Prepared in cooperation with the U.S. Army Corps of Engineers, Seattle District

Bathymetric and Streamflow Data for the Quillayute, Dickey, and Bogachiel Rivers, Clallam County, Washington, April–May 2010

Data Series 537

U.S. Department of the Interior
U.S. Geological Survey

Cover: Photogrpah showing view of Quillayute River and side channels looking downstream of the Mora Road turn-off toward the river mouth and Pacific Ocean, with James Island in the distance, Washington, June 13, 2010. Photograph taken by Christiana Barnas, U.S. Geological Survey

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Contents

Figures

Tables

Conversion Factors, Datums, and Abbreviations and Acronyms

Conversions Factors

Inch/Pound to SI

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
Flow rate		
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88) in U.S. Survey feet.

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83) State Plane Washington North in U.S. Survey feet.

Elevation, as used in this report, refers to distance above the vertical datum.

Abbreviations and Acronyms

ADCP	acoustic Doppler current profiler
GPS	global positioning system
kHz	kilohertz
LiDAR	Light Detection and Ranging
NAIP	National Agricultural Imagery Program
PDT	Pacific Daylight Time
RM	river mile
RTK	real-time kinematic
RTN	real-time network
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WSDOT	Washington State Department of Transportation

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Abstract

To facilitate the development of a two-dimensional hydrodynamic model of the Quillayute River estuary, the U.S. Geological Survey conducted a bathymetric survey of the Quillayute River and its tributaries, upstream of the La Push Harbor. Streamflow also was measured concurrent with the bathymetric survey. This report documents the bathymetric and streamflow data collected in the Quillayute (river mile 0.4–5.7), Dickey (river mile 0–0.4), and Bogachiel Rivers (river mile 0–0.8) on April 20–21 and May 4–6, 2010, including a longitudinal profile, about 7-miles long, of water-surface and riverbed elevations. In all, 173,800 bathymetric points were collected and streamflow measurements in the mainstem Quillayute River ranged from 3,630 to 7,800 cubic feet per second.

Introduction

The Quillayute River drains approximately 630 mi^2 of the northwestern Olympic Peninsula in Clallam and Jefferson Counties, Washington (fig. 1). The U.S. Army Corps of Engineers (USACE) is updating an existing digital terrain model of the Quillayute River estuary to include current bathymetric conditions. The USACE plans on using the updated terrain data to construct a two-dimensional hydrodynamic model focused primarily on evaluating sea-dike repairs (Zac Corum, U.S. Army Corps of Engineers, written commun., 2010). A sea dike protects about 1 mi of the right bank (when viewed looking downstream) of the Quillayute River at its mouth (fig. 1). In this report, right bank and left bank are relative to an observer looking downstream. A USACE contractor surveyed the lower 0.4 river miles (RM) of the Quillayute River near La Push Harbor but the USACE needed additional bathymetric data upstream. To assist with the development of the model, USACE requested that the U.S. Geological Survey (USGS) conduct a streamflow and bathymetric survey of the Quillayute River and part of its tributaries, upstream of the La Push Harbor.

The objectives of the study were to measure streamflow in the Quillayute and Dickey Rivers and to collect sufficient bathymetric data to adequately represent major morphologic features in the lower Quillayute, Dickey, and Bogachiel Rivers.

Purpose and Scope

This report documents the bathymetric and streamflow data collected in the Quillayute (RM 0.4–5.7), Dickey (RM 0–0.4), and Bogachiel Rivers (RM 0–0.8) on April 20–21 and May 4–6, 2010. A longitudinal profile of the Bogachiel River streamflow measurement site to a location near the mouth of the Quillayute River on May 6, 2010, provides about 7 mi of water-surface and riverbed elevations. The hydraulic and bathymetric data can be used in conjunction with existing terrestrial Light Detection and Ranging (LiDAR) data to construct and calibrate a two-dimensional hydrodynamic model.

Description of Study Area

The headwaters of the Quillayute River tributaries originate in the Olympic Mountains at an altitude of about 6,100 ft. The Quillayute River begins at the confluence of the Sol Duc and Bogachiel Rivers and flows approximately 6 mi before entering the Pacific Ocean at La Push, Washington (fig. 1). The Dickey River is the only major tributary to the mainstem Quillayute River and enters near RM 1.6, where the RM is referenced to the river mouth (fig. 1). Parts of the Quillayute River basin are within the Olympic National Park. The Quileute Tribal Reservation is located at the mouth of the Quillayute River, and the river is a traditional fishing ground still used by members of the Quileute Indian Tribe. The maritime climate in the Quillayute River basin consists of relatively mild, wet winters and cool, dry summers. Streamflow primarily is derived from rainfall in the winter and from snowmelt during spring and summer (National Oceanic and Atmospheric Administration, 2010).

