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United States Department of Energy Sandia National Laboratories, California Arroyo Seco Improvement Program Annual Report for 2019

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ABSTRACT

The Arroyo Seco Improvement Program is being carried out at Sandia National Laboratories, California in order to address erosion and other streambed instability issues in the Arroyo Seco as it crosses the Sandia National Laboratories, California. The work involves both repair of existing eroded areas, and habitat enhancement. This work is being carried out under the requirements of Army Corps of Engineers permit 2006-400195S and California Regional Water Quality Control Board, San Francisco Bay Region Water Quality Certification Site No. 02-01-C0987.

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Table of Contents

List of Figures

List of tables

Executive Summary

The Arroyo Seco Improvement Program (ASIP) is intended to provide active channel improvements and stream zone management activities that will reduce current flood and erosion risk while providing additional and improved habitat for critical species that may use the Arroyo Seco at the United States Department of Energy (DOE), Sandia National Laboratories, California (SNL/CA) location. The objectives of the ASIP are:

- Correct existing channel stability problems associated with existing arroyo structures (i.e. bridges, security grates, utility crossings, and drain structures).
- Correct bank erosion, and provide protection against future erosion.
- Reduce the risk of future flooding.
- Provide habitat improvement and creation of a mitigation credit for site development and management activities.

The ASIP is being carried out under the requirements of Army Corps of Engineers (ACOE) permit 2006-400195S and California Regional Water Quality Control Board, San Francisco Bay Region (SFRWQCB) Water Quality Certification Site No. 02-01-C0987. Four of the project locations were undertaken under a previous permit from the ACOE (File No. 27943S). The status of these projects will also be discussed in this and future reports.

The ASIP was divided into eighteen projects. Construction on the final project was completed in September of 2015.

Area 17 and an area at the boundary of Area 8 and Area 9 experienced significant erosion during the heavy rains of the 2016/2017 winter season. Repairs to Area 17 were completed during 2018. DOE and SNL/CA personnel completed repairs to Area 9 during FY 2019. A time extension to December 31, 2020 was granted by the ACOE on June 27, 2018 in order to complete repairs of the erosion damage.

Annually, SNL/CA personnel will report on the status of the project areas. This report is the tenth of these annual reports.

SNL/CA personnel are required to monitor and maintain the individual project sites for a minimum of ten (10) years from the completion of the individual projects, or until compliance with the ASIP performance goals as defined in the SFRWQCB Clean Water Certification is achieved. Project areas that have achieved the performance goals are identified in the body of the report.

With the permission of the SFRWQCB and the ACOE, the percent cover calculation has been revised to include native shrub cover, as well as native grasses (a grass/shrub seed mixture was used for hydroseeding). Some sites still do not meet the 75% cover criterion. However, many of these sites show evidence that the grass and shrubs are establishing themselves well. Those project sites where the native grasses and shrubs do not appear to

be establishing themselves well will be re-seeded or otherwise planted as needed. Various locations in the report are also noted as not meeting the survival and cover criteria for trees. These areas will be replanted in order to meet the criteria. These locations are identified in the body of the report.

In addition, SNL/CA personnel are required to report on wildlife and avifauna use of the restored Arroyo Seco project sites. In 2019, SNL/CA personnel contracted with an ecology consultant to perform a wildlife and avifauna survey. The results of this study are presented in this Annual Report. The next survey is expected to be performed in 2020.

With this year's monitoring, the following areas have been monitored for ten years, and have met the ten-year performance criteria, and are therefore considered complete. Area 6, Area 7, Area 9, Area 12, Area 13, Area 14A, Area 14B, Area 15, and Area 16.

In conclusion, DOE and SNL/CA personnel feel that we are making good progress on successfully meeting the terms of the permit.

Projects Undertaken Through 2019

The following table shows all of the approved projects. Projects 1, 3, 10, 12, and 13 were completed under the previous ACOE Permit. All construction projects are now complete, and the ASIP has entered a monitoring and maintenance phase.

Table 1. Approved Projects

Project Number	Description	Year Construction Completed	Year of Monitoring in 2019
1	Sewer crossings on LLNL and SNL/CA site.	2006	N/A
2	Improvements to box culvert at East Avenue	2013	N/A
3	Remove concrete and debris upstream of East Ave Crossing.	2006	N/A
4	Stabilize storm drain outlet near old sewer crossing.	2013	Year 6
5	Remove pine trees near Sandia Drive bridge and stabilize bank.	2012	Year 7
6	Correct erosion upstream of security grate.	2009	Site is complete[1]
7	Repair erosion at pedestrian bridge.	2009	Site is complete[1]
8*	Repair storm drain outlet between C Street bridge and pedestrian bridge. Create small inset bench.	2013	Year 6
9*	Repair erosion at C Street bridge.	2009	Site is complete[1]
10	Remove concrete debris between A Street and C Street	2006	N/A
11	Repair storm drain outlet between A Street and C Street	2008	N/A
12	Repair erosion at A Street bridge.	2006	Site is complete[1]
13	Repair storm drain outlet upstream of A Street bridge.	2006	Site is complete[1]
14A	Repair storm drain outlet down stream of land bridge.	2009	Site is complete[1]
14B	Create inset floodplain downstream of land bridge.	2009	Site is complete[1]
15	Remove land bridge.	2009	Site is complete[1]
16	Repair erosion at Thunderbird Lane bridge.	2009	Site is complete[1]
17A	Remove abandoned concrete structure and steel posts in streambed.	2015	Year 4
17B*	Grade an inset floodplain adjacent to wetland area upstream of Thunderbird Lane.	2015	Year 4
18	Correct surface drainage problems campus wide by installing curbs, catch basins, and storm water retention facilities.	various	N/A

*An extension to the permit was granted in 2018 to repair erosion damage suffered in 2016/2017 at these locations. The extension expires 12/31/2020.

[1]The permits require 10 years of monitoring if performance criteria are met. This site was monitored for 10 years and met 10 Year performance criteria, therefore this site is considered complete and monitoring is no longer required. Photopoints and the final year of data for this site is included in this report

Project 1. Remove Sewer Crossings at LLNL and SNL/CA

Year Completed: 2006

Since this project was completed in 2006 under the previous ACOE Permit, only the status of plantings will be presented here. There are no as-built drawings for these Projects.

The plantings at the LLNL crossing have grown well. Since there were no survival or coverage criteria in the previous ACOE Permit, no data was collected. Pre and post-construction photographs were included in the 2009 Annual Report. Photographs are not included in this report. The plantings at the SNL/CA sewer crossing have not survived. This area was replanted when SNL/CA personnel completed project 4 in 2013.

Project 2. Improvements to Box Culvert at East Avenue

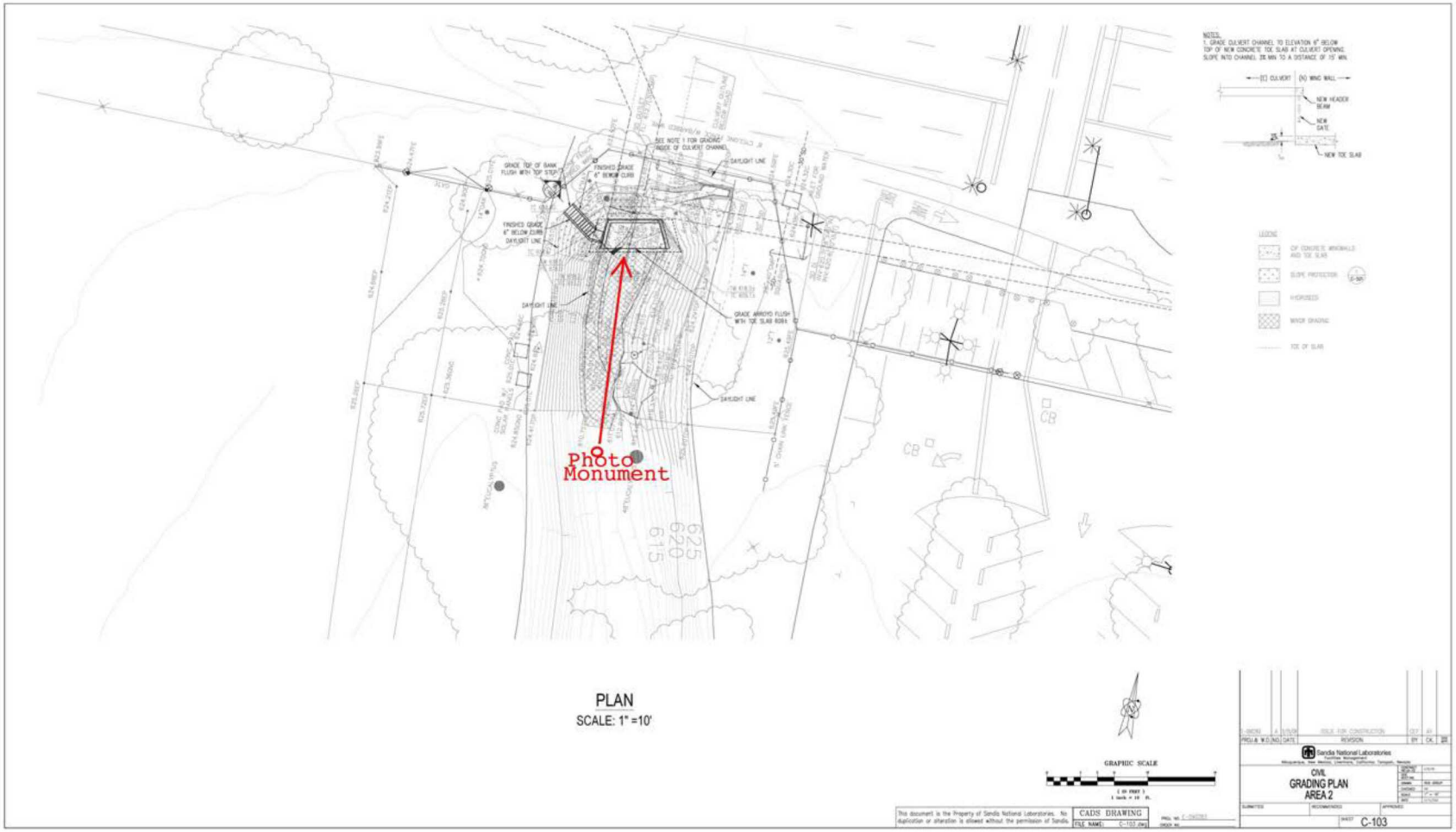
Year Completed: 2013

Site 2 involved installation of a new concrete approach and concrete wing walls. Protruding re-bar was also removed from the culvert face. A staircase and ladder were added to the west wing wall to facilitate safe access to the arroyo bed. All disturbed areas were hydroseeded with native grasses and shrubs. No further plantings were required at this location.

