MONITORING OF BIOENGINEERING STABILIZATION PROJECTS

Final Report

SPR 353

MONITORING OF BIOENGINEERING STABILIZATION PROJECTS

SPR 353

by

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for

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16. Abstract

Four sites with bioengineered stream banks were monitored for four years. Observations included quantitative measurements of stream discharge, stage and velocity. No bank erosion was observed to have affected the stream banks at any of the monitoring sites.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	M
yd	yards	0.914	meters	M
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	M^2
yd^2	square yards	0.836	meters squared	M^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	M^3
yd^3	cubic yards	0.765	meters cubed	M^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	G
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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The author would like to thank the USGS personnel who fulfilled the contract to monitor the flows at our study sites. They were Glenn Hess, Richard Kittelson, Greg Olsen, and Jay Spillum. The author would also like to thank the members of the original Technical Advisory Committee (TAC): William Fletcher of ODOT, Tom Herrett of USGS, Bill Jablonski of ODOT, Tim Rogers of FHWA, and Steve Narkiewicz of ODOT. Thanks also to the original problem statement submitter: Bo Miller of ODOT.

This project, by virtue of its long duration as a monitoring project, became an unintended casualty of the reorganization of the ODOT Highway Division. Two members of the original TAC could not continue their service due to new assignments under the reorganization. The original Principal Investigator also changed assignments a number of times, was unable to continue, and a replacement was not available. The most critical result of the reorganization was that the baseline channel survey data for the test sites was misplaced in all the shuffling of personnel and duties. Thus one major objective of the project, quantitative performance data, was not achieved. This report is published in the hope that the quantitative flow data and the qualitative performance observations will still be a useful addition to the body of knowledge regarding bioengineered stream bank stabilization.

DISCLAIMER

MONITORING OF BIOENGINEERING STABILIZATION PROJECTS

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1.0 INTRODUCTION

Historically, engineers designed stream bank stabilization projects using solely riprap. Recently, restrictions arising from the Endangered Species Act have required engineers to consider alternative methods to stabilize banks. Lower riprap quantities along with large woody debris, riparian vegetation, and geosynthetic matting are now the components often used. NCHRP Report 544, *Environmentally Sensitive Channel- and Bank-Protection Measures*, summarizes the wide range of techniques available (*McCullah and Gray 2005*). The Oregon Department of Transportation has made these kinds of adjustments to its practices in the numerous locations where its highways cross, or are adjacent to, rivers and streams.

Specific design guidance based on empirical data is scarce or lacking in the bioengineering field. Thus any information, particularly regarding hydraulic tolerances of specific types of installations, is very useful to designers faced with challenges in this ever-growing arena. Monitoring existing bioengineered sites to develop information useful for design is a tangible approach to the problem.

This research project undertook to measure the hydraulic flow conditions at, and the corresponding performance of, four bioengineered stream banks in Northwest Oregon.

This report is organized into three major sections. The first section deals with the sites themselves. The site selection process is briefly described, and the four sites selected are summarized. Then each of the four selected sites is described as to its location and setting, the bioengineering features used, and the flow monitoring gages installed.

The next section describes the results of the flow monitoring. This section begins with an overview of the monitoring protocol used by the U.S. Geological Survey (USGS), the types of equipment used, and a table of the most significant flow measurements obtained during the project. The section then proceeds to give tables of discharge, gage height, and velocity for each of the four sites. Details of the monitoring activities are included in Appendix A.

The final section presents qualitative observations of the performance of the bioengineering features and changes observed at the four sites over the course of the monitoring project. This study originally intended to also collect quantitative data regarding changes to the channel position and geometry, but the baseline data was lost during organizational and personnel changes. Despite the lack of quantitative data, it was clear from the qualitative observations that no changes of any engineering significance occurred during the monitoring. While the lack of quantitative data was frustrating, the fact that the bioengineering features performed their purpose under the measured flows over a period of four peak flow seasons was still a significant finding regarding the performance of these bioengineering features.

2.0 SITE DESCRIPTIONS

2.1 SITE SELECTION

This project was intended to monitor four bioengineering sites from the outset. The intent was also to monitor a variety of different types of bioengineering features. In the earliest stages of planning three Oregon Department of Transportation (ODOT) sites were considered as likely candidates. These three sites were Agency Creek (Three Rivers Highway, Oregon Route 22N, Mile Post (MP) 21.8), West Fork Dairy Creek (Sunset Highway, US Route 26, MP 45.7), and Johnson Creek (Pacific Highway East, Oregon Route 99E, MP 4.4). After a field visit it was decided that the Agency Creek site was not suitable for this project. The West Fork Dairy Creek and Johnson Creek sites were kept in the study. Two sites in Salem, not owned by ODOT, were selected to complete the complement of four sites. These two sites will be referred to as Pringle Creek and Shelton Ditch. Table 2.1 lists the four sites with a brief description of their characteristics.

Table 2.1: Table of monitoring sites with names and descriptions

USGS Site Name	Site Number	ODOT Site Designation	Bioengineered characteristics
West Fork Dairy Creek near Buxton	14204950	US Route 26, Mile Post (MP) 45.7 Sunset Highway	Turf reinforcement mats planted with grass and assorted woody shrubs. A single deflector constructed of boulders and a log.
Johnson Creek at McLoughlin Boulevard at Portland	14211530	OR Route 99E MP 4.4, Pacific Highway East and SE Tacoma Street Interchange	Vegetated mechanically stabilized earth constructed of terraced cobbles stabilized with geogrid, a riprap toe, and planted with live willows.
Shelton Ditch near Cottage Street at Salem	14191650	Shelton Ditch between Church Street SE and Winter Street SE North bank opposite Pringle Creek Park	Soil covered vegetated riprap with vegetation consisting of grasses, woody shrubs, and riparian trees.
Pringle Creek near Leslie Middle School at Salem	14190915	East of Leslie Middle School on the former grounds of the Fairview Training Center	Jute matting, anchored large woody debris, and vegetative plantings intended to re-establish a complete riparian vegetative community within the floodplain.

2.2 INSTRUMENTATION

All of the sites were instrumented similarly. Each site was equipped with a data logger housed in a 3 ft x 4 ft x 10 in metal shelter mounted on a 6 in x 6 in wooden post about 4 feet above ground. Reference gages, consisting of an outside staff gage covering a range of about six feet, were placed on the bank of the stream. A crest stage gage was paired with the staff gage and covered approximately the same range of stages.

The data loggers recorded data from two acoustic Doppler stage-velocity sensors. One of these stage-velocity sensors was anchored to the stream bed in the channel thalwag. The second sensor was anchored to the stream bank with the objective of recording the flow velocities affecting the bioengineering features during high water flow. For the start of the 2006 Water Year (October 2005 through September 2006), a submersible pressure transducer was added to supplement the stage sensor in the stream thalwag. See Appendix A for the details of the installations at each site.

The following sections give detailed descriptions of each of the four sites monitored as part of this project.

2.3 WEST FORK DAIRY CREEK SITE

2.3.1 Location

The West Fork Dairy Creek bioengineering monitoring site is located adjacent to US Route 26 at MP 45.7. The water-stage recorder was at Latitude 45°40'51", Longitude 123°11'32" referenced to North American Datum of 1927, near Buxton, Washington County, Oregon. This is Hydrologic Unit 17090010, 0.2 miles upstream of Mendenhall Creek and at river mile 15.3 upstream from Dairy Creek. The Gage Datum was 250 ft. above sea level.

The West Fork Dairy Creek bioengineering site is located where the stream is transitioning from a relatively constricted stream valley in the Oregon Coast Range into a broadening, open meadow-like valley. The current US Route 26 is completely straight in the vicinity of the site and located parallel to the current course of the stream. The highway's present location encroaches on the historic location of the stream in several places, including the bioengineering site.

The cut bank of the stream at the bioengineering site forms the embankment supporting US Route 26.

2.3.2 Bioengineering features

Over time West Fork Dairy Creek eroded away the cut bank supporting the highway to the point that ODOT personnel became concerned that the stability of the road was threatened. Rather than using rip-rap armoring to halt any further erosion of the embankment, ODOT used what is here referred to as a bioengineering approach. Very large boulders were placed at the very base of the embankment to the level of normal high water (see Figure 2.1). Above the level of normal high water the embankment was built out slightly with soil material covered with woven jute fabric. The jute fabric was anchored in place with rebar and steel plate gussets (see Figure 2.2). The embankment was then seeded and planted with cuttings of woody vegetation (see Figure 2.3). An additional feature present at the upstream edge of the bioengineering is a log that projects obliquely into the stream and redirects some of the stream's energy away from the cut bank.

Figure 2.1: West Fork Dairy Creek looking downstream. US Route 26 is immediately to the left of the photo. Prior to remedial work at this site, the stream had begun to abandon the channel on the right of the photo and establish the new channel on the left, which was eroding away the embankment supporting the highway. This photograph was taken in May 2003.

Figure 2.2: Close-up view of the soft engineering used to stabilize the embankment. Visible in this photo are a steel plate & rebar anchor along with exposed woven jute matting. This photograph was taken in May 2002.

Figure 2.3: Vegetated cut bank of West Fork Dairy Creek, which also serves as the embankment supporting US Route 26. This photograph was taken in May of 2002.

2.4 JOHNSON CREEK SITE

2.4.1 Location

The Johnson Creek bioengineering monitoring site is located where Johnson Creek passes under Oregon Route 99E at (current) MP 4.4. The water-stage recorder was at Latitude 45°27'50", Longitude 122°38'12" referenced to North American Datum of 1927 in the Sellwood neighborhood, Portland, Multnomah County, Oregon. This is Hydrologic Unit 17090012, 1.7 miles upstream from the Willamette River, at river mile 1.7. The gage datum was 50 ft. above sea level.

The location of the Johnson Creek bioengineering monitoring site is where Johnson Creek switches from flowing in the roughly westerly direction it follows for over ten miles to a roughly southerly direction that it follows until joining the Willamette River. This abrupt change in trend is a natural result of the topography in the area. In fact the topographic high ground that diverts the course of Johnson Creek includes Waverly Heights, which is the location of the easternmost exposure of seamount basalts accreted onto North America in the Eocene Epoch (*Bishop 2003*).

2.4.2 Bioengineering features

The place where Johnson Creek crosses under the interchange of Oregon Route 99E and Tacoma Street has been an unnatural channel configuration for decades. The stream channel was altered when the highway was originally built and likely was altered long before the highway as well. A survey map from 1852 shows the area as a swamp with a lake that may or may not be natural. When the interchange between Oregon Route 99E and Tacoma Street was reconstructed in 1993, the stream channel was realigned yet again. Bioengineering features were installed to protect the interchange structures while also helping to reestablish a more natural riparian habitat along this reach of Johnson Creek (*Sotir 2009*).

The features installed consist of the cut bank being terraced with geogrid-encased gravel planted with willows. Figure 2.4 shows a portion of the geogrid-encased gravel at the level of normal high water. Note that the very base of the terraced cut bank was armored with large cobble to small boulder-sized rip-rap. The remainder of the stream channel was reconstructed to resemble a natural meander bend with a gravel point bar. Figure 2.5 shows the nature of the realignment, and Figure 2.6 shows the details of the planned reconstruction. Figures 2.7 and 2.8 show the cut bank terraces being built. Figure 2.9 shows the bioengineered reach in 1997 after the vegetation had had a chance to get established. Note the abundance of willows. Three of the several larger canopy forming trees that were planted on the top level terrace can also be seen upon close inspection.

Figure 2.4: Small rip-rap overlain by the geogrid-enclosed gravel with woody vegetation at the Johnson Creek site

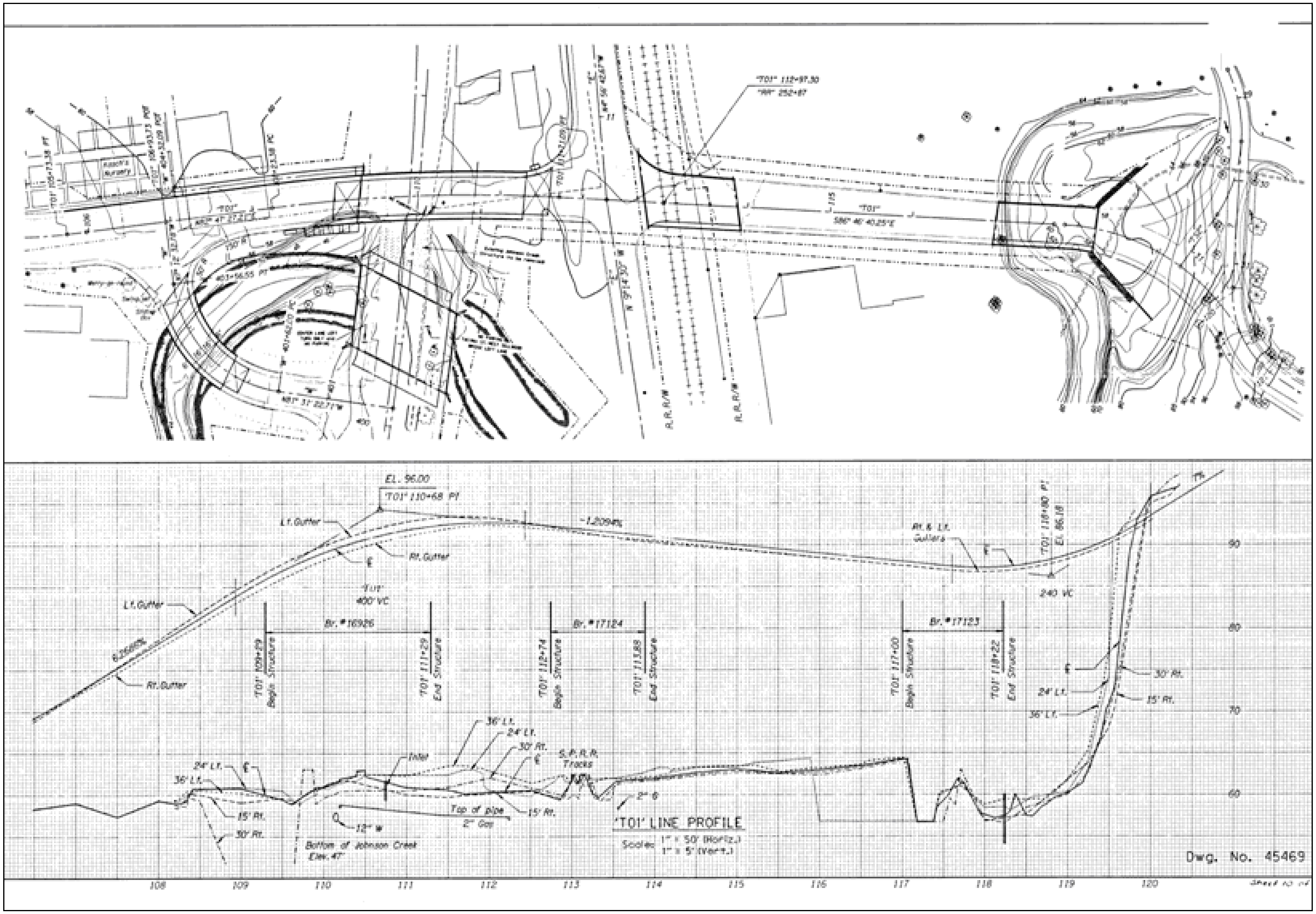

Figure 2.5: Planned modifications to the Johnson Creek channel as part of the construction of the new interchange

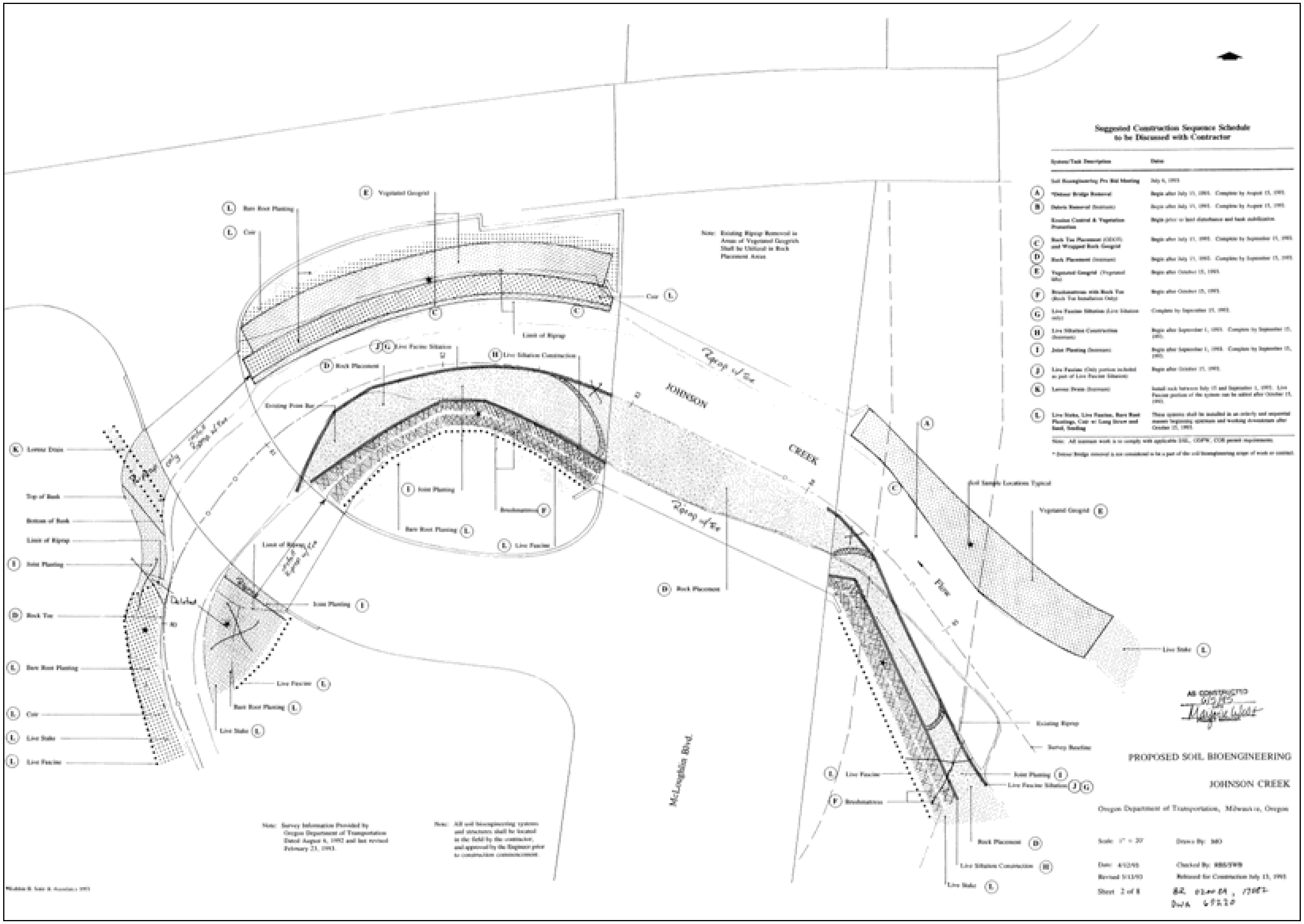

Figure 2.6: Plans for the bioengineering of the realigned Johnson Creek channel

Figure 2.7: Beginning of construction of the Johnson Creek bioengineering features in 1993

Figure 2.8: Johnson Creek bioengineering features in 1993 after construction but before planting of vegetation

Figure 2.9: Johnson Creek bioengineering site after establishment of vegetation in late summer/early fall 1997

2.5 SHELTON DITCH SITE

2.5.1 Location

The Shelton Ditch bioengineering monitoring site is located at the edge of the downtown Salem business district. The stream is bounded on the north side by an office building and on the south side by Pringle Park, parking for Salem Hospital, and Oak Street SE. The water-stage recorder is located at Latitude 44° 56'04", Longitude 123° 02'06" referenced to North American Datum of 1927, Marion County, Salem, Oregon, 0.1 miles upstream from where the ditch joins Pringle Creek. The gage datum was 135 ft. above sea level.

While the stream is referred to as Shelton Ditch on maps, maps from 1856 would seem to indicate that the stream is actually a channelization of a natural stream that had been appropriated to carry water diverted from Mill Creek approximately 2 miles away. This reach of Shelton Ditch is very straight and constrained by concrete retaining wall acting as the south bank. The sidewalk for the office building is only a few feet away from the edge of the water at low to high stream flows. When the stream floods it covers the sidewalk unless constrained with sand bags. Figures 2.10 and 2.11 show Shelton Ditch and the office building during flooding in 1996. The repairs to damage done during this flooding included the bioengineering that was monitored.

Figure 2.10: Photograph of the Shelton Ditch bioengineering site taken when the water was near its peak crest during flooding in February 1996. Photo courtesy of Jon Hazen, http://www.oregonlink.com/flooding/

Figure 2.11: Photograph of the Shelton Ditch bioengineering site taken during flooding in February 1996 after the stream had receded back into its banks. Photograph courtesy of Jon Hazen, http://www.oregonlink.com/flooding/

The bioengineering features as this site are limited to simply planting riparian vegetation on the banks, as shown in Figure 2.12. Comparing Figure 2.11 with Figure 2.12, one can see some of the vegetation added between the water and the sidewalk to the right (upstream) of the row of trees. Figure 2.13 shows that modest sized rip-rap is still part of the bank protection at the site.

Figure 2.12: Shelton Ditch bioengineering monitoring site in January 2006. Note the brushy, woody plants on the far (north) bank in the right-hand portion of the photograph that were absent in 1996.

Figure 2.13: Small rip-rap protecting the northern stream bank from erosion. Photograph was taken in July 2005 at the Shelton Ditch bioengineering monitoring site.

2.6 PRINGLE CREEK SITE

2.6.1 Location

The Pringle Creek bioengineering monitoring site is located on what used to be the grounds of the Fairview Training Center. Pringle Creek runs across the northern portion of the grounds. To the west (upstream) the creek passes between Leslie Middle School and a group of sport fields. The water-stage recorder was located at Latitude 44°53'59", Longitude 123°01'12" referenced to North American Datum of 1927, Marion County, Salem, Oregon. The gage datum was 230 ft. above sea level. It is Hydrologic Unit 17090007, upstream from Mill Creek.

2.6.2 Bioengineering features

The bioengineering at this location consisted of reestablishing a broad, natural riparian habitat in areas previously disrupted by a pond and a diversion. Woven jute fabric was used to stabilize the stream banks of the traditional channel (see Figure 2.14). Large woody debris (in the form of one- to two-foot diameter logs) was placed in the stream to promote complexity (see Figure 2.15). This large woody debris was in fact the main objective of the work adjacent to the Fairview Training Center. Willows were planted along the stream banks where the pond once was (see Figure 2.16). Woody vegetation was planted in the area of the reclaimed diversion with a photodegradable plastic mat placed to control canary reed grass until vegetative shading could accomplish the same objective (see Figure 2.17).