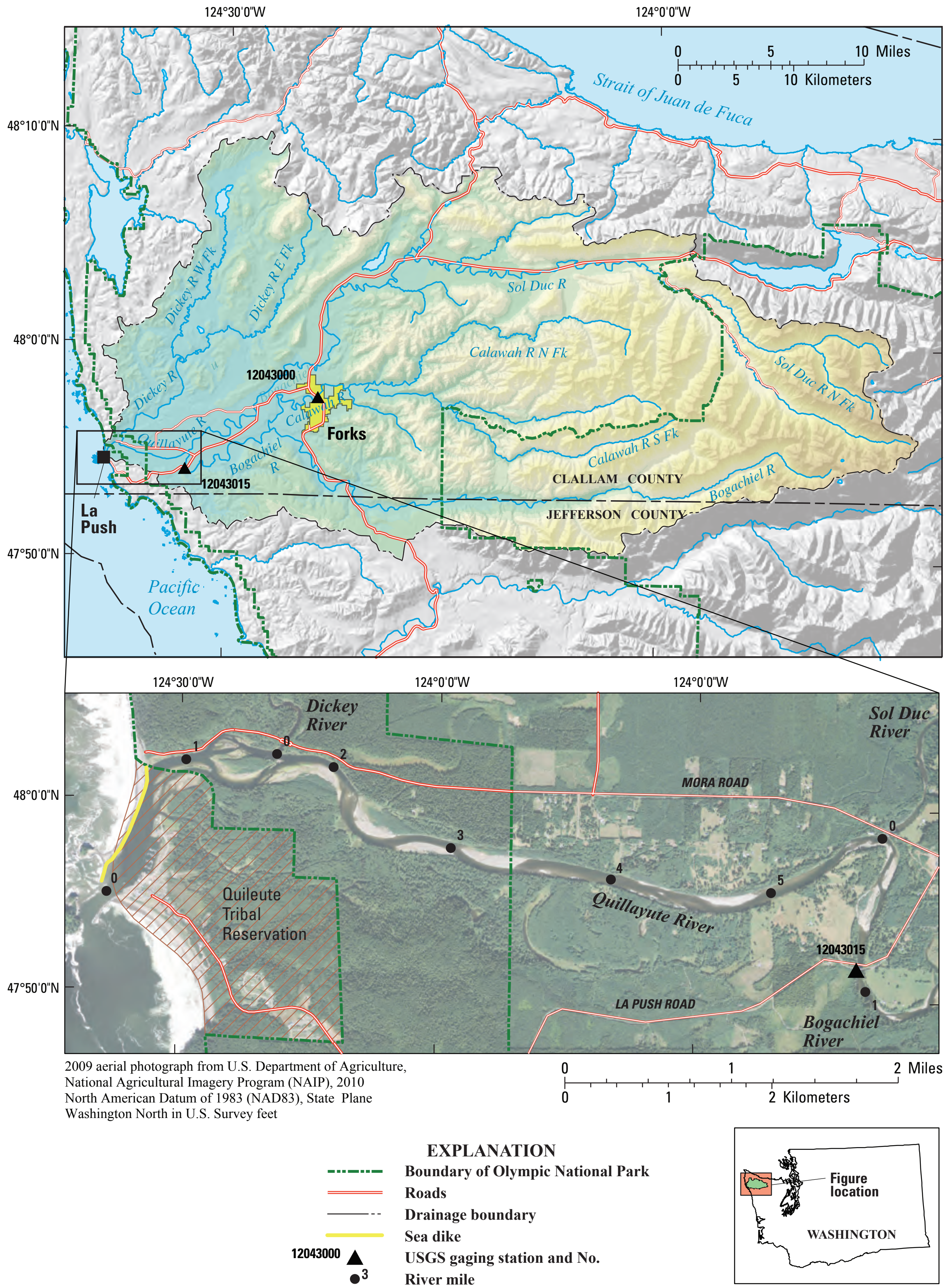


Figure 1. The Quillayute River system of the northwestern Olympic Peninsula, Washington, and the location of the study area. Approximate river miles were developed from 2009 aerial imagery to aid in the description of data collected in this study.

The study area is the Quillayute (RM 0.4–5.7), Dickey (RM 0–0.4), and Bogachiel Rivers (RM 0–0.8) (fig. 1). Approximate river miles shown in figure 1 were developed from 2009 aerial imagery to aid in the description of data collected in this study. The Quillayute and Dickey Rivers are subject to semidiurnal tides from the Pacific Ocean. Surface-salinity measurements collected during the time of the survey did not indicate the presence of saltwater in the study area; however, these measurements do not rule out the presence of a salt wedge. General observations indicated that the channel-bed material was coarse (gravel and cobble) in the free-flowing channels and sand was dominant in the estuary; however, measurements of sediment size were not made during the field survey. There were no indications of active sediment transport and the channel geometry did not appear to be altered by any streamflow or erosional processes during the field survey.