The Ordinary High Water mark (OHWM) was determined using the two-year recurrence interval flow, 100 cfs from a hydraulic study performed by Questa, Inc. of Arroyo Seco flow through Lawrence Livermore National Laboratory (LLNL) property. A typical open channel flow calculator was used to determine average flow depth at OHWM. Using a slope of 0.01, channel top width of 40 feet, channel bottom width of 5 feet, channel height of 15 feet, and roughness coefficient, n-value, 0.04, a flow depth of 2.5 feet was calculated. Thus, cut and fill quantities above and below the OHWM were calculated from 2.5 feet above the channel bottom through Site 2.

- Linear feet of stream bank affected = 120 feet
- Excavation below OHWM = 25 cubic yards
- Fill below OHWM = 25 cubic yards
- Excavation below top of bank = 60 cubic yards
- Fill below top of bank = 40 cubic yards.

Figure 1. As-built drawing for Project 2



Photos for this location will be taken from the streambed. The photo location is noted on Figure 1. Pre-construction and post-construction photos are shown below.

Figure 2. Photo Project 2 looking north pre-construction 2013

Figure 3. Photo Project 2 looking north post-construction, 2019

Project 3. Concrete and Debris Removal Upstream of East Avenue

Year Completed: 2006

Since this project was completed in 2006 under the previous ACOE Permit, only the status of plantings will be presented here. Since there were no survival or coverage criteria in the previous ACOE Permit, no data was collected. There are no as-built drawings for these Projects. Pre and post-construction photographs were included in the 2009 Annual Report. Photographs are not included in this report.

The original native grasses planted in 2006 did not survive. During the 2009 construction season, this area was seeded again with a native grass mixture. Since the irrigation system at this area is not functional, the grasses did not survive. Replanting of this area with willow stakes was undertaken along with the completion of Project 4 during 2013. Fifty willow stakes were planted in 2013. Growth will be monitored in future years. A new irrigation system was installed in 2013.

Project 4. Install Grouted Rock Apron

Year Completed: 2013

Site 4 involved installing a grated rock apron extending down the channel bank and along the stream bottom to function as a splash curtain for the storm drain outlet.

The Ordinary High Water mark (OHWM) was determined using the two-year recurrence interval flow, 100 cfs from a hydraulic study performed by Questa, Inc. of Arroyo Seco flow through Lawrence Livermore National Laboratory (LLNL) property. A typical open channel flow calculator was used to determine average flow depth at OHWM. Using a slope of 0.01, channel top width of 40 feet, channel bottom width of 5 feet, channel height of 15 feet, and roughness coefficient, n-value, 0.04, a flow depth of 2.5 feet was calculated. Thus, cut and fill quantities above and below the OHWM were calculated from 2.5 feet above the channel bottom through Site 4.

- Linear feet of stream bank affected = 20 feet
- Excavation below OHWM = 8 cubic yards
- Fill below OHWM = 8 cubic yards
- Excavation below top of bank = 12 cubic yards
- Fill below top of bank = 12 cubic yards.

Proposed plantings for Site 4 only included hydroseed of native grasses and shrubs, however, SNL/CA personnel planted 40 willow stakes at Site 4. In January 2016, addition container plantings were planted including 10 Coyote bush, 8 California sagebrush, 6 California mugwort, and 8 California rose. A native seed mix was also spread.

Table 2. Proposed and actual plantings for Project 4

Species	Proposed	Actual	2019 Survival[1]
Arroyo willow stakes	0	40	3
Willow trees	0	0	
California buckeye	0	0	
Blue elderberry	0	0	
Maples	0	0	
California sycamore	0	0	
Coast live oak	0	0	
Valley oak	0	0	
Fremont cottonwood	0	0	
Native grass seed	Yes	Yes	
Total	**0**	**40**	**N/A**
Native tree cover			56%
Native Shrub Cover			80%
Native Grass/Ground Cover			69%

[1]Number of trees

Construction of Site 4 was completed in September 2013, therefore monitoring of this site began in spring 2014. This is year 6 of monitoring Site 4.

Since willow plantings were not required for Site 4, there is no percent survival criterion.

Native tree cover, comprised entirely of willows, was 56% which does not meet the year 5 or 10 performance criteria. Shrub cover was 80% which meets the year 5 and 10 performance criteria. Grass/ground cover was 69%, which does not meet the year 5 or year 10 performance criteria.

The site looks good, with healthy growth of native plantings including coyote brush, California sagebrush, and mugwort. It is expected these will increase in cover over the years. The slope just north of the culvert is covered in dense native creeping wildrye (*Elymus triticoides*). The native tree cover requirements have not been met. Grass and shrub cover taken together meet the 75% cover criteria. Additional willow plantings at this area will be undertaken to increase the tree cover.

Site 4 has one photo monument, designated 4. The location of this monument is shown in the as-built drawing, Figure 4. Photographs are shown for this monument before and after construction.

Figure 4. Drawing for Project 4

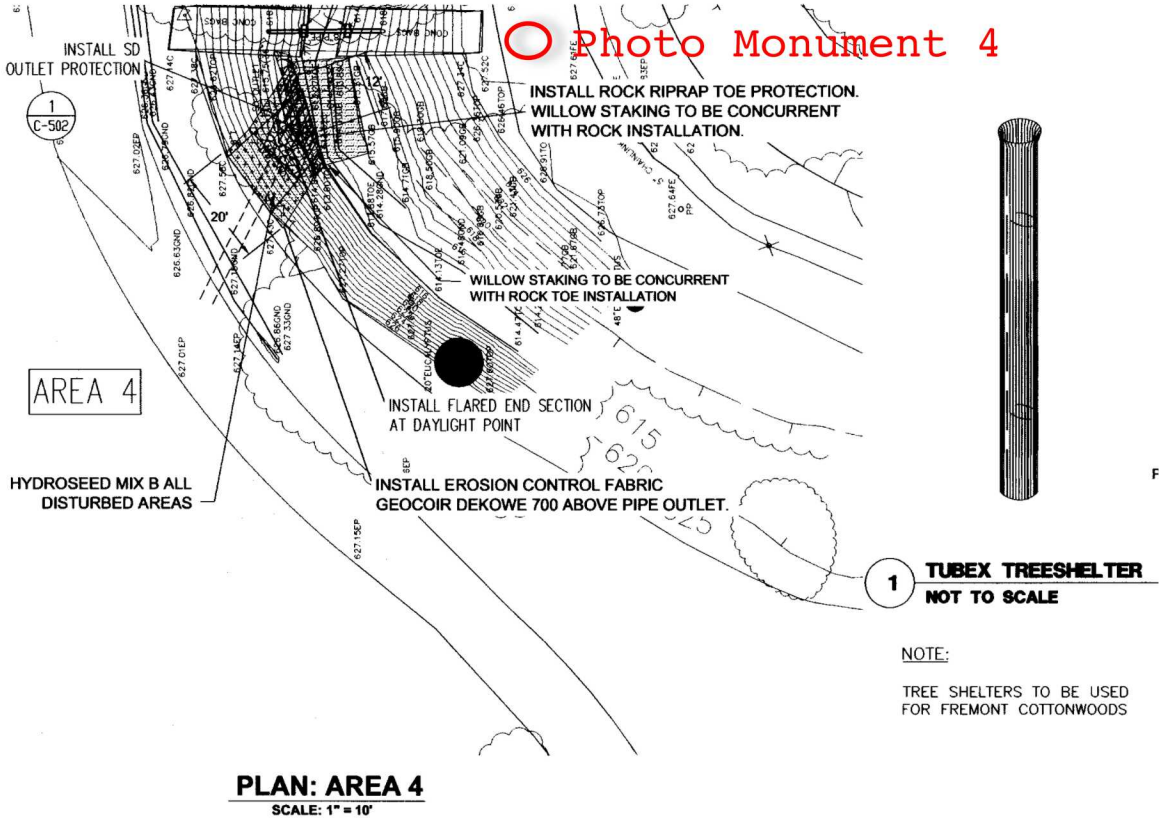


Figure 5. Photo Project 4 looking west pre-construction, 2013

Figure 6. Photo Project 4 looking west post-construction, 2019

Project 5. Remove Pine Tree and Stabilize Bank Downstream of Sandia Drive Bridge

Year Completed: 2012

Site 5 involved stabilizing the north bank of Arroyo Seco downstream of the Sandia Drive bridge. The project involved removal of a pine tree on the north bank, and re-grading the bank.

The Ordinary High Water mark (OHWM) was determined using the two-year recurrence interval flow, 100 cfs from a hydraulic study performed by Questa, Inc. of Arroyo Seco flow through Lawrence Livermore National Laboratory (LLNL) property. A typical open channel flow calculator was used to determine average flow depth at OHWM. Using a slope of 0.01, channel top width of 40 feet, channel bottom width of 5 feet, channel height of 15 feet, and roughness coefficient, n-value, 0.04, a flow depth of 2.5 feet was calculated. Thus, cut and fill quantities above and below the OHWM were calculated from 2.5 feet above the channel bottom through Site 5.

- Linear feet of stream bank affected = 100 feet
- Excavation below OHWM = 45 cubic yards
- Fill below OHWM = 65 cubic yards
- Excavation below top of bank = 85 cubic yards
- Fill below top of bank = 120 cubic yards.

Plantings for Site 5 are somewhat different than those originally proposed. The changes were made based on the recommendations from Questa, Inc. based on their experience with streambed restoration in the Livermore Valley. The total quantity of plants used meets or exceeds the original proposal, although the species composition may be different. Table 3 shows the actual plantings.

Construction of Site 5 was completed in 2012, therefore monitoring of this site began in spring 2013. This is Year 7 of monitoring at Site 5.

Overall the site contains dense native shrubs on the slope and willows in the channel. Willow stakes had 82% survival, which does not meet the performance criteria. Sandbar willow (*Salix exigua*) is present and widespread on site and is spreading upstream in the channel, which provides high willow cover. These natural sandbar willow recruits have been included in the count of surviving trees. The one remaining coast live oak appeared healthy. Table 3 shows the proposed and actual plantings and survival rates as noted during a 2018 survey.

Native tree cover, comprised primarily of dense willows, was 75% which meets the performance criteria for Year 5 and Year 10. Shrub cover was 60% which meets the performance criteria for Year 5 and Year 10. Grass/ground cover was 75% which meets the Year 5 and Year 10 performance criteria. The shrubs along the slope have grown

significantly since last year and are providing good ground cover. Tree survival and cover performance criteria were met, but have not been met for five consecutive years.