Figure 2.14: Exposed woven jute fabric installed to stabilize stream banks at the Pringle Creek site

Figure 2.15: One of three artificial log jams placed in Pringle Creek to help create deeper pools for fish habitat

Figure 2.16: Willows planted along Pringle Creek's riparian zone in what, at one time, was an artificial pond created by a small dam

Figure 2.17: Willows planted along Pringle Creek. The black plastic is intended to inhibit the growth of canary reed grass until shading by the willows can accomplish that same objective.

3.0 OBSERVED FLOWS

During the summer and fall of 2003, the USGS constructed equipment gage structures and stage gages at each of the four sites. They also deployed two acoustic Doppler velocity sensors at each of the sites. Hydrologic and hydraulic data collection began in fall 2003. During the winter months of approximately November to May (2003-2006), regular visits were made every other month to collect the logged data. Event specific visits were used to collect flood data and observe stream conditions. These data observations were logged during the study period.

In 2004 it became apparent that the data logger power requirements were more than the battery power available. More frequent visits were made to collect logged data after 2004. A few velocity sensors failed during early 2004, creating additional data gaps. During the summer of 2004 these sensors were either fixed or replaced. In the summer of 2005 an additional stage sensor was deployed at each site to quality assure the existing stage sensors. In some instances, when surplus data loggers were available, data logger capacity was increased at some sites. In 2006, after reviewing the data collected during the proposed study period, it was apparent that the hydraulic data collected was during a relatively dry period. Thus the USGS decided to collect another year of data in 2006-2007, unfunded, to better supplement the study period data. These 2007 data are included here.

Discharge measurements for each water year were published in the annual data reports for 2004-2006. Data for 2004-2005 are available online at http://pubs.usgs.gov/wdr/, and 2006 data can be accessed at http://web10capp.er.usgs.gov/imf/sites/adr06/launch2.jsp. Hydraulic data such as stage and lower and upper velocities were computed using USGS data and processing software. Annual summary and quality assurance reports for each site can be found in Appendix A.

The summary data in Table 3.1 are for individual peaks when the stage was above the upper velocity sensor. This table shows both the flow velocities in the main stream channel and the velocities near the bioengineering features. The flood frequency information in Table 3.1 was derived from either nearby long-term gaging stations or regression equations. The data in all the tables in this section are as reported in Hess (*2007*).

Tables 3.2 through 3.9 present two types of data for each of the sites. The first table for each site shows the discharge data, and the second table shows the gage height and velocity data for significant events during the period of monitoring. These tables provide a complete picture of the measured flows to which the bioengineering features were subjected during the monitoring.

Table 3.1: Stream gage height and velocity data for flow events that reached the upper velocity sensors

Date	Gage Height (feet)	Lower Velocity (feet per second)	Upper Velocity (feet per second)	Flood Frequency (years)
West Fork Dairy Creek at US Route 26				
Elevation of upper velocity sensor = 10.93 ft				
January 30,2004	14.26	4.20	1.90	<2
January 18,2005	10.98	2.42	1.06	<2
March 27,2005	19.38	6.87	2.47	<2
December 30,2005	17.58	6.45	2.26	<2
January 10,2006	20.09	7.97	2.66	<2
January 30, 2006	19.74	7.75	2.60	<2
November 6,2006	14.55	4.36	1.78	<2
November 23,2006	13.90	4.01	1.68	<2
December 14,2006	19.38	6.87	2.55	<2
January 6,2007	14.02	4.08	1.70	<2
Johnson Creek at Oregon Route 99				
Elevation of upper velocity sensor = 9.50 ft				
Dec. 14, 2003	9.93	10.21	No data	2
Dec. 30, 2005	9.89	10.14	No data	2
Shelton Ditch near Cottage Street				
Elevation of upper velocity sensor = 5.23 ft				
Dec. 14,2003	7.06	11.4	3	10
Dec. 29,2003	6.36	11.4	2.6	<2
Jan. 30,2004	5.92	10.2	1.8	<2
Dec. 31,2005	9.36	12.9	3.2	2
Jan. 11,2006	7.76	9.5	2.5	2
Jan. 18,2006	8.21	9	3.2	<2
Nov. 7,2006	6.9	10.8	2.2	25
Nov. 24,2006	6.78	10.5	2.5	<2
Pringle Creek near Leslie Middle School				
Elevation of upper velocity sensor = 7.14 ft				
Dec. 5,2003	7.52	4.1	2.1	2
Dec. 7,2003	7.34	3.4	1	<2
Dec. 13,2003	7.43	4.9	1.9	>2
Dec. 31,2004	7.23	3.7	no data	<2
Mar. 29,2005	6.95	3.9	no data	<2
Dec. 30,2005	7.66	5	4.8	<5
Jan. 10, 2006	7.39	4.9	3.5	>2
Jan. 20,2006	7.33	4.6	2.4	2
Nov. 10,2006	7.11	No data	no data	<2
Dec. 14,2006	7.19	No data	no data	<2
Dec. 26,2006	7.39	No data	1.7	2

Table 3.2: West Fork Dairy Creek site discharge data

NO	DATE TIME	MADE BY	WIDTH	AREA	MEAN VEL.	GAGE HEIGHT	DISCHARGE CFS	SHIFT ADJ.	PCT. DIFF.	NO. SECT.	GHT. CHG.	TIME	RATED	CONTROL
1	2003/05/30 1240	AJS			1.50	8.81		0.00				0.0		
	REMARKS: took pygmy velocity at starflow; starflow vel = 1.19 fps													
2	2003/07/31 1715	DAM			0.17	7.50		0.00				0.0		
	REMARKS: used flow tracker for velocity; starflow vel 0.24													
3	2003/10/28 1157	AJS	11.8	2.50	1.42	7.57	3.56	0.00		15	0.00	0.2	P	LGT DEBRIS
	REMARKS: starflow vel = 0.29; velocity at lower starflow about 1.3fps from pygmy													
4	2004/01/16 1300	AJS/JDS			2.32	10.73		0.00				0.0		CLEAR
	REMARKS: Starflow Velocity at 1300= 2.20. Portion of Rivercat Moving bed test used as check of starflow V.													
5	2004/10/05 0940	AJS			0.23	7.57		0.00						
	REMARKS: took pygmy velocity at starflow; starflow vel = 0.22													
6	2004/11/09 1303	AJS	20.4	7.90	1.35	7.86	9.94	0.00		24		0.0	F	LGT DEBRIS
	REMARKS: reset gh to 7.87 to match OSS @ 1255; starflow vel = 0.72													
7	2004/12/10 1247	JDS			1.93	9.76		0.00				0.0		
	REMARKS: 3 point starflow vel = 2.35; 1.98; 1.47; CSG = 10.93; starflow vel = 2.05													
8	2005/01/24 1009	AJS	28.0	35.3	1.92	9.03	67.8	0.00		31	0.00	0.0	F	CLEAR
	REMARKS: csg = 11.24; starflow vel = 2.05													
9	2005/03/15 0923	AJS			0.76	7.89		0.00				0.0		
	REMARKS: corr = 1.21, reset offset at 1005; starflow vel = 0.77													
10	2006/03/27 1016	AJS			2.51	8.89								
	REMARKS: no h310 corr, starflow vel = 0.44 (constant); lower CSG overtopped (GH = 15.8)													

Table 3.3: Gage heights and velocities for significant events during the period of monitoring at the West Fork Dairy Creek site

Date	Gage Height	Velocity at Lower Starflow	Velocity at Upper Starflow
Jan. 30, 2004	14.26[E]	4.20[1] fps	1.90
Feb.27, 2004	unknown	unknown	1.02
Nov. 2, 2004	10.87	2.27 fps	No water over this sensor
Dec. 11, 2004	10.64	2.24 fps	No water over this sensor
Jan. 18, 2005	10.98 ft	2.42fps	1.06
Mar. 27, 2005	19.38[E] ft*	6.87[1] fps	2.47
Dec. 30, 2005	17.58	6 45 fps	2.26[2]
Jan. 10, 2006	20.09*	7.97[1] fps	2.66[2]
Jan. 30, 2006	19.74 ft	7.75[1] fps	2.60[2]
Nov. 6, 2006	14.55	4.36[1] fps	1.78[2]
Nov. 23, 2006	13.90	4.01[1] fps	1.68[2]
Dec. 14, 2006	19.38*	6.87[1] fps	2.55[2]
Jan. 6, 2007	14.02	4.08[1] fps	1.70[2]

* - Maximum recorded
E - Estimated from CSG mark
1 - Using the stage vs. lower Starflow index relation, and velocity rating no. l, the velocity at the lower Starflow was estimated
2 - Using the stage vs. upper Starflow index relation, the velocity at the upper Starflow was estimated

Table 3.4: Johnson Creek site discharge data

NO.	DATE TIME	MADE BY	WIDTH	AREA	MEAN VEL.	GAGE HEIGHT	DISCHARGE CFS	SHIFT ADJ.	PCT. DIFF.	NO. SECT.	GHT. CHG.	TIME	RATED	CONTROL
6	2004/11/10 1045	GWO/GWH				5.03						0.0		
		REMARKS: LOWER STARFLOW VELOCITY= 0.50. VELOCITY WITH PLOWTRACKER= 0.57.												
7	2004/12/10 0858	JDS	44.0	65.2	2.32	6.53	152			31	-0.01	0.6	F	CLEAR
		REMARKS: LOWER STARFLOW VELOCITY= 2.78. MEASURED VELOCITY= 2.93 @ 0925.												
8	2004/12/10 0948	JDS				6.53								
		REMARKS: LOWER STARFLow VELOCITY= 3.00. MEASURED VELOCITY= 2.80 @ 0947.												
9	2004/12/22 1023	GWO				5.80								
		REMARKS: REPROGRAMMED CR510. LOWER STARFLOW VELOCITY= 1.7. MEASURED VELOCTTY= 1.5 @ 1023.												
10	2005/02/23 1318	DOC/GWO	27.0	25.3	0.49	5.18	12.4			24	0.00	0.6	G	CLEAR
		REMARKS: LOWER STARFLOW VELOCITY= 0.40. MEASURED VELOCITY= 0.41. HWM ON CSG= 7.54.												
11	2005/03/28 1325	GWO/JDS				7.45								
		REMARKS: HWM ON CSG= 7.97. STARFLOW VELOCITY= 6.14. VELOCITY IS TOO FAST FOR RIVERCAT ADP TO MEASURE?												
12	2005/11/09 1412	RLK/GWH	26.0	21.2	1.82	5.58	38.5			27				
		REMARKS: HWM ON CSG= 7.97. STARTED UP CR10. LOWER STARFLOW VELOCITY= 1.35. MEASURED VELOCITY= L.72 @ 1420.												
13	2005/12/30 1449	REW/DOC	89.0	306	4.38	9.50	1340			4			P	
		REMARKS: ADCP QM FROM DWST SIDE OF BRIDGE UPST FROM GAGE. STARFLOW NOT WORKING.												
14	2006/01/13 1511	RLK	50.0	136	3.09	7.54	420			9	+0.01	0.3	P	CLEAR
		REMARKS' QM FROM UPST SIDE BRIGDE 75 FT DWST OF GAGE. LOWER STARFLOW= 6.5. VEL NOT DETERMINED AT STARFLOW.												
15	2006/03/16 1410	RLK				6.08								
		REMARKS: HWM ON CSG= 9.97. STARFLOW VELOCITY= 2.6. TIMED DRIFT VELOCITY= 3.0.												
16	2006/05/31 0952	RLK/JDS				5.27								
		REMARKS: NO HWM ON CSG. LOWER STARFLOW VELOCITY= 1.21. ESTIMATED VELOCITY AT STARFLOW= 1.3.												
17	2006/11/07 7238	RLK				8.52								
		REMARKS: STARTED LOGGER UP FOR SEASON. LOWER STARFLOW VELOCITY= 8.4. TrMED DRTFT, VEr,ocrry= 7.3.												
18	2007/02/28 0920	RLK				6.46								
		REMARKS: FAINT HWM ON CSG= 7.69. LOWER STARFLOW VElOCITY= 3.1. TIMED DRTFT, VElOCITY= 3.4.												
19	2007/04/18 1045	RLK				5.85								
		REMARKS: HWM ON CSG = 8.07. LOWER STARFLOW VELOCITY= 1.95. TIMED DRIFT, VELOCITY= 1.79												

Table 3.5: Gage heights and velocities for significant events during the period of monitoring at the Johnson Creek site

Date	Gage Height	Velocity at Lower Starflow	Velocity at upper Starflow
Dec. 14, 2003	9.93[E]	10.21[1] fps	
Jan.24, 2004	8.38[E]	7.12[1] fps	
Mar. 5, 2004	7.00 ft*	4.0 fps	
Mar. 27, 2004	6.23 ft	2.2 fps	
Aug. 25, 2004	unknown	5.4 fps*	
Sept. 18, 2004	unknown	2.4 fps	
Dec. 8, 2004	unknown	4.5 fps	No water over this sensor
Dec. 11, 2004	7 54 [E]	6.2 fps	No water over this sensor
Mar. 27, 2005	7.97 [E]	7.7 fps*	Unknown if water over this sensor
Apr. 16, 2005	7.47 [E]	4.8 fps	No water over this sensor
May 18, 2005	unknown	4.2fps	No water over this sensor
Dec. 3, 2005	7.52 ft	6.5 fps	No water over this sensor
Dec.30, 2005	9.89 ft*	unknown	unknown
Jan. 17, 2006	8.49 ft	8.3 fps*	No water over this sensor
Jan. 30, 2006	7 99 ft	7.2 fps	No water over this sensor
Nov. 24, 2006	7.91 ft	7.8 fps	No water over this sensor
Dec. 14, 2006	9.44 ft*	8.3 fps	Not enough water over this sensor
Dec. 25, 2006	8.58 ft	8.1 fps	No water over this sensor
Jan. 3, 2007	9.14 ft	8.5 fps*	No water over this sensor
Feb. 24, 2007	1.13 ft	6.7 fps	No water over this sensor

*maximum recorded

E - Estimated from CSG mark

1 - Using the stage vs. lower starflow index relation, and velocity rating no. 1, the velocity at the lower starflow was estimated

Table 3.6: Shelton Ditch site discharge data

NO.	DATE TIME	MADE BY	WIDTH	AREA	MEAN VEL.	GAGE HEIGHT	DISCHARGE CFS	SHIFT ADJ.	PCT. DIFF.	NO. SECT.	GHT. CHG.	TIME	RATED	CONTROL
1	2003/11/13 1002	AJS	45.9	29.9	0.36	2.50	7.79			29	0.00	0.5	G	LGT DEBRIS
	REMARKS: DID NOT COLLECT A VELOCITY AT LOWER STARFLOW, 0.36 IS THE MEAN VELOCITY OF THE X-SECTION 70 FT DWST.													
2	2004/03/12 1314	AJS				3.11		0.00						
	REMARKS: COLLECTED DATA. AVERAGE VEL AT LOWER STARFLOW USING PYGMY METER= 0.86 FPS. STARFLOW VEL=0.90 FPS													
3	2004/05/13 1013	GWO	47.0	47.5	1.53	2.97	72.4				0.00		G	
	REMARKS: DID NOT COLLECT A VELOCITY AT LOWER STARFLOW, 1.56 IS THE MEAN VELOCITY OF X-SECTION 100 FT DWST													
4	2004/11/10 1520	GWO/GWH				2.87						0.0		
	REMARKS: FLOWTRACKER VELOCITY AT STARFLOW= 0.45 FPS. STARFLOW VELOCITY= 0.30 FPS. NEW CDT AND CRlO PROGRAM.													
5	2004/12/21 1517	GWO				3.20		0.00				0.0		
	REMARKS: REPROGRAMMED CR510. FLOWTRACKER VELOCITY AT STARFLOW= 0.89 FPS. AVERAGE STARFLOW VEL= 0.56 FPS													
6	2005/02/03 1329	GWO/RLK				2.90								
	REMARKS: COLLECTED DATA. FLOWTRACKER VELOCITY AT STARFLOW= 0.61 FPS. STARFLOW VELOCITY= 0.24 FPS.													
7	2005/05/13 1535	REW/GWH				3.34		0.00				0 .O		
	REMARKS: NO HWM ON CSG. PYGMY METER AT STARFLOW= 1.57 FPS. LOWER STARFLOW= 1.24 FPS. SHUT SITE DOWN													
8	2006/01/10 1552	RLK/GWO	6.88											
	REMARKS: FOUND BATT DEAD. TIMED DRIFT IN THALWAG, VELOCITY=8.7 FPS. UPPER STARFLOW= 2.38. LOWER NOT WORKING.													
9	2006/03/23 1500	RLK	40.0	81.2	1.88	3.61	153			19	0.00	0.4	F	CLEAR
	REMARKS: FOUND BATTS DEAD. MEASURED VELOCITY AT LOWER STARFLOW WITH **AA** METER= 1.57. STARFLOW= 1.82 FPS.													
10	2006/11/07 1519	RLK				6.90								
	REMARKS: RESTARTED LOGGER FOR THE SEASON. TIMED DRIFT IN THALWAG, VELOCITY= 9.0 FPS. STARFLOW= 6.17. FPS.													
11	2007/01/11 1344	RLK				4.37								
	REMARKS: FOUND BATTS DEAD. TIMED DRIFT IN THALWAG, VELOCITY= 5.8 FPS. STARFLOW= 3.32 FPS.													
12	2007/02/28 1427	RLK				4.57								
	REMARKS: FOUND BATTS DEAD. TIMED DRIFT IN THALWAG, VELOCITY= 6.5 FPS. STARFLOW= 3.80 FPS													
13	2007/04/18 1411	RLK				3.53								
	REMARKS: FOUND BATTS DEAD. TIMED DRIFT IN THALWAG, VELOCITY= 4.1 FPS. STARFLOW = 1.66 FPS.													

Table 3.7: Gage heights and velocities for significant events during the period of monitoring at the Shelton Ditch site

Date	Gage height	Velocity at Lower Starflow	Velocity at Upper Starflow
Dec. 14, 2003	7.06 ft*	11.4 fps*	3.0 fps*
Dec. 29, 2003	6.36	11.4 fps*	2.6 fps
Jan. 24, 2004	5.19	9.6 fps	No water over this sensor
Jan. 30, 2004	5.92	10.2 fps	1.8 fps
Dec. 11	4.78 ft*	8.2 fps*	No water over sensor
Mar. 29	4.67 ft	7.4 fps	No water over sensor
Apr. 18	4.18 ft	5.7 fps	No water over sensor
May 11	4.07 ft	5.2 fps	No water over sensor
Dec. 31, 2005	9.36 ft*	12.9 fps*	3.2 fps*
Jan. 11, 2006	7.76 ft	9.5 fps	2.5 fps
Jan. 18, 2006	8.21 ft	9.0 fps	3.2 fps
Nov. 7, 2006	6.90 ft*	10.8 fps*	2.2 fps
Nov. 24, 2006	6.78 ft	10.5 fps	2.5 fps*

*maximum recorded for water year

Table 3.8: Pringle Creek site discharge data

NO.	DATE TIME	MADE BY	WIDTH	AREA	MEAN VEL.	GAGE HEIGHT	DISCHARGE CFS	SHIFT ADJ.	PCT. DIFF.	NO. SECT.	GHT. CHG.	TIME	RATED	CONTROL
1	2003/11/06 1041	AJS	11.4	4.68	0.28	5.52	1.30			18		0.4	F	MOD DEBRIS
		REMARKS: SET CR510 AND BOTH STARFLOWS. NOT SURE IF GHT IS SET. NO STARFLOW VELOCITY. MANY LEAVES ON CONTROL.												
2	2004/01/16 1444	GWO	13.0	6.13	1.34	5.66	8.30	20	+0.01	0.4	G	CLEAR		
		REMARKS: FLOWTRACKER VELOCITY AT STARFLOW= 1.6. STARFLOW VELOCITY= 0.61. HWM ON CSG= 7.51 FT. PZF= 5.21 FT.												
3	2004/03/02 1433	GWO				5.59								
		REMARKS: FLOWTRACKER VELOCITY AT STARFLOW= 2.02 FPS. LOWER STARFLOW NOT WORKING.												
4	2004/03/05 1015	GWO				5.59								
		REMARKS: LOST FLOWTRACKER DATA FILE. STARFLOW VELOCITY NOT WORKING.												
5	2004/03/12 1028	AJS				5.59								
		REMARKS: MEASURED VELOCITY WITH PYGMY METER= 1.29. LOWER STARFLOW VELOCITY= 0.28.												
6	2004/05/13 1320	GWO	11.2	2.80	0.49	5.39	1.38				0.00	0.4		CLEAR
		REMARKS: MAXIMUM MEASURED VELOCITY OF QM= 0.76. STARFLOW VELOCITY= 0.48.												
7	2004/11/10 1330	GWO/GWH				5.41								
		REMAXKS: FLOWTRACXER VELOCITY AT STARFLOW= 0.70. STARFLOW VELOCITY= 0.54												
8	2004/12/14 1435	RLK/GWO			1.55	5.54		0.00				0.0		
		REMARKS: MEASURED VELOCITY WITH PYGMY METER AT STARFLOW= 1.55. STARFLOW VELOCITY= 1.3.												
9	2004/12/16 1127	RLK/GWO				5.48						22.0		
		REMARKS: MEASURED VELOCITY WITH PYGMY AT STARFLOW= 1.4. STARFLOW VELOCITY= 0.51.												
10	2004/12/21 1031	GWO				5.42								
		REMARKS: MEASURED VELOCITY WITH FLOWTRACKER AT STARFLOW= 0.71. STARFLOW= 0.54. LOADED NEW CR510 PROGRAM.												
11	2005/05/13 1437	REW/GWH				5.38								
		REMARKS: MEASURED VELOCITY WITH PYGMY AT STARFLOW= 0.99. VELOCITY AT STARFLOW= 0.20. HWM ON CSG= 7.33.												
12	2005/12/15 1045	GWO				5.41								
		REMARKS: REPLACED BATTERIES. STARFLOW VELOCITY= 0.29; LOST FT FILE												
13	2006/01/11 1120	RLK				6.28								
		REMARKS: MEASURED VELOCITY WITH AA METER AT STARFLOW= 4.2. STARFLOW VELOCITY= 4.51. HWM ON CSG= 7.88												
14	2006/01/11 1229	RLK				6.18								
		REMARKS: MEASURED VELOCITY WITH AA METER AT STARFLOW= 3.5.STARFLOW VELOCITY= 3.6 (AVG)												
15	2006/03/23 1020	RLK	10.6	4.33	0.62	5.45	2.67			13	-0.01	0.2	P	CLEAR
		REMARKS: MEASURED VELOCITY WITH PYGMY AT STARFLOW= 0.46 FPS. STARFLOW VELOCITY = 0.24.												

