TECHNICAL MEMORANDUM

Date:	11/03/2023
To:	Floodplains Reimagined Program Team
From:	Kiernan Kelty, Scott Wright, and Chris Campbell (cbec)
Subject:	Technical Assistance for Benden Farms

1 INTRODUCTION

The Floodplains Reimagined program is exploring opportunities for improving floodplain habitats for multi-beneficial use in the Butte, Colusa, and Sutter Basins. Some of the opportunities involve exploring winter floodplain/field inundation and habitat enhancement opportunities around key flood control structures on the Sacramento River. The area around Moulton Weir could provide these opportunities but may also impact downstream landowners, presenting a need for further investigation and potential mitigation. This Technical Memorandum (TM), requested by the landowners of Benden Farms (Ben and Denise Carter), describes technical work to evaluate and quantify the opportunities and impacts of Moulton Weir spills on their property (Figure 1). Benden Farms is located immediately downstream of Moulton Weir on the east side of the Sacramento River.

The TM first addresses a known impact of Moulton Weir spills: the inundation of key road crossings on the channels traversing the property, causing access restrictions for extended periods of time. The TM quantifies these impacts and provides proposed infrastructure updates to the crossings to eliminate or reduce inundation for select weir flows. The TM also describes investigation of potential overbank winter flooding opportunities on Benden Farm fields (outside of Sacramento River levees), and habitat enhancement opportunities on the fields within the Sacramento River corridor (inside the levees).

2 HYDRODYNAMIC MODEL DEVELOPMENT

A truncated version of the 1D-2D Butte Basin hydrodynamic model that was developed for Floodplains Reimagined (cbec, 2023) was utilized for evaluating road crossings and field overbank flooding opportunities. The model boundary extended from the eastern levee of the Sacramento River and encompasses Benden Farms and immediately adjacent surrounding fields (Figure 2). The model inflow boundary was set on the downstream side of Moulton Weir and outflow boundaries were defined by water surface elevation (WSE) slopes from the larger Butte Basin model. The finest grid resolution of the model was reduced from 25 ft to 12.5 ft to better capture the complexity of the channels traversing the property.

Two survey campaigns were completed to effectively represent key hydrologic and hydraulic features within the model boundary. The first field effort was completed on 3/24/2023 with a focus on collecting the topography of channel cross-sections and drainage canals, road crossings, and fields where data gaps existed. The second campaign on 4/25/2023 collected channel bathymetric and cross-sectional points along the main drainage canal through the property (Figure 3). The collected survey data was used to supplement the digital elevation model (DEM) developed for the large-scale model.

3 EVALUATION OF ROAD CROSSINGS

Moulton Weir has an historic spill range of 0 – 37,300 cfs (Moulton Weir Spill to Butte Basin near Princeton, WDL, A02986) that impact downstream road crossings and fields in Benden Farms. A probability of exceedance analysis was performed on the historical record of the weir to identify potential flow conditions for the study (Figure 4). Four inflows: 1,000 (1K), 2,000 (2K), 3,000 (3K), and 6,000 (6K) cfs were selected for the study based on their relative frequency and range of exceedance values: 80% (1K), 69% (2K), 59% (3K), and 35% (6K), respectively (Figure 4). Because it is likely not feasible to keep crossings from inundating during the highest weir spills, the analysis was focused on smaller, more frequently occurring events. Spills over Moulton Weir split into three distinct channels shortly downstream from the weir, shown as channels A, B, and C in Figure 5. Thus, the first step in evaluating the crossings was to determine the flow splits into these channels under the selected weir spills; results are detailed in Table 1 below.

Table 1. Channel flow splits for 1K, 2K, 3K, and 6K cfs weir spills.

	Total Weir Spill			
Channel	**1,000 cfs**	**2,000 cfs**	**3,000 cfs**	**6,000 cfs**
A	893	1,548	2,136	4,030
B	106	358	589	1,170
C	1	94	275	800
Total (cfs)	1,000	2,000	3,000	6,000

Model results showed that channel A conveys the largest portion of the weir spill, followed by channel B and then channel C, for all conditions. Several road crossings located on the outflow channels are known to flood during spill events. Six road crossings were identified for evaluation (C1, C2, C3, C4, C5, and C6, Figure 5); crossing C1 is located on outflow channel A, crossing C2 on outflow channel B, and crossings C3 to C6 on outflow channel C. Flood impacts were evaluated at these crossings for the 3K and 1K model runs (Figures 6 - 11). For the 3K run, all crossing points were inundated by the flow event. For the 1K run, only crossings C1 and C2 were inundated due to the marginal flow conveyed in channel C (Table 1).

The flow split results were used to evaluate the potential for raising the road elevations across the channels and providing conveyance through the roads with culverts. New potential road crossing elevations (Figures 6 - 11) were determined using flow split results from the 3K model run and the HY-8 Culvert Hydraulic Analysis Program. The program was first used to determine an initial estimate of culvert sizes and numbers for each crossing. The upstream (US) and downstream (DS) inverts for the structures were determined from survey data and updated DEM queries. Model results from the 3K and 1K runs were then utilized to estimate realistic box culvert sizes with the following constraints: 1) US freeboard ≥ 1 ft from maximum water surface elevations and, 2) earthen fill thicknesses above culverts ≥ 1 ft. The optimal sizes to meet these constraints were then determined through an iterative process.

Tables 2 and 3 contain the culvert sizing results for the 3K and 1K flow conditions, respectively. Model results of maximum WSE are shown in Figures 12 – 17 where all crossings achieve an US freeboard ≥ 1 ft and earthen fill thickness above culvert ≥ 1 ft for the flow conditions.

Table 2. Culvert specifications for crossings C1 – C6 for the 3,000 cfs flow condition.

Variable	C1	C2	C3	C4	C5	C6
Current Road XS Elevation (ft)	62.91	63.82	63.80	62.82	62.69	61.60
New Road XS Elevation (ft)	69.00	68.50	66.50	66.00	65.00	65.00
Structure Type	Bridge	Box Culvert	Box Culvert	Box Culvert	Box Culvert	Box Culvert
US Invert (ft)	61.50	63.60	62.90	59.00	59.00	58.00
DS Invert (ft)	61.00	62.60	58.00	60.50	60.50	58.50
Bridge / Culvert width (ft)	90	12	12	12	12	12
Height (ft)	4	3	3	3	3	3
Number of culverts	1	4	2	4	5	5

Table 3. Culvert specifications for crossings C1 – C6 for the 1,000 cfs flow condition.

Variable	C1	C2	C3	C4	C5	C6
Current Road XS Elevation (ft)	62.91	63.82	63.80	62.82	62.69	61.60
New Road XS Elevation (ft)	69.00	68.50	66.50	66.00	65.00	65.00
Structure Type	Circular Culvert	Circular Culvert	Circular Culvert	Circular Culvert	Circular Culvert	Circular Culvert

Variable	C1	C2	C3	C4	C5	C6
US Invert (ft)	61.50	63.60	62.90	59.00	59.00	58.00
DS Invert (ft)	61.00	62.60	58.00	60.50	60.50	58.50
Bridge / Culvert width (ft)	4	3	3	3	3	3
Height (ft)	4	3	3	3	3	3
Number of culverts	6	2	1	1	1	1

To test how the proposed roads and culverts would affect the flow splits in the three channels, the model was re-run with all culverts in place. Updated flow splits are shown in Table 4, and it was generally found that flows slightly increased for channels B and C, and slightly decreased for channel A.

Table 4. Channel flow splits for 1,000 and 3,000 cfs weir spills, with and without culverts.

	Total weir spill			
Channel	**1,000 cfs**	**1,000 cfs**	**3,000 cfs**	**3,000 cfs**
	No Culverts	**Culverts**	**No Culverts**	**Culverts**
A	893	836	2,136	2,097
B	106	135	589	607
C	1	29	275	296
Total	1,000	1,000	3,000	3,000

4 Evaluation of Overbank Winter Flooding Opportunities

Moulton Weir spills provide opportunities for targeted winter flooding on Benden Farm fields for multi-benefit habitat creation. GIS layers for the property containing information on field number, land use, and the drainage network were provided by the landowner and compiled to identify potential flooding locations (Figure 18). Existing conditions for fields susceptible to flooding were identified through conversations with the landowners and via an aerial drone survey completed on 3/16/2023 during the rising limb of a spill event where flows ranged from 1,383 – 2,098 cfs during the flight time (Figure 19). The imagery indicated that fields 307, 404, 405, 406, 407, and 408 were inundated from the spill event (Figure 20). The drone imagery footprint did not cover the fields in the 100s and 200s so it was not possible to evaluate their inundation. In addition to the drone imagery, airplane imagery was collected on 1/17/2023 as part of a separate technical assistance agreement (cbec, 2023b). The weir was not spilling at the time of the flight; however, a similar magnitude spill (2,233 cfs) had occurred about 28 hours prior (Figure 21). This imagery showed residual flooding on fields 114, 208, 209, 210, 306, 307, 308, 406, and 407 (Figures 22 & 23).

Crop cover maps from 2021 - 2023 for the inundated fields (Figures 24 – 26) were reviewed and found to be a mixture of row and cover crops, pasture, wheat, vetch, and fallow depending on the year. Preliminary results were shared with the landowner to ensure that the identified fields (114, 208, 209, 210, 306, 307, 308, 406, 407, and 408) were consistent with their observations and that these fields could potentially be targeted for winter flooding opportunities with minimal impacts to planned agricultural operations.

Flooding opportunities for the fields were further explored by calculating the difference between the mean field elevation and the outlet WSE from the 1K run (Figure 27 and Table 5), as this elevation difference is indicative of the feasibility of controlled flooding of a given field.

Table 5. Mean field elevations and outlet WSE for the 1,000 cfs model run

Field	Outlet WSE (ft)	Mean Field Elevation (ft)	Mean Field Elevation above Outlet WSE (ft)
114	63.57	64.69	1.12
207	60.74	64.15	3.41
208	63.19	64.70	1.51
209	62.70	64.58	1.88
210	60.72	63.90	3.18
306	64.18	67.11	2.93
307	64.18	64.99	0.81
308[1]	-	67.67	-
402	64.52	71.06	6.54
403	64.94	71.70	6.76
404	66.55	69.61	3.06
405	65.33	67.79	2.46
406	64.18	66.08	1.90
407	64.18	64.90	0.72
408	64.15	66.93	2.78

[1] Field 308 does not have an outlet WSE because it is not immediately adjacent to a channel

The analysis found that most fields with inundated outlets had a mean field elevation within about 3.5 ft from the outlet WSE of the 1K run. For the identified fields (114, 208, 209, 210, 306, 307, 308, 406, 407, and 408), the analysis showed that fields 114, 208, 307, and 407 had mean field elevations within about 1.5 ft while fields 209 and 406 were within about 2.0 ft of the outlet WSE. Fields 210, 306, and 408 had the largest elevation difference from the outlet WSE that fell within 3.5 ft. No elevation difference was calculated for Field 308 because 1K flows did not reach the field's outlet (Figure 27).

Because most of the identified fields (114, 208, 307, and 407) had mean field elevations within 1.5 ft of the outlet WSE, potential winter habitat was calculated by incrementally adding 0.5, 1.0, and 1.5 ft to the identified field outlet WSE. Potential inundation areas were calculated within the fields for each WSE increase (Figure 28 & Table 6).

Table 6. Estimated potential winter habitat for WSE increases of +0.5, +1.0, and +1.5 ft

		Estimated Habitat (acres)		
Field	Approximate 1K WSE at field outlet (ft)	WSE +0.5 ft	WSE +1.0 ft	WSE +1.5 ft
114	64.0	19.8	43.2	53.3
207	61.0	0.0	0.0	0.001
208	63.0	9.5	22.4	38.7
209	63.0	5.9	18.3	35.4
210	61.0	0.20	3.3	9.5
306	64.0	0.64	1.2	3.7
307	64.0	21.3	60.7	95.8
404	66.5	0.0	0.01	0.58
405	65.0	0.0	0.0	0.0
406	64.0	2.8	5.2	8.5
407	64.0	1.6	23.0	28.7
408	64.0	0.0	0.0	0.08

The calculations indicated that field 307 had the largest estimated habitat potential followed by fields 114, 208, 209, 407, 210, 406, 306, 404, 408, 207, and 405 respectively, for the WSE +1.5 ft scenario. A focused inundation depth analysis was performed for Field 307 (Figure 29) for the outlet WSE + 1.5 ft scenario. The majority of the field would have water depths between 0.0 – 1.0 ft (Table 7) with a considerable amount of area with depths > 1.0 ft located near the field outlet (Figure 29).

Table 7. Estimated inundation depth acreage for Field 307 under the 1K run outlet WSE +1.5 ft.

Depth range (ft)	**Field 307 Estimate Acres (65.5 ft WSE)**
0.0 – 0.5	35.1
0.5 – 1.0	39.4
1.0 – 1.5	14.3
> 1.5	7.0

Inundation scenarios shown in Figures 28 and 29 could be realized through weir inflows exceeding 1,000 cfs or through installment of water level control structures at key points on the drainage canals and field outlets to raise water levels and control retention times. Two locations where flow control structures (i.e., sluice gates or bladder dam weirs, etc.) could be installed are at the inflow channel to the Wattis Audubon Sanctuary and the southern terminus of the north-south running drainage canal along the east side of the property (Figure 28). Additionally, fields could have outlet structures updated or modified to allow for a controlled release of flood waters to optimize retention times and habitat potential on respective fields.

5 EVALUATION OF WITHIN – CHANNEL RESTORATION OPPORTUNITIES

Two of the Benden Farms fields (103 and 301, see Figure 18) are located within the Sacramento River project levees, and are thus unaffected by Moulton Weir spills. These fields were thus evaluated for potential habitat improvements based on mainstem Sacramento River flows. Flow activation thresholds were estimated for the fields under existing conditions and these estimates were used, along with information on ecological flow requirements for juvenile salmon, to assess potential restoration opportunities for these fields.

The large-scale hydrodynamic model developed as part of Floodplains Reimagined (cbec, 2023) was paired with cbec's Ecological Floodplain Inundation Potential (EcoFIP) tool (cbec, 2022) to quantify flow activation footprints for the Sacramento River corridor between Hamilton City and Colusa. First, the hydrodynamic model representing the leveed Sacramento River corridor (represented in 1D) between Hamilton City and the Tisdale Bypass, including flood weir connections to the Butte Basin, was run at stepped flows from 10,000 to 80,000 cfs to determine the inundated area of the river corridor. Flows above 80,000 cfs were not simulated as those conditions activate the three natural overflows upstream from Moulton Weir and are indicative of valley-wide flooding conditions.