The Sol Duc River passes through a steep riffle as it joins the Bogachiel River to form the Quillayute River (fig. 1). The Quillayute River is relatively straight downstream of this confluence, with a recently developed cut-off meander apparent in aerial imagery between RM 3.6 and 4.3. The river near RM 3.6 transitions to a meandering reach with alternating gravel point bars (fig. 1). Photography sites are shown in figure 2. In the meandering reach of the Quillayute River upstream of the Dickey River, the banks along the outside of river bends are slumping and eroding (fig. 3). Point bars along the inside of these bends are coarse (composed primarily of gravels and cobbles), lack vegetation, and are covered with scattered woody debris (fig. 4). Downstream of the Dickey River tributary, the Quillayute River is braided with several side channels (figs. 5, 6, and 7), with large woody debris blocking the flow in one side channel (fig. 5) and large woody debris along the banks of another side channel (fig. 7). In the Dickey River, large woody debris spans nearly the entire width of the river, limiting its navigable extent (fig. 8). The Quillayute River near the mouth is a straight single channel confined by a sea dike on its right bank before it drains into the Pacific Ocean near La Push, Washington (fig. 1).

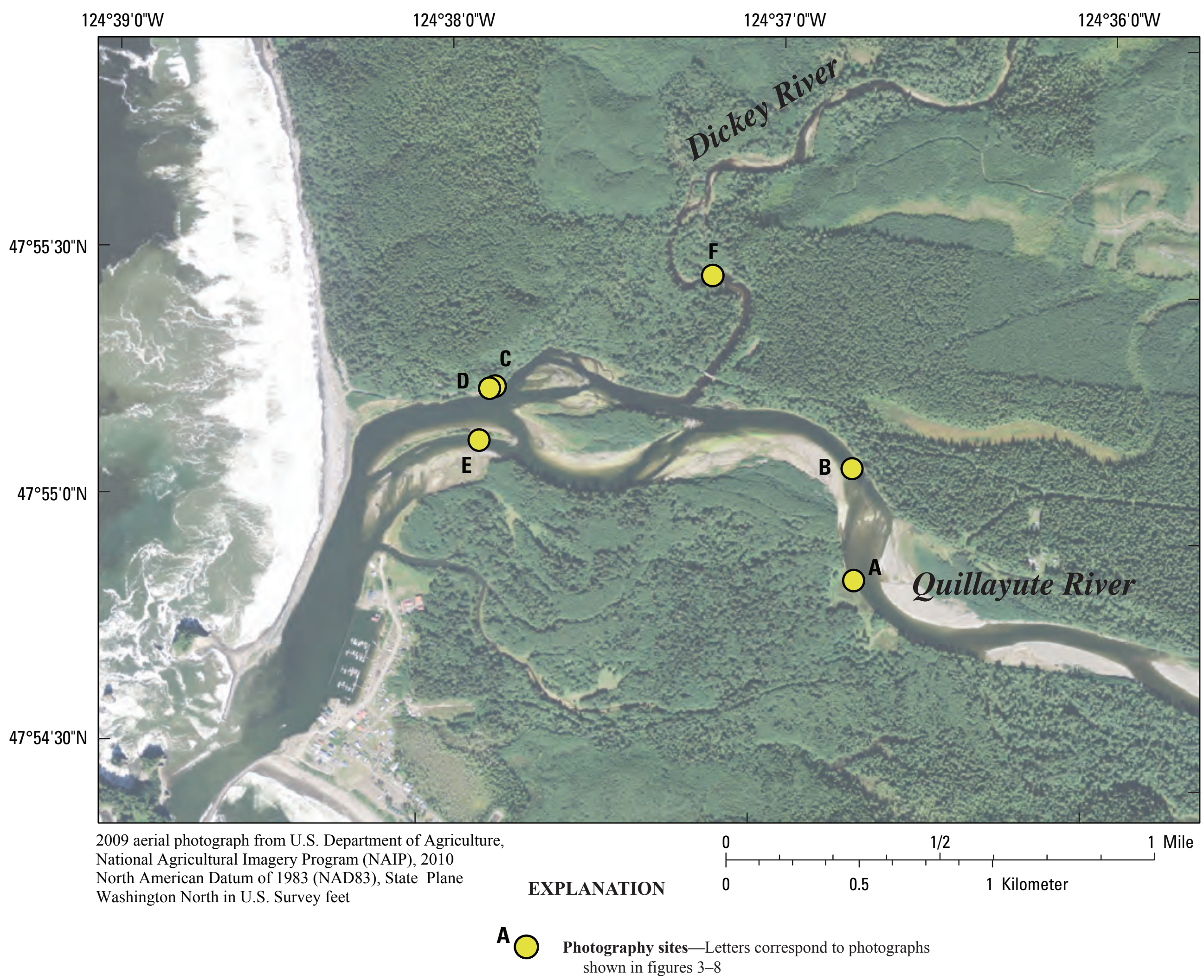


Figure 2. Location of photography sites in the Quillayute River system of the northwestern Olympic Peninsula, Washington.

Figure 3. View looking upstream along the slumping left bank of the Quillayute River, Washington, May 4, 2010. Location of photography site shown in figure 2, point A. Photograph taken by Christiana Barnas, U.S. Geological Survey.

