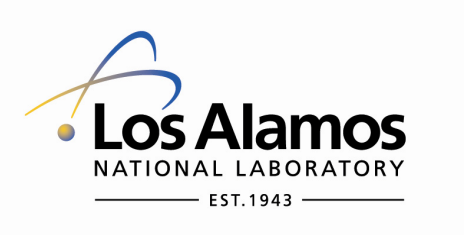
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2011 Geomorphic Changes at Sediment Transport Mitigation Sites in the Los Alamos and Pueblo Canyon Watersheds



Prepared by the Environmental Programs Directorate

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2011 Geomorphic Changes at Sediment Transport Mitigation Sites in the Los Alamos and Pueblo Canyon Watersheds

May 2012

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Appendix

Appendix A Photographs of Sediment Transport Mitigation Sites

Attachment

Attachment 1 Cross-Section Survey Data (on CD included with this document)

1.0 INTRODUCTION

This report evaluates geomorphic changes that occurred in 2011 at sediment transport mitigation sites in the Los Alamos and Pueblo Canyon watersheds within and near Los Alamos National Laboratory (LANL or the Laboratory). Survey data reported previously (LANL 2011, 200902) are compared with subsequent survey data obtained in fall 2011 and winter 2012, following the summer 2011 monsoon season, as specified in the "2011 Monitoring Plan for Los Alamos and Pueblo Canyons Sediment Transport Mitigation Project" (LANL 2011, 201578). These surveys will be repeated after the 2012 monsoon season, and results will be presented in a report to the New Mexico Environment Department (NMED) by May 31, 2013. NMED has specified that results of inspections of stream bank armoring in the south fork of Acid Canyon be included in the annual report on geomorphic changes in the Los Alamos and Pueblo Canyon watersheds (NMED 2010, 109693), and these results are included herein. NMED has also specified that future reports include information on the health and success of willow plantings and photographic documentation of willow plantings, grade-control structures (GCSs), and examples of erosion and deposition at surveyed cross-sections (NMED 2011, 204349), and these are also included herein. Figure 1.0-1 shows the locations of sites discussed in this report, and Appendix A presents photographs of the sediment transport mitigation sites.

A previous study used repeat cross-section surveys between 1998 and 2001 to document geomorphic changes in sediment investigation reaches in Pueblo Canyon associated with the Cerro Grande fire (Lyman et al. 2005, 089414). Some of these cross-sections were relocated and resurveyed in fall 2011 and spring 2012 to provide a longer-term perspective on the geomorphic changes documented in the current study, and potential future geomorphic changes, and these resurveys are also included in this report.

2.0 HYDROLOGIC EVENTS DURING 2011 MONSOON SEASON

The largest runoff events in 2011 at the sediment transport mitigation sites in the Los Alamos and Pueblo Canyon watersheds occurred following heavy rain on the Los Alamos townsite (for events in Acid, DP, and Pueblo Canyons) or the Las Conchas burn area (for events in Los Alamos Canyon) (LANL 2012, 211396). The maximum measured discharge at these sites occurred on August 21, 2011, at the E039.1 gaging station below the DP Canyon GCS. The peak discharge at E039.1 was 290 cubic feet per second (cfs), slightly less than measured in 2010 (315 cfs; LANL 2011, 207072). Other gages near the sediment transport mitigation sites also had maximum measured discharges on August 21, 2011:

- In Pueblo Canyon above the Los Alamos County wastewater treatment plant (WWTP) outfall at gage E059, peak discharge is estimated at 131 cfs, which is less than measured in 2010 (250 cfs; LANL 2011, 207072). This event did not reach the E060.1 gaging station, below the Pueblo Canyon GCS.
- In the south fork of Acid Canyon at gage E055.5, peak discharge is estimated at 20 cfs, which is less than measured in 2010 (69 cfs; LANL 2011, 207072).

At gages E042.1 and E050.1, above and below the Los Alamos Canyon low-head weir, estimated peak annual discharges are 207 and 188 cfs, respectively, on September 4, 2011. This event involved runoff from the Las Conchas burn area in the upper Los Alamos Canyon watershed and was the largest event measured in this part of Los Alamos Canyon since 2006, when a peak discharge of 240 cfs was estimated at the gage above the low-head weir (Romero et al. 2007, 100140).

Gaging station E060.1, in Pueblo Canyon below the GCS, had only one measured runoff event in 2011, with an estimated peak discharge of 4 cfs on September 7 (LANL 2012, 211396). There was no flow measured at E059 that day, indicating that the source of the E060.1 event was local precipitation.

3.0 SURVEYS AT SEDIMENT TRANSPORT MITIGATION SITES

Surveys were conducted at all sediment transport mitigation sites specified in the 2011 monitoring plan (LANL 2011, 201578). Surveys were conducted using a combination of a differentially corrected global positioning system (GPS) and a total station tied to GPS control points, depending on tree cover. Surveys were supplemented with sediment thickness measurements obtained from hand-dug or hand-augered holes at some locations. The general locations of all survey areas are shown in Figure 1.0-1, and these surveys are discussed below. Surveyed cross-sections are shown in figures with a vertical exaggeration (VE) of 2.5 times, and channel thalweg profiles are shown with a VE of 5 times, 15 times, or 20 times. Raw survey data (x and y coordinates using the New Mexico State Plane coordinate system and elevations of all survey points) for surveyed cross-sections are included electronically as Attachment 1 (on CD included with this document). The calculated distances along each cross-section and along each thalweg profile that are used for the figures in this report are also included in Attachment 1. These calculations involved basic trigonometry (Pythagorean theorem). The figures showing cross-sections include prior survey data and the latest resurvey data, indicating where erosion and deposition have occurred along each section over the last year. Each surveyed cross-section was field checked to confirm that elevational differences between surveys indicated erosion or deposition and were not artifacts of the surveys (such as can result from different survey point spacing or slight differences in survey location) or topographic changes not related to flooding (e.g., gopher mounds or road blading outside the floodplain). The net changes in cross-sectional area along each section were calculated and used to estimate total deposition or erosion over the surveyed area, normalized as m^3 per km of channel for comparison with previous studies. In tables, the net deposition or erosion that occurred in each area in 2011 is compared with changes that occurred in 2010. At each cross-section, the changes in thalweg elevation from 2009 to 2010 and from 2010 to 2011 are also compiled in tables and used to indicate whether, on average, the channel elevation has been stable, aggrading, or incising. In the figures showing channel thalwegs, the distance along the survey can vary between the original survey and the resurvey because of changes in thalweg sinuosity, resulting in changes in thalweg gradient. These changes in thalweg gradient are also summarized in this report.

3.1 Pueblo Canyon Cross-Vane Structures

Two cross-sections were originally surveyed in the vicinity of each of the three Pueblo Canyon cross-vane structures (CVSs) in April 2010, one 50 ft upcanyon and one 50 ft downcanyon of the apex rock of each structure. Channel thalweg profiles were also surveyed over these 100-ft distances. These cross-sections and thalweg profiles were resurveyed in December 2010 and October 2011. Cross-section and thalweg profile locations for all CVSs are shown on an orthophotograph in Figure 3.1-1, and the cross-sections and thalweg profile for the upper CVS (CVS #1) are also shown on a geomorphic map in Figure 3.1-2 (geomorphic mapping from 1997; LANL 2004, 087390). The cross-sections and thalweg profiles for CVS #1, CVS #2, and CVS #3 are shown in Figures 3.1-3, 3.1-4, and 3.1-5, respectively. Net sediment deposition occurred at five of the six CVS cross-sections during the summer 2011 monsoon season, as summarized in Table 3.1-1. Maximum aggradation (net sediment deposition) was 0.6 ft at CVS#1 +50 ft (Figure A-1, Appendix A), and the maximum incision (net erosion) was 0.4 ft at CVS#3 −50 ft (Figure A-2, Appendix A). Normalized net sediment deposition at the CVSs averaged 268 m^3/km, compared with an estimated 17,680 m^3/km of post-1942 sediment in reach P-2W, which contains CVS #1, as measured in 1997 (LANL 2004, 087390). This net deposition, 2% of the estimated 1942–1997 total, represents a

modest increase. Net deposition also occurred at these sites in 2010, and 2011 average net deposition is approximately 82% less than 2010 net deposition (Table 3.1-1). On average, the channel thalweg at the CVS cross-sections aggraded by 0.1 ft in 2011, compared with 0.2 ft of aggradation in 2010 (Table 3.1-1). Figures 3.1-3 through 3.1-5 also indicate changes to the channel thalweg that occurred during the summer 2010 monsoon season. At two of the three CVSs, the thalweg gradient increased associated with sediment deposition, incision, and slight decreases in sinuosity.

Four cross-sections had been previously surveyed in reach P-2W between 1998 and 2001 (Lyman et al. 2005, 089414), and two of these (P-2 West XS-2, or P2W-X2; and P-2 West XS-1, or P2W-X1; Figures 3.1-1 and 3.1-2) were relocated and resurveyed in fall 2011 and spring 2012. Figures 3.1-6 and 3.1-7 show geomorphic changes that occurred at these cross-sections between 1998 and 2001, which included floods that followed the Cerro Grande fire, and between 2001 and 2011, which included the largest flood recorded in Pueblo Canyon, on August 6, 2006 (Romero et al. 2007, 100140). At P2W-X1, the floods that followed the Cerro Grande fire resulted in net sediment deposition and 0.9 ft of channel aggradation, whereas subsequent floods resulted in an additional 2.5 ft of channel aggradation and net sediment deposition. At P2W-X2, net sediment deposition occurred in the floods following the Cerro Grande fire, and channel aggradation and minor net sediment deposition occurred between 2001 and 2011. These data indicate that this part of Pueblo Canyon has been relatively stable with net sediment deposition since 1998.

3.2 Upper Pueblo Canyon Willow-Planting Area

A total of 18 cross-sections were surveyed in November 2009 in the part of Pueblo Canyon downstream from the new Los Alamos WWTP outfall and upstream from the access road to the WWTP where willows were planted in spring 2008 and spring 2009. These cross-sections were divided into groups of six within the upper, middle, and lower thirds of the willow-planting area, and within each group the cross-sections were spaced at 100-ft intervals. Longitudinal channel thalweg profiles were also surveyed over 500-ft intervals through each of these three areas. These cross-sections and thalweg profiles were resurveyed in April 2011 and October 2011. Stream banks in this area were surveyed in March 2012. Cross-section locations, thalweg profile locations, and stream banks are shown on an orthophotograph in Figure 3.2-1, and the cross-sections, thalweg profile, and stream banks for the middle and lower thirds of the area are also shown on a geomorphic map in Figure 3.2-2 (geomorphic mapping from 1997; LANL 2004, 087390). The cross-sections and thalweg profiles in the upper, middle, and lower thirds of the willow-planting area are shown in Figures 3.2-3, 3.2-4, and 3.2-5, respectively. Geomorphic changes that occurred at these cross-sections during the summer 2011 monsoon season are summarized in Table 3.2-1.

Maximum deposition of new sediment was 1.7 ft at section UW-3 in the upper third of the upper Pueblo Canyon willow-planting area (also referred to as the upper willow-planting area), and the maximum erosion was 5.5 ft at section LW-4 in the lower third of this area. The new sediment at section UW-3 was associated with burial of the previous channel in an area of extensive sediment deposition immediately downstream from a southside tributary draining the new Los Alamos Entrada Park (Figure A-3, Appendix A). The erosion at section LW-4 was associated with lateral migration of the stream bank [Figure A-4(a), Appendix A], and bank migration was also recorded at several other sections (UW-3, LW-3, LW-5, and LW-6). Much of the erosion was into young sediment deposits that postdated the May 2000 Cerro Grande fire [Figure A-4(b), Appendix A]. Thirteen of the cross-sections had net sediment deposition during the summer 2010 monsoon season, and five had net erosion. Normalized net sediment deposition in the upper willow-planting area averaged 12 m^3/km, compared with an estimated 33,570 m^3/km of post-1942 sediment in reach P-3W, which includes part of the surveyed area, as measured in 1997 (LANL 2004, 087390). This net deposition, <0.1% of the estimated 1942–1997 total, represents an insignificant increase that is probably within the measurement error. On average, the

channel thalweg in the upper third of the upper willow-planting area aggraded by 0.4 ft in 2011, whereas the channel thalweg incised by 0.2 to 0.3 ft in the middle and lower thirds of this area (Table 3.2-1). This general pattern of upstream aggradation and downstream incision also occurred in 2010. Figures 3.2-3 through 3.2-5 also indicate changes to the channel thalweg gradient that occurred during the summer 2010 monsoon season. In the upper third of the willow-planting area, the thalweg gradient increased since the previous survey; and at the other two areas, the thalweg gradient decreased, associated with changes in sinuosity and bed elevation.

One cross-section in reach P-3W previously surveyed between 1998 and 2001 (P3 West, XS-1, or P3W-X1); and one cross-section surveyed in 2001 (P3 West, X-8, or P3W-PUX8) (Figures 3.2-1 and 3.2-2; Lyman et al. 2005, 089414) were relocated and resurveyed in spring 2012. Figures 3.2-6 and 3.2-7 show geomorphic changes that occurred at these cross-sections between 1998 and 2001, which included floods that followed the Cerro Grande fire, and between 2001 and 2011, including the record August 6, 2006, flood event (Romero et al. 2007, 100140). At P3W-X1, the floods that followed the Cerro Grande fire in 2001 resulted in net sediment deposition. At P3W-PUX8, extensive sediment deposition occurred between 2001 and 2011. These data indicate that this part of Pueblo Canyon has been relatively stable with net sediment deposition since 1998, consistent with the deposition measured in 2010 and 2011.

3.3 Pueblo Canyon Wing Ditch

Five cross-sections were surveyed at 100-ft intervals downcanyon from the Pueblo Canyon wing ditch in November 2009. Longitudinal thalweg profiles of the active channel and a formerly abandoned channel to the south where the wing ditch directs water were also surveyed over this distance. These cross-sections and thalweg profiles were resurveyed in May 2011 and October 2011. The wing ditch is a short distance downstream from where the road to the Los Alamos County WWTP crosses the Pueblo Canyon stream channel, and the culverts at this crossing were plugged during a runoff event on August 16, 2010. In 2011, the County of Los Alamos rebuilt the road crossing to better withstand large runoff events and to pass flow more effectively (Figure 3.3-1). The formerly abandoned channel to the south now receives flow during periods of high effluent discharge and stormwater runoff, helping to effectively distribute water across this part of the wetland (a function that the wing ditch was designed to perform; it is no longer needed for this purpose). Figure A-5, Appendix A, shows flow in the north channel during high effluent discharge. Figure A-6, Appendix A, shows similar flow in the south channel. Cross-section and thalweg profile locations are shown on an orthophotograph in Figure 3.3-1, and the cross-sections and thalweg profile locations are also shown on a geomorphic map in Figure 3.3-2 (geomorphic mapping from 1996–1997; LANL 2004, 087390). The cross-sections are shown in Figure 3.3-3, and the thalweg profiles are shown in Figure 3.3-4. Geomorphic changes that occurred at these cross-sections during the summer 2011 monsoon season are summarized in Table 3.3-1.

Maximum sediment deposition was 1.3 ft in the main channel at cross-section WD-1 (Figure A-5, Appendix A), and the maximum incision (net erosion) was 0.9 ft along the southern channel at cross-section WD-3 (Figure A-6, Appendix A). Four of the cross-sections had net sediment deposition during the summer 2011 monsoon season, and one had net erosion. Normalized net sediment deposition over the surveyed area below the wing ditch averaged 137 m^3/km, compared with an estimated 69,910 m^3/km of post-1942 sediment in reach P-3E, a short distance east of the surveyed area, as measured in 1997 (LANL 2004, 087390). This net deposition, 0.2% of the estimated 1942–1997 total, represents a small increase. On average, the main channel thalweg near the wing ditch aggraded by 0.4 ft in 2011, compared with 1.3 ft of aggradation in 2010 (Table 3.3-1). As presented in Figure 3.3-4, the average thalweg gradient of the active channel remained essentially constant in 2011, whereas the gradient of the abandoned channel to the south increased slightly.

3.4 Lower Pueblo Canyon Willow-Planting Area

A total of 23 cross-sections were surveyed in September 2009 at 100-ft intervals within reaches P-3FE and P-4W in an area where willows were planted in spring 2009. The surveys extended for 1100 ft above and below a transition area separating a broad upcanyon wetland (P-3FE) from a narrower downcanyon wetland within incised geomorphic surfaces (P-4W). A longitudinal channel thalweg profile was also surveyed over this 2200-ft interval. These cross-sections and thalweg profiles were resurveyed in April and May 2011 and in October and November 2011. Stream banks in this area were surveyed in January and March 2012. Cross-section and thalweg profile locations and stream banks are shown on an orthophotograph in Figure 3.4-1, and these are also shown on a geomorphic map in Figure 3.4-2 (geomorphic mapping from 1996–1997; LANL 2004, 087390). The cross-sections are shown in Figure 3.4-3, and the channel thalweg profiles are shown in Figure 3.4-4. Geomorphic changes that occurred at these cross-sections during the summer 2011 monsoon season are summarized in Table 3.4-1.

In the upper half of the lower Pueblo Canyon willow-planting area (also referred to as the lower willow-planting area, which is reach P-3FE), maximum deposition of new sediment was 0.8 ft at cross-section PU −1000 ft (1000 ft upstream from the transition zone), and the maximum erosion was 2.6 ft at cross-section PU −300 ft (Figure 3.4-3 and Table 3.4-1). The deposition at PU −1000 ft was associated with sediment transported off side slopes to the north, and the erosion at PU −300 ft was associated with lateral bank migration (Figure A-7, Appendix A). Three of the 11 cross-sections above the approximate transition point (PU 0-ft section) had net sediment deposition, 7 had net erosion, and 1 had no measureable change. Normalized net sediment deposition in the upper half of the lower willow-planting area averaged 26 m^3/km, compared with an estimated 51,172 m^3/km of post-1942 sediment in reach P-3FE, which includes the surveyed area, as measured in 1997 (LANL 2004, 087390). This net deposition, less than 0.1% of the estimated 1942–1997 total, represents an insignificant increase that is probably within measurement error.

In the lower half of the lower willow-planting area (reach P-4W), maximum deposition of new sediment was 1.0 ft at cross-section PU +600 ft, and the maximum erosion was 3.8 ft, also at section PU +600 ft (Figure 3.4-3; Figure A-8, Appendix A; and Table 3.4-1). The erosion and deposition were both associated with lateral bank migration. Cross-section PU +600 ft also had the highest measured erosion and deposition in 2010, indicating that the channel is continuing to adjust in this area. Eight of the 11 cross-sections below the approximate transition point had net sediment deposition, 2 had net erosion, and 1 had no measureable change. Net erosion also occurred at cross-section PU 0 ft, where the emergence of alluvial groundwater perched on Puye Formation bedrock results in seepage erosion. The surface above the headcut is dry, whereas wetland vegetation (reed canary grass and willows) is established below the headcut (Figure A-9, Appendix A). Net sediment erosion occurred in the lower half of the lower willow-planting area, averaging 191 m^3/km, compared with an estimated 98,710 m^3/km of post-1942 sediment in reach P-4W, which includes the surveyed area, as measured in 1997 (LANL 2004, 087390). This calculated net erosion, 0.2% of the estimated 1942–1997 total, represents a minor change.

On average, the thalweg aggraded by 0.3 to 0.4 ft in 2011 both above and below the transition point (Table 3.4-1). The thalweg in both areas also aggraded by an average of 0.3 ft in 2010. Figure 3.4-4 presents thalweg profiles in the lower willow-planting area in May 2011 (top panel) and October 2011 (bottom panel). Average channel gradients above and below an outcrop of Puye Formation bedrock did not change between these surveys, although some local scour and fill occurred.

3.5 Pueblo Canyon Grade-Control Structure

A total of 15 cross-sections were surveyed in April 2010 at 100-ft intervals upstream of the Pueblo Canyon GCS, and 3 cross-sections were surveyed at 100-ft intervals downstream from the GCS. A longitudinal channel thalweg profile was also surveyed over this 1800-ft interval. Because some ground disturbance associated with site restoration occurred after the April 2010 surveys were completed, the area of disturbance was resurveyed in June 2010. These surveys were repeated in April and October 2011. Stream banks in this area were surveyed in January 2012. Cross-section and thalweg profile locations and stream banks are shown on an orthophotograph in Figure 3.5-1, and these are also shown on a geomorphic map in Figure 3.5-2 (geomorphic mapping from 1996–1997; LANL 2004, 087390). The cross-sections and the channel thalweg profile are shown in Figure 3.5-3. Geomorphic changes that occurred at these cross-sections during the summer 2011 monsoon season are summarized in Tables 3.5-1 and 3.5-2. Photographs of the GCS are shown in Figure A-10, Appendix A.

During the summer 2011 monsoon season, net sediment deposition occurred at eight cross-sections above the GCS, net sediment erosion occurred at four cross-sections, and no measureable change occurred at four cross-sections, as summarized in Table 3.5-1. Maximum sediment deposition was 0.5 ft at four cross-sections (for example, Figure A-11, Appendix A), and the maximum erosion was 1.1 ft at section PUGCS −1100 ft (1100 ft above the GCS) (Figure A-12, Appendix A). There was little surface-water flow through this area in 2011, and the erosion and deposition were both localized. The maximum erosion was at a location where the stream bank eroded laterally about 1 ft. Averaged over the 1500-ft distance above the GCS, net sediment deposition occurred, normalized to 72 m^3/km. For comparison, there was an estimated 70,210 m^3/km of post-1942 sediment in reach P-4E, which includes the GCS, as measured in 1997 (LANL 2004, 087390). This net deposition, 0.1% of the estimated 1942–1997 total, represents a minor increase that may be within measurement error. This deposition was probably not significantly affected by the presence of the GCS because most of it occurred far upstream from the structure, where there would have been no related hydrologic effects.

Below the Pueblo Canyon GCS, minor net deposition (0.4 ft) occurred at one cross-section in 2011 and no measureable change occurred at the other two cross-sections (Table 3.5-2).

On average, the thalweg aggraded by 0.2 ft in 2011 above the GCS and had no significant change below the GCS (Tables 3.5-1 and 3.5-2). In 2010, the thalweg had incised by 0.1 to 0.2 ft in these areas. Both above and below the GCS, the thalweg gradient remained relatively constant through this period (Figure 3.5-3). Note that the apparent increases in gradient below the GCS shown in the thalweg profile in Figure 3.5-3 are artifacts of varying survey distances.

One cross-section in reach P-4E previously surveyed between 1996 and 2001 (P4 East, X-1, or P4E-X1; Figures 3.5-1 and 3.5-2; Lyman et al. 2005, 089414) was relocated and resurveyed in spring 2012. Figure 3.5-4 shows geomorphic changes that occurred at this cross-section between 1996 and 2001, which includes floods that followed the Cerro Grande fire, and between 2001 and 2011, including the record August 6, 2006, flood event (Romero et al. 2007, 100140). The floods that followed the Cerro Grande fire resulted in net sediment deposition and channel aggradation at this location, and subsequent floods since 2001 have resulted in net sediment deposition and channel aggradation. These data indicate that this location has been relatively stable over the last 15 yr, despite the presence of a headcut a short distance downstream.

3.6 Upper Los Alamos Canyon Sediment Detention Basins

The upper Los Alamos Canyon sediment detention basins, constructed at the base of the drainage below Solid Waste Management Unit 01-001(f) (LA-SMA-2 or Hillside 140), were excavated on July 8 to July 11, 2011, after the Las Conchas fire (LANL 2011, 206488). The basins were resurveyed in July 2011 after excavation to provide a new base line for measuring subsequent deposition. The basins were visited in October 2011 to examine sediment deposition that occurred during the 2011 monsoon season. In the western basin (basin 1), a small delta had formed where the drainage entered the basin, and approximately 20 cm of sediment, mostly coarse-grained, was measured in hand-dug holes. In the center of basin 1, up to 12 cm of fine-grained sediment was measured. No appreciable sediment deposition was observed in the eastern basin (basin 2). In October 2011, basin 1 was resurveyed, and the topography existing at that time is presented in Figure 3.6-1. Based on the size of the sediment deposition area in basin 1 (285 m^2) and an estimated average sediment thickness of 5–10 cm, approximately 15–30 m^3 of sediment was deposited in basin 1 during the 2011 monsoon season. Photographs of the sediment detention basins are shown in Figure A-13, Appendix A.

3.7 DP Canyon Grade-Control Structure

A total of 11 cross-sections were surveyed in April and May 2010 at 100-ft intervals upstream of the DP Canyon GCS, and 2 cross-sections were surveyed at 125 ft and 225 ft downstream from the GCS, downstream from the E039.1 gaging station. A longitudinal channel thalweg profile was also surveyed over this 1325-ft interval. The area above the GCS was first resurveyed in November and December 2010, and the area below the GCS was resurveyed in March 2011 (after ice melted from the channel bed) and again resurveyed in October 2011. Cross-section and thalweg profile locations are shown on an orthophotograph in Figure 3.7-1 and on a geomorphic map in Figure 3.7-2 (geomorphic mapping from 1998; LANL 2004, 087390). The cross-sections and thalweg profile are shown in Figure 3.7-3. Photographs of the GCS are shown in Figure A-14, Appendix A.

Net sediment deposition occurred at nine cross-sections above the GCS during the summer 2011 monsoon season (Figure A-15, Appendix A), and net sediment erosion occurred at two cross-sections, as summarized in Table 3.7-1. Maximum sediment deposition was 1.7 ft at the cross-section 800 ft above the GCS [Figure A-15(a), Appendix A], and the maximum erosion was 2.6 ft at the cross-section 200 ft above the GCS (Figure A-16, Appendix A). Normalized net sediment deposition above the GCS averaged 167 m^3/km, compared with an estimated 7490 m^3/km of post-1942 sediment in reach DP-2, which contains the GCS, as measured in 1999 (LANL 2004, 087390). This net deposition, 2% of the estimated 1942–1999 total, represents a modest yearly increase. The sediment deposition was probably not significantly affected by the presence of the GCS because most of it occurred far upstream from the structure, where there would have been no related hydrologic effect, and the two cross-sections closest to the GCS actually experienced net sediment erosion. The net erosion above the structure was associated with channel scour and bank erosion (Figure A-16, Appendix A), and the areas farther upstream experiencing the most net sediment deposition were associated with channel aggradation (Figure A-15, Appendix A). Net sediment erosion occurred at both cross-sections below the GCS, with 1.4 ft of channel incision at the section 125 ft below the GCS (Figure 3.7-3 and Table 3.7-2). This erosion occurred mostly in areas that had aggraded in 2010.

On average, the stream channel upstream of the GCS aggraded by 0.1 ft in 2011, compared with no net change in 2010 (Table 3.7-1). Downstream of the GCS, the channel incised an average of 0.5 ft in 2011, compared with 0.8 ft of aggradation in 2010 (Table 3.7-2). As shown in Figure 3.7-3, no net change occurred to the channel thalweg gradient above the GCS in 2011, and a slight decrease in gradient occurred below the GCS.

3.8 Los Alamos Canyon Low-Head Weir

The sediment retention basins above the Los Alamos Canyon low-head weir were excavated from July 8 to July 11, 2011, following the Las Conchas fire (LANL 2011, 206488), and the postexcavation topography is shown in Figure 3.8-1. The upper two basins (basins 1 and 2) were resurveyed in October 2011, after the 2011 monsoon season, and the lower basin (basin 3) was resurveyed in March 2012 after ponded water had evaporated. Figure 3.8-1 also shows variations in total sediment thickness determined by subtracting the July 2011 topographic surface from the October 2011 to March 2012 surface. Maximum sediment thickness resulting from the 2011 monsoon season is 1.1 m (3.6 ft) in basin 3. Table 3.8-1 summarizes volume changes in each of the three sediment retention basins during this period. Photographs of the weir are shown in Figure A-17, Appendix A; and photographs of the retention basins are shown in Figures A-17(b) and A-18, Appendix A.

An estimated 780 m^3 of sediment accumulated in the upstream, western basin (basin 1) above the weir during the 2011 monsoon season (Table 3.8-1). Field observations indicated that approximately 50% of this is coarse-grained sediment that was transported as bed load. The remainder of the basin fill is fine-grained sediment that was transported as suspended load. An estimated 1440 m^3 of sediment accumulated in the middle basin (basin 2), and it is estimated that approximately 5% of this is coarse-grained sediment. An estimated 4700 m^3 of sediment accumulated in the eastern basin (basin 3), consisting of fine-grained sediment. The total sediment accumulation rate in the basins above the weir during the 2011 monsoon season was much higher than measured in previous years, as shown in Table 3.8-2. The higher sedimentation rate after the Las Conchas fire than after the Cerro Grande fire is probably related to the presence of the Los Alamos Reservoir. After the Cerro Grande fire, the reservoir was maintained to impound floodwaters, which let most of the sediment from the burn area settle out (Lavine et al. 2006, 213454; Reneau et al. 2007, 102886). In contrast, after the Las Conchas fire, floodwaters were allowed to bypass the dam because it was being rebuilt when the fire occurred and was not considered able to withstand large floods. The high percentage of fine sediment accumulated above the weir in 2011, 93% of the total, is consistent with observations after the Cerro Grande fire when the transport of fine-grained sediment was much higher than that of coarse-grained sediment in the first year, and the transport distance greater for fine-grained sediment (Lavine et al. 2006, 213454; Reneau et al. 2007, 102886).

4.0 OBSERVATIONS OF WILLOWS IN PUEBLO CANYON

In 2008 through 2010, willows were planted in three areas in Pueblo Canyon downstream from the new Los Alamos WWTP, with the goal of enhancing riparian habitat, stabilizing surfaces, and slowing floodwaters. These areas are referred to as the upper willow-planting area (section 3.2), the lower willow-planting area (section 3.4), and the Pueblo Canyon GCS (section 3.5). Observations were made of willows in these areas during fall 2011. Willow success was variable in these areas and appears to be related to substrate conditions and preexisting vegetation, as well as the occurrence and persistence of water and substrate stability, as discussed below.

The upper willow-planting area had the tallest willows and the thickest patches of willows in the surveyed areas. In the upper, middle, and lower thirds of the upper willow-planting area, willows reached maximum measured heights of 4.1, 4.8, and 2.9 m, respectively. Willow patches were locally thick, with continuous foliage between stems, in parts of the upper and middle thirds of this area (Figure A-19, Appendix A). In between the thickest willow patches, willows that had been laid down by floods in August 2010 had resprouted (Figure A-20, Appendix A), indicating that their root systems remained viable. This area has continuous surface-water flow and a sandy or gravelly, aggrading substrate, and the willows were planted

in generally bare ground with little competition from other vegetation. These conditions appear to be ideal for the success of willow plantings.

In the lower third of the upper willow-planting area, willows were less continuous and there were generally gaps between the foliage from nearby stems. No willows were observed in most of the area between the LW-3 and LW-5 cross-sections, and they were sparse between the LW-5 and LW-6 cross-sections. This corresponds to an area of unstable conditions in both 2010 and 2011, with eroding banks and an incising channel (Figure 3.2-5 and Figure A-4, Appendix A). The poor willow success in this area appears to be directly related to the unstable substrate conditions.