Activation flow thresholds from EcoFIP were evaluated for the Benden Farms fields located within the river corridor (Figure 30) and were generally found to range from 40,000 – 80,000 cfs for the property. EcoFIP results were verified by comparing the 80,000 cfs activation flow extent to discolored field areas in aerial imagery (Figure 31) collected on 1/17/2023 as part of the Floodplains Reimagined rearing opportunities technical assistance (cbec, 2023b). The comparison showed the discolored areas from the flood event (max flow = 81,636 cfs, Sacramento River at Ord Ferry – Main Channel Gage (ORD)) showed good agreement with the 80,000 cfs activation flow contours from EcoFIP. The verified EcoFIP results were next used to determine stage and flow values for the Benden Farms fields that coincide with suitable rearing habitat for juvenile winter run Chinook salmon, as described below.

The Hydrologic Engineering Center Ecosystems Functions Model (HEC-EFM) is a statistical model designed to determine stage and flow values for different ecological responses of a river reach using flow criteria such as season, duration, rate of change, and percent exceedance. Using established criteria from Floodplains Reimagined (cbec, 2023), an ideal flow value for rearing habitat of juvenile winter run

Chinook salmon was determined for the river reach around the property. Historical gage data (9/30/1997 – 9/29/2021) from Water Data Library (WDL) gage A02500 Sacramento River at Butte City was used for the analysis. The season of December to May, with a duration of 14 days, and event occurrence of 1 out of every 3 years, were used for analysis criteria. The HEC-EFM model determined a flow of about 37,000 cfs as the threshold to meet these criteria. Based on this, the EcoFIP activation flow footprint for 35,000 cfs (Figure 30) was selected, which coincides with a stage of about 66 ft NAVD88 based on the USGS 2018 LiDAR on the river left bank of the Sacramento River adjacent to the Benden Farms property. These flow and stage values were used to evaluate five concepts for habitat enhancements on the fields:

1. Grading of both fields 301 and 103 to 65 ft NAVD88 (one foot below the 35,000 cfs stage, Figure 32 left panel).
2. Grading of field 301 only to 65 ft NAVD88 (Figure 32 right panel).
3. Grading of field 103 only to 65 ft NAVD88 (Figure 32 right panel).
4. Grading of the 75,000 cfs EcoFIP activation extent to 65 ft NAVD88 (Figure 33 left panel).
5. Grading of a 60 ft wide channel to 65 ft NAVD88 with complementary floodplain bench graded to 70 ft NAVD88 (Figure 33 right panel).

Grading cut estimations for each of the concepts were determined via GIS analysis of the 2018 USGS LiDAR surface for the property (Table 8). Enhancement concept 1 had the largest cut estimation followed by concepts 2, 4, 3, and 5. While concepts 1 – 4 would provide a greater amount of habitat enhancement compared concept 5, these concepts may be unfeasible due to their large cut estimations.

Table 8. Cut estimations via GIS analysis for the 5 habitat enhancement concepts.

Concept #	Habitat Enhancement Concept	Estimated Cut Volume (yd^3)
1	Lower Fields 301 and 103	2,644,465
2	Lower Field 301 only	1,766,444
3	Lower Field 103 only	877,256
4	Lower 75,000 cfs Activation Extent	1,345,192
5	60 ft wide Channel and Floodplain Bench	204,070

The EcoFIP tool was used to further explore concept 5 by incorporating the concept footprint into the activation flow analysis and providing more accurate estimates of cut and fill volumes for the channel and floodplain features (Figure 34). The cut estimation decreased slightly compared to the GIS analysis. Overall, the concept would provide about 37 acres of potential rearing habitat for juvenile winter run Chinook salmon, with the area distributed approximately equally between channel and floodplain habitats (Figure 34).

6 SUGGESTIONS FOR FUTURE WORK

The analyses described herein provide a pre-feasibility level assessment of potential habitat enhancements and infrastructure improvements on Benden Farms. Refinements and expansions of the analyses would require the following future work items:

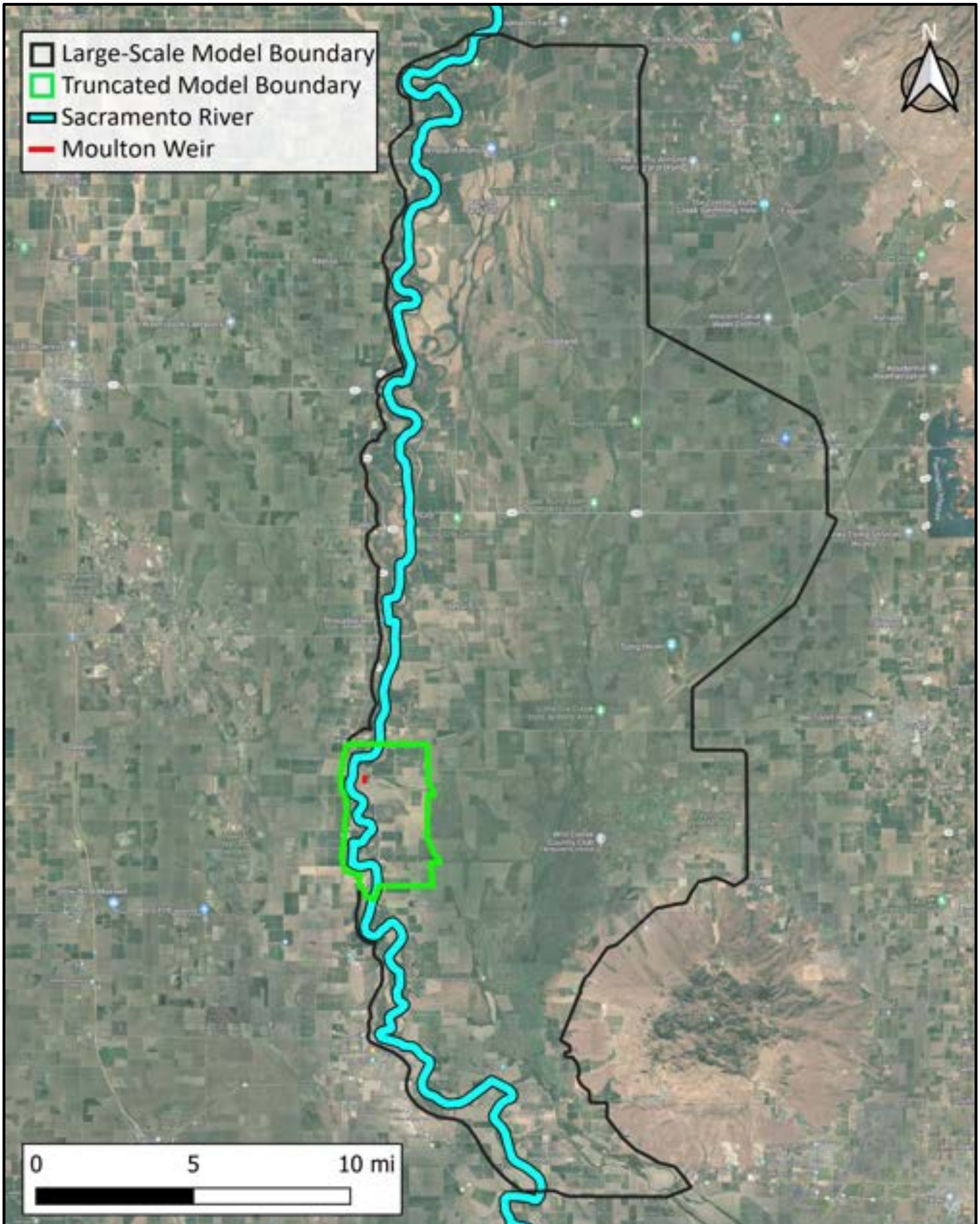
- Conversion of the 1D hydrodynamic model of the Sacramento River into a 2D model, for the reach around Moulton Weir. This is necessary to further evaluate depths and velocities for the proposed within-levee enhancements, assess how these changes might affect the spill frequency at Moulton Weir, and to evaluate potential geomorphic changes in the reach due to the enhancements.
- Incorporation of weir spill duration into the analysis of road crossings and overbank field flooding analysis. The current analysis only addressed a range of steady flows over Moulton Weir. Modeling a range of weir spill magnitudes and durations would allow for a more detailed analysis of juvenile habitat and fish food production potential, as the duration of inundation is an important component for these processes.
- Engagement and coordination with other landowners downstream from Moulton Weir, such as the Wattis Audubon Sanctuary and property owners along the east-west drainage canal that conveys water to Drumheller Slough and ultimately Butte Creek. The truncated model could be extended downstream to evaluate flooding impacts and potential habitat enhancements similar to those described herein for Benden Farms. Previous discussions with Hans Herker, a landowner along the east-west canal, indicated significant flooding problems and costs associated with Moulton Weir spills.

7 REFERENCES

cbec. 2023a. IN PROGRESS. Exploration of Floodplain Reactivation at a Landscape Scale within the Sacramento Valley: Baseline Hydrodynamic Model Development for the Butte Basin, Colusa Basin, and Sutter Bypass.

cbec. 2023b. Juvenile Salmon Rearing Habitat Restoration Opportunities Within the Sacramento River Corridor.

cbec. 2022. Ecological Floodplain Inundation Potential and Managed Aquifer Recharge Upper San Joaquin River Pilot Study.



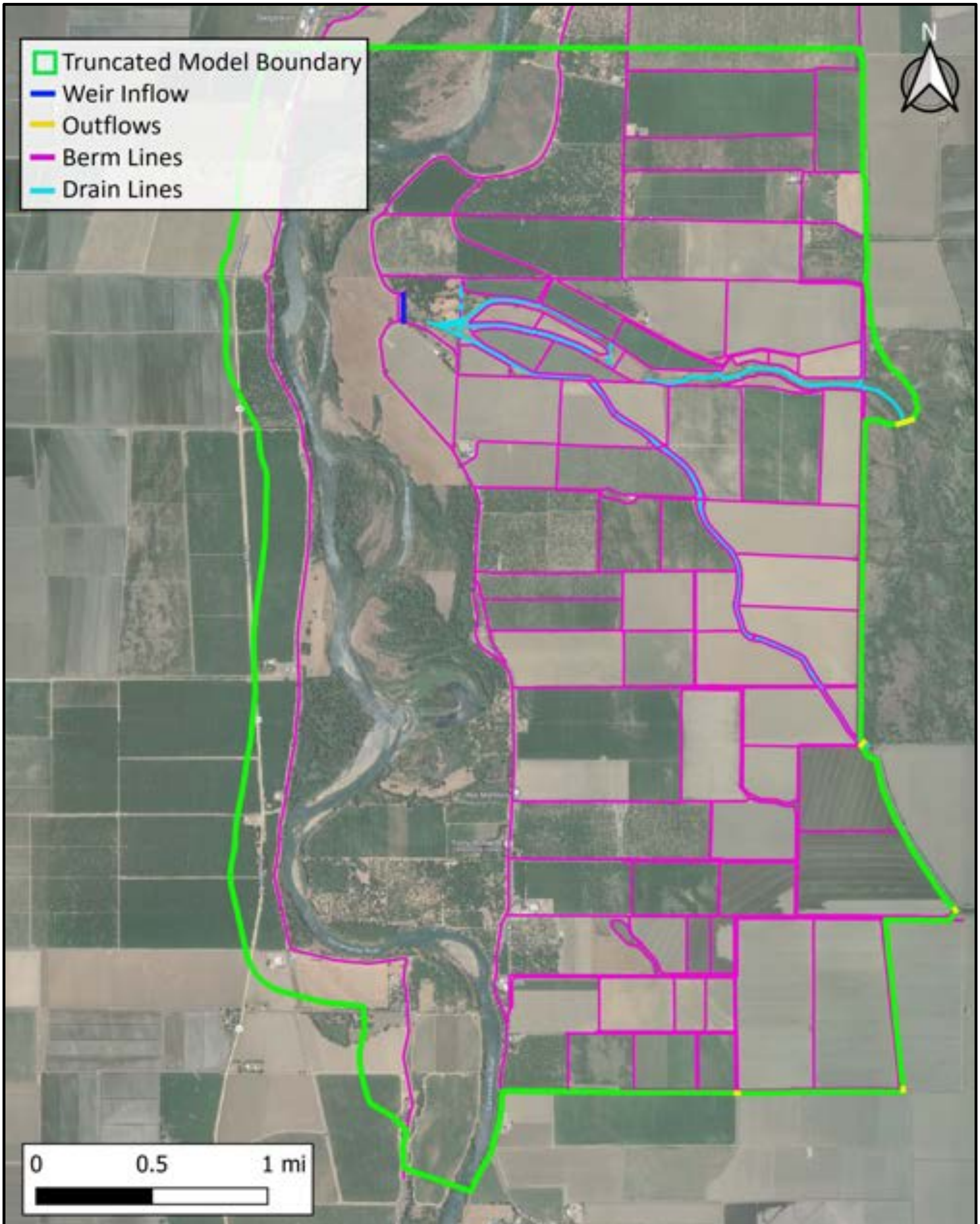
Notes:

