable; there was no evidence of aggradation or incision. Evidence of approximately 1 foot of aggradation just after the gage was moved to the new location is shown on the plot; however, there has not been a long enough period of record to determine if this is a long-term trend.

Aquatic Habitat and Substrate

Aquatic habitat in lower Speelyai Creek, the canal, and the lower 0.5 mile of upper Speelyai Creek was mapped during September, 2000. Complete aquatic habitat and large woody debris data is included in WTS 3 Appendix 1 and is summarized below.

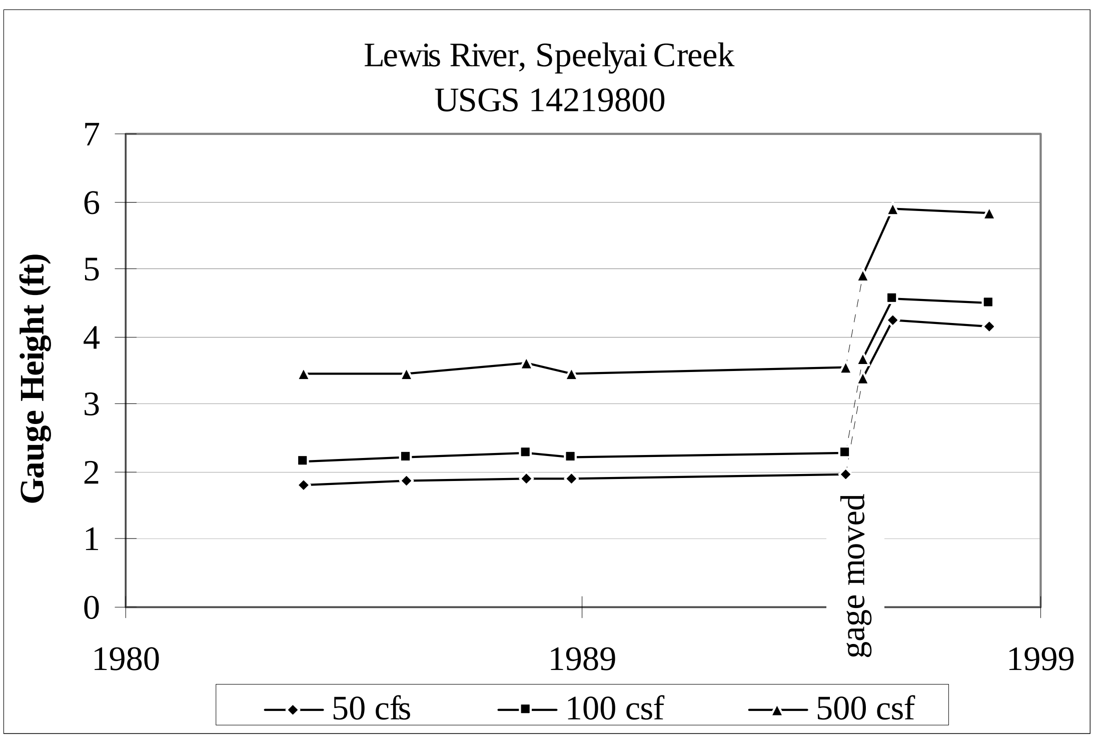


Figure 2.3-16. Gage height versus given flow for Speelyai Creek near Cougar (upstream of diversion).

Lower Speelyai Creek has the characteristics of a spring-fed system. Flow increased gradually from only a trickle just below the upper diversion to an estimated 15-20 cfs at the Speelyai Hatchery diversion during the September survey. The stability of streamside vegetation close to the September water level, along with instream statuary and low bridges built by recent residents, indicates that flows in the lower creek do not vary dramatically, event during winter rains. In general, aquatic habitat appears to be in good condition, with a mix of riffle, glide, and pool habitat, abundant woody debris and cover, many active beaver dams, and cobble/gravel substrate. The riparian zone consisted of a diversity of riparian species and habitats (see TER 9, Riparian Synthesis Report).

Lower Speelyai was divided into 2 reaches for summary statistics; the reach from the hatchery (confluence with Lake Merwin) to the Highway 503 bridge, and from the highway bridge to the upper diversion. The highway bridge marks the approximate boundary between the upper wide, unconfined valley and the lower, slightly more confined valley where the stream has begun incising into the underlying flat volcaniclastic deposits. Summary information for habitat unit lengths, widths, total area, substrate, and spawning gravel availability is shown in Table 2.3-18.

Table 2.3-18. Summary of aquatic habitat in Lower Speelyai Creek.

Hatchery (Lake Merwin) to Highway 503 bridge	**Riffle**	**Glide**	**Pool**	**Beaver Complex**	**Cascade**
Average length (ft)	166	182	173	213	25
Average wetted width (ft)	27	28	31	50	24
Average bankfull width (ft)	43	45	50	100	42
Total wetted area (sq ft)	133,609	169,974	81,208	10,650	1,242
Dominant substrate	CO	CO	SA	CO	BO/CO
Subdominant substrate	GR	SA	SI	GR	CO/GR
Spawning gravel area (sq ft)	8,850	9,300	550	500	0
Highway 503 bridge to upper diversion	**Riffle**	**Glide**	**Pool**	**Glide/Pool Complex**	**Riffle/Glide Complex**
Average length (ft)	93	219	77	703	203
Average wetted width (ft)	15	19	24	25	18
Average bankfull width (ft)	25	28	31	45	25
Total wetted area (sq ft)	30,891	116,524	7,587	17,575	15,887
Dominant substrate	CO	GR	GR	SI	CO/GR
Subdominant substrate	GR	CO	SA	CO	CO
Spawning gravel area (sq ft)	100	400		0	500

BO = boulder CO = cobble GR = gravel SA = sand SI = silt

Lower Speelyai Creek is dominated by glides and riffles, with abundant pools in the lowest reach, and fewer pools in the upstream portion. Wetted channel width is close to 30 feet in the lowest reach, and closer to 20 feet in the upstream portion, where there is less flow. The ratio of bankfull:wetted width is 1.5, indicating a stream system with few peak flows. Substrate is dominantly cobble gravel, with sand and silt in habitat types with slower moving water.

Upper Speelyai Creek, upstream of the PacifiCorp diversion, is typical of a high energy stream with large peak flow events. The reach is dominated by riffles and glides, with a few pools and cascades (Table 2.3-19). Average wetted width is 23 feet, and the bank-full:wetted width ratio is 3, indicating large peak flows. Dominant substrate is cobble and boulder, with minor gravel in pools. The riparian zone is dominated by upland species, likely due to the flashy nature of the streamflow.

Table 2.3-19. Summary of aquatic habitat in Upper Speelyai Creek.

Stream Reach	Riffle	Glide	Pool	Cascade	Riffle/Glide
Average length (ft)	145	115	61	50	159
Average wetted width (ft)	23	27	19	21	25
Average bankfull width (ft)	69	70	61	62	70
Total wetted area (sq ft)	38,770	29,142	2,257	3,107	8,810
Dominant substrate	CO	CO/BO	CO	BO	CO
Subdominant substrate	BO	CO/BO	GR	CO	GR/BO
Spawning gravel area (sq ft)	0	50	0	0	0

BO = boulder CO = cobble GR = gravel

The canal reach of Speelyai Creek, the constructed channel between Yale Lake and the upper diversion, is a straight channel with very high, near-vertical earth walls. The reach is dominated by riffles and glides, with a few pools (Table 2.3-20). Average wetted width is 20 feet, and the bankfull:wetted width ratio is 1.5 due to the completely confined, dug channel. Dominant substrate is cobble and sand, with minor gravel in pools. The length of the canal reach that is riverine varies with the level of Yale Lake.

Table 2.3-20. Summary of aquatic habitat in the canal reach of Speelyai Creek.

Canal Reach	Riffle	Glide	Pool
Average length (ft)	152	95	221
Average wetted width (ft)	21	24	14
Average bankfull width (ft)	37	35	18
Total wetted area (sq ft)	17,315	9,973	3,094
Dominant substrate	CO	SA	CO
Subdominant substrate	SA	CO	GR
Spawning gravel area (sq ft)	0	0	0

CO = cobble GR = gravel SA = sand

Woody debris was counted in all surveyed stream reaches (Table 2.3-21). There was abundant wood of all sizes in the stream reaches, with no wood in the canal reach (likely flushed through the confined channel to Yale Lake). The reach between the Highway 503 bridge and the upper diversion had less wood but, many beaver dams that provided good cover. There were no beaver dams in upper Speelyai Creek, likely due to the fact that they would be washed out by high flows.

Table 2.3-21. Summary of large woody debris in Speelyai Creek.

Reach	Class 4			Class 3			Class 2		Class 1		Instream LWD/mi*	Root wad or jams	Beaver Dams
	Wet	Bnk	Pot	Wet	Bnk	Pot	Wet	Bnk	Wet	Bnk			
Hatchery to Highway 503 bridge	15	5	16	27	4	65	112	40	175	44	160.5	12 RW, 8 Jams	28
Highway 503 bridge to upper diversion	4	4	11	2	3	8	16	1	9	5	26.0	5 RW, 1 Jam	20
Total Lower Reach	***19***	***9***	***27***	***29***	***7***	***73***	***128***	***41***	***184***	***49***	***107.9***	***17 RW, 9 Jams***	***48***
Upper Speelyai	0	2	5	3	10	7	1	15	4	16	76.6	8 RW, 2 Jams	none
Canal reach	0	0	0	0	0	0	0	0	0	0	0.0	1 Jam	none
Total Upper Reach	***0***	***2***	***5***	***3***	***10***	***7***	***1***	***15***	***4***	***16***	***76.6***	***8 RW, 3 Jams***	***none***

Class 4 = >36"diam,
Class 3 = >24"diam,
Class 2 = >12"
Class 1 = >6" diam, >25' long
Wet = within wetted channel
Bnk = within bankfull channel (exclusive of those counted in wetted channel)
Pot = potential; standing but leaning over bankfull channel
* Instream LWD/mile includes wetted and bankfull

Substrate armor and sub-armor samples were collected in upper and lower Speelyai Creek during the field survey. Results of the substrate sampling are included in WTS 3 Appendix 2.

The median (D_{50}) diameter of the armor layer varies between 30 and 55 mm along Speelyai Creek (Figure 2.3-17). There is no systematic upstream or downstream fining trend, with the exception of the sample just downstream of the Speelyai Hatchery diversion structure. This sample has a larger median diameter due to a higher percentage of large particles (Figure 2.3-18). Finer-grained particles are trapped in the hatchery diversion pool and are not transported downstream.

Spawning-sized gravel is more abundant in lower Speelyai Creek, particularly downstream of the Highway 503 bridge (Figures 2.3-19 and 2.3-20).

Hydraulic Modeling

Hydraulic modeling using the WINXSPRO program was performed at 7 cross-sections in lower Speelyai Creek, 3 cross-sections in upper Speelyai Creek, and at 3 bridges in lower Speelyai Creek to assess the effects of different flow scenarios on water levels, bridges, and structures along lower Speelyai Canal. Details of the computations and output files are included in WTS3 Appendix 4. A discussion of the different flow scenarios modeled is included in the Speelyai Connectivity and Hatchery Protection Study (Section 2.12).

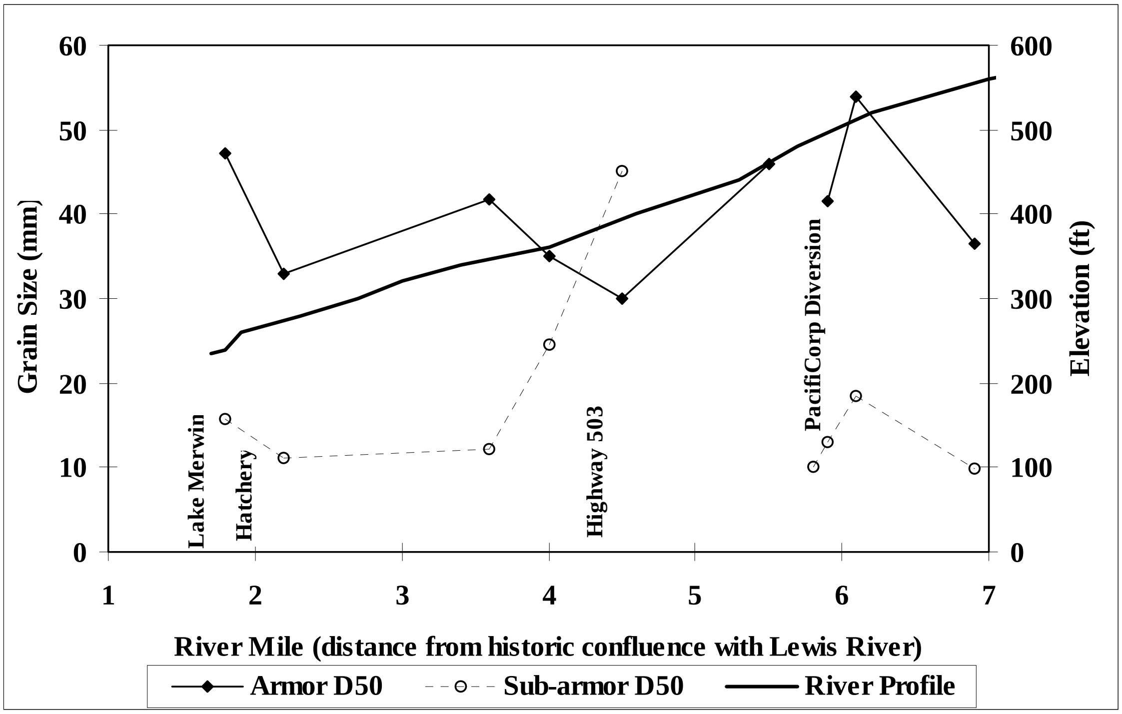


Figure 2.3-17. Change in median (D_{50}) surface armor and sub-armor gravel samples in Speelyai Creek.