In the upper half of the lower willow-planting area, above the transition zone, willows were planted in a thin strip along the main channel and locally along a side channel (Figures A-7 and A-21, Appendix A). This is an area with thick preexisting vegetation dominated by reed canary grass (*Phalaris arundinacea*), and much of the area has a fine-grained substrate. Most planted willow stalks did not survive, with willow success ranging from 0% to about 50% in different parts of this area. The living willows are mostly stump sprouts or root sprouts, with the sprouts commonly clustered around the base of the original stems. Willow spacing is typically 1 m to 10 m. The tallest measured willow above the transition zone was 2.9 m tall, near the PU −500 ft cross-section. The poor success in this area appears to be related to the thick preexisting vegetation, which would provide competition for the willows, and/or the commonly fine-grained substrate. Damage to willow stalks by animals was also observed [Figure A-21(b), Appendix A], which may contribute to the poor success rate in this area.

In the lower half of the lower willow-planting area, below the transition zone, willows were also planted with a typical spacing of 1 m to 10 m in a thin strip along the main channel (Figure A-8, Appendix A), and the success rate here was also generally low. Willow success was best near the lower end of the planting area, where the area between incised banks widens and coarse sediment has been deposited (Figure A-22, Appendix A). Many of the living willows in this area are stump sprouts. Willows have also been successfully established in an area of seepage in the transition zone (Figure A-9, Appendix A).

There is one dense willow patch located on a post-1942 geomorphic surface near the PU +100 ft cross-section, with willows up to 4.4 m tall (Figure A-23, Appendix A). These willows were established before the recent planting and indicate locally favorable conditions on higher surfaces, at least at the time of their establishment. The channel has probably incised since they were established, and, because of the relatively low water table, it is uncertain if new willows could be successfully established at this time on high surfaces in this area.

Upstream from the Pueblo Canyon GCS, willows were planted in the disturbed area along the channel for a distance of approximately 250 ft. Approximately 10% of these willows survived, often consisting of short sprouts from the base of the stems or the roots. Maximum measured height of living foliage was 0.5 m on one of the original stems. In summer and fall 2011, effluent released from the WWTP did not extend this far downstream, and the dry conditions probably contributed to the poor success rate in this area.

In summary, the willow plantings were most successful in areas with little or no existing vegetation at the time of planting, a stable or aggrading surface with a sandy or gravelly substrate, and continuous surface-water flow. Willow success was generally poor in areas with thick existing vegetation, fine-grained or unstable substrate, and little or no surface-water flow. Replanting in these areas with low past success rates may also be generally unsuccessful.

5.0 SOUTH FORK OF ACID CANYON INSPECTION

The stream bank armoring that was emplaced in the south fork of Acid Canyon in April 2010 (LANL 2010, 109280) was inspected after the 2011 monsoon season. The rock armoring remained intact, as shown in Figure A-24, Appendix A.

6.0 SUMMARY

Net sediment deposition occurred in most surveyed areas in the Los Alamos and Pueblo Canyon watersheds in 2011, which is consistent with the goal of the sediment transport mitigation work plans (LANL 2008, 101714; LANL 2008, 105716). Net sediment deposition for 2011 is less than that recorded in 2010. Except for sediment accumulated behind engineered structures, such as the Los Alamos Canyon low-head weir, it is not certain if the mitigation actions enhanced sediment deposition, as sediment deposition is a natural geomorphic process. Nevertheless, the surveys document that these parts of the watersheds are currently operating as desired and are not undergoing net erosion. Bank erosion was documented in several areas, but bank erosion is to be expected, associated with lateral channel migration, and the surveys indicate that this eroded sediment was largely redeposited within each canyon. Field observations also indicate that much of the eroded sediment in Pueblo Canyon, which contains relatively low contaminant concentrations, was originally deposited in the floods that occurred after the Cerro Grande fire. In addition, some of the bank erosion includes noncontaminated pre-1943 sediment, and erosion of these areas does not contribute to the contaminant load in stormwater. No actions are recommended at this time except for continued annual resurveys.

7.0 REFERENCES AND MAP DATA SOURCES

7.1 References

The following list includes all documents cited in this report. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

LANL (Los Alamos National Laboratory), April 2004. "Los Alamos and Pueblo Canyons Investigation Report," Los Alamos National Laboratory document LA-UR-04-2714, Los Alamos, New Mexico. (LANL 2004, 087390)

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LANL (Los Alamos National Laboratory), September 2011. "Stormwater Performance Monitoring in the Los Alamos/Pueblo Watershed During 2010, Revision 1," Los Alamos National Laboratory document LA-UR-11-5459, Los Alamos, New Mexico. (LANL 2011, 207072)

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Reneau, S.L., D. Katzman, G.A. Kuyumjian, A. Lavine, and D.V. Malmon, February 2007. "Sediment Delivery After a Wildfire," *Geology,* Vol. 35, No. 2, pp. 151–154. (Reneau et al. 2007, 102886)

Romero, R.P., D. Ortiz, and G. Kuyumjian, August 2007. "Surface Water Data at Los Alamos National Laboratory: 2006 Water Year," Los Alamos National Laboratory report LA-14328-PR, Los Alamos, New Mexico. (Romero et al. 2007, 100140)

7.2 Map Data Sources

The following list provides data sources for maps included in the main body of this report.

Title; Owner ID; Intended Scale; Publication Date.

2000 LIDAR Hypsography; Los Alamos National Laboratory, Earth and Environmental Sciences GISLab; 1:1,200; Work in progress.

Drainage; Los Alamos National Laboratory, Environment and Remediation Support Services; 1:24,000; May 15, 2006.

Gaging stations; Los Alamos National Laboratory, Waste and Environmental Services Division; 1:2,500; March 19, 2011.

Grade control structures; Los Alamos National Laboratory, Environment and Remediation Support Services; Unknown; May 17, 2011.

LANL boundary; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; Unknown; August 16, 2010.

LANL area orthophoto; Los Alamos National Laboratory, Earth and Environmental Sciences GISLab; 1'=200'; February 25, 2009.

Location IDs; Los Alamos National Laboratory, ESH&Q Waste and Environmental Services Division; 1:2,500; May 19, 2011.

Other property boundary; Los Alamos National Laboratory, Earth and Environmental Sciences GISLab; Unknown; August 16, 2010.

Pueblo and DP Canyon cross sections and thalwegs; Los Alamos National Laboratories, Earth and Environmental Sciences GISLab; Unknown; May 2011.

Roads, surfaced; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; Unknown; November 30, 2010.

Technical area boundary; Los Alamos National Laboratory, Site Planning and Project Initiation Group, Infrastructure Planning Office; Unknown; August 16, 2010.

Watershed; Los Alamos National Laboratory, Environment and Remediation Support Services; 1:2,500; November 2, 2006.

Wells; Los Alamos National Laboratory, ESH&Q Waste and Environmental Services Division; 1:2,500; May 19, 2011.

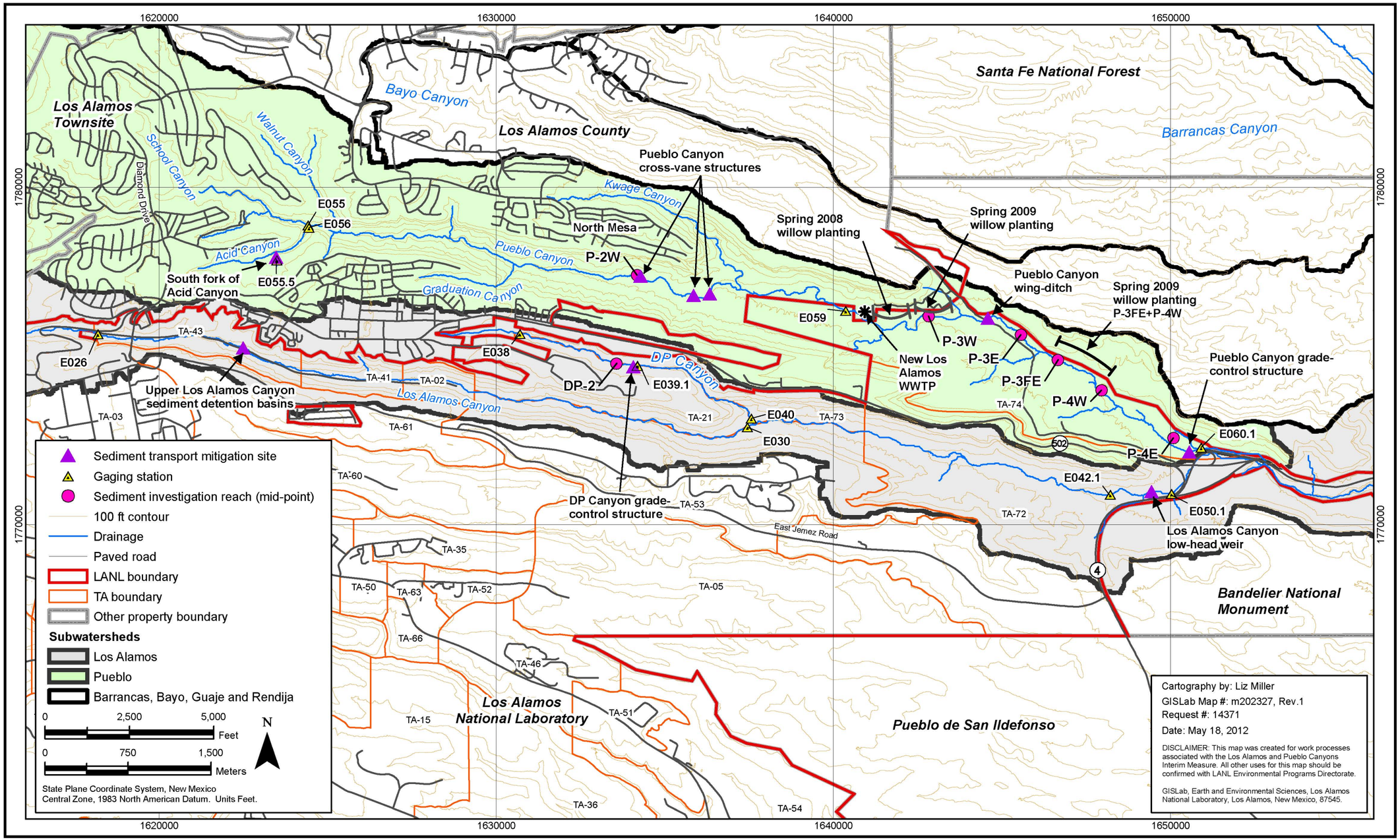


Figure 1.0-1 Los Alamos and Pueblo Canyon watersheds, showing sediment transport mitigation sites and stream gages

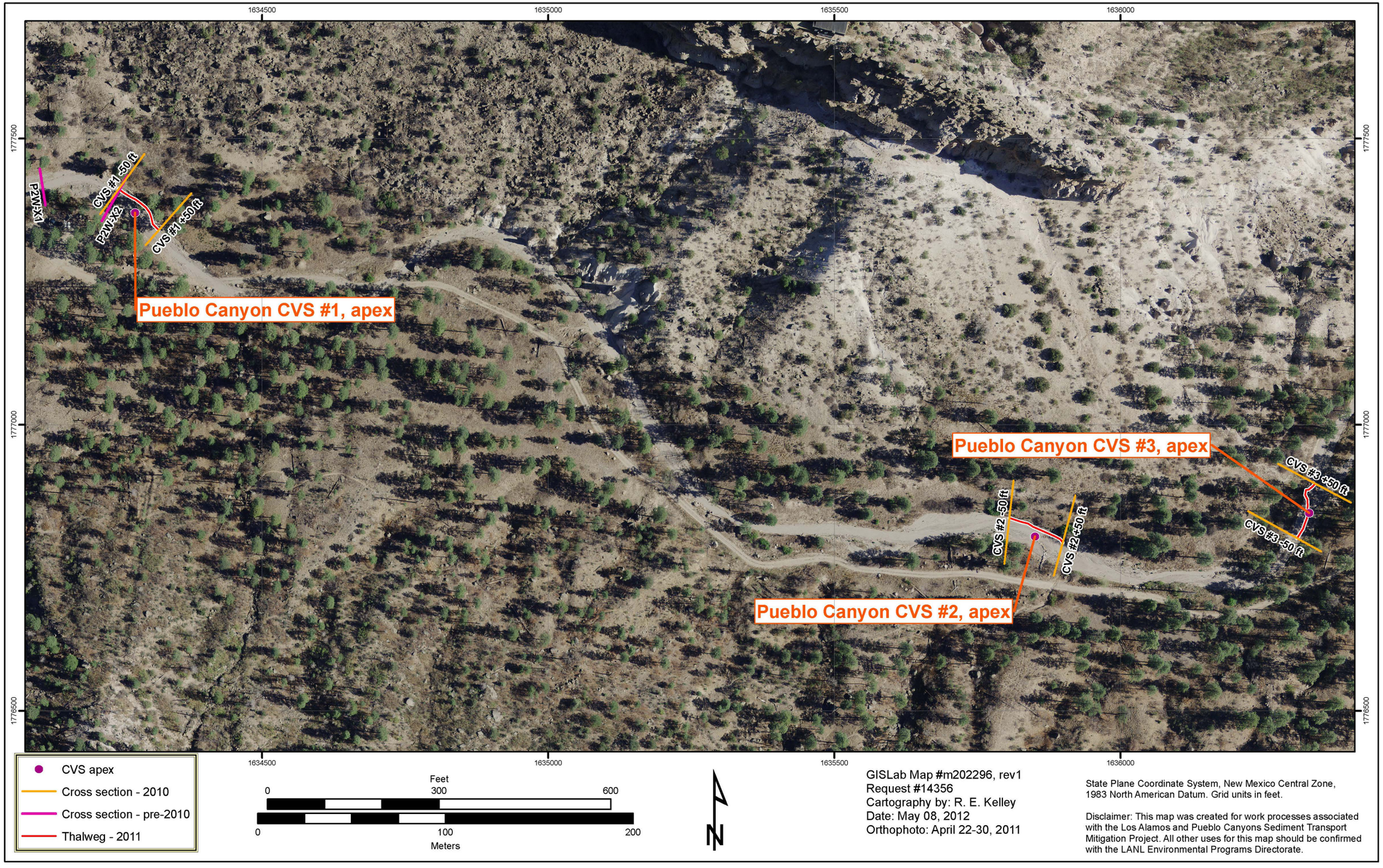


Figure 3.1-1 Orthophoto showing the locations of surveyed cross-sections and thalweg profiles at the Pueblo Canyon CVSs

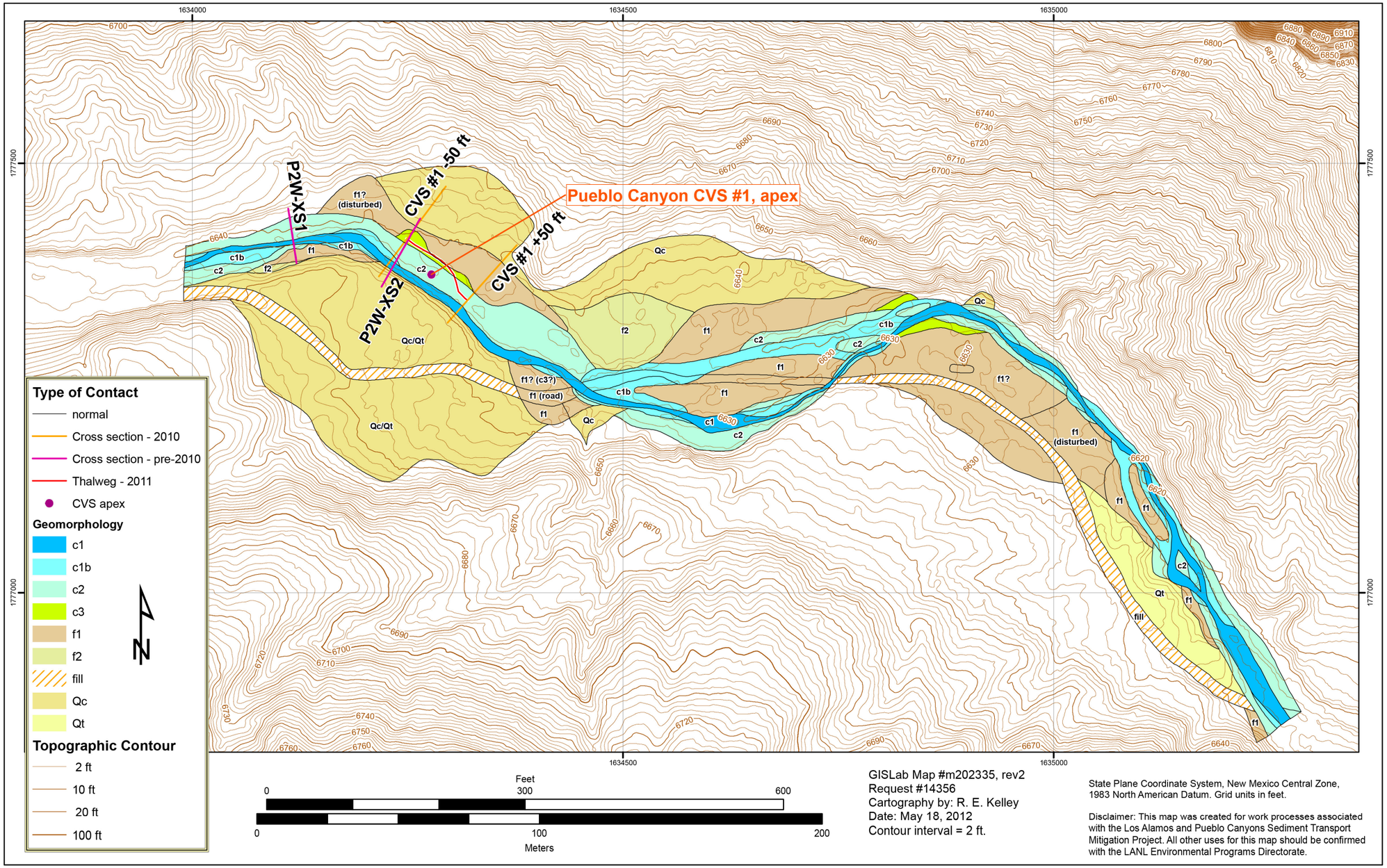


Figure 3.1-2 Geomorphic map showing the locations of surveyed cross-sections and thalweg profile at Pueblo Canyon CVS #1; geomorphic mapping from 1997

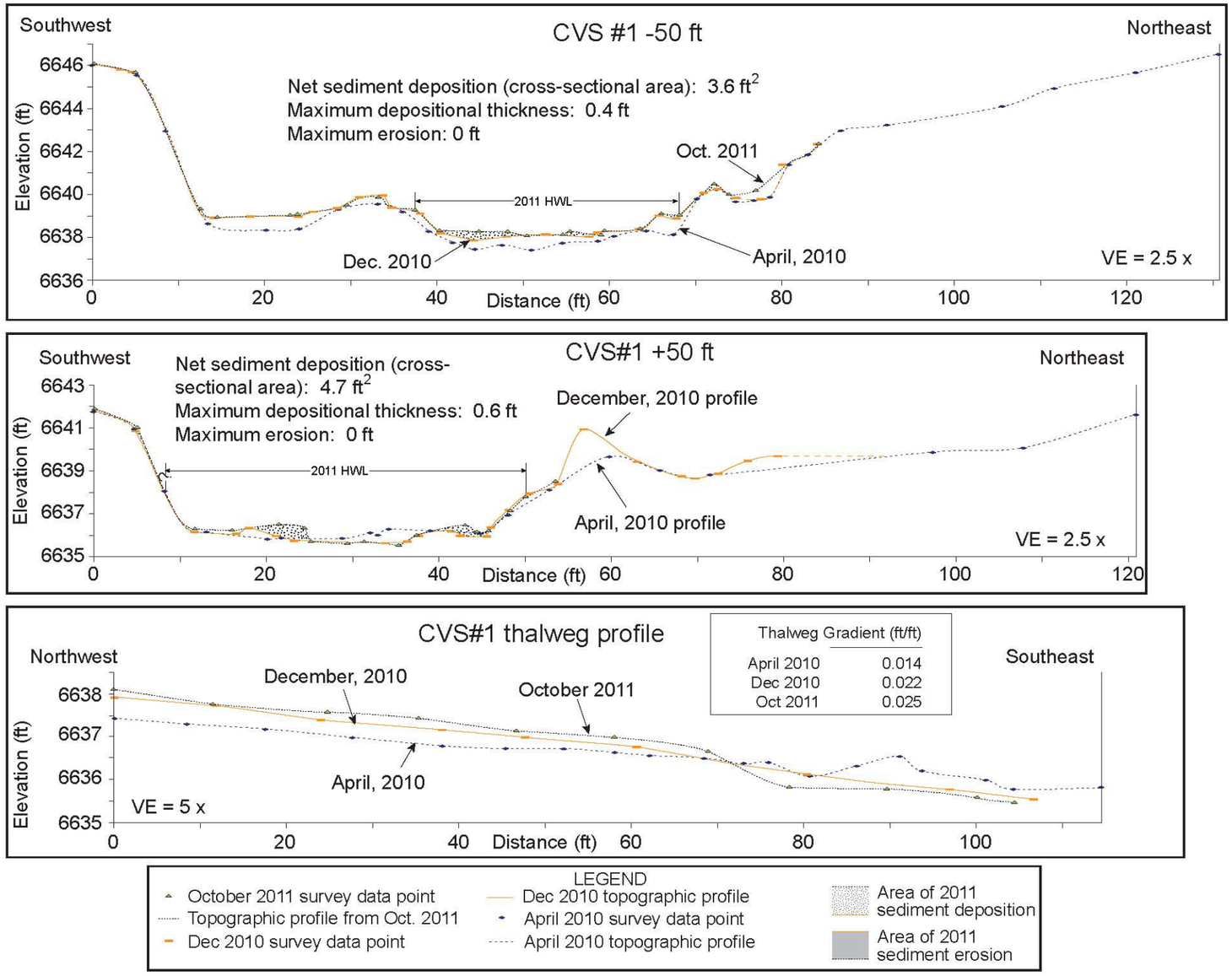


Figure 3.1-3 Cross-sections and thalweg profile at Pueblo Canyon CVS #1

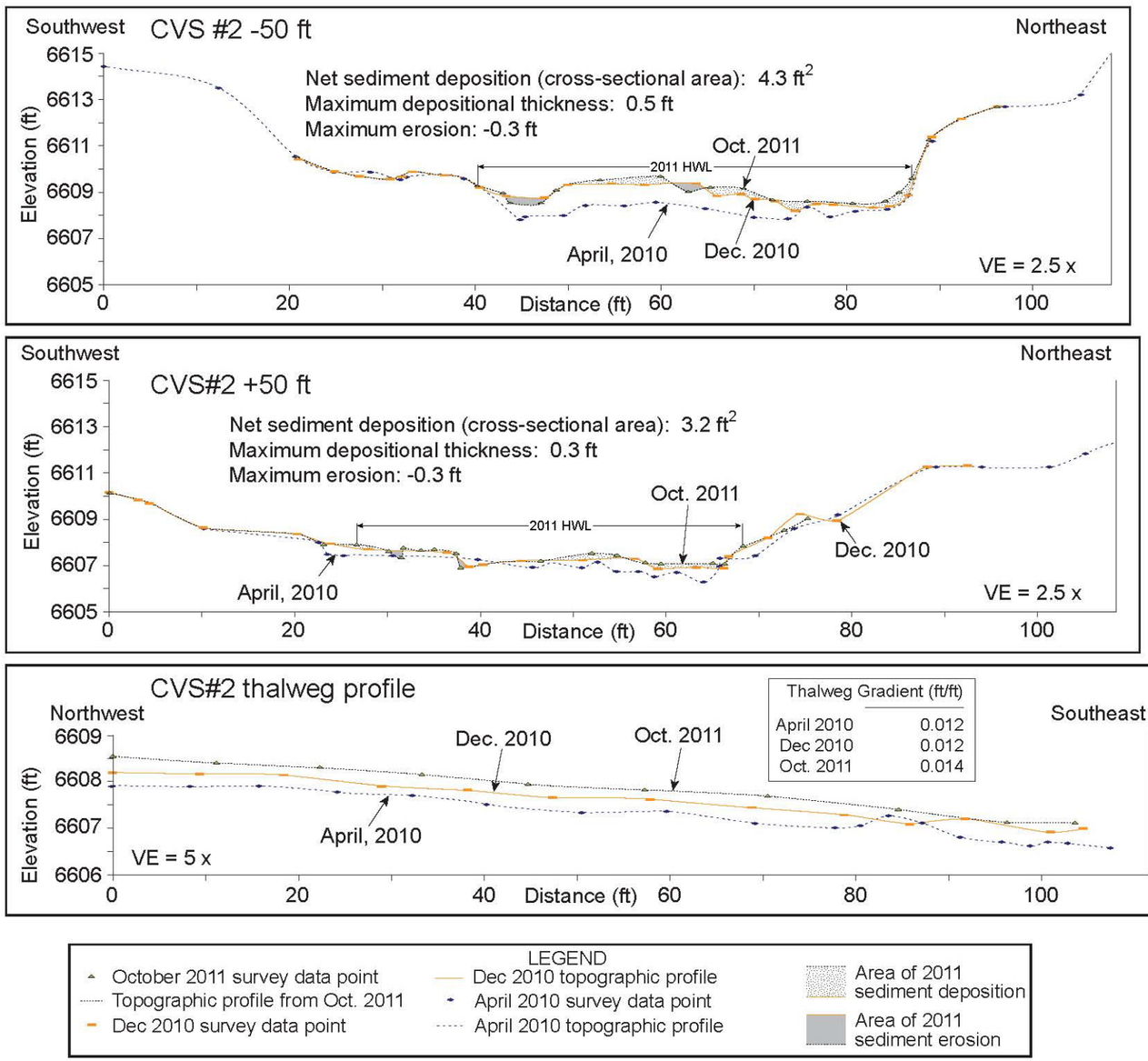
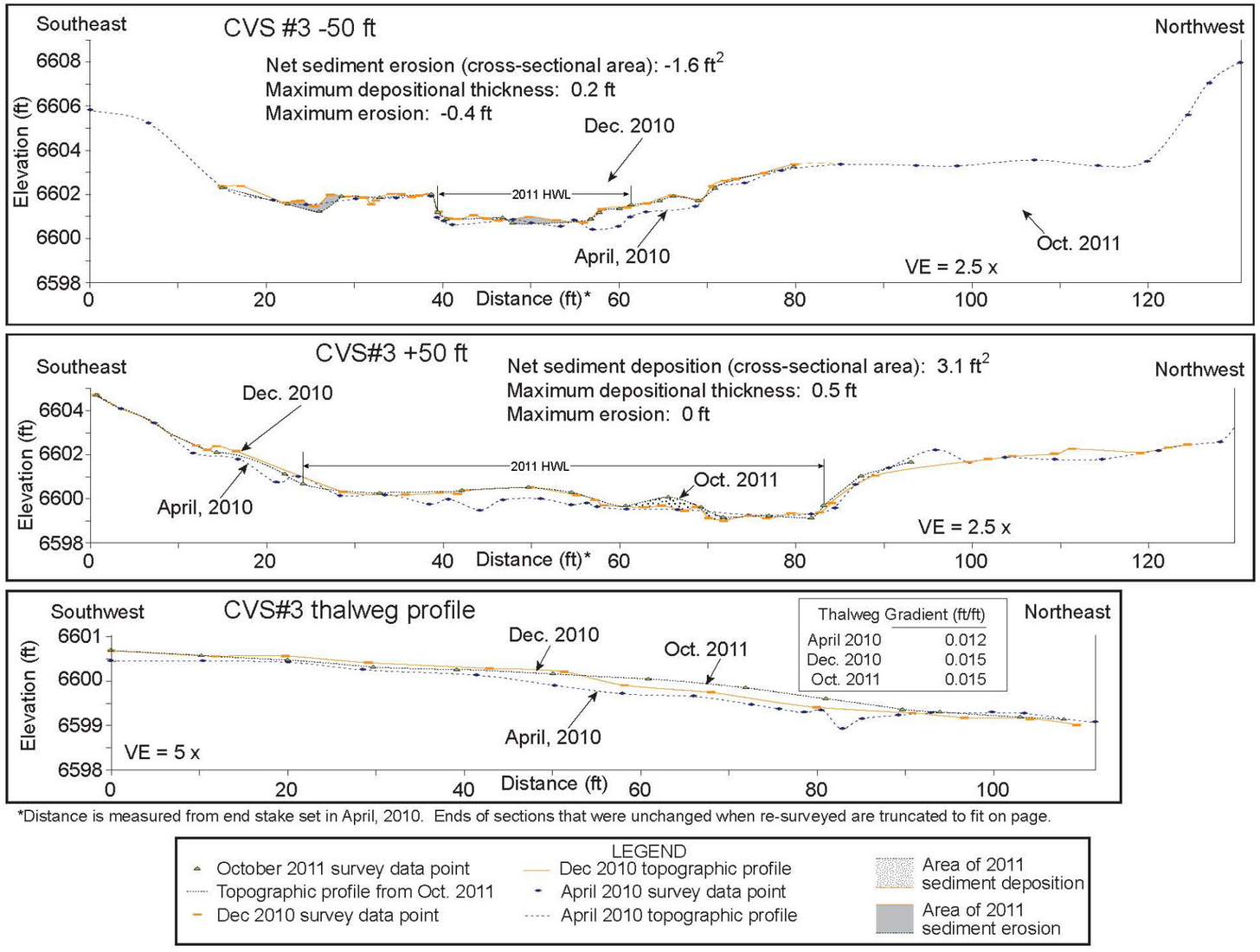
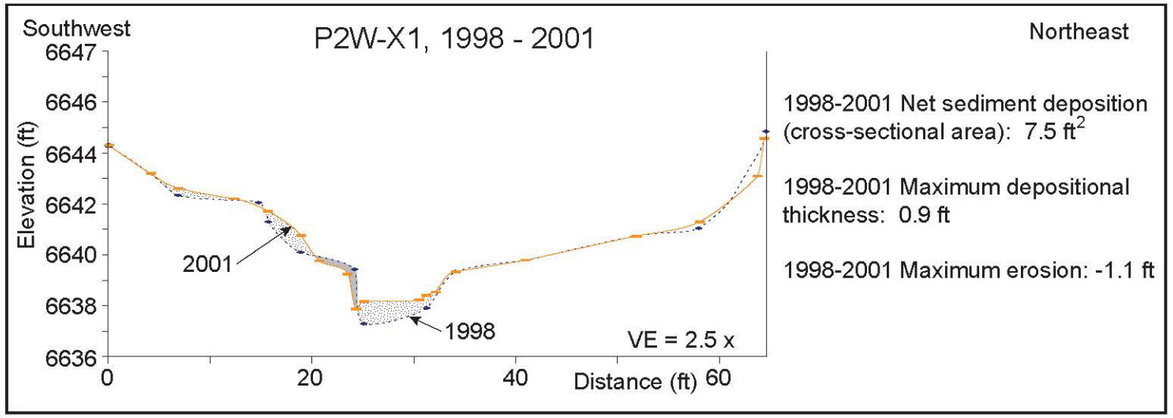


Figure 3.1-4 Cross-sections and thalweg profile at Pueblo Canyon CVS #2



*Distance is measured from end stake set in April, 2010. Ends of sections that were unchanged when re-surveyed are truncated to fit on page.