Figure 4. View looking downstream at the left bank of the Quillayute River, Washington, May 4, 2010. Note the coarse (gravel and cobble) point bar lacking vegetation and covered with scattered woody debris. Location of photography site shown in figure 2, point B. Photograph taken by Christiana Barnas, U.S. Geological Survey.

Figure 5. View of Quillayute River side channels looking upstream of the Mora Road turn-off, Washington, May 6, 2010. Note the large woody debris blocking the old side channel in the center of the photograph. Location of photography site shown in figure 2, point C. Photograph taken by Christiana Barnas, U.S. Geological Survey.

Figure 6. View of Quillayute River and side channels looking downstream of the Mora Road turn-off, Washington, May 6, 2010. Location of photography site shown in figure 2, point D. Photograph taken by Christiana Barnas, U.S. Geological Survey.

Figure 7. View of Quillayute River side channel looking upstream, Washington, May 5, 2010. Note the large woody debris along the banks of the side channel in the left and right sides of the photograph. Location of photography site shown in figure 2, point E. Photograph taken by Christiana Barnas, U.S. Geological Survey.

Figure 8. View looking upstream, Dickey River, Washington, April 21, 2010. Note the large woody debris across the river in the center of the photograph limiting the extent of the bathymetric survey. Location of photography site shown in figure 2, point F. Photograph taken by Jonathan Czuba, U.S. Geological Survey.

Methods

An acoustic Doppler current profiler (ADCP) was used to measure streamflow and bathymetry. Bathymetry was rectified to real-world coordinates using a real-time kinematic (RTK) global positioning system (GPS) that received real-time network (RTN) corrections via a mobile phone. Dual frequency Trimble® R8 GPS receivers, Trimble Survey Controller®, and Trimble® GPS antennas were used for all GPS work. Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD83) State Plane Washington North in U.S. Survey feet and vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD88) in U.S. Survey feet. Geoid model GEOID03 (National Geodetic Survey, 2010) was used to convert GPS-derived heights above the ellipsoid to orthometric heights or elevations above NAVD88.

Streamflow Measurements

Streamflow was measured using a 1,200-kHz ADCP on the Quillayute and Bogachiel Rivers and a 2,000-kHz ADCP on the Dickey River. An ADCP uses acoustic energy to measure water velocity and depth (Simpson, 2002). By traversing from one riverbank to the other (called a transect), the water velocity and depth measurements are used to compute streamflow. Streamflow was measured following standard USGS procedures for measuring streamflow with ADCPs (Mueller and Wagner, 2009).

Streamflow was measured on the Quillayute River at RM 5.3 (USGS streamflow-gaging station No. 12043018), on the Dickey River at RM 0.1 (USGS station No. 12043103), and on the Bogachiel River at RM 0.8 (USGS station No. 12043015) (fig. 9). The location of the Quillayute River streamflow measurement site was in a relatively straight, narrow reach located upstream of the tidal influence allowing for accurate measurements of the water depths and velocities. The streamflow measurement site on the Dickey River, the best available site in the study area, was tidally affected. The streamflow measurement site on the Bogachiel River was coincident with the real-time USGS streamflow-gaging station 12043015, Bogachiel River near La Push, Washington, downstream of the La Push Road bridge.

Bathymetric Survey

River bathymetry was surveyed using a 1,200-kHz ADCP to measure the water depth and a RTK-GPS to track the position of the ADCP and measure the water-surface elevation. The ADCP used during this survey included four transducers arranged in a Janus configuration oriented at 20 degrees from the vertical. Each transducer emits an acoustic ping that reflects off the riverbed and calculates the water depth based on the two-way travel time of the ping (Simpson, 2002).

Real-time differential corrections for the RTK-GPS were computed by the Washington State Reference Network from a network of base stations (RTN) and transmitted to the on-board GPS through a mobile-phone Internet connection (Washington State Reference Network, 2010). The RTK-GPS was mounted directly above the ADCP and was used to georeference the ADCP water-depth measurements and to measure the water-surface elevations. RTK-GPS measurements also were made at Washington State Department of Transportation (WSDOT) survey monument THUNDER, last updated on May 20, 2008, located on the bridge over the Sol Duc River, just upstream of its confluence with the Bogachiel River (Washington State Department of Transportation, 2010). The reported accuracy of the THUNDER monument is 0.07 ft in the horizontal and 0.03 ft in the vertical (Washington State Department of Transportation, 2010). The estimated accuracy of positions obtained by the RTK-GPS survey to the WSDOT survey monument was 0.2 ft horizontally and 0.1 ft vertically.

Bathymetric data were collected in a combination of cross sections, winding paths, and longitudinal profiles. All channels that were accessible by boat were surveyed, including areas around side-channel blockages when practical. The practical navigable limitations of the surveying boat and equipment required a channel at least 20-ft wide and 2-ft deep. Efforts were made to survey shallow areas in the lower reaches during high tides to maximize coverage of bathymetric data. Large woody debris near the banks often prohibited surveying along the toe of the bank.