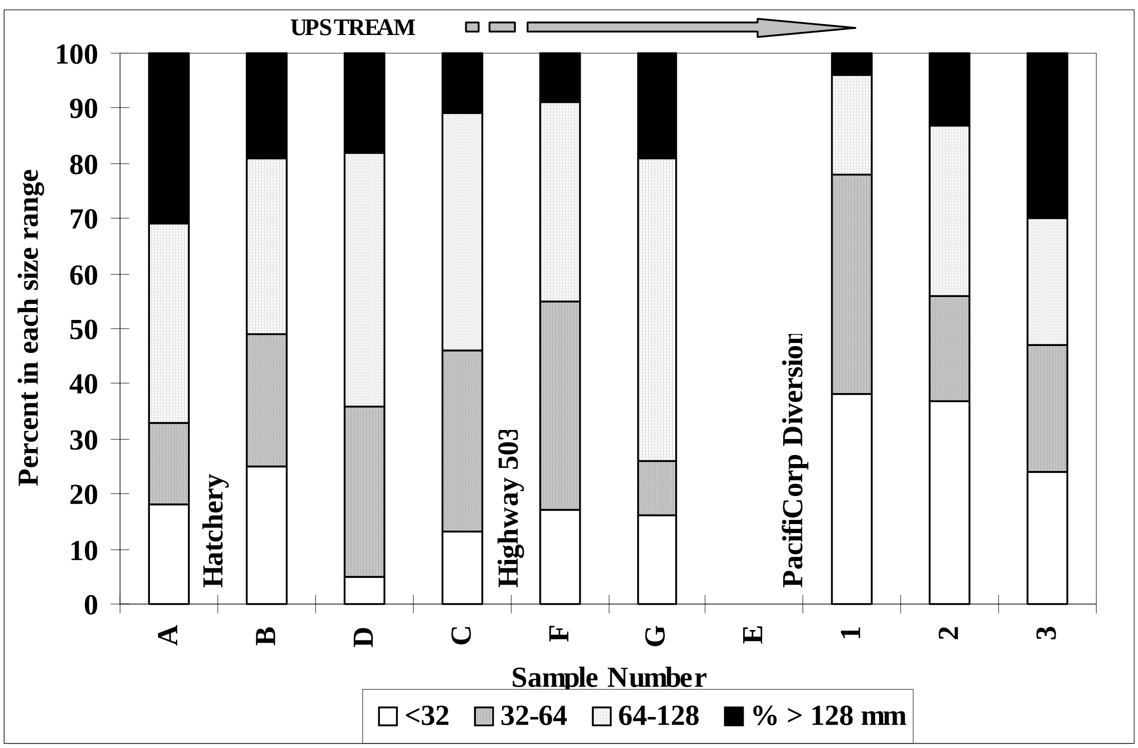


Figure 2.3-18. Change in grain size distribution of surface (armor) gravel samples in Speelyai Creek.

Spawning Gravel

The area of spawning gravel was recorded in each habitat unit during the Speelyai Creek field survey. There is very little gravel in Speelyai Creek upstream from the upper diversion (Figure 2.3-19). A few patches of gravel and one 50-square-foot deposit were found.

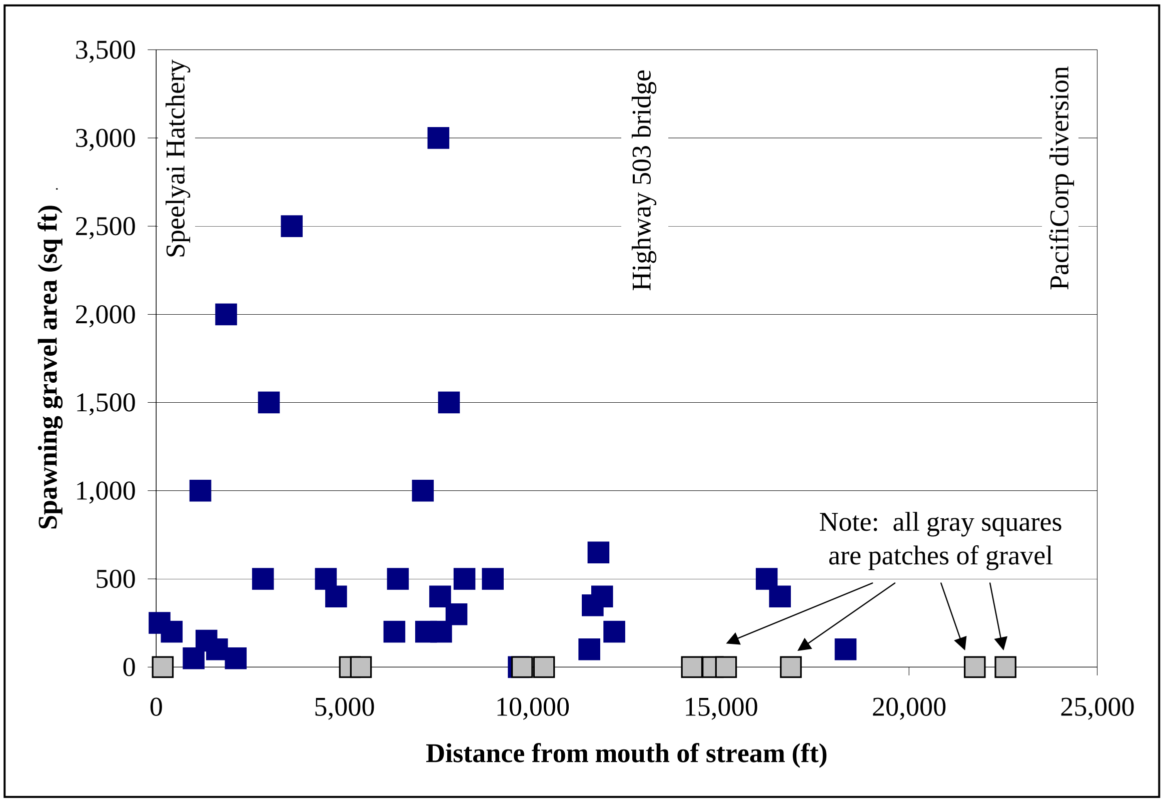


Figure 2.3-19. Distribution of spawning gravel in upper Speelyai Creek.

2.3.6 Discussion

The Lewis River watershed has experienced several natural and anthropogenic disturbances in the past 100 years that have influenced the input, transport, and processing of water, wood and sediment in basin streams. Expansion of roads and settlements into the watershed took place as Woodland and surrounding communities grew, and as agriculture in the lower basin and timber harvest in the upper basin became dominant land uses. Harvesting of timber associated with development and lumber production resulted in removal of large trees from riparian areas that had previously been a source of large woody debris. Input of large amounts of sediment from increased mass wasting and surface erosion was also associated with timber harvesting. Removal of large woody debris to reduce flooding, gravel mining, and bank protection measures in the lower Lewis River had lasting effects on the morphology and functioning of the lower channel.

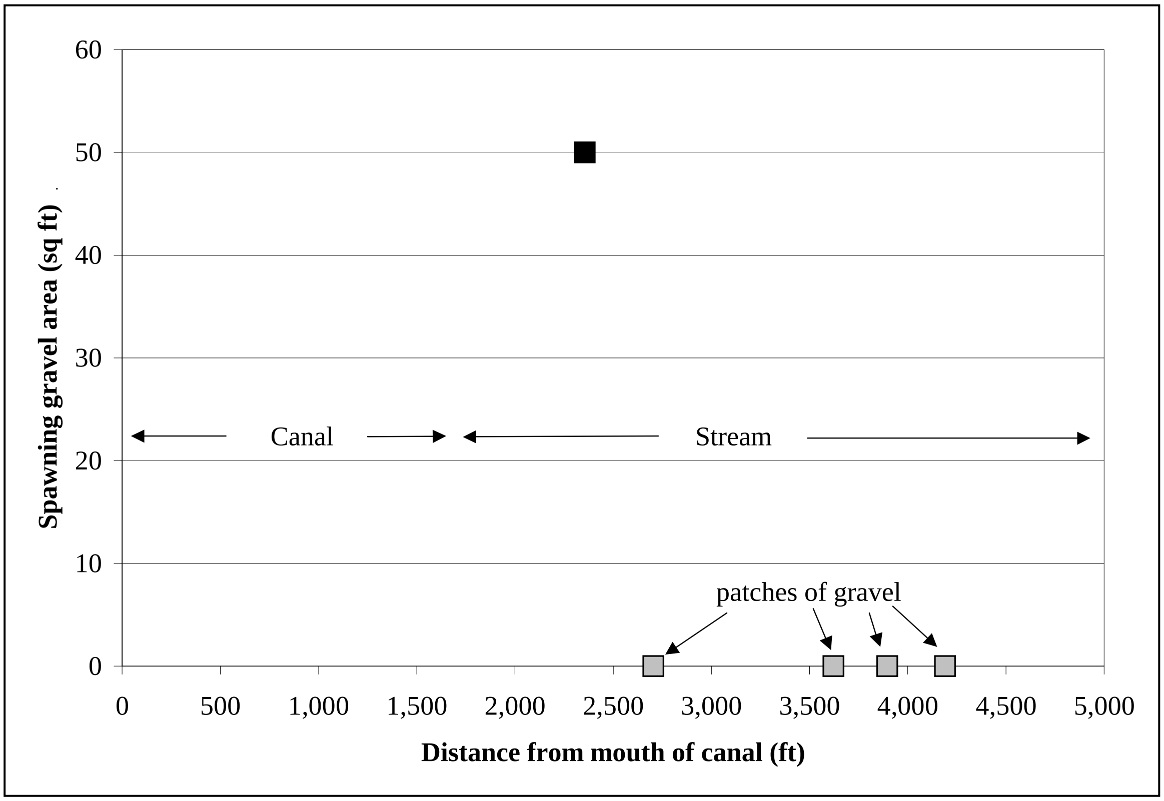


Figure 2.3-20. Distribution of spawning gravel in lower Speelyai Creek.

Construction of Merwin Dam in 1932, Yale Dam in 1952, and Swift Dam and the upper Speelyai diversion in 1958 altered the transport of water, wood, and sediment into stream reaches below these structures. Continued operation of the hydroelectric projects under current operational guidelines will continue to block the transport of sediment and large woody debris and reduce the magnitude of peak flows.

The eruption of Mount St. Helens in 1980 profoundly changed the character of several tributaries upstream of Swift Dam. Mudflows during the eruption swept nearly 18 million cubic yards of water, wood, and debris down these streams and into Swift Reservoir (Tilling et al. 1990). These streams are still carrying large volumes of sediment into the reservoir; over 15 million tons of sediment were transported by the streams from 1982 through 1990 (Dinehart 1997). The wood and sediment resulting from the St. Helens eruption was trapped in Swift Reservoir and prevented from moving into the lower river. In the absence of the project reservoirs, the lower Lewis River would have very different characteristics from its current condition, as millions of tons of sediment and wood would have been transported downstream following the eruption.

The combined effects of all of these actions and circumstances have resulted in the current condition of the Lewis River watershed. The following sections summarize the condition of channel morphology and aquatic habitat in the 3 project-affected reaches and discuss continued effects of the hydroelectric projects on these resources.

2.3.6.1 Lewis River Downstream of Merwin Dam

The Lewis River downstream of Merwin Dam is used by anadromous fish, resident fish, and a variety of other aquatic and terrestrial organisms. There is a healthy population of naturally-spawning fall Chinook that use the river, with most spawning between Merwin Dam and the Lewis River Hatchery. The river is confined to a narrow valley between the dam and the hatchery, and flows through an unconfined valley downstream of the hatchery. Aquatic habitat in the confined reach is characterized by glides, riffles, and pools. Bedrock outcrops are the dominant pool-forming mechanism. Substrate in this reach is cobble/ gravel in the glides and riffles, and boulder/bedrock/cobble in the pools. Over 1,000,000 square feet of spawning-sized gravel was mapped, distributed throughout the reach. Samples of the gravel show it has a low percent fines and a size distribution suitable for use by anadromous fish. The good quality of the gravel is substantiated by the high use of the reach for spawning. There is an average of 10 pieces of large woody debris per mile in this reach of river, the majority of which are located on bars within the bankfull channel, but above the wetted channel.

The unconfined reach of the Lewis River between the hatchery and the downstream end of Eagle Island is characterized by glides, side channels, and riffles. The river is freer to migrate across the valley in this reach, but several of the migrating meanders have been cut off as a result of human intervention through the years. These cut-off meanders have formed side channels that are connected to the river and provide good off-channel rearing and protection from high flows. Dominant substrate in this reach is cobble/gravel in the main channel and gravel/silt/sand in the side channels. The gradient of the river decreases toward the end of this reach and the substrate is dominantly sand and gravel by the down-stream end of Eagle Island. There is an average of 20 pieces of large woody debris/mile in the unconfined reach. Large wood is located on bars; submerged wood is also located in the channel near Eagle Island. The gradient of the river is very low in this section, and the influence of tides and backwater effects from the Columbia River extend upstream to this reach. Submerged large woody debris is common in other large rivers at the head of the tidal influence (Collins et al. 2002).

Historical Stream Channel Changes

In the 70 years since Merwin Dam was built, some changes to the river downstream of the dam have occurred. The 3 dams on the Lewis River have blocked the supply of sediment and large woody debris from the watershed downstream of Merwin Dam. Flood control operations have also reduced the magnitude of peak flows. In addition to the effects of the hydroelectric projects, non-project effects, including harvesting of riparian forests, gravel mining, projects to re-direct the flow of the river, and bank protection measures, have affected the lower Lewis River.

The confined reach of the lower Lewis River (between Merwin Dam and just downstream of the Lewis River Hatchery) has not changed position since the earliest aerial photographs

(1938). A decrease in active bars was noted between 1938 and 1974, with little change in active bar areas between 1974 and 1996, indicating the river may have stabilized.

