DOCKETED

Docket Number:	02-AFC-01C
Project Title:	Sonoran Energy Project (formerly Blythe Energy Project Phase II) - Compliance
TN #:	210520
Document Title:	Sonoran Energy Project Water Conservation Plan
Description:	N/A
Filer:	Jerry Salamy
Organization:	CH2M HILL
Submitter Role:	Applicant Consultant
Submission Date:	2/23/2016 5:36:07 PM
Docketed Date:	2/24/2016

TECHNICAL MEMORANDUM

Sonoran Energy Project Water Conservation Plan

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DATE:	February 23, 2016

AltaGas Sonoran Energy Inc. (AltaGas) has a license from the California Energy Commission (CEC) for the Blythe Energy Project Phase II to construct, own, and operate an electrical generating plant in Blythe, California. A Petition to Amend is under review by the CEC to change the generation technology and update the name to the Sonoran Energy Project (SEP).

Operation of the SEP will remain within the parameters of existing Condition of Certification Water Res-4 and will not exceed a maximum of 2,800 acre-feet per year of water use, based on the facility operating 7,000 hours per year. Consistent with earlier CEC decisions, AltaGas is proposing a Water Conservation Offset Program (WCOP) to offset its use of up to 2,800 acre-feet per year of groundwater. CEC conditions of approval require appropriate monitoring of verifiable conservation (Condition Water Res-1), installation of metering devices to record daily groundwater withdrawals (Condition Water Res-2), and reporting of annual water use (Condition Water Res-7).

The SEP resides within the boundaries of the Palo Verde Irrigation District (PVID) (Attachment 1). To offset SEP water use, AltaGas, in coordination with PVID, proposes a canal-lining program to reduce water conveyance losses of PVID irrigation water by an amount equal to or exceeding the SEP's maximum allowed yearly water use (2,800 acre-feet). Canal lining represents a reduction in the quantity of water diverted at the Colorado River. Reductions in diversion rates result in more water in-stream, and an increase in the Colorado River water level. Accordingly, canal lining enhances local water resources and supplies for surface water and groundwater.

This Technical Memorandum (TM) presents an evaluation of water savings from lining PVID canals. The TM is organized into the following sections:

- Existing Facilities
- Analysis of Seepage
- Proposed Mitigation
- Cost Estimate
- Conclusions
- Attachments
  - 1 Location Map
  - 2 Typical Lined Cross-Section
  - 3 D Canal—Soil Boring Map
  - 4 C Canal—Soil Boring Map

Existing Facilities

During a field visit conducted in December 2015 with PVID staff, two stretches of canal were identified for lining. The first section is located on the D canal in the northeast portion of the PVID and the second section is to the southwest on the C canal (see Attachment 1). Both sections are continuations of existing lining projects (Figure 1). All PVID delivery canals are in continuous use throughout the year with exception of the 2-week shutdown period during the month of January for maintenance.

Figure 1. Termination of Current Lining on Canal D

The canal side slopes and depth were obtained from as-built drawings and field measurements from PVID operations staff. The following assumptions of average canal dimensions were used to calculate the seepage rate:

- Canal top width at water surface= 30 feet
- Canal depth= 5 feet
- Canal side slope= 1.5:1

The resulting approximate cross-section of the canal is provided in Attachment 2.

Analysis of Seepage

To establish a reasonable quantification of seepage from canals C and D, two common methods of determining seepage were used: (1) Darcy's Law using infiltration parameters from known soils in the area, and (2) samples taken within each canal to determine hydraulic conductivity and correlated seepage values through computer modeling.

Seepage Rate Using Darcy's Law

Darcy's Law, an equation that describes the flow of a fluid through a porous medium, was used to calculate seepage rates based on the local soil conditions. The following two sources of information were referenced to identify and verify soil type and characteristics near canals C and D:

- **Soil Survey of Palo Verde Area, California (USDA, 1974)—**This report provides general soil characteristics in the Palo Verde area, including permeability data by soil type.
- **Web Soil Survey, Natural Resources Conservation Service (NRCS) (www.websoilsurvey.nrcs.usda.gov; Retrieved December 2015)—**This information was used to verify that the soil conditions in the vicinity of canals C and D are consistent with those found in the Palo Verde Soil Survey.

The soil properties for this evaluation were based on general soil information available from NRCS-mapped soil units. The permeability, or hydraulic conductivity, of the soil is estimated to vary from rates typical for relatively clean sand (20 inches per hour) to silty or clayey loam (0.1 inch per hour) based on the NRCS-mapped soil units that the canal passes through.

The permeability of the native soil often varies with depth within each mapped unit, and the canal passes through several different mapped units, which causes a theoretical determination of infiltration losses to be very approximate. The upper 3 to 4 feet generally contains more fines (greater than 15 percent silt and clay). Below 4 feet, the soil is generally clean (less than 10 percent fines). A recent farming practice in this area is to deep rip through the clay layer to a depth of 5 to 6 feet to increase soil drainage, as illustrated in Figure 2.

Figure 2. Example of Deep Ripping Soil to Penetrate Clay Layer and Reach Sandy Soils Beneath for Improved Field Drainage

The infiltration will vary by several orders of magnitude depending on whether the canal was cut into the cleaner soil, or whether some of the upper fine-grained soil remains at the bottom of the canal. Depending on the soil type within the canal, permeability could range from $2x10^{-6}$ to $5x10^{-4}$ centimeters per second.

The estimated infiltration losses were evaluated using a finite element seepage analysis for saturated, steady-state flow conditions. The analysis was performed using the finite element module in the computer program SLIDE Version 7.0, by Rocscience. The seepage rate calculations for this program are based on Darcy's Law where:

- Darcy's Law Q = -K*(*dh/dl*)*A
- Soil permeability (K) of $2x10^{-6}$ to $5x10^{-4}$ centimeters per second
- Surface area (A) of canal per LF = 33 ft^2/LF (as shown in Attachment 2)
- Gradient (*dh/dl*) = static 12.5 feet (distance from ground water level to mid canal water depth as shown in Attachment 2)

From the finite element seepage analyses, the estimated flow out of the canal caused by infiltration was calculated.