Water-depth measurements were filtered in WinRiver2® ADCP data-processing software and then imported into MatLab® for further processing. Water-depth measurements from each of the four transducers were processed as individual riverbed-elevation points in the bathymetric dataset. Water-depth measurements were corrected in MatLab® for transducer orientation and instrument pitch and roll using the instrument's compass and tilt sensor. The water-depth measurements were compensated for water temperature using the instrument's temperature sensor near the transducers. Independent water-temperature measurements made periodically verified that the instrument was reading temperature correctly. Compensation for salinity was not made to the water-depth measurements. Even though the periodic surface-salinity measurements collected during the survey did not indicate the presence of saltwater, the presence of a salt wedge would bias water-depth measurements by less than 2 percent. Therefore, if the actual water depth was 10.2 ft, the measured depth would be 10 ft with no salinity correction. Riverbed elevations were computed from the water-depth measurements using the RTK-GPS position measurements.

Longitudinal Profile

A longitudinal profile, about 7 mi long, was surveyed from the Bogachiel River streamflow measurement site to a location near the mouth of the Quillayute River (fig. 9). The methods for data collection and processing of the longitudinal-profile data were almost the same as those described for the bathymetric data. For the longitudinal profile, effort was made to follow the thalweg of the river, but river conditions did not always make this possible. The longitudinal profile represents the four-transducer average depths and the measured water-surface elevations.

Bathymetric and Streamflow Data

Streamflow was measured four times in the Quillayute River and five times in the Dickey River from April 20 to 21, 2010. Streamflow was measured four times in the Quillayute River and once in the Bogachiel River from May 4 to 6, 2010. Bathymetric data were surveyed in the Quillayute, Dickey, and Bogachiel Rivers from May 4 to 6, 2010, including a longitudinal profile of water-surface and riverbed elevations, about 7 mi long, surveyed from the Bogachiel River streamflow measurement site to a location near the mouth of the Quillayute River during the afternoon of May 6, 2010.

Streamflow Measurements

Streamflow measurements in the Quillayute River indicated that streamflow was decreasing on April 20 and 21, with some variability on April 21 (table 1). Measured streamflow in the Dickey River was tidally affected except for the measurement at 11:41–12:24 PDT during low tide on April 21, 2010 (table 1). Tidally affected streamflow measurements reflect the net flow downstream, which is the streamflow and a tidal component that flows upstream or downstream depending on the tide. Measured streamflow indicates that the Bogachiel River was contributing about two-thirds of the flow to the Quillayute River on May 6, 2010 (table 1).

Table 1. Measured streamflow at three locations, at one site on each of the Quillayute, Dickey, and Bogachiel Rivers, Washington.

[Locations of measurement sites are shown in figure 9. **Abbreviations**: USGS, U.S. Geological Survey; PDT, Pacific Daylight Time; ft^3/s, cubic foot per second]

Date	Time (PDT, 24:00 hour)	Number of transects	Streamflow (ft^3/s)	Streamflow standard deviation (ft^3/s)
Quillayute River, USGS gaging station No. 12043018				
Apr 20, 2010	15:11–15:33	8	4,110	259
Apr 21, 2010	09:28–09:38	4	3,830	50
	10:45–10:56	4	3,630	123
	15:02–15:13	4	3,780	40
May 4, 2010	10:44–10:56	4	7,800	165
	16:18–16:27	4	7,310	132
May 5, 2010	13:04–13:17	4	6,000	94
May 6, 2010	13:19–13:29	4	4,830	99
Dickey River, USGS gaging station No. 12043103				
Apr 20, 2010	08:31–09:31	8	[1]317	20
	16:26–17:10	8	[1]178	37
Apr 21, 2010	07:56–08:36	8	[1]396	35
	11:41–12:24	8	249	8
	16:43–17:01	4	[1]193	30
Bogachiel River, USGS gaging station No. 12043015				
May 6, 2010	13:58–14:13	8	3,250	149

[1]Streamflow measurement was tidally influenced.

Bathymetric Survey

Bathymetric data measured in the Quillayute, Dickey, and Bogachiel Rivers represent the major morphologic features of these rivers (fig. 10). Deep scour holes are at several locations between RM 0.4 and 2.2 on the Quillayute River (figs. 9 and 10); another deep scour hole is just downstream of the confluence of the Sol Duc and Bogachiel Rivers (fig. 10). Where the river meanders (RM 1.8–3.6), the riverbed was lowest along the outside of the bend and progressively increased in elevation toward the point bar along the inside of the bend (figs. 9 and 10).