cbec eco engineering

Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

Butte Basin − Benden Farms 2D Hydraulic Model Location

Project No. 21−1028−1	Created By: KMK	Figure 1



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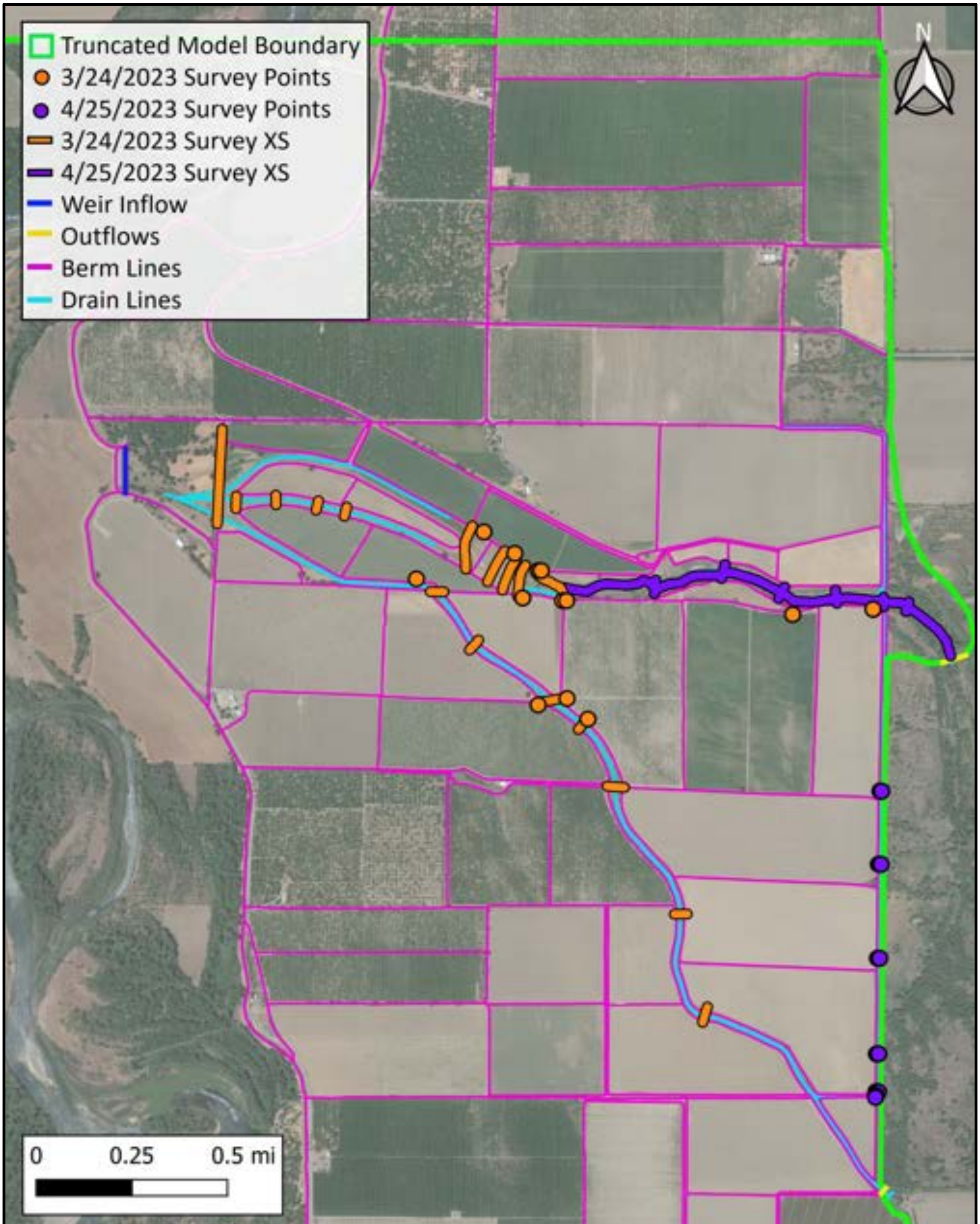
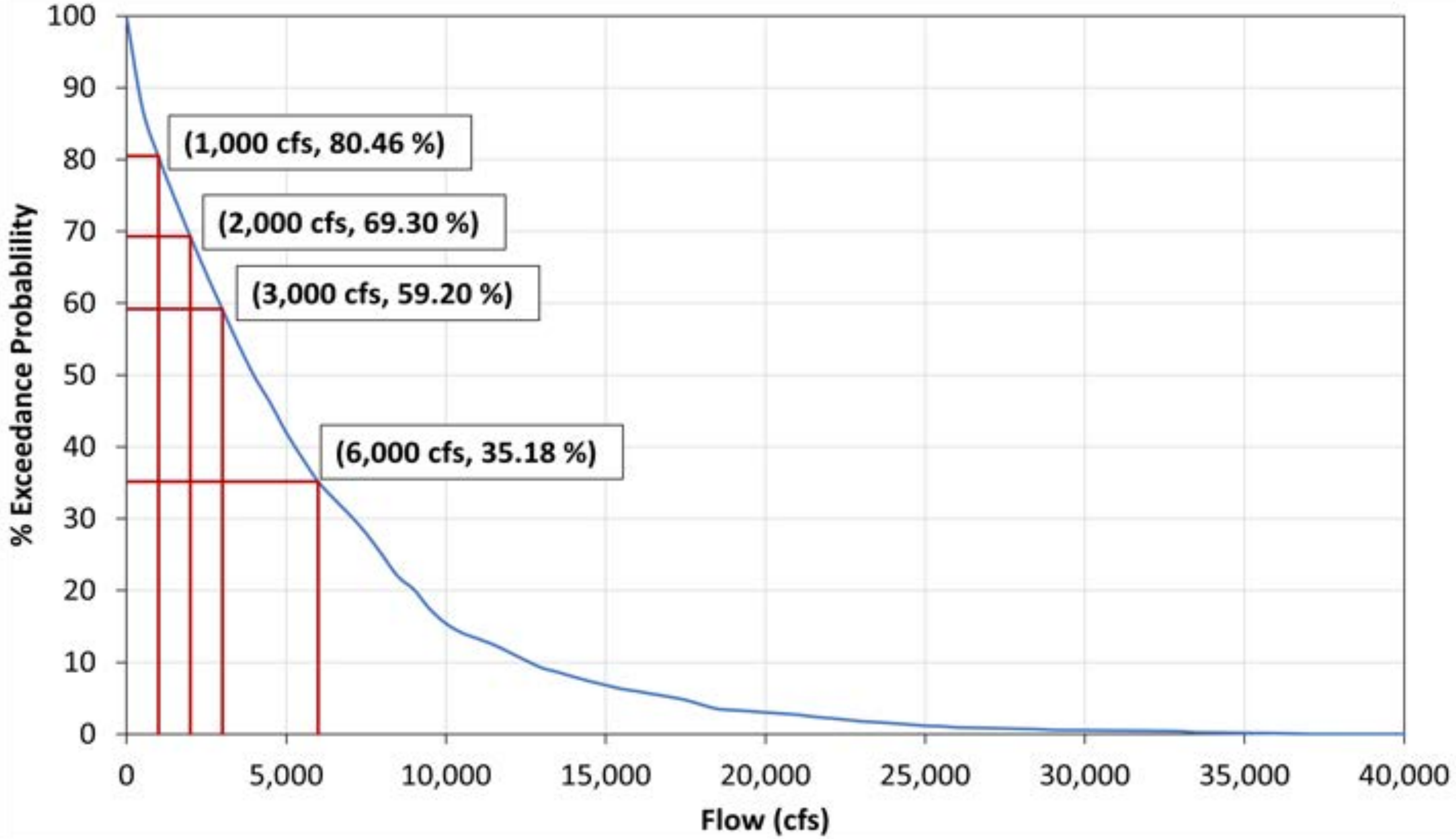
Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

Truncated 2D Hydraulic Model

Project No. 21−1028−1	**Created By: KMK**	**Figure 2**



Notes:	cbec eco engineering	*Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance* **Field Surveys**		
		Project No. 21−1028−1	**Created By: KMK**	**Figure 3**



Notes: Data used for analysis taken from Moulton Weir Spill to Butte Basin near Princeton Gage, A02986, Water Data Library

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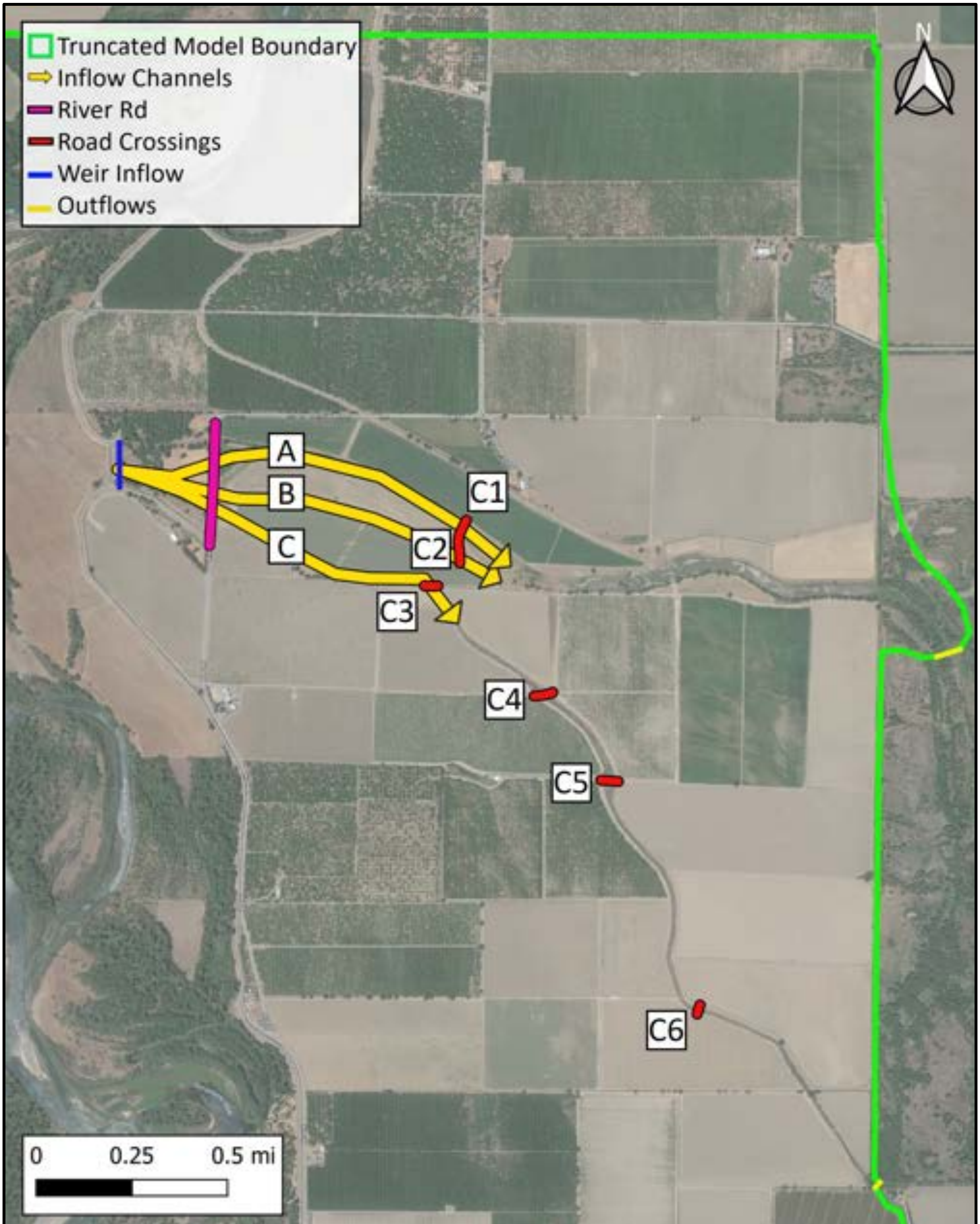
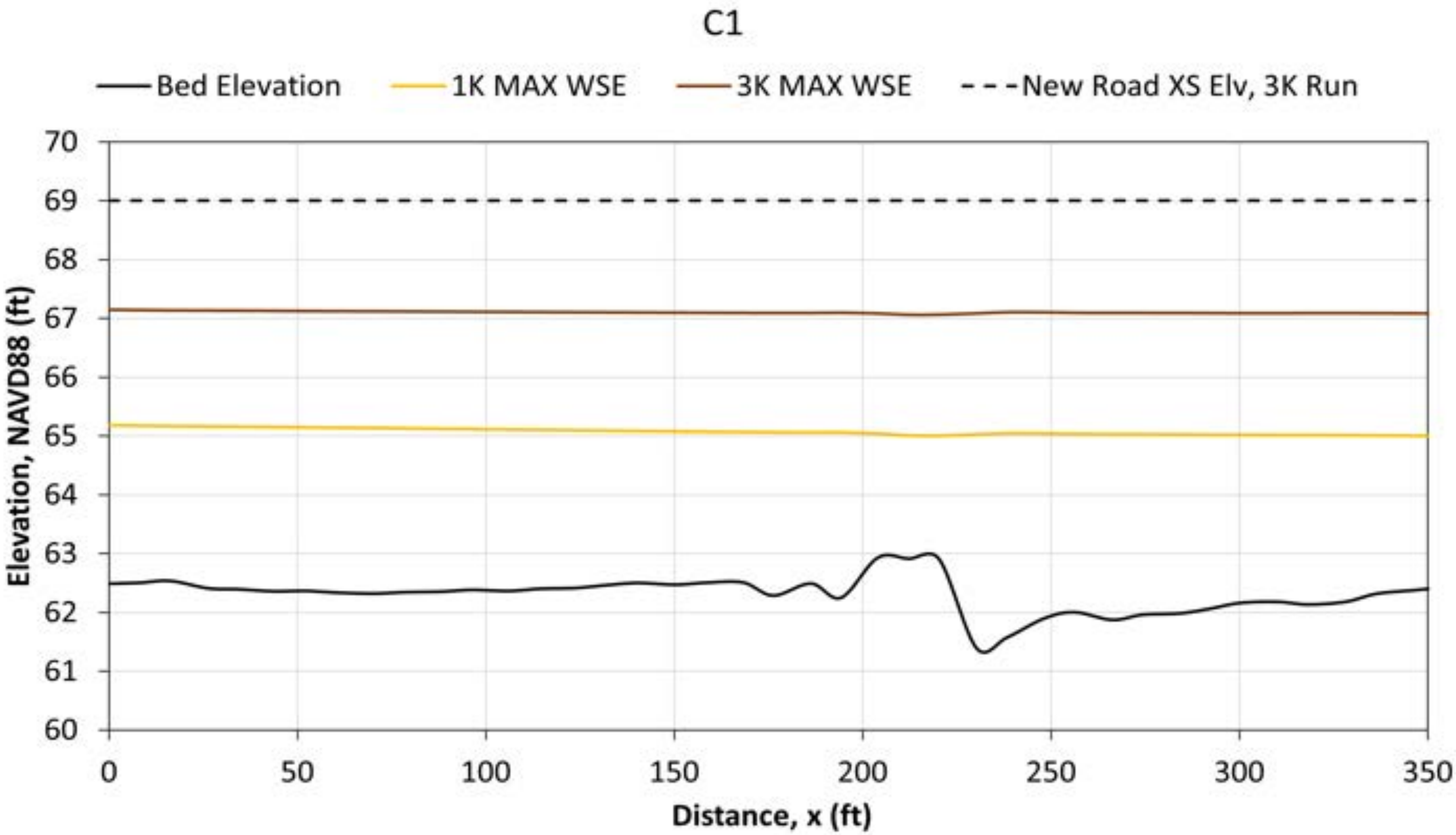
Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