Table 3.9: Gage heights and velocities for significant events during the period of monitoring at the Pringle Creek site

Date	Recorded Gage height	Lower Starflow Velocity	Upper Starflow Velocity
Dec. 5, 2003	7.52*	4.1	2.1
Dec. 7, 2003	7.34	3.4	1.0
Dec. 13, 2003	7.43	4.9*	1.9
Jan. 31, 2004	6.98	4.4	No water over this sensor
Feb.24, 2004	7.10	4.5	No water over this sensor
Oct. 9, 2004	Unknown	3.6	No water over this sensor
Nov. 2, 2004	Unknown	4.3*	No water over this sensor
Dec. 8, 2004	Unknown	3.6	No water over this sensor
Dec. 31, 2004	7.23*	3.7	No water over this sensor
Mar. 23, 2005	6.95	3.9	No water over this sensor
May 1, 2005	6.47	3.2	No water over this sensor
Dec. 22, 2005	7.55	4.7	Unknown
Dec. 28, 2005	7.57	4.3	2.7
Dec. 30, 2005	7.66	5.0	4.8
Jan. 6, 2006	7.07	4.8	No water over this sensor
Jan. 10, 2006	7.39	4.9	3.5
Jan. 17, 2006	7.09	4.8	No water over this sensor
Jan. 20, 2006	7.33	4.6	2.4
Jan. 30, 2006	7.16	4.7	Unknown
Nov. 10, 2006	7.11	Unknown	No water over this sensor
Nov. 21, 2006	7.01	Unknown	No water over this sensor
Nov. 22, 2006	7.19	Unknown	No water over this sensor
Nov. 23, 2006	7.16	Unknown	No water over this sensor
Dec. 14, 2006	7.19	Unknown	No water over this sensor
Dec. 26, 2006	7.39	Unknown	1.7

*maximum recorded in a given season

4.0 BIOENGINEERING PERFORMANCE

The performance of the bioengineering features was good at each of the sites in that no bank erosion was observed during the four years of monitoring. While quantitative measurements are not available, photos taken of the sites over the duration of the monitoring project confirmed what seems evident to casual observation. The lack of changes occurring during monitoring can be given context by comparing this four year period with the changes occurring during historic times. To this end, maps and air photos of the sites from the 1850's, 1936, the 1960's or 1970's, 1995, and 2005 were collected for comparison.

This section presents the historic changes and changes during the monitoring period for each site. A suite of five maps is presented. The maps are at a common scale. A common reference frame is superimposed around each stream. Each set of five maps is followed by a map combining the trace of the apparent stream thalwag for each of the time periods. A discussion of changes observed at each site during the four-year monitoring period then follows. Photographs of the changes are also presented where they are judged to be informative.

4.1 WEST FORK DAIRY CREEK SITE

4.1.1 Historic Changes

The historic record for the West Fork Dairy Creek site begins with a General Land Office Survey Map from 1856. Figure 4.1 shows this map, which depicts West Fork Dairy Creek in largely the same position as it is today; but the map depicts the stream channel being much straighter than in any of the subsequent maps or images. While the map matches surrounding landforms fairly well, the primary purpose of this map was to establish the public land survey system for Oregon and property boundaries. It should be considered likely that the stream was actually just as sinuous in 1856 as it is now, and that the map makers simply drew a wavy straight line down the middle of a broad riparian zone.

Figure 4.2 shows the next information from an aerial photo taken in 1936. This image shows that by 1936 the level ground surrounding the stream is under cultivation, leaving only a narrow strip of trees along the banks of the stream. Near the bioengineering site there is also a small but steep hillside that is still forested. Immediately downstream of the bioengineering site there is a strip of cultivated land between the hillside and the stream. The most straightforward interpretation of the stream's location in this image would put it to the northeast of the current highway. The main roadway at this time is about ½ mile northeast of the current highway's location.

Figure 4.3 shows the USGS 7.5 minute topographic quadrangle map of the area. This map is dated 1979, while the aerial photographs used for its compilation were taken in 1973. The map shows the current highway with West Fork Dairy Creek to the southwest of the highway and a tributary creek to the northeast. The previously cultivated strip between the stream and the steep slope is depicted as being forested on this map.

Figure 4.4 shows the 1995 aerial image with features that are consistent with the map from 1979. The 2005 aerial image (Figure 4.5) does not show any change from 1995. It is important to note that the 1979 topographic map erroneously interpreted the trees on the northeast side of the road as being a creek that crosses under the highway to the southeast of the bioengineering site. In fact the creek has crossed under the highway to the northwest of the site since the highway was built. The trees are just a remnant of the riparian zone of the stream from before the current highway was built.

Summarizing the historic record, the only observable change that has occurred with respect to West Fork Dairy Creek is the construction of the highway. Figure 4.6 shows that when the highway was built the creek was forced to the southwest of the highway. This was likely done to maintain the long straight alignment of the roadway while eliminating the need for two bridges or large culverts.

The bioengineering site is located immediately downstream of where the tributary creek joins West Fork Dairy Creek via a culvert and at the beginning of the stream reach that was relocated and constrained by the highway. This portion of the highway was built sometime between 1939 and 1949 (when the entire Sunset Highway was complete). Erosion at the site did not become a concern until the 21st century; thus the stream took over six decades to migrate enough to affect the highway. In the late 1960's the previously 28-foot wide highway was widened by 9 feet in the direction of West Fork Dairy Creek.

The current southwest bank of West Fork Dairy Creek at the site is formed by the beginning of a steep hillside that is forested with mature trees. That bank was never significantly farther from the centerline of the highway than it is today. In all likelihood the stream has only migrated, at the most, a distance equivalent to the width of the small islet and its side channel shown in the photos of the site in Section 4.1.2. This is currently a distance of approximately a dozen feet.

Figure 4.6 shows a map combining the trace of the apparent stream thalweg for each of the time periods.

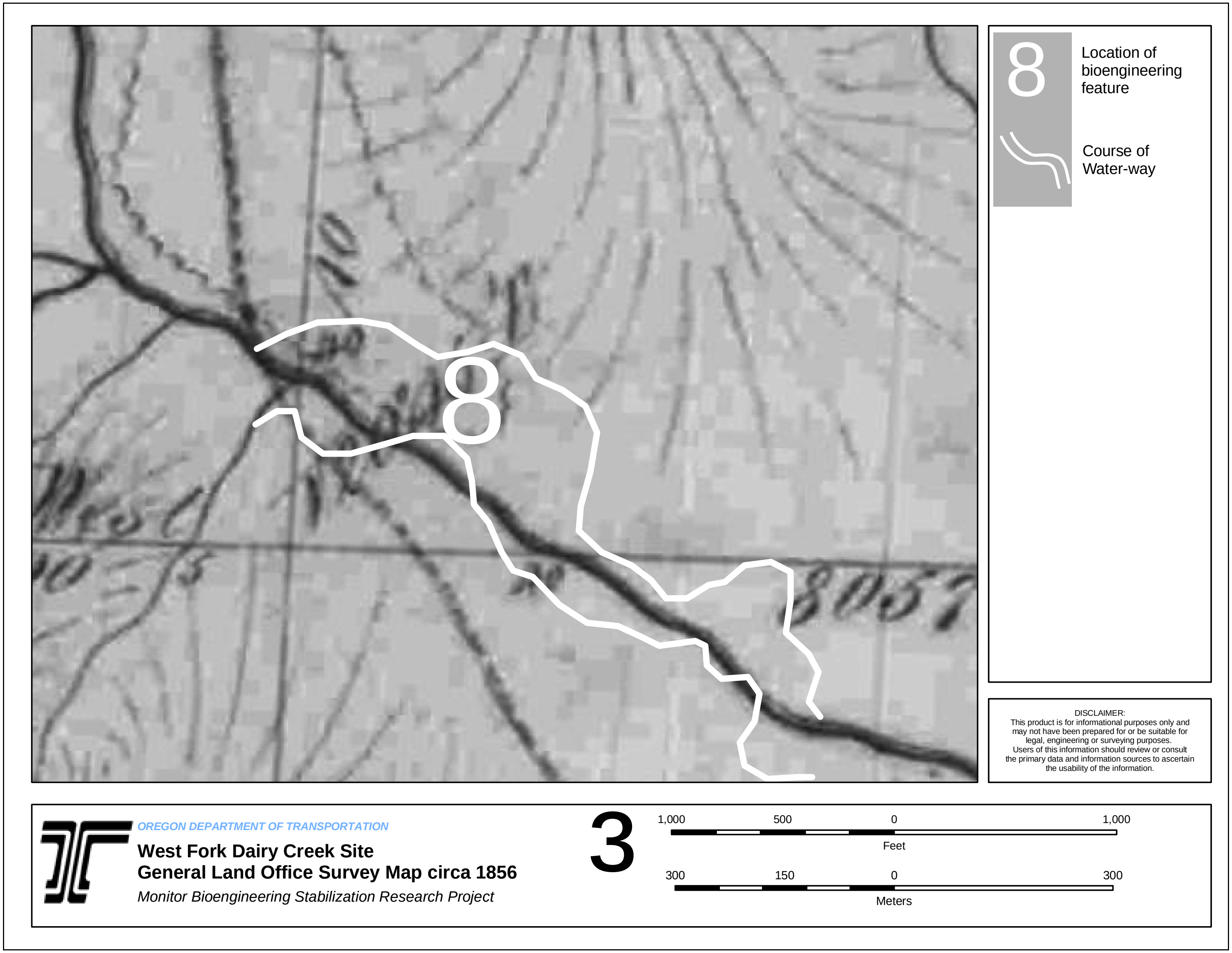

Figure 4.1: Map of the West Fork Dairy Creek bioengineering site as depicted on a General Land Office Survey Map dated 1856

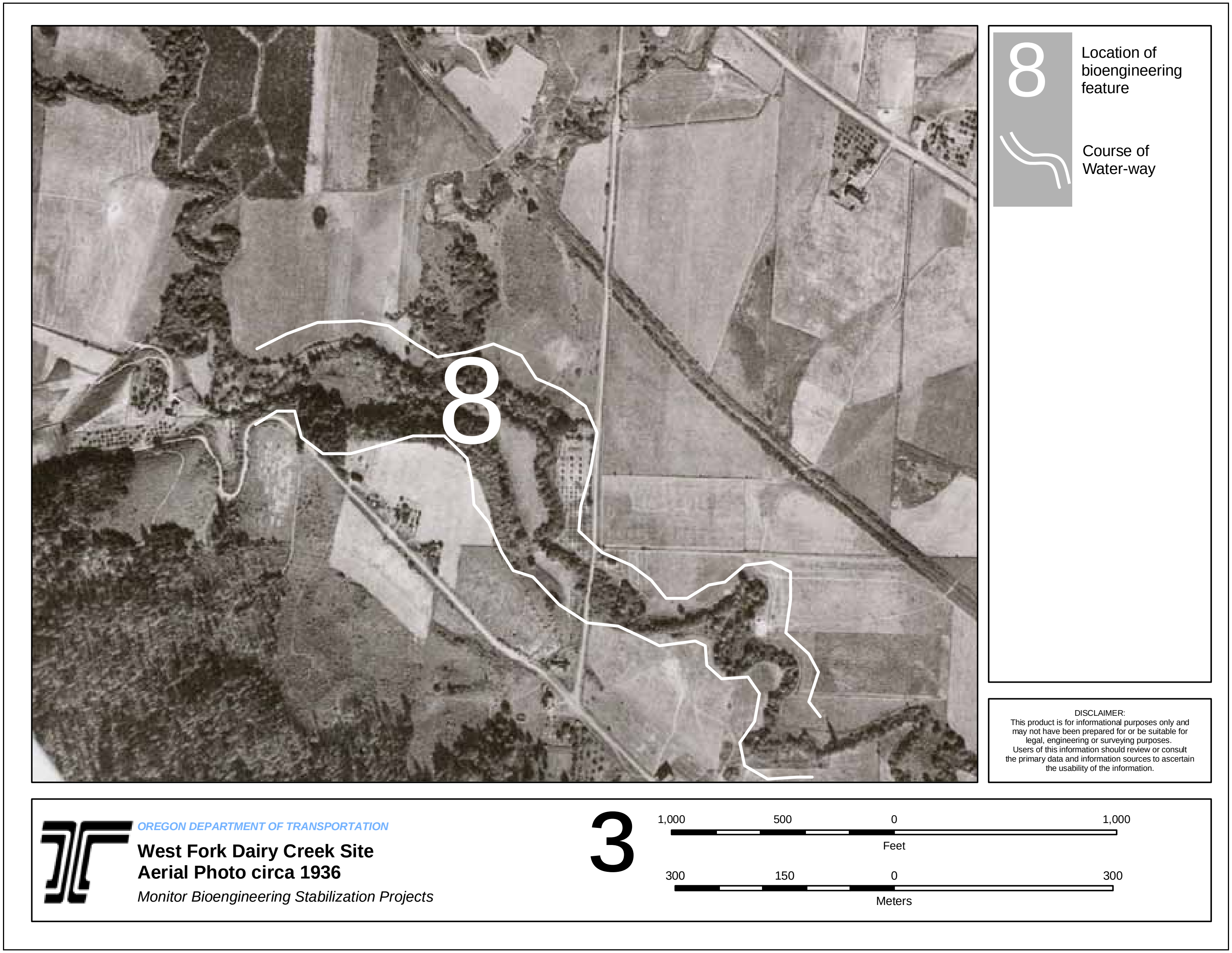

Figure 4.2: Map of the West Fork Dairy Creek bioengineering site as depicted in an aerial photograph dated 1936

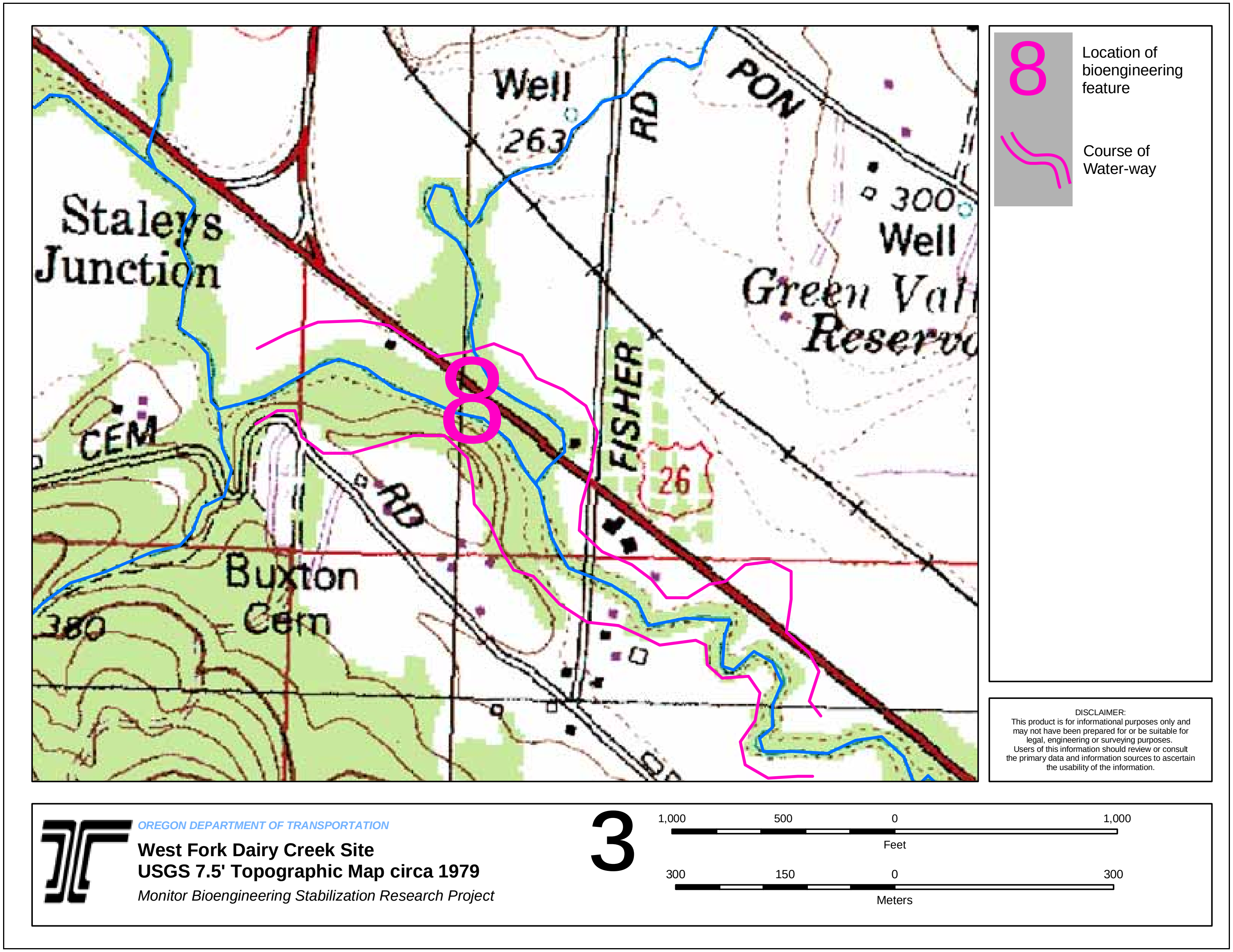

Figure 4.3: Map of the West Fork Dairy Creek bioengineering site as depicted on a U.S. Geological Survey 7.5’ topographic map (Buxton Quadrangle) dated 1979

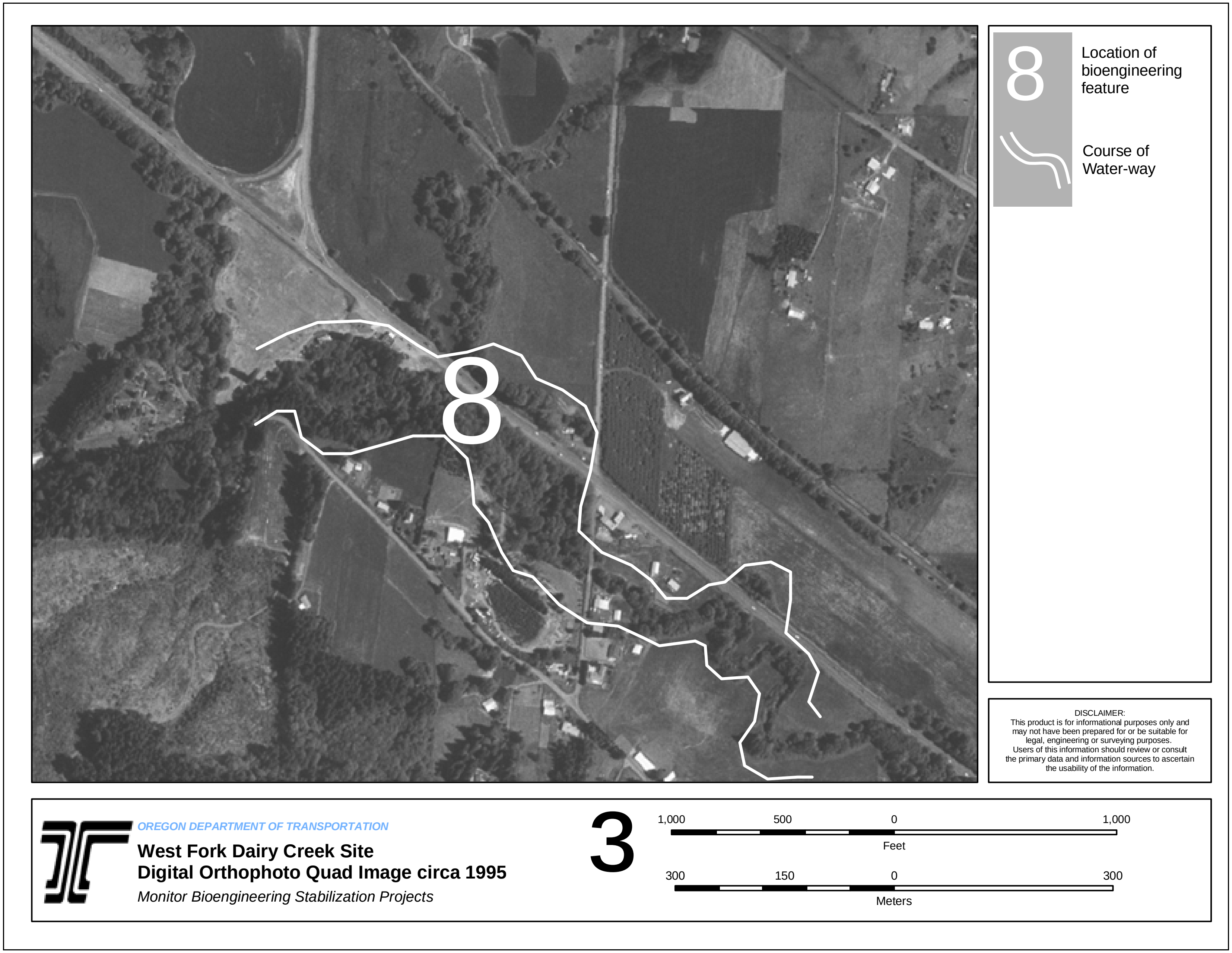

Figure 4.4: Map of the West Fork Dairy Creek bioengineering site as depicted on a digital-orthophoto dated 1995