Figure 3.1-5 Cross-sections and thalweg profile at Pueblo Canyon CVS #3



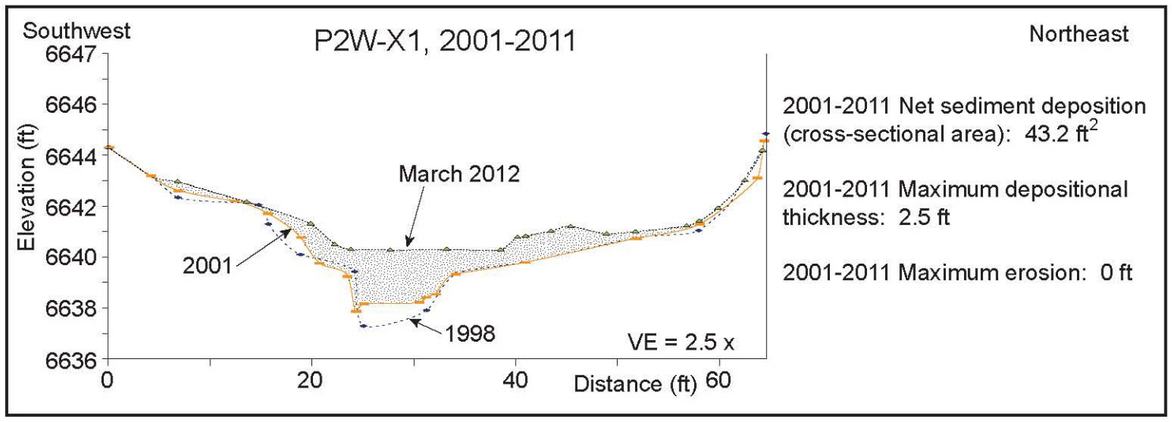
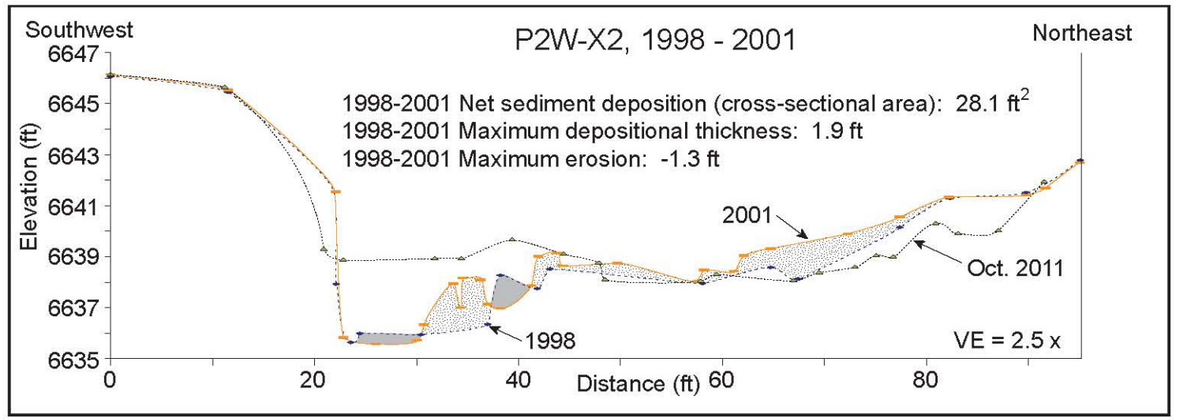




Figure 3.1-6 P2W-X1 cross-section in 1998, 2001, and 2011



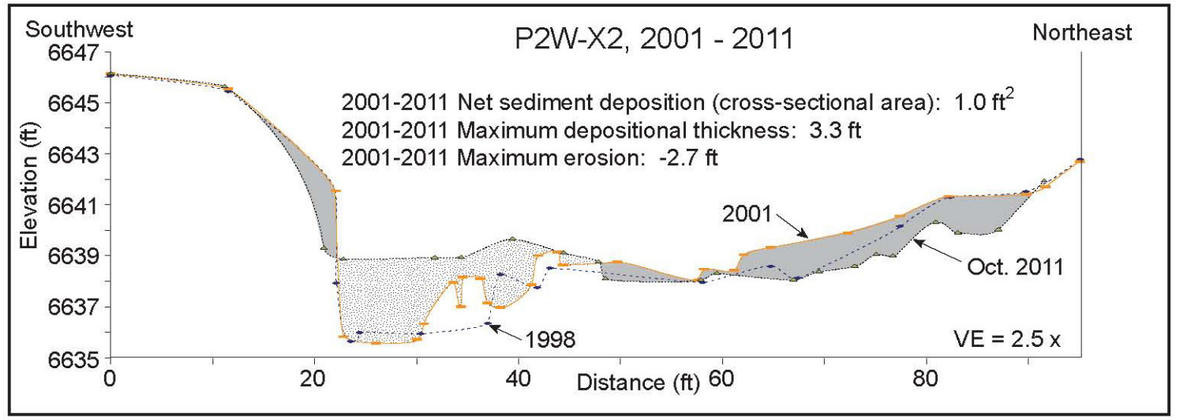




Figure 3.1-7 P2W-X2 cross-section in 1998, 2001, and 2011

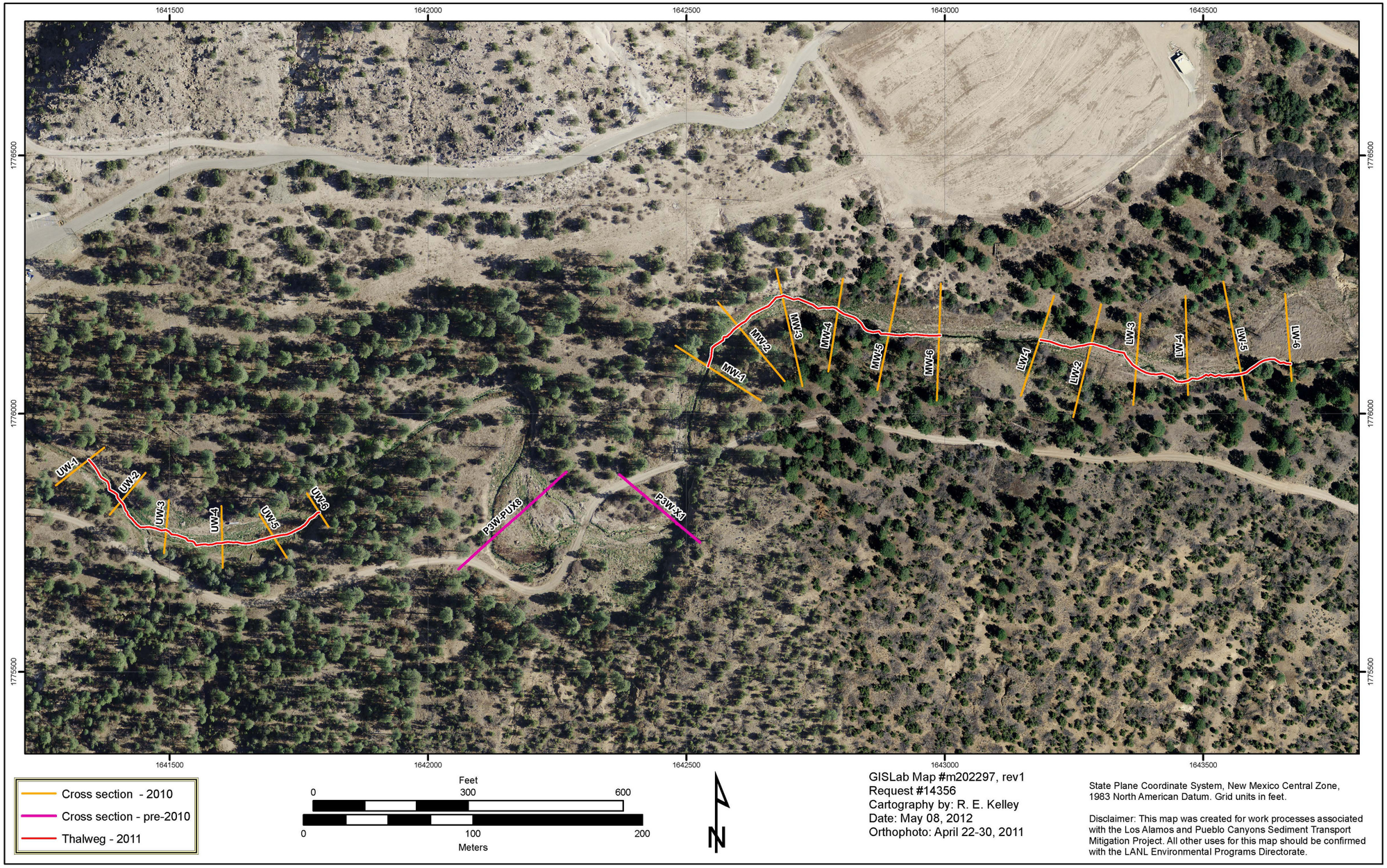


Figure 3.2-1 Orthophoto showing the locations of surveyed cross-sections and thalweg profiles in the upper Pueblo Canyon willow-planting area

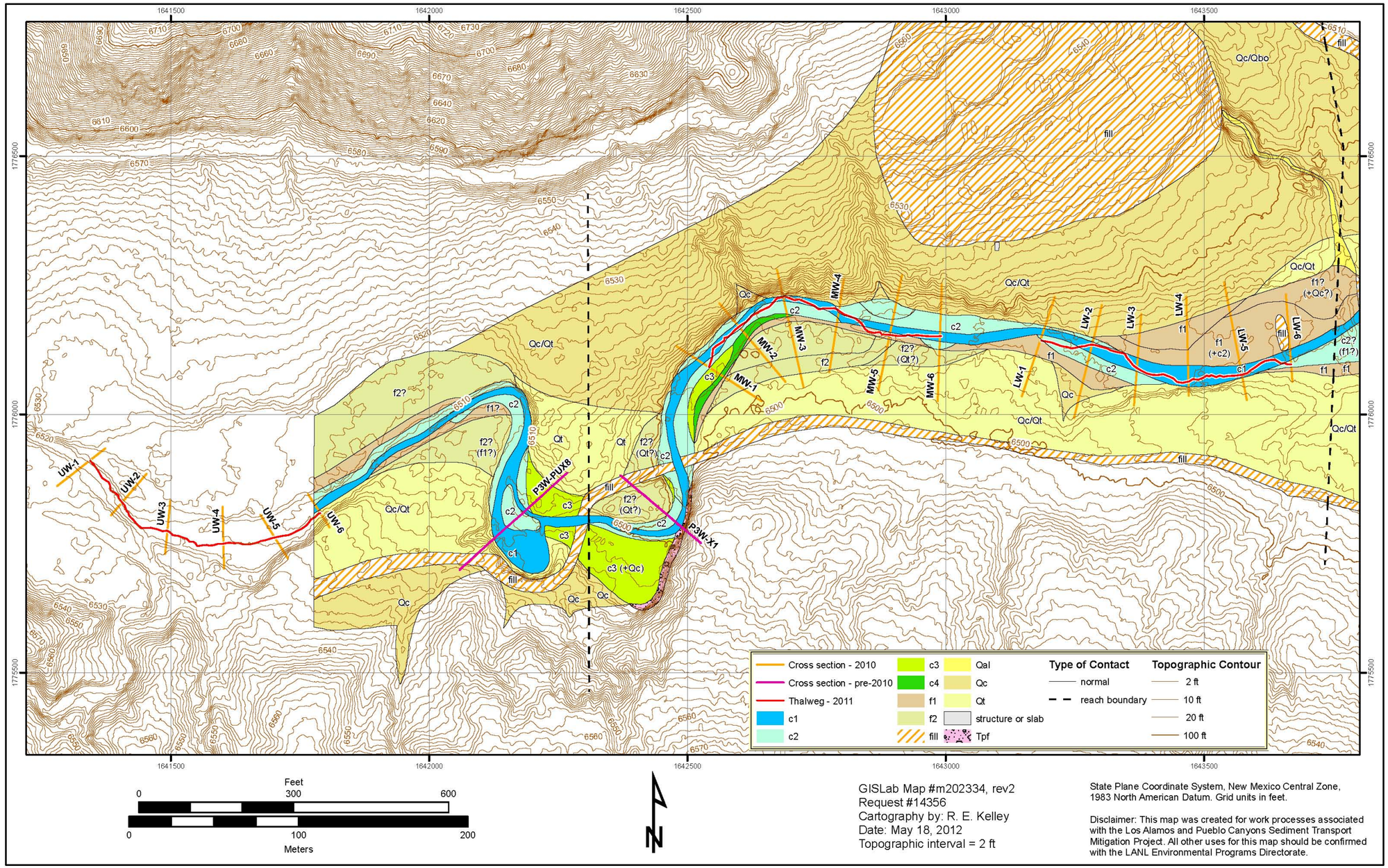


Figure 3.2-2 Geomorphic map showing the locations of surveyed cross-sections and thalweg profiles in the upper Pueblo Canyon willow-planting area; geomorphic mapping from 1997

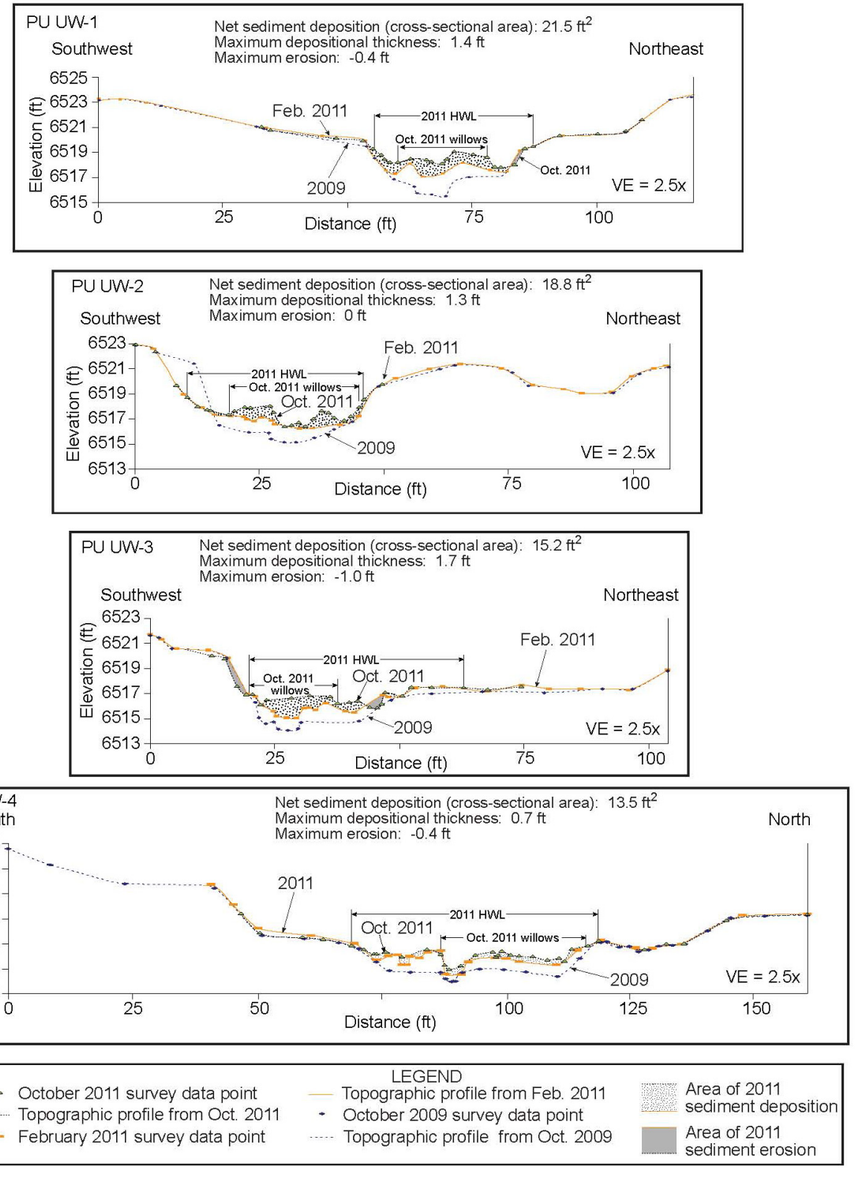


Figure 3.2-3 Cross-sections and thalweg profile in upper third of upper Pueblo Canyon willow-planting area

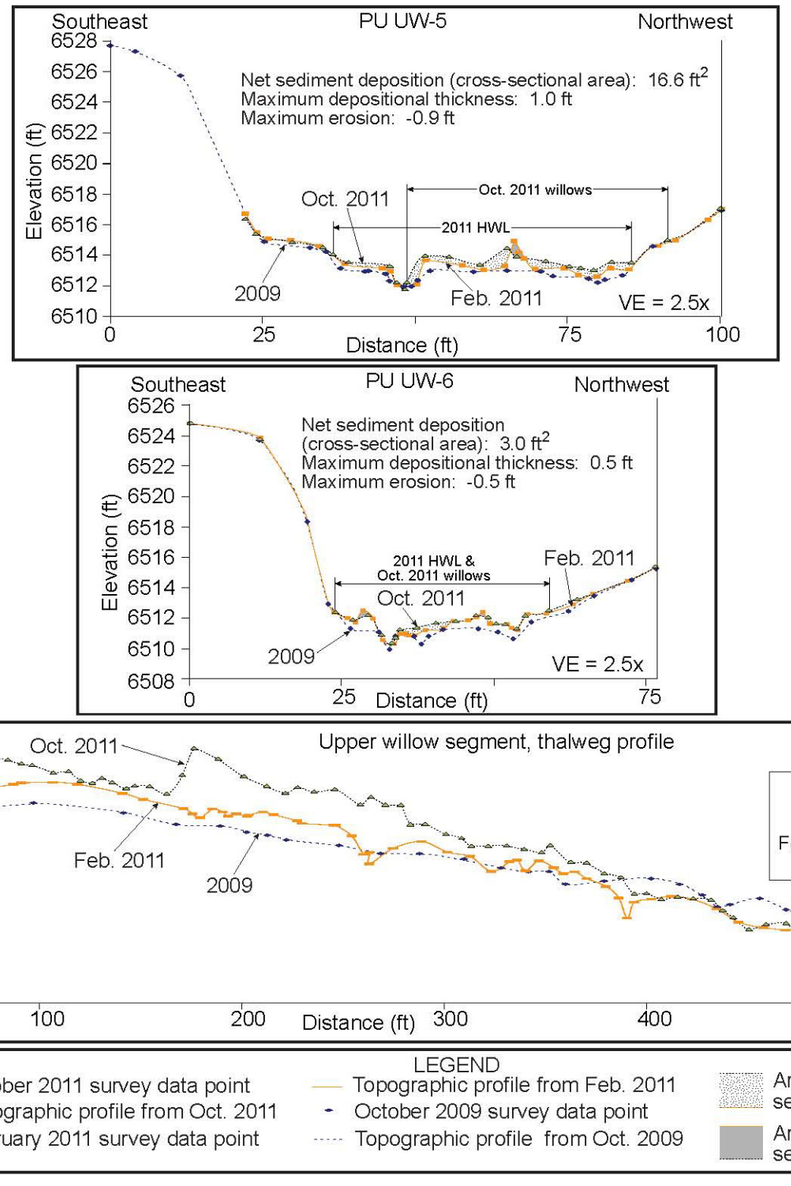
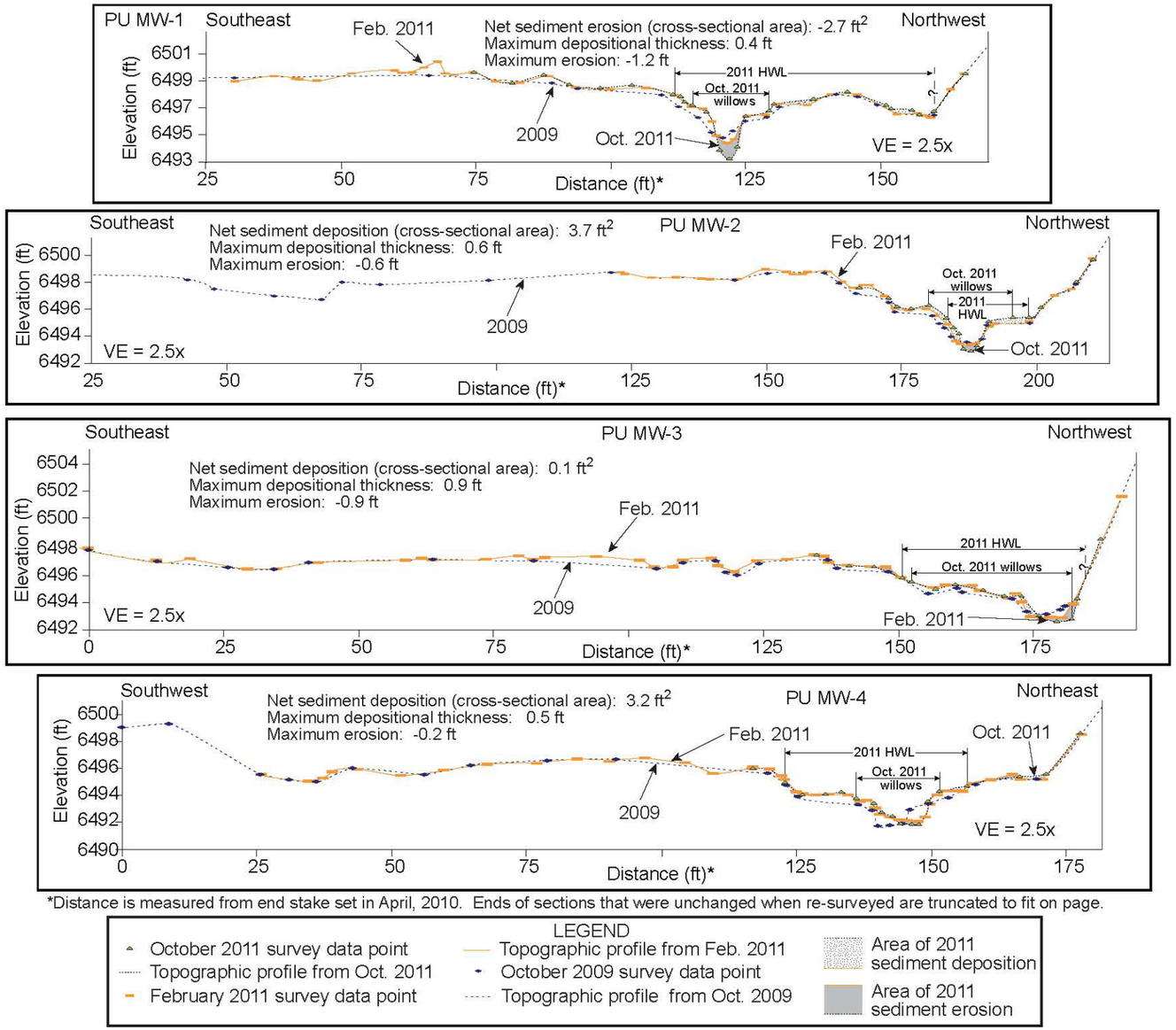
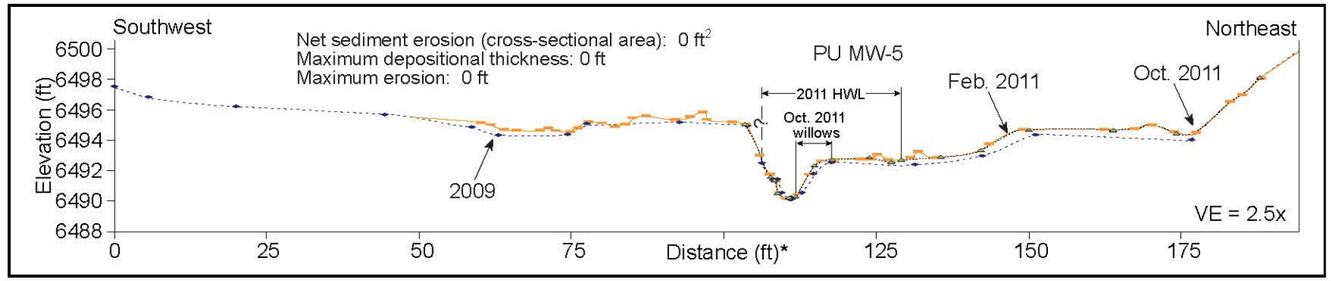


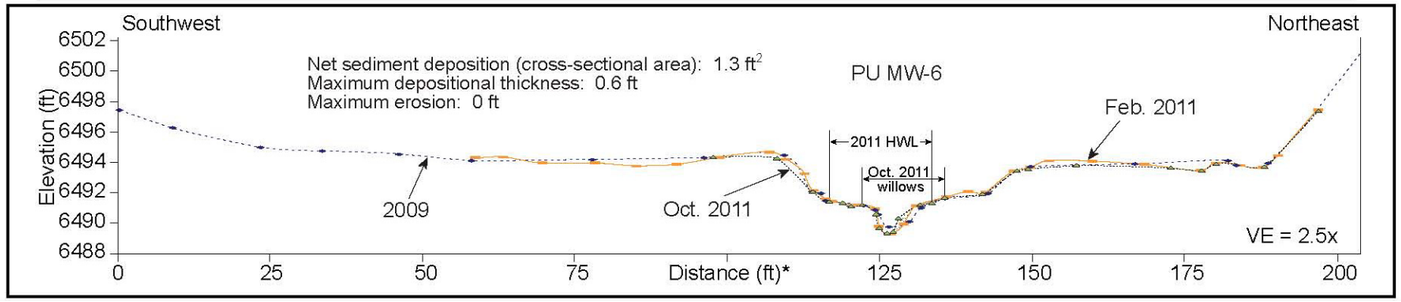
Figure 3.2-3 (continued) **Cross-sections and thalweg profile in upper third of upper Pueblo Canyon willow-planting area**

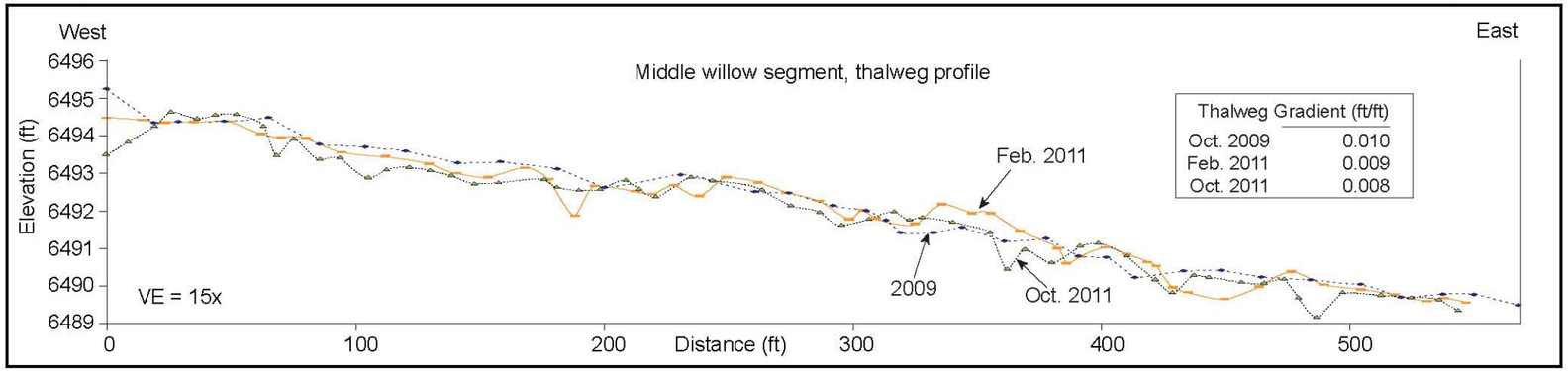


*Distance is measured from end stake set in April, 2010. Ends of sections that were unchanged when re-surveyed are truncated to fit on page.

Figure 3.2-4 Cross-sections and thalweg profile in middle third of upper Pueblo Canyon willow-planting area







*Distance is measured from end stake set in April, 2010. Ends of sections that were unchanged when re-surveyed are truncated to fit on page.