Bathymetric data are represented by 173,800 individual points of riverbed elevation. The accuracy of the bathymetric data is around 0.3 ft and is limited by instrument error and the accuracy in measuring instrument offsets. The bathymetric data also captures local variations in riverbed topography, which is on the order of the riverbed-sediment size. The greatest density of bathymetric measurements is in the Quillayute River between RM 0.4 and 3.6 (figs. 9 and 10). The extent of the bathymetric survey on the Dickey River was impeded by a significant accumulation of large woody debris (fig. 6). Collecting detailed bathymetric data upstream of RM 3.6 was a low priority for the USACE (figs. 9 and 10). The bathymetric survey in the upper reaches included only a few cross sections at the crest of all major riffles, a longitudinal profile, and a winding path capturing major bathymetric features (for example, the deep scour hole at the confluence of the Sol Duc and Bogachiel Rivers; fig. 10).

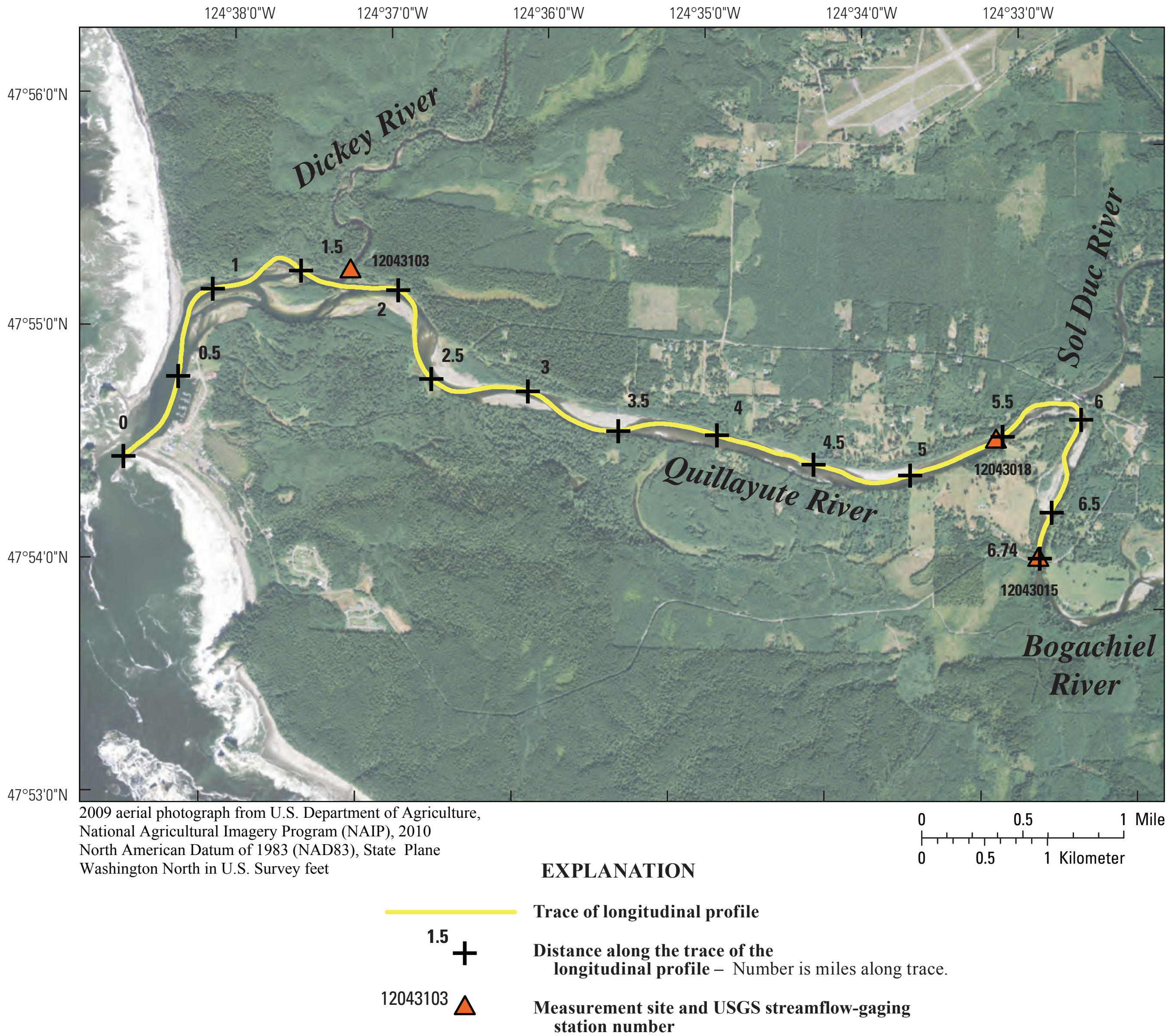
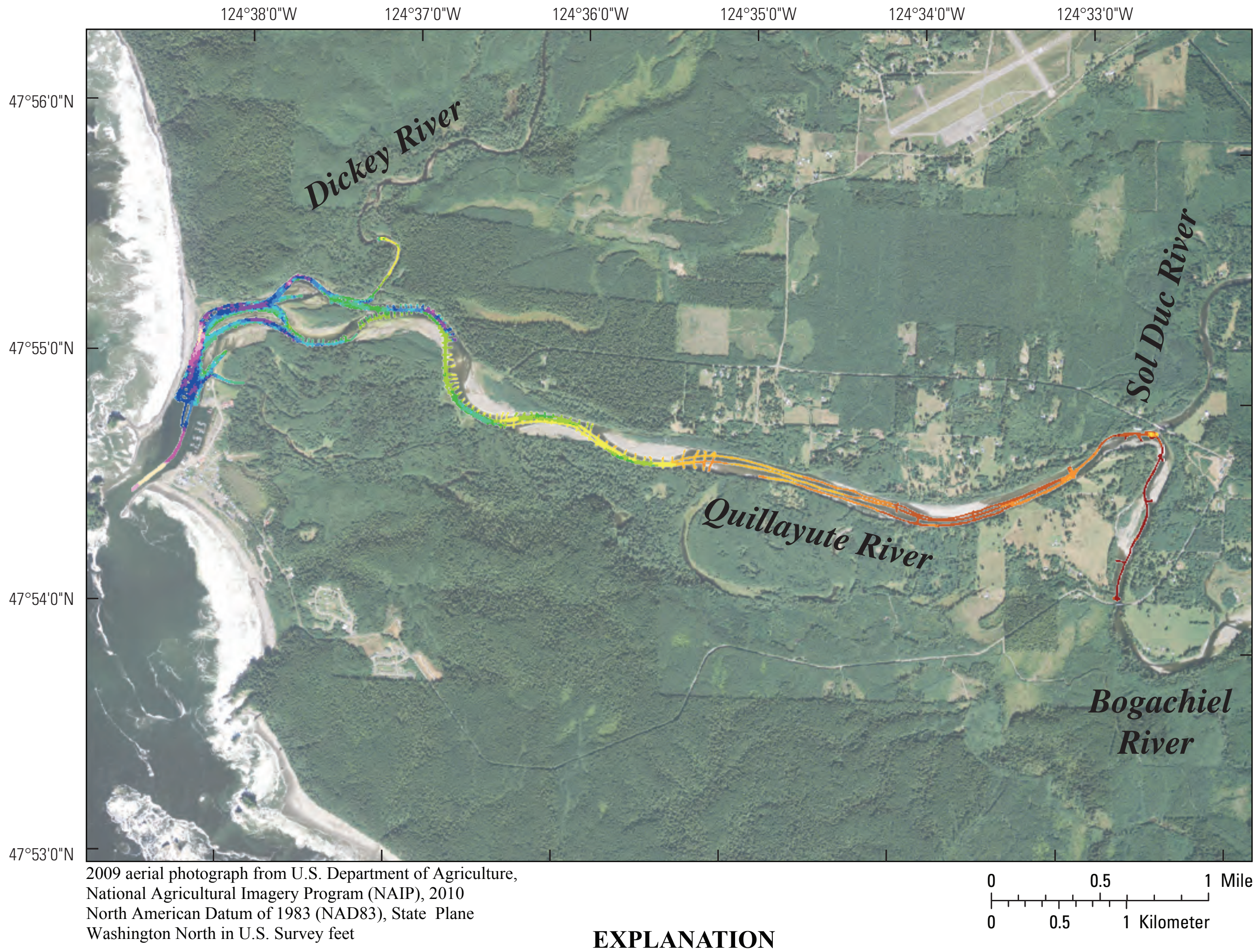