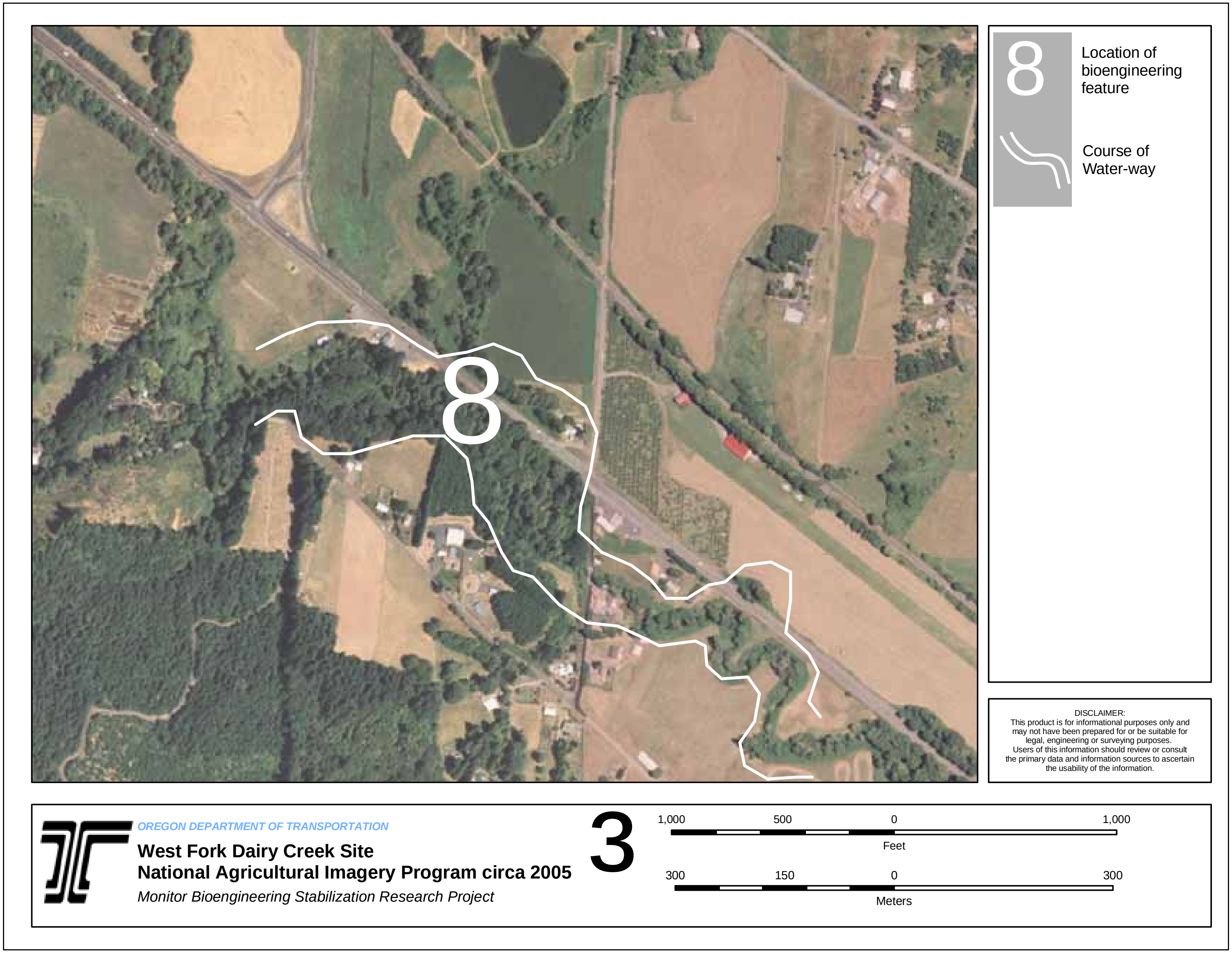

Figure 4.5: Map of the West Fork Dairy Creek bioengineering site as depicted in a National Agricultural Imagery Program image dated 2005

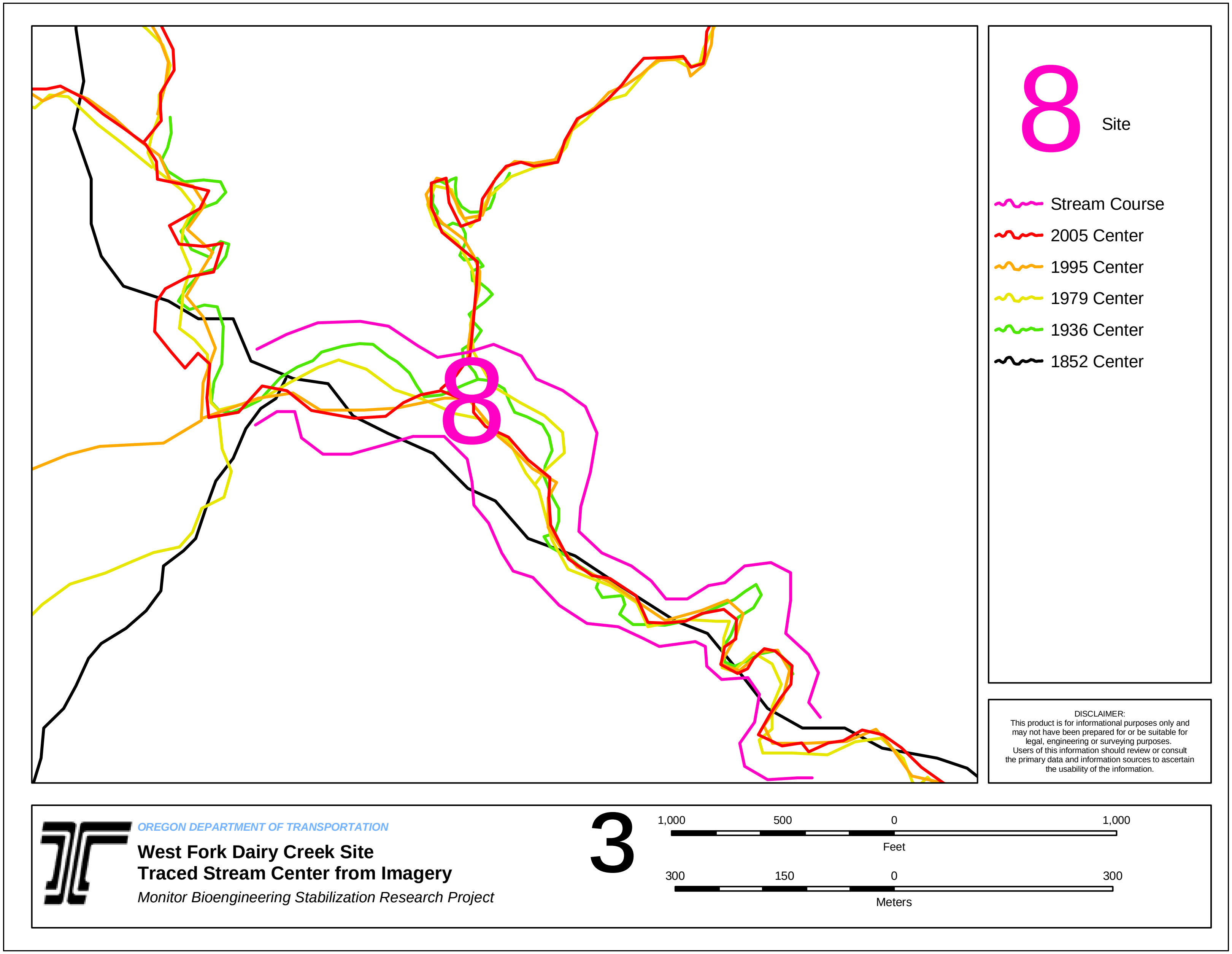

Figure 4.6: Map of the West Fork Dairy Creek bioengineering site with the interpreted center of the stream channel as depicted on maps and imagery over historic times

4.1.2 Changes during monitoring

The positions of the stream bank did not change noticeably during monitoring, as shown in Figures 4.7 through 4.17. The most noticeable differences over time were the seasonal changes in vegetation and the slow succession of vegetation over the years following construction.

The large rip-rap at the base of the slope has remained in place, and the size and form of the small islet in the stream was surprisingly consistent. The vegetation on the bioengineered slope quickly recovered following flood flows.

The fabric and anchors are now completely and continuously covered in vegetation. In Figure 4.8 woody plantings placed in the slope can be seen marked with orange flagging. It does not appear that any of these actually established themselves, but in Figures 4.11, 4.15, and 4.17 it can be seen that Oregon Grape and some sort of Maple tree (Bigleaf?) established themselves high on the slope.

Figure 4.7: Photograph taken May 2003 showing the West Fork Dairy Creek site, looking downstream

Figure 4.8: Photograph taken December 2003 showing the West Fork Dairy Creek site, looking downstream

Figure 4.9: Photograph taken July 2005 showing the West Fork Dairy Creek site, looking downstream

Figure 4.10: Photograph taken September 2006 showing the West Fork Dairy Creek site, looking downstream

Figure 4.11: Photograph taken November 2006 showing the West Fork Dairy Creek site, looking downstream

Figure 4.12: Photograph taken May 2003 showing the West Fork Dairy Creek site, looking upstream

Figure 4.13: Photograph taken December 2003 showing the West Fork Dairy Creek site, looking upstream

Figure 4.14: Photograph taken July 2005 showing the West Fork Dairy Creek site, looking upstream

Figure 4.15: Photograph taken January 2006 showing the West Fork Dairy Creek site, looking upstream


Figure 4.16: Photograph taken September 2006 showing the West Fork Dairy Creek site, looking upstream


Figure 4.17: Photograph taken November 2006 showing the West Fork Dairy Creek site, looking upstream

4.2 JOHNSON CREEK SITE

4.2.1 Historic Changes

The historic record for the Johnson Creek site begins with a General Land Office Survey Map from 1852 (Figure 4.18). On this map it can be seen that the bioengineering site is located in what at that time was a lake surrounded by a wetlands area. All of the features of the 1852 map are very consistent with subsequent maps/images. It would appear that the area around the site had an extremely low natural gradient.

Figure 4.19 shows that in 1936 there was no longer any evidence of the lake. The wetlands appear to be dry as well. The stream channel has established itself in broad loops across the former location of the lake and wetlands. All the subsequent maps/images (Figures 4.20, 4.21, and 4.22) show the channel of Johnson Creek in essentially the same location. The changes made to its location for the construction of the new interchange do not appear to have significantly altered the stream from the course it established following whatever changes eliminated the lake and wetlands (Figure 4.23).

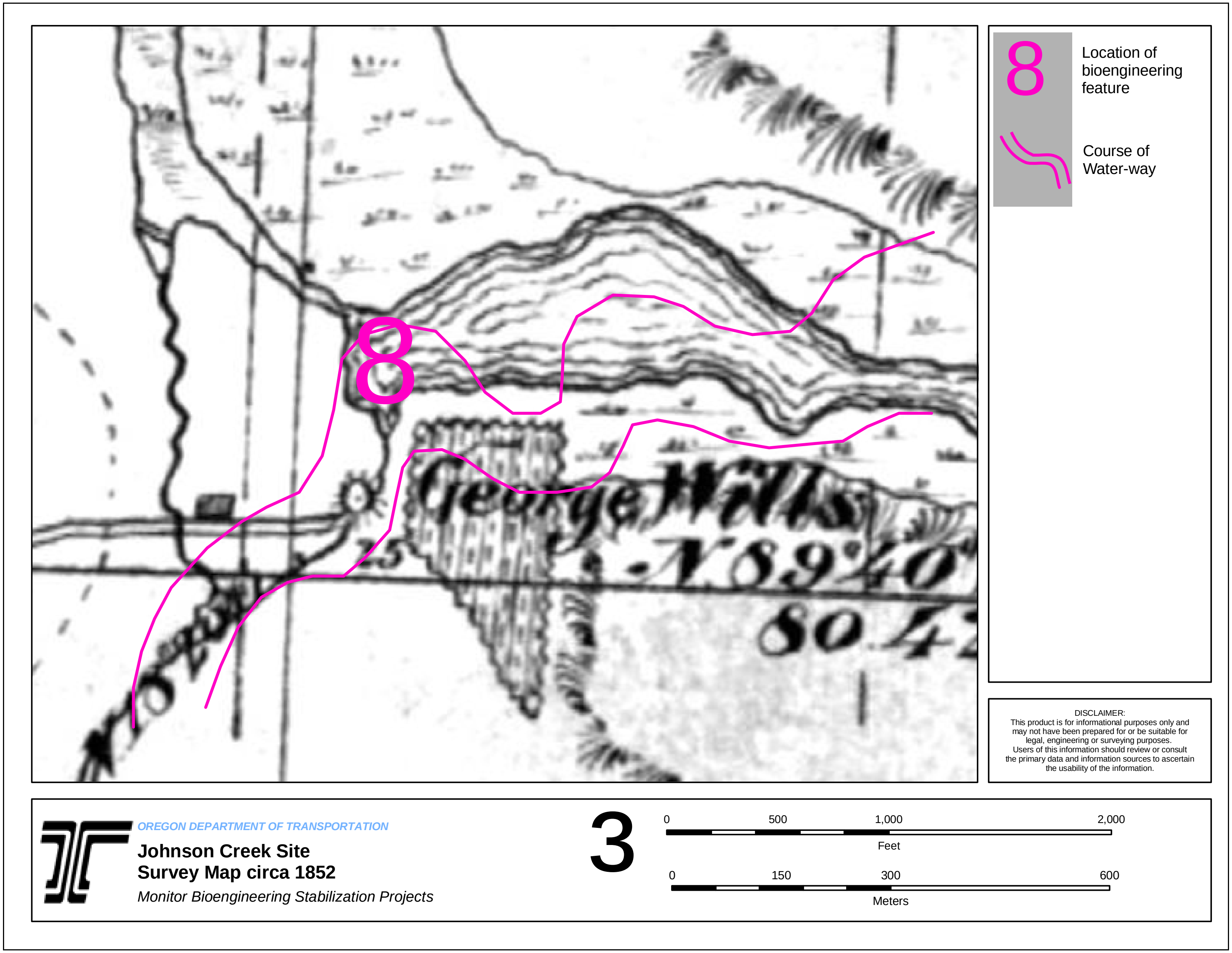

Figure 4.18: Map of the Johnson Creek bioengineering site as depicted on a General Land Office Survey Map dated 1852

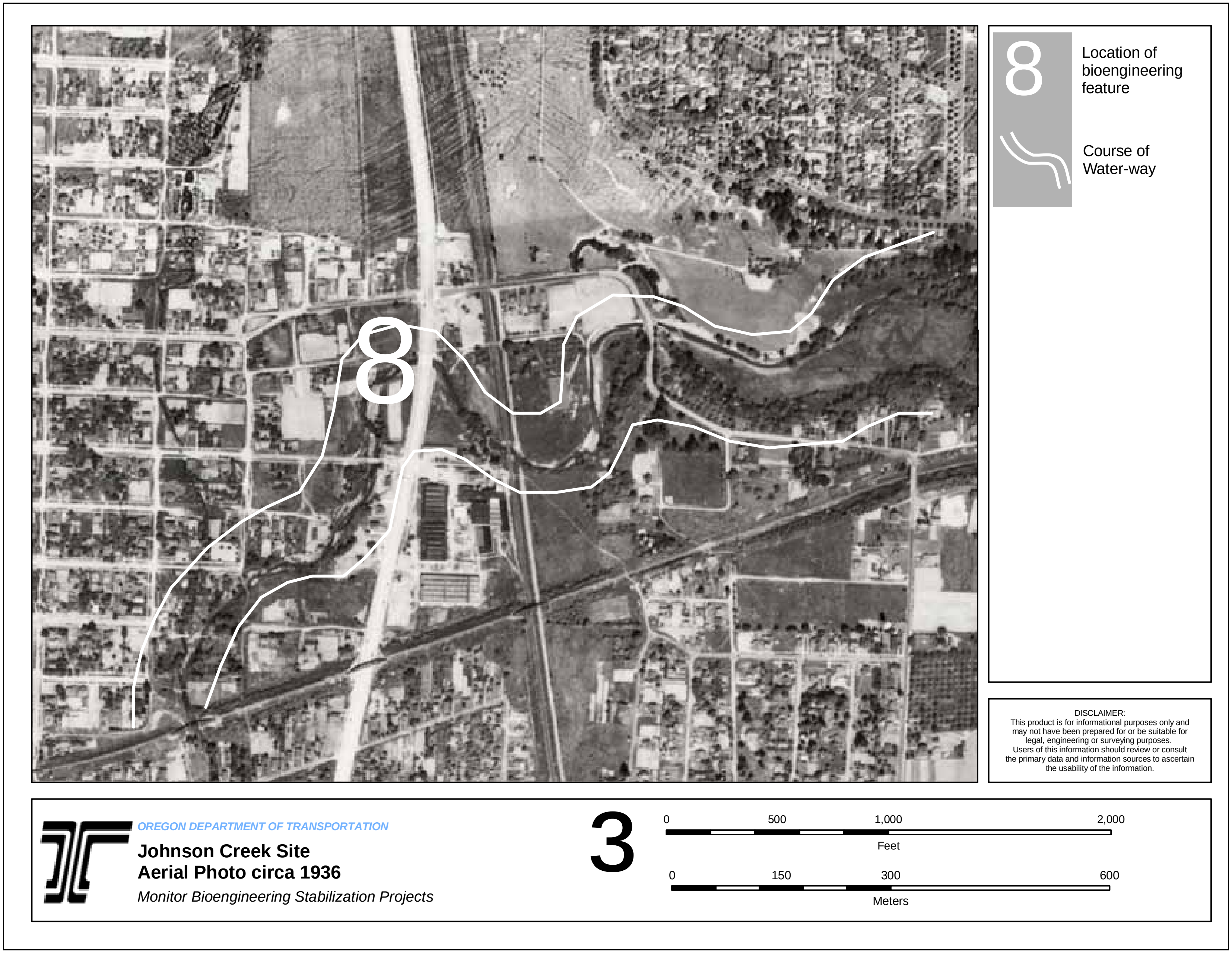

Figure 4.19: Map of the Johnson Creek bioengineering site as depicted in an aerial photograph dated 1936

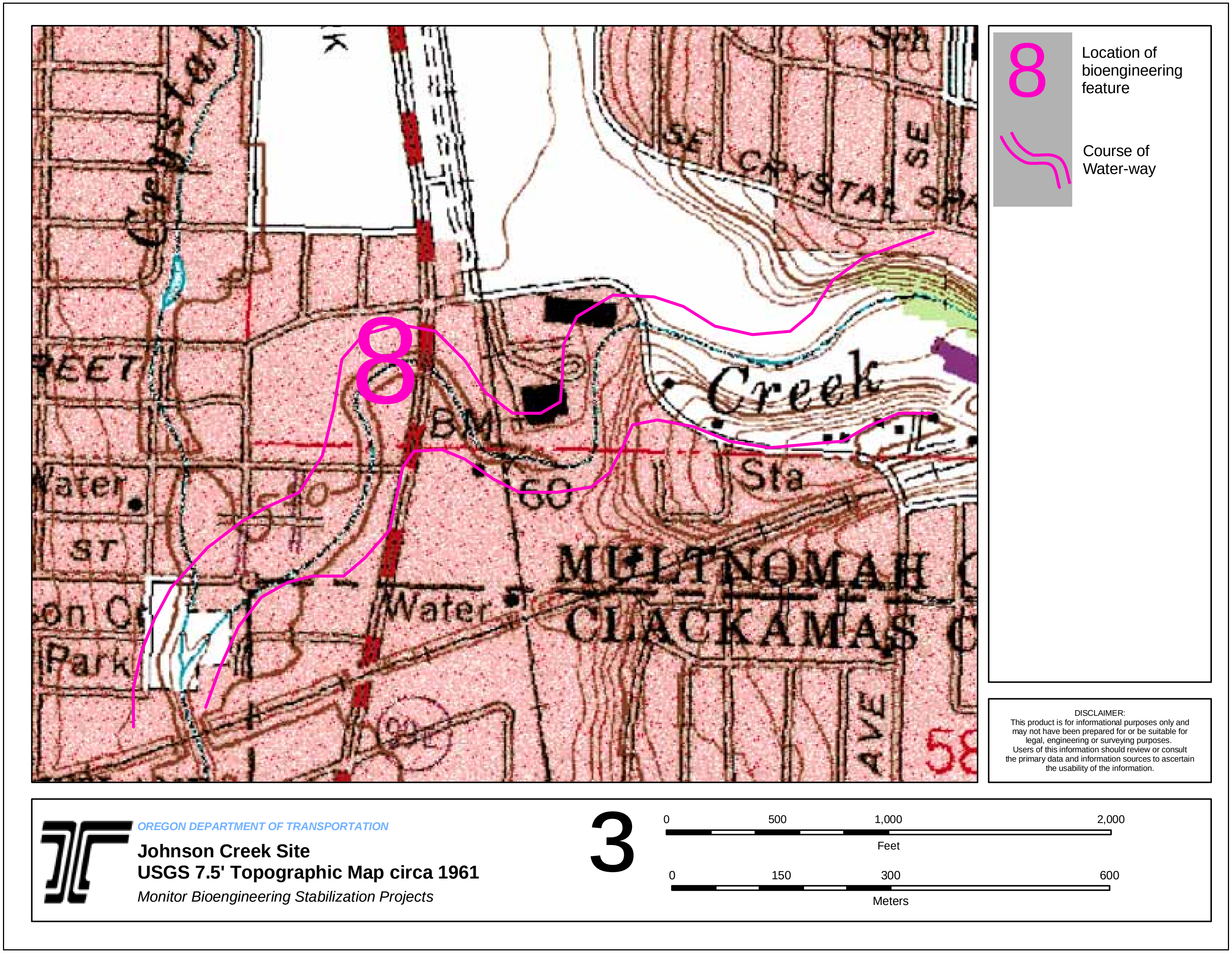

Figure 4.20: Map of the Johnson Creek bioengineering site as depicted on a USGS 7.5’ topographic map (Lake Oswego Quadrangle) dated 1961

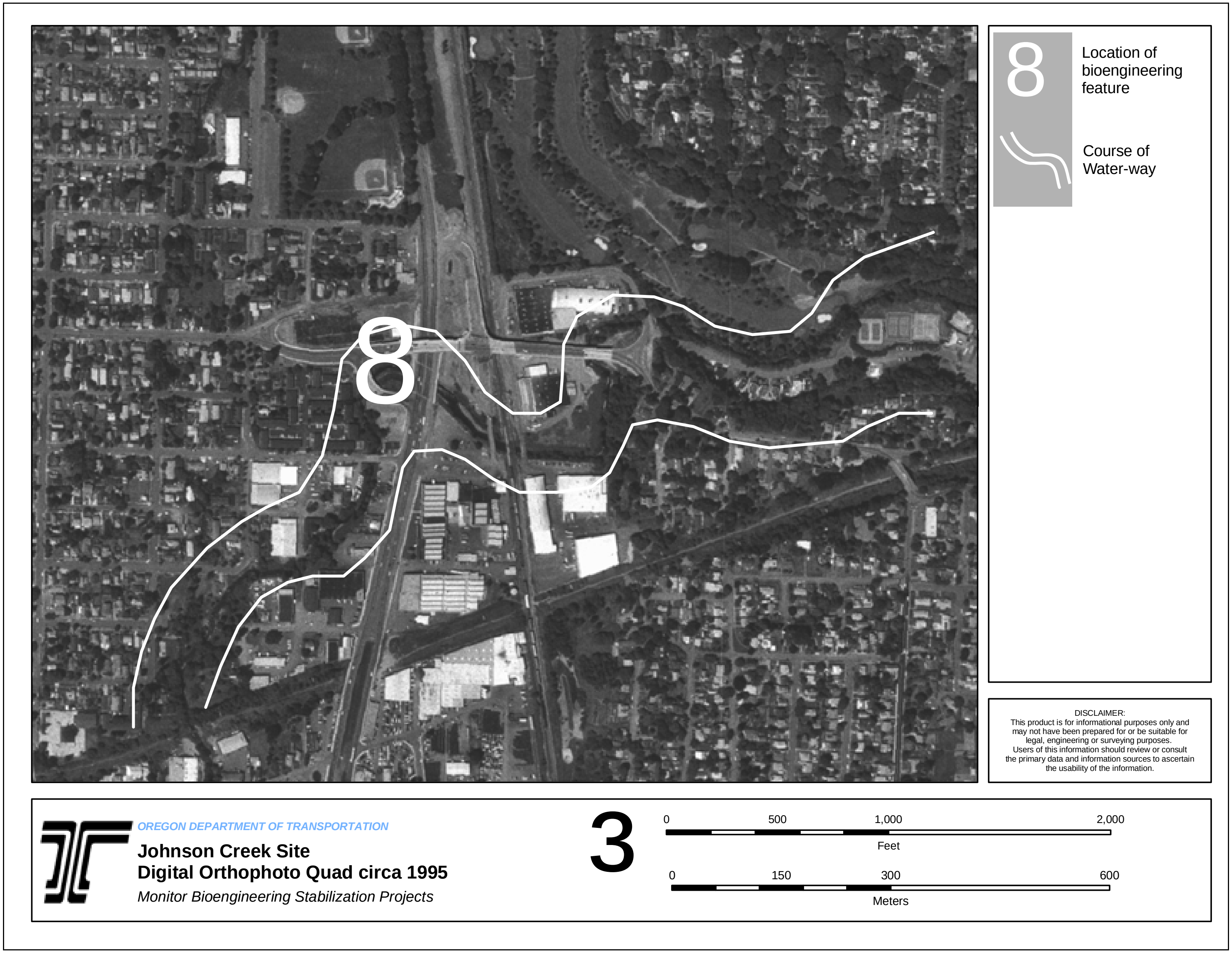

Figure 4.21: Map of the Johnson Creek bioengineering site as depicted in a digital orthophoto dated 1995