The canal was modeled with 1.5H:1V side slopes, a water depth of 5 feet, and a bottom width of 15 feet. The infiltration rate varied from 0.1 to 18 cubic feet per day per square foot ($ft^3/day/ft^2$) of canal.

The results are shown in Table 1 in acre/feet of seepage per linear feet of canal.

Table 1. Theoretical Seepage Volumes Based on Darcy's Law

Permeability (cm/second)	Seepage (acre-feet/month/LF)
$5x10^{-4}$	0.400
$2x10^{-6}$	0.0016

As demonstrated in Table 1, the calculated infiltration rate varies by several orders of magnitude depending on the soil material type exposed on the bottom of the canal. This range provides a starting point for analysis but clearly showed additional fieldwork was necessary to determine seepage rates necessary to validate recommendations for a water conservation offset program.

Seepage Rates Determined from Field Investigation

Field sampling was conducted on January 14, 2016, by Wayne Ohlin, Civil Engineer and Mark Twede, Geotechnical Engineer of CH2M HILL Engineers, Inc., accompanied by JR Echard, PVID Operations Manager. Samples were collected by hand at 3 locations along the D canal, and 12 locations along the C canal. Sample frequency was approximately every mile of canal, more frequent if changing soil conditions were observed. Samples were generally taken at a depth of 6 to 18 inches below the existing ground surface (Figure 3) from hand-excavated pits on the bottom of the canal. Where water was present in the canal, samples were taken from the side slopes, generally designated with an "A" postscript on the sample number. At three locations, samples were collected from both the bottom of the canal and the side slope of the canal (Figure 4). The sample locations are shown in Attachments 3 and 4-1 through 4-4.

Figure 3. Soil Samples Taken at a Depth of 6 to 18 Inches

Figure 4. Samples Taken at Three Locations in the Side Slopes Because of Water in Canals

The built-up sediment in the canal is periodically removed, and an attempt was made to collect samples below the settled fines. This often proved difficult, and the samples may have higher fines content than what would be present at greater depth. The soil samples consisted of silty and clayey sand. The sand was poorly graded, fine-grained sand. The silt and clay was generally of low plasticity.

Samples were delivered to Landmark Geo-Engineers and Geologists for laboratory testing. The gradation of each sample collected from the canal was tested in accordance with American Society of Testing and Materials (ASTM) D422. Adjacent to sample locations C3 and D3, thin-walled brass tubes were pushed into the soil to obtain relatively undisturbed soil samples (Figure 5). The brass tubes were 2.5-inches in diameter and 6 inches in length. The brass tubes were capped and packaged for delivery to Geo-logic Associates of Grass Valley, California, for hydraulic conductivity testing. Hydraulic conductivity tests were performed using a flexible wall permeameter in accordance with ASTM D5084.

Figure 5. 2.5-inch-Diameter Brass Tube Inserted into Canal for Hydraulic Conductivity Sample

The results from these tests were used to correlate the gradation with actual measured hydraulic conductivity rates. The hydraulic conductivity of the other samples was extrapolated from these correlated values. The variation of hydraulic conductivity with gradation that was used to evaluate infiltration along the canal is shown in Figure 6.

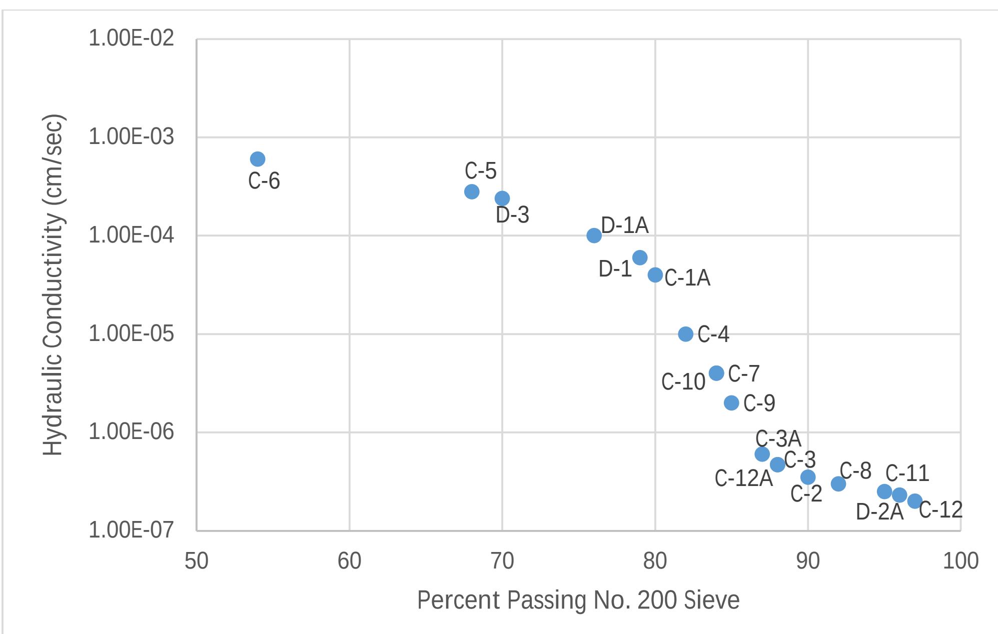


Figure 6. Relationship between Native Soil Gradation and Hydraulic Conductivity

Based on the hydraulic conductivity values, the seepage out of the canal was evaluated using steady-state finite element seepage modeling in the computer program SLIDE, Version 7.0, by Rocscience. The canal was modeled as a two-dimensional section assuming homogeneous soil conditions both horizontally and vertically, with a hydraulic conductivity value equal to the values extrapolated from the laboratory test results. A canal width of 15 feet and a water depth of 5 feet were assumed for the analyses. The resulting infiltration rates from the canal are summarized in Table 2. These infiltration rates correlate with the theoretical range calculated above.