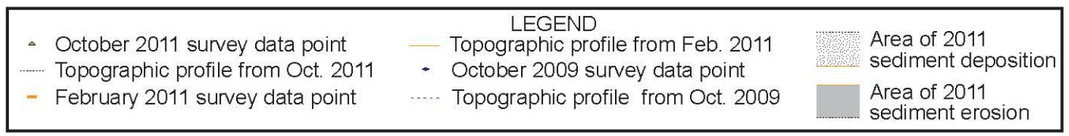
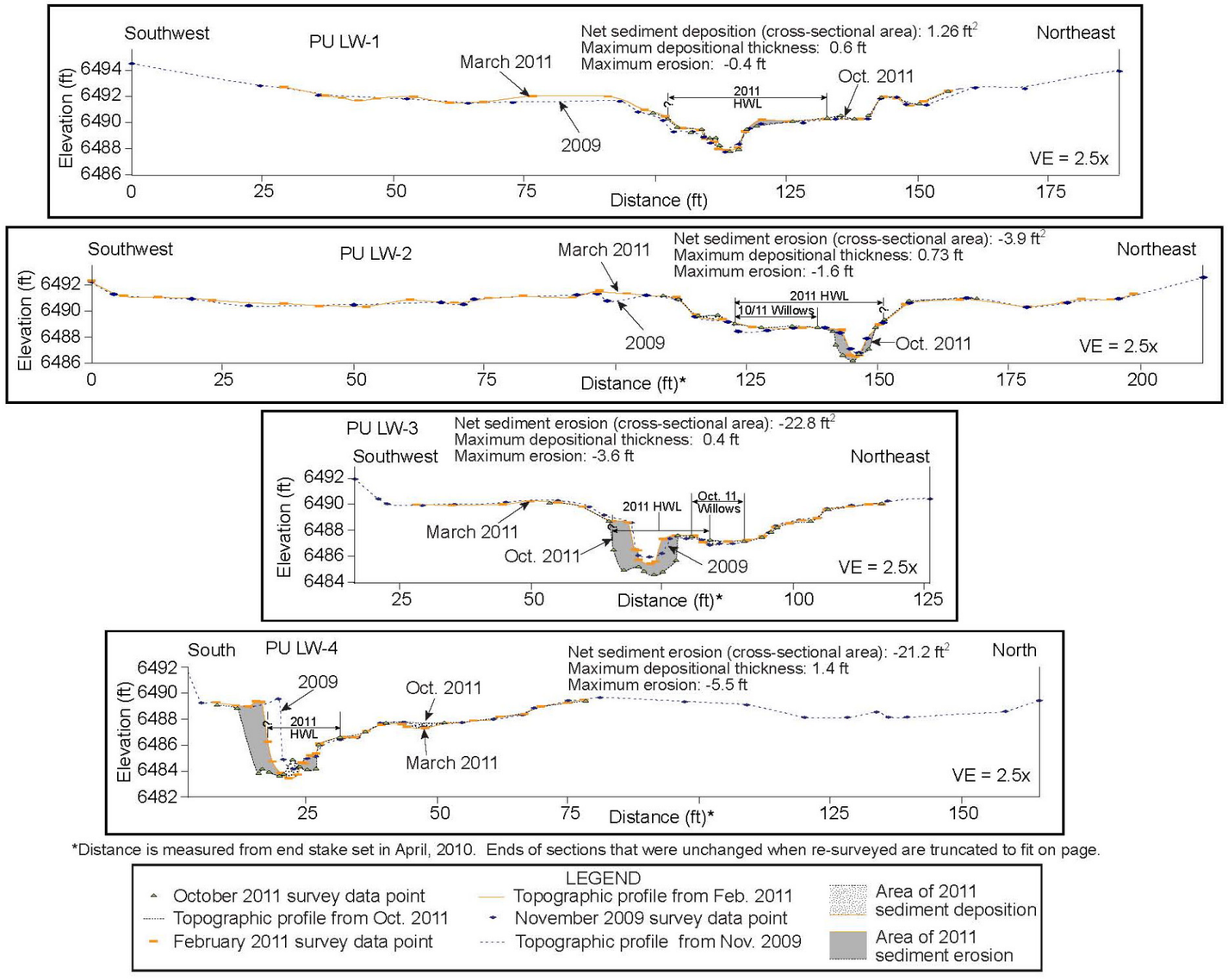
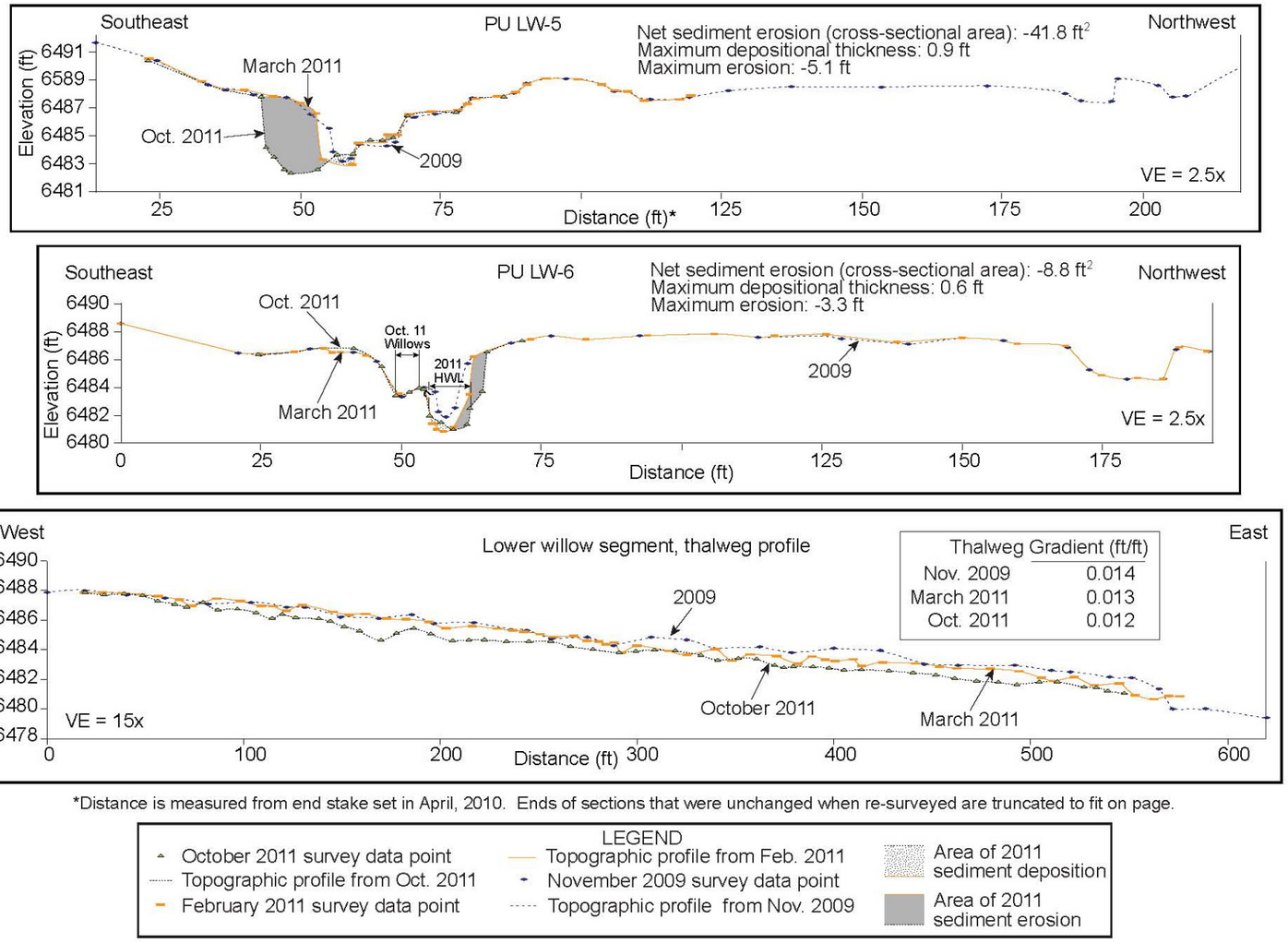


Figure 3.2-4 (continued) **Cross-sections and thalweg profile in middle third of upper Pueblo Canyon willow-planting area**



*Distance is measured from end stake set in April, 2010. Ends of sections that were unchanged when re-surveyed are truncated to fit on page.

Figure 3.2-5 Cross-sections and thalweg profile in lower third of upper Pueblo Canyon willow-planting area



*Distance is measured from end stake set in April, 2010. Ends of sections that were unchanged when re-surveyed are truncated to fit on page.

Figure 3.2-5 (continued) **Cross-sections and thalweg profile in lower third of upper Pueblo Canyon willow-planting area**

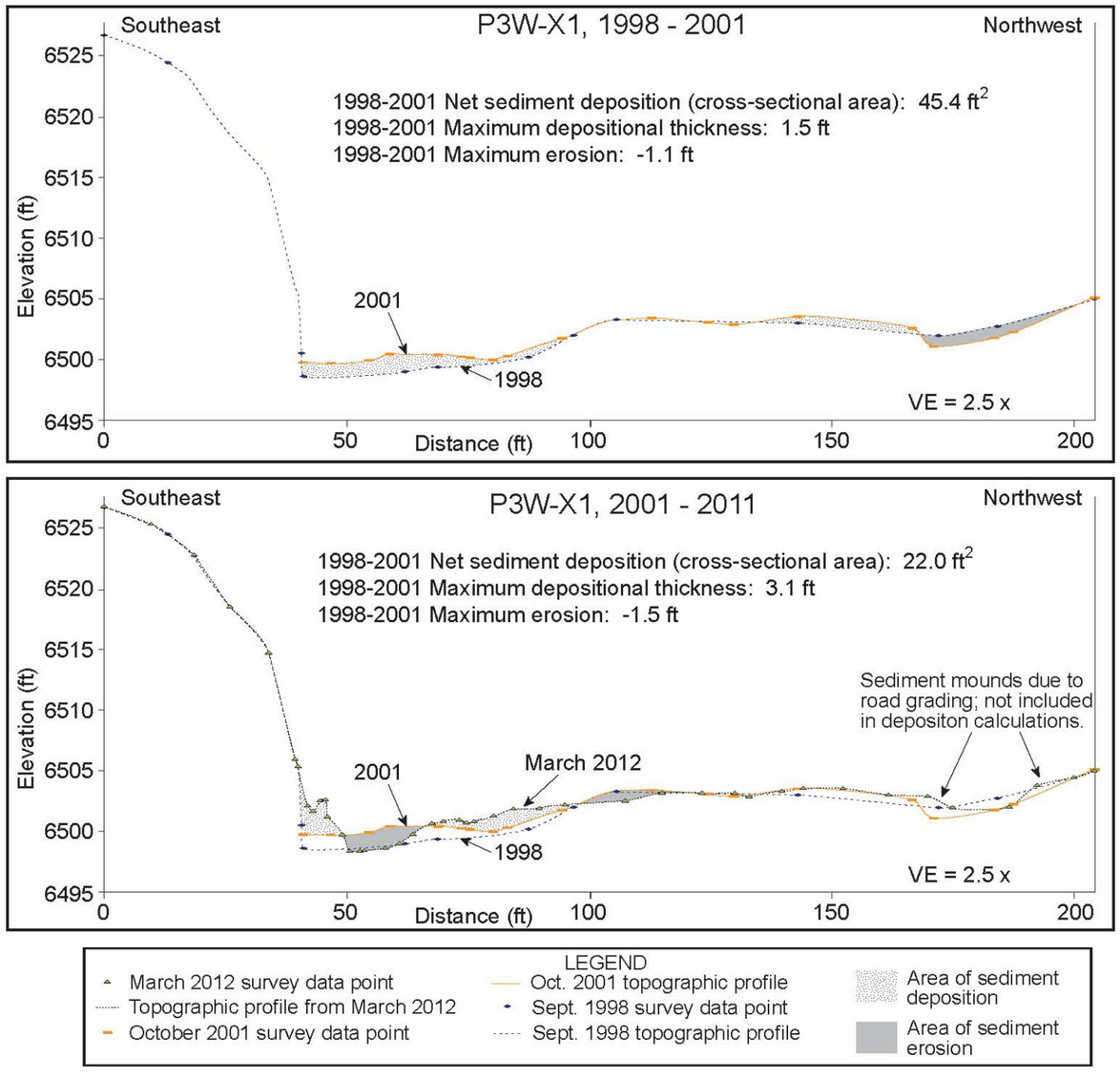


Figure 3.2-6 P3W-X1 cross-section in 1998, 2001, and 2011

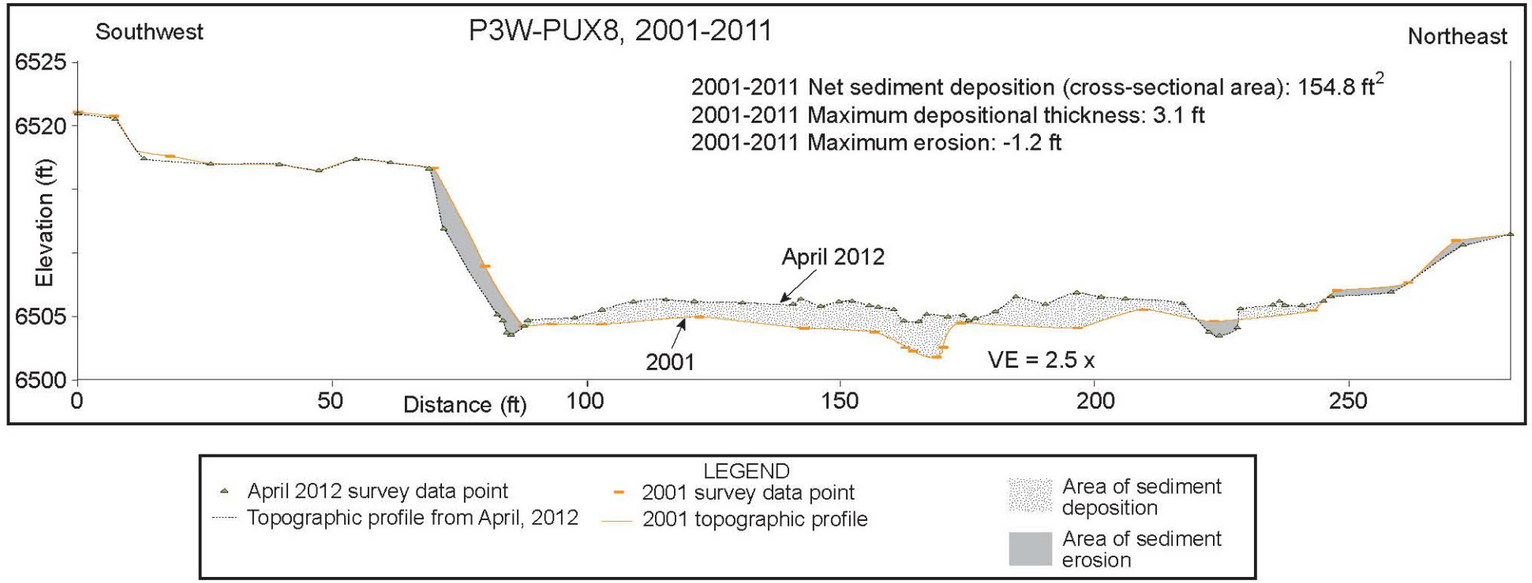


Figure 3.2-7 P3W-PUX8 cross-section in 1998, 2001, and 2011

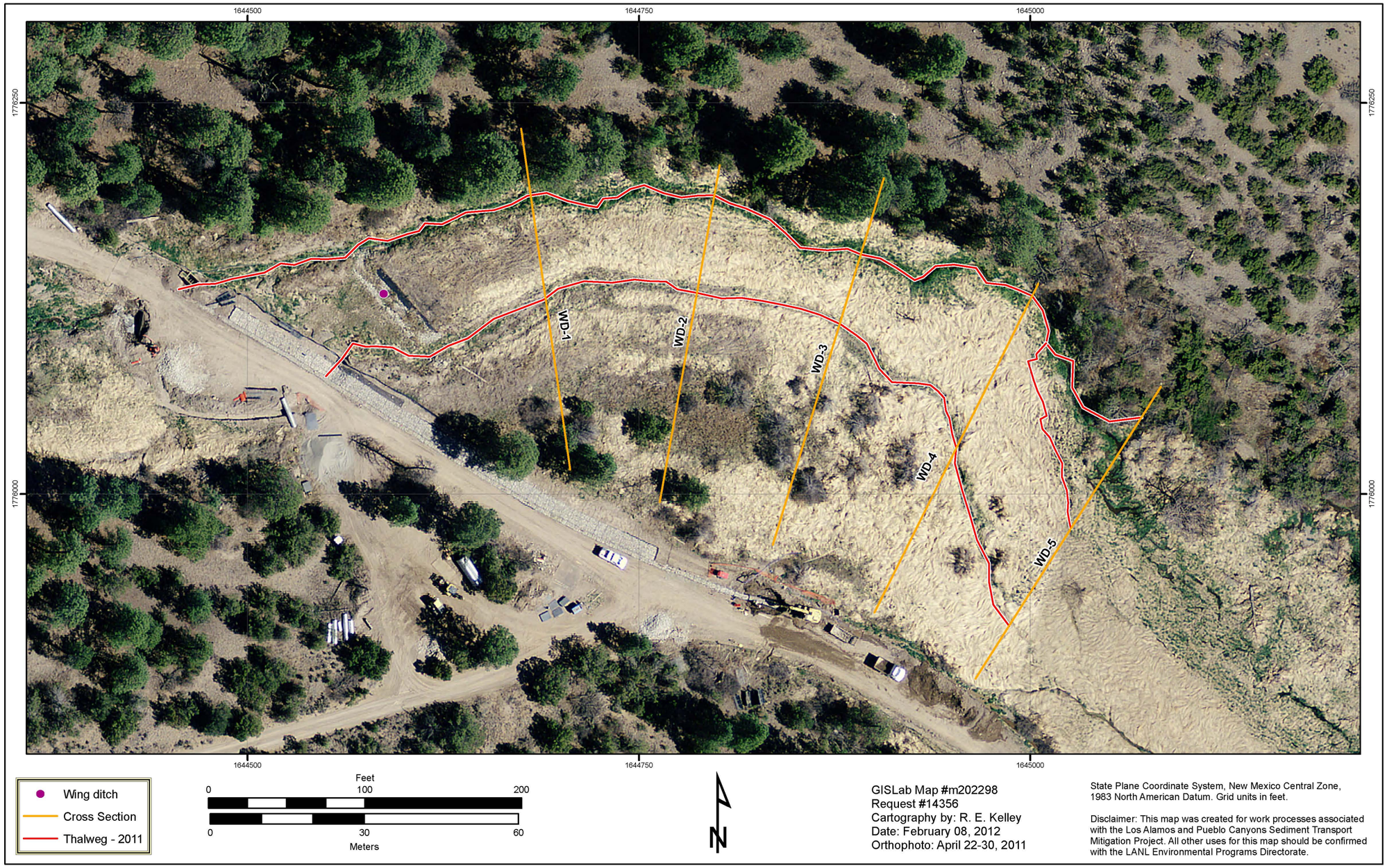


Figure 3.3-1 Orthophoto showing the locations of surveyed cross-sections and thalweg profiles near the Pueblo Canyon wing ditch; also shown is road reconstruction in progress by Los Alamos County

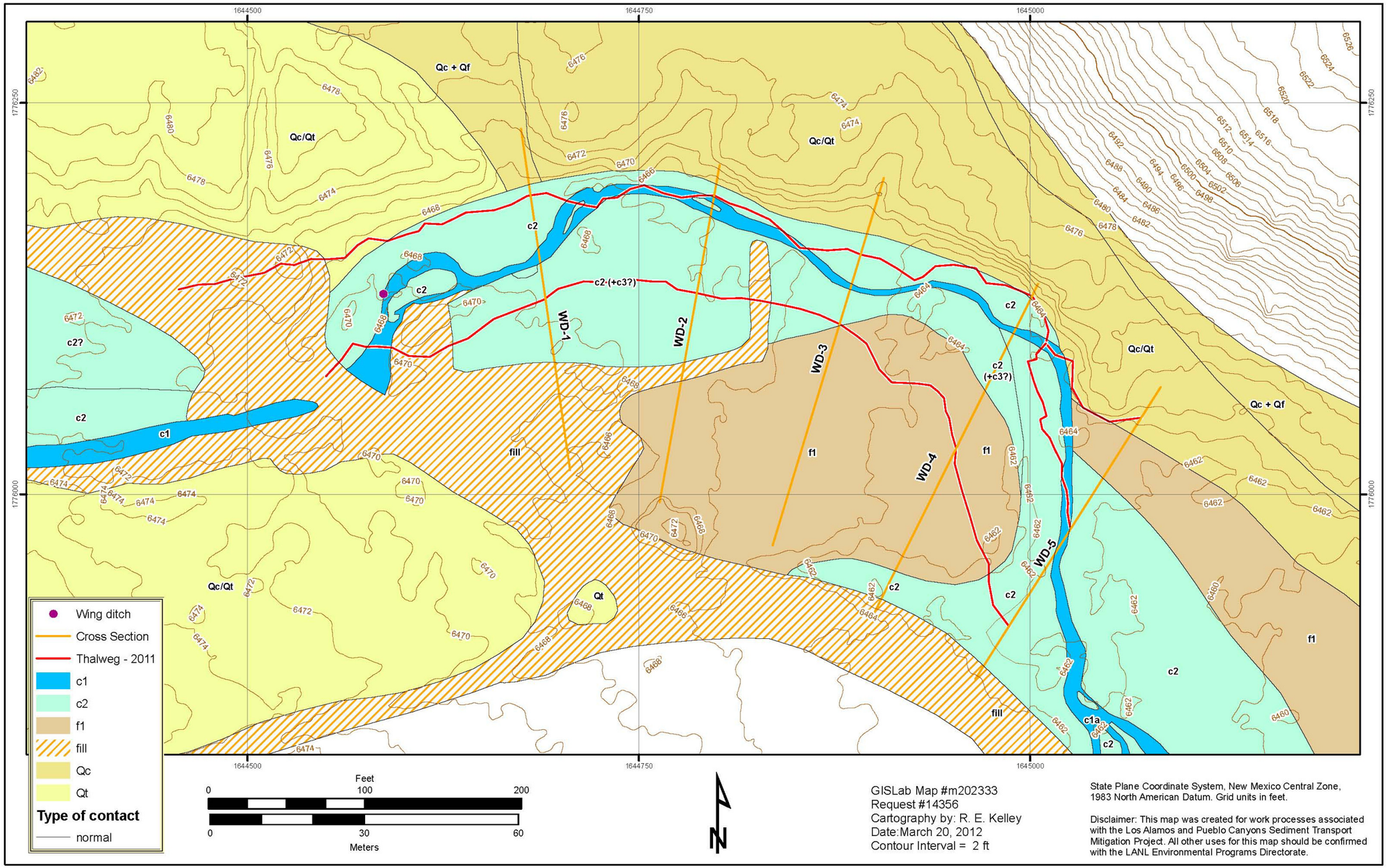
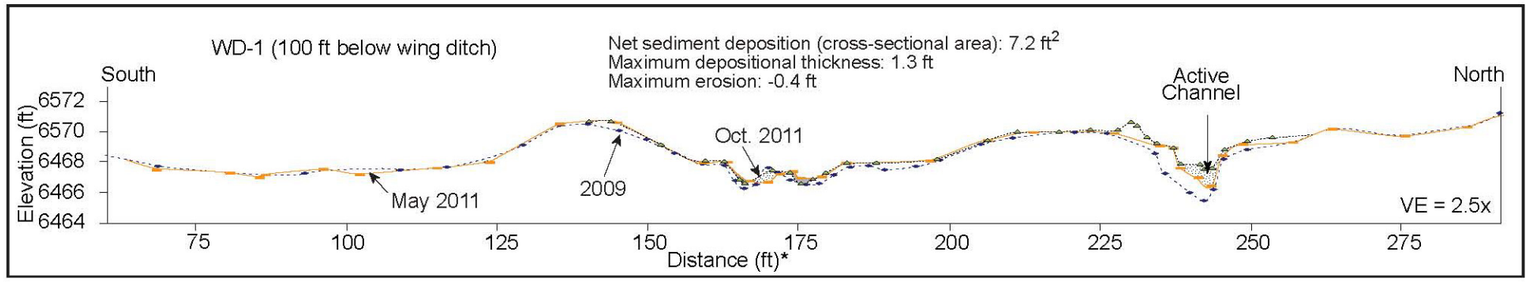
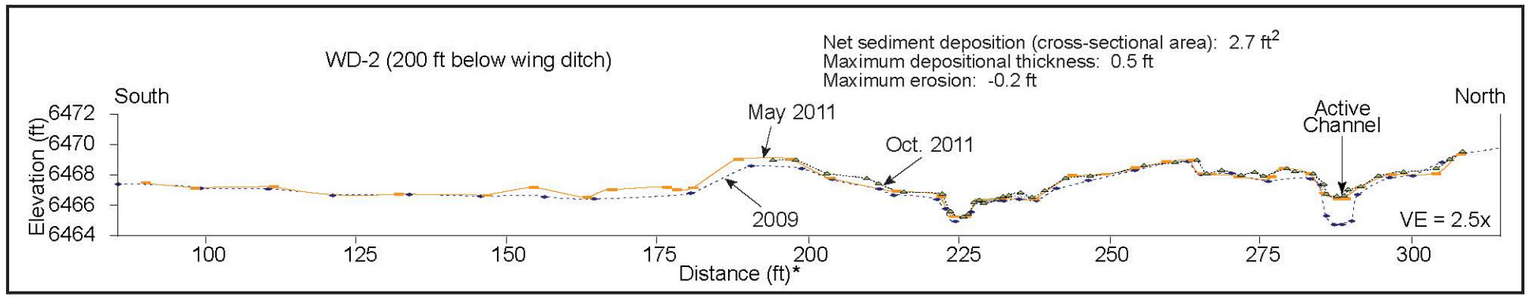
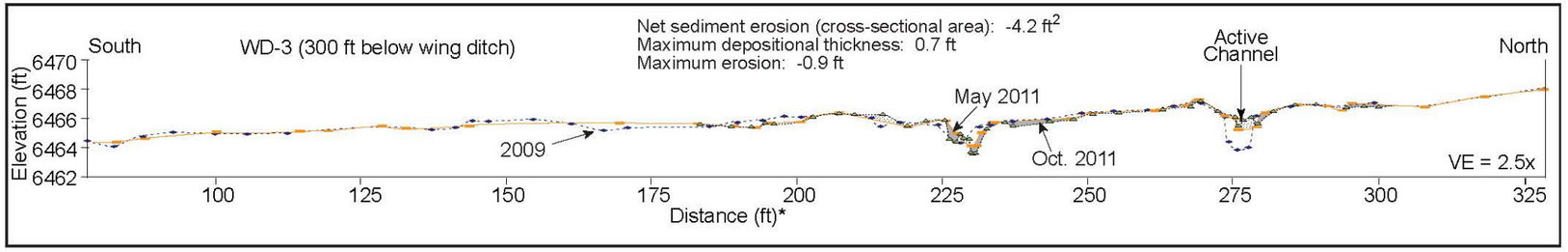


Figure 3.3-2 Geomorphic map showing the locations of surveyed cross-sections and thalweg profiles near the Pueblo Canyon wing ditch; geomorphic mapping from 1997







*Distance is measured from end stake set in November, 2009. Ends of sections that were unchanged when re-surveyed are truncated to fit on page.

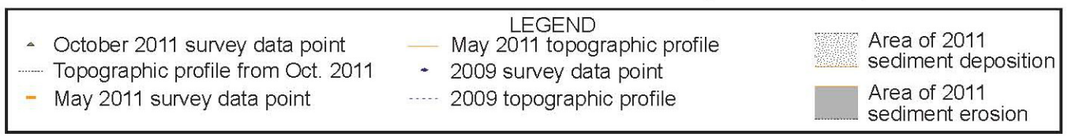
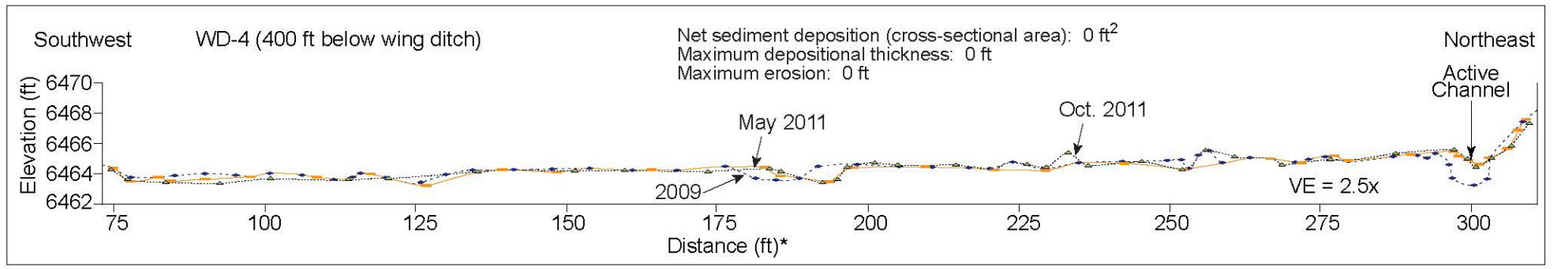
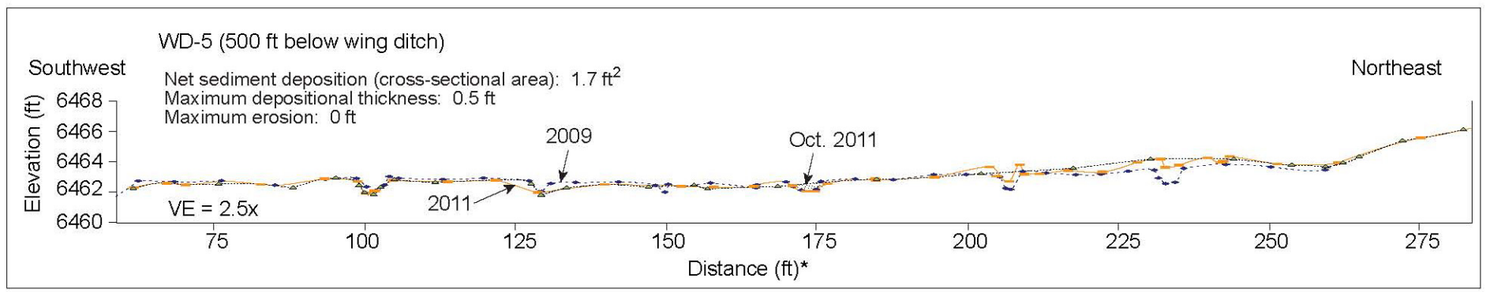


Figure 3.3-3 Cross-sections below the Pueblo Canyon wing ditch





*Distance is measured from end stake set in November, 2009. Ends of sections that were unchanged when re-surveyed are truncated to fit on page.