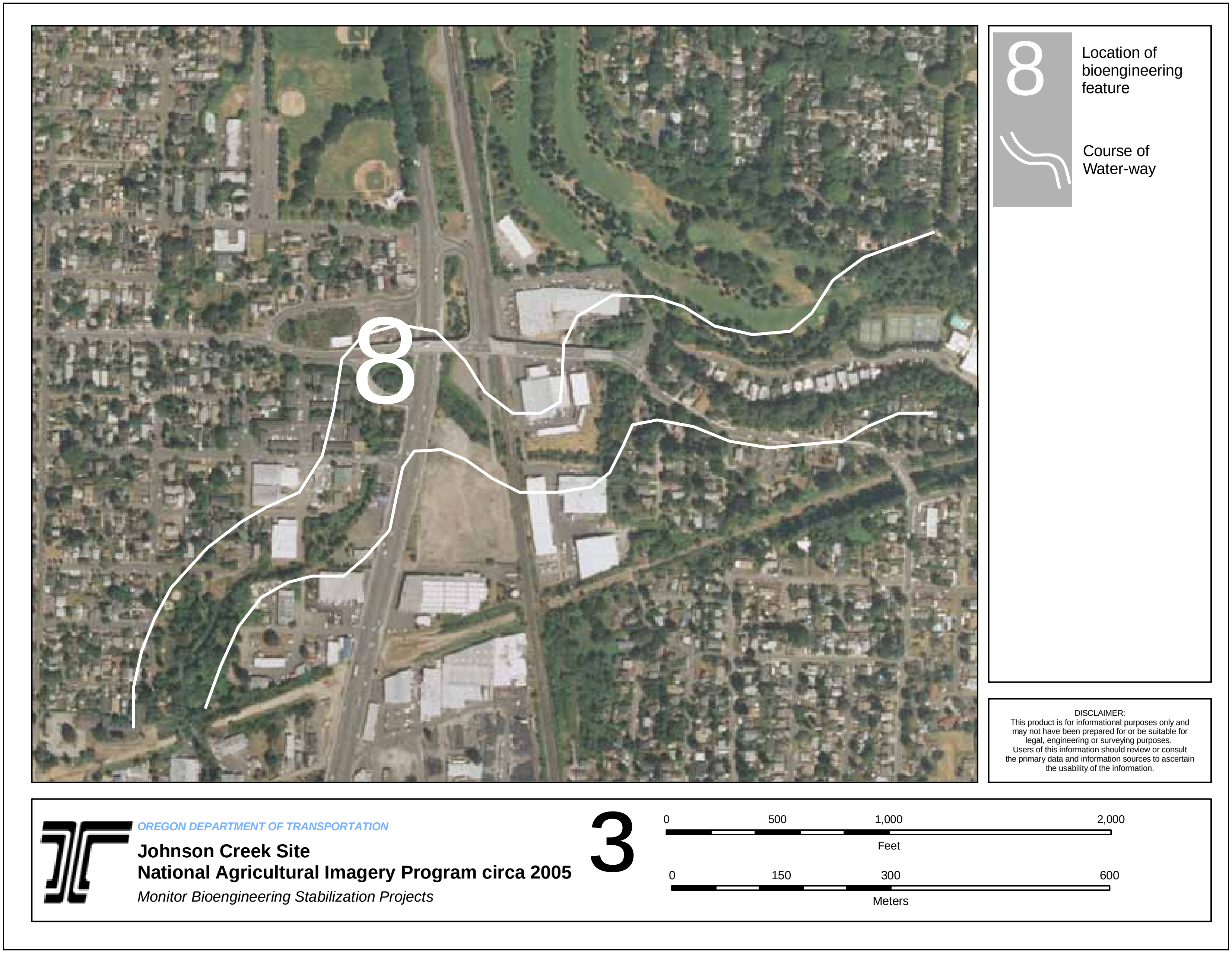

Figure 4.22: Map of the Johnson Creek bioengineering site as depicted in a National Agricultural Imagery Program image dated 2005

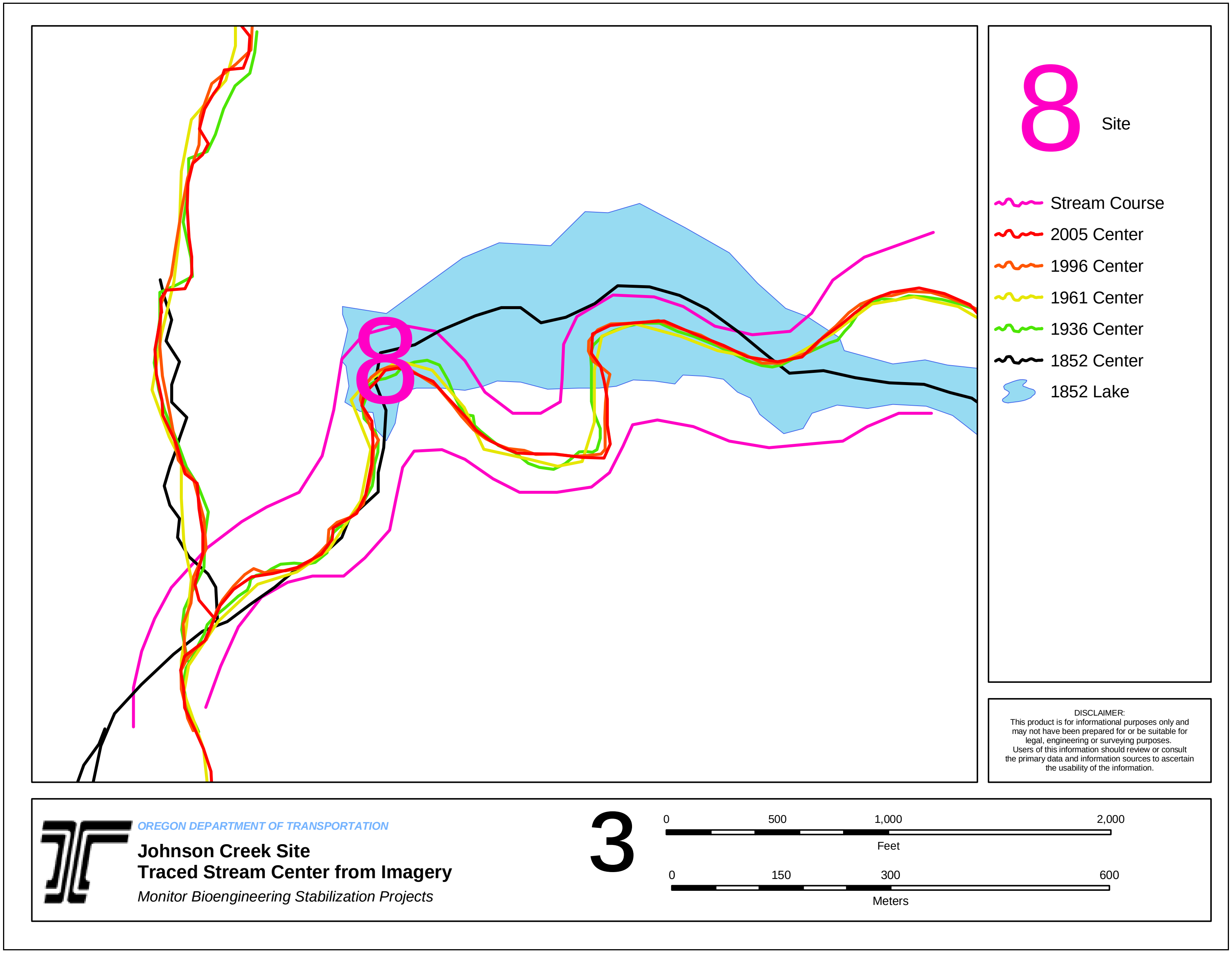

Figure 4.23: Map of the Johnson Creek bioengineering site with the interpreted center of the stream channel as depicted on maps and imagery over historic times

4.2.2 Changes during monitoring

The construction of the bioengineering features was better documented at this site than at the other sites, and this is also true of the monitoring. The bioengineering site was monitored as part of the original construction (*Sotir 2009*). Because of this earlier monitoring, photographs are available for a period spanning 10 years (Figures 4.24 through 4.31).

Initially the willows planted on both the point bar and the bioengineered cut bank flourished. On the point bar they have continued to do so up to the present. On the cut bank, however, most of the willows were eventually overrun by blackberry bushes. This kept the site looking green and verdant during the growing season, but blackberries are not the vegetation that is desired at the site. In 2006 the site was mowed essentially to ground level, leaving only the few large trees at the site (see Figures 4.26, 4.27, 4.29, 4.30, and 4.31).

At the beginning of this monitoring project in 2003 it was noted that much of the row of rip-rap installed in the stream at the base of the cut bank had been plucked away. This allowed the stream to undermine the geogrid-encased gravel by as much as three feet. Over the course of the monitoring project it appears that no additional rip-rap has been lost. The geogrid-encased gravel continues to be stable, and the stream has not encroached on the interchange retaining wall at all.

Figure 4.24: Photograph taken late summer/early fall 1997 showing the Johnson Creek site, looking downstream

Figure 4.25: Photograph taken July 2005 showing the Johnson Creek site, looking downstream

Figure 4.26: Photograph taken September 2006 showing the Johnson Creek site, looking downstream

Figure 4.27: Photograph taken November 2006 showing the Johnson Creek site, looking downstream

Figure 4.28: Photograph taken July 2005 showing the Johnson Creek site, looking downstream from the overpass

Figure 4.29: Photograph taken January 2006 showing the Johnson Creek site, looking downstream from the overpass

Figure 4.30: Photograph taken September 2006 showing the Johnson Creek site, looking downstream from the overpass

Figure 4.31: Photograph taken November 2006 showing the Johnson Creek site, looking downstream from the overpass

4.3 SHELTON DITCH SITE

4.3.1 Historic Changes

The historic record for the Shelton Ditch site begins with a General Land Office Survey Map from 1852 (Figure 4.32). This map shows that what is now called a ditch likely began as a small natural tributary to Pringle Creek that was extended and connected to a diversion ditch from Mill Creek. The ditch was completed in the mid-19th century; thus Shelton Ditch has been largely an artificial stream for most of the historic era (*Lutz 2009*).

Figure 4.33 shows that in 1936 Shelton Ditch was a broad, sinuous stream with a fair degree of complexity in the vicinity of the bioengineering site. The encroachment of urbanization is evident, even though there is still a buffer of open space along most of the stream's length. The stream banks are largely free of trees and to a degree that is notably different from nearby Pringle Creek.

By the time of the topographic map of 1969 (Figure 4.34) the city has surrounded Shelton Ditch with the exception of Pringle Park. The stream has been straightened and is obviously much more constrained by adjacent development.

The images from 1995 (Figure 4.35) and 2005 (Figure 4.36) show that, while the stream is still straight and held to a restrictive channel, there are trees growing along and shading almost the entire length of the stream. The ironic exception to the current riparian shading is the bank of the stream within Pringle Park. Figure 4.37 shows that the location of Shelton Ditch has not changed much since the ditch was built.

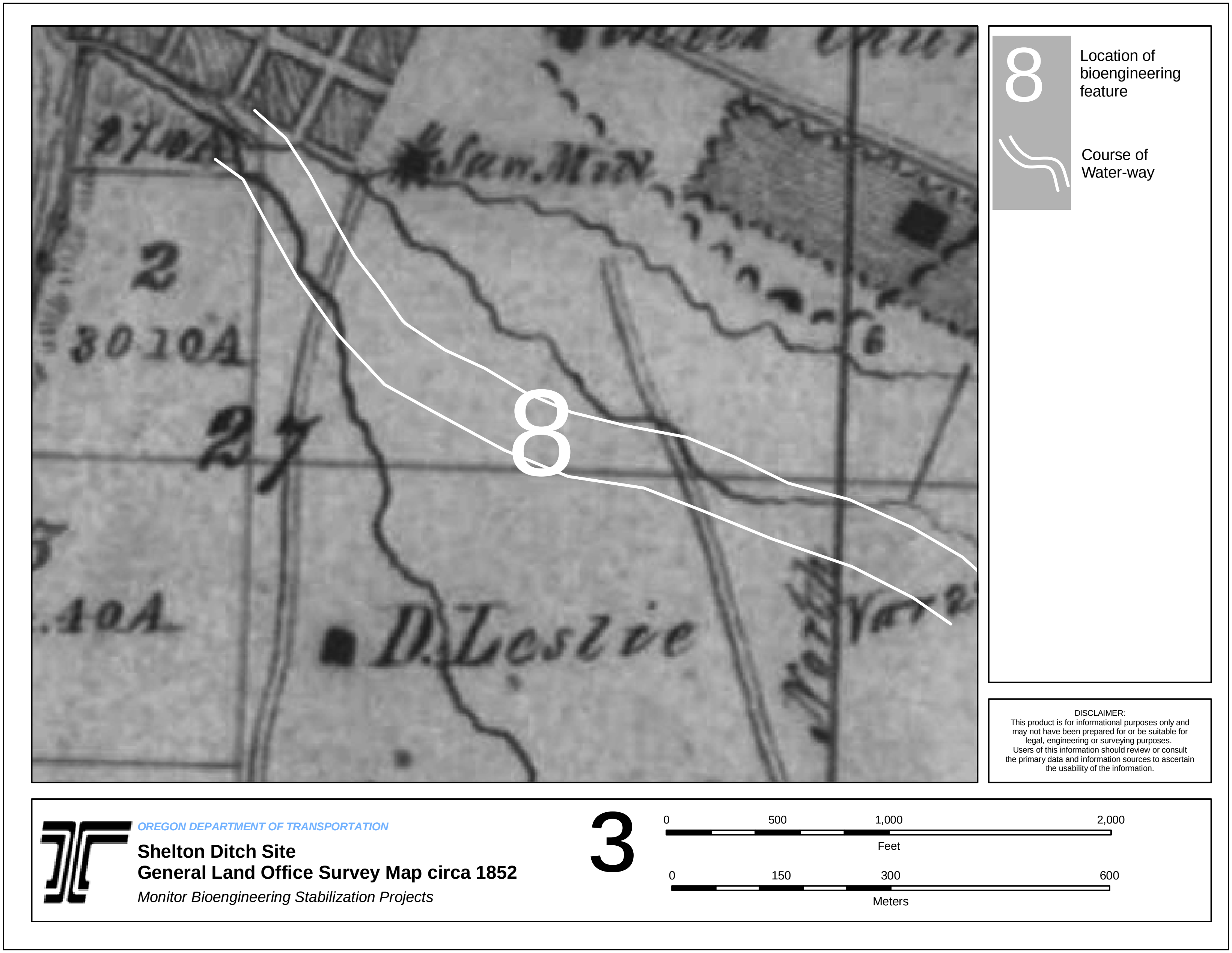

Figure 4.32: Map of the Shelton Ditch bioengineering site as depicted on a General Land Office Survey Map dated 1852

Figure 4.33: Map of the Shelton Ditch bioengineering site as depicted in an aerial photograph dated 1936

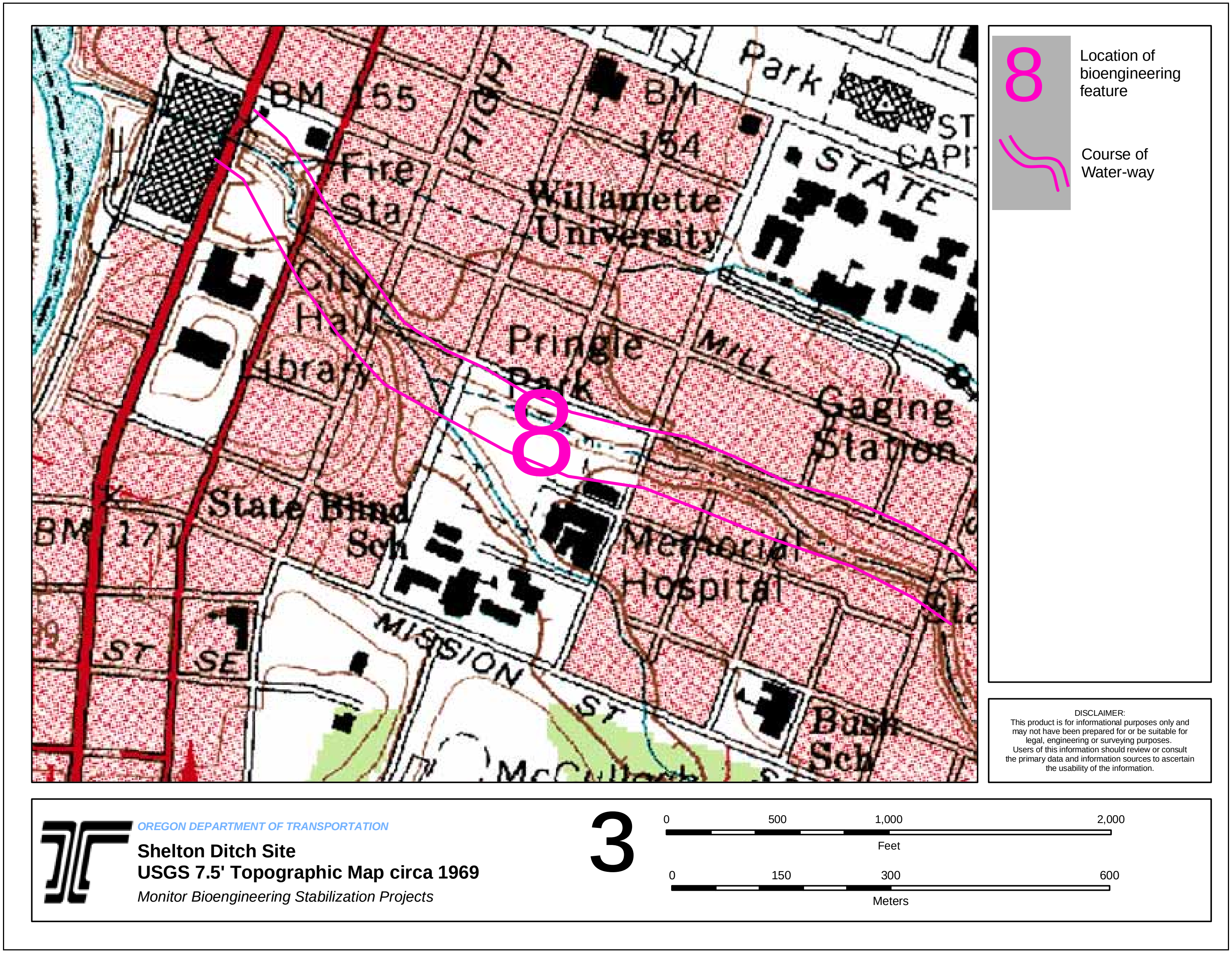

Figure 4.34: Map of the Shelton Ditch bioengineering site as depicted on a USGS 7.5' topographic map (Salem West Quadrangle) dated 1969

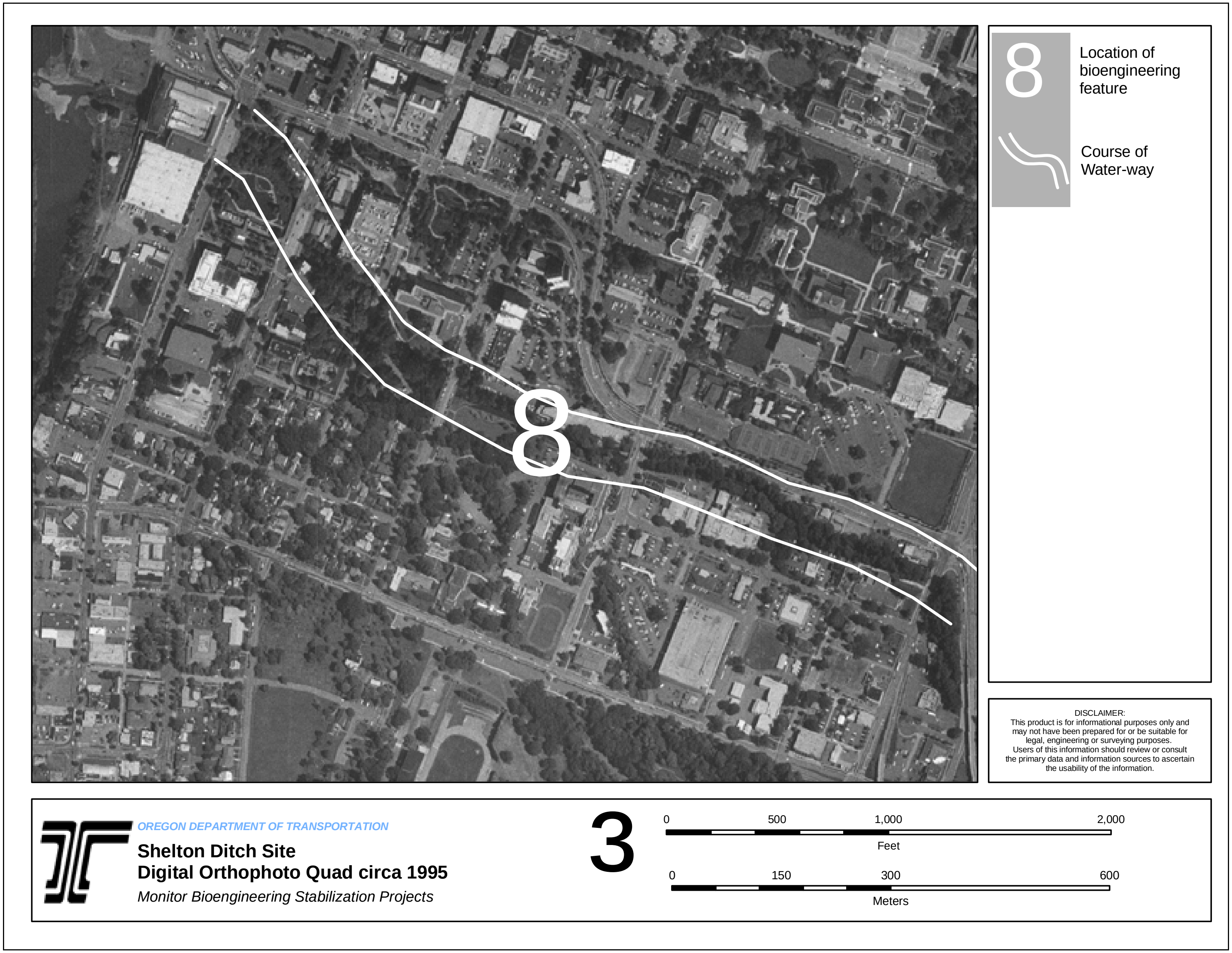

Figure 4.35: Map of the Shelton Ditch bioengineering site as depicted in a digital orthophoto dated 1995