In the unconfined reach (Lewis River Hatchery through Eagle Island) the channel has undergone shifting, primarily as a result of gravel mining operations and efforts to reduce the migration of river meanders that threatened the highway in the 1940s and 1950s. These efforts have resulted in a straighter channel than in 1938, with the cut-off meanders forming side channels in the present-day river system. A reduction in active bars and increase in vegetated bars and islands also occurred in this reach between 1938 and 1963/74. The area of active bars has been fairly stable since 1974.

It appears that the Lewis River projects have had little influence on the channel position of the lower Lewis River based on a comparison of the 1938 and more recent aerial photographs. The primary effect on channel form has been a decrease in active channel bars and an increase in the area of vegetated bars and islands between 1932 (construction of Merwin Dam) and 1974. There were few changes in river morphology between 1974 and present, and few changes in morphology from the present conditions are anticipated over the period of the new license as a result of continued project operations. However, the projects continued to block sediment and debris produced in the watershed area upstream of Merwin Dam from being transported into the lower river. If the dams were not in place, the eruption and subsequent mudflows from Mt. St. Helens in the 1980's would have resulted in a dramatically different lower river now and in the future. Swift Reservoir captured an estimated 18 million cubic yards of water, mud and debris during the May 1980 eruption. In addition, over 15 million cubic yards of sediment and a large, but un-quantified volume of debris has been trapped since the eruption, originating from the Muddy River and Swift and Pine creeks. If this material had been transported into the lower river, it would have transformed the channel abruptly into a river with a braided channel in unconfined areas (i.e. downstream of the Lewis River Hatchery) and much more active san/gravel bars in the confined reach. This would have had dramatic effects not only on stream morphology, but on aquatic and riparian habitat and flood characteristics in the lower river. The river would have continued to experience a high sediment and debris load in the time since the 1980 eruption as sediment stored in the upstream channel was transported downstream and would have much different characteristics today and in the future.

Large Woody Debris

The role of large woody debris in shaping the geomorphology and aquatic habitat in large river systems has been a topic of much recent research (Abbe and Montgomery 1996, Bilby and Bisson 1998, Collins et al. 2002). Compared to small streams, single pieces of large woody debris in large river systems (>60 feet wide) are less of an influence on channel dynamics because the pieces are not very stable in large flows, are usually confined to the banks instead of within the wetted channel, and are so small compared to the size of the river they do not have enough influence on channel hydraulics to form reach-scale elements of habitat complexity (Bilby and Bisson 1998, Lassettre and Harris 2001). Recent investigations of the historical role of large woody debris in large river systems have confirmed that single pieces do not have the same function as they do in smaller systems. Historically, wood formed large log jams or log rafts that influenced the morphology of large rivers on many scales (Collins et al. 2002).

These accumulations of wood were started by a few key pieces of very large wood, often with root wads intact. Additional large and small pieces of wood collected, resulting in log jams that often spanned the channel, and were stable over a period of decades to centuries. The log jams influenced the channel dynamics and aquatic habitat on many different scales (Collins et al. 2002). At a local scale, the wood formed pools and provided cover. At the reach scale, the jams formed and maintained multiple channels and flood-plain sloughs. At a valley bottom scale, the large log jams influenced water, sediment, and wood routing during high flows by increasing flooding and recharge of floodplains and associated wetlands, trapping sediment and additional wood.

Large woody debris and log jams were removed from most large western Washington streams in the late 1800s and early 1900s by settlers and the Corps of Engineers to decrease flooding and improve navigation. The combination of instream wood removal and harvesting of lowland riparian forests resulted in very little large woody debris in or being recruited to most large western Washington streams by the early to mid 1900s (Collins et al 2002). It is very likely that there were historic accumulations of large woody debris in log jams in the lower Lewis River that were removed in the late 1800s since there was very little wood in the river in the earliest (1938) aerial photographs, even as far downstream as the confluence with the Columbia River.

Continued capture of large woody debris by the Lewis River dams will result in no large wood transport into the lower Lewis River from upstream sources, except under extremely high flow conditions such as the flood of 1996, when the gates are fully opened and wood can pass through the projects. The small to moderate size of trees in current lower river riparian stands and limited lateral migration of the river restricts the potential for recruit-ment of woody debris large enough to be stable or function in log jams in the lower river. Single pieces of wood are not likely to function in the same way. Recent research into placement of wood in log jams has shown that engineered log jams can be made stable in large rivers. Such placement would be the most effective method to increase wood loading in the lower Lewis River.

Sediment Input, Sediment Transport and Spawning Gravel

Current sediment input to the Lewis River downstream of Merwin Dam is limited to inputs from tributaries and erosion/landslides from the valley walls. An average of 8,200 tons/yr of sediment (1,000 tons/yr of gravel and larger particles) is delivered to the river between Merwin Dam and Eagle Island. Despite the relatively small amount of sediment inputs and the continued trapping of sediment from the upper watershed, there is a large amount of spawning-sized gravel distributed throughout the reach that sustains a run of wild fall Chinook salmon as well as other aquatic species. Studies of reaches downstream of other large dams in the area often show a lack of gravel and finer particles. This occurs because the finer sediment is flushed out of the bed during high flows and not replenished from upstream sources (Table 2.3-22). This increase in grain size and lack of gravel does not seem to be occurring downstream of Merwin Dam.

Table 2.3-22. Water surface slope and surface (armor layer) particle size characteristics downstream of large reservoirs.

River System	Gradient downstream of dam	Sediment characteristics upstream of dam(s)	Sediment characteristics downstream of dam
Lewis River downstream of Merwin	0.06%	--	D_{50} = 40 - 60 mm
Lewis River Swift bypass reach	0.5%	--	cobble/boulder
Deschutes (Fassnacht 1997)	0.04%-0.45%	--	D_{50} = 75 - 85 mm
Cowlitz River	0.18%	gravel/cobble	D_{50} = 45 – 50 mm
North Umpqua	0.5%	D_{50} = 30 – 40 mm	D_{50} = 45 – 50 mm
Elwha	0.6%	D_{50} = 60-80 mm	D_{50} = 110-160 mm
North Fork Skokomish	1.3%	cobble/gravel	cobble
Nisqually River	8.0%	cobble/gravel	boulder/bedrock

-- Indicates sediment characteristics not noted. Cobble = 64 – 256 mm; Boulder >264 mm.
Data from Deschutes River from Fassnacht 1997; all other data from author's files.

There are several possible reasons for the retention of gravel in the Lewis River. Comparison of the gradient of the Lewis River downstream of the dam with other studied rivers shows the gradient is very low; an order of magnitude lower than most other rivers (Table 2.3-22). The ability of a river to entrain sediment particles is dependent upon the shear stress at the bed of the river, calculated as:

$$\tau_b = \rho g h S$$

where τ_b = shear stress
ρ = density of water
g = acceleration of gravity
h = water depth
S = water surface slope

Thus, as slope and water depth increase, shear stress increases. The shear stress required to entrain a particle of a certain size has been a topic of much research (see summary in Reid and Dunne 1996). However, the following formula is generally accepted:

$$\tau_{cr} = C(\rho_s - \rho) g D$$

where τ_{cr} = critical shear stress required to entrain a particle
C = a constant, defined as 0.039 to 0.09 by different researchers
ρ_s = density of sediment
D = diameter of particle

Thus, the shear stress required to entrain a particle on the bed does not vary with flow, but the shear stress exerted on that particle increases with increasing flow depth. This is why there is little sediment transport in gravel-bedded rivers at low flows; high flows with deep water are required before the river has enough energy to pick up the gravel and transport it. This also can explain why gravel does not move very much in the Lewis

River. The gradient of the river is so low that very high flows are required (compared to other, steeper rivers) to move the gravel. An analogy would be trying to roll a ball down a hill. The ball will easily roll down a steep hill, but does not roll as easily or quickly down a very gentle hill.

A more quantitative examination of this phenomenon was performed based on hydraulic information from the Lewis River at Ariel gage. This gage is located just downstream of Merwin Dam. There is a large deposit of gravel on the north side of the river at the gage site that is used annually by spawning fish. The shear stress at the gage was calculated based on the USGS rating table for discharges from 5,000-80,000 cfs. The critical shear stress range for gravel-sized particles was also calculated and both curves were plotted on the same graph (Figure 2.3-21). The critical shear stress range for the particles was calculated based on the range of C values (0.039 to 0.09) noted by researchers.

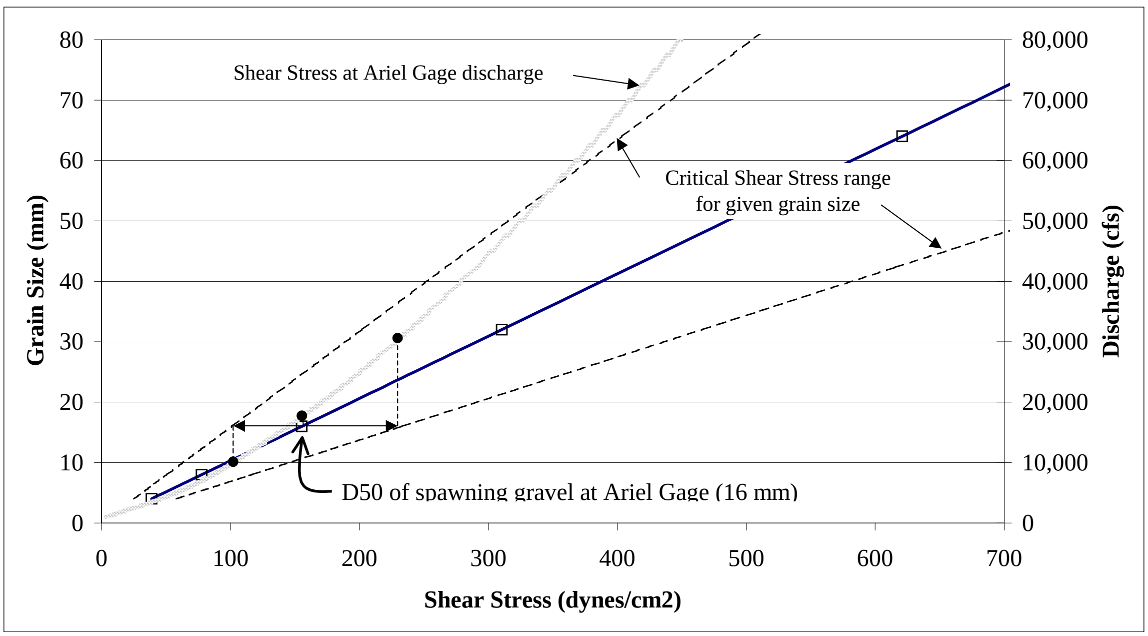


Figure 2.3-21. Critical particle shear stress compared to computed shear stress at the Lewis River at Ariel stream gage site.

The range of critical shear stresses for the median (D_{50}) size of the spawning gravel measured at the site (16 mm) is 100-230 dynes/cm^2. A shear stress of 100 dynes/cm^2 occurs when a discharge reaches 10,000 cfs; 30,000 is required for a shear stress of 230 dynes/ cm^2. Based on this analysis, a flow of 10,000-30,000 is required to initiate movement of the spawning gravel at the Ariel gage. Anecdotal information from WDFW researchers who have been performing the fall Chinook spawning surveys downstream of the dam indicate that they notice movement of gravel in the survey reaches when flows are higher than 30,000 cfs (pers. comm. Shane Hawkins, WDFW). This is at the upper end of the flow predicted to initiate gravel transport, and suggests the gravel is more stable than predicted by sediment transport equations.

One potential reason the gravel is more stable than predicted could be caused by the bedrock knobs that cause local changes in channel hydraulics not accounted for in most flow and sediment transport equations. These bedrock knobs cause back (recirculating) eddies at low flows, resulting in water flowing upstream along one or both channel margins. Back eddies were noted during the field survey at low flow (Figure 2.3-6) and occurred in the vicinity of most of the spawning gravel areas mapped in the confined reach. It is not known if these back eddies are persistent features at high flows, but researchers in other rivers flowing through bedrock canyons have documented sediment deposits in recirculating eddies downstream of obstructions (Cenderelli and Cluer 1998, Schmidt and Rubin 1995) and described the difficulties predicting flow patterns using 1-dimensional hydraulic models (Miller and Cluer 1998).