Moulton Weir Cumulative Flow Exceedance

Project No. 21−1028−1	**Created By: KMK**	**Figure 4**



Notes:	cbec eco engineering	*Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance* **Moulton Weir Outflow Channels and Road Crossings**		
		Project No. 21−1028−1	**Created By: KMK**	**Figure 5**

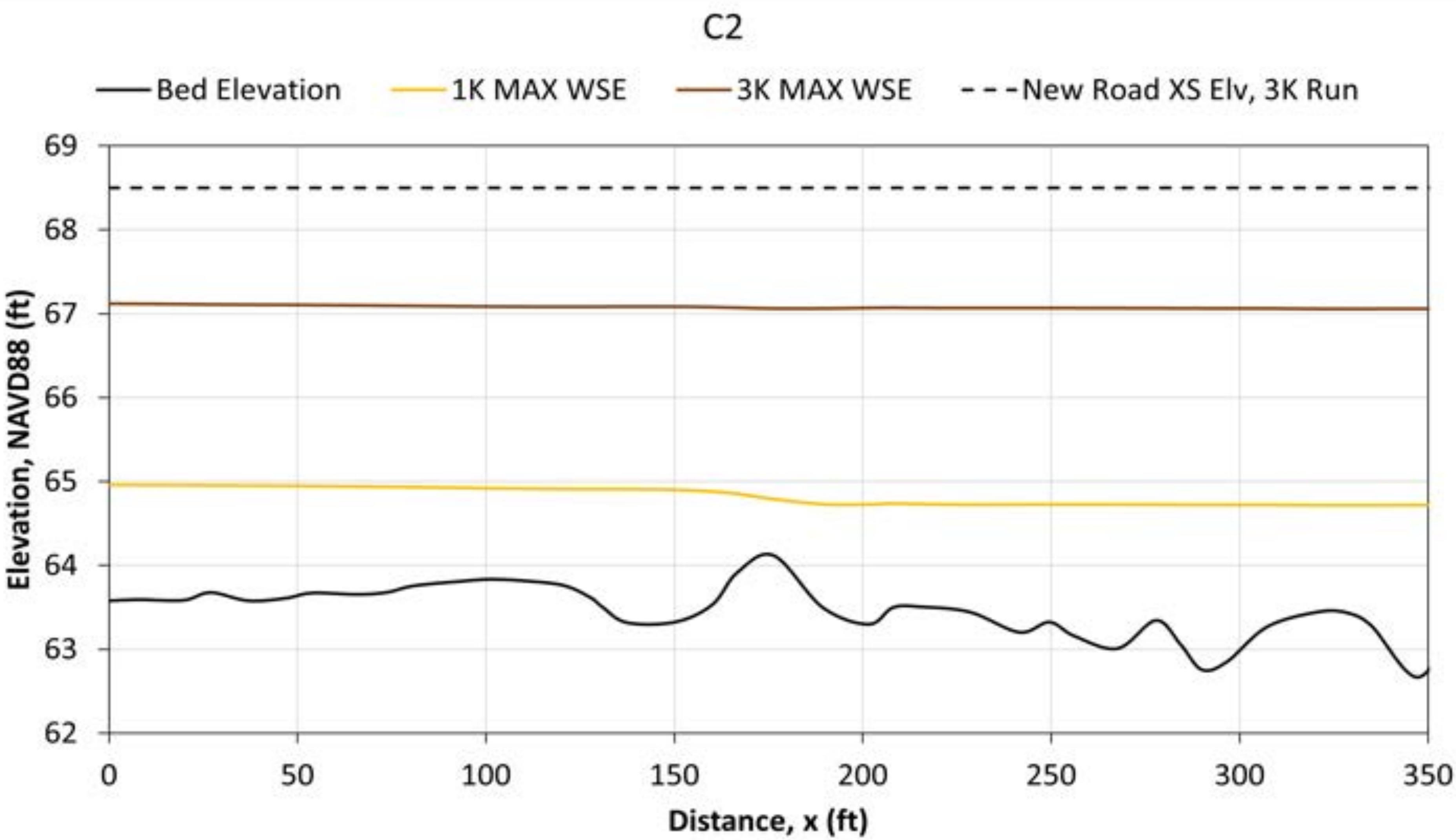


Notes: X origin relative to how cross section was drawn.

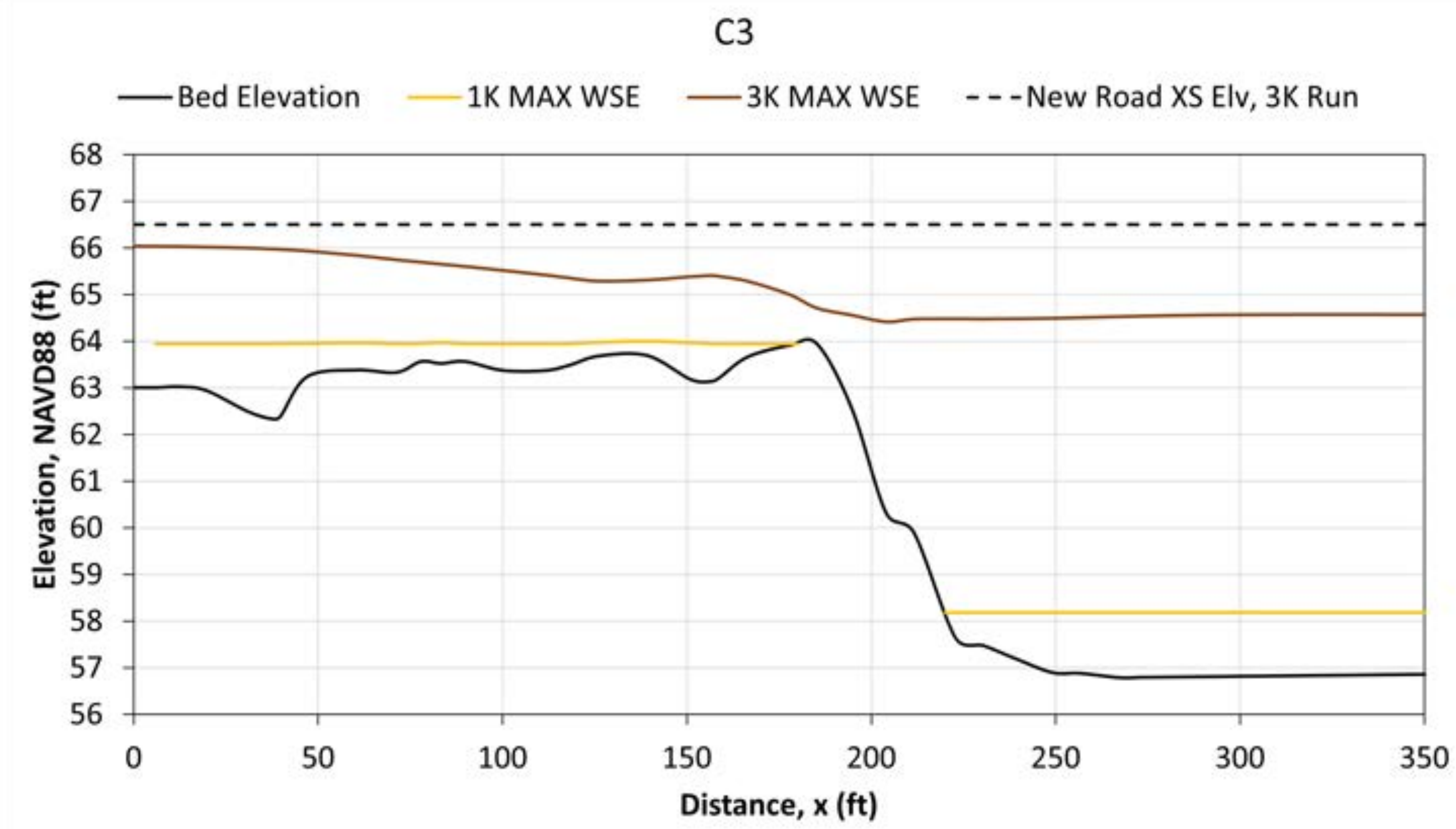
Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

Existing Conditions − Road Crossing 1, C1

Project No. 21−1028−1	Created By: KMK	Figure 6



Notes: X origin relative to how cross section was drawn.	cbec eco engineering	*Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance* **Existing Conditions − Road Crossing 2, C2**	
		Project No. 21−1028−1	**Created By: KMK**	**Figure 7**

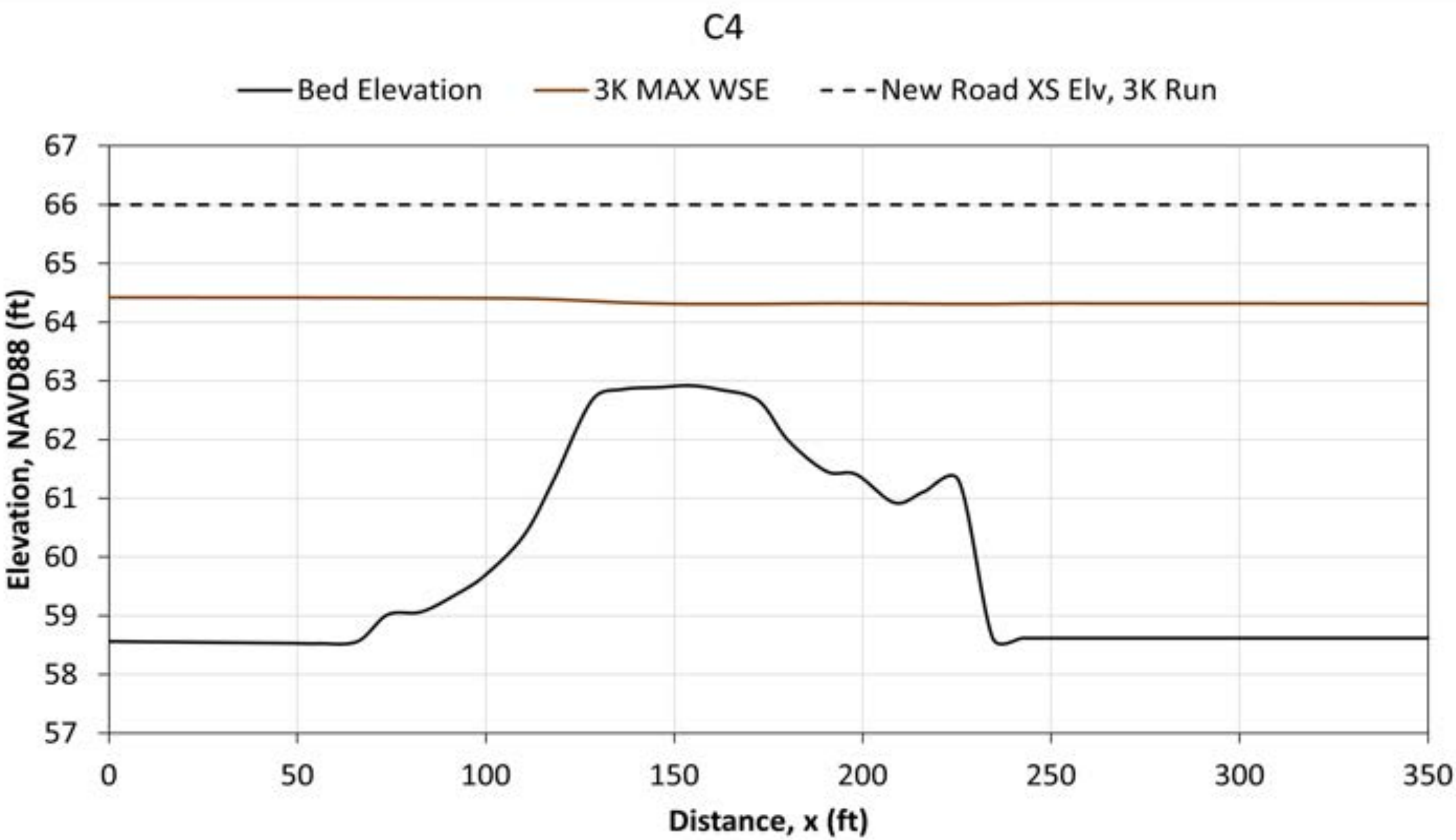


Notes: X origin relative to how cross section was drawn.

Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

Existing Conditions − Road Crossing 3, C3

Project No. 21−1028−1	Created By: KMK	Figure 8

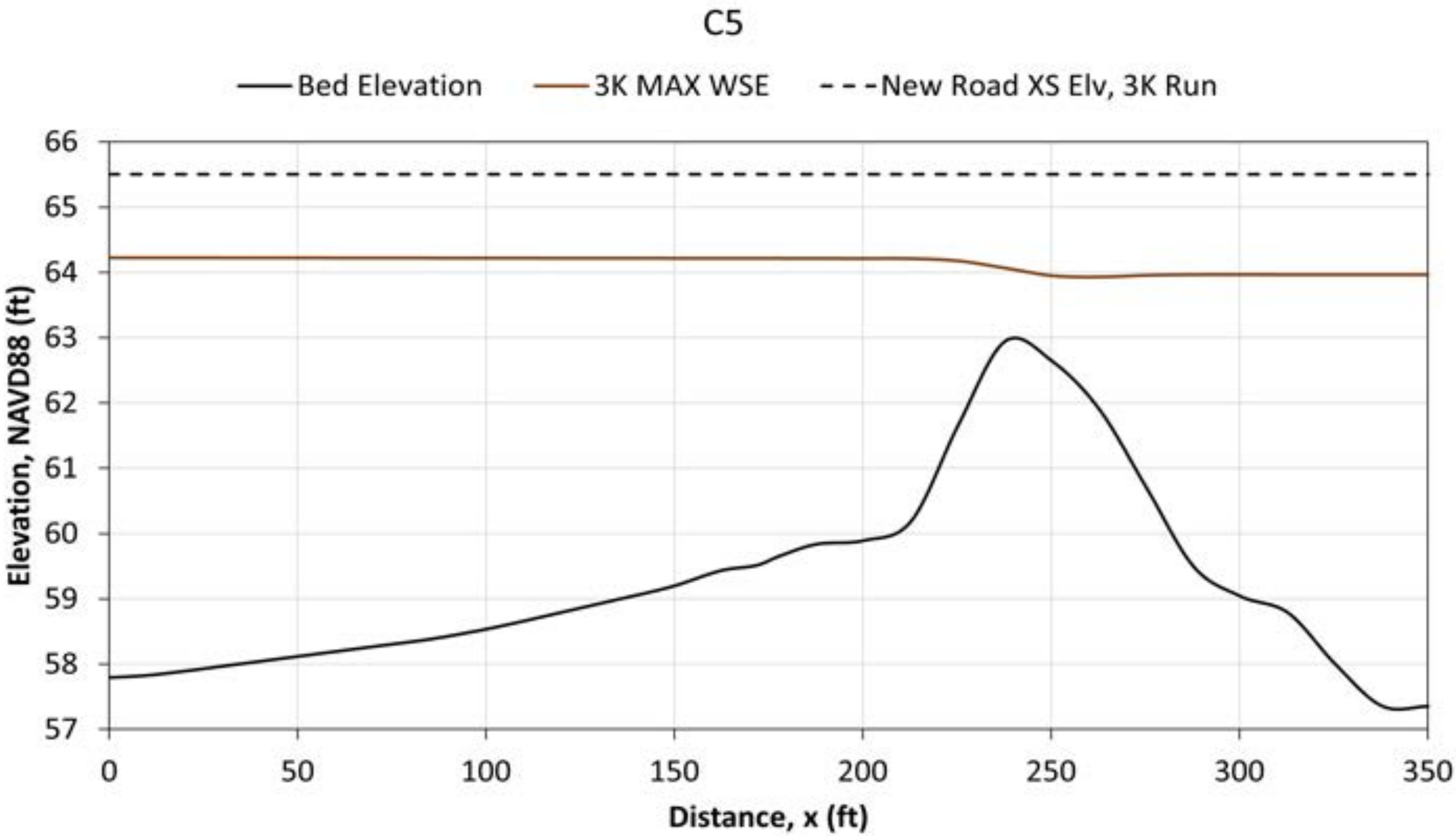


Notes: X origin relative to how cross section was drawn.

Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

Existing Conditions − Road Crossing 4, C4

Project No. 21−1028−1	**Created By: KMK**	**Figure 9**

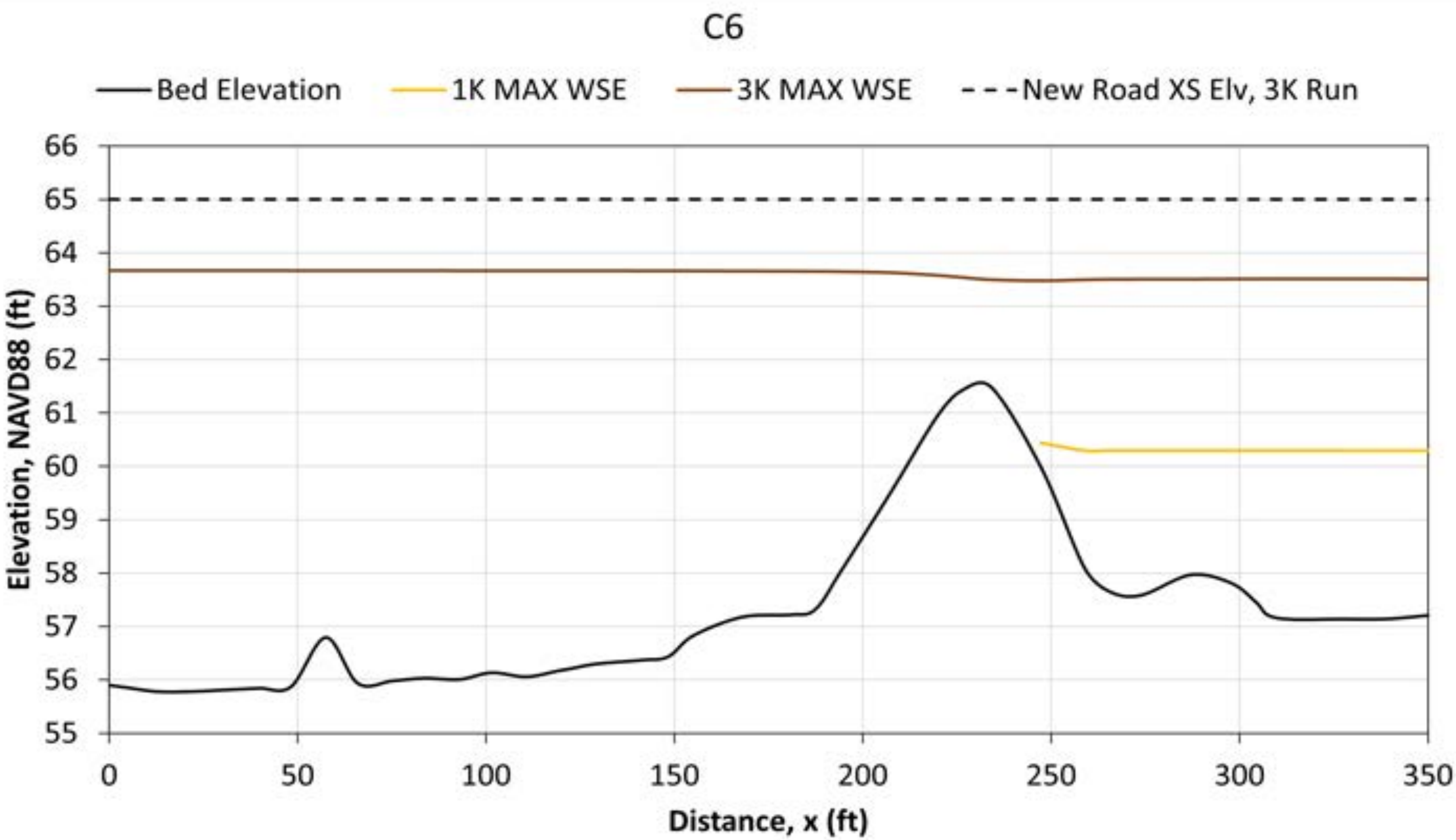


Notes: X origin relative to how cross section was drawn.

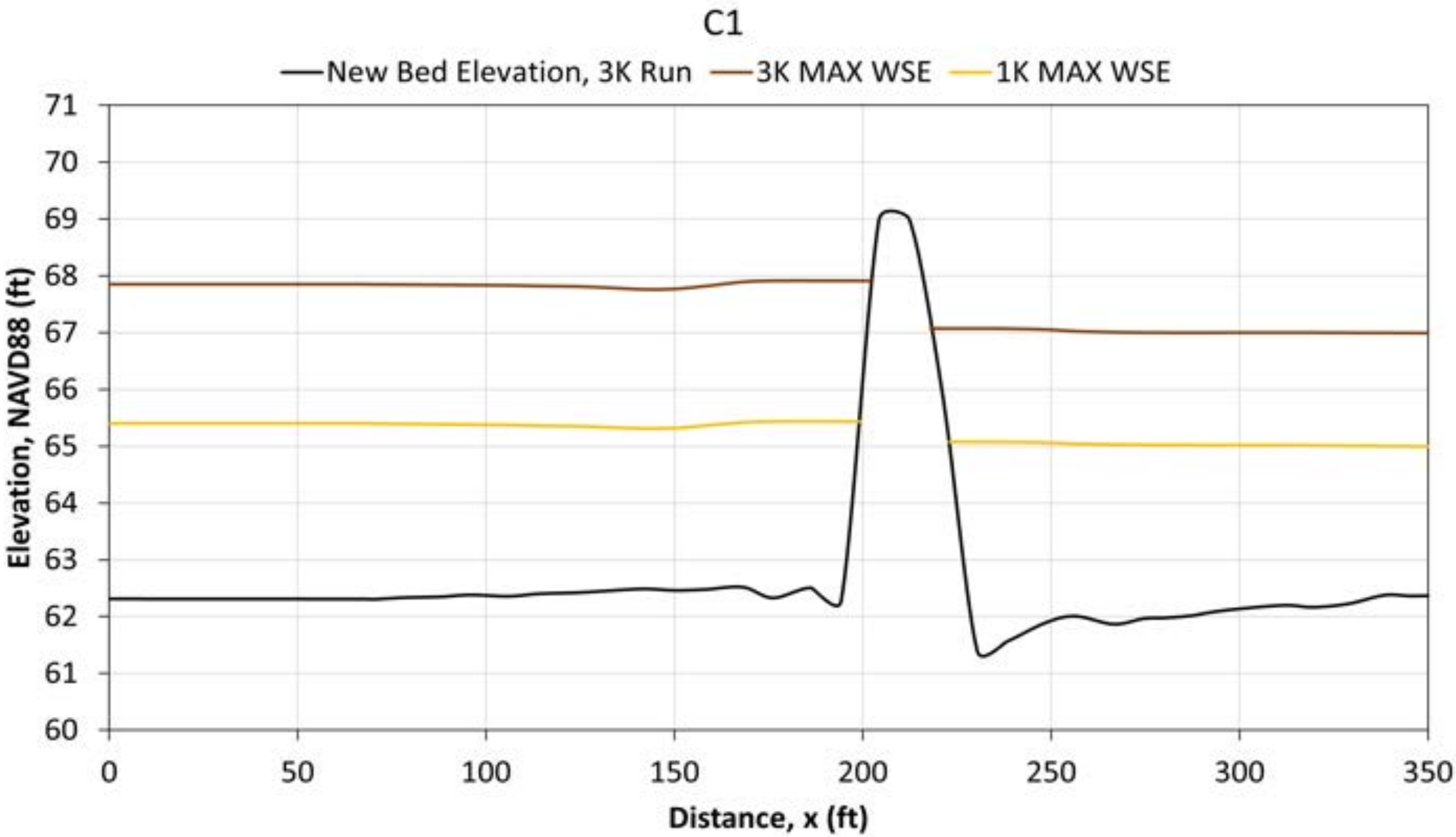
Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

Existing Conditions − Road Crossing 5, C5

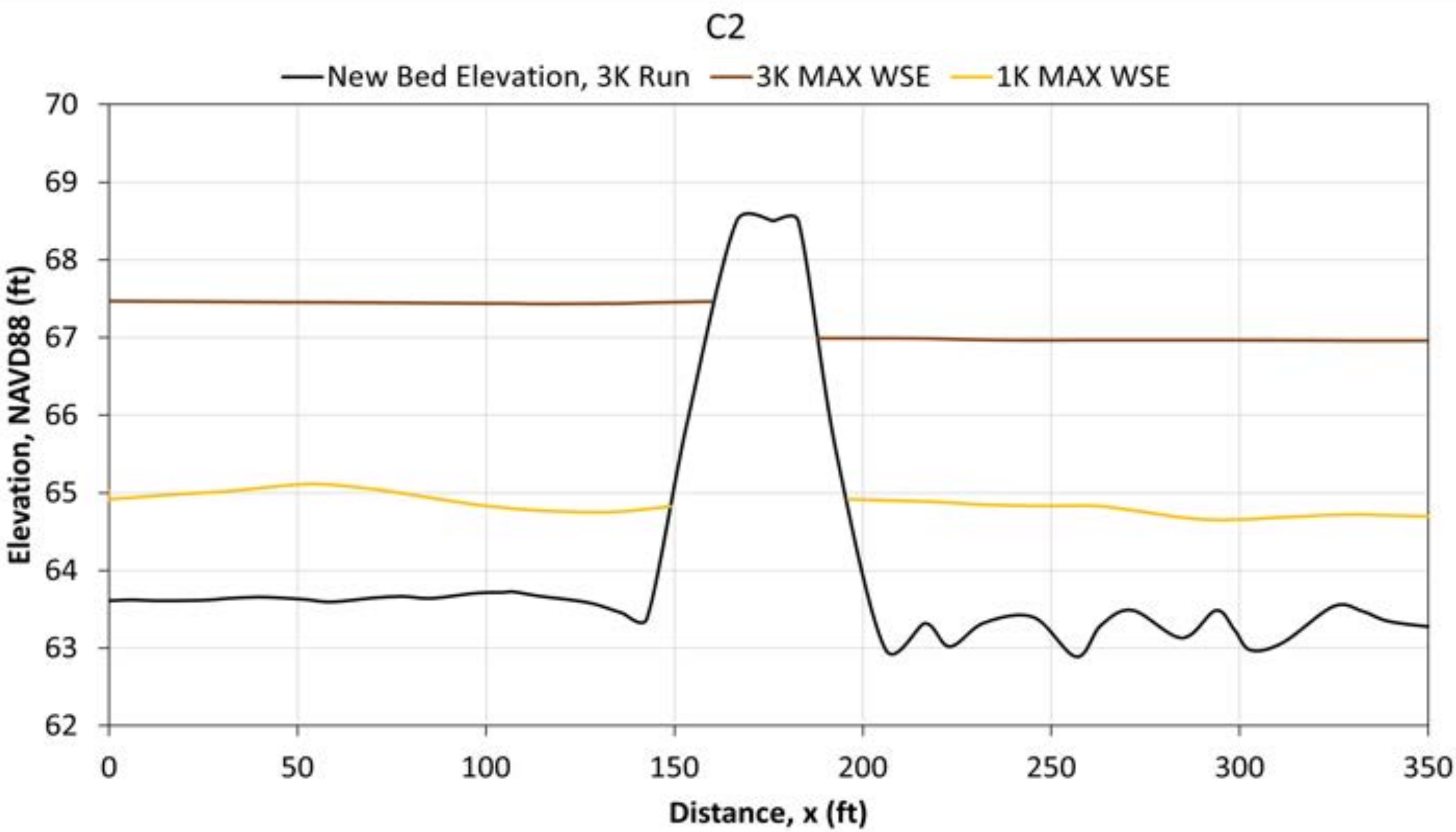
Project No. 21−1028−1	**Created By: KMK**	**Figure 10**



Notes: X origin relative to how cross section was drawn.	cbec eco engineering	*Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance* **Existing Conditions − Road Crossing 6, C6**
		Project No. 21−1028−1 | **Created By: KMK** | **Figure 11**



Notes: X origin relative to how cross section was drawn.	cbec eco engineering	*Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance* **Proposed Conditon 3K cfs Run − Road Crossing 1, C1**		
		Project No. 21−1028−1	**Created By: KMK**	**Figure 12**