Table 3. Proposed and actual plantings for Project 5

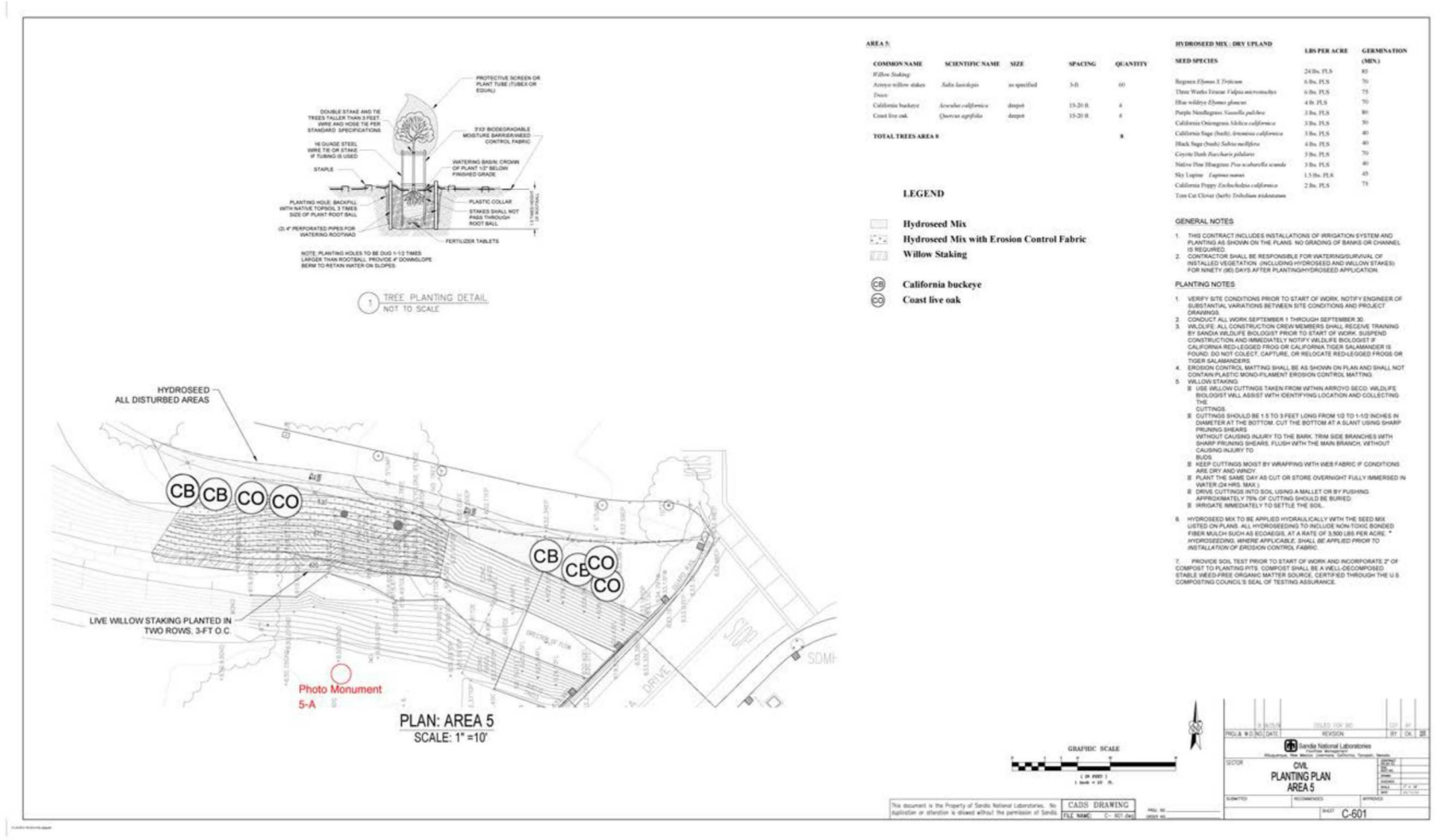
Species	Proposed	Actual	2019 Survival[1]
Arroyo willow stakes	60	90	76[2]
Willow trees	30	0	
California buckeye	0	4	0
Blue elderberry	0	0	
Maples	0	0	
California sycamore	0	0	
Coast live oak	0	4	1
Valley oak	0	0	
Fremont cottonwood	0	0	
Native grass seed	No	Yes	
Total	**90**	**98**	**82%**
Native Tree Cover			75%
Native Shrub Cover			60%
Native Grass/Ground Cover			75%

[1]Number of trees

[2]Willow stakes and willow trees were combined for the count. Natural sandbar willow recruits in the restoration area were also included in the count.

Project 5 has one photo monument, designated 5-A. The location of this monument is shown on the as-built drawing, figure 7.

Figure 7. Drawing for Project 5



Pre-construction and post-construction photographs are shown below for the photo monument.

Figure 8. Photo Monument 5-A, looking northeast, pre-construction, 2012

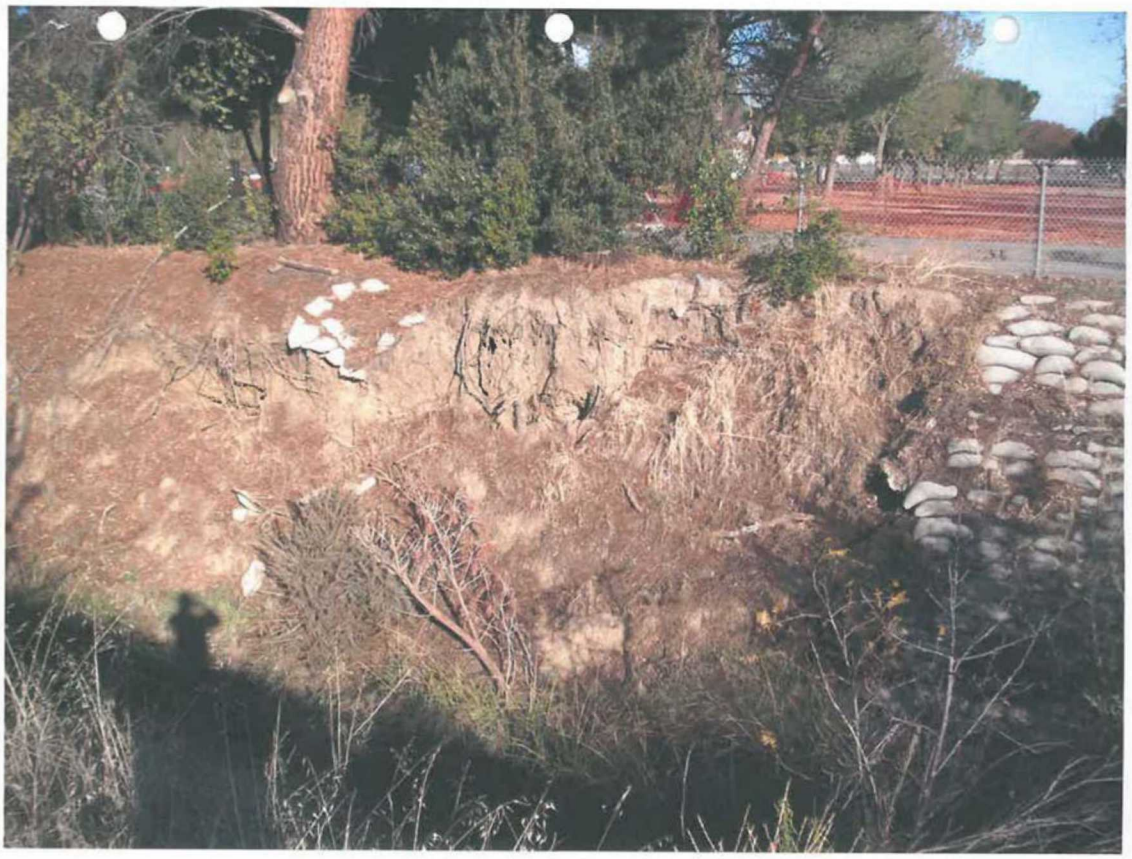


Figure 9. Photo Monument 5-A looking northeast, post-construction, 2019

Project 6. Correct Erosion Upstream of Security Grate and Project 7. Repair Erosion at Pedestrian Bridge

Year Completed: 2009
Project 6 involved the "Correction of Erosion Upstream of a Security Grate". Due to the proximity to Project 7, "Repair of Erosion at the Pedestrian Bridge", these two projects are considered together. Calculations for length of stream bank and cut and fill volumes were combined for the two Projects.

The Ordinary High Water mark (OHWM) was determined using the two-year recurrence interval flow, 100 cfs from a hydraulic study performed by Questa, Inc. of Arroyo Seco flow through LLNL property. A typical open channel flow calculator was used to determine average flow depth at OHWM. Using a slope of 0.01, channel top width of 40 feet, channel bottom width of 5 feet, channel height of 15 feet, and roughness coefficient, n-value, 0.04, a flow depth of 2.5 feet was calculated. Thus, cut and fill quantities above and below the OHWM were calculated from 2.5 feet above the channel bottom through Project areas 6 and 7.

- Linear feet of stream bank affected = 400 feet
- Excavation below OHWM = 200 cubic yards
- Fill below OHWM = 250 cubic yards
- Excavation below top of bank = 500 cubic yards
- Fill below top of bank = 500 cubic yards.
-

Plantings for Project 6 and 7 were somewhat different from those originally proposed. The changes were made based on the recommendations from Questa, Inc. based upon their experience with streambed restoration in the Livermore Valley. The total quantity of plants used meets or exceeds the original proposal, although the species composition may be different. No tree plantings were proposed in this area, so percent survival performance criteria are not applicable, and are not shown here.

Construction of Sites 6 and 7 were completed in 2008, therefore monitoring of this site began in spring 2009. All performance criteria were met in 2018, and this site is considered complete.

Table 4 shows the plantings met performance criteria in 2018.

Table 4. Proposed and actual plantings for Projects 6 and 7

Metric	2018 Percent Cover	5-Year Performance Criteria	10-Year Performance Criteria
Native Tree Cover	83	60	75
Native Shrub Cover	71	30	45
Native Grass/Ground Cover	75	75	75

Since this site is considered complete, progress photos will no longer be presented in this annual report.

Project 8. Repair Storm Drain Outlet Between C Street Bridge and Pedestrian Bridge

Year Completed: 2013

Site 8 involved repairing a storm drain outlet between the C Street Bridge and the Pedestrian Bridge. Grading of the existing slope was done to create a small inset bench. The existing erosion gully was filled with riprap and compacted fill.

The Ordinary High Water mark (OHWM) was determined using the two-year recurrence interval flow, 100 cfs from a hydraulic study performed by Questa, Inc. of Arroyo Seco flow through Lawrence Livermore National Laboratory (LLNL) property. A typical open channel flow calculator was used to determine average flow depth at OHWM. Using a slope of 0.01, channel top width of 40 feet, channel bottom width of 5 feet, channel height of 15 feet, and roughness coefficient, n-value, 0.04, a flow depth of 2.5 feet was calculated. Thus, cut and fill quantities above and below the OHWM were calculated from 2.5 feet above the channel bottom through Site 8.

- Linear feet of stream bank affected = 90 feet
- Excavation below OHWM = 40 cubic yards
- Fill below OHWM = 40 cubic yards
- Excavation below top of bank = 140 cubic yards
- Fill below top of bank = 140 cubic yards.