Understanding that there are difficulties in predicting sediment transport in the confined reach of the Lewis River using 1-dimensional sediment transport equations, an estimate of transport rates of the spawning-sized gravel at the Ariel site (median grain size 16 mm) was made using the Meyer-Peter and Parker equations to see how well calculated transport compares with observations. Annual transport was calculated for the period 1932-2001 (Figure 2.3-22). Estimated transport correlates well between the two equations except under the flow of record (1933) when the Parker equation predicts 3 times as much transport as the Meyer-Peter equation. Despite this difference, the calculations show that gravel transport has been very low at the Ariel gage site. Total transport since construction of Merwin Dam in 1932 is estimated at 35,000-60,000 tons. The majority of

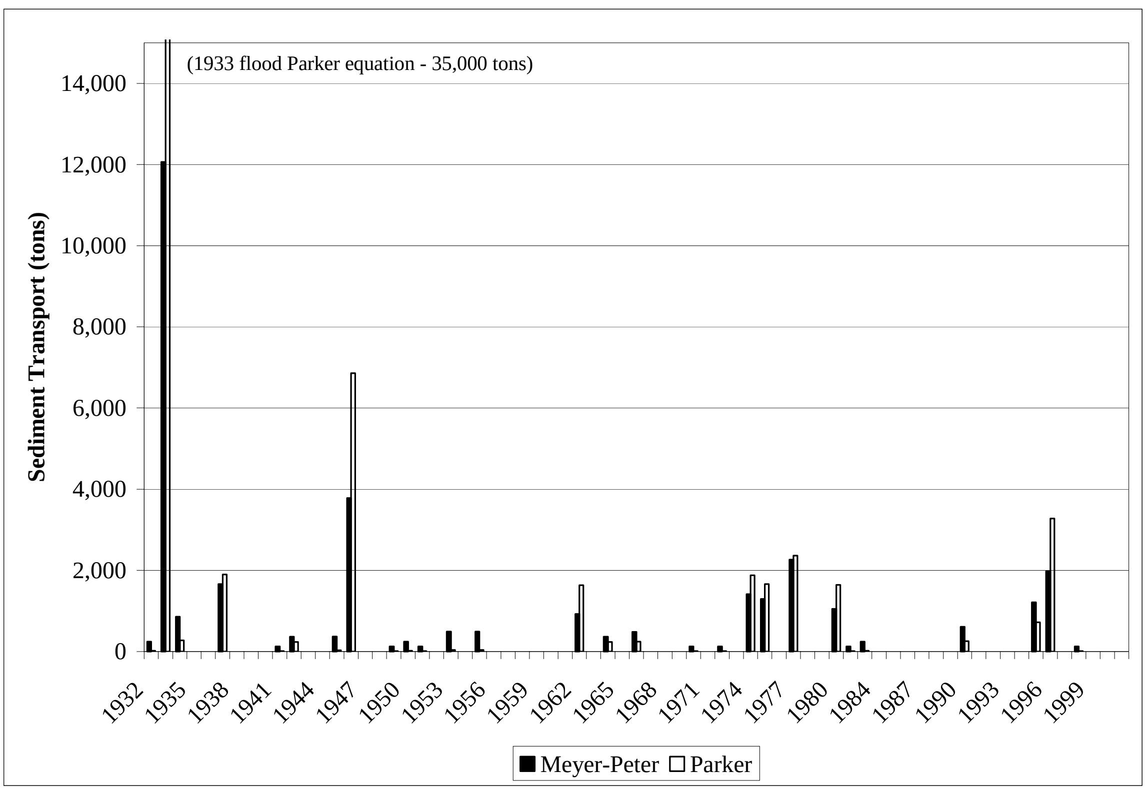


Figure 2.3-22. Predicted spawning gravel transport in the Lewis River at Ariel stream gage site.

this gravel was transported prior to the construction of Swift Dam and associated flood management procedures in 1958. Total estimated transport in the past 20 years is 4,000 tons. If it is assumed that spawning gravel deposits are 10 feet deep (a low estimate), the total gravel transported since Merwin Dam was closed is the equivalent of 65,000-100,000 square feet of gravel area. An equivalent of 8,000 square feet of gravel has been transported in the past 20 years. The current estimate of spawning gravel-size deposits near the Ariel gage (Habitat Units 2 and 3) is 125,000 square feet.

The sediment transport analysis, along with aerial photograph, spawning survey, and observational data suggest that the spawning gravel deposits downstream of Merwin Dam are relatively stable. Continued operation of the Lewis River projects will likely result in the slow depletion of these resources over several decades to a century, depending upon peak flow conditions and flood management procedures. It does not appear that supplementing the gravel is necessary at the present time, but monitoring of gravel deposits (field mapping in years following large peak flow events to determine if the gravel areas are diminishing) would be helpful to assure protection of the important fall Chinook spawning areas in the reach.

2.3.6.2 Swift Bypass Reach

The Swift bypass reach extends between Swift Dam and the upstream end of Yale Lake (approximately 2.8 miles long). The reach is currently used by resident fish and a variety of other aquatic and terrestrial organisms. Under current conditions, flow in the reach is limited to canal seepage and tributary inflow, except when water is spilled into the reach during high flow events. Ole Creek flows into the reach approximately 2.5 miles downstream of Swift Dam and provides a source of water, gravel, and large woody debris during the fall, winter, and spring.

The majority of the Swift bypass reach is characterized by cobble/boulder substrate lacking in gravel and smaller-sized particles. The substrate characteristics limit the availability of suitable fish spawning habitat. There is very little large woody debris within the wetted or bankfull channel in the reach; however, the numerous large boulders provide cover and habitat complexity. Continued operation of the Lewis River Hydroelectric Projects using the current operating procedures will result in a continued lack of water, wood, and gravel/silt/sand-sized particles in the bypass reach. Periodic spill events will continue to transport wood and gravel particles from the reach. Input of water, wood and sediment from Ole Creek will continue to provide better quality habitat downstream of its confluence.

During the relicensing process, several options for management of the bypass reach will be considered, including changes to the flow regime and changes to the fish species that have access to the reach. A discussion of different flow management options are included in the Swift Bypass Synthesis Report (WTS 4). A discussion of potential flood management scenarios that would change the frequency and magnitude of spill events in the reach is included in the Flood Management Report (FLD 1).

In addition to other studies that consider changes in flow, spills, and fish species, the present study considered the potential for improving aquatic habitat through the addition of spawning-sized gravel and/or large woody debris in the Swift bypass reach. It is not realistic to analyze the effects of the entire range of potential actions in the reach on gravel/wood additions since the size of gravel needed depends upon the species of fish using the gravel; the placement of gravel and wood depends upon the flow in the reach; and the stability of added habitat elements depends upon the frequency and magnitude of spill events under the flood management constraints. However, the following general observations can be made.

Adding gravel-sized particles to areas with suitable water depths and velocities in the Swift bypass reach would increase the amount of spawning habitat. Under current conditions, there is very little flow in the upper portions of the reach; gradual accretion occurs through the reach. Under current conditions, the reach 1 to 1.5 miles downstream of Swift Dam does not have sufficient flow to provide any spawning habitat. Downstream to the confluence with Ole Creek, flows are likely marginal for spawning, depending upon the fish species of interest. If flows in the reach are increased, areas with suitable depths and velocities would be present in spots throughout the reach.

Different fish species prefer different sizes of gravel for spawning. Chinook, coho and chum prefer particles in the 13-100 mm (0.5 to 4 inches). Steelhead prefer gravel in the 6-100 mm (0.25 to 4 inch) size range, and resident salmonids prefer smaller gravel, 5-50 mm (0.25 to 2 inches). Assuming a mix of gravel with a median grain size of 32 mm was added to the reach, sediment transport modeling suggests the gravel would be mobilized in riffles at flows of approximately 500 cfs. The gravel would be transported downstream during spill events, and would likely need to be replaced following such events over 1,000-2,000 cfs. Such events have occurred on average every 2 years over the past 20 years. Use of a gravel/cobble mix, or placement of gravel in gravel holding structures or in conjunction with large woody debris, would improve the retention of gravel, but in spills over 10-20,000 cfs (occurring on average every 5 years) it is likely that the added gravel would still be transported downstream and would need to be replaced.

Addition of large woody debris to the Swift bypass reach would provide additional structure, cover, and habitat diversity. Options for placement include passing wood around Swift Dam (wood is currently removed from Swift Reservoir), placing loose logs and/or root wads, cabling, embedding, or otherwise securing placed wood, and placing wood in log jams. The wood would likely be stable during lower magnitude spill events, but during spills over 20,000-30,000 cfs it is likely that even secured pieces would be moved downstream. This prediction is based on the evidence of uprooted trees in the bypass reach following the 40,000 cfs spill event in 1996.

Single pieces of wood would not be naturally stable in a channel with high flows as large as the bypass reach. Instead, a few large pieces of wood would become lodged at the top end of mid-channel bars or at sharp bends in the river. These large pieces would trap other smaller pieces of wood and form log jams that would be stable for decades or longer (Collins et al. 2002). If some of the wood that is collected in Swift Reservoir were placed downstream of Swift Dam, this wood would be transported downstream during large spills and eventually could accumulate as log jams. Some of the wood would be transported through the reach into Yale Lake. Wood floating in Yale Lake could cause a hazard to boaters. Balancing these conflicting issues is a task for the Settlement Team.

2.3.6.3 Speelyai Creek

The Speelyai Creek watershed is located north of Merwin and Yale reservoirs. All of the flow from the upper portion of Speelyai Creek is currently diverted into Yale Lake by the PacifiCorp diversion structure and canal. Lower Speelyai Creek is primarily spring fed and provides a high quality source of water for the Speelyai Hatchery. The hatchery diversion dam near the mouth of Speelyai Creek diverts flow into the hatchery and prevents upstream migration of fish from Lake Merwin into the lower reaches of the creek.

Upper Speelyai Creek experiences large peak flows, transports a high sediment load, and has a wide, active channel. Lower Speelyai Creek has lower, more stable flows and less sediment movement. A discussion of habitat in Speelyai Creek and a variety of management options for the creek are described in the Speelyai Connectivity and Hatchery Protection Study (AQU 9).

2.3.6.4 Peer Review of Results

At the request of certain stakeholders, an independent peer review of this report was conducted. A December 19, 2002 memorandum presenting the opinion of Stillwater Sciences is included as Section 2.3.10.

2.3.7 Schedule

The report is complete.

2.3.8 References

Abee, T.B., and D.R. Montgomery. 1996. Large Woody Debris Jams, Channel Hydraulics and Habitat Formation in Large Rivers. Regulated Rivers: Research and Management 12:210-221.

AFS (American Fisheries Society). 1985. Aquatic Inventory: Glossary and Standard Methods. Western Division American Fisheries Society, Habitat Inventory Committee. 34p.

Bilby, R.E. and P.A. Bisson. 1998. Function and Distribution of Large Woody Debris. *In* R.J. Naiman and R.E. Bilby, eds. River Ecology and Management: Lessons from the Pacific Coastal Ecoregion. Springer, New York. pp. 324-346.

Bisson, P.A., J.L. Nielson, R.A. Palmason, and L.E. Grove. 1981. A System for Mapping Habitat Types in Small Streams, with Examples of Habitat Utilization by Salmonids During Low Stream Flow. *In* N.B. Armantrout, ed., Acquisition and Utilization of Aquatic Habitat. Western Division American Fisheries Society, Portland, OR. pp. 2-73.

Cenderelli, D.A. and B.L. Cluer. 1998. Depositional Processes and Sediment Supply in Resistant-Boundary Channels: Examples from Two Case Studies. *In* Rivers Over Rock, Fluvial Processes in Bedrock Channels. American Geophysical Union Geophysical Monograph 107, pp. 105-131.

Collins, B.D., D.R. Montgomery, and A.D. Haas. 2002. Historical Changes in the Distribution and Functions of Large Wood in Puget Lowland Rivers. Can. Journ. of Fish. and Aquat. Sci. 59:66-76.

Dinehart, R.L. 1997. Sediment Transport at Gaging Stations near Mount St. Helens, Washington, 1980-90, Data Collection and Analysis. USGS Professional Paper 1573.

Lassettre, N.S. and R.R. Harris. 2001. The Geomorphic and Ecological Influence of Large Woody Debris in Streams and Rivers. Located on the internet at http://frap.cdf.ca.gov/publications/lwd/LWD_paper.pdf

Meyer-Peter, R. and R. Müller. 1948. Formulas for Bedload Transport. In: Proceedings 2nd Meeting International Association of Hydraulic Research. Stockholm, pp. 39-64.

Miller, A.J. and B.L. Cluer. 1998. Modeling Considerations for Simulation of Flow in Bedrock Channels. *In* Rivers Over Rock, Fluvial Processes in Bedrock Channels. American Geophysical Union Geophysical Monograph 107, pp. 61-104.

Nelson, Jonathan M., William W. Emmett, and J. Dungan Smith. 1991. "Flow and Sediment Transport in Rough Channels." *Proceedings of the Fifth Federal Interagency Sedimentation Conference*, Las Vegas, NV.

Parker, G.., P.C. Klingeman, and D.G. McLean. 1982. Bedload and Size Distribution in Paved Gravel-Bed Streams. Journal of the Hydraulics Division, Am. Soc. Civil Engr., vol 108, No. HY4, pp. 544-571.

Reid, L.M., and T. Dunne. 1996. Rapid Evaluation of Sediment Budgets. Catena Verlag:Germany. 164 pp.

Schmidt, J.C. and D.M. Rubin. 1995. Streamflow, Fine-Grained Deposits, and Effective Discharge in Canyons with Abundant Debris Fans. *In* Natural and Anthropogenic Influences in Fluvial Geomorphology. American Geophysical Union Geophysical Monograph 89, pp. 177-194.

Schuett-Hames, D., B. Conrad, M. McHenry, P. Peterson, and A. Pleus. 1994. Salmonid Spawning Gravel Composition Module. In: Timber-Fish-Wildlife Ambient Monitoring Program Manual. Northwest Indian Fisheries Commission. August 1994.

Thorne, Colin R., and Lyle W. Zevenbergen. 1985. "Estimating Mean Velocity in Mountain Rivers." *Journal of Hydraulic Engineering*, ASCE, Vol. 111, No. 4, pp. 612-624.

Tilling, R.I., L. Topinka, and D.A. Swanson. 1990. The Eruptions of Mount St. Helens: Past, Present, and Future. USGS General Interest Publication.

USDA Soil Conservation Service. 1972. Soil Survey of Clark County, Washington.

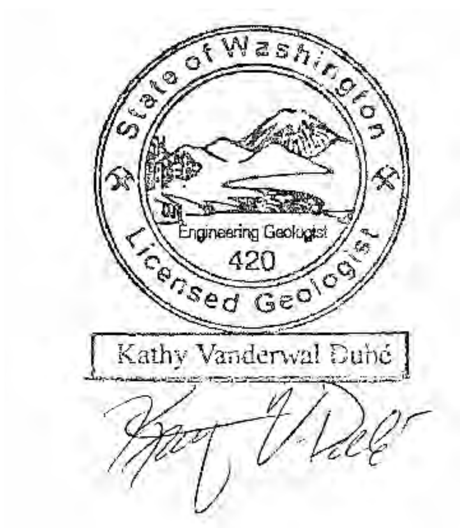
USDA Soil Conservation Service. 1974. Soil Survey of Cowlitz County Area, Washington.

USDA Soil Conservation Service. 1989. Soil Survey of Skamania County Area, Washington.

WDFW (Washington Department of Fish and Wildlife). 2001. Lewis River Fall Chinook: Trends in Natural Production. Unpublished Report by Josua Holowatz, WDFW Fish Program – Southwest Region 5. Vancouver, WA.