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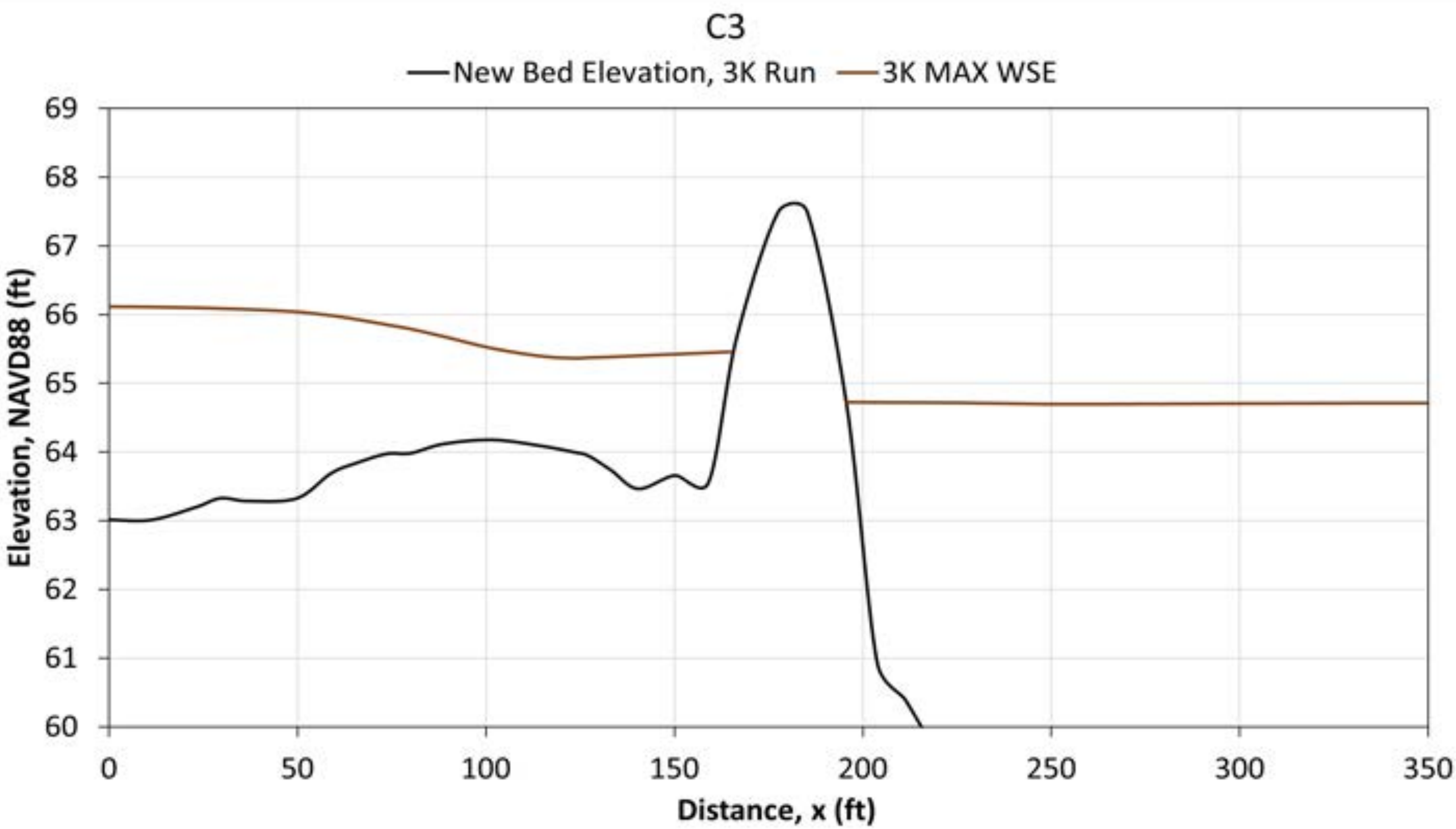
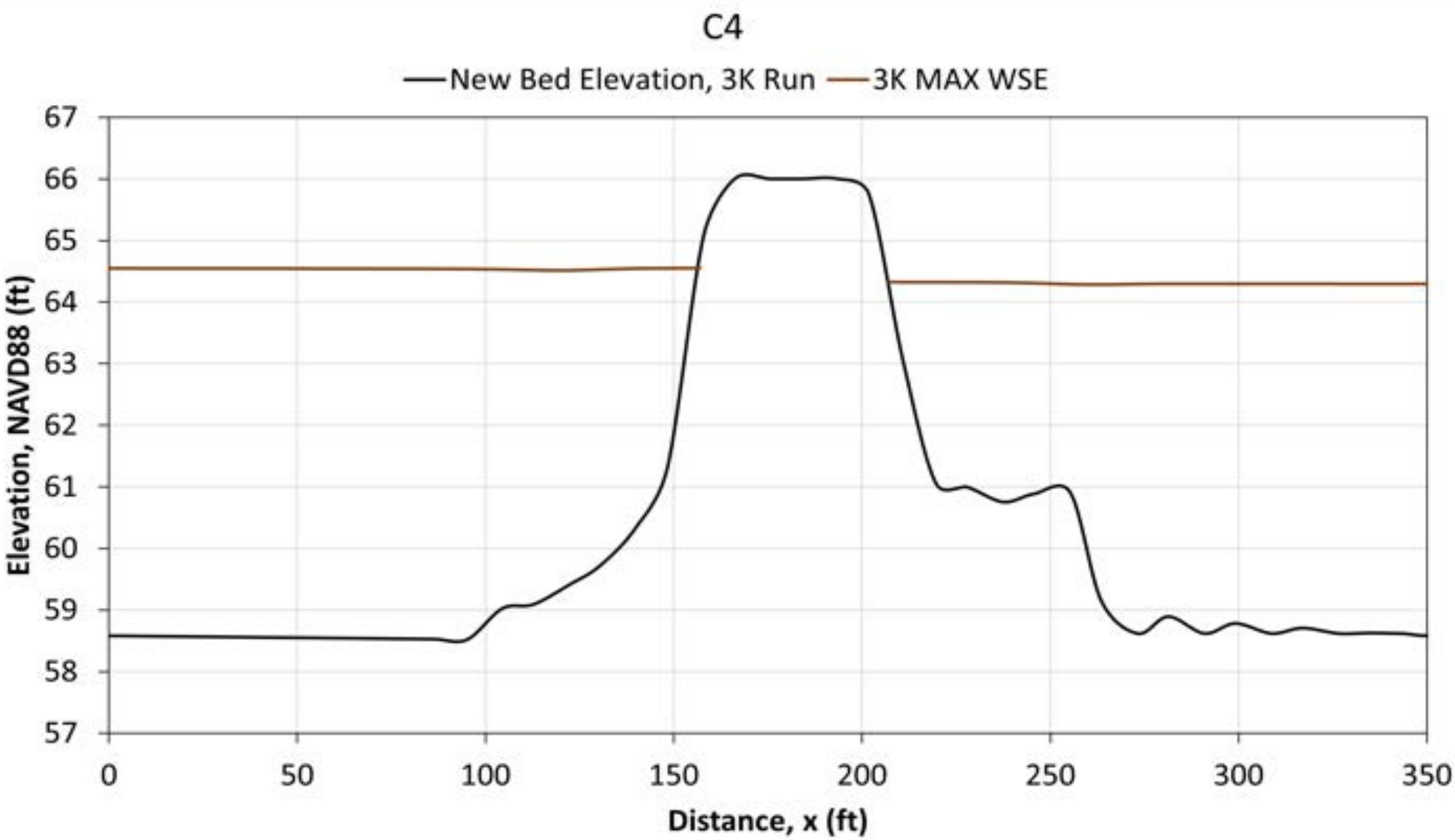
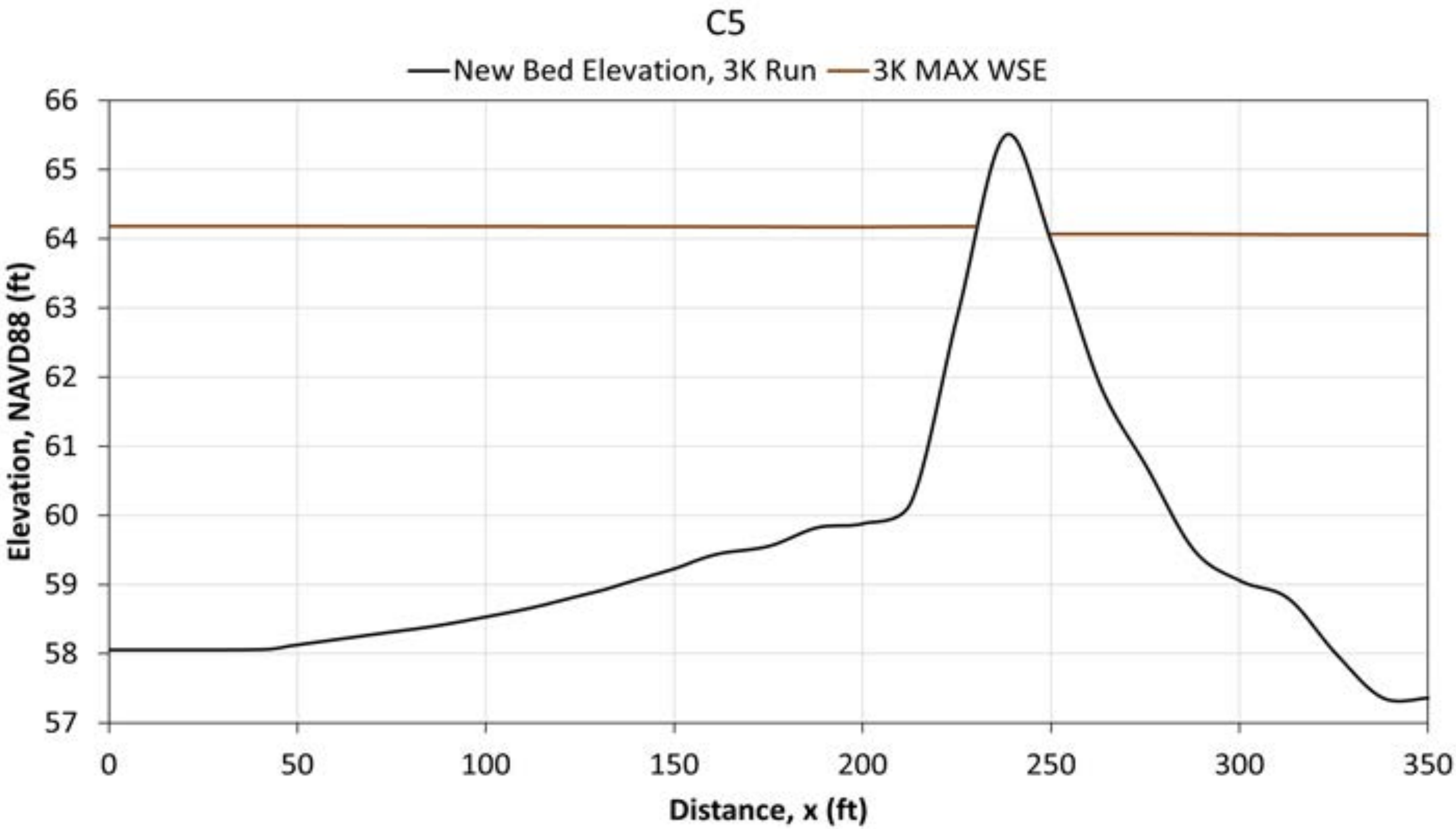
		Project No. 21−1028−1	**Created By: KMK**	**Figure 13**



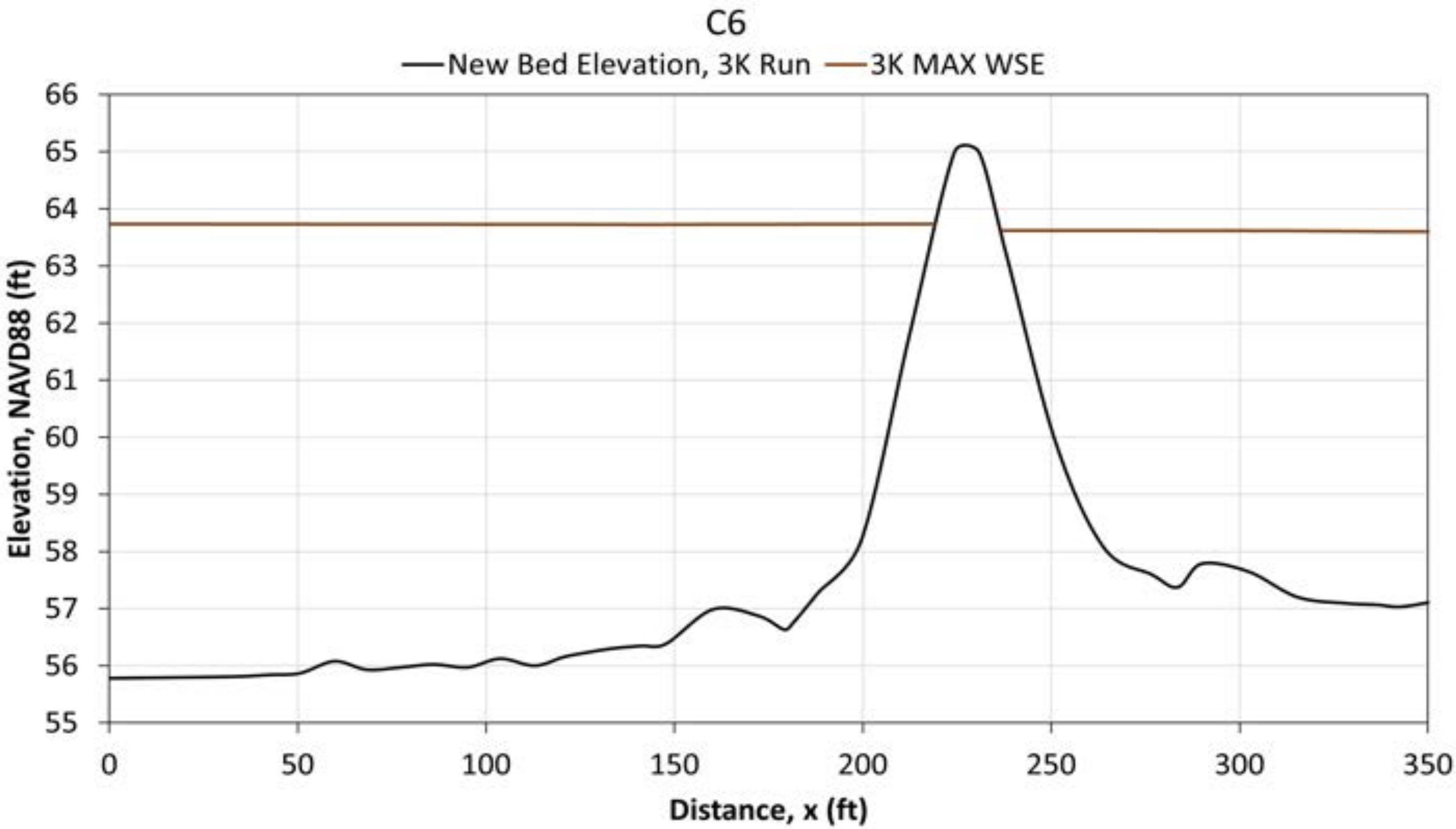
Notes: X origin relative to how cross section was drawn.		*Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance* **Proposed Conditon 3K cfs Run − Road Crossing 3, C3**		
		Project No. 21−1028−1	**Created By: KMK**	**Figure 14**