Table 2. Hydraulic Conductivity, Infiltration Rate, and Seepage at Sample Locations along PVID Canal

Sample No.	Percent Fines	Hydraulic Conductivity (cm/sec)	Hydraulic Conductivity (ft/sec)	Calculated Infiltration (ft^3/day per foot of canal)[a]	Length of Canal (ft)	Yearly Seepage (ac-ft/yr)
C-1A	80	4.00E-05	1.31E-06	2.1	750	12.7
C-2	90	3.50E-07	1.15E-08	0.02	750	0.1
C-3	88	4.70E-07	1.54E-08	0.03	750	0.2
C-3A	87	6.00E-07	1.97E-08	0.03		
C-4	82	1.00E-05	3.28E-07	0.5	1,000	4.3
C-5	68	2.80E-04	9.19E-06	14.8	5,280	631.8
C-6	54	6.00E-04	1.97E-05	31.8	6,550[b]	1,679.9
C-7	84	4.00E-06	1.31E-07	0.2	5,280	8.9
C-8	92	3.00E-07	9.84E-09	0.02	5,280	0.7
C-9	85	2.00E-06	6.56E-08	0.1	5,280	4.6
C-10	84	4.00E-06	1.31E-07	0.2	5,280	8.9
C-11	95	2.50E-07	8.20E-09	0.01	5,280	0.6
C-12	97	2.00E-07	6.56E-09	0.01	5,280	0.5
C-12A	88	4.70E-07	1.54E-08	0.03		
D-1A	76	1.00E-04	3.28E-06	5.3	5,280	227.0
D-2A	96	2.30E-07	7.55E-09	0.01	2,250	0.2
D-3	70	2.40E-04	7.87E-06	12.8	2,500	257.1

[a] Infiltration rate based on 351 operating days per year.

[b] Includes 1,250 feet of C-28.

These validated seepage results represent actual field conditions and were used to determine the quantity of canal lining needed to offset future SEP water use, as discussed under Proposed Mitigation below.

Proposed Mitigation

Several options are available for mitigating canal seepage, including (1) lining the canal with concrete or other material, and (2) enclosing the canal in a pipeline. A pipeline would have the added benefit of eliminating evaporation losses, but has a significantly higher cost than lining and makes removal of sediment deposited during operation prohibitive. For the purposes of this TM, the concrete lining option was evaluated as a result of prior practices by PVID.

Using the range of seepage volumes from Table 2 calculated above, Table 3 summarizes the portions of canal that would need to be lined, as shown in the highlighted portions of Attachments 3, 4-1, and 4-2, to mitigate seepage for maximum annual water use of the SEP, 2,800 acre-feet. For canal D, as shown in

Attachment 3, the lining will start at station 16W and proceed south to the end of the canal with the exception of portions currently lined. Lining for canal D totals 10,030 linear feet. For canal C, lining starts at station 15S, where the current lining stops, and proceeds southwest to the check structure at station 40N. Additionally, as shown in Attachment 4-2, 1,250 feet of the C-28 lateral will be lined. The lining for canal C and lateral C-28 totals 15,080 linear feet.

Table 3. Required Lining Length by Volume of Water

Sample Location	Length of Lining (feet)	Seepage Reduction (Acre-feet/year)
C-1A	750	12.7
C-2	750	0.1
C-3	750	0.2
C-4	1,000	4.3
C-5	5,280	631.8
C-6	6,550	1,679.9
D-1A	5,280	227.0
D-2A	2,250	0.2
D-3	2,500	257.1
Total	**25,110**	**2,813**

Cost Estimate

Currently the PVID has both slip-lined (2.5-inch unreinforced concrete, Figure 7) and 4-inch-thick shotcrete-lined (Figure 8) canals. According to PVID staff, both canals have performed well over periods exceeding 15 years with minimal cracking. Current minimum planned life for the SEP is 30 years. A canal lining of a 4-inch-thick wire mesh or steel reinforced concrete section is recommended based on observed field conditions and design life. This would allow the water savings achieved for the WCOP to continue throughout the life of the power plant.

Figure 7. Example of Existing PVID Slip-lined Canal

Figure 8. Example of Existing PVID Shotcrete-lined Canal

Unit costs for this lining are based on the 2002 Bureau of Reclamation Canal-Lining Demonstration Program (Oregon Water Resources Commission Annual Conference, December 2002) and escalated to 2015 costs using the RS Means cost index (34th edition, 2015). Table 4 provides the estimated cost to line the canal in order to reduce seepage volumes that exceed the anticipated maximum water demand of 2,800 acre-feet for the SEP, as shown in Table 3.

Table 4. Conceptual Design Cost Estimate Summary

Item	Unit	Quantity	Unit Cost	Item Total Cost
Concrete Lining	LF	25,110	$115.00	$2,887,700
Earthwork	LF	25,110	$50.00	$1,255,500
Subtotal				$4,143,200
Contingency (25%)				$1,035,800
Construction Total Cost				$5,179,000
Admin, Eng, Const Manag. (20%)				$1,035,800
Total				**$6,214,800**