WDNR (Washington Department of Natural Resources). 1997. Standard Methodology for Conducting Watershed Analysis. Washington Forest Practices Board, November 1997.

This report was prepared by:



2.3.9 Comments and Responses on Draft Report

This section presents stakeholder comments provided on the draft report, followed by the Licensees' responses. The final column presents any follow-up comment offered by the stakeholder and in some cases, in italics, a response from the Licensees.

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
WDFW – KAREN KLOEMPKEN	1	WTS 03	Pagination.	Missing pages 11-46, 49-54, 59-70, 79-90, 93-94,	These pages are 11x17 maps. Figure numbers rather than page numbers were assigned to each. Each 11x17 is counted as two pages.	
WDFW – JIM BYRNE	1	WTS 03	Key Questions.	Not much discussion of differences in gravels between study areas or gravel size. No detailed discussion of LWD in mainstem, only bypass reach and Speelyai. No recommendation for LWD placement.	A discussion of the quality and quantity of gravel in the study areas of the Lewis River are included in the report, but a comparison between reaches was not included. A discussion of LWD in the mainstem downstream of Merwin Dam is included in the "Large Woody Debris" section on pages 3-109 and 3-110. Recommendations for LWD placement were not part of this report.	
WDFW – JIM BYRNE	1	WTS 03 Fig. 2.3-12d	Figure 2.3-12d.	In this figure the bypass channel disappears in 1998.	Figure 2.3-12d shows the Swift bypass reach mapped from 1988 aerial photographs. The discontinuous channel was mapped as a result of either coverage of the water surface	Confusing

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
					by vegetation or intermittent flow at the scale of the photographs.	
WDFW – KAREN KLOEMPKEN	1	WTS 03-?	Figure for changes in cannel position over time, for Swift Bypass Reach.	This Figure is missing.	Figure 2.3-12 (a through f) was included in the original document. We regret this printing error.	
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-2	"Large woody debris visible on historic photos was also counted on the 1938/39 photos to provide some indication of historic wood loading levels."	The 1938/39 photos do not characterize pre-project conditions with respect to wood loadings or wood volume historically present, for 2 reasons: the report later argues that wood was removed as part of widespread stream cleaning in the late 19th century (p. WTS3-109); 1939 is not representative of the pre-project condition because in 1933, a year after operations at Merwin began, there was a large flood which would have altered any pre-project condition with respect to wood in the reach downstream of Merwin. The statement should be modified to end after the word "photos".	The report does not suggest that the 1938/39 photos are indicative of pre-anthropogenic changes; it says "historic wood loading levels." Perhaps a more precise term should have been used since "historic" pertains to some point in the past but does not specify the time. However, wood loading in the 1938/39 photos does give an indication of pre-project conditions because during the 1933 flood, only Merwin Dam was in place, and the gates at Merwin were open, allowing wood from the upper watershed to be transported downstream. While some wood undoubtedly was retained in the lake, much of the wood coming from upstream was able to pass	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
					through the project. In reviewing operator log books from the first years of operations, it was quite clear that with only one unit in operation, the project spilled most of the time and wood was not retained. Information from "old-timers" that worked at the project indicates that Lake Merwin was used for transport of logs whereby logs were "rafted" in the reservoir and periodically passed through and taken out at an old railroad spur approximately ½ mile downstream of the project. A log raft is visible in the 1939 aerial photos of Merwin.	
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-3	"Information from other studies of sediment transport and movement in bedrock channels was collected to shed light on potential reasons that gravel in the reach	This statement appears in the methods section. Therefore, "that gravel in the reach downstream of Merwin appears to be stable" is apparently an assumption and not a finding of the report. If the report assumes that the gravel in the reach downstream of Merwin dam is stable, then the data which supports the assumption should be cited at the end of this statement. If the statement is a finding of the study, the statement should not appear in the methods section.	The statement in the methods section will be re-phrased as, "Information from other studies of sediment transport and movement in bedrock channels was collected for comparison with the reach downstream of Merwin."	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
			downstream of Merwin appears to be stable.”			
USDA Forest Service: John Kinney	1	WTS 03-3 2.3.3.1	Facility operators were queried on quantity and quality of large wood captured and decked at each project.	I could not locate the actual data even though the question indicated that data had been collected. Frank Shrier (personal omm.. 2002) stated that the data was unavailable or had not been collected as stated in WTS-3.	The facility operators were queried on the quantity and quality of large woody debris captured at each project, but they responded that they did not have records of the amount or size of wood captured and removed from the reservoirs.	We would suggest initiating an inventory process that accounts for all usable/marketable Large Wood captured at each project. It was our understanding that all marketable Large Wood was sold. There are probably records of the amount of marketable wood available.
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-4	“Anthropogenic constraints on the channel, such as rip rap, boat ramps or levees were also marked [during field surveys].”	Complete results of these observations should be provided in Figure 2.3-6, and the figure should be cited in this sentence. While some areas of rip-rap are noted on this figure, boat ramps and levees are absent. Since channel controls in this reach have often been described as extensive in Aquatics Resource Group (ARG) meetings, it would be useful to participants to find a description of the full extent of channel controls, both related and unrelated to the projects, in the reach downstream of Merwin dam. This information is needed for understanding effects of the projects, and for understanding project effects in the context of non-project effects (i.e., cumulative effects).	Figure 2.3-6 does show all the anthropogenic constrains that were noted during the field survey. However, in the final printing, some of the labels were incorrect (i.e. “rip rap dock” in some cases should have been “rip rap” and in other cases “rip rap and boat ramp”). The labels will be corrected. No levees were noted in the reach upstream from Eagle Island. There are levees farther downstream.	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-9	"A sediment input budget was prepared for the Lewis River watershed between Merwin dam and the downstream end of Eagle Island."	A method for and results of quantification of sediment volumes that will not be delivered to the reach downstream of Merwin over the term of the next license as a result of the projects should be included in this study. Quantification of sediment transport processes that will affect development of spawning habitat for wild fall Chinook and other anadromous fish species in the reach below Merwin dam is necessary for understanding project effects, and for development of mitigation and enhancement measures. Limiting the assessment of sediment inputs to the watershed reach downstream of the dam provides insufficient information for understanding project effects. Please see the letter from the Conservation Groups to the Licensees dated March 6, 2002.	The study plan for WTS 3 did not include quantification of the volume of sediment produced upstream of the projects or an analysis of the potential transport of sediment from upstream sources into and/or through the reach downstream of Merwin. FERC has defined "existing conditions" as current, with-project conditions. Analysis of future effects of the projects is based on these current conditions, not the without-project condition. However, information on the quantity of sediment transported through streams upstream of Swift Reservoir as the result of the Mt. St. Helens eruption was collected from other sources as part of WTS 1 (page WTS 1-6) and is discussed on page WTS 3-107.	Verbal comments to Frank Shier (PacifiCorp) reiterated disagreement with assumptions about baseline conditions. **Licensees' Response**: *Mike Henry of the FERC attended the 10/1/02 ARG meeting and described FERC's interpretation of baseline conditions. In a subsequent email, he provided citations and excerpts from court cases that affirm the definition being used in Lewis River studies.*
J. Sampson, Technical Advisor to the Conservation	1	WTS 03-47 para 1	"Gravel mining in the bar just downstream of RM 15 was evident in 1939 photos."	Several sections of this report refer to river mile locations. River mile locations should be indicated on figures for which they are referenced. For example, the figures referred to in the statement is 2.3-1a, b, and c.	River mile locations were inadvertently left off the figures for reaches downstream of Merwin Dam; they will be added.	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
Groups				River mile locations should be indicated on these figures.		
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-47 para 1	"Gravel mining…resulted in the main flow migrating to the south side of the river…"	In this statement and later conclusory remarks (p. WTS 3-108 paragraph 3), much of the observable channel changes over the time period represented by the aerial photo data base are attributed to gravel mining. Therefore, the spatial extent and location of gravel mining should be included on Figures 2.3-1a through f. If possible, records on the volumes removed or mining rates should be provided. A quantitative assessment of the volumes of sediment not transported to the reach as a result of the projects is necessary to inform interpretation of the phenomenon described in this statement: the volumes of sediment that were removed by gravel mining should be compared to the sediment volumes that would have been transported to the reach in the absence of the projects. Such a quantitative comparison is the only way to determine whether the projects or the gravel mining had a greater role in changes to the river channel. As an illustration, consider the statement on page WTS 3-107 regarding the effect of Mount St. Helens on sediment input: "…over	The location and extent of gravel mining noted on the aerial photos will be added to Figures 2.3-1. See the response to comment on page WTS 3-9 for discussion of volumes of sediment that would have been transported into the reach if the projects were not in place.	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
				15 million tons of sediment were transported by the [tributaries upstream of Swift dam] from 1982 to 1990." It would surprise anyone to learn that removal of sediment by gravel mining somehow outweighed this sediment input in terms of effects on channel geomorphology. Without specific information about the volumes of sediment extracted by gravel mining and the volumes prevented from transport to the reach by the projects, there can be no independent judgment of the role of gravel mining relative to the projects on channel changes. The conclusion that gravel mining was more important than the projects themselves to channel changes during the period of project operation is unsupported and invalid.		
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-48 para 3	"'…the acreage of channel features…was obtained from GIS maps of the channel through time (Table 2.3-5; Figure 2.3-3)."	According to the figure referenced, flows at the time of the photographs were variable. For example, at the time of the 1974 photos, flows were 8,000 cfs for part of the reach, and in 1993, flows were 1,250 at the time of the photos. These types of differences suggest that direct comparison of habitat areas between photos is accompanied by some uncertainty. These caveats should be noted to the reader, and their implications on the findings should	There is uncertainty in direct comparison of the photos associated with differences in flow, primarily the 1974 photos in the middle and lower reaches. This will be described in the text.	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
				be stated. For example, in 1974 flows in the middle section of the reach were 8,000 cfs when the pictures were taken. With 8,000 cfs flows, some of the bar and island habitat would be under water. If so, the difference in habitat area between 1974 and 1988 actually represents an even greater habitat loss than would be apparent if the flows were equal for both photos. The effects of the uncertainties in the analysis need to be made explicit to the reader.		
WDFW – JIM BYRNE	1	WTS 03-48 – 58	Pagination.	Pagination is incorrect, missing pages 78-91.	Figure 2.3-12 (a-f) is presented on these pages. These are 11X17 figures.	Very confusing.
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-48 para 5	"Gravel deposits used for spawning by anadromous fish are located at the gage site."	This sentence is not relevant and should be deleted. The use of this area by fish can be brought in to the discussion section of this study, this section deals with geomorphology of the channel – whether or not fish spawn there is not relevant to the question of the degree to which bed load is transported from the reach.	The sentence was intended to inform the reader that the specific site being described has gravel deposits used by anadromous fish for spawning since that was one of the important resources being investigated.	
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-48 para 5	"An analysis of the rating curves for the Lewis River near Ariel gage was also completed to help determine if there was any systematic	The term "degradation" has multiple meanings, and can be interpreted to describe a general process of decay, a decline in habitat quality or other resource values. The author is speaking of a process more properly termed <u>incision</u> (T. Abbe, personal communication). Where "degradation" or "degrading" is used in this paragraph, it should be	Incision is a better term for the process being referred to. Thank you for the suggestion (the replacement will be made it in the text) The location of the Ariel gage will also be added to the figures.	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
			aggradation or degradation of the channel bed."	replaced with "channel incision" or "incising." Also, the specific location of the Ariel gage should be included on relevant figures within the Figure 2.3-1a through f series. This is necessary to understand the information on rating curves and channel aggradation.		
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-48 para 5	"An analysis of the rating curves for the Lewis River near Ariel gage was also completed to help determine if there was any systematic aggradation or degradation of the channel bed."	Plotting of rating curves (Figure 2.3-4) is the only direct empirical analysis provided to address the question of whether the channel in the reach downstream of Merwin dam is aggrading or becoming incised. This analysis is incomplete and inconclusive. The analysis is incomplete because it deals with a small area very far upstream, near the dam. The results should not be presented as representative of the reach. The analysis is also incomplete because there is evidence given throughout the study to indicate that the channel has been undergoing incision: ▪ The data presented in Figure 2.3-3 show a decrease in wetted area over time, especially in the middle portion of this reach. ▪ On p. WTS 3-47, paragraph 2, the report states that "[n]ormally, meanders migrate towards the	The report states that the analysis of the gage data only indicates that the channel was not aggrading or incising "at the gage location" (p. WTS3-48, paragraph 5) and is not presented as "representative of the reach" as the comment suggests. We disagree that the 3 bulleted items in the comment are indicative of channel incision as explained below: Comparison of wetted area over time in Figure 2.3-3 should take into consideration the flow in each set of aerial photographs (see x-axis titles on figure). In the middle section of the river (Lewis River Hatchery to Eagle Island), flows range	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
				outside of the bend, but this meander migrated northwest toward the inside of the bend resulting in a straighter channel." This is direct evidence of a process of channel incision. ▪ Simple visual comparison of Figure 2.3-1b with Figure 2.3-1f indicates that the channel in the unconfined reach is narrower, straighter and less complex in 1996 than it was in 1939. These changes indicate a process of incision. This evidence should be included in the discussion of Channel Aggradation/Degradation. The likely role of the projects in the apparent process of channel incision, including preventing sediment transport to the reach, should be discussed. Data presented elsewhere in the report also indicate that gravel is being exported. The following should also be noted here or in the final discussion on page WTS 3-111 to 3-113: "[the old meander bend at the golf course] has been slowly filling with sediment based on the successive aerial photographs, as have other cutoff meanders in the system." (p. WTS 3-47, para 2). This, and the presence of unvegetated bars	from unknown in 1939 to 3,200 cfs, 8,000 cfs, 2,000 cfs, 1,250 cfs, and 2,500cfs in 1963, 1974, 1988, 1993, and 1996, respectively. One could suggest that between 1963 (3,200 cfs) and 1988 (2,000 cfs) there was a slight decrease in wetted area in this reach; however, it has remained quite consistent since 1988; very consistent throughout all photos in the downstream (Eagle Island) reach; and appears to have increased in the upstream confined reach (Merwin Dam to Lewis River Hatchery). The text describes the reason for the change in meander migration pattern as a direct result of gravel mining just upstream of this bend. The report describes the reasons for channel straightening as primarily caused by in-channel gravel mining and/or filling to protect the highway (page 3-47 and 3-48). Filling of old cutoff meanders with fine sediment	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
				throughout the reach indicate that the gravel in this reach in indeed being transported downstream. The apparent absence of changes in bed elevation just below the dam (at Ariel) is not conclusive for the whole reach. The plotting of rating curves for Ariel gage is inconclusive because the gage is so near to the dam itself. To understand the degree of aggradation or incision throughout the "project area" downstream of Merwin requires at least several more gages along the reach, analysis of rating curves at each one for a longer period of time, and comparison of patterns among these sites. The analysis presented does not provide any assurances that gravel is not mobilized and moved downstream by flooding in parts of the reach downstream of the Ariel gage. Therefore, the following should be added as the last sentence in this paragraph: "However, the dynamics of sediment movement here and elsewhere in the reach are poorly understood and cannot be described with existing data."	is a natural process in river systems. As noted on Figure 2.3-6, the substrate filling these cutoff meanders is sand and silt, not gravel as the comment suggests. The report does not suggest that gravel is not moving in the system, but that transport of gravel is occurring slowly (page WTS3-113). There is only one stream gage in the Lewis River downstream of Ariel. More gage locations and more data is always useful in geomorphic studies; however, the combination of many types of analysis of channel processes, as	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
					presented in the text, provides us with cumulative evidence pointing to the conclusions we reached.	
WDFW – KAREN KLOEMPKEN	1	WTS 03-55 Fig. 2.3-3	Changes in Lewis River.	Missing X axis title.	The x-axis shows the year of each aerial photograph mapped.	
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-56 Table 2.3-5	"Changes in area of different channel features downstream of Merwin dam (acres)."	It's not clear what is being presented in the table. If the values represent *changes in area*, the direction of change (negative or positive) should be indicated next to the value in the table. If the values are remaining acreages at the time of the photo, then the title should be "Areas of different channel features…"	Your suggested title is much clearer than the original title. Thank you for the suggestion.	
WDFW – KAREN KLOEMPKEN	1	WTS 03-57 Fig. 2.3-4	Gage height.	Missing X & Y axis titles.	The x-axis is year.	
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-57 para 3	"…it is clear that there was little wood in the lower Lewis River in the mid- 1930s."	This analysis does not provide information relevant to the question of what will be the likely effects of the projects over the period of the next license. While some pre-project/post-project comparisons are relevant, in this case the authors have already stated that stream cleaning in the 19th century resulted in loss of wood in the main stem, and therefore comparisons of photo data over time do not inform the question of project effects.	It was intended, as stated in the study plan, that information on the amount of wood captured in Swift Reservoir would be available to help provide the data requested in this comment. However, records of wood removed from the reservoir were not available, so the data could not be included in the report.	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
				To understand the effects of the proposed licensing action on the dynamics of large wood in the reach downstream of Merwin dam, wood volumes that will not be delivered to the reach below Merwin over the term of the next license as a result of the projects should be estimated quantitatively (please see the letter from the Conservation Groups to the Licensees, dated March 6, 2002). This estimate is necessary to the determination of project effects, and to guide development of mitigation and enhancement measures.		
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-58 Substrate mapping and sampling		The grain sizes associated with the terms used in substrate maps (Figures 2.3-6) should be provided in a table.	The grain sizes associated with the substrate mapping terms are listed in the methods section describing the mapping work (page WTS 3-4, 3rd paragraph).	
WDFW – KAREN KLOEMPKEN	1	WTS 03-75 Fig. 2.3-10	Fall Chinook redd counts in LR.	Missing X & Y axis titles.	The x-axis is year; the y-axis is number of redds.	
USDA Forest Service: John Kinney	1	WTS 03-76 2.3.5.2	Sediment budget and load	That is a lot of sediment! What is the relationship between size of watershed and sediment production between the Rain and Ole creeks? Where is that sediment sitting in those drainages? What is the estimated delivery rate and time frame of transport to the SWR? Are there opportunities to place gravels	Information on the relative size of the Rain and Ole Creek watersheds, as well as average tons/sq mi/yr in each watershed is displayed in Table 2.3-9 on page 3-77. A detailed analysis of sediment transport in the	It would seem reasonable to develop a sediment budget for the basin, by project, in order to estimate potential pool filling (loss of pool volume), or to predict any potential maintenance issues related to overall project operations. This relates also to the amount of