Due to heavy rainfall during the winter of 2016-2017, and consequent high flows in the Arroyo Seco, a scour hole formed in the bed of the Arroyo at the junction of Project 8 and Project 9. The scour hole was repaired during the summer of 2019.

Plantings in this area were originally listed to be 5 maples, 20 willows and native grass/shrub hydroseed. Actual plantings were 2 California buckeye, 2 California sycamore, 2 coast live oak, and 2 Fremont cottonwood and 60 willow stakes as shown in Table 5.

Construction of Site 8 was completed in September 2013. Monitoring of this site was initiated in spring 2014, and is in Year 6 of monitoring.

Tree planting had 100% survival in 2018. Trees on site appeared healthy and shrubs are present throughout the site. Tree survival performance criteria was met for 5 consecutive years last year (2014-2018), therefore survival no longer needs to be monitored.

Tree cover was 65% which meets Year 5 performance, but does not meet Year 10 performance criteria. Shrub cover was 81% which meets the Year 5 and Year 10 performance criteria. Grass/ground cover was 78% which meets Year 5 and Year 10 performance criteria.

The surviving willows look healthy. As the plantings continue to grow, it is expected that Year 10 performance criteria will be met.

Table 5 shows tree, shrub, and grass/ground cover as noted during a 2019 survey. Survival percentages are not shown since the criteria were met for five consecutive years in 2018.

Table 5. Proposed and actual plantings for Project 8

Metric	2019 Percent Cover	5-Year Performance Criteria	10-Year Performance Criteria
Native Tree Cover	65	60	75
Native Shrub Cover	81	30	45
Native Grass/Ground Cover	78	75	75

Site 8 has one photo monument, designated 8. The location of this monument is shown in Figure 31.

Photographs are shown for this monument before and after construction.

Figure 10. Drawing for project 8

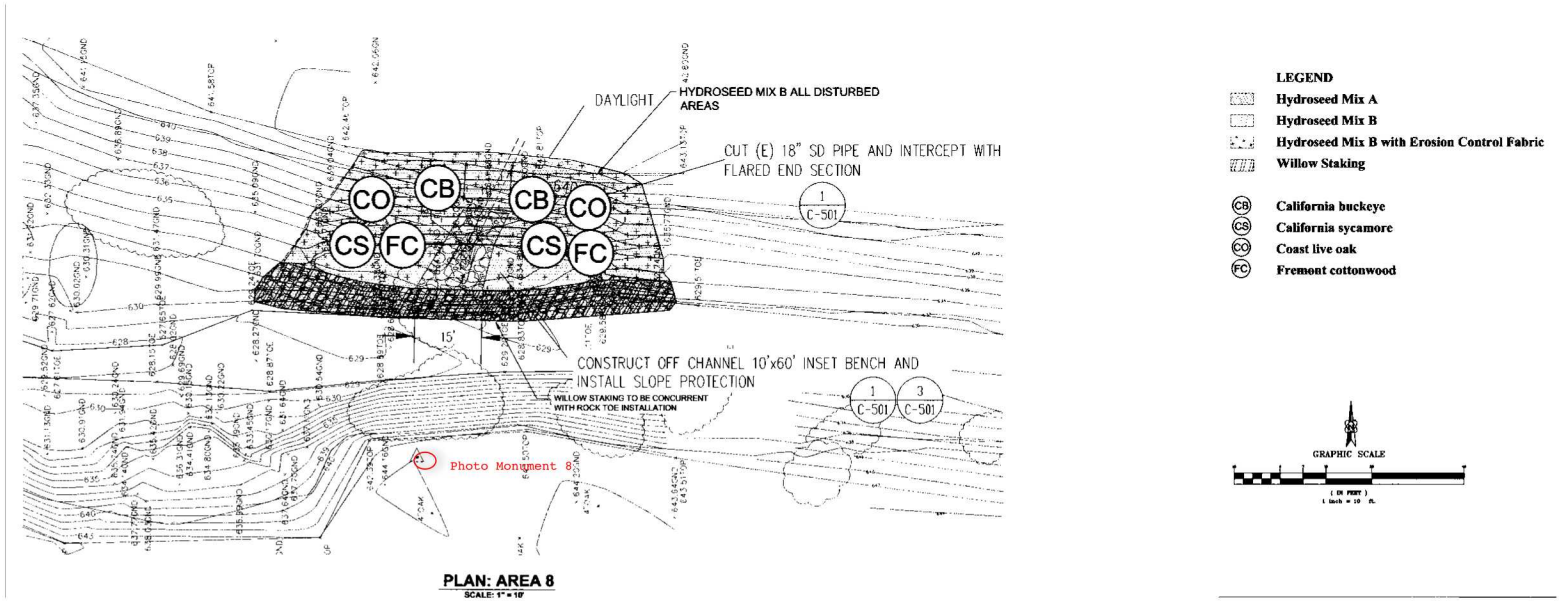


Figure 11. Photo Monument 8, looking north, pre-construction, 2013

Figure 12. Photo Monument 8, looking north, post-construction, 2019

Project 9. Repair Erosion at C Street Bridge

Year Completed: 2009
Replanted: 2013

Project 9 involved the correction of erosion at the C Street bridge. This included removal of large blocks of concrete that had been placed earlier for energy dissipation, and the repair of a scour hole downstream of the structure.

The Ordinary High Water mark (OHWM) was determined using the two-year recurrence interval flow, 100 cfs from a hydraulic study performed by Questa, Inc. of Arroyo Seco flow through LLNL property. A typical open channel flow calculator was used to determine average flow depth at OHWM. Using a slope of 0.01, channel top width of 40 feet, channel bottom width of 5 feet, channel height of 15 feet, and roughness coefficient, n-value, 0.04, a flow depth of 2.5 feet was calculated. Thus, cut and fill quantities above and below the OHWM were calculated from 2.5 feet above the channel bottom through Project area 9.

- Linear feet of stream bank affected = 200 feet
- Excavation below OHWM = 25 cubic yards
- Fill below OHWM = 450 cubic yards
- Excavation below top of bank = 25 cubic yards
- Fill below top of bank = 900 cubic yards.

Plantings for Project 9 were somewhat different from those originally proposed. The changes were made based on the recommendations from Questa, Inc. based upon their experience with streambed restoration in the Livermore Valley. The total quantity of plants used meets or exceeds the original proposal, although the species composition may be different.

Construction of Site 9 was completed in 2009, therefore monitoring of this site began in spring 2010. This is Year 10 of monitoring at Site 9. However, the site does not meet the performance criteria for grass/ground cover (see below), so this site will continue to be monitored until the performance criteria is met.

Due to heavy rainfall during the winter of 2016-2017, and consequent high flows in the Arroyo Seco, a scour hole formed in the bed of the Arroyo at the junction of Project 8 and Project 9. The scour hole was repaired during the summer of 2019.

Tree plantings had greater than 85% survival which meets performance criteria. All of the container plantings were alive with the exception of one California buckeye. Trees on site appeared healthy and shrubs are present throughout the site. Tree survival performance criteria have been met for 5 consecutive years (2010-2014), therefore survival does not need to be monitored further.

Tree cover was 80% which meets the Year 10 performance criteria. Shrub cover was 70% which meets the Year 10 performance requirement. Grass/ground cover was 63%

which does not meet the Year 10 performance criteria. Grass and shrub cover taken together meet the 75% cover criteria. The area on the south bank under the jute netting is very compacted and vegetation cover is low, however several native grasses and shrubs, including purple needle grass, foothill needle grass (*Stipa lepida*), and coyote brush are established and doing well.

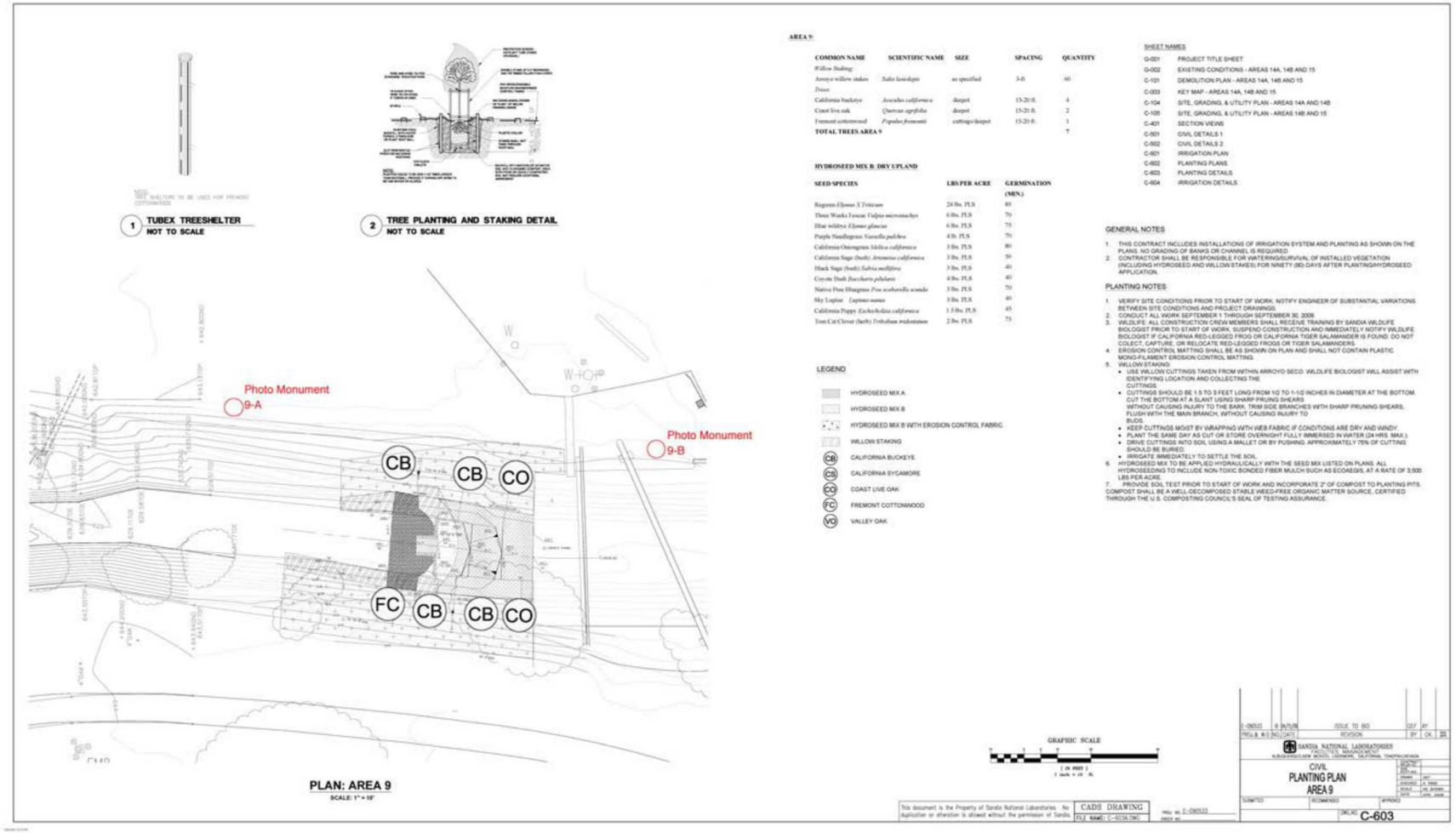
Table 6 shows tree, shrub, and grass/ground cover as noted during a 2019 survey. Survival percentages are not shown since the criteria were met for five consecutive years in 2014.