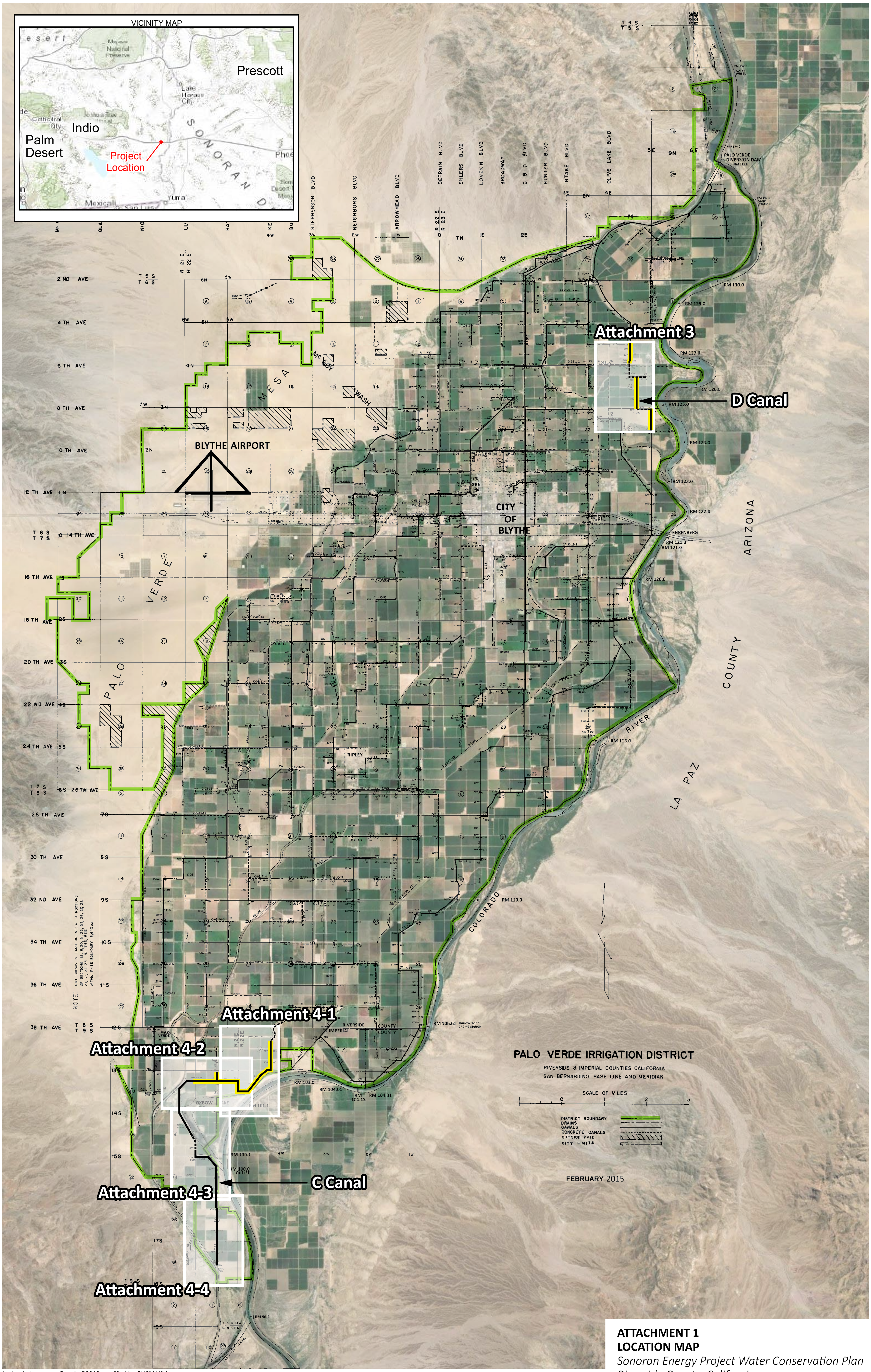
LF = lineal foot

This Class 4 estimate is prepared based on limited information, where the preliminary engineering is from 1 to 15 percent complete. Detailed strategic planning, business development, project screening, alternative scheme analysis, confirmation of economic and technical feasibility, and preliminary budget approval are needed to proceed. Examples of estimating methods used would be equipment or system process factors, scale-up factors, and parametric and modeling techniques. The development of this type of estimate requires more time expenditure than other types. The expected accuracy ranges for this estimate are -15 to -30 percent on the low side and +20 to +50 on the high side.

Conclusions

Of the 4.76 miles of canal recommended for lining, some of the lengths, as shown in Table 2, do not have the highest seepage values. They are included to create a continuous length of lining within the C and D canals. Continuous lengths of lining, versus intermittent lining, will increase the overall life of the lining project. The increased longevity will result in water savings that exceed the maximum needs of the SEP for the life of the project and beyond.

Attachment 1
Location Map



ATTACHMENT 1
LOCATION MAP
Sonoran Energy Project Water Conservation Plan
Riverside County, California

Aerial photo source: Google ©2016, modified by CH2M HILL.