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
				upstream of Ole Creek using various large boulder configurations that would accommodate large flows and stabilize gravel deposits? Rosgen j-hooks, vortex rock weirs, "w" vortex rock weirs, etc.	creeks was not undertaken as part of the relicensing studies; however, field evidence indicates that large volumes of sediment are stored in the low-gradient, downstream 1-1.5 miles of the channels (see discussion in AQU 12-12, section 4.12.5.6). This sediment will eventually be transported into the lower end of the Swift bypass reach during peak flows; the timing of this transport was not modeled. It is possible to place gravel in the Swift bypass reach upstream of Ole Creek using gravel retention structures, although it is likely that gravel would not be stable under the highest spills through the reach.	bedload material that was transported pre-project, and how that material shaped the biological and physical attributes of the Lewis River. That argument has a temporal component that influences enhancement of the SBR. If the HIGHEST flows are "arrested" by the project and only occur infrequently (once every X years) it would seem a well developed channel enhancement program is totally feasible. We would suggest consulting with Dave Rosgen on this opportunity.
WDFW – KAREN KLOEMPKEN	1	WTS 03-76 Fig. 2.3-11	Distribution of redds.	Missing X axis title.	The x-axis is year.	
WDFW – JIM BYRNE	1	WTS 03-77	Sediment contributions.	If old landslide were not contributing sediment why include them? It states the streams are still continuing to process this sediment and gravel.	The old landslides were included since they were a large source of gravel in the past and the streams are likely still processing this sediment.	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
WDFW – KAREN KLOEMPKEN	1	WTS 03-91 Fig. 2.3-13	Gage height vs. given flow.	Missing X axis title.	The x-axis is year.	
USDA Forest Service: John Kinney and WDFW – Jim Byrne	1	WTS 03-91 Last para	First sentence, "…Lewis river between Merwin Dam and Eagle Island…"	I think this section covered the SBR.	You are correct, the sentence should read, "The changes in median substrate size along the Lewis River in the Swift bypass reach." It will be modified.	Thank you!
WDFW – JIM BYRNE	1	WTS 03-92	Table.	Table is mis-numbered.	Reference is made to this table on page 3-78. We believe it is numbered correctly.	
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-95	"…gravel, 0.5 – 6.0 inches in diameter…"	Units of length should be consistently expressed using the metric system. For analysis of particle sizes and mobility of gravel, units should be consistent to aid reviewers in comparisons between elements of the studies.	Particle sizes will be described in both English and metric units throughout the report since geomorphologists generally use the metric system and fisheries biologists generally use English units to describe substrate.	
WDFW – JIM BYRNE	1	WTS 03-95 – 100	Flow regimes.	Never explained flow regimes to move painted rocks; flow rate, duration, etc.	Little movement of the painted rocks was noted at any of the instream flow study releases. Modeling of 3 transects in the bypass reach indicated that flows of 500 cfs would likely initiate transport of gravel-sized particles (page 3-100, 1st paragraph).	Should incorporate response. **Licensees' Response:** *This information has been incorporated into the report***.**

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
WDFW – KAREN KLOEMPKEN	1	WTS 03-101 Fig. 2.3-16	Gage height vs. flow for Speelyai Cr.	Missing X axis title.	The x-axis is year.	
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-106	"The Lewis River has experienced several natural and anthropogenic disturbances in the past 100 years…"	This entire paragraph should be deleted or moved to the end of the discussion. The study does not analyze "several natural and anthropogenic disturbances." According to the objectives, the study analyzed the effects of the projects on stream morphology and habitat values during the term of the next license. The study provides very little data and no analysis to describe non-project effects. Non-project effects should not be the emphasis of this section, and should therefore not be the subject of the opening paragraph to the conclusions.	While a primary goal of WTS 3 is to describe the effects of the projects on the geomorphology of the Lewis River and project-affected tributaries, it is not possible to do this without an understanding of other actions in the basin that have affected the river system.	
USDA Forest Service: John Kinney	1	WTS 03-109 Historical Stream Channel Section	It appears that the Lewis River projects have had little influence on the channel position of the lower Lewis River. Continued operation of the projects between 1974 and present	This interpretation is false. Fluvial mechanics play a large role in geomorphic process. There is thought to be a balance between driving and resisting forces that control river dynamics, i.e., where velocity represents the balance between energy causing flow and energy consumed by flow (Ritter 1986). River channels migrate, aggrade and degrade based upon known variables. Naturally occurring stochastic events play a role in river systems.	The quoted statements were intended to indicate the effects of the projects on river position, not on other aquatic habitat or biological resources. Certainly the Lewis River downstream of the dams would look much different if the dams were not present and the sediment and debris load from the eruption of Mt. St. Helens had traveled down the channel. This section will be re-phrased to indicate that	How will you re-phrase this section to reflect this perspective? **Licensees' Response**: *Please refer to the revised text.*