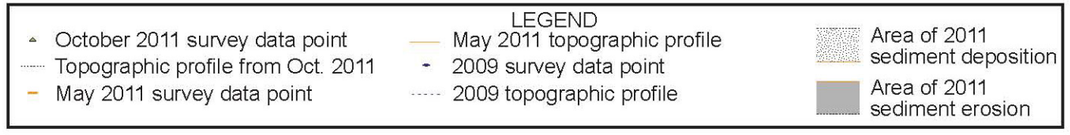
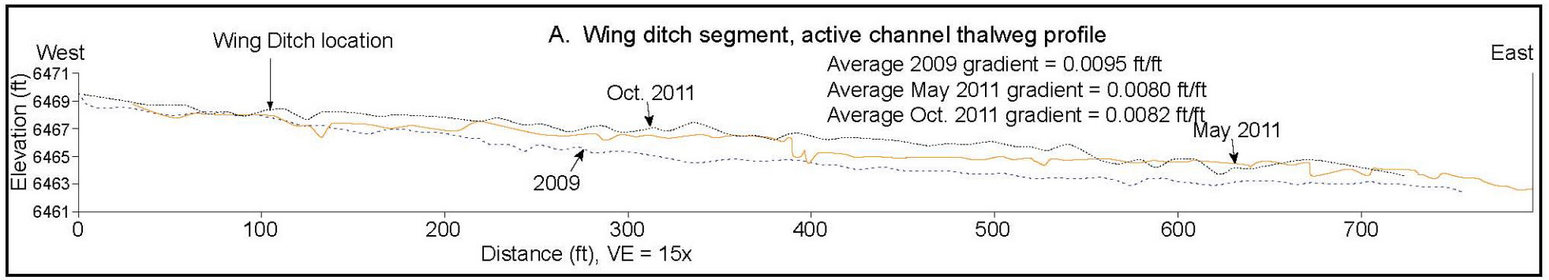
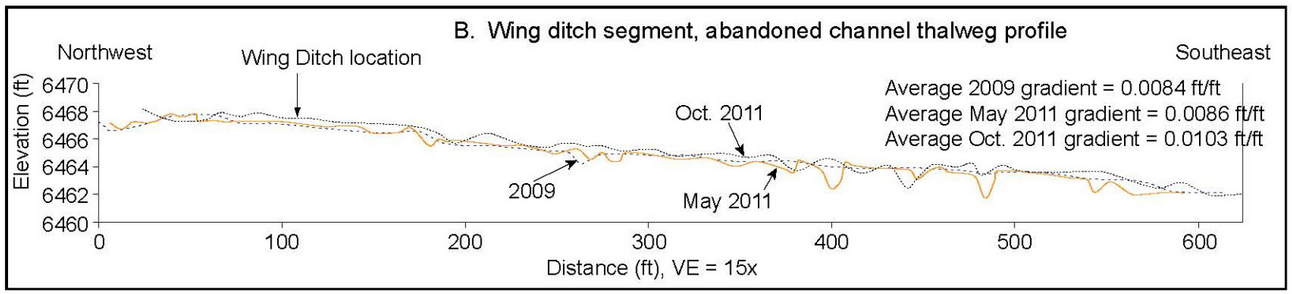


Figure 3.3-3 (continued) **Cross-sections below the Pueblo Canyon wing ditch**





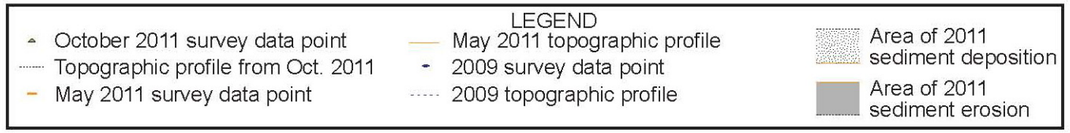


Figure 3.3-4 Thalweg profiles near the Pueblo Canyon wing ditch

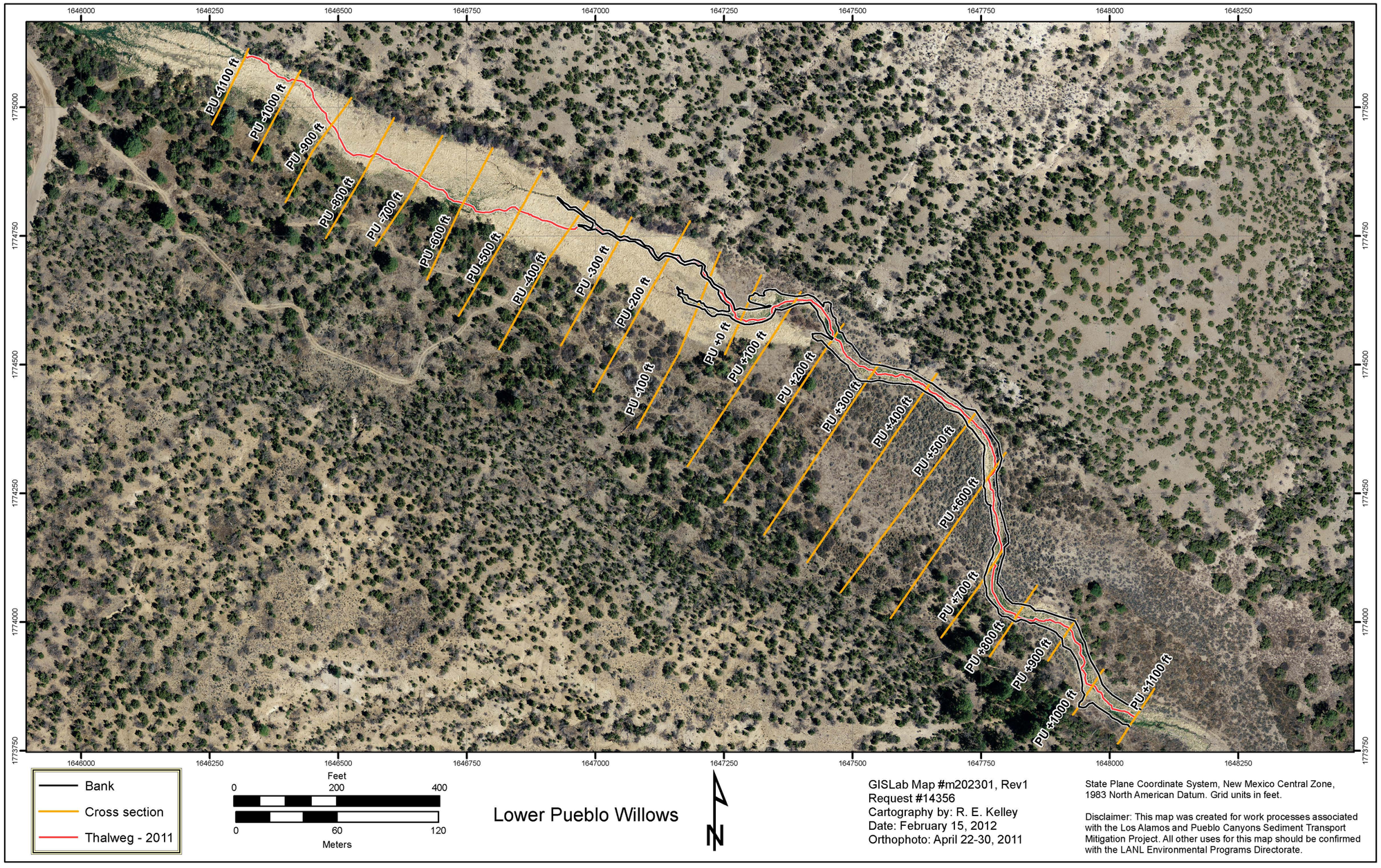


Figure 3.4-1 Orthophoto showing the locations of surveyed cross-sections, thalweg profiles, and stream banks in the lower Pueblo Canyon willow-planting area

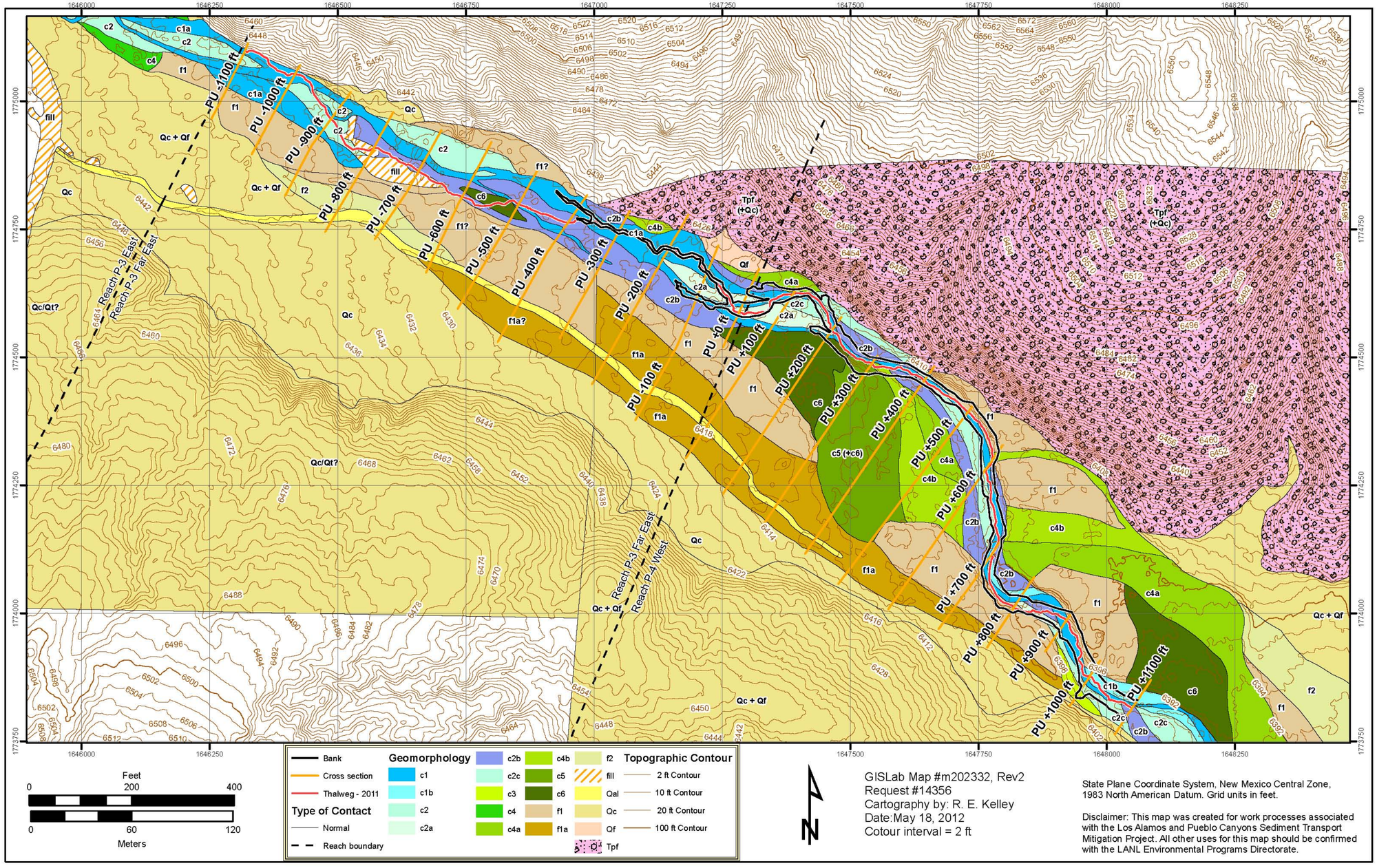
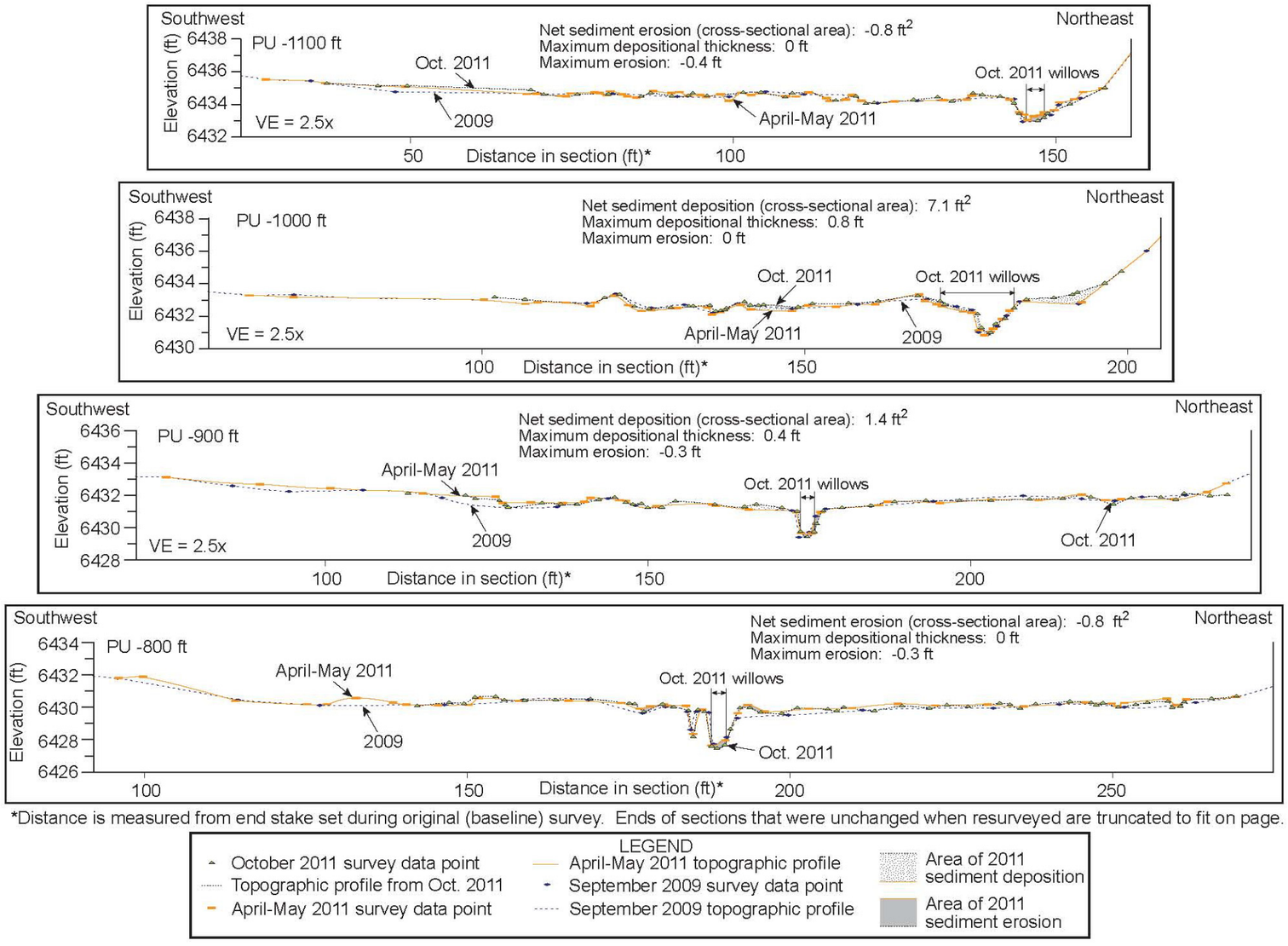


Figure 3.4-2 Geomorphic map showing the locations of surveyed cross-sections, thalweg profiles, and stream banks in the lower Pueblo Canyon willow-planting area; geomorphic mapping from 1996–1997



*Distance is measured from end stake set during original (baseline) survey. Ends of sections that were unchanged when resurveyed are truncated to fit on page.

Figure 3.4-3 Cross-sections in the lower Pueblo Canyon willow-planting area

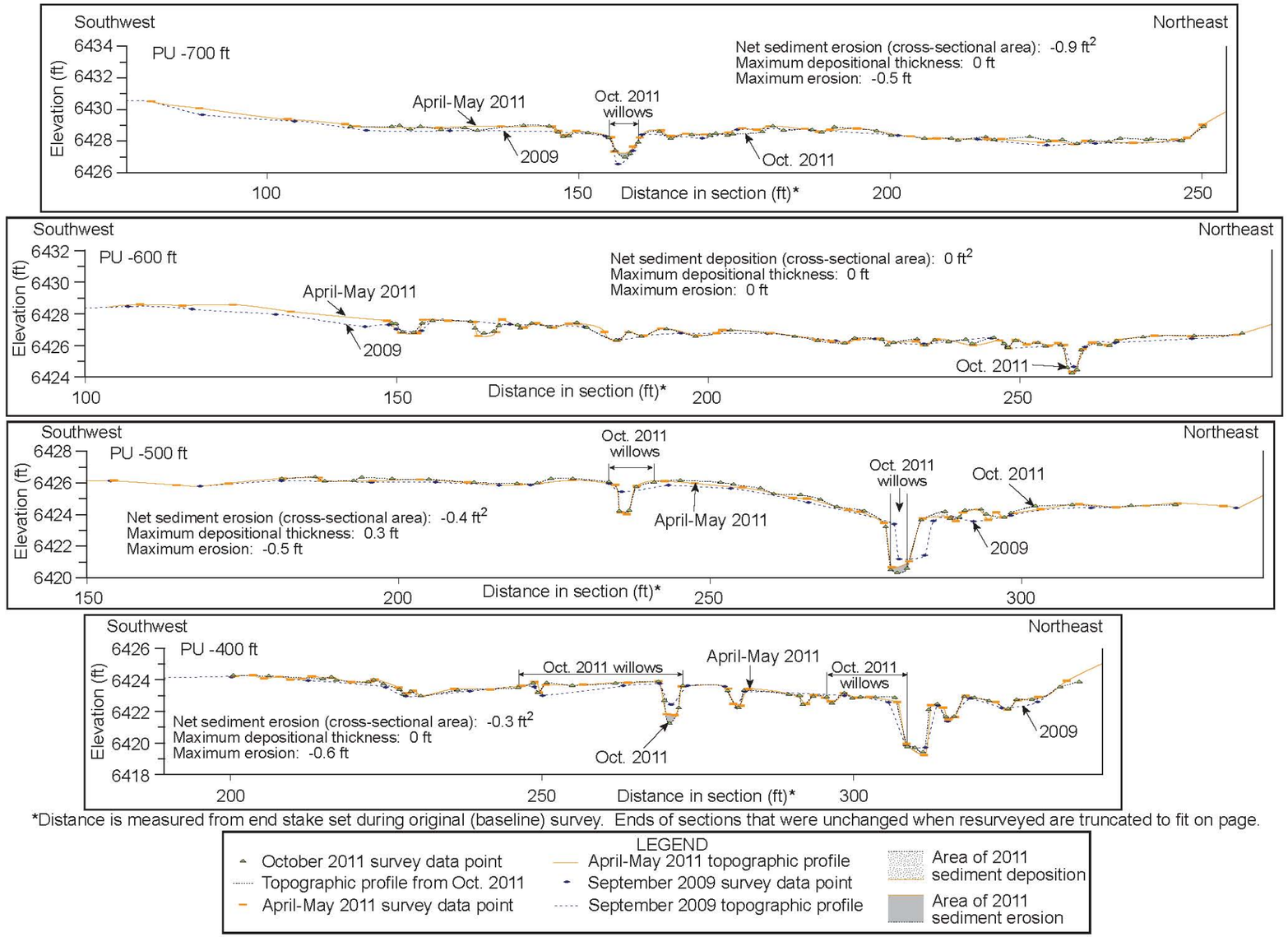
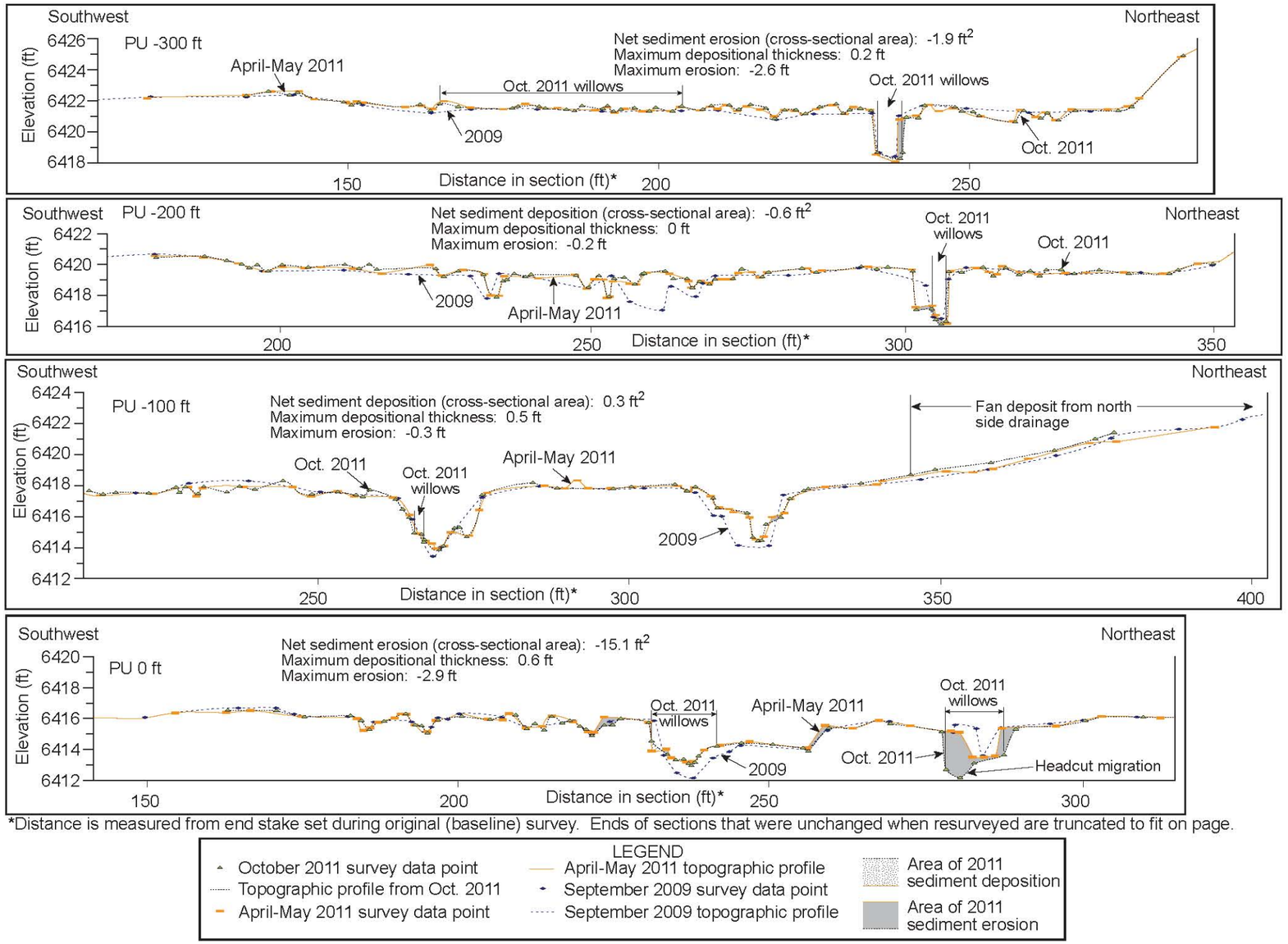
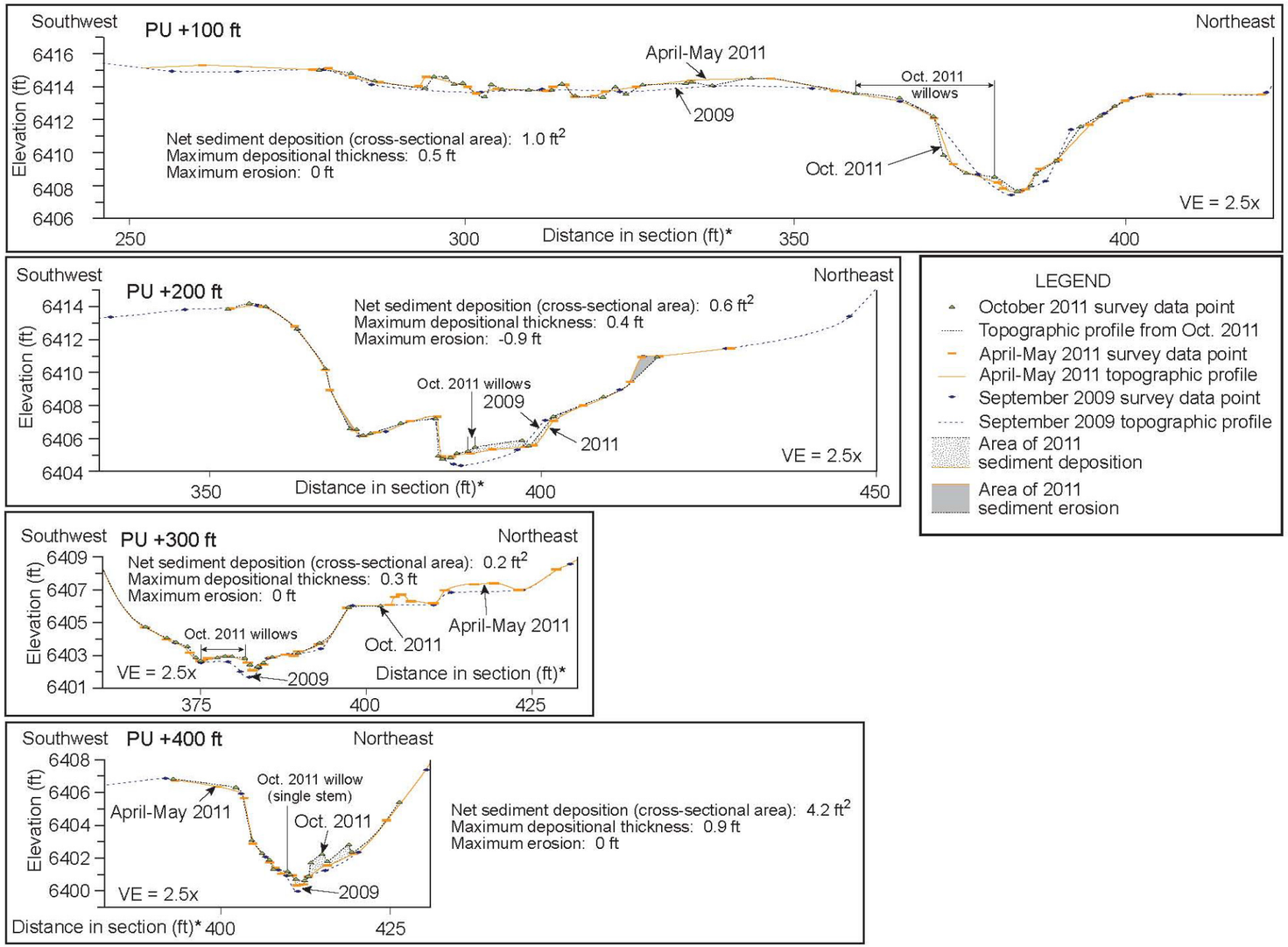


Figure 3.4-3 (continued) **Cross-sections in the lower Pueblo Canyon willow-planting area**



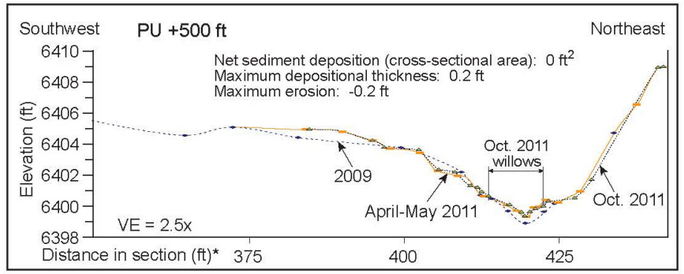
*Distance is measured from end stake set during original (baseline) survey. Ends of sections that were unchanged when resurveyed are truncated to fit on page.

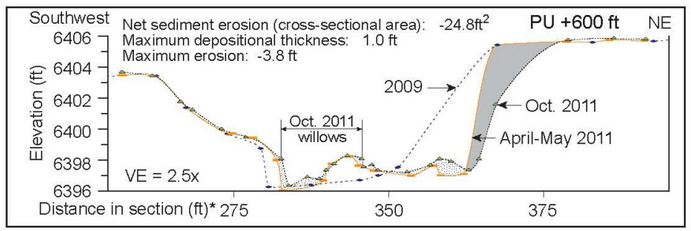
Figure 3.4-3 (continued) **Cross-sections in the lower Pueblo Canyon willow-planting area**

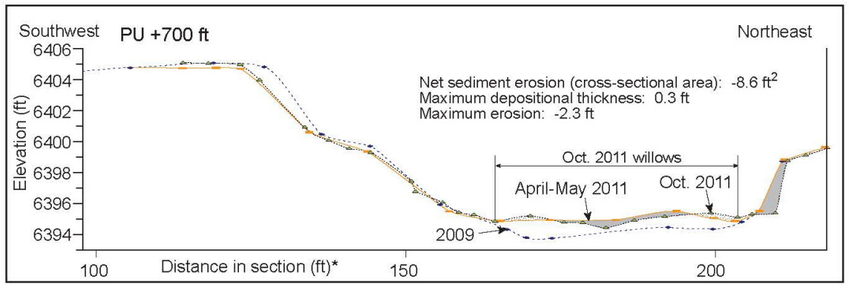


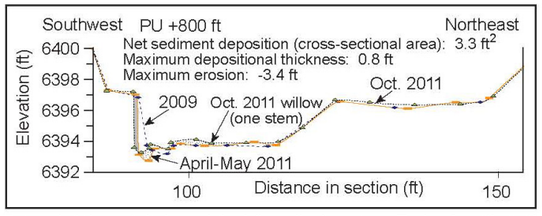
*Distance is measured from end stake set during original (baseline) survey. Ends of sections that were unchanged when resurveyed are truncated to fit on page.

Figure 3.4-3 (continued) Cross-sections in the lower Pueblo Canyon willow-planting area





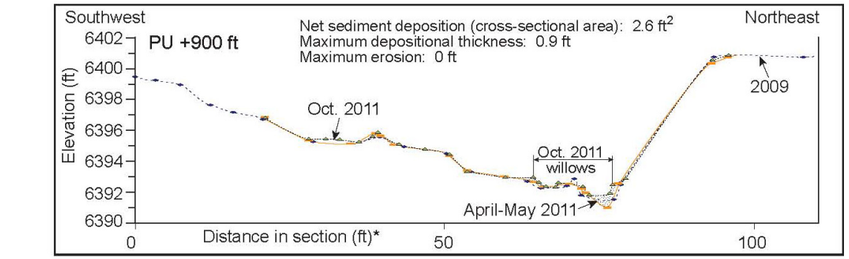


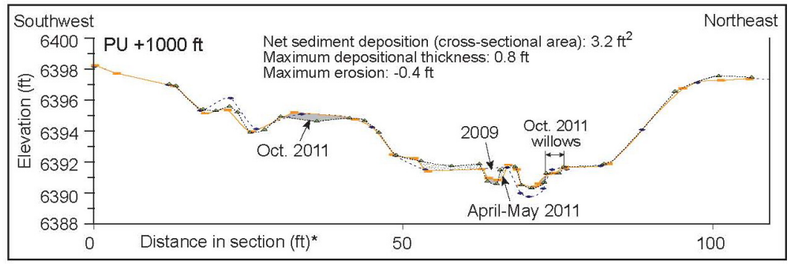


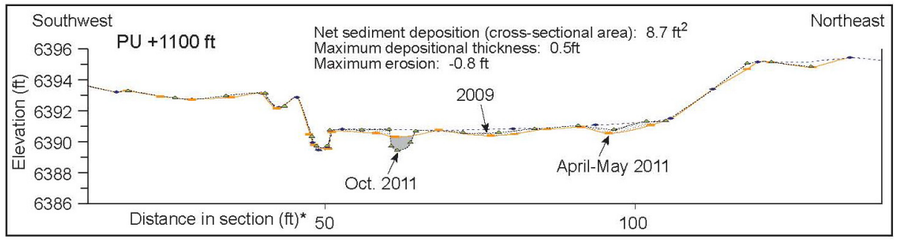
*Distance is measured from end stake set during original (baseline) survey. Ends of sections that were unchanged when resurveyed are truncated to fit on page.



Figure 3.4-3 (continued) Cross-sections in the lower Pueblo Canyon willow-planting area



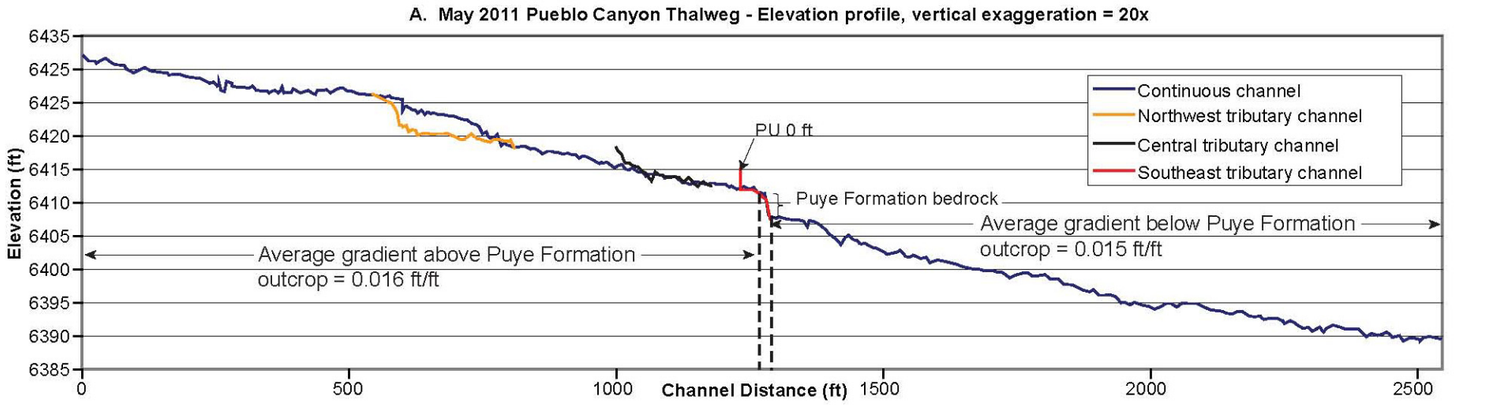




*Distance is measured from end stake set during original (baseline) survey. Ends of sections that were unchanged when resurveyed are truncated to fit on page.