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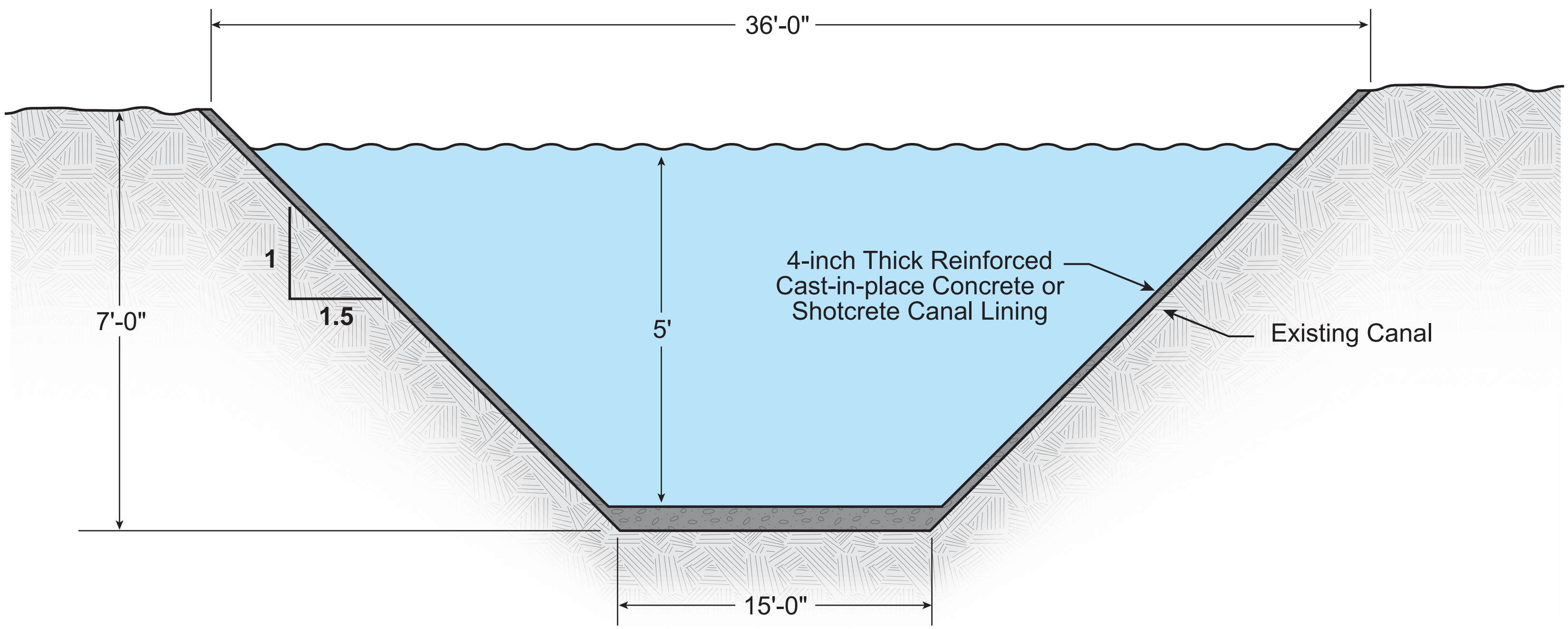
Attachment 2
Typical Lined Cross-Section



Notes:

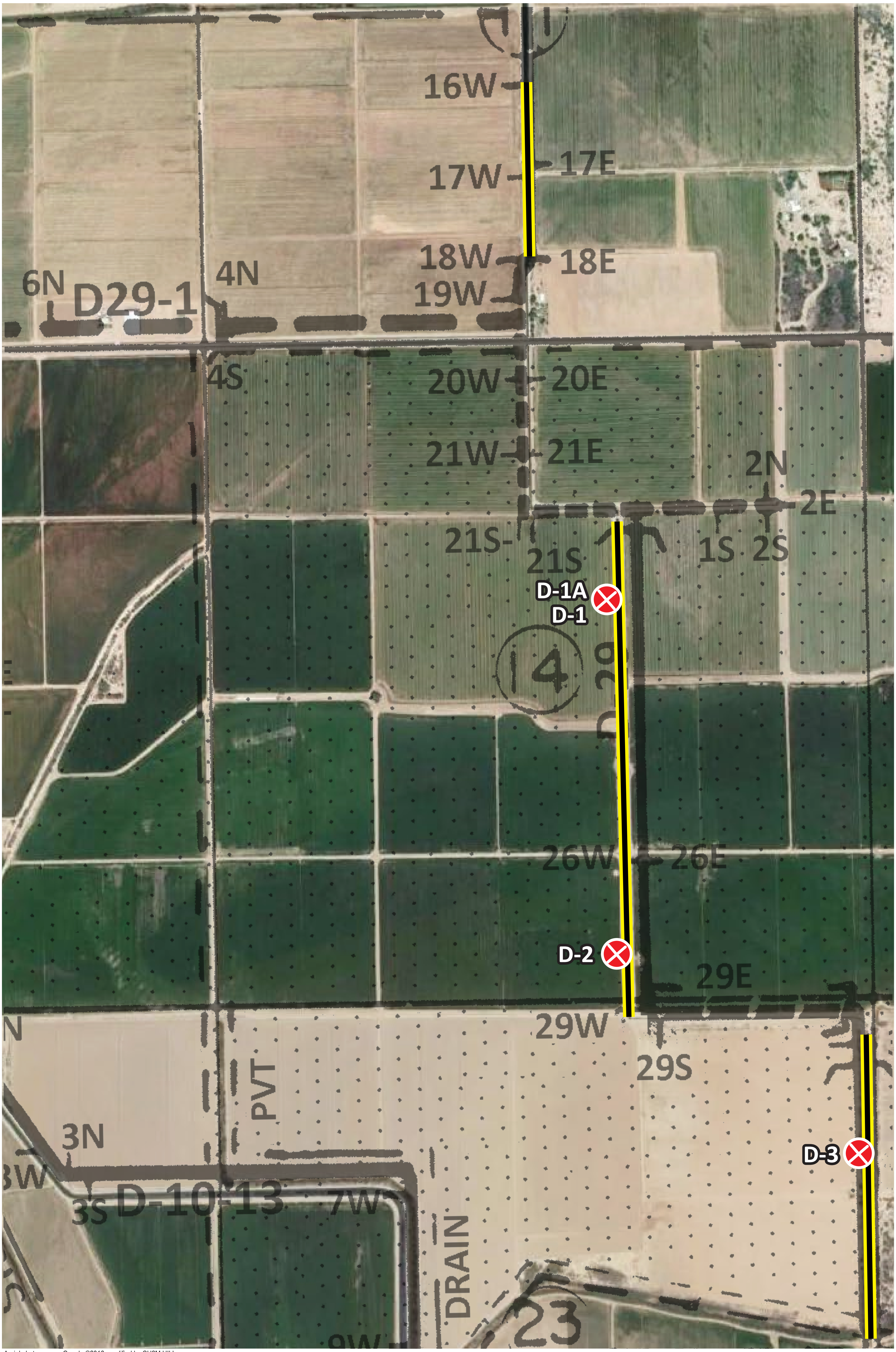
1. Wetted perimeter (A) = bottom width + 2 ($\sqrt{\text{depth}^2 + (\text{depth} * 1.5)^2}$)

$$A = 15 + 2 (\sqrt{5^2 + (5*1.5)^2} = 33\text{ft}^2/\text{ft of canal}$$

2. Typical depth from bottom of canal to groundwater is 10'

ATTACHMENT 2
TYPICAL LINED CROSS-SECTION
Sonoran Energy Project Water Conservation Plan
Riverside County, California

Attachment 3
D Canal—Soil Boring Map



Aerial photo source: Google ©2016, modified by CH2M HILL.