Figure 9. Location of streamflow measurement sites and the trace of the longitudinal profile with distance along the trace in miles, Quillayute, Dickey, and Bogachiel Rivers, Washington.



EXPLANATION

Bathymetric elevation data, May 2010, in feet above North American Vertical Datum of 1988

-23.31 – -18.03	-7.39 – -5.64	-0.25 - 1.74	11.37 – 14.78
-18.04 – -13.69	-5.65 – -3.88	1.75 - 4.28	14.79 – 20.18
-13.70 – -9.95	-3.89 – -2.07	4.29 - 7.90	20.19 – 29.33
-9.96 – -7.38	-2.08 – -0.24	7.91 - 11.36	

Figure 10. Bathymetric data from the Quillayute, Dickey, and Bogachiel Rivers, Washington, surveyed on May 4–6, 2010.

Longitudinal Profile

The length (almost 7 mi long) from the Bogachiel River streamflow measurement site to a location near the mouth of the Quillayute River was surveyed from 14:15 to 15:10 PDT on May 6, 2010 (figs. 9 and 11). Water-surface elevations ranged from approximately 32 to 0.5 ft and riverbed elevations ranged from 28.4 to -21.8 ft (fig. 11). Sequences of pools and riffles are apparent in the longitudinal profile. The relatively flat line from the longitudinal-profile distance of 0–1.2 mi represents the tidal backwater influence when the water-surface elevation profile was measured (fig. 11). At a longitudinal-profile distance of 5.6 mi, the water-surface elevations varied several tenths of a foot as the boat passed over standing waves at a large riffle (fig. 11).