Figure 3.4-3 (continued) Cross-sections in the lower Pueblo Canyon willow-planting area



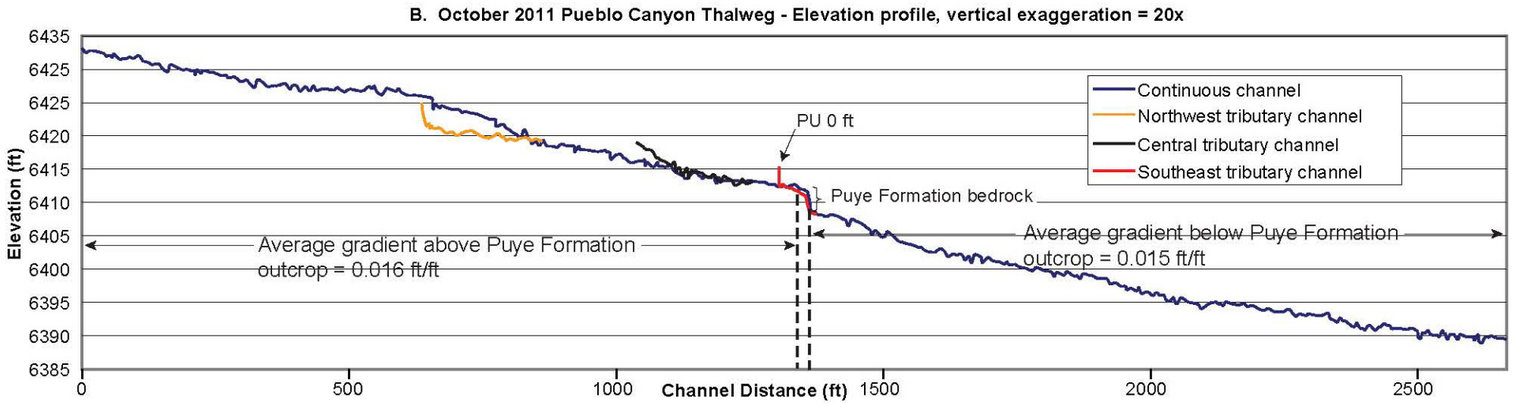


Figure 3.4-4 Thalweg profiles in the lower Pueblo Canyon willow-planting area

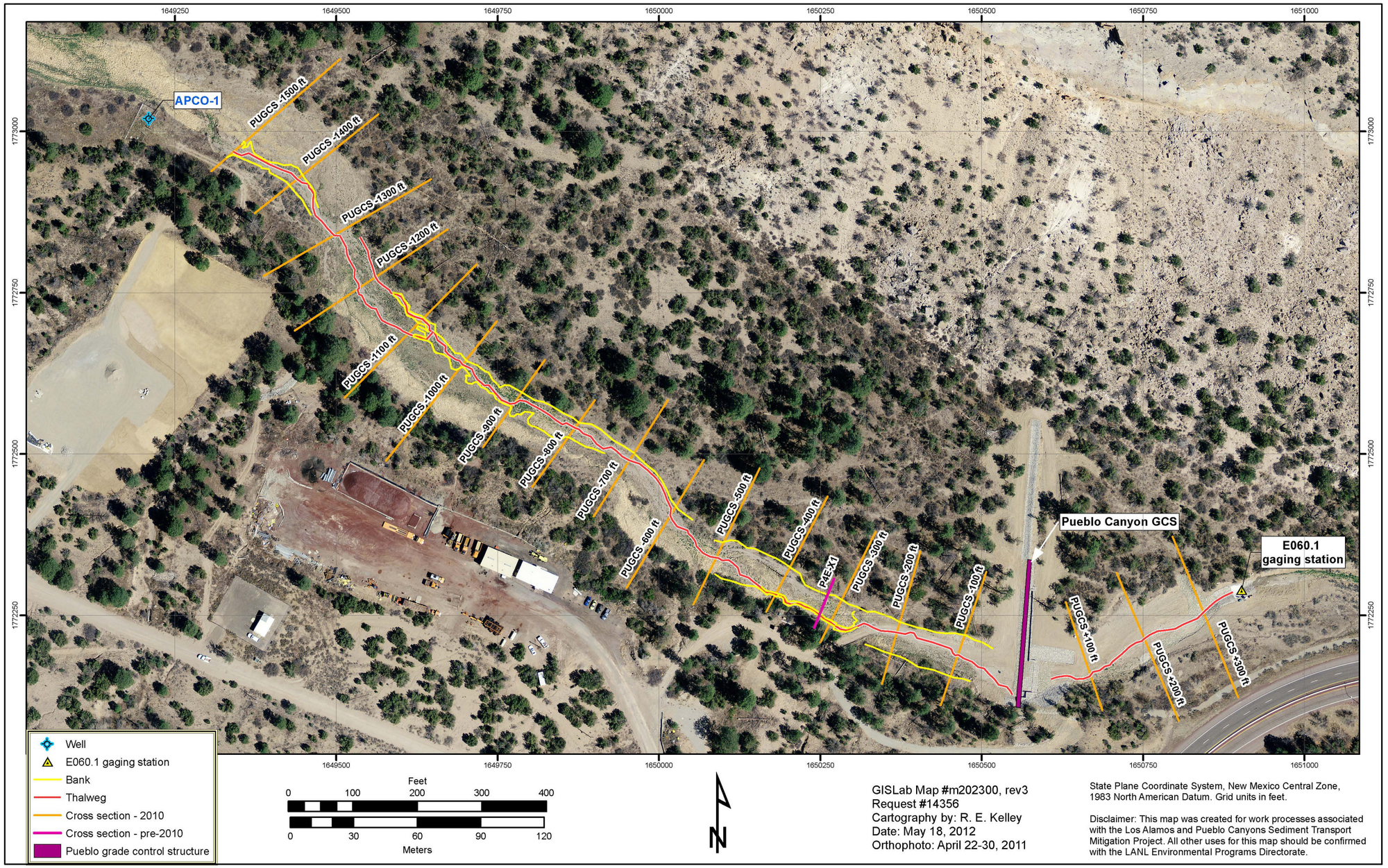


Figure 3.5-1 Orthophoto showing the locations of surveyed cross-sections, thalweg profiles, and stream banks near the Pueblo Canyon GCS

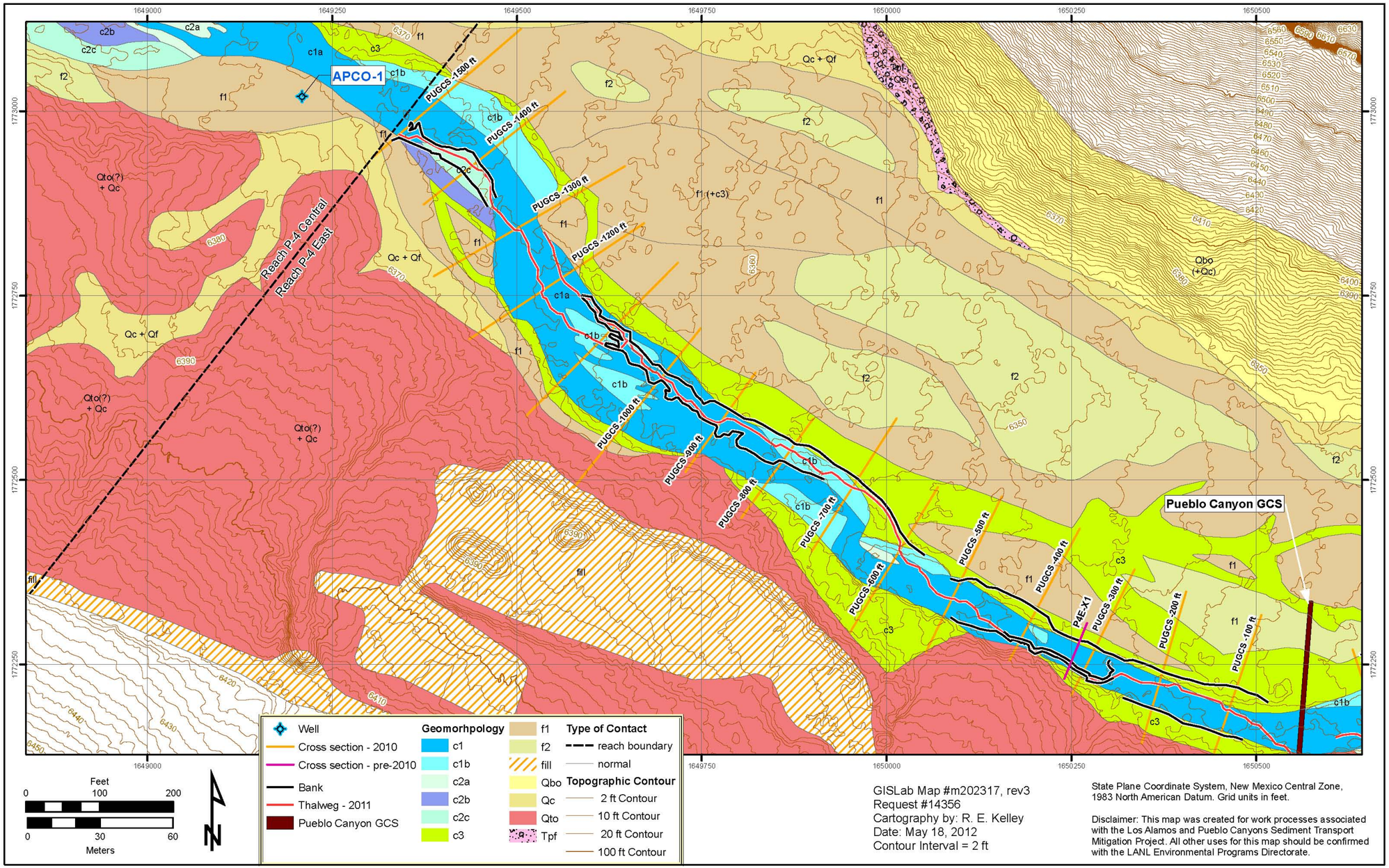


Figure 3.5-2 Geomorphic map showing the locations of surveyed cross-sections, thalweg profiles, and stream banks above the Pueblo Canyon GCS; geomorphic mapping from 1996–1997

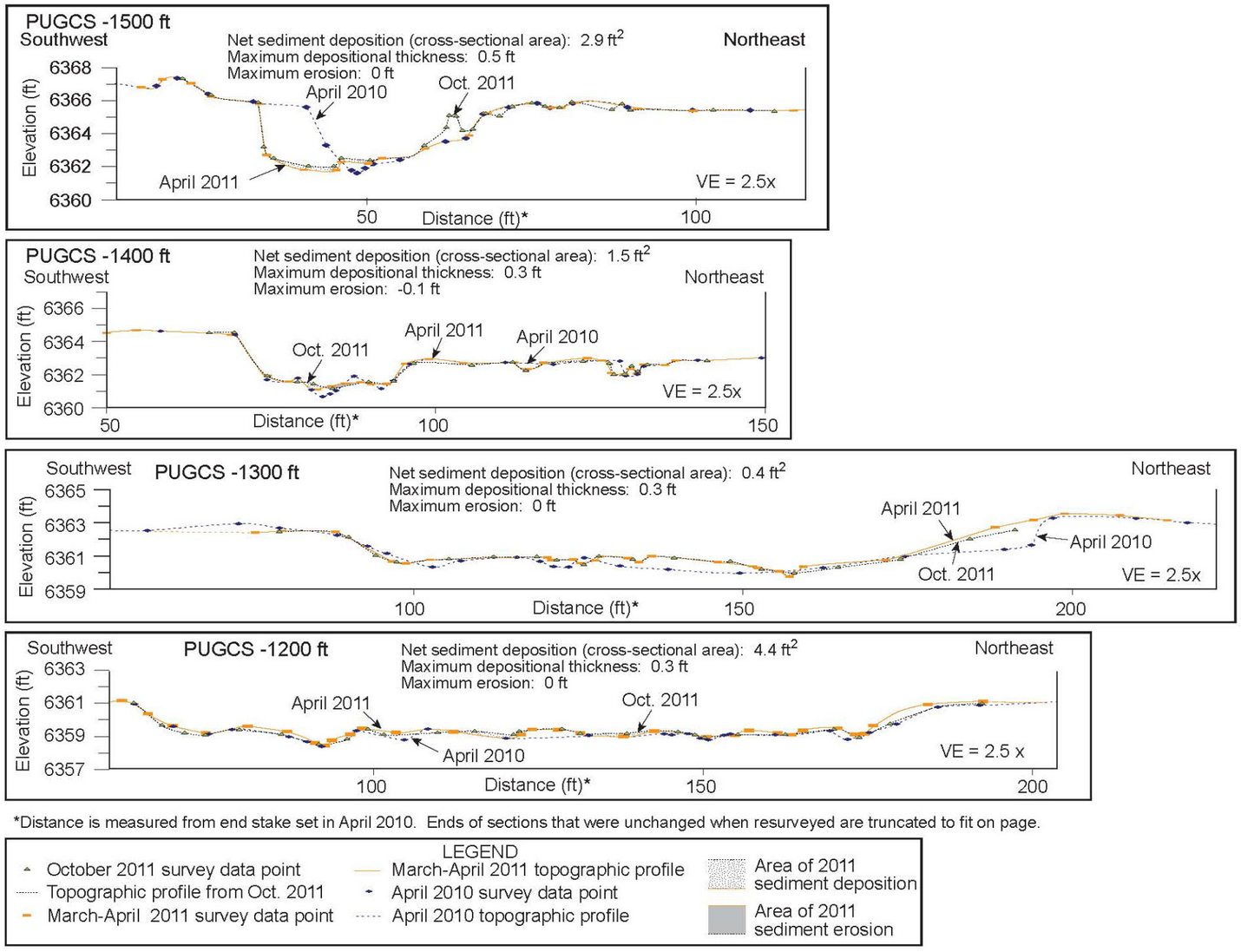
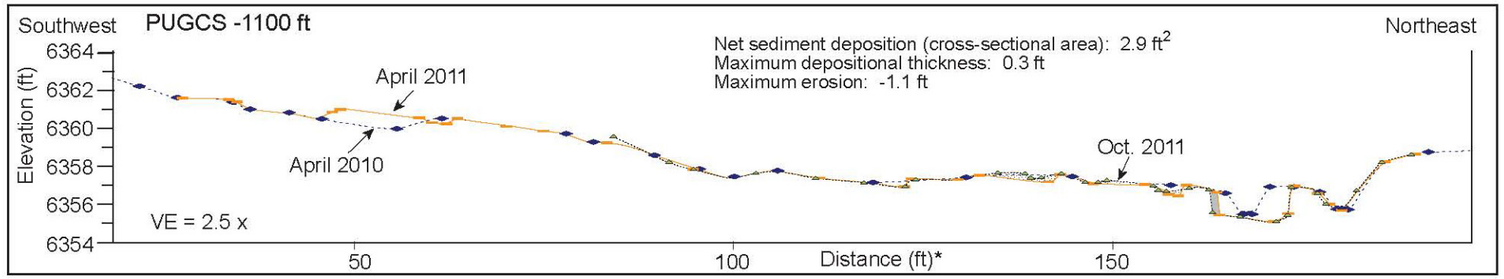
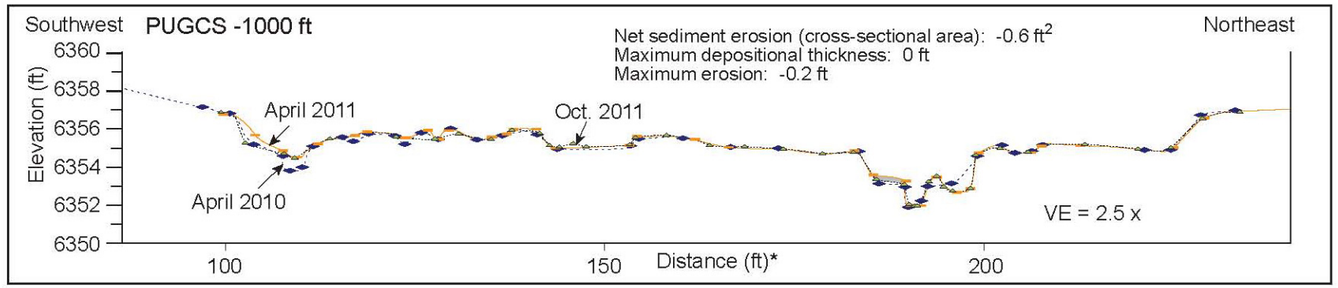
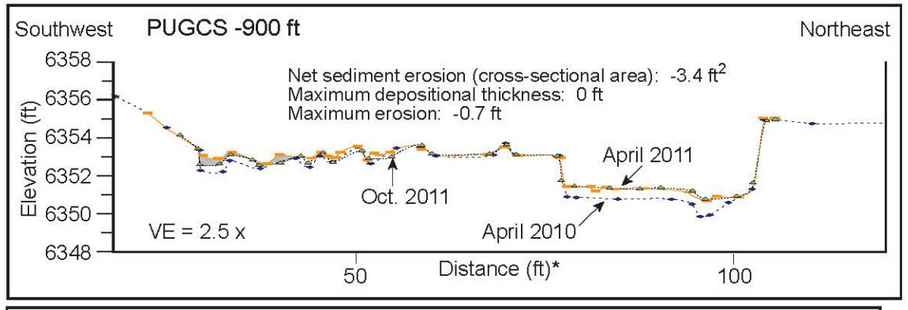
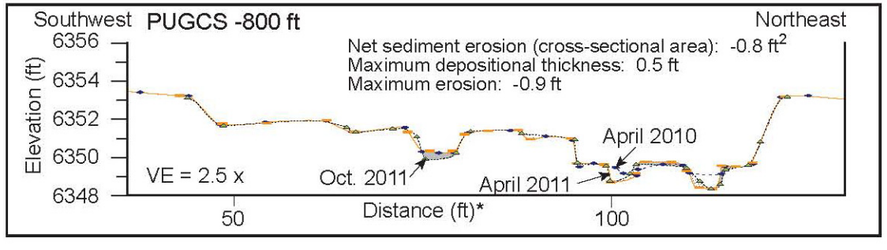


Figure 3.5-3 Cross-sections and thalweg profile near the Pueblo Canyon GCS









*Distance is measured from end stake set during original (baseline) survey. Ends of sections that were unchanged when resurveyed are truncated to fit on page.

Figure 3.5-3 (continued) **Cross-sections and thalweg profile near the Pueblo Canyon GCS**

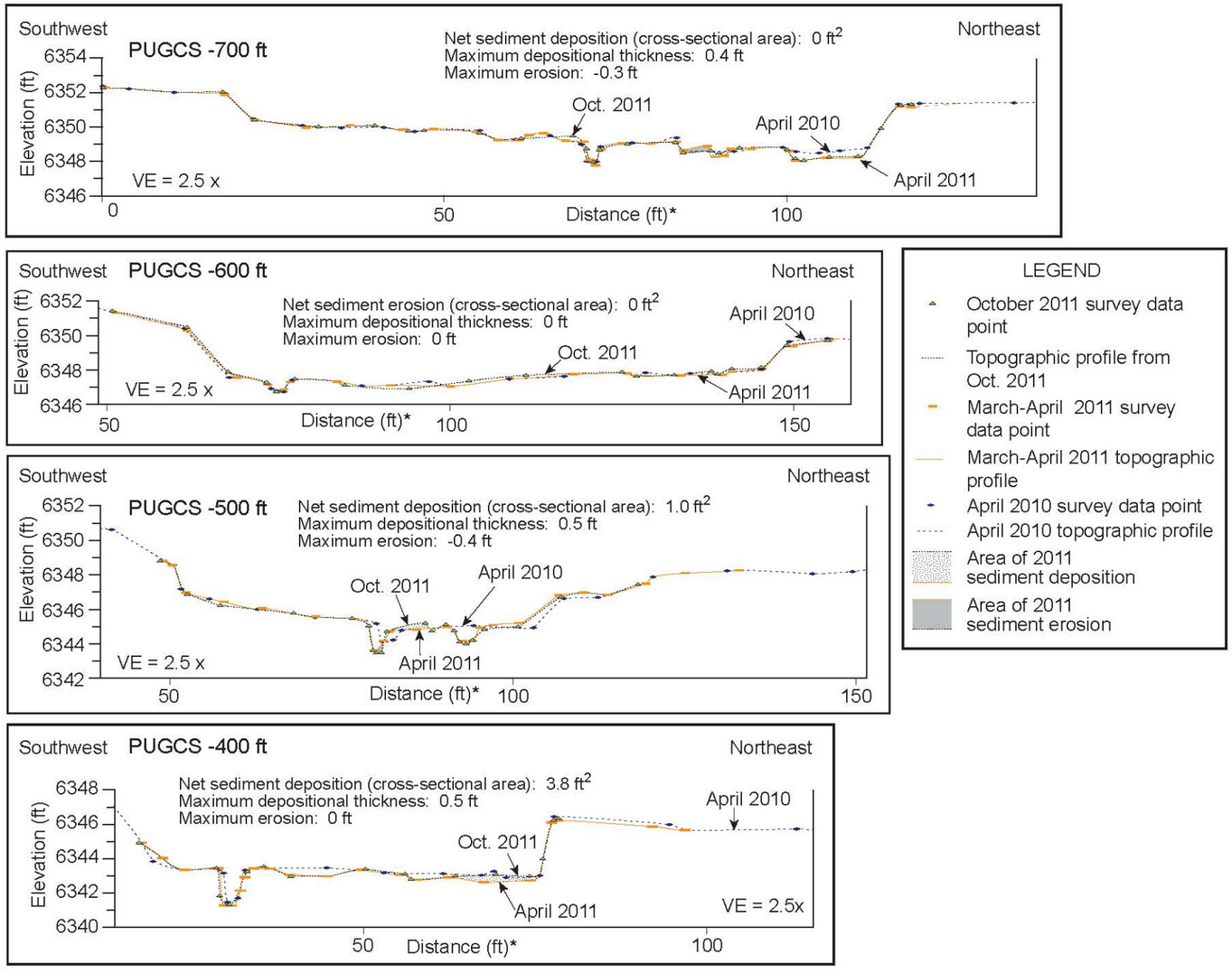
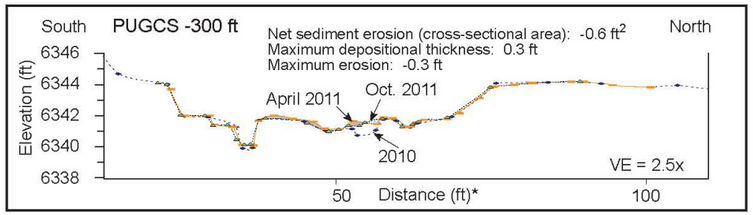
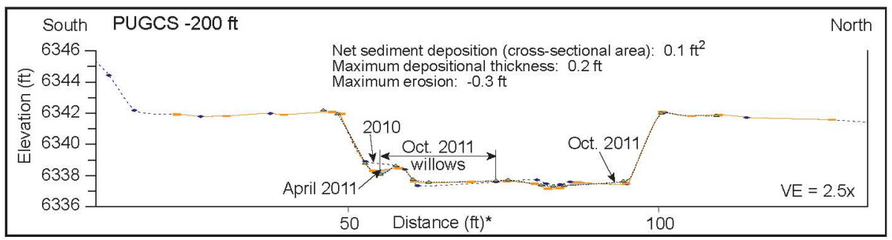
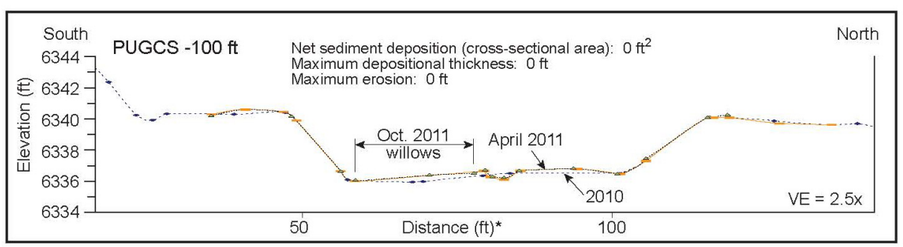
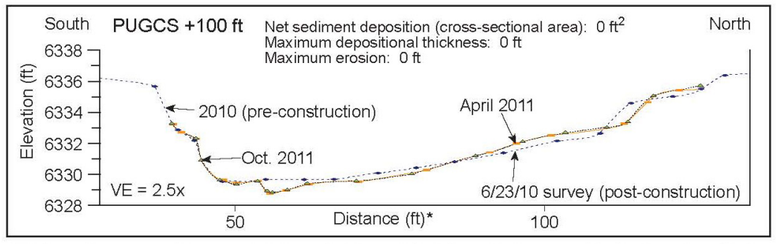


Figure 3.5-3 (continued) **Cross-sections and thalweg profile near the Pueblo Canyon GCS**





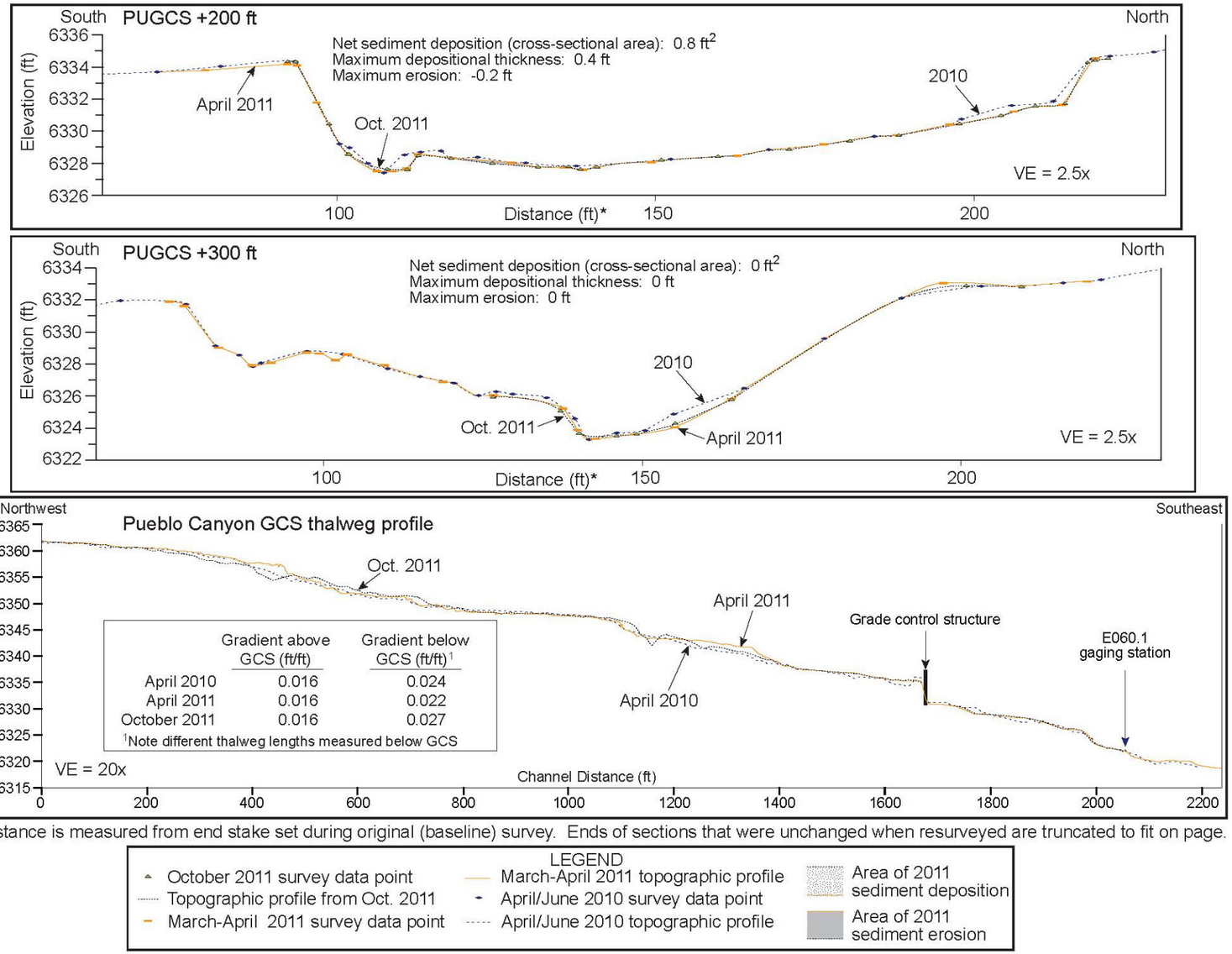




*Distance is measured from end stake set during original (baseline) survey. Ends of sections that were unchanged when resurveyed are truncated to fit on page.

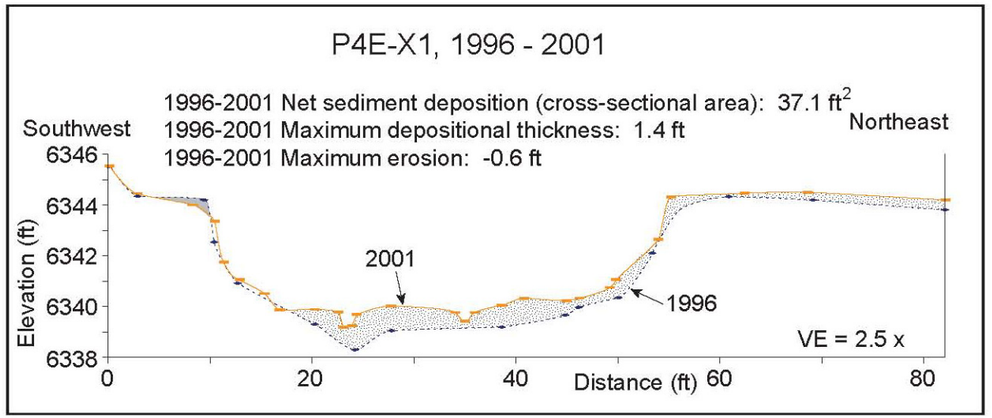


Figure 3.5-3 (continued) Cross-sections and thalweg profile near the Pueblo Canyon GCS



*Distance is measured from end stake set during original (baseline) survey. Ends of sections that were unchanged when resurveyed are truncated to fit on page.