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
			does not appear to have had major effects on river morphology.	Although one could argue the benefits derived from serial discontinuity (in the form of "dams") in a river system when addressing catastrophic events (MSH), another argument could be made against dams arresting the ability of a fluvial system to function properly in terms of natural processes. Therefore, continued operation of the projects has had major effects on the Lewis River in terms of its ability to function within its natural range of variability, both from a geomorphologic and biologic perspective.	perspective.	
WDFW – KAREN KLOEMPKEN	1	WTS 03-109 para 2	Historical Steam Channel Changes.	This paragraph doesn't appear scientifically sound. The Lewis River Projects have prevented all LWD and large gravels from being transported downstream. But the Projects "have had no major effects on the river morphology."	The Lewis River downstream of the dams would look much different than its present condition if the dams were not present and the sediment and debris load from the eruption of Mt. St. Helens had traveled down the channel. This section will be re-phrased to indicate that perspective.	
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-109 para 2	"It appears that the Lewis River projects have had little influence on the channel position of the	This statement conflicts with a statement on page WTS 3-48, paragraph 1: "Operation of the Lewis River projects has decreased the supply of sediment and large woody debris to the river downstream of Merwin dam, and	The quoted statement was intended to indicate the effects of the projects on river position, not on other aquatic habitat or biological resources. Certainly the Lewis River downstream of	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
			lower Lewis River."	reduced the magnitude of high flows in the reach. These changes have undoubtedly also contributed to altering the river channel." This statement conflicts with a statement on page WTS 3-107, paragraph 2: "In the absence of the project reservoirs, the lower Lewis River would have very different characteristics from its current condition, as millions of tons of sediment and wood would have been transported downstream following the eruption [of Mt. St. Helens]." This statement also conflicts with data presented in Table 2.3-5. The data in this table indicate that between 1939 and 1996, active bars have been reduced by 40 percent in the confined reach, by 67 percent in the unconfined reach, and by 96 percent in the split channel (Eagle Island). This is likely to be the result of the projects blocking the movement of sediment from the upper watershed to the reach downstream of Merwin dam, and changing the flood regime. The area of wetted channel has decreased by 20 percent in the unconfined reach during the same period. This indicates a process of channel incision, which is also linked to the	the dams would look much different than its present condition if the dams were not present and the sediment and debris load from the eruption of Mt. St. Helens had traveled down the channel. This section will be re-phrased to make the intent of the sentence clearer and to add the discussion regarding Mt. St. Helens.	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
				lack of sediment and wood transport from the upper watershed to the reach caused by the projects. Forested island habitat in the split channel reach has increased by 23 percent. This indicates a change of riparian habitat to stable upland forest habitat, and is probably caused by a decrease in the frequency and variability of flooding in this reach, the lack of wood and sediment input, and channel incision. This statement should be deleted because it is inconsistent with evidence presented in the report and creates conflicts within the report. The problems with this statement could also be resolved if the word "little" was replaced with the word "tremendous."		
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-109 para 2	"The primary effect on channel form has been a decrease in active channel bars and an increase in the area of vegetated bars and islands between 1932…and	This statement is unsubstantiated by the data presented, because the study ignores the effects of the projects on sediment and wood transport to the reach downstream of Merwin dam, and downplays evidence presented in Table 2.3-5. As described in the comment on WTS 3-48, paragraph 5, this statement ignores evidence of channel incision in the report which is very likely related to the projects. The weight of evidence indicates that the projects have affected vertical	As described above (response to comment on p. WTS 3-48 paragraph 5), we disagree with the commenter's interpretation of data indicating the channel is incising. The report presents the available data on changes to vertical and horizontal channel position through time, information on sediment transport in the reach downstream from	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
			1974."	channel position, possibly lowering the channel bed, and has simplified riparian habitat. The comment above describes how the channel has been simplified and straightened since 1939. Thus it is inappropriate to name an effect as "primary" when all the effects are not understood or described. This study fails to provide the empirical data needed for a complete analysis of channel aggradation or incision, instead relying largely on anecdote and conjecture. For example, on page WTS 3-75, in paragraph 2 the report states that "…there does not seem to be any systematic decrease in total number of redds through the years…" Redd counts might stay the same if transport of gravel the reach simply uncovers other gravel. In other words, statements such as this one appear to be reaching past the data presented to explain what is not understandable with available information. Because the study overall is incomplete in its analysis of project effects, the statement that loss of active bars is a "primary effect" is unsubstantiated. The weight of evidence indicates that the channel position is affected by the projects, that the channel is incising, and the	Merwin, and available information on fish spawning patterns. Taken together, we feel the weight of evidence does not indicate channel incision. It is also unclear how the "net 20 percent loss in wetted channel since 1939" was calculated. Based on Table 2.3-5, the total wetted channel in the 1939 photos was 372 acres and the total wetted channel in the 1996 photos was 358 acres, a 4% decrease in wetted channel. Flow in the 1939 photos is unknown, but there was spill at Merwin Dam suggesting flows were likely more than the single turbine capacity of 3,800 cfs (only 1 turbine was present in 1939). Flow in the 1996 photos was 2,500 cfs.	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
				river channel is becoming less diverse in terms of habitat as a result. This statement should be deleted or changed to the following (underline added to indicate revision): "One effect on channel form resulting from operation of the projects has been a decrease in active channel bars and an increase in the area of vegetated bars and islands between 1932…and 1974. As indicated by a net 20 percent loss in wetted width since 1939, the channel is apparently undergoing a process of incision. Because the projects block the input of large wood and sediment to the reach downstream of Merwin dam, incision of the channel is likely to be due to project operations. "		
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-110 para 2	"Studies of reaches downstream of other large dams…show a lack of gravel and finer particles… This increase of grain size and lack of gravel does not seem to be occurring downstream of	This statement is inconsistent with data provided in Figures 2.3-7 and 2.3-8. Figure 2.3-7 indicates that the mean size of gravel decreases with distance from the dam, and Figure 2.3-8 indicates that there is a fairly consistent increase in the percent of particles 64 mm and below in diameter with distance from the dam, until these small particles comprise 98 percent of the sample nearest Eagle Island, relative to about 15 percent at Merwin dam. The data presented suggest that smaller	The size distribution of substrate at any point in a river is dependent upon the size of sediment supplied to that point from upstream sources and the ability of the river to move the supplied sediment past that point. The river's ability to move sediment is a function of the substrate size, and water depth and gradient (see discussion on page WTS 3-111). Thus, in most	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
			Merwin dam."	particles are being transported downstream. The influence of tides, which extends all the way up to the lower half of Eagle Island, may slow the transport of finer-grained sediment completely out of the reach (K. Dube, ARG Meeting notes, January 11, 2000). If so, the change in grain size depicted in Figures 2.3-7 and 2.3-8 is consistent with processes of gravel transport out of the reach. The conclusion in this statement is inconsistent with the data. The statement should be modified, so that the last sentence reads: "Given the tidal influence at Eagle Island, and the lack of smaller gravel in upstream areas suggests that smaller gravel has already been exported from the reach near Merwin dam." The following sentence should then be added: "However, a lack of detailed information on the form of the river bed, the bed elevation, actual sediment transport rates, and other parameters related to transport of sediment within this reach result in uncertainty regarding sediment transport rates and processes, and	mountain river systems, as gradient decreases from steeper headwater streams to lower-gradient mainstem rivers to very low gradient, tidally-influenced river mouths, there is a general decrease in substrate size. This general pattern can be affected by inputs of sediment (such as where a steeper tributary contributes coarser sediment than the mainstem river can transport), locally steeper or lower-gradient reaches within the river, or by blockage of sediment from upstream sources, such as storage of sediment in a dammed reservoir. The substrate data from the Lewis River downstream of Merwin Dam, presented in Figure 2.3-7 and 2.3-8, reflect the supply, transport, and local stream gradient of the river. Samples 7-12 (RM 15-19) were collected in the confined reach of the river, where the average slope ranges between 0.0006 and 0.0009. These samples are generally slightly coarser	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
				overall sediment dynamics."	than samples in the downstream, unconfined reach. Sample 12, immediately downstream of Merwin Dam is much coarser than other samples, suggesting that finer sediment has been transported downstream from this location. Sample 7 is slightly coarser than upstream samples, suggesting that sediment supplied by Cedar Creek, immediately upstream of this sample point, is coarser-grained than can be transported by the Lewis River at this point. Samples 1-6 were taken in the unconfined reach of the Lewis River. The gradient of the river at sites 4-6 ranges between 0.0007 and 0.001, the same or slightly steeper than the upstream sites; however, the unconfined nature of the channel allows the water to spread out, resulting in lower water depths for a given flow compared to the upper, confined reach (recall that the ability of a river to transport sediment is a function of the	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
					depth-slope product). The gradient of the river at sites 1-3 is much lower than upstream sites, 0.0001-0.00027, resulting in finer substrate. Export of finer sediments from the upstream-most sample (immediately downstream of Merwin Dam) is apparent. This phenomenon may be occurring to a much smaller extent at other sample sites, but consideration of the slope and confinement characteristics of the Lewis River in the reach downstream from Merwin provide an explanation for the downstream-fining trend in substrate sizes at these sites.	
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-110 para 1	"However, placement of log jams may raise concerns from local residents…Balancing these issues is a task for the settlement team"	These two sentences are not a conclusion of the report, nor are they relevant to interpretation of the data. The statement should be deleted.	One of the key questions for this report asked about where LWD placement may be appropriate; this comment was in reference to the potential for LWD placement in the reach.	Verbal comments were offered to Frank Shier (PacifiCorp) at the 10/1/02 ARG meeting. Ms. Sampson maintains that the referenced statement reflects an opinion about a social reaction that does not belong in a biological report. **Licensees' Response**: *We have removed this statement from the final report.*

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-111 equation 2	"C = a constant, defined as 0.039 to 0.09 by different researchers"	The value of the constant used by the authors in subsequent calculations should be identified and a rationale for its use should be provided with a citation to the primary literature.	The range of C values (0.039 to 0.09) was used to provide the "Critical Shear Stress range" in Figure 2.3-21 and in subsequent discussions on Page WTS 3-112.	
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-111 equation 2	"$(\rho_s - \rho)$"	The difference in the definitions of ρ and ρ_s should be given.	The definition of ρ_s should read, "density of particle." The parameter ρ is defined in the previous equation (density of water). Therefore $(\rho_s\text{-}\rho)$ is the density of the particle minus the density of water, essentially the buoyant weight of the particle.	
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-111 para 1	"There are several possible reasons for the retention of gravel in the Lewis River."	A statement that presumes "retention of gravel" is an over-conclusion of the data. The report does not provide enough information to substantiate a claim that the gravel is retained in the reach downstream of Merwin dam The only empirical data emphasized is the rating curves for one site which is very close to the dam, which is insufficient as the basis for a conclusion that gravel is retained in the reach. Other evidence provided by the study (see comments on WTS 3-48, paragraph 5 and on WTS 3-111 paragraph 2) is not discussed by the authors (as for Figures 2.3-7 and 2.3-8) in terms of sediment transport processes, or is anecdotal or conjectural. The report is inconclusive regarding sediment	Figure 2.3-9 shows that there is a large amount of gravel throughout the reach; Figure 2.3-11 suggests that fish have been using the gravel in a fairly consistent pattern since at least 1971. The sediment transport calculations were produced at the only existing gage in the reach (gage locations have the best hydraulic information). That the gage is located close to the dam, in a confined reach with little to no input of gravel from upstream sources, and that this location has a large amount of gravel used by spawning anadromous fish even after	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
				transport within the reach downstream of Merwin dam. Therefore this statement should be deleted.	nearly 70 years of project operation and several major floods indicates that gravel is retained in the reach.	
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-111 para 3	"This also can explain why gravel does not move very much in the Lewis River."	As discussed in the comment on WTS 3-11, paragraph 1, the idea that "gravel does not move very much in the Lewis River" is not substantiated by the data presented in the report, and is in fact contradicted by some evidence. The statement should be deleted.	See response to the comment on WTS 3-111, paragraph 1.	
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-111 para 4	"The shear stress at the gage was calculated based on the rating table for discharges from 5,000 to 80,000 cfs."	The value of the constant C used in this calculation should be provided. The need for using the rating table is not explained. If the rating table provides a value for depth at different flows, the use of the value should be explained, since there is no depth parameter in either of the two shear stress equations given. In general, the process described in this paragraph should be more clearly spelled out for the reviewer. The reason this is important is because of the apparent inconsistency between flows required to move gravel in the Swift bypass and flows required to move gravel in the reach downstream of Merwin dam.	The range of C values stated in the definition of the equation (0.039 to 0.09) was used to calculate the range of shear stress in Figure 2.3-21 and subsequent discussions. The rating table was used to provide change in water depth with flow, the parameter "h = water depth" in the bed shear stress equation (τ_b). This section is a bit complicated; we will try to make it more understandable if possible. The primary reason that lower flows are required to move gravel in	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
				On page WTS 3-100, paragraph 1, in reference to the sediment transport modeling, is a statement that "gravel sized particles" are expected to move when there is 500 cfs in the Swift bypass reach. The results of the painted rock study analysis indicate that flows of 360 cfs at transect 10-1 (for which gradient is not given) results in movement of gravel 12 – 150 mm in diameter. In contrast, the discussion on page WTS 3-112 concludes that 30,000 cfs is required to move particles of 16 mm diameter. These statements seem to be in conflict. Details of calculations are not provided, so independent verification of the two conclusions is not possible. Details of calculations should be provided, or a direct explanation of why flow volumes required to move gravel in the reach downstream of Merwin are 60 times greater than those expected to devastate spawning areas with particles 10 times larger, in Swift bypass. Specific reference to the local gradient at transect 10-1 and in the modeled reach below Merwin (as reported in AQU-4) should be included.	the Swift bypass reach is the difference in water surface slope. Study of the two equations presented on page WTS 3-111 provides the reasoning required to understand this. The critical shear stress required to move a particle of a given size is essentially constant. The only 2 parameters that effectively change in the bed shear stress equation are water depth and slope. Therefore, changes in these 2 parameters govern the size of particles that are mobile at a given flow at a location. As seen in Table 2.3-22, the slope in the Swift bypass reach is 0.5% and the slope downstream of Merwin is 0.06%. This order of magnitude lower slope downstream of Merwin is the reason that particles that move in the Swift bypass reach at a given flow are not mobile in the reach downstream of Merwin at the same flow. (Of course the change in water depth with flow also enters the equation, but the difference in flow	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
					depth between the 2 reaches is much less than the difference in slope).	
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-111 para 2	"The ability of the river to entrain sediment particles is dependent upon the shear stress at the bed of the river, calculated as…"	The units of the parameters in the equations that follow this statement should be reported.	The equations can be calculated using any units. Metric or English units are most commonly used. The C values noted, and the shear stress values given in the report were calculated in cgs units, resulting in shear stress reported in dynes/cm^2.	
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-112 para 1	"…a discharge between 10,000 and 30,000 cfs would be required to move the spawning gravel (at the Ariel gage site)."	It should be noted here that the return interval for a flow volume of 30,000 cfs in this reach is less than 2 years, according to the Flood Management Study, and presented in Figure 11.1-2.	The flood frequency curve for regulated conditions shown in Figure 11.1-2 of the Flood Management Study is for the hypothetical condition where only the mandatory flood control storage (70,000 acre feet) is available. Furthermore, Figure 11.1-2, and the associated table of flood magnitudes (Table 11.1-4), only provides data on floods with return intervals of 10-years and greater. Analysis of actual peak flow data for the past 20 years (reflecting both mandatory and incidental flood control storage) shows that a flow of 30,000 cfs has a return period of about 2.5	

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
					years. The results of flood frequency analyses will be clarified in the final Technical Report.	
J. Sampson, Technical Advisor to the Conservation Groups	1	WTS 03-112 para 1	"If it is assumed that spawning gravel deposits are 10' deep…the total gravel transported [between 1932 and present] is the equivalent of 60,000 to 80,000 square feet of gravel area. The current estimate of spawning gravel size deposits near the Ariel gage is 125,000 SF."	The following should be added to the end of this statement: "It would therefore appear that within 70 years, or just over the period of the next license, at least half of the gravel that remains at the Ariel site will be transported downstream."	The period of the new license is not known but is unlikely to be nearly 70 years. An analysis of the effects of the project on gravel resources during the period of the new license will take place as part of the Settlement and PDEA process.	
WDFW – JIM BYRNE	1	WTS 03-115	LWD.	LWD in bypass reach could be hazard to Yale boaters. But there is a lot of floating wood and debris in Swift reservoir and boaters manage to operate there.	The recreation study indicated that the boating use of Yale Lake is approaching capacity, and is much higher than Swift Reservoir (Page REC 5-8, Table 7.5-2). In addition, Yale is used for many different types of watercraft sports (power boating, jet skis, waterskiing)	Logs affect boating in both reservoirs. Anglers speed to fishing spots in Swift.

Commenter	Volume	Page/ Paragraph	Statement	Comment	Response	Response to Responses
					and Swift Reservoir is used primarily for fishing-related boating, where boat speeds are not as high.	

2.3.10 Third-party Review Comments on WTS 3

An independent review of WTS 3 was performed by Stillwater Sciences. Their comments, dated December 19, 2002, are presented on the following pages.

This page intentionally blank.

Stillwater Sciences

2532 Durant Avenue, Suite 201, Berkeley, CA 94704 Phone (510) 848-8098 Fax (510) 848-8398

TECHNICAL MEMORANDUM

DATE: December 19, 2002

TO: Frank C. Shrier, PacifiCorp

FROM: Pete Downs, Yantao Cui, and Christian Braudrick

SUBJECT: Review of Draft Report on Lewis River Geomorphology Study (updated version)

PacifiCorp asked Stillwater Sciences to review and provide comments on the Lewis River Technical Report WTS-3 entitled "Stream channel morphology and aquatic habitat study." We were asked to include our opinion on the interpretation and analysis of the following three topics:

- a review of channel changes downstream of Merwin Dam;
- past and present LWD conditions downstream of Merwin Dam; and
- gravel condition and stability downstream of Merwin Dam.