LEGEND

Soil Sample Location

Canal Proposed to be Lined

North

0 500 1,000

Approximate scale in feet

ATTACHMENT 3
D CANAL – SOIL BORING MAP
Sonoran Energy Project Water Conservation Plan
Riverside County, California

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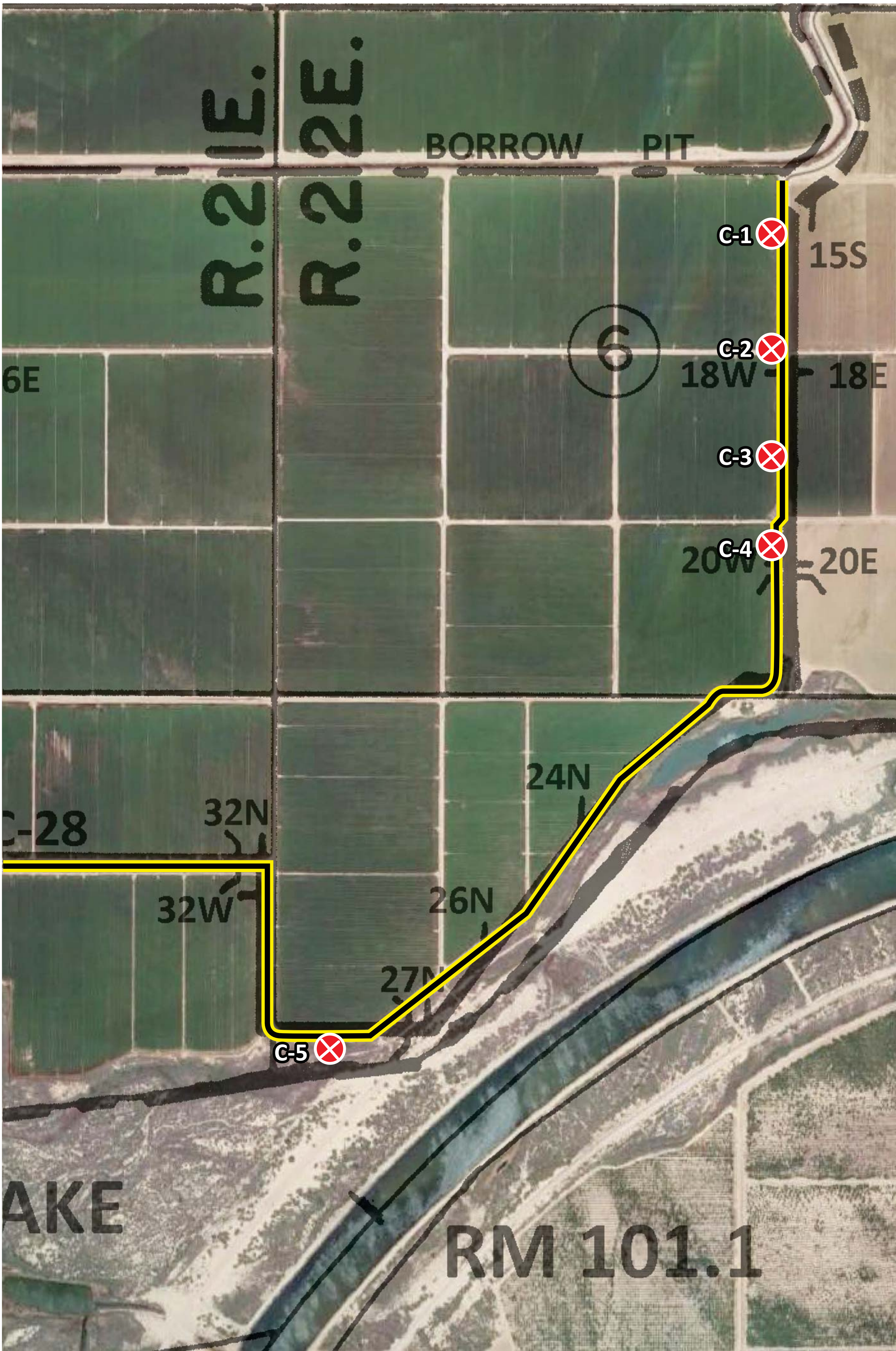
Attachment 4
C Canal—Soil Boring Map



Aerial photo source: Google ©2016, modified by CH2M HILL.

LEGEND

Soil Sample Location

Canal Proposed to be Lined

North

0 500 1,000

Approximate scale in feet

ATTACHMENT 4-1
C CANAL – SOIL BORING MAP
Sonoran Energy Project Water Conservation Plan
Riverside County, California