Figure 3.5-3 (continued) **Cross-sections and thalweg profile near the Pueblo Canyon GCS**



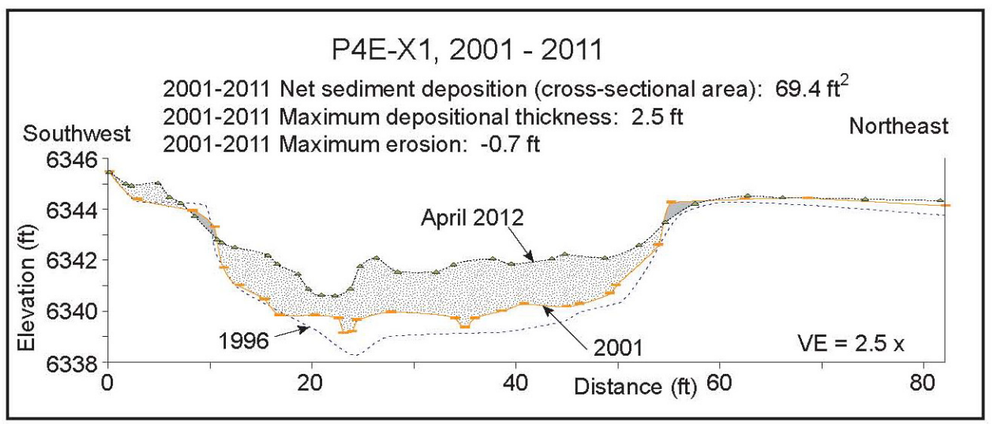




Figure 3.5-4 P4E-X1 cross-section in 1998, 2001, and 2011

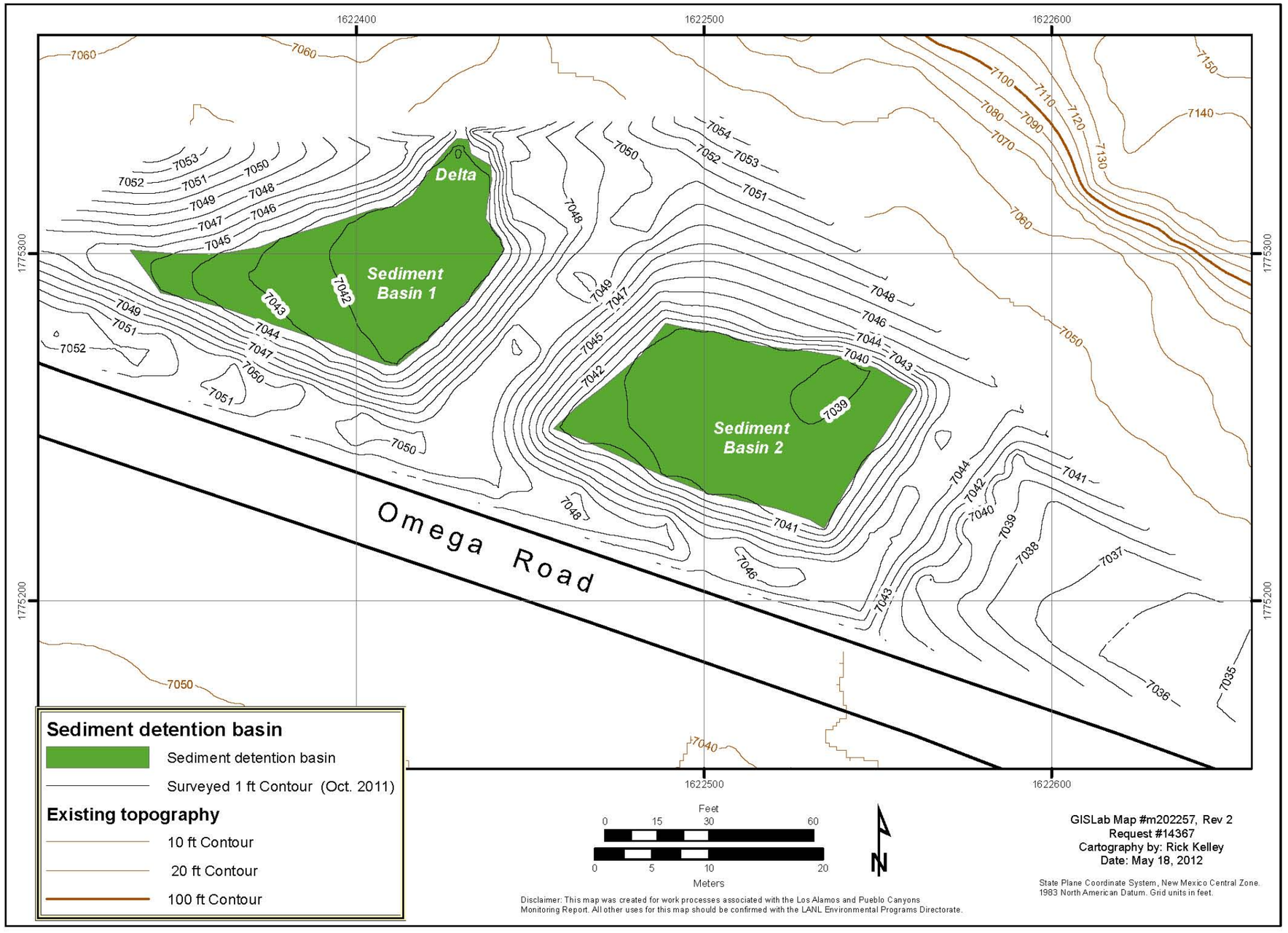


Figure 3.6-1 October 2011 topography at the upper Los Alamos Canyon sediment detention basins

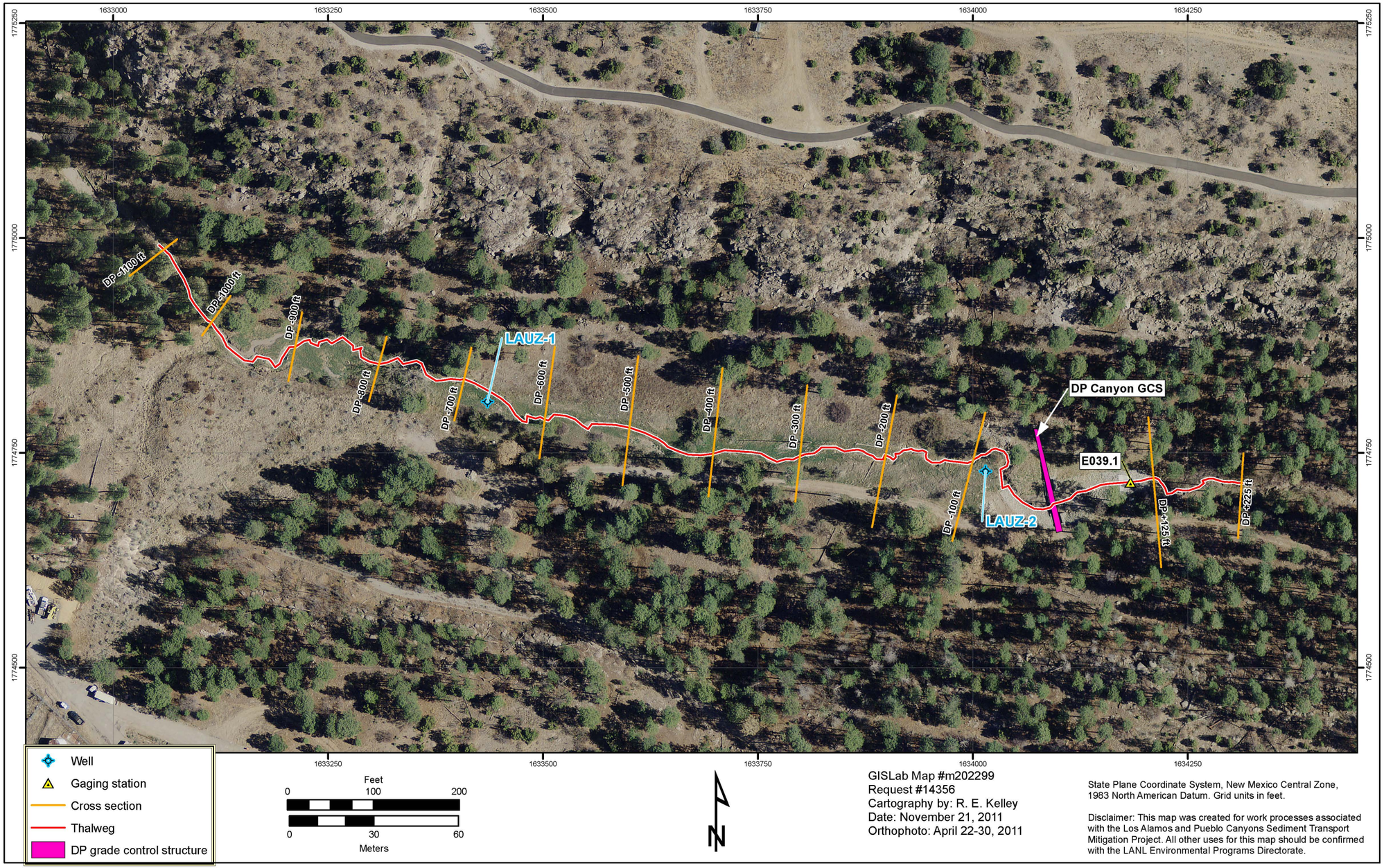


Figure 3.7-1 Orthophoto showing the locations of surveyed cross-sections and thalweg profile near the DP Canyon GCS

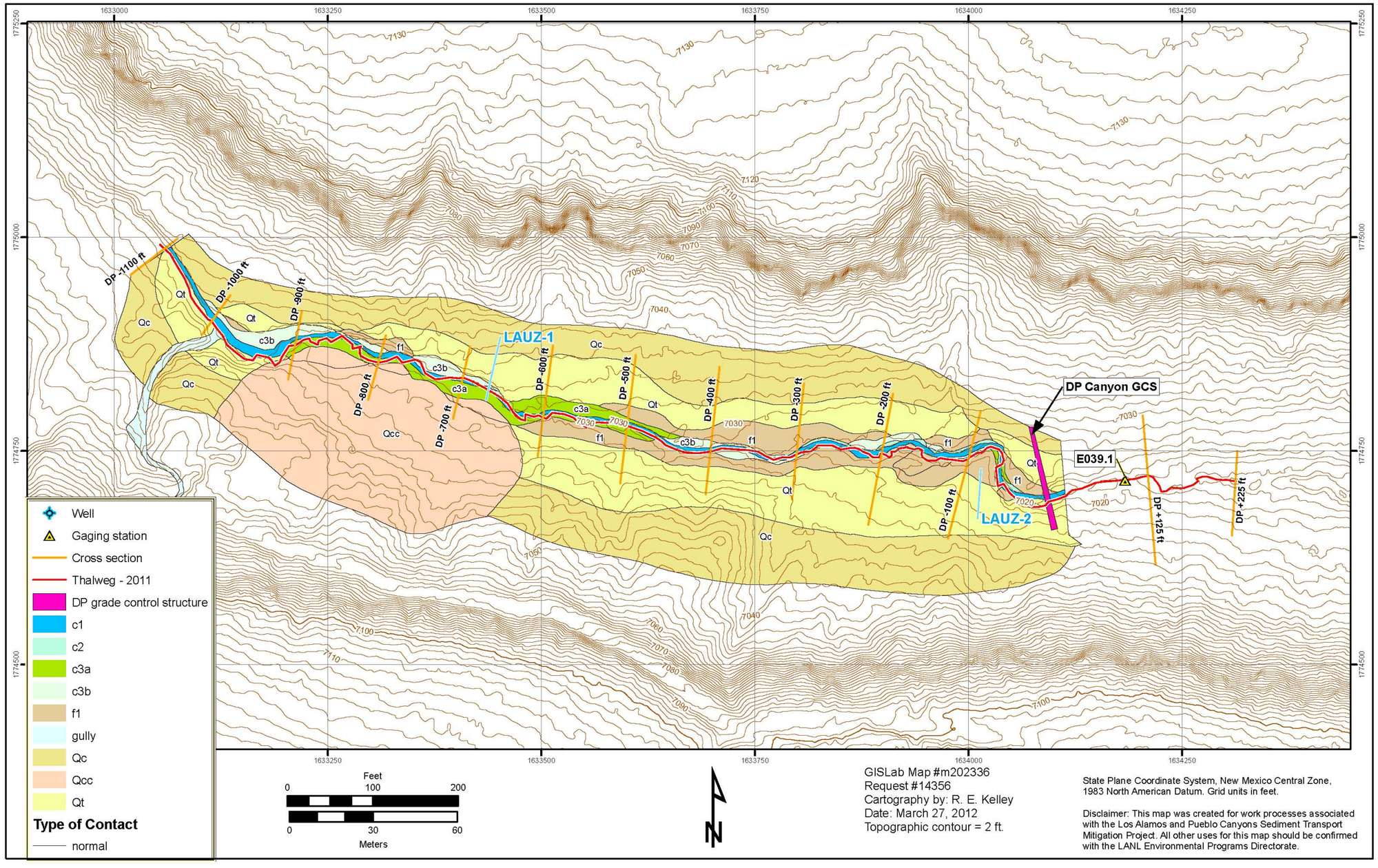


Figure 3.7-2 Geomorphic map showing the locations of surveyed cross-sections and thalweg profile near the DP Canyon GCS; geomorphic mapping from 1998

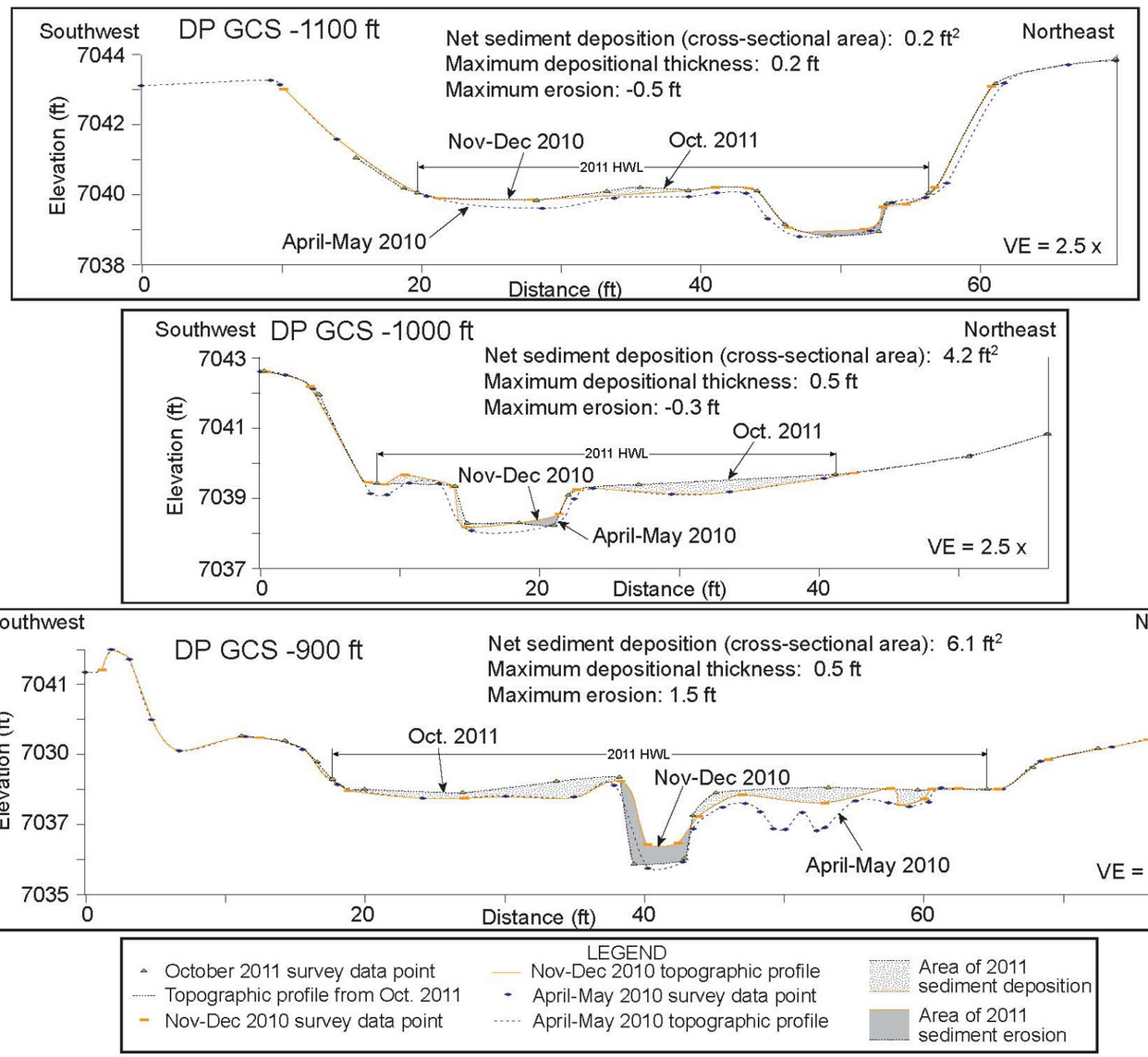
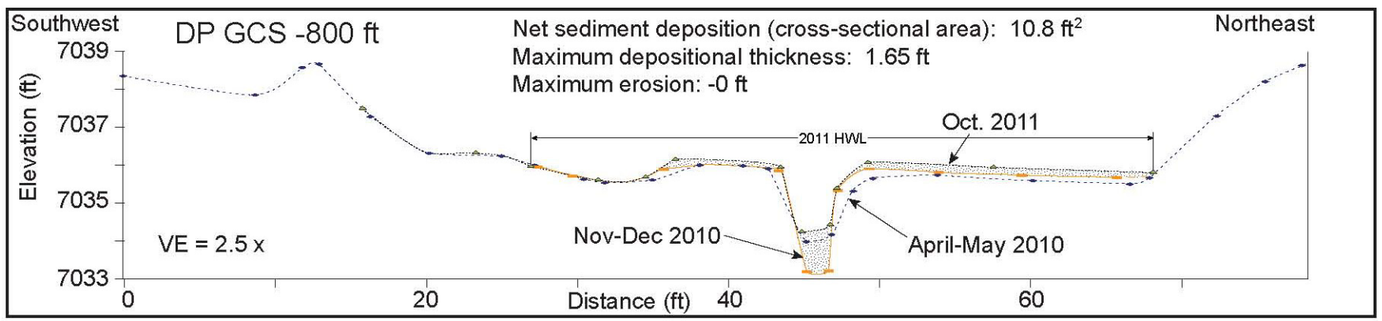
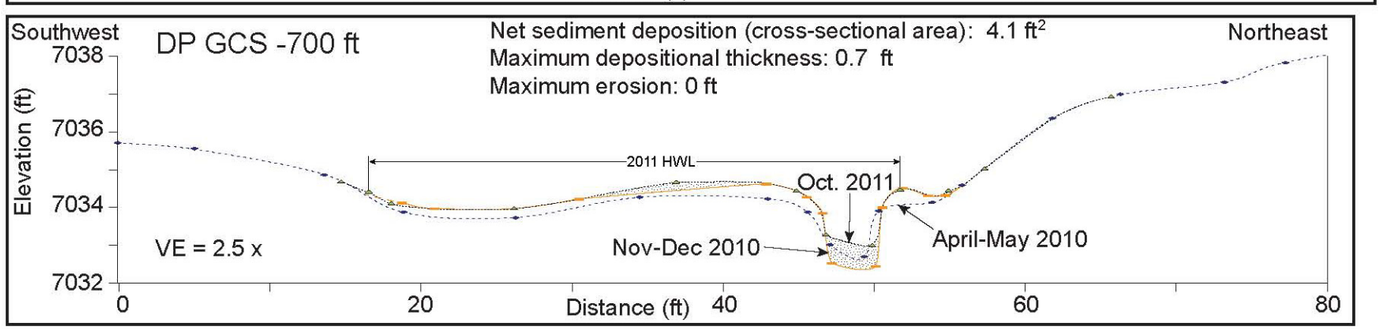


Figure 3.7-3 Cross-sections and thalweg profile near the DP Canyon GCS





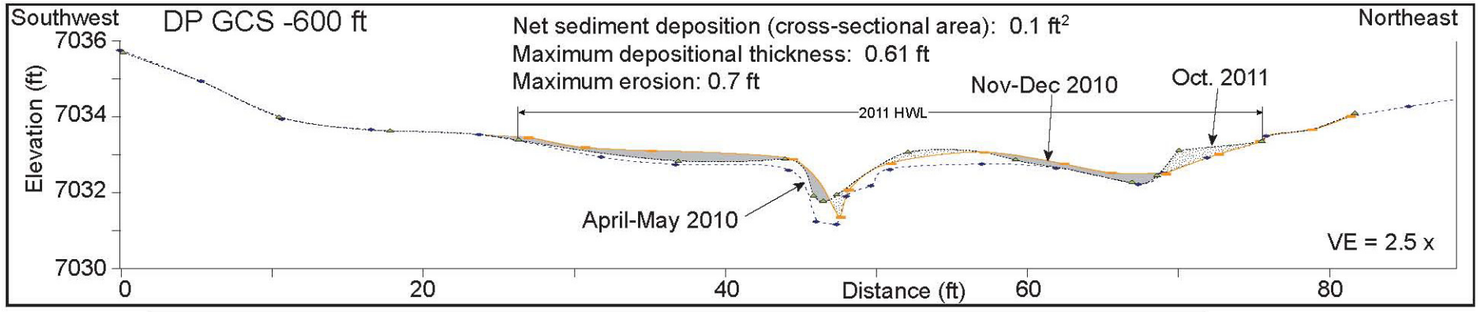
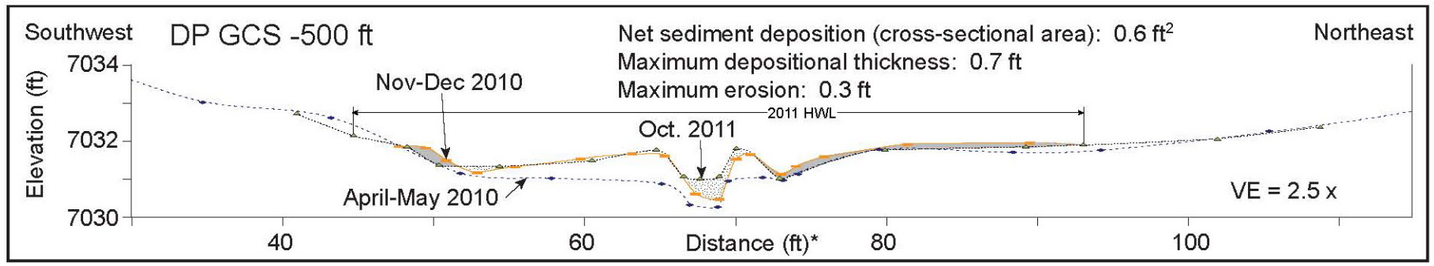
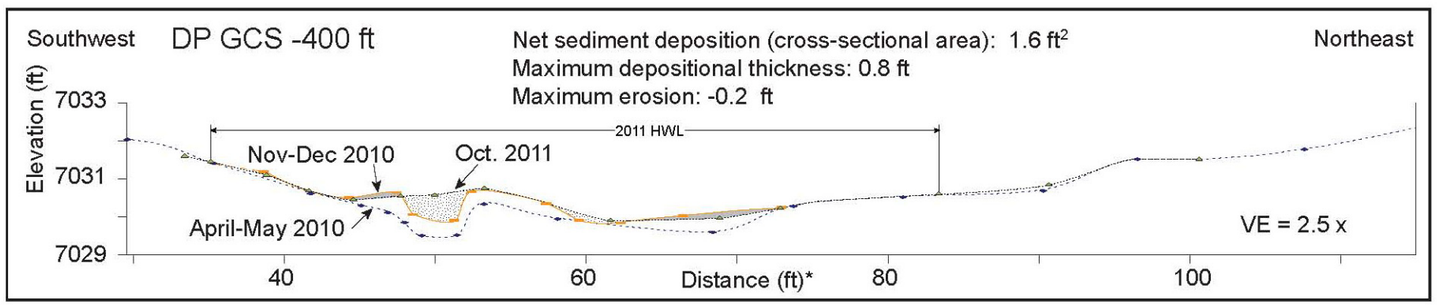
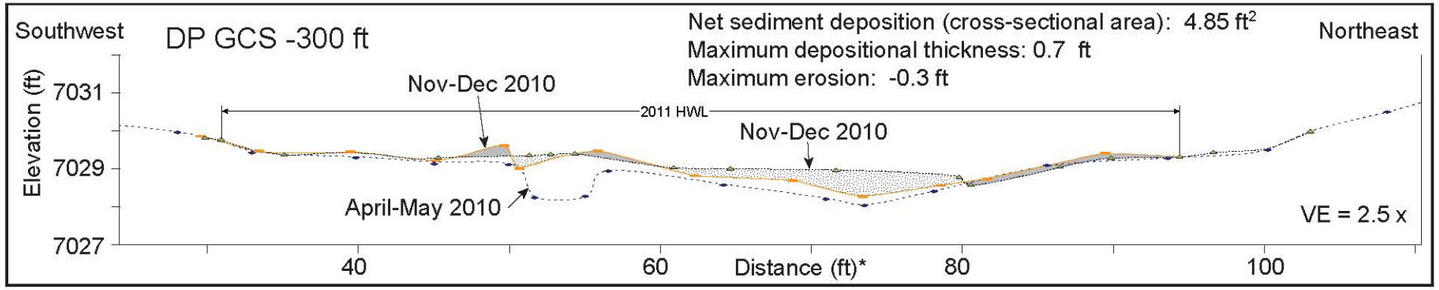


Figure 3.7-3 (continued) **Cross-sections and thalweg profile near the DP Canyon GCS**



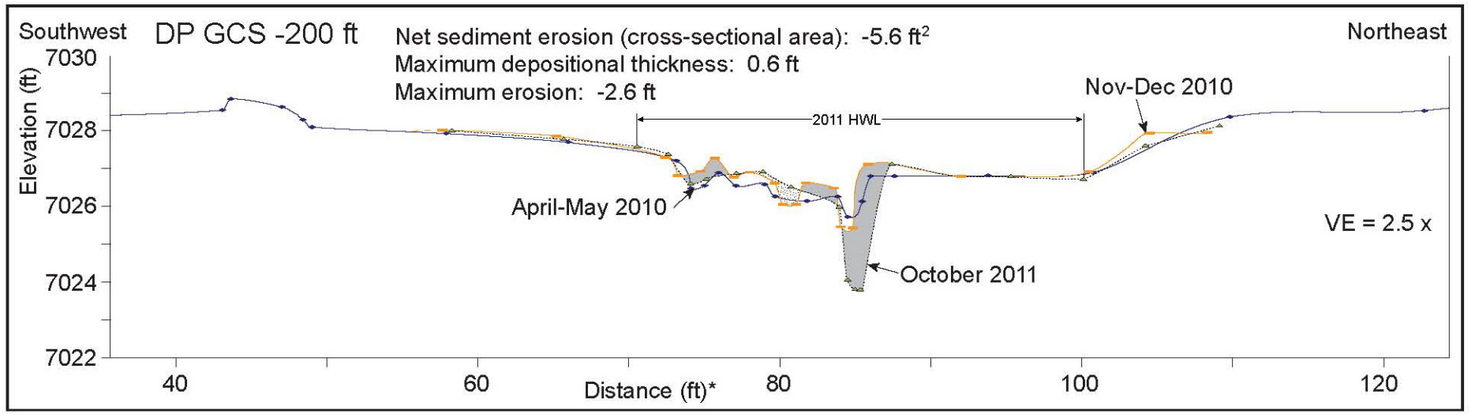


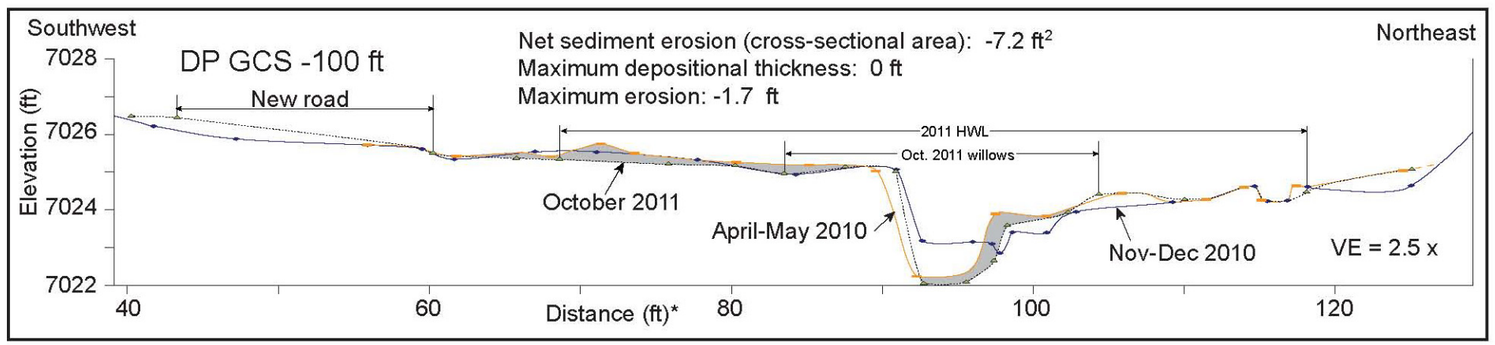


*Distance is measured from end stake set in April, 2010. Ends of sections that were unchanged when re-surveyed are truncated to fit on page.



Figure 3.7-3 (continued) Cross-sections and thalweg profile near the DP Canyon GCS

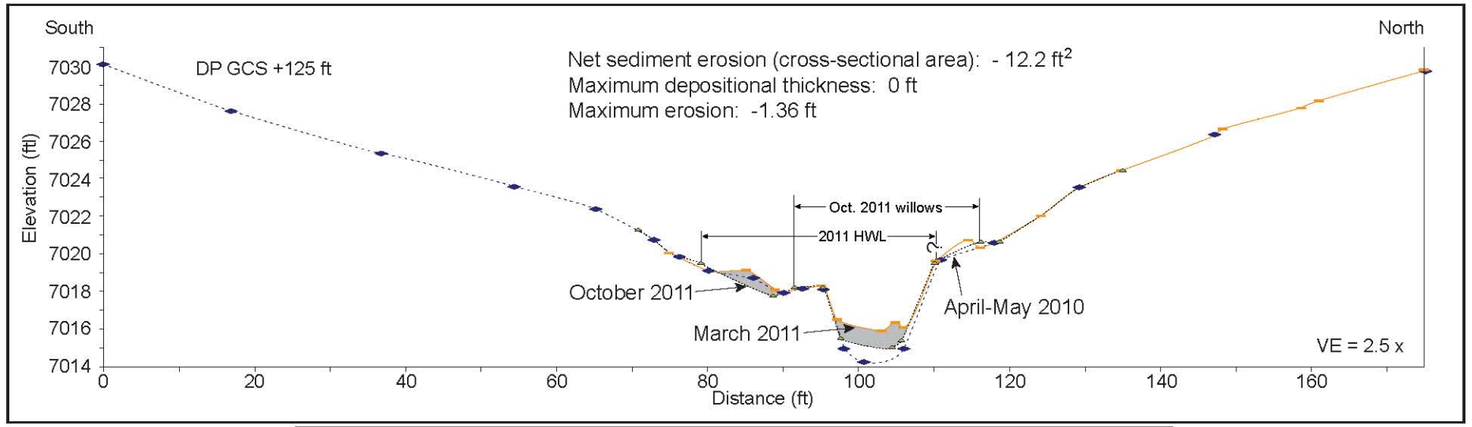


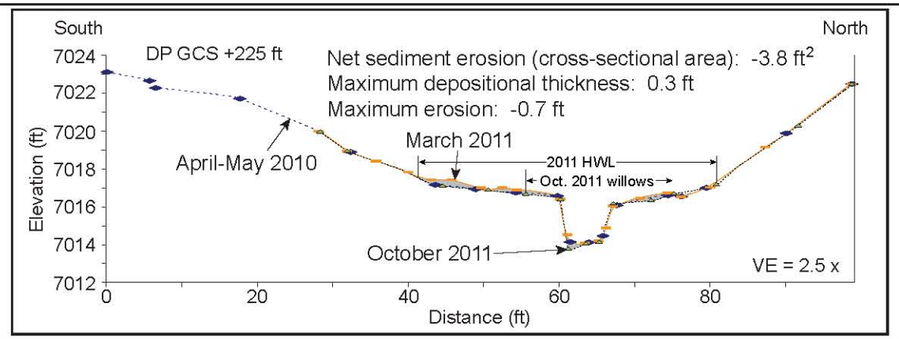


*Distance is measured from end stake set in April, 2010. Ends of sections that were unchanged when re-surveyed are truncated to fit on page.