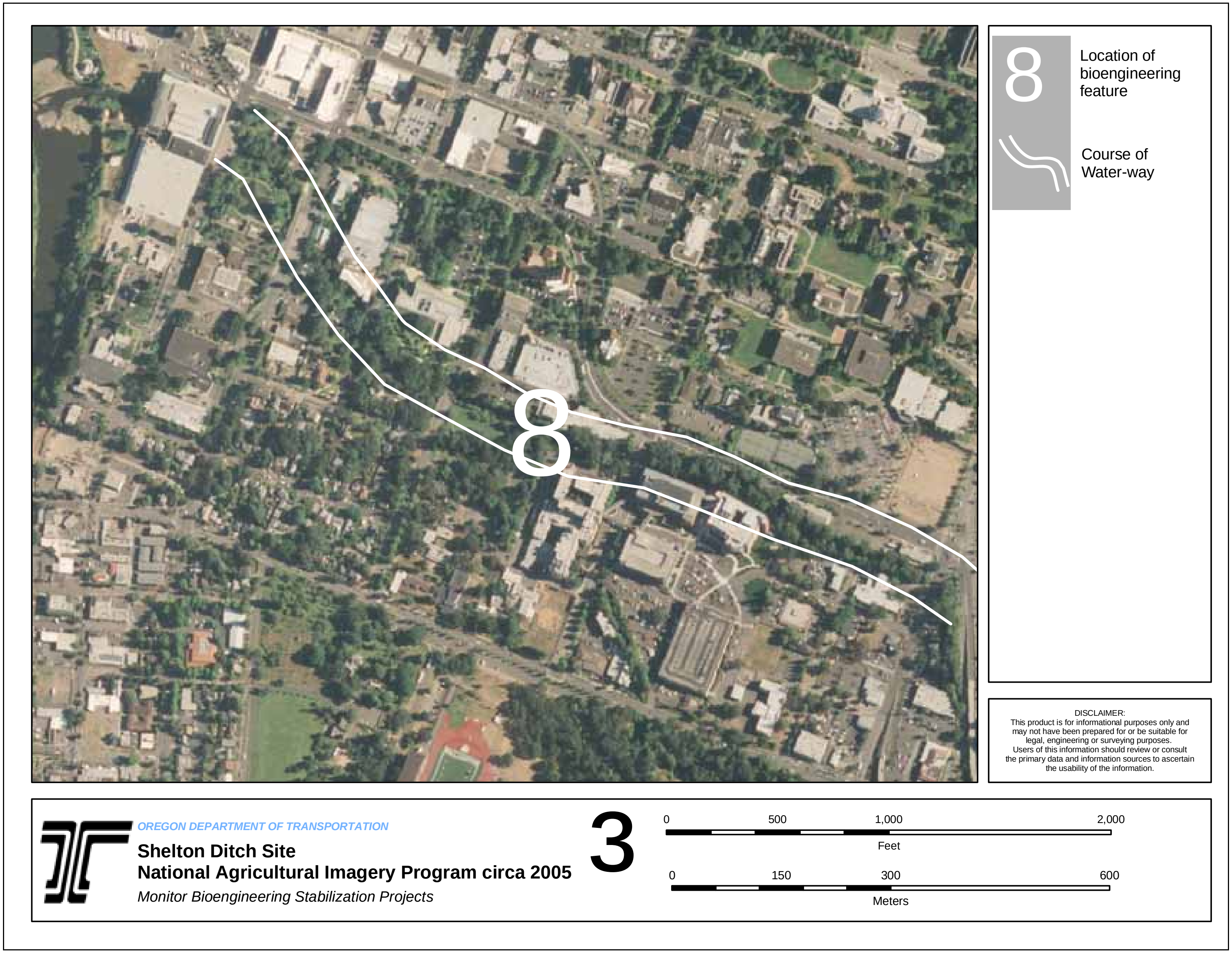

Figure 4.36: Map of the Shelton Ditch bioengineering site as depicted in a National Agricultural Imagery Program image dated 2005

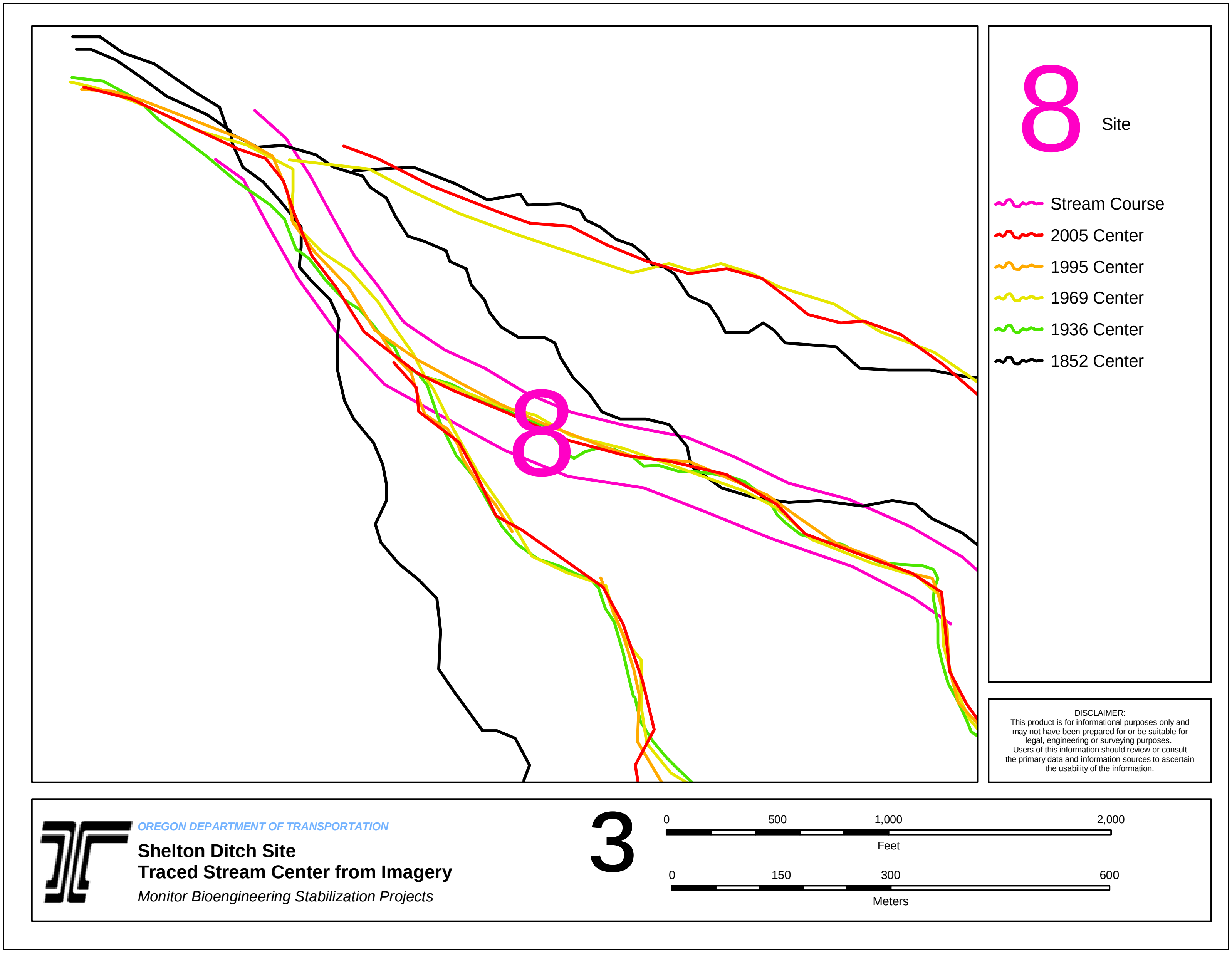

Figure 4.37: Map of the Shelton Ditch bioengineering site with the interpreted center of the stream channel as depicted on maps and imagery over historic times

4.3.2 Changes during monitoring

No changes were observed at this site, even though the monitoring period included peak flows with stages high enough to reach the sidewalk on the northern bank of the stream.

4.4 PRINGLE CREEK SITE

4.4.1 Historic Changes

The historic record for the Pringle Creek site ostensibly begins with a General Land Office Survey Map from 1852 (Figure 4.38). Unfortunately this map shows the creek flowing up over a hill in a very different position from the current stream. For reasons that are unknown, the 19th century map of this area bears little resemblance to the actual physical features present at the site.

The Fairview Training Center (originally called Oregon State Institute for the Feeble Minded) was opened in 1908 (*Bell 2009*). By the time the first aerial photographs were taken of this area in 1936 (Figure 4.39), the area around the stream was being intensively cultivated. The cultivation seems to have stopped at the edge of the flood plain of Pringle Creek, and a flourishing riparian zone with a gently meandering stream is preserved through the fields. At the east end of the area a forested, park-like area makes up the south bank of the stream. On the east side of the Fairview Training Center the stream is channelized into a straight northern course.

In 1965 the Fairview Training Center built a fishing pond at the site (*White 2009*) as shown on the topographic map of 1969 (Figure 4.40). The pond was removed after safety issues arose in 1972. While the pond was in place, the outlet of the pond diverted the stream to the north of its 1936 course.

The aerial image from 1995 (Figure 4.41) shows the pond gone and the stream returned to its previous course. The location of the pond and the diversion channel are still quite evident in this image.

The 2005 color aerial photograph (Figure 4.42) shows willows beginning to reestablish themselves along the stream where the pond had disrupted the riparian vegetation. Figure 4.43 shows that the significant change to Pringle Creek over history was the construction and removal of the fishing pond.

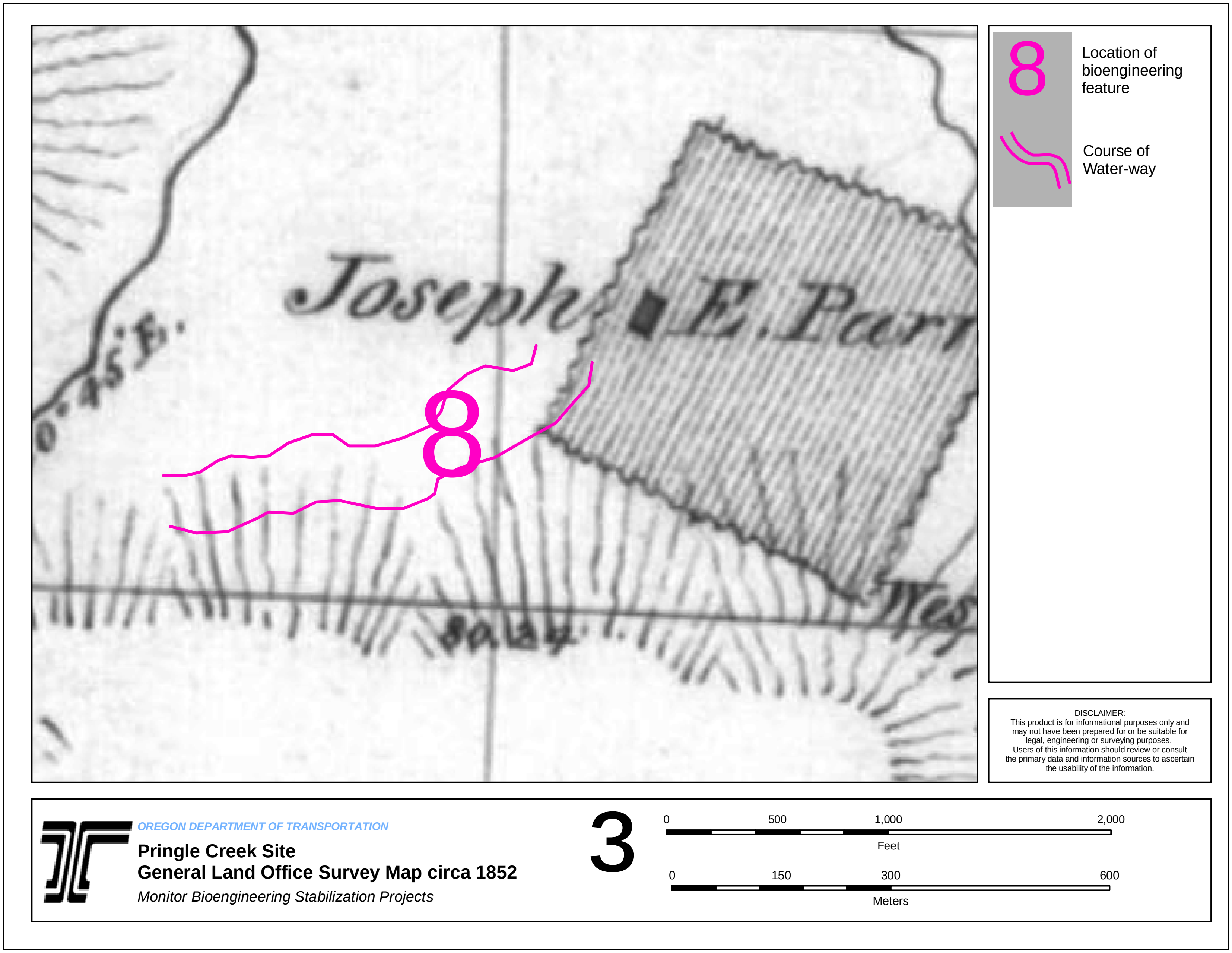

Figure 4.38: Map of the Pringle Creek bioengineering site as depicted on a General Land Office Survey Map dated 1852

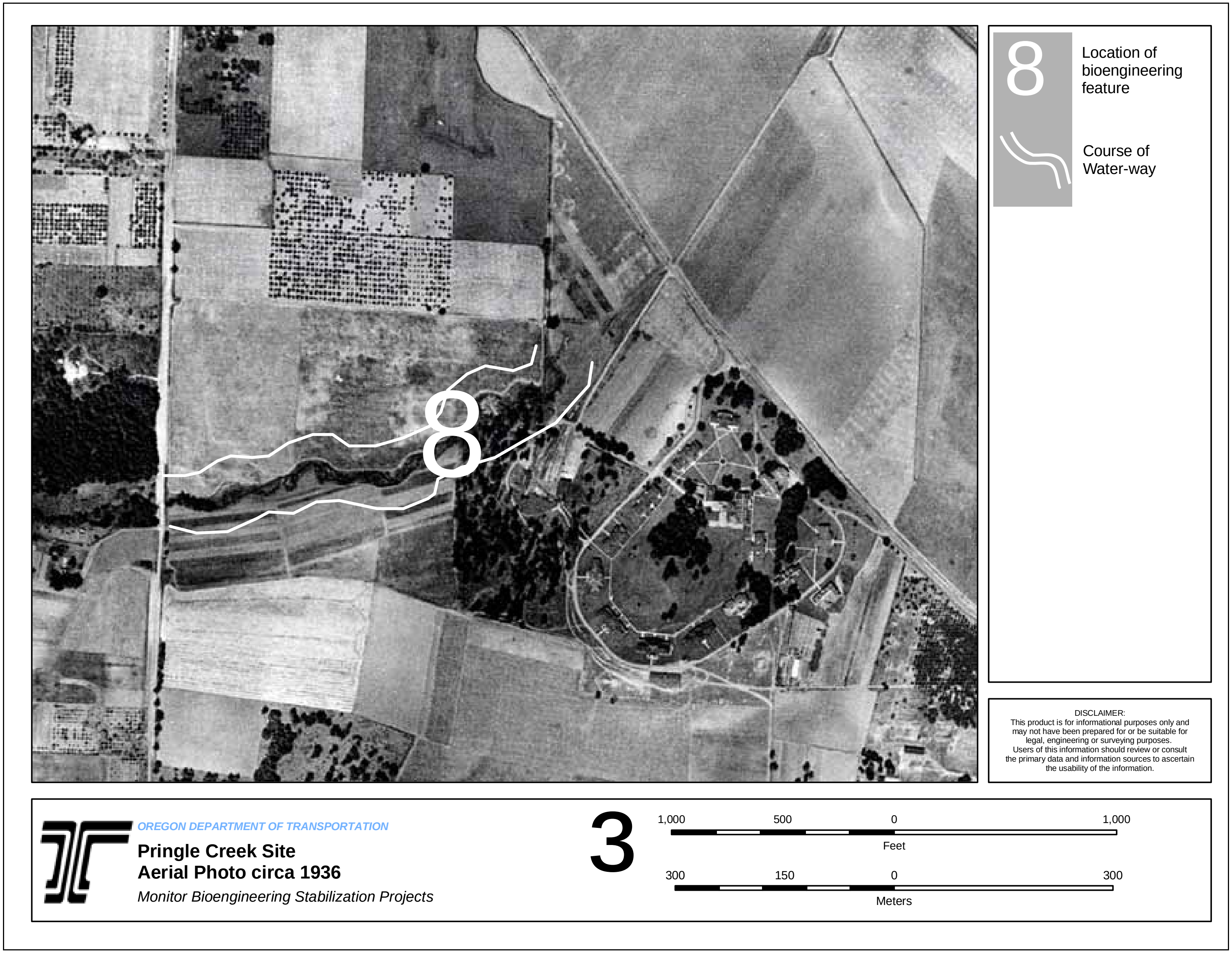

Figure 4.39: Map of the Pringle Creek bioengineering site as depicted in an aerial photograph dated 1936

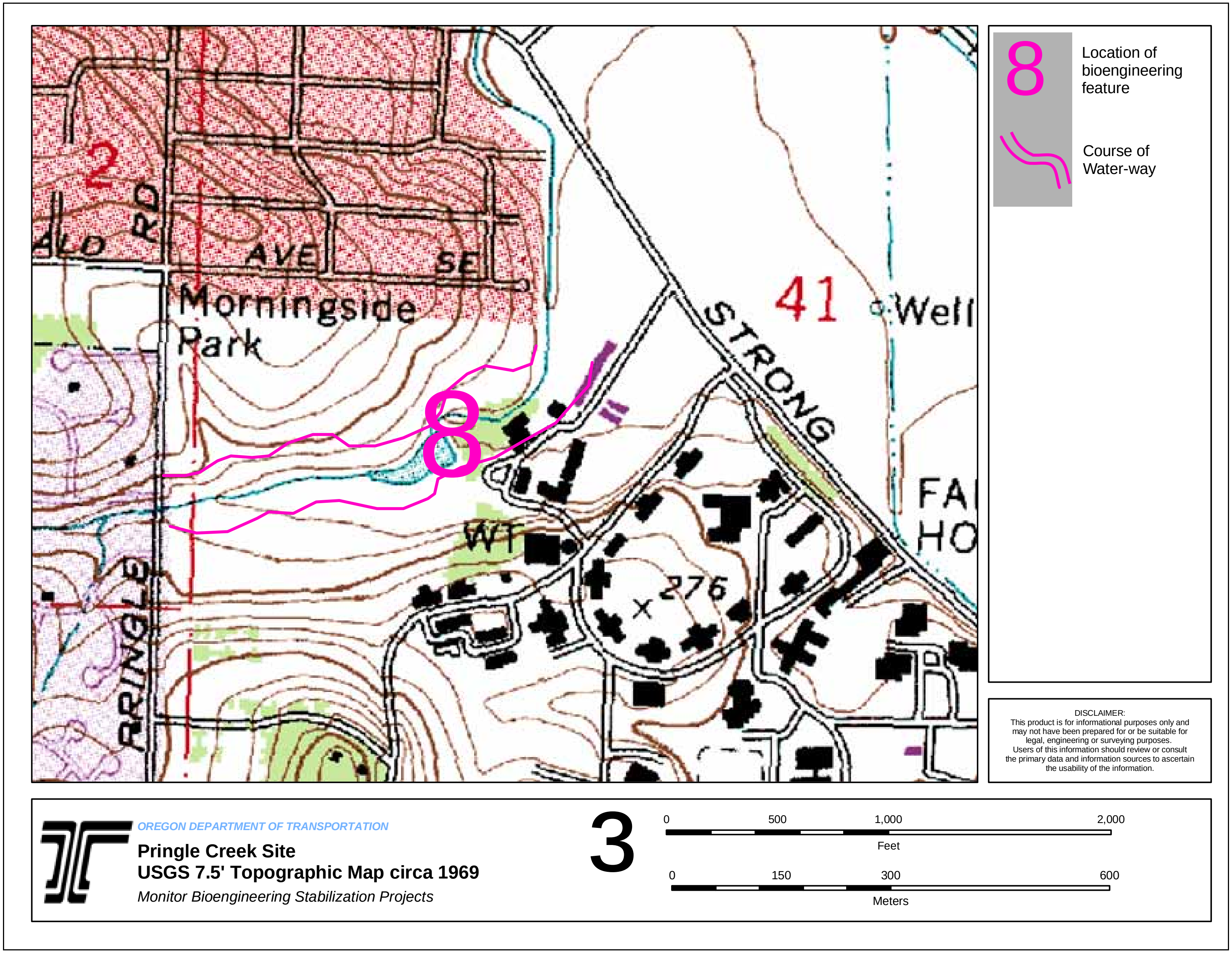

Figure 4.40: Map of the Pringle Creek bioengineering site as depicted on a USGS 7.5' topographic map (Salem West Quadrangle) dated 1969

Figure 4.41: Map of the Pringle Creek bioengineering site as depicted in a digital orthophoto dated 1995