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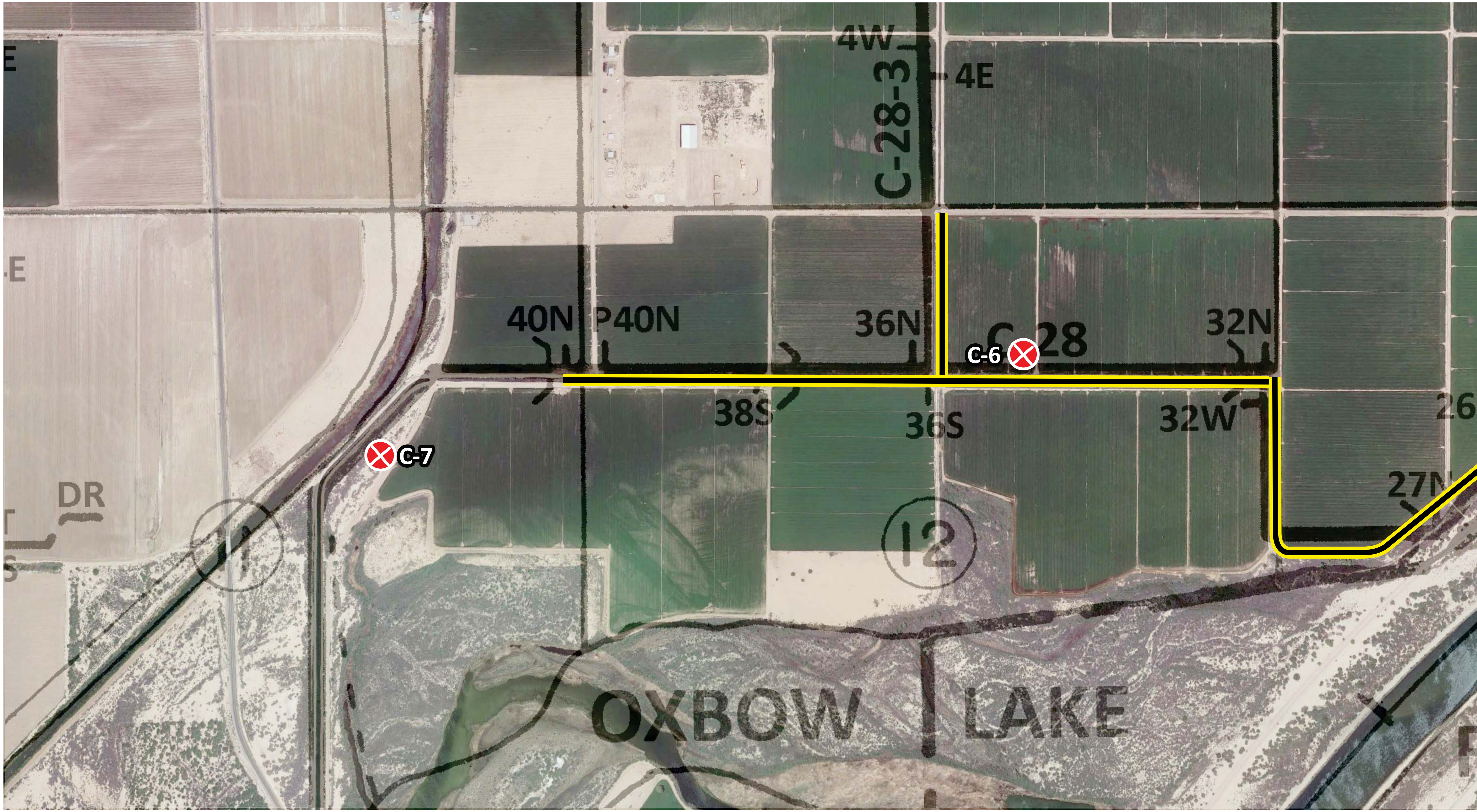

Aerial photo source: Google ©2016, modified by CH2M HILL.

LEGEND

- Soil Sample Location
- Canal Proposed to be Lined

North

0 500 1,000

Approximate scale in feet

ATTACHMENT 4-2
C CANAL – SOIL BORING MAP
Sonoran Energy Project Water Conservation Plan
Riverside County, California

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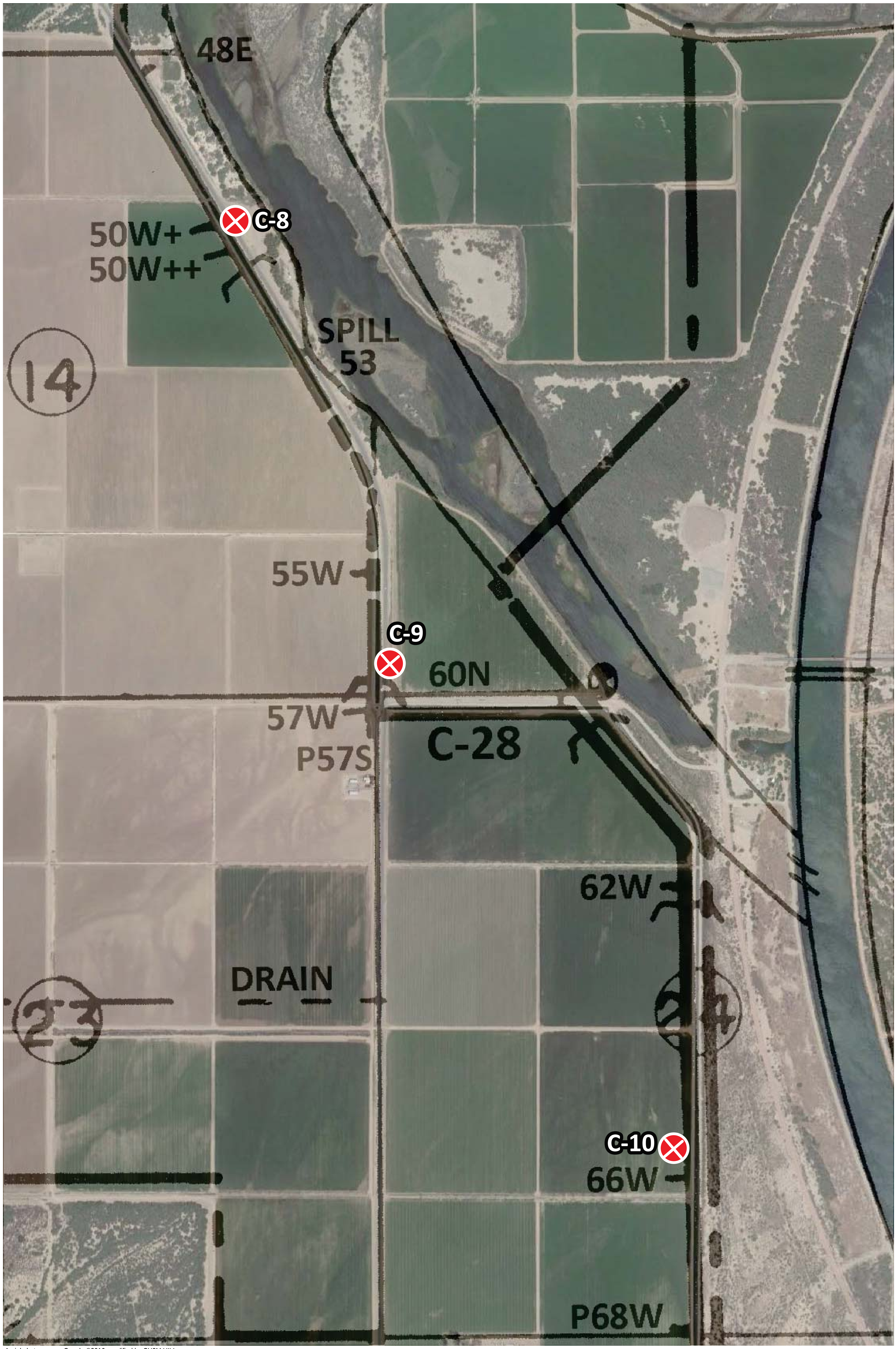