Table 6. Proposed and actual plantings for Project 9

Metric	2019 Percent Cover	5-Year Performance Criteria	10-Year Performance Criteria
Native Tree Cover	80	60	75
Native Shrub Cover	70	30	45
Native Grass/Ground Cover	63	75	75

Two photo monuments were established for Project 9, designated 9-A and 9-B. The location of these monuments is shown on the as-built drawing, figure 34.

Figure 13. Drawing for Project 9



Pre-construction and post-construction photos are shown for each of the monuments below.

Figure 14. Photo Monument 9-A looking southwest, pre-construction, 2009

Figure 15. Photo Monument 9-A looking southwest, post-construction, 2019

Figure 16. Photo Monument 9-B looking southeast, pre-construction, 2009

Figure 17. Photo Monument 9-B looking southeast, post-construction, 2019

Project 10. Remove Concrete Debris Between A Street and C Street

Year of Completion: 2006

Project 10 was completed under the previous ACOE Permit, therefore no calculations of cut and fill were required to be performed, and no photo monuments were established. No replanting was performed at this location. Pre and post-construction photographs were included in the 2009 Annual Report. Photographs are not included in this report.

Project 11. Repair Storm Drain Outlet Between A Street and C Street

Year of Completion: 2008

During the winter of 2008, the storm drain associated with Project 11 became completely blocked, causing flooding in the vicinity of Buildings 916 and 919. SNL/CA personnel undertook an emergency fix of this location. Because of the emergency nature of the project, the SFRWQCB was not notified in advance, nor were photo monuments established. Pre and post-construction photographs were included in the 2009 Annual Report. Photographs are not included in this report. No replanting was performed at this location.

Project 12. Repair Erosion at A Street Bridge

Year of Completion: 2006
Replanting: 2009

Project 12 was completed under the previous ACOE Permit, therefore no calculations of cut and fill were required to be performed, and no photo monuments were established. The grass seed used at this location did not survive. Even though the previous ACOE permit did not include survival or cover requirements, during the 2009 projects, the area was reseeded. In addition, some trees were added as shown in Table 7. Photos show the status of the plantings before the 2009 replanting and during a 2017 survey.

Construction of Site 12 was completed in 2008, therefore monitoring of this site began in spring 2009. Ten years of monitoring were completed in 2018, and this site is considered complete.

Tree survival performance criteria have been met for 5 consecutive years (2009-2013), therefore survival does not need to be monitored further. Tree, shrub cover, and grass/ground performance criteria were met in 2018 (Year 10).

Table 7 shows the plantings met percent cover performance criteria in 2018. Survival percentages are not shown since the criteria were met for five consecutive years in 2013.

Table 7. Replanting at Project 12

Metric	2018 Percent Cover	5-Year Performance Criteria	10-Year Performance Criteria
Native Tree Cover	80	60	75
Native Shrub Cover	86	30	45
Native Grass/Ground Cover	75	75	75

Since this site is considered complete, progress photos will no longer be presented in this annual report.

Project 13. Repair Storm Drain Outlet Upstream of A Street

Year Completed: 2006
Re-planting 2009

Project 13 was completed under the previous ACOE Permit, therefore no calculations of cut and fill were required to be performed, and no photo monuments were established. The plantings used at this location did not survive. Even though the previous ACOE permit did not include survival and cover requirements, during the 2009 projects, the area was replanted. The replanting is shown below in Table 8. Photos show the status of the plantings before the 2009 replanting and during a 2017 survey.

Construction of Site 13 was completed in 2006, therefore monitoring of this site began in spring 2007. Tree survival performance criteria have been met for 5 consecutive years (2012-2016) and therefore do not need to be monitored further. In 2016, the site met all performance criteria, was considered successful, and is considered complete.

Table 8 shows the project met performance criteria in 2016. Survival percentages are not shown since the criteria were met for five consecutive years in 2016.

Table 8. Replanting at Project 13

Metric	2016 Percent Cover	5-Year Performance Criteria	10-Year Performance Criteria
Native Tree Cover	80	60	75
Native Shrub Cover	45	30	45
Native Grass/Ground Cover	86	75	75

Since this site is considered complete, progress photos will no longer be presented in this annual report.

Project 14A. Repair Storm Drain Outlet Downstream of Land Bridge

Project Completed: 2009
Replanting: 2013
Project 14A involved repair of a heavily eroded storm drain outlet downstream of the land bridge. During the creation of the inset floodplain at Project 14B, the storm drain was relocated.

The Ordinary High Water mark (OHWM) was determined using the two-year recurrence interval flow, 100 cfs from a hydraulic study performed by Questa, Inc. of Arroyo Seco flow through LLNL property. A typical open channel flow calculator was used to determine average flow depth at OHWM. Using a slope of 0.01, channel top width of 40 feet, channel bottom width of 5 feet, channel height of 15 feet, and roughness coefficient, n-value, 0.04, a flow depth of 2.5 feet was calculated. Thus, cut and fill quantities above and below the OHWM were calculated from 2.5 feet above the channel bottom through Project area 14A.

- Linear feet of stream bank affected = 50 feet
- Excavation below OHWM = 40 cubic yards
- Fill below OHWM = 40 cubic yards
- Excavation below top of bank = 200 cubic yards
- Fill below top of bank = 200 cubic yards.

Plantings for Project 14A were somewhat different from those originally proposed. The changes were made based on the recommendations from Questa, Inc. based upon their experience with streambed restoration in the Livermore Valley. The total quantity of plants used meets or exceeds the original proposal, although the species composition may be different

Construction of Site 14A was completed in 2009, therefore monitoring of this site began in spring 2010. This is Year 10 of monitoring at Site 14A. The site has met the 10 Year performance criteria and is considered complete.

One coast live oak, one California sycamore, and two Fremont cottonwood trees were alive and vigorous. Trees had greater than 100% survival in 2019 because more trees were planted than were required by permits (Table 9), which meets the performance criteria for tree survival. The site has not met survival performance criteria for five consecutive years, but has met performance criteria for the last two years (2018-2019).

Tree cover was 78%, which meets the Year 10 performance criteria (Table 9). Shrub cover was 80%, which meets the Year 10 performance criteria (Table 9). Grass/ground cover was 75%, which meets Year 10 performance criteria (Table 9). The site had good patches of native purple needlegrass (*Stipa pulchra*) throughout.

Table 9 shows the proposed and actual plantings, and survival rates as noted during a 2019 survey.

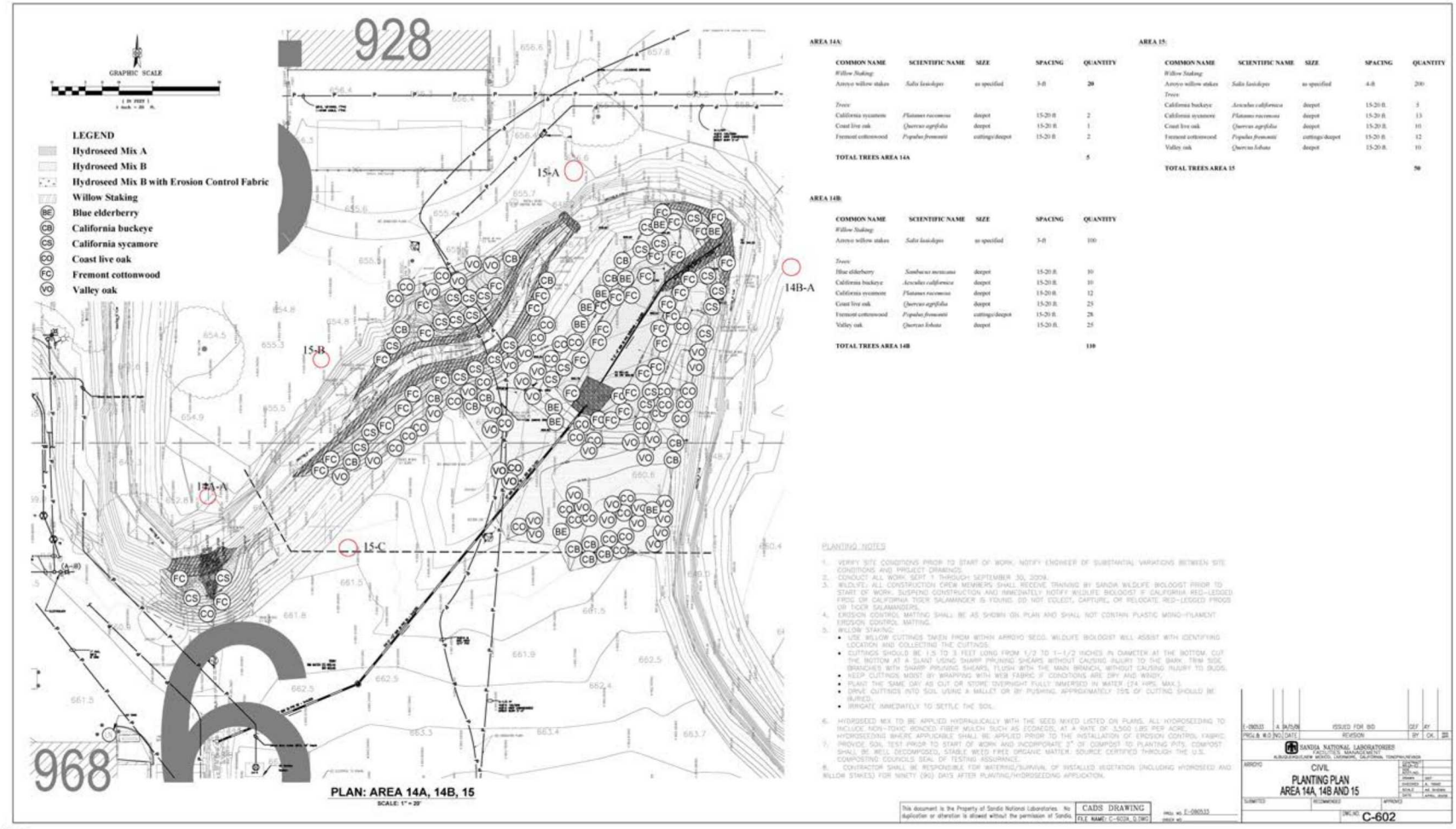
Table 9. Proposed and actual plantings for Project 14A

Species	Proposed	Actual	2019 Survival[1]
Arroyo willow stakes	0	31	22[2]
Willow trees	20	0	
California buckeye	0	0	
Blue elderberry	0	0	
Maples	5	0	
California sycamore	0	2	1
Coast live oak	0	1	1
Valley oak	0	0	
Fremont cottonwood	0	2	2
Native grass seed	Yes	Yes	
Total	**25**	**36**	**130%[3]**
Native Tree Cover			*78%*
Native Shrub Cover			*80%*
Native Grass/Ground Cover			*75%*

[1]Number of trees
[2]Willow stakes and trees were combined for percent survival calculations
[3]Expressed as a percentage of the number of trees proposed

One photo monument was established for Project 14A, labeled as photo monument 14A-A. The location of this monument is shown on the as-built drawing shown in Figure 43.