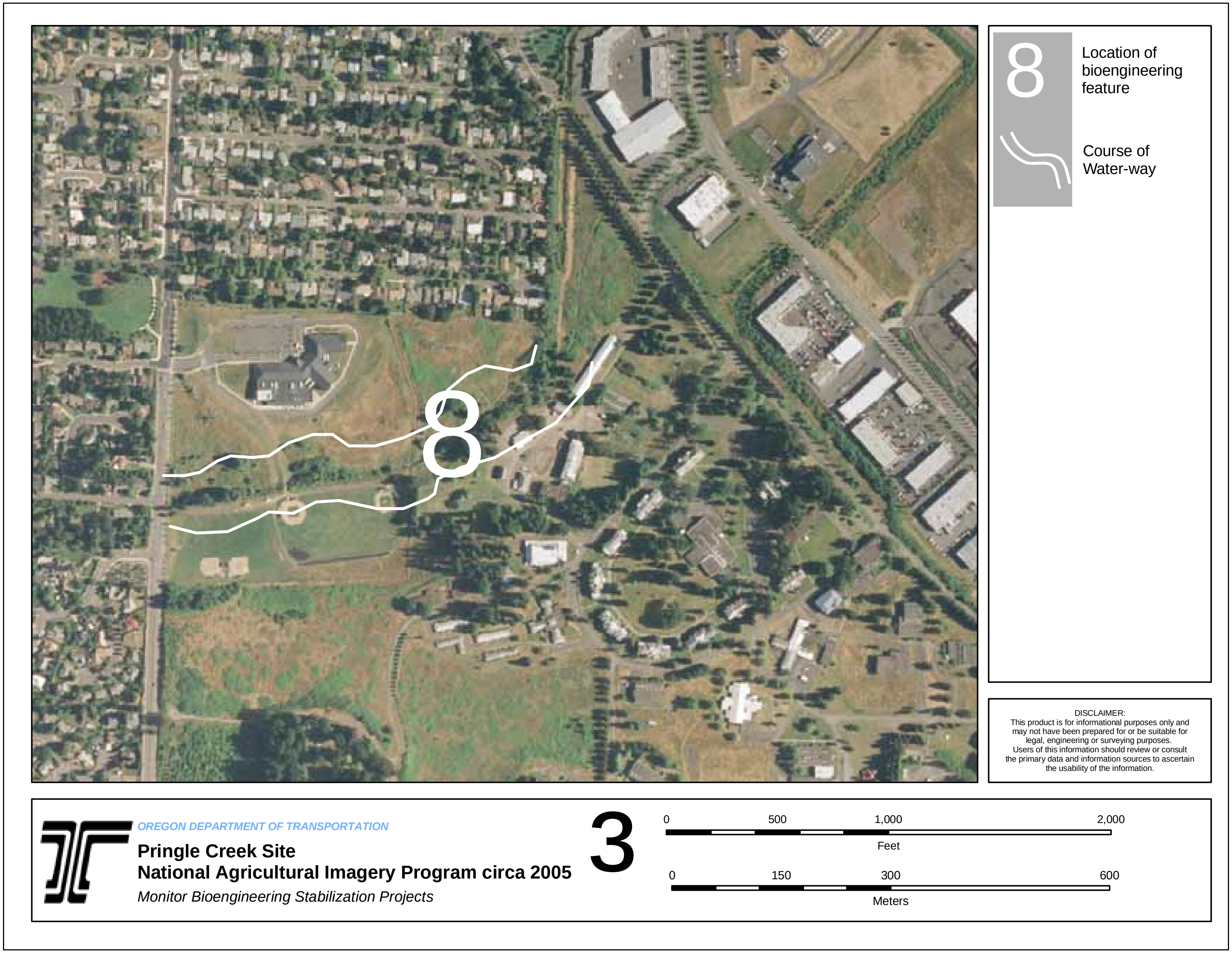

Figure 4.42: Map of the Pringle Creek bioengineering site as depicted in a National Agricultural Imagery Program image dated 2005

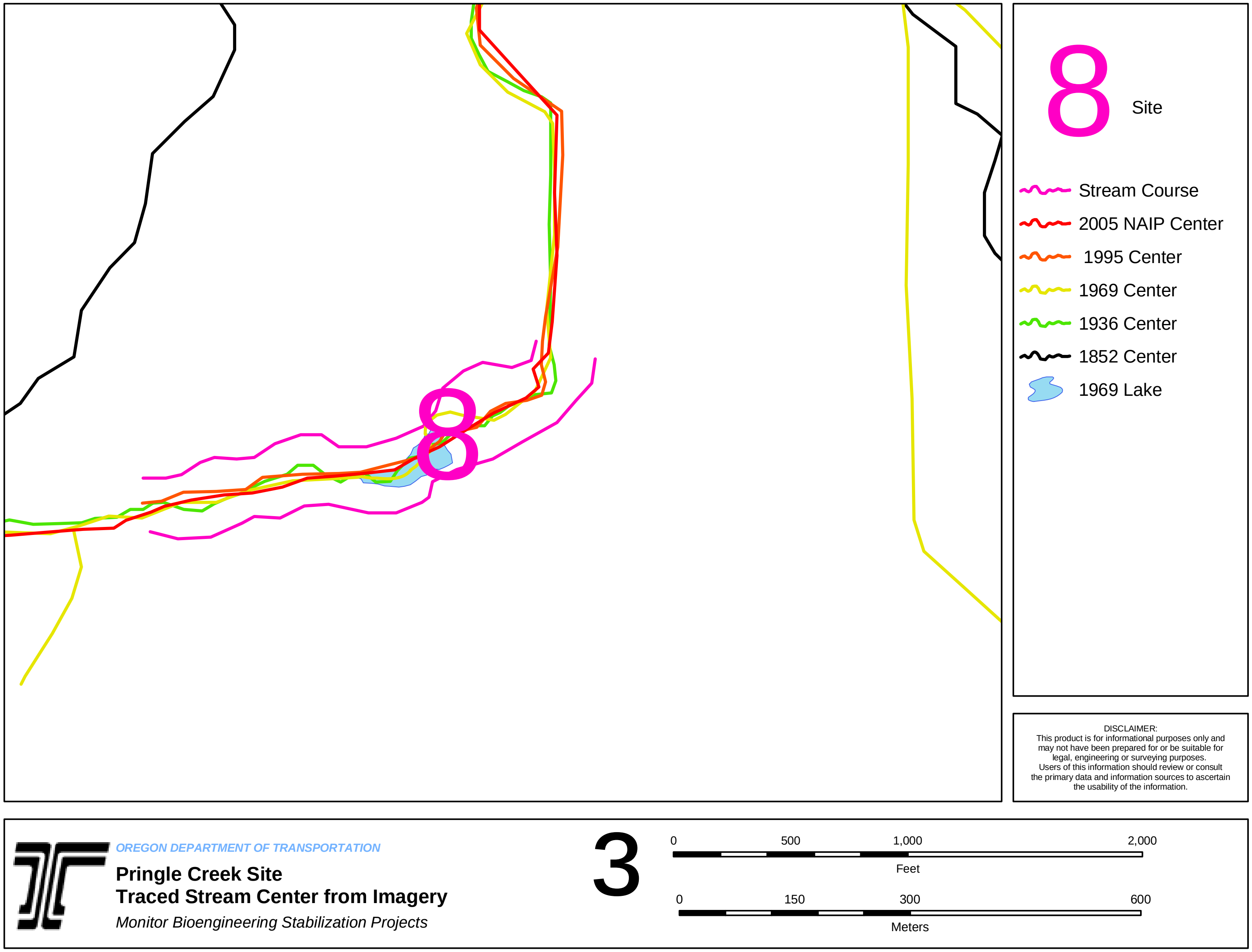

Figure 4.43: Map of the Pringle Creek bioengineering site with the interpreted center of the stream channel as depicted on maps and imagery over historic times

4.4.2 Changes during monitoring

The location of the low water channel of Pringle Creek at the bioengineering monitoring site was not observed to have changed at all over the duration of the monitoring project. Several flood events sent the stream out of its banks. Evidence of water flowing through broad areas of the riparian zone was obvious. These flood flows were not observed to have adversely affected the vegetation or to have caused any erosion. The willows continued to grow and flourish throughout the period of monitoring.

The objective of placing the large logs in the stream had been to create deeper pools for improved habitat for fish species such as Steelhead Trout (*White 2009*). The stream had already been through one complete wet season before monitoring was begun. No noticeable change in the size or depth of the pools around the logs was observed during monitoring. The stream seems to have adjusted itself to the presence of the logs in one wet season.

5.0 CONCLUSIONS

All four bioengineering sites monitored for this project performed as desired, in that there was no noticeable stream bank erosion. It is reasonable to conclude that the various bioengineering methods employed are adequate for the flow conditions measured.

Future efforts to collect empirical data about bioengineering performance can likely benefit from several lessons learned in this project. First, with the exception of exceedingly rare events, the changes in the stream banks will likely be subtle; thus precise and detailed measurements will be needed to quantitatively observe any changes. One suggestion would be the use of ground-based LIDAR scanning done while the stream is at a low stage and the vegetation has died back in the winter.

The second suggestion would be to develop monitoring methods that could measure flow velocities without needing to significantly prune the vegetation around the stream bank sensors. This might require using an acoustic Doppler sensor that makes point measurements rather than profile measurements. It is likely that non-automated measurements during peak flow will be needed to truly capture what the flow parameters are throughout the stream. This is especially true close to the vegetated stream banks. The use of only two sensors was likely also an unnecessary limitation on data collection, especially since the upper sensors so rarely had the opportunity to measure flows. Turbulence should also be measured in addition to velocity.

The originally planned three years of monitoring was clearly too brief a period of time. Future efforts might consider a much longer period of monitoring. Clearly, the longer the monitoring period, the more carefully the data will need to be archived for later retrieval.

6.0 REFERENCES

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APPENDIX

This appendix contains the USGS's explanation of stage and discharge records and the notes from the USGS monitoring reports for each of the four bioengineering sites. All are from Hess (2007).

EXPLANATION OF STAGE AND WATER DISCHARGE RECORDS

Data Collection and Computation

The base data collected at gaging stations consist of records of stage and measurements of discharge of streams or canals, and stage, surface area, and volume of lakes or reservoirs. In addition, observations of factors affecting the stage-discharge relation or the stage-capacity relation, weather records, and other information are used to supplement base data in determining the daily flow or volume of water in storage.

Records of stage ale obtained from a water-stage recorder that is either downloaded electronically in the field to a laptop computer or similar device or is transmitted using telemetry such as GOES satellite, landline or cellular-phone modems, or by radio transmission. Measurements of discharge are made with a current meter or acoustic Doppler current profiler, using the general methods adopted by the USGS. These methods are described in standard textbooks, USGS Water-Supply Paper 217 5, and the Techniques of Water-Resources Investigations of the United States Geological Survey (TWRIs), Book 3, Chapters A1 through ,A.19 and Book 8, Chapters A2 and 82, which may be accessed from http://water.usgs.gov/pubs/nvri/. The methods are consistent with the American Society for Testing and Materials (ASTM) standards and generally follow the standards of the International Organization for Standardization (ISO).

For stream-gaging stations, discharge-rating tables for any stage are prepared from stage-discharge curves. If extensions to the rating curves are necessary to express discharge greater than measured, the extensions are made on the basis of indirect measurements of peak discharge (such as slope-area or contracted-opening measurements, or computation of flow over dams and weirs), step-backwater techniques, velocity-area studies, and logarithmic plotting. The daily mean discharge is computed from gage heights and rating tables, then the monthly and yearly mean discharges are computed from the daily values. If the stage-discharge relation is subject to change because of frequent or continual change in the physical features of the stream channel, the daily mean discharge is computed by the shifting-control method in which correction factors that are based on individual discharge measurements and notes by engineers and observers are used when applying the gage heights to the rating tables. If the stage-discharge relation for a station is temporarily changed by the presence of aquatic growth or debris on the controlling section, the daily mean discharge is computed by the shifting-control method.

The stage-discharge relation at some stream-gaging stations is affected by backwater from reservoirs, tributary streams, or other sources. Such an occurrence necessitates the use of the slope method in which the slope or fall in a reach of the stream is a factor in computing discharge. The slope or fall is obtained by means of an auxiliary gage at some distance from the base gage.

An index velocity is measured using ultrasonic or acoustic instruments at some stream-gaging stations, and this index velocity is used to calculate all average velocity for the flow in the stream. This average velocity along with a stage-area relation is then used to calculate average discharge. At some stations, the stage-discharge relation is affected by changing stage. At these stations, the rate of change in stage is used as a factor in computing discharge.

At some stream-gaging stations in the northern United States, the stage-discharge relation is affected by ice in the winter; therefore, computation of the discharge in the usual manner is impossible. Discharge for periods of ice effect is computed on the basis of gage-height record and occasional winter-discharge measurements. Consideration is given to the available information on temperature and precipitation, notes by gage observers and hydrologists, and comparable records of discharge from other stations in the same or nearby basins.

For a lake or reservoir station, capacity tables giving the volume or contents for any stage are prepared from stage-area relation curves defined by surveys. The application of the stage to the capacity table gives the contents, from which the daily, monthly, or yearly changes are computed.

If the stage-capacity curve is subject to changes because of deposition of sediment in the reservoir, periodic resurveys of the reservoir are necessary to define new stage-capacity curves. During the period between reservoir surveys, the computed contents may be increasingly in error due to the gradual accumulation of sediment.

For some stream-gaging stations, periods of time occur when no gage-height record is obtained or the recorded gage height is faulty and cannot be used to compute daily discharge or contents. Such a situation can happen when the recorder stops or otherwise fails to operate properly, the intakes are plugged, the float is frozen in the well, or for various other reasons. For such periods' the daily discharges are estimated on the basis of recorded range in stage, prior and subsequent records, discharge measurements, weather records, and comparison with records from other stations in the same or nearby basins. Likewise, lake or reservoir volumes may be estimated on the basis of operator's 1og, prior and subsequent records, inflow/outflow studies, and other information.

Identifying Estimated Daily Discharge

Estimated daily-discharge values published in the water-discharge tables of annual State data reports are identified. This identification is shown either by flagging individual daily -values with the letter "e" and noting in a table footnote, "e-Estimated," or by listing the dates of the estimated record in the REMARKS paragraph of the station description.

Accuracy of Field Data and Computed Results

The accuracy of streamflow data depends primarily on (1) the stability of the stage-discharge relation or, if the control is unstable, the frequency of discharge measurements, and (2) the accuracy of observations of stage, measurements of discharge, and interpretations of records.

The degree of accuracy of the records is stated in the REMARKS in the station description. "Excellent" indicates that about 95 percent of the daily discharges are within 5 percent of the true value; "good" within 10 percent; and "fair," within 15 percent. "Poor" indicates that daily discharges have less than "fair" accuracy. Different accuracies may be attributed to different parts of a given record.

Values of daily mean discharge in this report are shown to the nearest hundredth of a cubic foot per second for discharges of less than 1 ft^3/s; to the nearest tenths between 1.0 and 10 ft^3/s; to whole numbers between 10 and 1,000 ft^3/s; and to three significant figures above 1,000 ft^3/s. The number of significant figures used is based solely on the magnitude of the discharge value. The same rounding rules apply to discharge values listed for partial-record stations.

Discharge at many stations, as indicated by the monthly mean, may not reflect natural runoff due to the effects of diversion, consumption, regulation by storage, increase or decrease in evaporation due to artificial causes, or to other factors. For such stations, values of cubic feet per second per square mile and of runoff in inches are not published unless satisfactory adjustments can be made for diversions, for changes in contents of reservoirs, or for other changes incident to use and control. Evaporation from a reservoir is not included in the adjustments for changes in reservoir contents, unless it is so stated. Even at those stations where adjustments are made, large errors in computed runoff may occur if adjustments or losses are large in comparison with the observed discharge.

Other Data Records Available

Information of a more detailed nature than that published for most of the stream-gaging stations such as discharge measurements, gage-height records, and rating tables is available from the USGS Water Science Center. Also, most stream-gaging station records are available in computer- usable form and many statistical analyses have been made.

Information on the availability of unpublished data or statistical analyses may be obtained from the USGS Oregon Water Science Center.

West Fork Dairy Creek

Gage

The gage house is a Hoffmann 3'x 4'x 10" metal shelter mounted on 6X6 wooden posts on left bank about 4 feet above ground. Orifice line is 1.5" by 21' GIP, and 7' flexi hose liquid tight conduit. CR1OX datalogger records data from 2 Unidata Systems Starflow stage/velocity sensors. The 2 Starflow velocity meters (installed in summer 2003) are mounted on metal plates. The lowest Starflow will record at all stages above 6.39. The lowest stage that the highest Starflow will record is 10.93 feet.
The reference gages up to a stage of 11.4 is RPl and RP2, located upstream of the gage on the LB. A lower OSS is located on the right bank for stages between 10.1 and 13.3. The upper OSS is located near the platform on the left bank (range 13.3 to 16.8 ft). Two crest stage gages are mounted on the staff plates, lower CSG pin elevation = 10.634 ft. (range = 10.6 to 15.8 feet) and upper CSG pin elevation = 14.778 ft.
A clothes line cableway was installed in December 2003 upstream of the gage house.
The lower starflow began logging N,4ay 29,2003. The upper starflow began logging Oct. 20, 2003. On October 7,2004 the lower starflow was replaced. On November 8, 2005, an auxiliary GH sensor, H-310, was installed upstream of the cableway platform. The data logger is a CR-510 inside a B-reel metal box mounted on the left bank cableway platform.

(levels of 5/30/2007)

A Campbell Scientific CR500 datalogger,

The reference gage consists of an outside staffs covering a range of 10.14 to 16.8 ft. Two crest-stage gages (CSG) are located near the outside staff gages. No other changes during the year.

The reference gage consists of two RPs and outside staffs covering a range of 10.14 to 16.8 ft. Two crest-stage 9a9es (CSG) are located near the outside staff gages.

A GH H-310 was installed November 8,2005 for auxiliary gage height. A separate data logger (CR510) collects the auxiliary gage height data.

Reference Marks

Levels were established June 6, 2003. Close out levels were run May 30, 2007
RM 1 is a standard USGS brass tablet in cement of upstream gage house support; elevation, 20.334ft gage datum. RM 1 is considered the base RM.
RM 2 is ½" wedge anchor set in boulder on upstream side of strap anchoring 1.5" pipe conduit for lower Starflow, located 15ft downstream and 10 ft shoreward of upper OSS; elevation, 8.628 ft gage datum.
RM 3/RP1 is ½" wedge anchor bolt 30 ft upstream and 15 ft streamward of upper OSS in downstream side of boulder; elevation, 8.620 ft (8.526 ft) gage datum.
RP2 is 1/2 " wedge anchor bolt 18 ft upstream and 8 ft streamward of upper OSS in streamward side of boulder; elevation is 11.404 ft (11.301) gage datum.

Gage Datum 250 ft. above sea level (USGS quad. sheet)
Close out levels were run May 30, 2007. The reference gage elevations used during the 2007 WY, RP1 and RP2, were changed based on these levels. The lower OSS was found off -0.088, but not reset.

Gage Height Record

Record for the period is as follows:
May 29,2003 - The lower Starflow began logging.
Oct.20, 2003 - The upper Starflow began logging.
July 31, 2003 to Aug. 11,2003 - data overwritten
Jan. 16, 2004 to Jan. 23, 2004 - data overwritten
Feb. 2, 2004 to Feb. 8, 2004 - data overwritten
Feb. 12, 2004 to Feb. 29, 2004 - data overwritten
Mar. 1, 2004 to Mar. 16, 2004 - data overwritten
Apr. 5, 2004 to May 19, 2004 - data overwritten
May 19, 2004 - data logging stopped for summer
October 1, 2004 to July 5, 2005 - There are several periods during 2004-2005 where the GH looks suspicious when compared to EF Dairy Creek.
Oct. 1, 2005 to June 2, 2006 - Starflow GH data was used Nov. 3-8, 2005. H-310 GH data was used for period Nov. 8, 2005-June 2, 2006. On Oct. 1, 2004 the lower Starflow was replaced. Nov. 3, 2005 - data logging began. Nov. 8, 2005 - H-310 was installed
Corrections from ADAPS are as follows:

Table A.1: Based on observations, the following corrections were applied

Date	Time	Input	Correction	Remark
2003/07/31	17:24:00	2.00	0.00	No og taken, keep same corr.
2003/10/03	12:30:00	2.00	-0.12	
2003/10/20	10:56:00	2.00	-0.13	
2003/10/20	11:16:00	2.00	0.00	reset CR10 offset
2003/10/28	10:46:00	2.00	0.15	
2003/10/28	11:36:00	2.00	0.00	reset offset
2003/10/29	09:40:00	2.00	-0.18	
2003/11/24	08:55:00	2.00	-0.19	
2004/03/22	09:03:00	2.00	0.29	need to replace starflow
2004/05/19	09:40:00	2.00	0.29	disconnect for summer
2004/05/19	09:41:00	2.00	0.00	
2004/10/01	13:30:00	2.00	0.00	restarted starflow
2004/05/19	09:41:00	2.00	0.00	
2004/10/01	13:30:00	2.00	0.00	restarted starflow
2004/10/05	09:30:00	2.00	-0.45	
2004/11/02	17:45:00	2.00	-0.45	based on CSG mark at peak
2004/11/09	12:45:00	2.00	-2.07	
2004/11/09	12:55:00	2.00	0.00	reset offset
2004/11/15	13:15:00	2.00	0.30	

Date	Time	Input	Correction	Remark
2004/12/02	13:51:00	2.00	-0.87	
2004/12/02	14:12:00	2.00	0.00	reset offset
2004/12/10	12:38:00	2.00	1.20	
2005/01/06	09:30:00	2.00	-0.33	
2005/01/24	09:50:00	2.00	1.29	
2005/02/15	13:40:00	2.00	0.80	
2005/03/15	09:59:00	2.00	1.21	reset offset
2005/03/15	10:00:00	2.00	0.00	
2005/03/31	10:36:00	2.00	0.00	
2005/05/19	19:00:00	2.00	-0.20	
2005/07/05	19:40:00	2.00	1.10	
2005/11/03	15:29:00	0.00	0.00	
2005/11/03	15:29:00	0.00	0.00	
2005/11/03	15:30:00	0.00	-0.04	start data collection
2005/11/08	15:45:00	0.00	0.00	install H-310
2005/12/09	13:34:00	0.00	-0.04	
2006/01/26	09:33:00	0.00	-0.05	
2006/02/28	13:30:00	0.00	-0.05	
2006/03/27	10:16:00	0.00	0.00	
2006/06/02	13:59:00	0.00	0.13	
2006/06/02	13:59:00	0.00	0.13	
2006/12/13	11:55:00	0.00	0.00	
2006/12/13	12:00:00	0.00	0.15	
2006/12/13	23:00:00	0.00	0.15	
2006/12/14	23:00:00	0.00	-0.14	change on falling limb
2007/03/20	12:11:00	0.00	-0.14	
2007/05/30	13:23:00	0.00	-0.20	data collection ended

Recorded peak stage of 13.67 ft. on Jan. 30, 2004 (looks like peak was a plateau) corresponds to a CSG reading of 14.26 ft.
Recorded peak stage of 15.05 ft. on March 27 (looks like recorded peak was a plateau) corresponds with a CSG reading of 19.38 ft.
There were several recorded CSG marks this year: 17.57 , 19.25, and above 15.8 that verified three peaks.
There was one recorded CSG mark this year: 19.66 that verified the peak of Dec. 14, 2006.