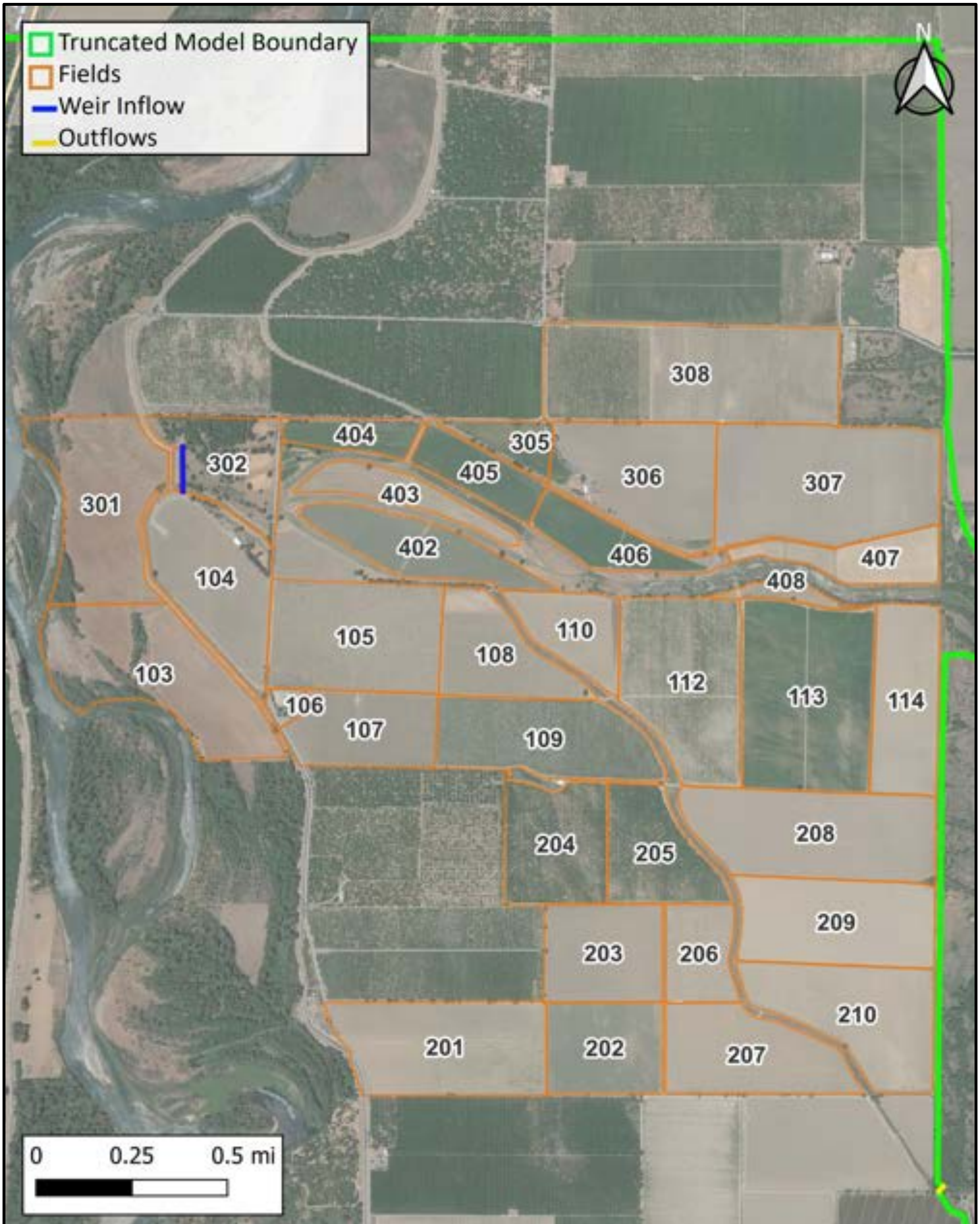
Notes: X origin relative to how cross section was drawn.	cbec eco engineering	*Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance* **Proposed Conditon 3K cfs Run − Road Crossing 4, C4**		
		Project No. 21−1028−1	**Created By: KMK**	**Figure 15**



Notes: X origin relative to how cross section was drawn.	cbec eco engineering	*Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance* **Proposed Conditon 3K cfs Run − Road Crossing 5, C5**		
		Project No. 21−1028−1	**Created By: KMK**	**Figure 16**



Notes: X origin relative to how cross section was drawn.	cbec eco engineering	*Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance* **Proposed Conditon 3K cfs Run − Road Crossing 6, C6**		
		Project No. 21−1028−1	**Created By: KMK**	**Figure 17**

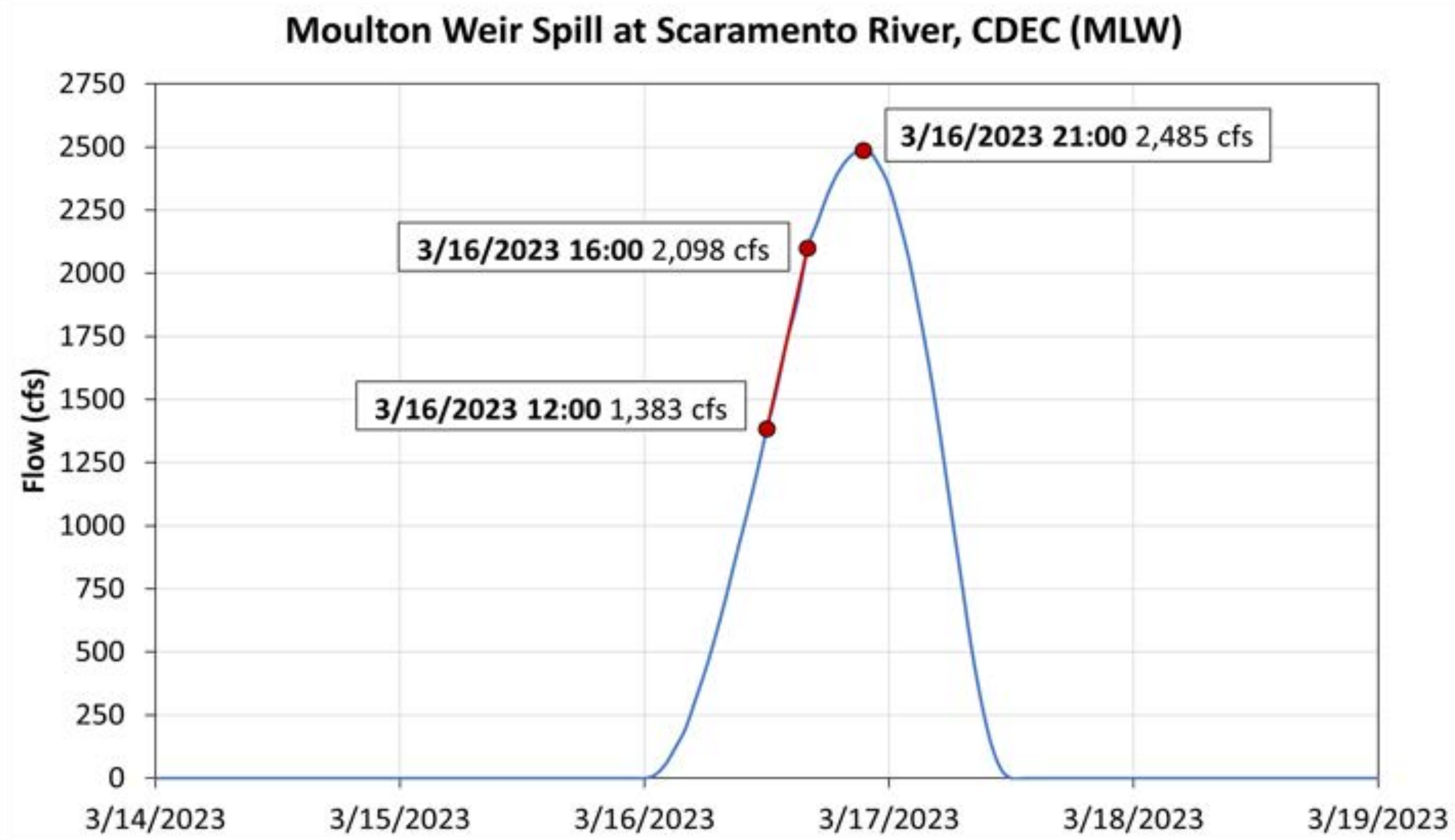


Notes:

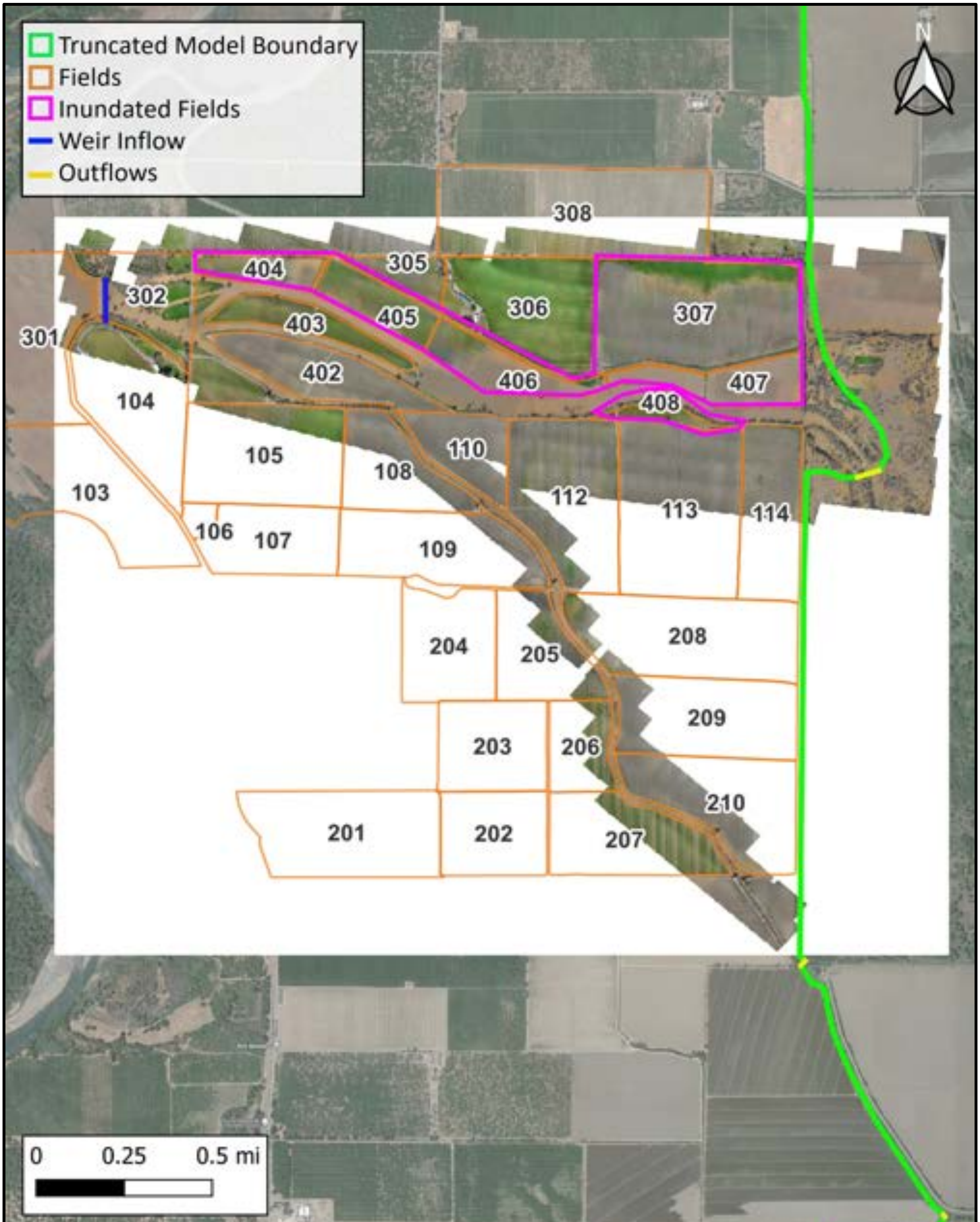
Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

Benden Farm Fields

Project No. 21−1028−1	Created By: KMK	Figure 18



Notes: Sacramento River at Moulton Weir, MLW, California Data Exchange Center (CDEC)	cbec eco engineering	*Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance* **Moulton Weir 3/16 − 18/2023 Spill Event Hydrogrpah**
		Project No. 21−1028−1 | **Created By: KMK** | **Figure 19**



Notes: Flooding indicated on indicated fields 307, 404, 405, 406, 407, and 408.