Figure 18. Drawing for Project 14A



Pre-construction and post-construction photos are shown for the photo monument below.

Figure 19. Photo Monument 14-A looking south, pre-construction, 2009

Figure 20. Photo Monument 14-A looking south, post-construction, 2019

Figure 21. Photo Monument 14-A looking west, pre-construction, 2009

Figure 22. Photo Monument 14-A looking west, post-construction, 2018

Project 14B. Create Inset Floodplain Downstream of Land Bridge and Project 15. Remove Land Bridge

Project Completed: 2009
Replanting: 2013

Project 14B involved creation of an inset floodplain between the land bridge and project 14A. The eroded storm drain from Project 14A was relocated to within this floodplain. Due to the proximity of Project 15, the two projects are considered together to eliminate any confusion over the boundaries of the two projects.

Project 15 involved removal of the land bridge and associated culverts upstream of A Street. Project 15 is located between Projects 14A and 14B, in very close proximity to Project 14B, therefore some of the photographs contain both projects.

Project 14B
The Ordinary High Water mark (OHWM) was determined using the two-year recurrence interval flow, 100 cfs from a hydraulic study performed by Questa, Inc. of Arroyo Seco flow through LLNL property. A typical open channel flow calculator was used to determine average flow depth at OHWM. Using a slope of 0.01, channel top width of 40 feet, channel bottom width of 5 feet, channel height of 15 feet, and roughness coefficient, n-value, 0.04, a flow depth of 2.5 feet was calculated. Thus, cut and fill quantities above and below the OHWM were calculated from 2.5 feet above the channel bottom through Project area 14B.

- Linear feet of stream bank affected = 90 feet
- Excavation below OHWM = 40 cubic yards
- Fill below OHWM = 40 cubic yards
- Excavation below top of bank = 80 cubic yards
- Fill below top of bank = 80 cubic yards.

Project 15
The Ordinary High Water mark (OHWM) was determined using the two-year recurrence interval flow, 100 cfs from a hydraulic study performed by Questa, Inc. of Arroyo Seco flow through LLNL property. A typical open channel flow calculator was used to determine average flow depth at OHWM. Using a slope of 0.01, channel top width of 40 feet, channel bottom width of 5 feet, channel height of 15 feet, and roughness coefficient, n-value, 0.04, a flow depth of 2.5 feet was calculated. Thus, cut and fill quantities above and below the OHWM were calculated from 2.5 feet above the channel bottom through Project area 15.

- Linear feet of stream bank affected = 220 feet
- Excavation below OHWM = 110 cubic yards

- Fill below OHWM = 65 cubic yards
- Excavation below top of bank = 563 cubic yards
- Fill below top of bank = 126 cubic yards.

Plantings for Project 14B and Project 15 were somewhat different from those originally proposed. The changes were made based on the recommendations from Questa, Inc. based upon their experience with streambed restoration in the Livermore Valley. The total quantity of plants used meets or exceeds the original proposal, although the species composition may be different.

Construction of Sites 14B and 15 was completed in 2009, therefore monitoring of these sites began in spring 2010. This is Year 10 of monitoring at Sites 14B and 15. Results for Site 14B and Site 15 were combined to avoid any discrepancy regarding the boundary of each site. This reduces potential error in plant counts and related calculations.

Overall the site looks good with healthy trees and stands of shrubs and native grasses. Willows, California sycamores, valley oaks, Fremont cottonwoods, California buckeye, blue elderberry, and coast live oak are all present. Tree survival performance criteria have been met for 5 consecutive years (2010-2014), therefore survival does not need to be monitored.

Tree cover was 76% which meets the Year 10 performance criteria (Table 10). Shrub cover was 79% which meets the Year 10 performance criteria (Table 10). Grass/ground cover was 75% which meets the Year 10 performance criteria (Table 10).

This site has been monitored for 10 years, tree cover, shrub cover, and grass/ground cover have met the Year 10 performance criteria (Table 10), and therefore this site is considered complete.

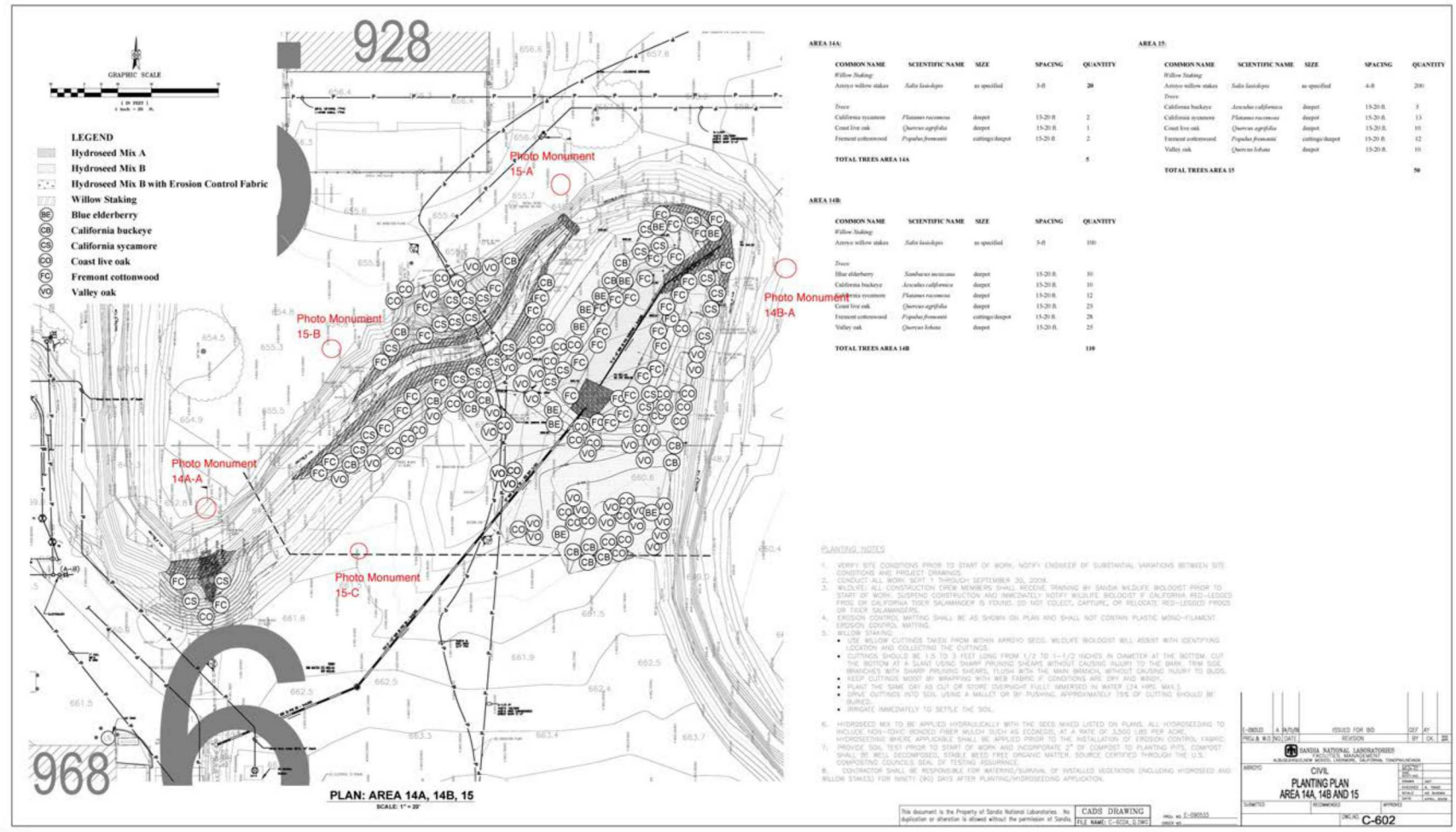
Table 10 shows the proposed and actual plantings and survival rates based on a 2019 survey. Survival percentages are not shown since the criteria were met for five consecutive years in 2014.

Table 10. Proposed and actual plantings for Projects 14B and 15

Metric	2019 Percent Cover	5-Year Performance Criteria	10-Year Performance Criteria
Native Tree Cover	76	60	75
Native Shrub Cover	79	30	45
Native Grass/Ground Cover	75	75	75

Four photo monuments were established for Projects 14B and 15, labeled as photo monuments 14B-A 15-A, 15-B, and 15-C. The location of these monuments is shown on the as-built drawing shown in Figure 48.

Figure 23. Drawing for Projects 14B and 15



Pre and post-construction photos for each of the photo monuments is shown in the figures below.

Figure 24. Photo Monument 15-A looking east, pre-construction, 2009

Figure 25. Photo Monument 15-B looking east, post-construction, 2019

Figure 26. Photo Monument 14-B looking west, pre-construction, 2009

Figure 27. Photo Monument 14-B looking west, post-construction, 2019

Figure 28. Photo Monument 15-C looking northeast, pre-construction, 2009

Figure 29. Photo Monument 15-C looking northeast, post-construction, 2019

Figure 30. Photo Monument 15-A looking southwest, pre-construction, 2009

Figure 31. Photo Monument 15-A looking southwest, post-construction, 2019

Project 16. Repair Erosion at Thunderbird Lane Bridge

Project Completed: 2009
Replanting: 2013

Project 16 involved repair of erosion damage at the Thunderbird Lane Bridge.
The Ordinary High Water mark (OHWM) was determined using the two-year recurrence interval flow, 100 cfs from a hydraulic study performed by Questa, Inc. of Arroyo Seco flow through LLNL property. A typical open channel flow calculator was used to determine average flow depth at OHWM. Using a slope of 0.01, channel top width of 40 feet, channel bottom width of 5 feet, channel height of 15 feet, and roughness coefficient, n-value, 0.04, a flow depth of 2.5 feet was calculated. Thus, cut and fill quantities above and below the OHWM were calculated from 2.5 feet above the channel bottom through Project area 16.

- Linear feet of stream bank affected = 400 feet
- Excavation below OHWM = 25 cubic yards
- Fill below OHWM = 80 cubic yards
- Excavation below top of bank = 50 cubic yards
- Fill below top of bank = 185 cubic yards.