Documents provided by PacifiCorp included:

- 2.1 Physiographic setting and stream channel classification (WTS 1)
- 2.2 Streamflow study (WTS 2)
- 2.3 Stream channel morphology and aquatic habitat study (WTS 3)
- WTS 2 Appendix 1: Monthly flow duration curves
- WTS 3 Appendix 1: Aquatic habitat unit data
- WTS 3 Appendix 2: Substrate samples
- WTS 3 Appendix 3: Spawning gravel samples
- WTS 3 Appendix 4: Hydraulic modeling for Swift Bypass Reach and Speelyai Creek

Our review focuses on WTS-3 and the related appendices.

We previously submitted several questions to PacifiCorp about the methods, calculations, and assumptions used in the analysis but not described in the report. We received Kathy Dube's response to these questions, and used the additional information to complete our evaluation of the conclusions given in the report. For many of the studies (e.g., sediment transport and sediment source analysis), the objectives or questions to be addressed were not included in the report. Ms. Dube explained several of the objectives to us, but including them in the report would help other readers to interpret the results.

In addition to the original material, we reviewed comments to the report submitted by the USDA Forest Service and Jennifer Sampson (representing the non-governmental organizations). We also examined the historical aerial photographs of the study site and the GIS overlays provided by

Montgomery Watson Harza. Finally, we reviewed a revised version of the report dated October 7, 2002.

In general, the assumptions and potential errors for each analysis should be clearly stated in the report; their omission makes it difficult to assess the results. This is particularly true for the sediment source and sediment transport analyses. Because different analytical methods have different assumptions, and therefore different potential errors, the assumptions for each method should be stated explicitly. Below, we provide comments on specific topics of the report.

Channel changes downstream of Merwin Dam

Channel changes downstream of Merwin Dam were evaluated in Technical Report WTS-3, primarily by reviewing a historical sequence of aerial photographs, and to a lesser degree by reviewing a long-term dataset from the USGS gauge at Ariel. These analyses led to the conclusion that the dam has had little effect on downstream channel morphology since 1974. While the project may have had little effect on channel morphology since 1974, we do not believe that data available for the analyses to date are sufficient to draw that conclusion.

Merwin Dam traps sediment and reduces peak flows to reaches downstream. WTS-3 discusses the impacts of Merwin Dam on channel morphology and sediment storage from Merwin Dam to the downstream end of Eagle Island. The change in the extent of bars on aerial photographs are used to assess channel changes and infer whether those changes were caused by the dam or other land uses in the basin such as gravel mining and urbanization. Other than at the USGS gauge site (which is a problematic place to assess channel stability, as discussed below), there is no record of changes in bed elevation downstream of the dam.

Aerial photographic series from 1938, 1963, 1974, 1988, 1993, and 1996 were compared in order to assess channel changes over time. The extent of emergent active bars, wetted channels, vegetated bars, and islands were mapped on the photographs and entered into a GIS database. Channel response since 1938 varied for the three reaches analyzed in WTS-3. The report concludes that between the 1938 and 1974 photos, the areal extent of active bars decreased by 43% from Merwin Dam to Lewis River Hatchery, 73% between the Lewis River Hatchery and Eagle Island, and 98% at Eagle Island (WTS-3, Table 2.3-5), but the areal extent of active bars has stabilized since 1974. The discharge at the time the photographs were taken ranged between 1,250 and 8,060 cfs. Using photographs taken during different discharges could add a significant error to the comparison of the areal extent of different features. This is particularly true for active bars, which tend to have less relief, and can therefore show large changes in exposed area with small changes in discharge. The changes in areal extent caused solely by discharge are important given the conclusion that the extent of active bars has stabilized since 1974, because the discharge in the 1974 photographs between the fish hatchery and the downstream end of Eagle Island (8,060 cfs) was the highest in any of the photographic series. For example, bars along Eagle Island appear to be in similar locations as in the other photo series, but the exposed extent of the bars is far smaller in the 1974 photographs than in subsequent years. Submerged traces of the bars are present in the photograph but not included in the mapped extent of the bars (which was likely done to be consistent). The mapped bars from 1974 therefore underestimate the areal extent of bars and therefore the conclusion that the areal extent of bars has not been reduced since 1974 is questionable. The extent of bars, however, does appear to have remained stable between 1988 and 1996[1], but eight years is a very short time relative to the period of record. In addition, while

[1] The 1996 photographs were taken after the 1996 high flow, the highest flow between the 1938 photos and the 1996 photos.

active bars in both the Lewis River Hatchery to Eagle Island Reach and the Eagle Island Reach have remained relatively stable since 1988, the extent of vegetated bars has decreased by 18% and 38%, respectively. The extent of emergent active bars does not necessarily correspond with changes in spawning habitat, but rather is a metric of changes in habitat complexity. Bar margins can have the highest local slope in the channel, and sediment can be redistributed from the bar margins to the remainder of the channel during high flow. This redistribution does not alter the amount of spawning habitat, but does alter habitat complexity. Because photographs taken at the different discharges will produce different results, and the areal extent of exposed bars does not necessarily indicate changes in the amount of spawning habitat, projecting future trends in spawning habitat from this analysis may not be appropriate.

We agree with the conclusion of the aerial photographic analysis that channel straightening (and hence channel incision) near the golf course road was likely not due to the hydroelectric project, but we are unable to assess whether the changes were natural, or due to gravel mining or other land uses. Erosion of the inside of meander bends (which caused the channel straightening at this site) can occur naturally without gravel mining or upstream dams. When a meander bend has a small radius of curvature and is unable to erode on the outside of the bend (e.g., when it is located against resistant bluffs, such as the site near the golf course road), the meander tends to "bounce" back away from the bluffs toward the center of the channel, which has the effect of causing erosion on the inside of the bend (Nanson and Page 1983). Aerial photographs show that land use and mass wasting from the adjacent road have supplied sediment to the outside of the bend, and there have been bars at the outside portion of the bend since the 1938 photographs. Bars on the outside portion of a meander bend do not conform to the typical pattern of meander bends, which tend to be shallow on the inside where velocity is low and deep on the outside of the bend where velocities are higher. Because the channel straightening in this reach is likely associated with other land uses in combination with natural processes, we do not infer that it is evidence of channel incision due to the dam.

The report notes that the stage-discharge relationship at the USGS gauge near Ariel has remained relatively stable between 1975 and 1999. This observation was used to conclude that channel has not incised at the gauge. There are several potential problems with analyzing channel stability using USGS stage-discharge relationships. USGS gauge locations are generally selected at stable sites (e.g., sites with bedrock in the bed or banks), and may not be representative of the reach as a whole (and WTS-3 does not imply that it is). In addition, the stage-discharge relationship is not only a function of channel depth, but also a function of slope, roughness, and channel form. It is likely that if the stage-discharge relationship is constant through time, that the cross section has not changed. However, the report should note that it is possible that the cross section changed and that there were compensatory changes in roughness or channel width.

Finally, the report states that following the May 1980 Mount St. Helens eruption, over 33 million tons of sediment entered the Lewis River watershed prior to 1990. This sediment was trapped in Swift Reservoir and would likely have moved downstream into the lower Lewis River if the dams were not present. The report correctly states that had the sediment been allowed to move into the lower Lewis River, the channel morphology would have changed dramatically. We have not analyzed the potential effect of this sediment on the Lewis River downstream of Merwin Dam.

Large woody debris

Large woody debris (LWD) was counted on aerial photographs for the years listed above. There were few pieces of LWD observed on even the earliest photographs. The report states that the degree to which wood was removed in the 1800s is unknown, and large jams could have been cleared prior to the first aerial photographs. Because the amount of wood removed from the river prior to the earliest photograph is unknown, the report does not assess the project effect on LWD, and recommends placing engineered log jams in the stream if the Settlement Team deems that adding wood is necessary. We agree with the analysis, methodology, and conclusions regarding LWD in the Lewis River stated in the report. We also agree with the remark that individual logs would likely be unstable in the reach, and believe that engineered jams could potentially be unstable as well.

Gravel stability downstream of Merwin Dam

Sediment transport analysis, in combination with redd surveys, was used to infer that sediment transport occurs infrequently in the Lewis River downstream of Merwin Dam, and that spawning gravels are relatively stable.

We checked the implementation of Parker et al.'s (1982) sediment transport equation and found that the results expressed in cubic meters per second were correct. The conversion from cubic meters per second to tons per day, however, seemed incorrect and underestimated the mass of sediment transported out of the reach. We informed the author of this discrepancy, and the sediment transport calculations have been corrected. In addition, if the river has been eroded since the dam was constructed, a strong armor layer may have developed, which would reduce future bed mobility. In that case, Parker's (1990) surface-based bedload equation may provide a more accurate measurement of the bedload transport capacity than the sediment transport equation used in the report[2].

The report would benefit from a discussion of the sediment transport equations and their applicability to analysis of changes in spawning gravels. Streams (such as the Lewis River) that are downstream of dams or have bedrock banks and boulder pavements are generally supply-limited. That is, they are able to transport more sediment than is delivered from upstream. In such streams, sediment transport equations provide the sediment transport capacity (the maximum amount of sediment transport that would occur if supply was not limited) rather than the rate at which sediment is transported. The predicted transport capacity can be several orders of magnitude higher than the actual sediment transport rate. The use of these equations to calculate sediment transport in the Lewis River can therefore overestimate the amount of gravel transport. A description of the site where sediment transport equations are applied and a discussion of how the specific site conditions affect the accuracy of sediment transport models would help to interpret the modeling results.

The estimate of the area of gravel lost since the construction of the dam based on the sediment transport modeling, given on page 3-113 of the report, is probably not accurate because erosion is more likely to change the depth of gravel than its areal extent. In addition, as discussed in the previous paragraph, the actual volume of gravel that is transported out of the reach is likely smaller than the 35,000 tons (651,000 cubic ft) estimated by the model. However, sediment transported out of the reach is not very large even if the 35,000 tons of gravel transport is accurate. This can be shown by estimating the average scour depth in the reach, which can be calculated as the total volume of sediment transported divided by the total area of fluvial deposits in the reach. For example, we estimate (based on the map provided by Ms. Dube) that the reach between Merwin Dam and the next major tributary downstream is approximately 5 miles long

[2] The actual equation used in the report is not given, but the spreadsheet supplied by Ms. Dube indicates that it is based on subsurface grain size rather than surface grain size.

and the channel is approximately 300 ft wide. The total area of this reach is therefore approximately 7,920,000 square ft. Even if only 50% of the modeled area is composed of alluvial deposits (rather than bedrock or boulders), the average scour depth in the reach would be about 0.16 ft over the past 70 years. Again, the actual scour should be less than the above value because the actual gravel transport rate should be less than 35,000 tons. Local sediment transport may occur in areas where the local slope is greater than for the reach as a whole (see the discussion of channel bar margins, above). This does not reflect sediment transported out of the system, but rather the redistribution of sediment from one portion of a local area to another (e.g., from a bar to the thalweg).

Sediment transport calculations used in the report appear to have used D_{50} measurements from spawning gravel patches. Typically, sediment transport equations use cross-sectional average grain size measurements, rather than measurements at individual patches. This was done to assess the mobility of spawning gravels at the USGS gauge (K. Dube, personal communication), but likely overestimates sediment transport as a whole.

Gravel stability was also inferred because field counts of salmonid redds did not systematically decrease through time. As stated in the report, redd counts can depend on many other factors and may not be an accurate proxy for gravel availability on their own. The redd count data are corroborated by the apparent persistence of gravels downstream of the dam, which indicates that sediment transport is likely infrequent. This concurs with the conclusion of the report that Merwin Dam has not had a significant affect on downstream gravel availability, but, as stated earlier, the methodology used in the report should be stated clearly, and in some cases, refined.

While neither the aerial photographs nor USGS gauge data are adequate to provide definitive proof that Merwin Dam has had little effect on channel morphology since 1988, it is clear that some of the common deleterious geomorphic effects of dams have not occurred on the Lewis River. For example, encroachment of riparian vegetation into the active channel does not appear to be as extensive as typically documented in other channels downstream of large dams. Also, high quality spawning habitat still occurs in the reaches just downstream of the dam. Often, in the absence of gravel augmentation, spawning gravels immediately below a dam tend to be displaced downstream, either eliminating the gravel bar entirely or causing the surface of the bar to become too coarse for salmon spawning. Observations of spawning gravel downstream of the dam are consistent with the sediment transport analysis in WTS-3, which found that very little sediment has been transported downstream (thereby producing little channel change). WTS-3 and Stillwater Sciences (1998) showed that high quality spawning habitat still occurs just downstream of Merwin Dam, and that gravels were present and not too coarse for spawning in the areas examined. This agrees with the findings of the sediment transport analysis and suggests that under the current flow regime, these gravel deposits are relatively immobile. Usually, gravel immobility is linked with fine sediment accumulation, which reduces salmonid egg survival. Again, this has not occurred in the two bars examined during the pilot assessment in 1998 (Stillwater Sciences 1998). The percentage of fine sediments found in these bars was quite low and gravel permeability was relatively high, both of which indicate that egg survival would be relatively high. WTS-3 shows that in the Lewis River as a whole, the percentage of fines is generally less than 15% in the sampled spawning gravels. We concur with the recommendation in WTS-3 that the extent of spawning habitat be monitored throughout the course of the license to evaluate possible changes in the availability of spawning gravel in the future.

References

Nanson G. C. and K. J. Page. 1983. Lateral accretion of fine-grained concave benches on meandering rivers. *In* Collinson, J. D. and Lewin, J. (eds), Modern and Ancient Fluvial Systems. Oxford: Blackwell, Special Publication of the International Association of Sedimentologists 6: 133-143.

Parker, G. 1990. Surface-based bedload transport relation for gravel rivers. Journal of Hydraulic Research 28: 417-436.

Parker, G., P. C. Klingeman, and D. G. McLean. 1982. Bedload and size distribution in paved gravel-bed streams. Journal of Hydraulic Engineering 108: 544-571.

Stillwater Sciences. 1998. Lewis River gravel quality pilot assessment. Prepared for the Lewis River Watershed Analysis Scientific Team. January 6, 1998.