Ice was not a factor during any of the years that data was collected.

Velocity Record

Record for the two velocity sensors is as follows:
Lower Sensor - (minimum GH = 6.39 ft)
July 31, 2003 to Aug. 11, 2003 - data overwritten
Jan. 16, 2004 to Jan. 23, 2004 - data overwritten
Feb. 5, 2004 to Feb. 8, 2004 - data overwritten
Feb. 9, 2004 to Feb. 29, 2004 - data overwritten

Mar. 1, 2004 to May 19, 2004 - data overwritten
May 19 - data logging stopped for summer
Oct. 1,2004 the lower starflow was replaced and logging began
Apr. 1, 2005 to Apr. 17, 2005 - logged erroneous values
July 5, 2005 - data logging stopped for summer
Nov. 3, 2005 - data collect¡on began
Jan. 10, 2006 to Jan. 26, 2006 - dead batteries
Jan. 26, 2006 to Mar. 27, 2006 - values held steady at 0.44
Mar. 27, 2006 to Apr. 10, 2006 - overwritten data
June 2, 2006 - data logging stopped for summer
Dec. 13, 2006 - data collection began
Dec. 23, 2006 to Dec. 28, 2006 - sporadic record collected.
January 1- Match 27 - dead batteries, the sensor may have been covered up with gravel through the whole period also.
Upper Sensor - Minimum GH = 10.93 ft
Collected velocity data during the period when the water was above the sensor:
January 29, 2004 to Feb. 4, 2004
Feb. 27, 2004 to Feb. 28, 2004
Oct. 1, 2004 - the logging began
Apr. 13, 2005- July 5, 2005 - logged erroneous data
July 5, 2005 - data logging stopped for summer.
Peaks occurred on Dec. 8, 2004, Jan. 18, 2005 and Mar. 26-31, 2005.
Apparently no data collected during 2005-2006 season due to sensor communication issues.
Apparently no data collected during 2006-2007 due to sensor communication issues.

Johnson Creek

Gage

The gage house is a Hoffmann 3'x 4'x 10" metal shelter mounted on 6X6 wooden posts on right bank about 4 feet above ground level. A Campbell Scientific CR500 datalogger was originally installed and then replaced by a CR10X datalogger records data from two Unidata Systems Starflow stage/velocity sensors and a Design Analysis H310 submersible pressure sensor (H310 installed Sept. 2005). Velocity meters are mounted on metal plates secured to the stream bed and the right bank with angle iron posts pounded into the ground. The lowest Starflow will record at all stages. The lowest stage that the highest Starflow will record is 3.3 feet.
The reference gage is a staff plate attached to a 6 X 6 inch post on the left bank ranging from 6.14 to 12.30 ft. A crest stage gage is located on the staff plate. CSG pin elevation 7.436 ft gage datum.

Velocity meters are mounted on metal plates. The lowest Starflow sensor is at 3.48 ft and will record at all stages. The upper Starflow is at 9.5 feet and will record stages above that.
The purpose of the gage is to collect velocity data at the point of the Starflow sensors. The Cooperator requested the location of the Starflows and wants to know the velocities at those

points, in order to characterize and Dredict bank and stream erosion. It is sufficient to collect velocities at the sensors, and not necessarily obtain a complete discharge measurement.

The lower Starflow will record stages above 3.3 ft. The upper Starflow sensor will record stages above 9.5 ft.
The reference gage is an outside staff gage on the left bank, which covers araîge of 6.74 to 12.30 ft.
Maintaining the gage in operating status was challenging. Frequently, the batteries were found dead due to the power requirements of the equipment.

The lowest Starflow sensor is at 3.48 ft and w¡l¡ record at all stages. The upper Starflow is at 9.5 feet and will record stages above that.

The lowestStarflow sensor is at 3.48 ft and will record at all stages. The upper Starflow is at 9.5 feet and will record stages above that.

Reference Marks

Levels were established and last run May 29, 2003.
RM 1 is a standard USGS brass tablet in cement of upstream gage house support post; elevation, 17.471 ft gage datum. RM 1 is considered the base RM.
RM 2 is top of fence post 3 feet shoreward , 5 feet downstream of gage house; elevation, 18.172 ft gage datum.
RM 3 is top of fence post 4 feet shoreward , 6 feet upstream of gage house; elevation, 18.832ft gage datum. RP. 1 is middle of downstream facing lip of lower starflow; elevation, 3.826 ft gage datum.

Gage Height Record

Gage height data was recorded for the following periods:
Oct. 1, 2003 to Nov. 12, 2003
Mar. 4, 2004 to Apr. 28, 2004
Gage-height record.-No valid gage height record was collected 2004-2005.
Nov. 10, 2005 to Dec. 19, 2005
Dec. 31, 2005 to Apr. 26, 2006
May 8, 2006 to May 17, 2006
May 22, 2006 to Aug. 22, 2006
Nov. 7, 2006 to -Feb. 28, 2007
The H310 submersible pressure sensor is the primary gage height record.

Table A.2: Based on observations, the following corrections were applied

Date	Time	Input	Correction	Remark
2005/09/30	23:59:00	0.00	0.00	
2005/11/09	14:00:00	0.00	0.00	INSIDE TO OUTSIDE READINGS ÀRE WITHIN CONFIDENCE LIMITS
2005/12/30	14:00:00	0.00	0.00	INSIDE T0 OUTSIDE READINGS ARE WITHIN CONFIDENCE LIMITS
2006/01/13	15:58:00	0.00	0.00	INSIDE TO OUTSIDE READINGS ARE WITHIN CONFIDENCE LIMITS
2006/03/16	14:20:00	0.00	0.00	INSIDE TO OUTSIDE READINGS ARE WITHIN CONFIDENCE LIMITS.
2006/05/31	09:53:00	0.00	-0.05	CORRECTION BASED ON INSIDE TO OUTSIDE OBSERVATION.
2006/09/30	23:59:00	0.00	-0.05	CARRY THIS CORRECTION TO THE END OF THE WATER YEAR
2006/11/07	09:47:00	0.00	0.00	INSIDE TO OUTSIDE GAGE READINGS ARE WITHIN CONFIDENCE LIMITS
2007/01/11	16:42:00	0.00	0.00	INSIDE TO OUTSIDE GAGE READINGS ARE WITHIN CONFIDENCE LIMITS
2001/02/28	09:00:00	0.00	0.00	INSIDE TO OUTSIDE GAGE READINGS ARE WITHIN CONFIDENCE LIMITS

2003-2004 A recorded peak stage of 7.00 was not verified. CSG pin elevation is 7 .44 ft.
A high water mark was found (discovered Jan. 15,2004) on the CSG at 9.93 ft .(12/14/2003)
A high water mark was found (discovered Mar. 4, 2004) on the CSG at 8.38 ft. (01/24/2004)
A high water mark was found (discovered Feb. 23, 2005) on the CSG at 7.54 ft. (12/11/2004)
A recorded peak stage of 9.89 feet on Dec. 30, 2005 was verified with a high water mark on the CSG at 9.97 ft.
A recorded peak stage of 9.44 feet on Dec. 14, 2006 was verified by a high water mark on the CSG at9.12 ft.
The dates of the HWM peaks were determined from the downstream gaging station
A high water mark was found (discovered Mar. 28, 2005) on the CSG at 7.97 ft*. (03/27/2005)
A high water mark was found (discovered May 24, 2005) on the CSG at 7.47 ft. (04/16/2005)
The dates of the HWM peaks were determined from the downstream gaging station

Ice was not a factor in 2003-2004.
Ice was not a Factor during in 2004-2005.
Ice was not a factor during in 2005-2006.
Ice was not a factor during in 2006-2007.

Velocity Record

Velocity data was recorded for the following periods:
Lower velocity sensor:
Oct. 1, 2003 to Nov. 12, 2003
Mar. 4, 2004 to Apr. 28, 2004
Aug. 23, 2004 to Sept. 30, 2004
Oct. 1, 2004 to Oct. 11, 2004
Nov. 10, 2004 to Dec. 22, 2004
Jan. 8, 2005 to Mar. 28, 2005
Apr. 8, 2005 to May 24, 2005
Nov. 9, 2005 to Dec. 17, 2005
Jan. 14, 2006 to Aug. 19, 2006
Upper velocity sensor:
No data was recorded. The stage does not appear to have gotten this high during 2003-2004.
No data was recorded. The stage does not appear to have gotten this high during 2004-2005.
No data recorded. There may not have been enough water over the sensor to obtain velocities during 2005-2006
No data recorded. Stage does not appear to have gotten this high during 2006-2007.

Data from the velocity sensors is erratic and numerous 'spikes' were deleted from the record. The remaining data looks reasonable.

A peak velocity of 8.34 fps was recorded on January 17, 2006.
A peak velocity of 8.5 fps was recorded on January 3, 2007.

<u>Shelton Ditch</u>

Gage

The gage house is a Hoffmann 3'x 4'x 10" metal shelter mounted on two 6x6 wooden posts on right bank about 4 feet above ground. Reference gages are two staff gages: 1) a sloping staff plate located on right bank ranging in stage from 2.3 to 7.4 feet, and 2) a vertical staff plate mounted on upstream side of upstream gage house 4x6 post ranging in stage from 6.75 to 13.54 feet. A crest-stage gage is attached to the downstram 6 X 6 inch post supporting the Hoffman enclosure. Pin elevation of the CSG is 7.087 ft (levels of 8-11-2003). The recording range of the CSG is 7.09- 12.09 ft. A Campbell Scientific CR510 datalogger A CR10X datalogger records data from two Unidata Systems Starflow stage/velocity sensors and a Design Analysis H310 submersible pressure transducer.. Velocity sensors are mounted on flat metal plates which are secured to angle iron posts pounded into the streambed. The lowest Starflow will record at all stages above 1.51 feet. The lowest stage that the highest Starflow will record is 5.23 feet. The Starflows were put into operation Nov. 4, 2003. The H310 submersible pressure transducer is housed inside 1 112 inch pipe extending from the right bank to the streambed. The H310 was put into operation the summer of 2004. On December 21 the datalogger program was re-written to collect data from this sensor.

Maintaining the gage in operating status was challenging. Frequently, the batteries were found dead due to the power requirements of the Starflow sensors.

Reference Marks

Levels were established and last run August 11,2003.
RM 1 is a standard USGS brass tablet in cement of upstream gage house support; elevation, 6.744 ft gage datum. RM 1 is considered the base RM.
RM 2 is % inch lag bolt set in shoreward side of downstream 4x6 leg of gage house , painted yellow ; elevation, 5.081 ft gage datum.
RM 3 is chiseled square in concrete walkway 5.2 ft shoreward and 7 ft downstream of downstream gage house leg ; elevation, 7.756 ft gage datum.

Gage Height Record

Data was recorded for the following periods:
Nov. 4, 2003 gage put into operation for the winter season.
Nov. 4-13, 2003
Nov. 24, 2004 to Mar. 12, 2004
Mar. 21, 2004 to May 13, 2004
July 28, 2004 to Sept. 30, 2004
Oct. 1, 2004 to Feb. 3, 2005

Note: Beginning December 21, 2004 the H310 sensor is the primary gage height record and the lower Starflow gage height record is used as backup record.

Mar. 29, 2005 to May 13, 2005
May 13, 2005 equipment was shut down for the season.
Nov. 10, 2005 equipment put into operation for the winter season.
NOV. 10, 2005 to 22, 2005
Dec. 15, 2005 t o Feb. 23, 2006
Mar. 23, 2006 to Apr. 22, 2006
May 31, 2006 equipment was s h u t down f o r t h e season.
Nov. 7, 2006equipment put into operation for the winter season.
Nov. 7, 2006 to Dec. 6, 2006
Jan. 11, 2007 to Jan. 31, 2007
Feb. 28, 2007 to Mar 23, 2007

A recorded peak stage of 7.06 on Dec. 14, 2003 was not verified by CSG reading (pin elevation 7.09 ft).
A recorded peak stage of 4.78 ft on Dec. 11, 2004 was not verified by CSG reading (pin elevation 7.09 ft).

A recorded peak stage of 9.36 ft on Dec. 31, 2005 was verified by a CSG reading of 9.39 ft.
A recorded stage of 6.90 ft on Nov. 7, 2006 was observed .

Based on observations, no corrections to the gage height record were necessary in 2003-2004.
Ice was not a factor during 2003-2004.
Ice was not a factor during 2004-2005.
Ice was not a factor during 2005-2006 .
Ice was not a factor during 2006-2007.

Table A.3: Based on observations, the following corrections were applied

Date	Time	Input	Correction	Remark
2004/05/13	12:00:00	0.00	0.00	BASED ON OBSERVATION, NO CORRECTION.
2004/11/10	15:00:00	0.00	0.00	BASED ON OBSERVATION, NO CORRECTION.
2004/11/10	15:45:00	0.00	0.50	CORRECTION BASED ON DROP IN GHT DUE TO AN OFFSET ISSUE.
2004/12/21	14:50:00	0.00	0.48	CORRECTION BASED ON OBSERVATION.
2004/12/21	14:55:00	0.00	0.00	RESET GHT, NO CORRECTION.
2005/02/03	13:26:00	0.00	0.02	CORRECTION BASED ON OBSERVATION.
2005/05/13	15:35:00	0.00	0.01	CORRECTION BASED ON OBSERVATION.
2005/11/10	12:48:00	0.00	0.00	
2005/12/15	09:25:00	0.00	0.00	
2006/01/10	15:52:00	0.00	0.09	
2006/01/11	14:15:00	0.00	0.06	
2006/01/31	14:40:00	0.00	0.02	
2006/03/23	13:02:00	0.00	0.00	
2006/05/31	12:44:00	0.00	0.00	
2006/11/07	15:06:00	0.00	0.04	
2007/01/11	13:03:00	0.00	0.00	
2007/02/28	13:42:00	0.00	0.00	

Velocity Record

Data was recorded for the following periods:
Lower and Upper Starflow velocity sensors The upper velocity sensor recorded data during these periods if the water was above 5.5 ft.:
Nov. 4, 2003 gage put into operation for the winter season.
Nov. 4, 2003 to Nov. 13, 2003
Nov. 24, 2003 to Mar. 12, 2004
Mar. 21, 2003 to May 13, 2004
July 28, 2004 to Sept. 30, 2004
Oct. 1, 2004 to Feb. 3, 2005
Mar. 29, 2005 to May 13, 2005
May 13, 2005 equipment was shut down for the season.

Nov. 10, 2005 equipment put into operation for the winter season .
Nov. 10, 2005 to Nov. 22, 2005
Dec. 15, 2005 to Feb. 23, 2006
Mar. 23, 2006 to Apr. 22, 2006
May 31, 2006 equipment was shut down for the season.
Nov. 7, 2006equipment put into operation for the winter season
Nov. 7, 2006 to Dec. 7, 2006
Jan. 11, 2007 to Jan. 28, 2007

Data was collected form the upper starflow when the stage was above 5.23 ft.
Dec. 12, 2003 to Dec. 16, 2003
Dec. 27, 2003 to Dec. 31, 2003
Jan. 28, 2004 to Dec. 31, 2004
Maximum recorded velocity from the lower starflow was 11.4 fps on Dec. 14 and 29, 2003.
Maximum recorded velocity from the upper starflow was 3.02 fps on Dec. 14, 2003.
Maximum recorded velocity from the lower stafflow was 8.16 fps on Dec. 11, 2004. The upper starflow was out of water the entire period.
Maximum recorded velocity from the lower starflow was 10.8 fps on Nov. 7, 2006.Maximum recorded velocity from the upper starflow was 2.5 fps on Nov 24, 2006.

Data from both velocity sensors is erratic and numerous 'spikes' were deleted from the record. The remaining data looks reasonable.

Pringle Creek

Gage

The gage house is a Hoffmann 3'x 4'x 10" metal shelter mounted on 6x6 wooden posts on left bank about 4 feet above ground.

The reference gage consists of an outside staff gage covering a range of 6.7 to 12.2 ft, located on the left bank. A crest stage gage is located on the left bank mounted on the same steel as the staff gage has a range of 7.01 to 12.21, CSG pin elevation is 7.01 1 (levels of 8-14-03)

CRlOX datalogger records data from two Unidata Systems Starflow stage/velocity sensors. Sept.15, 2005 a Design Analysis H-310 submersible pressure transducer was installed and the CR500 datalogger was replaced with a CRlOX. However, this equipment was not put into operation until the 2006 WY.

The lower Starflow sensor is secured to the stream bed at 5.16 ft elevation. The upper Starflow sensor is on the left bank adjacent to the lower Starflow, at 7.14 ft elevation. Velocity meters are mounted on metal plates. Both starflow started logging Nov. 6,2003

Maintaining the gage in operating status was challenging. Frequently, the batteries were found dead and the equipment was not dependable.

Reference Marks

Levels were established and last run August 14,2003.
RM 1 is a standard USGS brass tablet in cement of upstream gage house support; elevation, 10.998 ft gage datum. RM 1 is considered the base RM.
RM 2 is ½ inch lag bolt set in stream ward side of downstream 4x6 leg of gage house , painted yellow ; elevation, 11.386 ft gage datum.
RM 3 is ½ inch concrete anchor bolt set vertically in concrete block 45 feet upstream of gage , 2 feet shoreward, painted yellow ; elevation, 6.348 ft gage datum.
RP. 1 is top of angle iron downstream of gage , downstream most upper edge of iron, located 2 feet upstream and 8 feet stream ward of CSG post; elevation, 6.226 ft gage datum.

Gage Height Record

The lower Starflow sensor was the source of the primary gage height record during the 2003-2004 and 2004-2005 seasons. A Design Analysis H-310 pressure sensor was the primary source of gage height record during the 2005-2006 and 2006-2007 seasons.

Gage height data was recorded for the following periods:
Nov. 24,2003 – Mar. 12,2004
Mar. 2 1,2004 – May 13,2004
Sept. 19,2004 – Sept. 30,2004
Dec. 16, 2004 – Jan. 18, 2005
Mar. 28, 2005 – May 13, 2005
Nov. 10, 2005 – June 1, 2006
Nov. 7, 2006 – Apr. 18, 2007

Table A.4: Gage height corrections were applied as follows

Date	Time	Input	Correction	Remarks
2003/11/06	10:41:00	0.00	0.00	Started logger for the season
2004/01/16	15:15:00	0.00	-0.11	
2004/03/02	14:08:00	0.00	-0.11	
2004/03/05	10:15:00	0.00	-0.11	
2004/03/12	09:45:00	0.00	-0.11	
2004/05/13	13:12:00	0.00	-0.36	
2004/05/13	14:00:00	0.00	-0.36	
2004/05/13	14:01:00	0.00	0.00	Shut down logger for the season
2004/12/16	08:54:00	0.00	2.06	Started logger for the season
2004/12/16	12:40:00	0.00	0.00	
2004/12/21	10:19:00	0.00	0.02	
2004/12/21	11:05:00	0.00	0.00	
2005/02/03	10:49:00	0.00	-0.17	
2005/02/03	12:32:00	0.00	0.00	
2005/05/13	14:50:00	0.00	-0.25	
2005/05/13	14:50:00	0.00	-0.25	Shut down logger for

				the season
2005/11/10	10:20:00	0.00	0.00	Started logger for the season
2005/12/15	10:26:00	0.00	-0.03	
2006/01/11	11:20:00	0.00	0.00	
2006/01/11	12:28:00	0.00	0.02	
2006/01/31	13:42:00	0.00	0.05	
2006/03/23	09:38:00	0.00	0.00	
2006/05/31	14:26:00	0.00	0.00	Shut down logger for the season
2006/11/07	20:06:00	0.00	-0.06	Started logger for the season
2006/05/31	14:26:00	0.00	0.00	
2006/11/07	16: 09:00	0.00	-0.06	
2006/11/13	15:27:00	0.00	0.00	
2007/01/11	10:58:00	0.00	0.02	
2007/02/28	11:36:00	0.00	0.03	
2007/04/18	12:58:00	0.00	0.00	Shut down logger for the season

During 2003-2004 the peak recorded stage of 7.52 was verified by a CSG reading of 7.51 ft. during 2003-2004
During 2004-2005 a peak gage height of 7.23 ft was recorded on Dec. 31, 2004. A high water mark on the CSG was found at 7.33 ft on the May 13, 2005 inspection. The event that produced this high water mark may have occurred on the Dec. 31, 2004 or from Jan. 18, 2005 - Mar. 28, 2005 when the Stafflow was not operating.
A HWM on the CSG at 8.26 ft was found on Nov. 10, 2005. Apparently, this event happened near the end of the 2005 WY or at the beginning of the 2006 WY, prior to the equipment being put back into operation.
A recorded peak stage of 7.66 ft on Dec. 30, 2005 was verified by a CSG reading of 7.88 ft

A HWM on the CSG at 7.67 ft was found on Nov. 7, 2006. Apparently, this event happened near the end of the 2006 WY (probably near Sept 30, 2006) or at the beginning of the 2007 WY, prior to the equipment being put back into operation.
A recorded peak stage of 7.39 ft. on Dec. 26, 2006 was verified by a CSG reading of 7.43 ft.

Ice was not a factor during any of the years monitored.

Velocity Record

Data from the velocity sensors was erratic and numerous 'spikes' were deleted from the record. The following periods of remaining data looked reasonable:

Lower velocity sensor:
Nov. 24, 2003 – Dec. 17, 2003
Dec. 23, 2003 – Mar. 12, 2004 Sporadic data.
Mar. 21, 2004 – Apr. 15, 2004
Oct. 1, 2004 – Dec. 14, 2004
Dec. 16, 2004 – Jan. 18, 2005
Mar. 28, 2005 – May 13, 2005

Nov. 10, 2005 – June 1, 2006
The lower velocity sensor did not function during the 2006-2007 season.

Upper velocity sensor:
Dec. 5, 2003
Dec. 7, 2003
Dec. 13, 2003
(During 2004-2005 the water was not high enough to obtain valid readings.)
Dec. 28, 2005
Dec. 30, 2005
Jan. 10, 2006
Jan. 20, 2006
Dec. 26, 2006