Plantings for Project 16 were somewhat different from those originally proposed. The changes were made based on the recommendations from Questa, Inc. based upon their experience with streambed restoration in the Livermore Valley. The total quantity of plants used meets or exceeds the original proposal, although the species composition may be different.

Construction of Site 16 was completed in 2009, therefore monitoring of this site began in spring 2010. This is Year 10 of monitoring at Site 16.

Tree survival is 50% (Table 11) which does not meet the performance criteria. Willows in the channel are large, dense, and vigorous. A single California buckeye and a single Fremont cottonwood are present.

Tree cover was 85% which meets the Year 10 performance criteria (Table 11). Shrub cover was 92% which meets the Year 10 performance criteria (Table 11). Grass/ground cover was 97% which meets the Year 10 performance criteria (Table 11).

Although this site has not met tree survival performance criteria and an additional 17 willows or other trees are required to meet the tree survival performance criteria, the existing willows are large, dense, growing vigorously, and form a canopy over the riparian corridor. Furthermore, as noted in previous reports, there is no room for additional willow plantings at Site 16, especially if the existing willows continue to grow as expected. We recommend the existing willows qualify as having met performance criteria for tree survival at this site and the site is considered complete.

Table 11 shows the proposed and actual plantings and survival rates based on a 2019 survey.

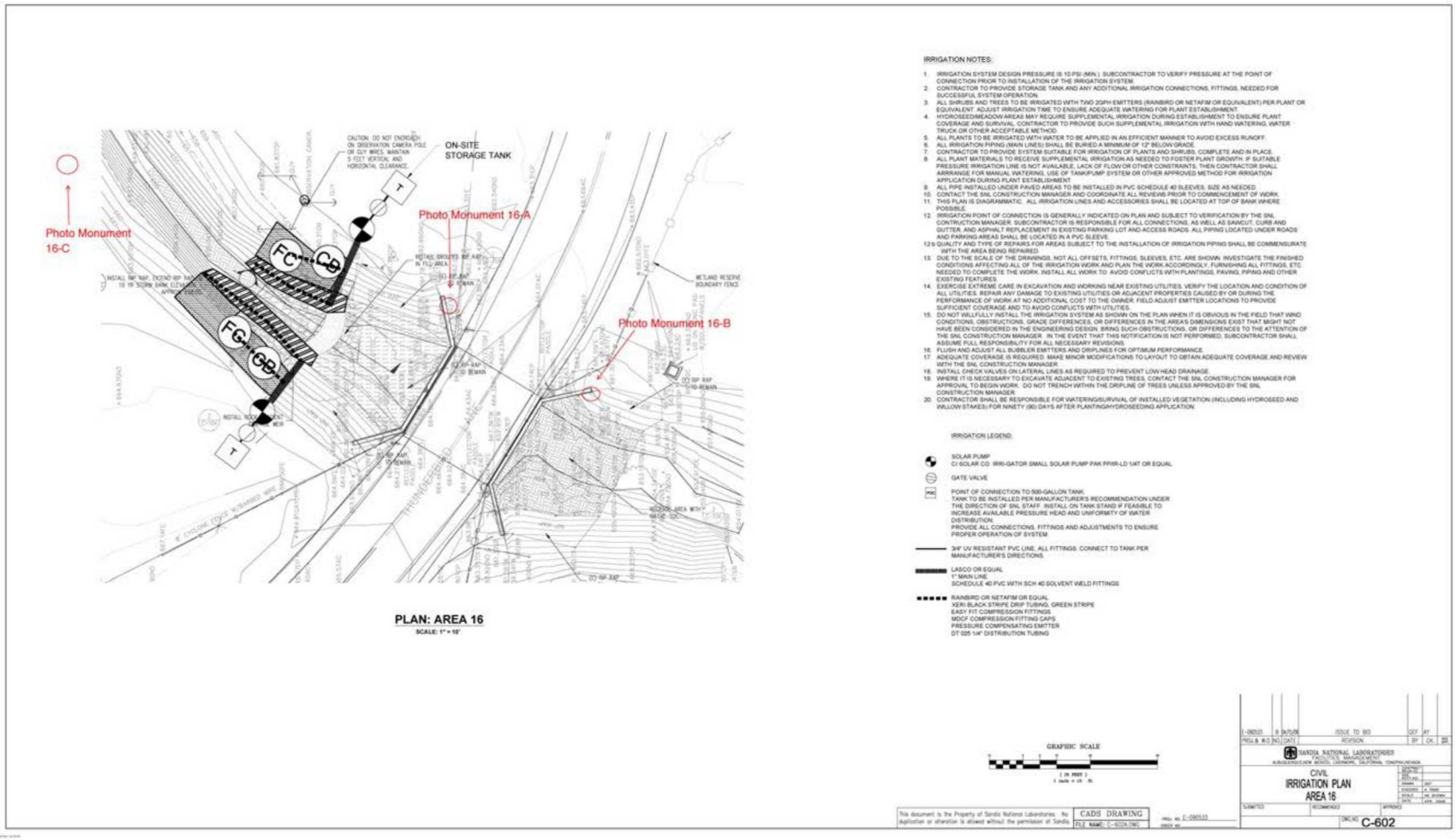
Table 11. Proposed and actual plantings for Project 16

Species	Proposed	Actual	2019 Survival[1]
Arroyo willow stakes	40	38	15
Willow trees	0	0	
California buckeye	0	2	0
Blue elderberry	0	0	
Maples	0	0	
California sycamore	0	0	
Coast live oak	0	0	
Valley oak	0	0	
Fremont cottonwood	0	2	1
Native grass seed	Yes	yes	
Total	**40**	**42**	**43%[2]**
Native Tree Cover			*85%*
Native Shrub Cover			*92%*
Native Grass/Ground Cover			*97%*

[1]Number of trees
[2]Expressed as a percentage of the number of trees proposed

Three photo monuments were established for Project 16, labeled as photo monuments 16-A, 16-B, and 16-C. The location of these monuments is shown on the as-built drawing shown in Figure 57.

Figure 32. Drawing for Project 16



Pre and post-construction photos for each of the photo monuments is shown in the figures below.

Figure 33. Photo Monument 16-A looking west, pre-construction, 2009

Figure 34. Photo Monument 16-A looking west, post-construction, 2019

Figure 35. Photo Monument 16-B looking southeast, pre-construction, 2009

Figure 36. Photo Monument 16-B looking southeast, post-construction, 2019

Figure 37. Photo Monument 16-B looking southwest, pre-construction 2009

Figure 38. Photo Monument 16-B looking southwest, post-construction, 2019

Figure 39. Photo Monument 16-C looking southeast, pre-construction, 2009

Figure 40. Photo Monument 16-C looking southeast, post-construction, 2019

Projects 17A and 17B. Remove Concrete and Create Floodplain

Project Completed: 2015

The close proximity of Areas 17A and 17B requires that they be considered as one project for the purposes of vegetation monitoring and reporting.

The project involved the removal of abandoned concrete structures in the channel and the creation of a two-acre inset floodplain and planting of 2.75 acres of riparian and upland species for habitat enhancement. This floodplain will establish a more functional floodplain that is more frequently inundated by arroyo flow.

The Ordinary High Water Mark (OHWM) was determined using the two-year recurrence interval flow of 100 cfs from a hydraulic study performed by Questa, Inc. of Arroyo Seco flow through LLNL property. A typical open channel flow calculator was used to determine average flow depth at OHWM. Using a slope of 0.01, channel top width of 40 feet, channel bottom width of 5 feet, channel height of 15 feet, and roughness coefficient, n-value, of 0.04, a flow depth of 2.5 feet was calculated. Thus, cut and fill quantities above and below the OHWM were calculated from 2.5 feet above the channel bottom through Site 17.

- Linear feet of stream bank affected = 162 feet
- Excavation below OHWM = 50 cubic yards
- Fill below OHWM = 55 cubic yards
- Excavation below top of bank = 240 cubic yards
- Fill below top of bank = 240 cubic yards
-

Due to heavy rainfall during the winter of 2016-2017, and consequent high flows in the Arroyo Seco, damage occurred to the inlet to the inset floodplain, and also to the two outlet structures from the inset floodplain. SNL/CA personnel repaired this damage during 2018.

Construction of Site 17a and 17B was completed in September 2015, therefore monitoring of this site was initiated in spring 2016 and 2019 is Year 4 of monitoring.

The ACOE permit required planting of maples, California sycamore, coast live oak, valley oak, and Fremont cottonwood. Trees did not meet the 85% survival permit requirements. A total of 29 trees on site are alive and an additional 56 are required to meet success criteria.

Tree cover was 10% which does not meet the Year 2 or Year 5 performance criteria (Table 12). Neither shrub cover (1%) nor grass/ground cover (7%) met Year 2 or Year 5 performance criteria (Table 12).

Parts of the flat area of this site were hydroseeded in autumn of 2018. It is mowed and irrigated as well, and although good stands of native grass are present, a majority of the site is weedy.

Additional trees are required to meet the permit requirements including 22 Maples, 19 California sycamore, 6 Coast live oak, 4 Valley oak, and 13 Fremont cottonwood. We recommend substituting Coast live oak and Valley oak for the maples, since maple is not likely to do well based on the site conditions.

Table 12 shows the proposed and actual plantings and survival rates based on a 2019 survey.