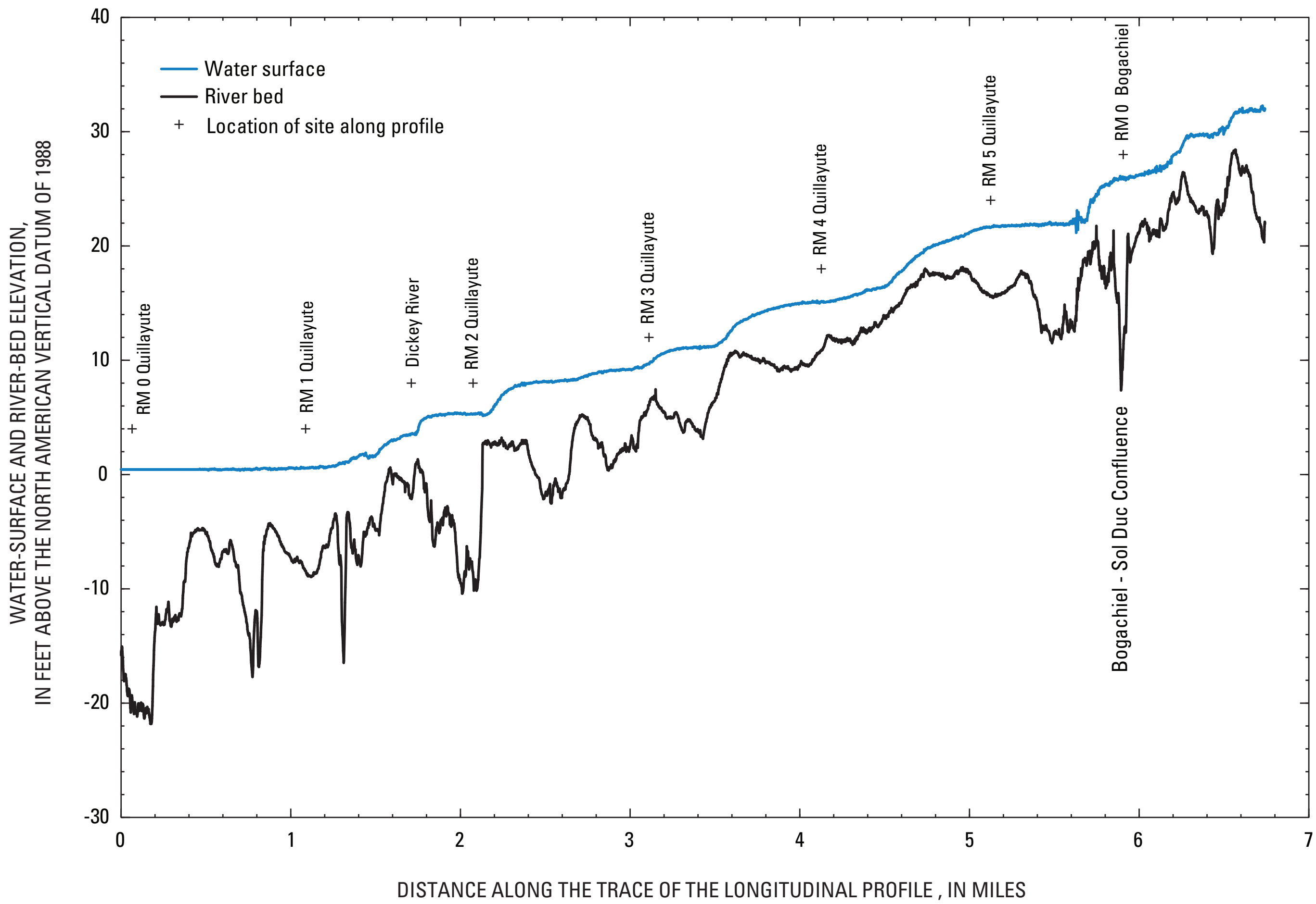


Figure 11. Longitudinal profile from the Bogachiel River to a location near the mouth of the Quillayute River, Washington, surveyed 14:15–15:10 PDT on May 6, 2010. The trace of the longitudinal profile and the distance along the longitudinal profile are shown in figure 9.

Summary

Bathymetric and streamflow data were collected in the Quillayute (RM 0.4–6.0), Dickey (RM 0–0.4), and Bogachiel Rivers (RM 0–0.8) on April 20–21 and May 4–6, 2010, including a longitudinal profile, nearly 7 mi long, of water-surface and riverbed elevations from the Bogachiel River streamflow measurement site to a location near the mouth of the Quillayute River on May 6, 2010. Streamflow and bathymetric measurements were made with an ADCP and the bathymetric data were rectified to real-world coordinates using an RTK-GPS. The bathymetric, streamflow, and water-surface data can be used in conjunction with terrestrial LiDAR data to construct and calibrate a two-dimensional hydrodynamic model for evaluating sea-dike repairs near the La Push Harbor, Washington.

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