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LEGEND

Soil Sample Location

North

0 500 1,000
Approximate scale in feet

ATTACHMENT 4-3
C CANAL – SOIL BORING MAP
Sonoran Energy Project Water Conservation Plan
Riverside County, California

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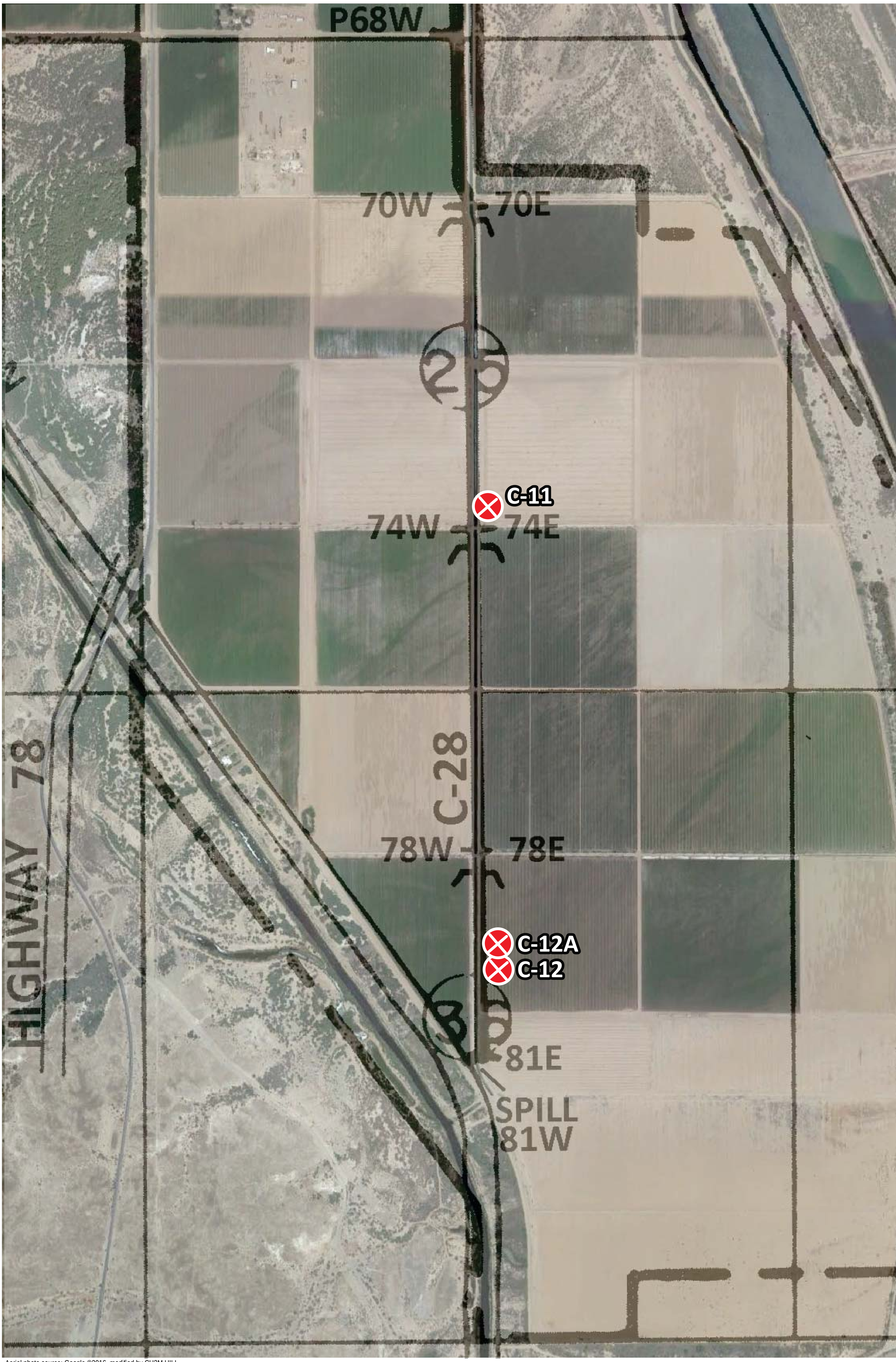

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LEGEND

Soil Sample Location

North

0 500 1,000
Approximate scale in feet

ATTACHMENT 4-4
C CANAL – SOIL BORING MAP
Sonoran Energy Project Water Conservation Plan
Riverside County, California

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WT0111161017RDD Attachment4-4_CCanal_SoilBoringMap_V3.ai cmont 02/05/16