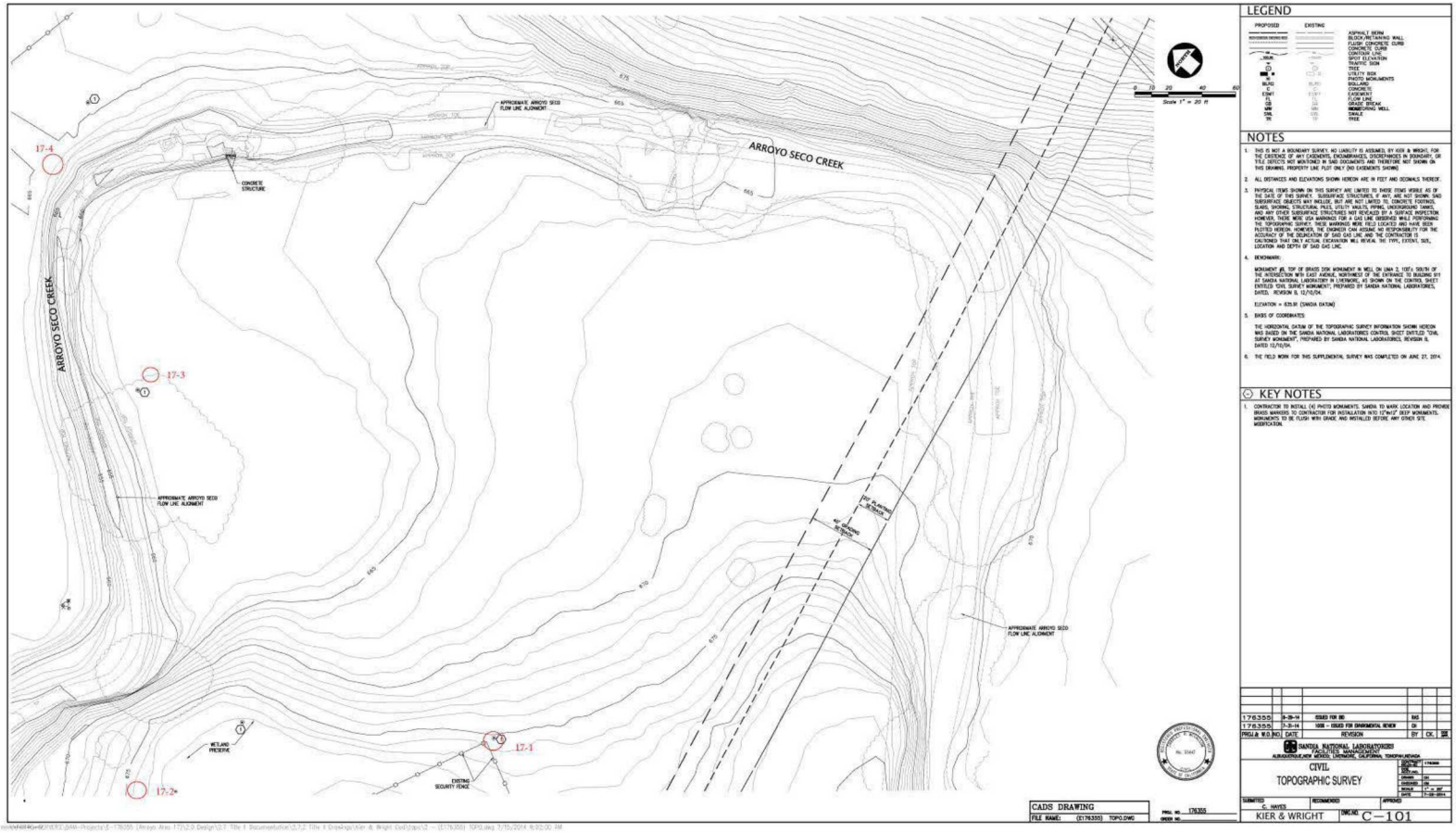
Table 12. Proposed and actual plantings for Project 17A and 17B

Species	Proposed	Actual	2019 Survival[1]
Arroyo willow stakes	0	-	0
Willow trees	0	0	-
California buckeye	0	0	-
Blue elderberry	0	15	8
Maples	25	10	0
California sycamore	25	15	1
Coast live oak	12	20	4
Valley oak	13	10	7
Fremont cottonwood	25	15	9
Black walnut	0	20	0
Native grass seed	Yes	Yes	
Total	**100**	**105**	**29%[2]**
Native Tree Cover			*10%*
Native Shrub Cover			*1%*
Native Grass/Ground Cover			*7%*

[1]Number of trees
[2]Expressed as a percentage of the number of trees proposed

Four photo monuments were established for Site 17, labeled as photo monuments 17-1, 17-2, 17-3, and 17-4. The location of these monuments is shown in Figure 68.

Figure 41. Photo Monuments for Site 17A and 17B



Pre and post-construction photos for each of the photo monuments is shown in the figures below.

Figure 42. Photo Monument 17-1 looking north, pre-construction 2015

Figure 43. Photo monument 17-1 looking north, post construction 2019

Figure 44. Photo monument 17-2 looking northeast, pre-construction, 2015

Figure 45. Photo monument 17-2 looking northeast, post-construction, 2019

Figure 46. Photo monument 17-2 looking east, pre-construction, 2015

Figure 47. Photo monument 17-2 looking east, post-construction 2019

Figure 48. Photo monument 17-3 looking east, pre-construction 2015

Figure 49. Photo monument 17-3 looking east, post-construction, 2019

Figure 50. Photo monument 17-3 looking southeast, pre-construction, 2015

Figure 51. Photo monument 17-3 looking southeast, post-construction, 2019

Figure 52. Photo monument 17-4 looking south, pre-construction, 2015

Figure 53. Photo monument 17-4, looking south, post-construction, 2019

Figure 54. Photo monument 17-4 looking southwest, pre-construction, 2015

Figure 55. Photo monument 17-4 looking southwest, post-construction, 2019

Wildlife and Avifauna Use

In 2019, SNL/CA personnel assessed the use of restored Arroyo Seco Project sites, as compared to a control site. The control sites were areas of the Arroyo Seco within the boundaries of SNL/CA, but that have not been subject to restoration. Avian and mammalian species diversity and abundance can be expected to vary.

The survey consisted of Bird and Nesting Surveys, Camera Trapping for mammals, and Bat Acoustical monitoring. The results are summarized below.

Bird and Nesting Surveys

Point counts were conducted to document avian species use and species richness. Sites of the point surveys were also surveyed for active nests. A total of 41 avian species were observed at the control sites, and 36 avian species were observed at the restoration sites. Twelve species were found exclusively at the control sites. Seven species were found exclusively at the restoration sites. The birds observed are shown in Table 13.

Table 13. Number of birds per species observed or heard

Common Name (Scientific Name)	Control	Restoration
American crow (Corvus brachyrhynchos)	3	13
American kestrel (Falco sparverius)	0	2
American robin (Turdus migratorius)	0	4
Anna's hummingbird (Calypte anna)	10	24
Ash-throated flycatcher (Myiarchus cinerascens)	3	1
Barn swallow (Hirundo rustica)	3	0
Bewick's wren (Thryomanes bewickii)	7	0
Black phoebe (Sayornia nigricans)	6	8
Bullock's Oriole (Icterus bullockii)	2	2
Bushtit (Psaltriparus minimus)	9	12
California scrub-jay (Aphelocoma californica)	21	24
California towhee (Melozone crissalis)	0	1
Canada goose (Branta canadensis)	5	16
Chestnut-backed chickadee (Poecile rufescens)	2	7
Cliff swallow (Petrochelidon pyrrhonota)	7	16
Common raven (Corvus corax)	7	4
European starling (Sturnus vulgaris)	15	11
House finch (Carpodacus mexicanus)	23	8
Killdeer (Charadrius vociferous)	2	1
Lesser goldfinch (Spinus psaltria)	13	13
Mourning dove (Zenaida macroura)	3	4
Northern flicker (Colaptes auratus)	0	3
Northern mockingbird (Mimus poplyglottos)	8	16
Nutall's woodpecker (Picoides nuttalli)	10	3
Oak titmouse (Baelophus inoratus)	4	0

Orange-crowned warbler (Vermivora celata)	1	8
Red-tailed hawk (Buteo jamaicensis)	9	13
Red-winged blackbird (Agelaius phoeniceus)	8	0
Rock pigeon (Columba livia)	2	0
Ruby-crowned kinglet (Regulus calendula)	4	1
Say's phoebe (Sayornis saya)	2	1
Song sparrow (Melospiza melodia)	0	6
Tree swallow (Tachycineta bicolor)	19	2
Turkey vulture (Cathartes aura)	17	18
Western bluebird (Sialia Mexicana)	0	8
Western kingbird (Tyrannus verticalis)	2	7
Western meadowlark (Sturnella neglecta)	1	1
White-crowned sparrow (Zonotrichia leucophrys)	20	9
Yellow-rumped warbler (Dendroica coronata)	15	10
Total:	307	281

Camera Traps

Five species were documented at both sites: black-tailed deer (Odocoileus hemionus columbianus), bobcat (Lynx rufus), coyote (Canis latrans), racoon (Procyon lotor), and striped skunk (Mephitus mephitis). Two species were captured by the camera only at the Restoration Site, red fox (Vulpes Vulpes), and Eastern fox squirrel (Sciurus niger).

Due to the small size and interspersed locations of the restoration sites, mammals utilizing the riparian corridor are expected to pass through both restored and non-restored areas. Therefore comparisons of diversity and population sizes cannot be made between the two sites. Camera traps were placed within or adjacent to restoration sites that provided greater canopy cover and ground vegetation where mammals are more likely to forage, rest, and find shelter. The data presented here are intended to provide an idea of the utilization of the sites by large mammals, as the camera trap triggers are heavily biased toward these species.

Table 14 details the species seen.

Table 14. Camera Trap- Species Observed

Common Name (Scientific Name)	Control	Restoration
Black-tailed deer (Odocoileus hemionus columbianus)	31	15
Bobcat (Lynx rufus)	6	9
Coyote (Canis latrans)	1	3
Gray fox (Urocyon cinereoargenteus)	0	1
Racoon (Procyon lotor)	2	3
Striped skunk (Mephitis mephitis)	1	2
Eaastern fox squirrel (Sciurus niger)	0	4

Bat Acoustical Monitoring

Acoustical monitoring was conducted during late April to early July when bat activity tends to be high. At the restoration site, the monitor was deployed for 11 nights from April 24 to May 4. At the control site the monitor was deployed from May 24-June 3 and June 23-July 3 for a total of 20 nights.

The bat composition at both sites was different. At the restoration site there were 26 calls from Mexican free-tailed bats (Tadarida brasiliensis mexicana) and one call from a hoary bat (Lasiurus cinereus). At the control site, there were six calls from California myotis (Myotis californicus). More total calls and species were recorded at the restoration site versus the control site (27 versus 6, and 2 versus 1, respectively). However we cannot extrapolate how many individual bats were recorded – a greater number of calls may be explained by a larger population of bats or a single bat repeatedly passing the acoustic unit, and therefore it may not be indicative of a more productive foraging habitat. Thus, number of calls recorded also has limited utility for determining relative abundances and activity.

The difference of species recorded at each site could be attributed to the placement of the microphone within (control site) and outside of (restoration site) the tree canopy. Strong inferences cannot be made to differentiate habitat quality or complexity between the two survey sites, nor to the relative abundances of bat species. However, none of the bat species recorded is considered a specialized indicator species whose presence indicates higher quality habitat or an added habitat feature.

Conclusion

The total number of individual birds and species of birds within the control sites was slightly greater than the restoration sites, but overall the restoration sites and control sites were nearly equivalent in bird diversity. The number of mammal species recorded in the camera traps at the restoration site was greater than the control site, but this could be partially attributed to the camera position and location in a more closed canopy area that had a smaller field of view than the restoration camera. Lastly, the bat species composition was different between the control site and restoration site, but this could be due to the microhabitat around the placement of the bat detector. Due to the connectivity of control and restoration sites and small sample sizes of our study, we cannot make dependable inferences as to the differences in habitat quality or complexity between restored and control areas. However, the data exhibits a strong similarity of species composition in control and restoration survey sites for birds and mammals, suggesting a similarity of habitat quality. These conclusions are similar to the conclusions in the 2014, 2016, 2017, and 2018 wildlife and avifauna assessments.