Figure 3.7-3 (continued) Cross-sections and thalweg profile near the DP Canyon GCS





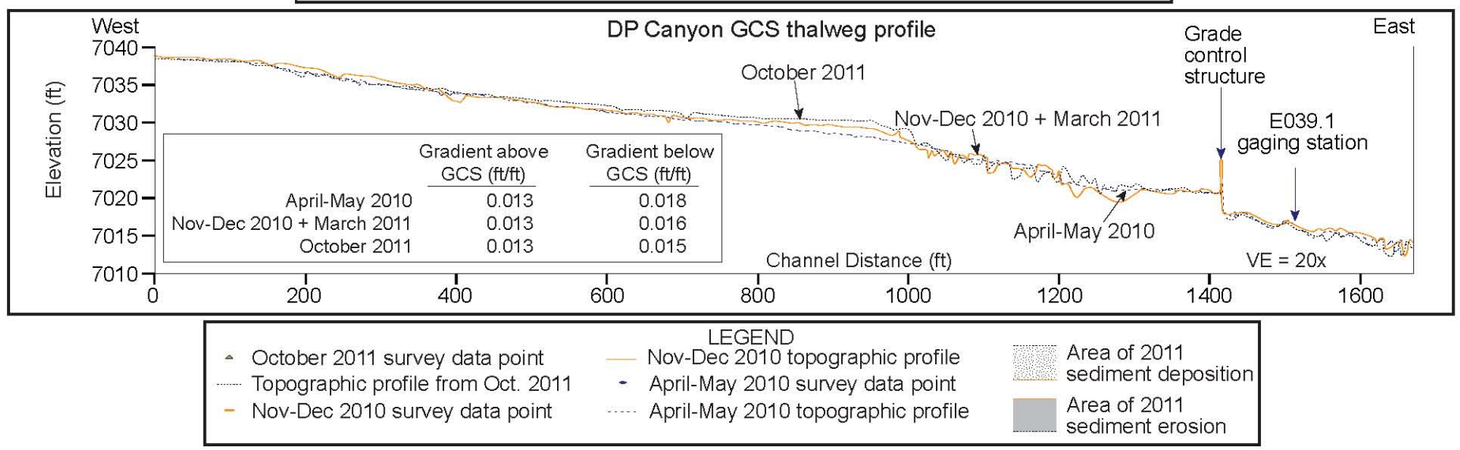


Figure 3.7-3 (continued) **Cross-sections and thalweg profile near the DP Canyon GCS**

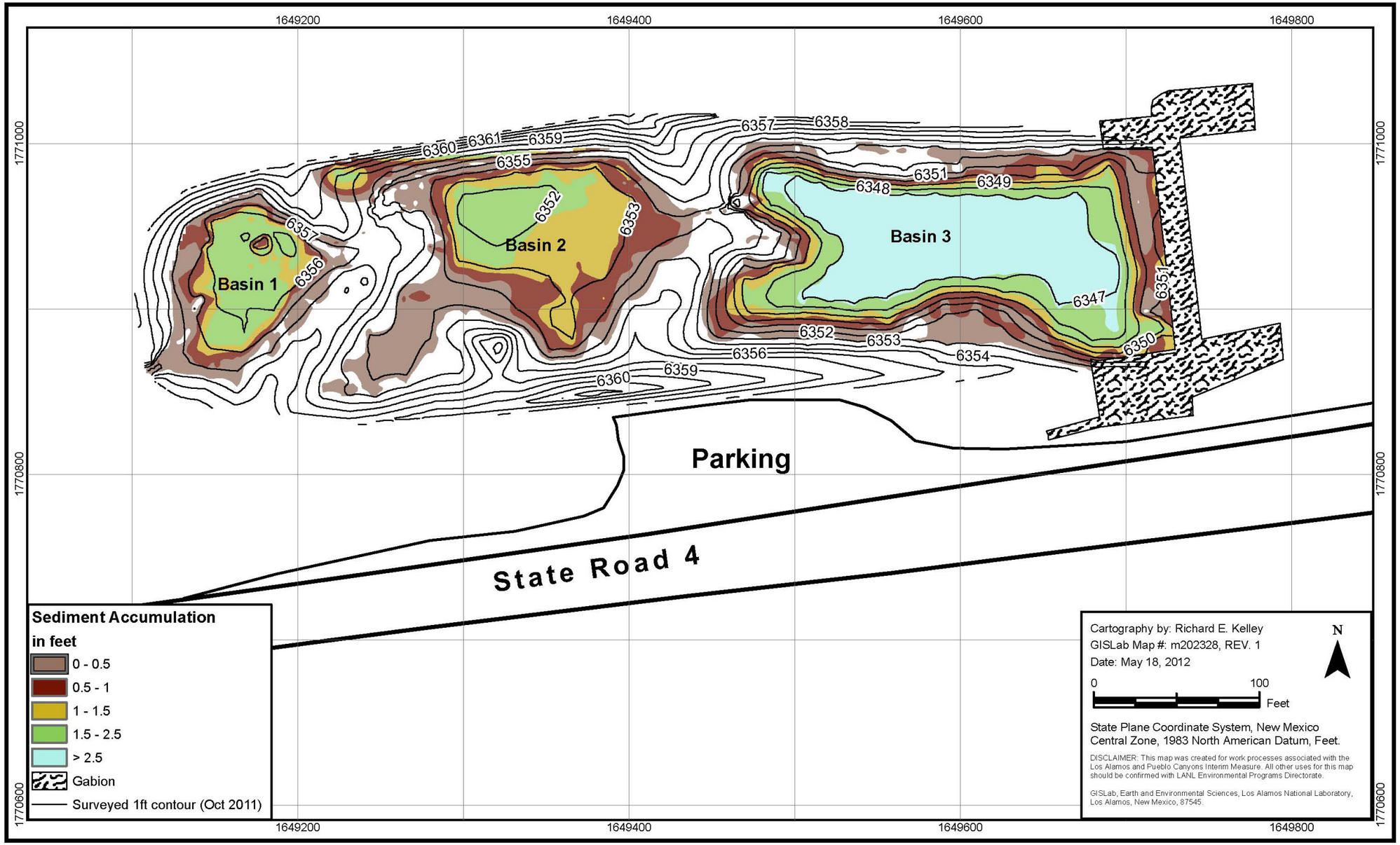


Figure 3.8-1 Postexcavation (July 2011) topographic map of sediment retention basins above the Los Alamos Canyon low-head weir and isopachs of total thickness of accumulated sediment from 2011 monsoon season

Table 3.1-1
Summary of Geomorphic Changes at Pueblo Canyon CVS Cross-Sections

Section Name	Maximum New Sediment Thickness (ft)	Maximum Erosion (ft)	Net Sediment Cross-Sectional Area (ft^2)	2011 Normalized Net Sediment Deposition (m^3/km)*	2010 Normalized Net Sediment Deposition (m^3/km)*	2011 Thalweg Elevation Change (ft)	2010 Thalweg Elevation Change (ft)
CVS#1 −50 ft	0.4	0	3.6	334	2070	0.2	0.5
CVS#1 +50 ft	0.6	0.0	4.7	436	1012	−0.1	−0.3
CVS#2 −50 ft	0.5	0.3	4.3	399	2813	0.4	0.3
CVS#2 +50 ft	0.3	0.3	3.2	297	808	0.1	0.4
CVS#3 −50 ft	0.2	0.4	−1.6	−149	1123	0.0	0.2
CVS#3 +50 ft	0.5	0.0	3.1	288	1179	0.1	0.0
Average			**2.9**	**268**	**1501**	**0.1**	**0.2**

* Normalized net sediment deposition is total estimated volume per 100 ft divided by distance between surveyed cross-sections (100 ft = 0.0305 km).

Table 3.2-1
Summary of Geomorphic Changes at the Upper Pueblo Canyon Willow-Planting Area Cross-Sections

Section Name	Maximum New Sediment Thickness (ft)	Maximum Erosion (ft)	Net Sediment Cross-Sectional Area (ft^2)	2011 Normalized Net Sediment Deposition (m^3/km)*	2010 Normalized Net Sediment Deposition (m^3/km)*	2011 Thalweg Elevation Change (ft)	2010 Thalweg Elevation Change (ft)
Upper Third							
PU UW-1	1.4	0.4	21.5	1996	2757	1.2	1.0
PU UW-2	1.3	0.0	18.8	1745	947	0.3	1.1
PU UW-3	1.7	1.0	15.2	1411	3713	0.8	1.0
PU UW-4	0.7	0.4	13.5	1253	4149	0.5	0.6
PU UW-5	1.0	0.9	16.6	1541	1745	-0.2	0.4
PU UW-6	0.5	0.5	3.0	278	1513	0.0	0.2
Average, Upper Third			**14.8**	**1371**	**2471**	**0.4**	**0.7**
Middle Third							
PU MW-1	0.4	1.2	2.7	251	1866	−0.9	−0.4
PU MW-2	0.6	0.6	3.7	343	900	−0.8	0.1
PU MW-3	0.9	0.9	0.1	9	2646	−0.1	−0.3
PU MW-4	0.5	0.2	3.2	297	1624	−0.2	0.4
PU MW-5	0.0	0.0	0.0	0	3880	0.1	0.0
PU MW-6	0.6	0.0	1.3	121	−408	0.0	−0.5
Average, Middle Third			**1.8**	**170**	**1751**	**−0.3**	**−0.1**
Lower Third							
PU LW-1	0.6	0.4	1.3	121	1290	−0.1	0.1
PU LW-2	0.7	1.6	−3.9	−362	696	−0.2	−0.3
PU LW-3	0.4	3.6	−22.8	−2116	19	−0.8	−0.5
PU LW-4	1.4	5.5	−21.2	−1968	−1467	0.1	−0.7
PU LW-5	0.9	5.1	−41.8	−3880	−37	−0.4	−0.3
PU LW-6	0.6	3.3	−8.8	−817	−1225	0.2	−1.0
Average, Lower Third			**−16.2**	**−1504**	**−121**	**−0.2**	**−0.4**
Average, Upper Pueblo Canyon Willow-Planting Area			**0.1**	**12**	**1367**	**0.0**	**0.0**

* Normalized net sediment deposition is total estimated volume per 100 ft divided by distance between surveyed cross-sections (100 ft = 0.0305 km).

Table 3.3-1
Summary of Geomorphic Changes at the Pueblo Canyon Wing Ditch Cross-Sections

Section Name	Maximum New Sediment Thickness (ft)	Maximum Erosion (ft)	Net Sediment Cross-Sectional Area (ft^2)	2011 Normalized Net Sediment Deposition (m^3/km)*	2010 Normalized Net Sediment Deposition (m^3/km)*	2011 Thalweg Elevation Change (ft)	2010 Thalweg Elevation Change (ft)
WD-1	1.3	0.4	7.2	668	2191	1.3	1.0
WD-2	0.5	0.2	2.7	251	4242	0.0	1.7
WD-3	0.7	0.9	−4.2	−390	501	0.7	1.3
WD-4	0.0	0.0	0.0	0	−1253	0.1	1.4
WD-5	0.5	0.0	1.7	158	585	0.0	1.1
		Average	**1.5**	**137**	**1253**	**0.4**	**1.3**

* Normalized net sediment deposition is total estimated volume per 100 ft divided by distance between surveyed cross-sections (100 ft = 0.0305 km).

Table 3.4-1
Summary of Geomorphic Changes at the Lower Pueblo Canyon Willow-Planting Area Cross-Sections

Section Name	Maximum New Sediment Thickness (ft)	Maximum Erosion (ft)	Net Sediment Cross-Sectional Area (ft^2)	2011 Normalized Net Sediment Deposition or Erosion (m^3/km)*	2010 Normalized Net Sediment Deposition or Erosion (m^3/km) *	2011 Thalweg Elevation Change (ft)	2010 Thalweg Elevation Change (ft)
Upper Half (P-3FE)							
PU −1100 ft	0.0	0.4	−0.8	−74	678	0.1	0.1
PU −1000 ft	0.8	0.0	7.1	659	−455	0.2	0.0
PU −900 ft	0.4	0.3	1.4	130	1188	−0.2	0.3
PU −800 ft	0.0	0.3	−0.8	−74	2358	−0.2	0.1
PU −700 ft	0.0	0.5	−0.9	−84	2525	−0.5	0.8
PU −600 ft	0.0	0.0	0.0	0	1792	2.3	0.3
PU −500 ft	0.3	0.5	−0.4	−37	1105	2.8	0.5
PU −400 ft	0.0	0.6	−0.3	−28	1300	1.3	0.5
PU −300 ft	0.2	2.6	−1.9	−176	965	−0.9	0.3
PU −200 ft	0.0	0.2	−0.6	−56	2553	−0.3	0.3
PU −100 ft	0.5	0.3	0.3	28	1420	−0.4	0.4
Average, Upper Half			**0.3**	**26**	**1273**	**0.4**	**0.3**
Lower Half (P-4W)							
PU 0 ft	0.6	2.9	−15.1	−1402	−158	−0.2	1.0
PU +100 ft	0.5	0.0	1.0	93	938	0.4	0.2
PU +200 ft	0.4	0.9	0.6	56	93	0.0	0.4
PU +300 ft	0.3	0.0	0.2	19	956	0.1	0.4
PU +400 ft	0.9	0.0	4.2	390	149	0.4	0.4
PU +500 ft	0.2	0.2	0.0	0	928	−0.2	0.4
PU +600 ft	1.0	3.8	−24.8	−2302	−2980	1.2	−0.2
PU +700 ft	0.3	2.3	−8.6	−798	1402	0.2	1.1
PU +800 ft	0.8	3.4	3.3	306	−241	0.4	−0.4
PU +900 ft	0.9	0.0	2.6	241	−56	0.6	−0.5
PU +1000 ft	0.8	0.4	3.2	297	−176	0.2	0.6
PU +1100 ft	0.5	0.8	8.7	808	−1160	0.1	0.1
Average, Lower Half			**−2.1**	**−191**	**−26**	**0.3**	**0.3**

* Normalized net sediment deposition is total estimated volume per 100 ft divided by distance between surveyed cross-sections (100 ft = 0.0305 km).

Table 3.5-1
Summary of Geomorphic Changes at Cross-Sections above the Pueblo Canyon GCS

Section Name	Maximum New Sediment Thickness (ft)	Maximum Erosion (ft)	Net Sediment Cross-Sectional Area (ft^2)	2011 Normalized Net Sediment Deposition or Erosion (m^3/km)*	2010 Normalized Net Sediment Deposition or Erosion (m^3/km)*	2011 Thalweg Elevation Change (ft)	2010 Thalweg Elevation Change (ft)
PUGCS −1500 ft	0.5	0.0	2.9	269	−2785	0.1	0.2
PUGCS −1400 ft	0.3	0.1	1.5	139	121	0.2	0.4
PUGCS −1300 ft	0.3	0.0	0.4	37	2813	0.0	0.3
PUGCS −1200 ft	0.3	0.0	4.4	408	1968	0.6	0.1
PUGCS −1100 ft	0.3	1.1	2.9	269	−678	−0.1	−0.4
PUGCS −1000 ft	0.0	0.2	−0.6	−56	678	0.1	0.1
PUGCS −900 ft	0.0	0.7	−3.4	−316	1903	0.6	0.8
PUGCS −800 ft	0.5	0.9	−0.8	−74	−232	0.2	−1.2
PUGCS −700 ft	0.4	0.3	0.0	0	−390	0.1	−0.5
PUGCS −600 ft	0.0	0.0	0.0	0	−121	0.7	0.1
PUGCS −500 ft	0.5	0.4	1.0	93	28	−0.1	−0.5
PUGCS −400 ft	0.5	0.0	3.8	353	−1170	0.1	−0.2
PUGCS −300 ft	0.3	0.3	−0.6	−56	371	0.1	0.2
PUGCS −200 ft	0.2	0.3	0.1	9	−111	0.1	−0.3
PUGCS −100 ft	0.0	0.0	0.0	0	808	0.1	0.2
		Average	**0.8**	**72**	**214**	**0.2**	**−0.1**

* Normalized net sediment deposition is total estimated volume per 100 ft divided by distance between surveyed cross-sections (100 ft = 0.0305 km).

Table 3.5-2
Summary of Geomorphic Changes at Cross-Sections below the Pueblo Canyon GCS

Section Name	Maximum New Sediment Thickness (ft)	Maximum Erosion (ft)	Net Sediment Cross-Sectional Area (ft^2)	2011 Normalized Net Sediment Deposition or Erosion (m^3/km)*	2010 Normalized Net Sediment Deposition or Erosion (m^3/km)*	2011 Elevation Change (ft)	2010 Thalweg Elevation Change (ft)
PUGCS +100 ft	0.0	0.0	0.0	0	−260	0.1	−0.8
PUGCS +200 ft	0.4	0.2	0.8	74	−1448	0.1	0.1
PUGCS +300 ft	0.0	0.0	0.0	0	−826	−0.1	0.0
Average			**0.3**	**25**	**−845**	**0.0**	**−0.2**

* Normalized net sediment deposition is total estimated volume per 100 ft divided by distance between surveyed cross-sections (100 ft = 0.0305 km).

Table 3.7-1
Summary of Geomorphic Changes at Cross-Sections above the DP Canyon GCS

Section Name	Maximum New Sediment Thickness (ft)	Maximum Erosion (ft)	Net Sediment Cross-Sectional Area (ft^2)	2011 Normalized Net Sediment Deposition or Erosion (m^3/km)*	2010 Normalized Net Sediment Deposition or Erosion (m^3/km)*	2011 Thalweg Elevation Change (ft)	2010 Thalweg Elevation Change (ft)
DPGCS −1100 ft	0.2	0.5	0.2	19	501	−0.4	0.2
DPGCS −1000 ft	0.5	0.3	4.2	390	260	0.1	0.1
DPGCS −900 ft	0.5	1.5	6.1	566	1105	−0.8	0.7
DPGCS −800 ft	1.7	0.0	10.8	1003	297	1.1	−0.8
DPGCS −700 ft	0.7	0.0	4.1	381	594	0.6	−0.5
DPGCS −600 ft	0.6	0.7	0.1	9	928	0.5	0.2
DPGCS −500 ft	0.7	0.3	0.6	56	1300	0.5	0.2
DPGCS −400 ft	0.8	0.2	1.6	149	1003	0.7	0.4
DPGCS −300 ft	0.7	0.3	4.9	455	1504	0.1	0.8
DPGCS −200 ft	0.6	2.6	−5.6	−520	501	−1.7	−0.3
DPGCS −100 ft	0.0	1.7	−7.2	−668	176	−0.2	−0.6
Average			**1.8**	**167**	**743**	**0.1**	**0.0**

* Normalized net sediment deposition is total estimated volume per 100 ft divided by distance between surveyed cross-sections (100 ft = 0.0305 km).

Table 3.7-2
Summary of Geomorphic Changes at Cross-Sections below the DP Canyon GCS

Section Name	Maximum New Sediment Thickness (ft)	Maximum Erosion (ft)	Net Sediment Cross-Sectional Area (ft^2)	2011 Normalized Net Sediment Deposition or Erosion (m^3/km)*	2010 Normalized Net Sediment Deposition or Erosion (m^3/km)*	2011 Thalweg Elevation Change (ft)	2010 Thalweg Elevation Change (ft)
DPGCS +125 ft	0.0	1.4	−12.2	−1133	1891	−0.9	1.7
DPGCS +225 ft	0.3	0.7	−3.8	−353	204	−0.1	0.0
Average			**−8.0**	**−743**	**1048**	**−0.5**	**0.8**

* Normalized net sediment deposition is total estimated volume per 100 ft divided by distance between surveyed cross-sections (100 ft = 0.0305 km).

Table 3.8-1
Sediment Volume Changes at Los Alamos Canyon Low-Head Weir, July 2011 to March 2012

Site	Total Net Change (m^3)	Estimated Percent Coarse Sediment	Estimated Percent Fine Sediment	Estimated Volume Coarse Sediment (m^3)	Estimated Volume Fine Sediment (m^3)
Basin 1 (west)	780	50%	50%	390	390
Basin 2 (central)	1440	5%	95%	72	1368
Basin 3 (east)	4700	0%	100%	0	4700
Total	**6920**			**462**	**6458**

Table 3.8-2
Sediment Accumulation at Los Alamos Canyon Low-Head Weir, 2000–2012

Period	Total Sedimentation (m^3)	Approximate Annual Sedimentation (m^3/yr)
June 2000 to May 2002	822	411
May 2002 to August 2005	3377	1126
August 2005 to July 2007	2555	1278
July 2007 to September 2008	138	138
September 2008 to May 2009	0	—*
May 2009 to July 2010	510	510
July 2010 to March 2011	274	274
March 2011 to July 2011	0	—
July 2011 to March 2012	6920	6920
June 2000 to March 2011	14,596	1216

*— = Not calculated; not in stormwater runoff season.

Appendix A

Photographs of Sediment Transport Mitigation Sites



Figure A-1 **March 2012 photograph of cross-section CVS#1 +50 ft, below Pueblo Canyon CVS #1, looking upstream**



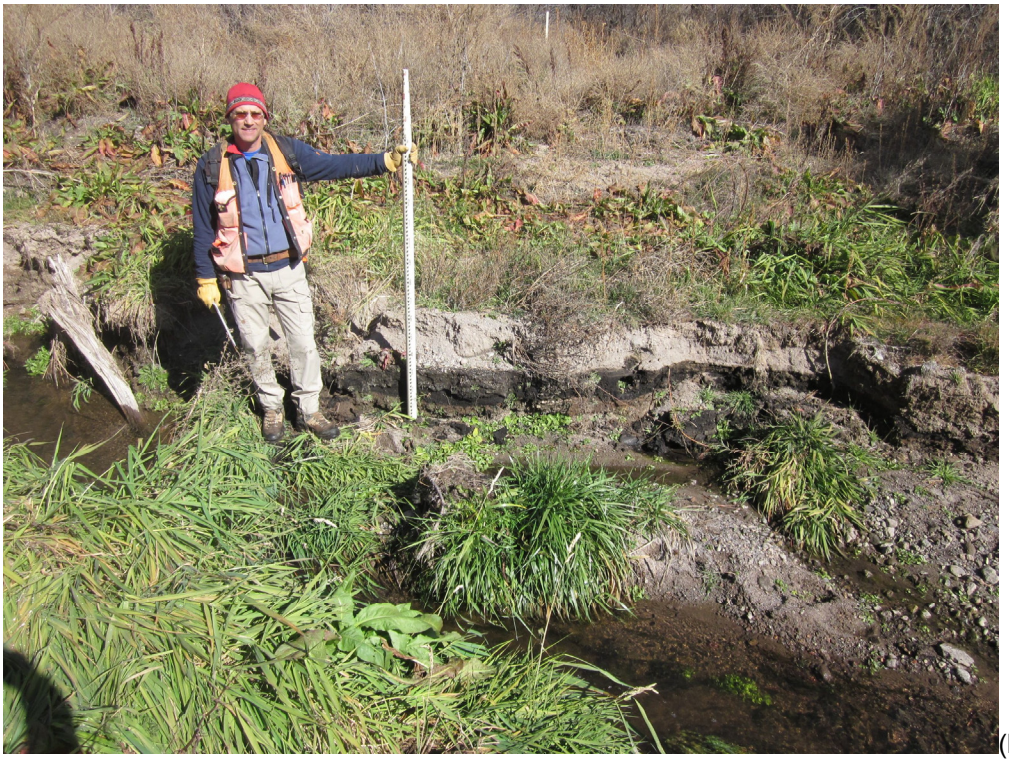
Figure A-2 **March 2012 photograph of cross-section CVS#3 −50 ft, above Pueblo Canyon CVS #3, looking upstream**



Figure A-3 **October 2011 photograph of aggraded area at cross-section UW-3, in the upper third of the upper Pueblo Canyon willow-planting area, where sediment from a tributary drainage buried the previous channel**



(a)



(b)

Figure A-4 **November 2011 photographs of eroding banks in post- Cerro Grande sediment in lower third of upper Pueblo Canyon willow-planting area: (a) cross-section LW-4, looking downstream (b) north bank above cross-section LW-3, showing buried Cerro Grande muck layer**



Figure A-5 **March 2012 photograph of main northern channel at cross-section WD-1 below the Pueblo Canyon wing ditch, which experienced aggradation during the summer 2011 monsoon season**



Figure A-6 **March 2012 photograph of southern channel at cross-section WD-3 below the Pueblo Canyon wing ditch, which experienced bank erosion during the summer 2011 monsoon season**



Figure A-7 **March 2012 photograph of main channel at cross-section PU −300 ft, in the upper half of the lower Pueblo Canyon willow-planting area, which experienced bank erosion during the summer 2011 monsoon season. Note sparse willow stems.**



Figure A-8 **March 2012 photograph of cross-section PU +600 ft, in the lower half of the lower Pueblo Canyon willow-planting area, which experienced bank erosion during the summer 2011 monsoon season. Note willow stems.**



Figure A-9 **November 2011 photograph of southern headcut at cross-section PU 0 ft, in the lower half of the lower Pueblo Canyon willow-planting area, where the emergence of alluvial groundwater perched on Puye Formation bedrock results in seepage erosion. Wetland vegetation and willows are established below headcut.**



(a)



(b)

Figure A-10 November 2011 photographs of Pueblo Canyon GCS: (a) view looking upstream to GCS (b) view looking downstream to GCS



Figure A-11 **March 2012 photograph of cross-section PUGCS −400 ft, above the Pueblo Canyon GCS, which experienced some sediment deposition during the summer 2011 monsoon season**



Figure A-12 **March 2012 photograph of cross-section PUGCS −1100 ft, above the Pueblo Canyon GCS, which some experienced some bank erosion during the summer 2011 monsoon season**


(a)


(b)

Figure A-13 **March 2012 photographs of upper Los Alamos Canyon sediment detention basins: (a) basin 1 (b) basin 2**



(a)



(b)

Figure A-14 November 2011 photographs of DP Canyon GCS: (a) view looking downstream to GCS (b) view looking upstream to GCS, past E039.1 gaging station


(a)

Figure A-15 November 2011 photographs showing aggradation at cross-sections above the DP Canyon GCS: (a) view looking upstream at cross-section DP GCS −800 ft



(b)

Figure A-15 (continued) **November 2011 photographs showing aggradation at cross-sections above the DP Canyon GCS: (b) view looking upstream at cross-section DP GCS −400 ft**


(c)

Figure A-15 (continued) **November 2011 photographs showing aggradation at cross-sections above the DP Canyon GCS: (c) view looking downstream at cross-section DP GCS −300 ft**



Figure A-15 (continued) **November 2011 photographs showing aggradation at cross-sections above the DP Canyon GCS: (d) view looking upstream at cross-section DP GCS −300 ft**

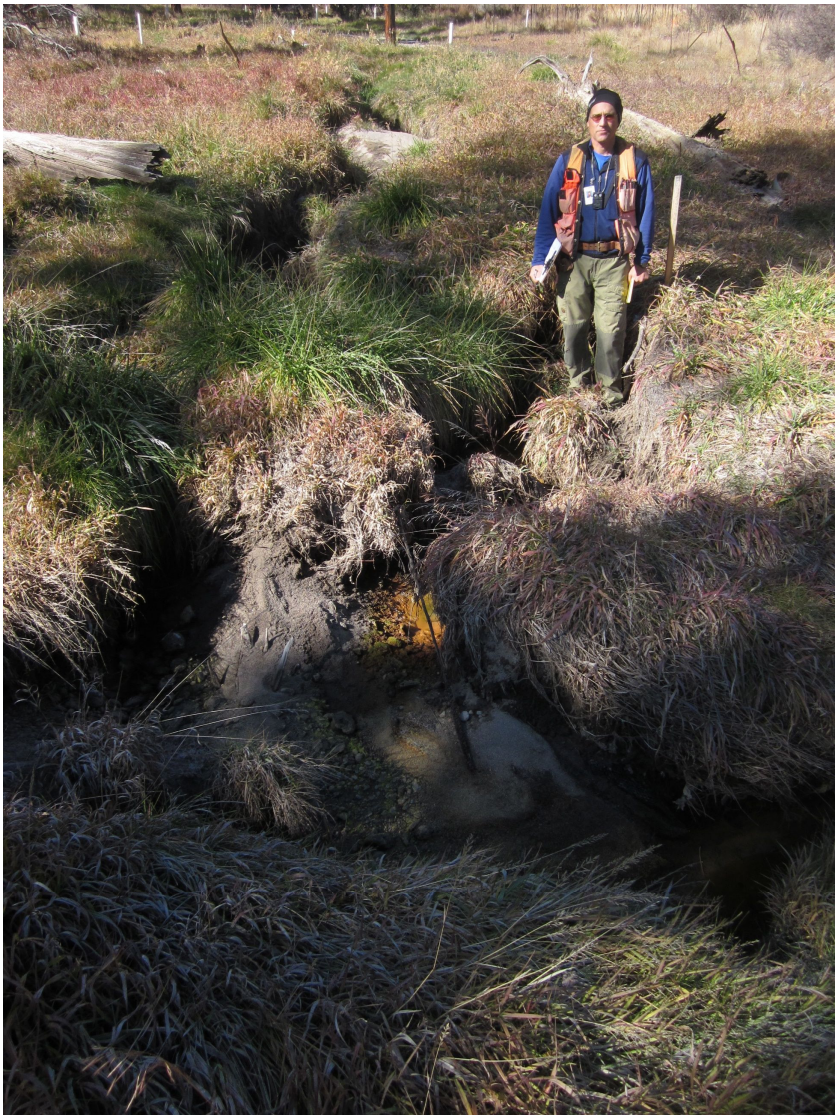


Figure A-16 November 2011 photograph showing scour at cross-section DP GCS −200 ft



(a)



(b)

Figure A-17 **March 2012 photographs of Los Alamos Canyon low-head weir: (a) view looking upstream to weir (b) view looking downstream over sediment retention basin 3 to weir**



(a)



(b)

Figure A-18 **March 2012 photographs of sediment retention basins above Los Alamos Canyon low-head weir: (a) view looking upstream over basin 1 (b) view looking upstream over basin 2**



Figure A-18 (continued) **March 2012 photographs of sediment retention basins above Los Alamos Canyon low-head weir: (c) view looking upstream over basin 3**



(a)



(b)

Figure A-19 **Thick willow patches in upper and middle thirds of upper Pueblo Canyon willow-planting area: (a) October 2011 photograph, view looking upstream, past cross-section UW-5 (b) November 2011 photograph, view looking upstream, past cross-section MW-2**



(a)



(b)

Figure A-20 **November 2011 photographs of willows laid down by floods and resprouting in upper third of upper Pueblo Canyon willow-planting area: (a) near cross-section UW-3 (b) near cross-section UW-4**



(a)

Figure A-21 **November 2011 photographs of sparse willows in upper half of lower Pueblo Canyon willow-planting area, in area with thick reed canary grass: (a) willows near cross-section PU −500 ft**



(b)

Figure A-21 (continued) **November 2011 photographs of sparse willows in upper half of lower Pueblo Canyon willow-planting area, in area with thick reed canary grass: (b) willow stem that has been damaged by animals**



Figure A-22 **November 2011 photograph of sparse willows in lower half of lower Pueblo Canyon willow-planting area, near cross-section PU −900 ft, in area with deposition of coarse-grained sediment**



Figure A-23 November 2011 photograph of thick willow patch on high surface near transition zone in lower Pueblo Canyon willow-planting area



Figure A-24 **March 2012 photograph of rock armoring along stream banks in the south fork of Acid Canyon, looking upstream**

Attachment 1

Cross-Section Survey Data
(on CD included with this document)