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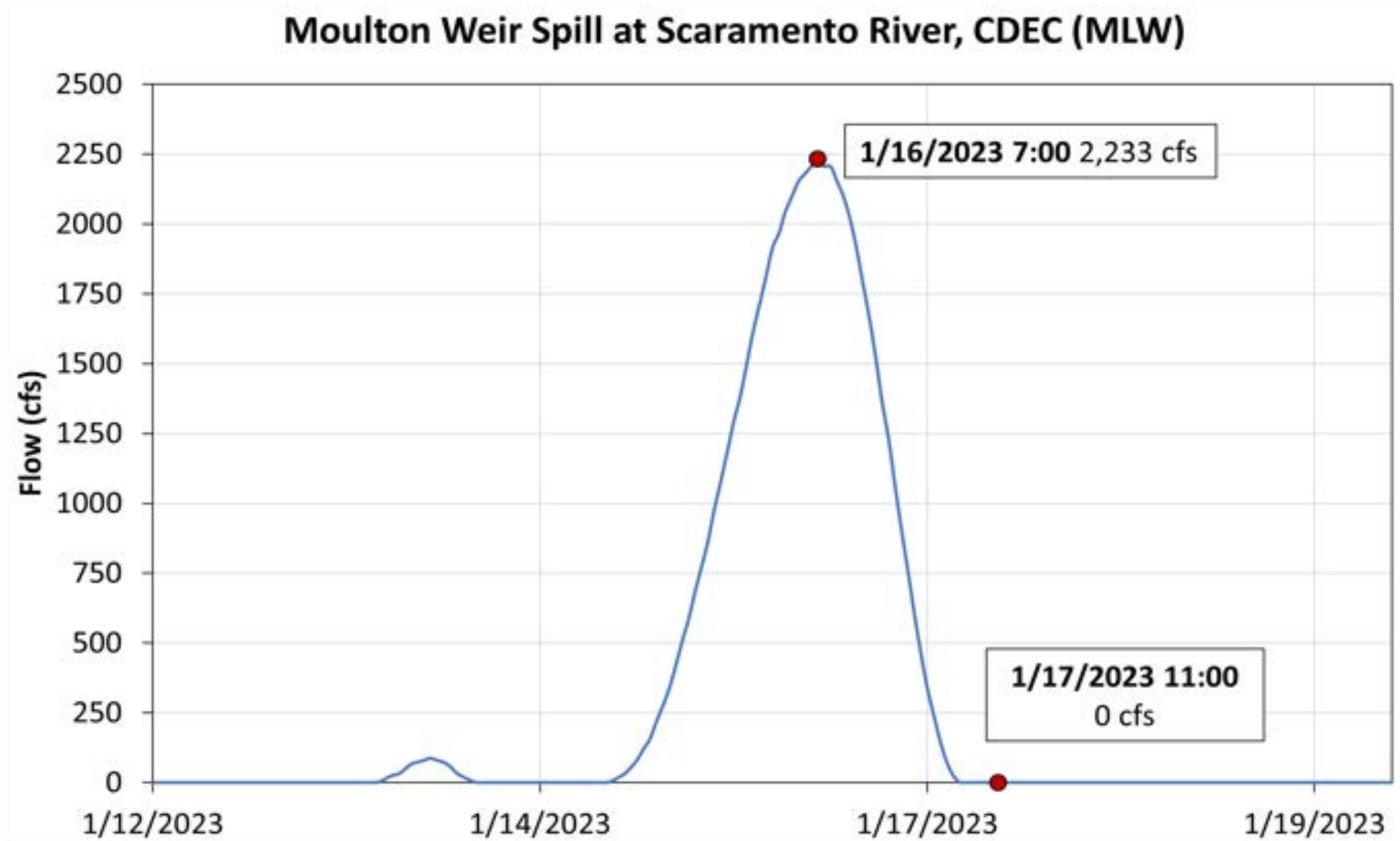
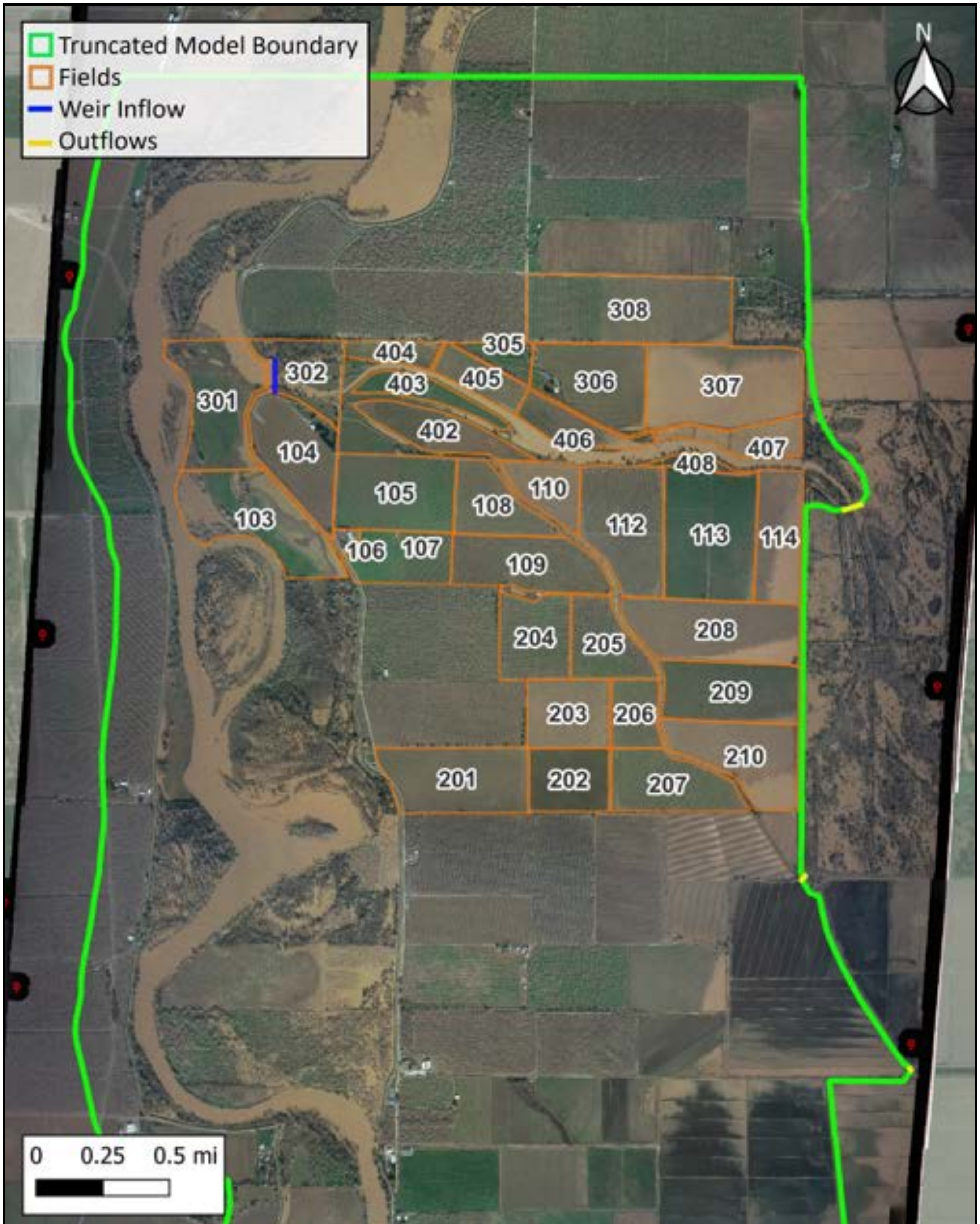
Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

Moulton Weir Spill Event 03/16/2023 − Drone Flight

Project No. 21−1028−1	Created By: KMK	Figure 20



Notes: Sacramento River at Moulton Weir, MLW, California Data Exchange Center (CDEC)	cbec eco engineering	*Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance* **Moulton Weir 1/14 − 18/2023 Spill Event Hydrograph**		
		Project No. 21−1028−1	**Created By: KMK**	**Figure 21**

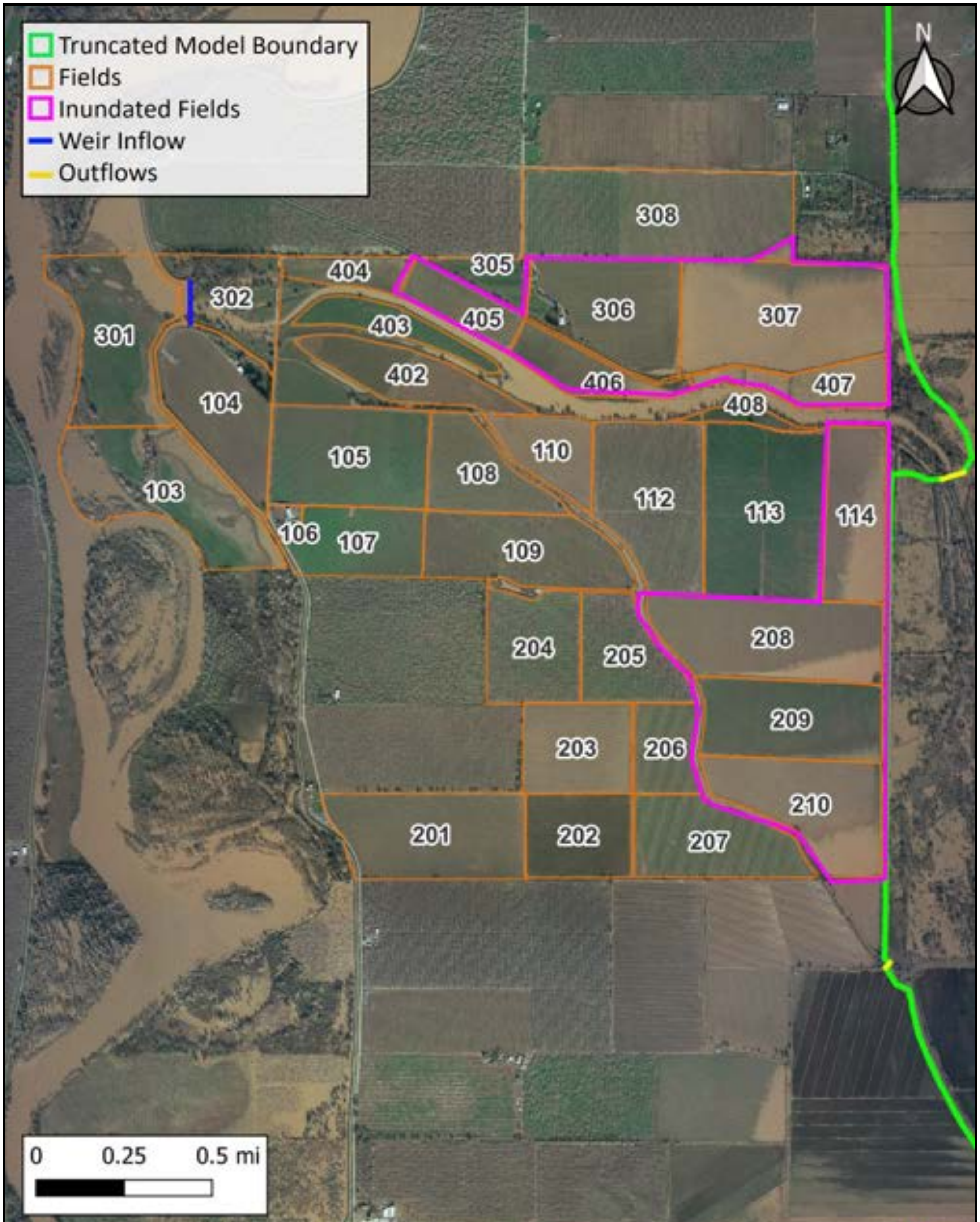


Notes: Flooding indicated on fields 114, 208, 209, 210, 306, 307, 308, 406, and 407.

Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

Moulton Weir Spill Event 01/17/2023 − Aerial Flight

Project No. 21−1028−1	Created By: KMK	Figure 22

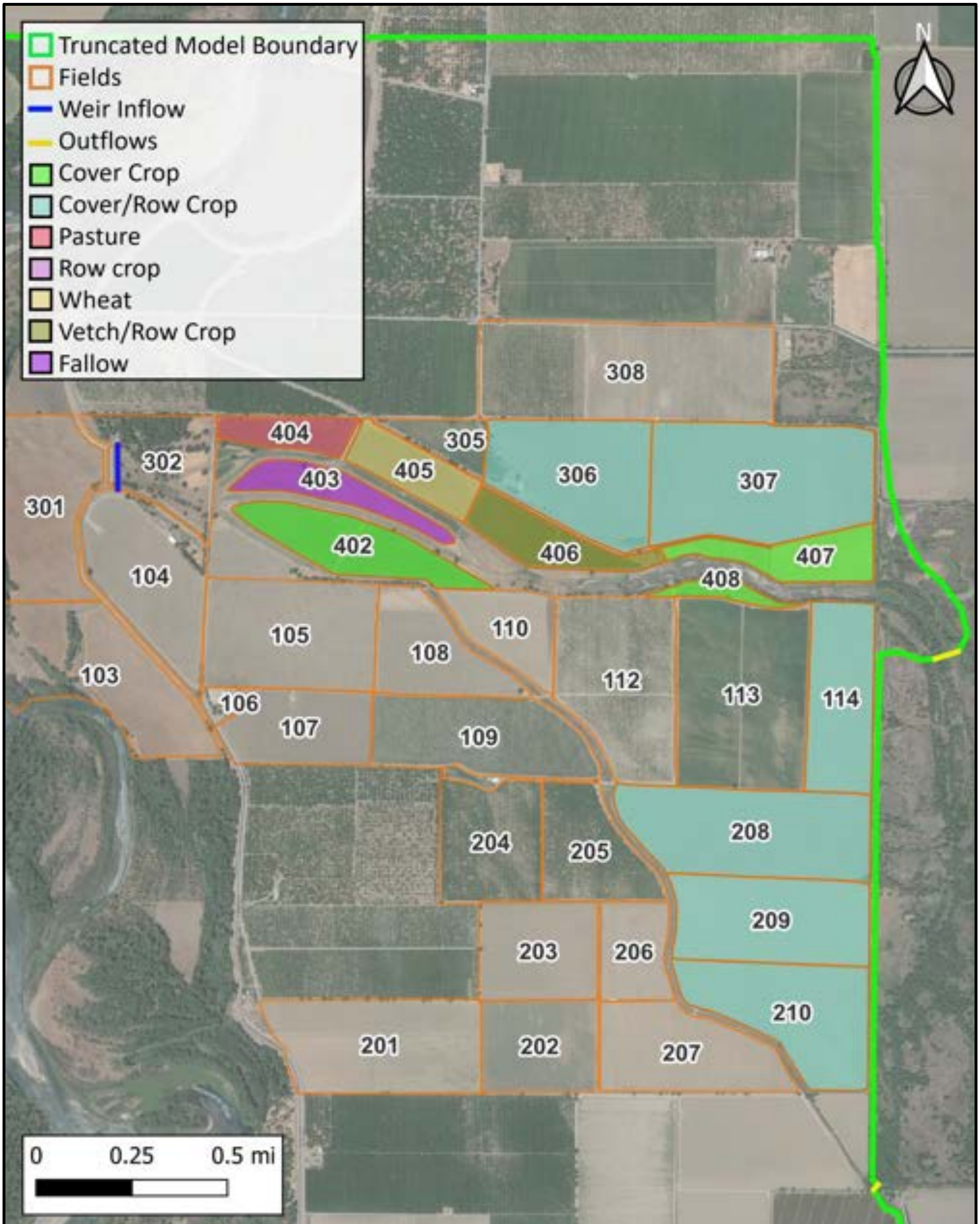


Notes:

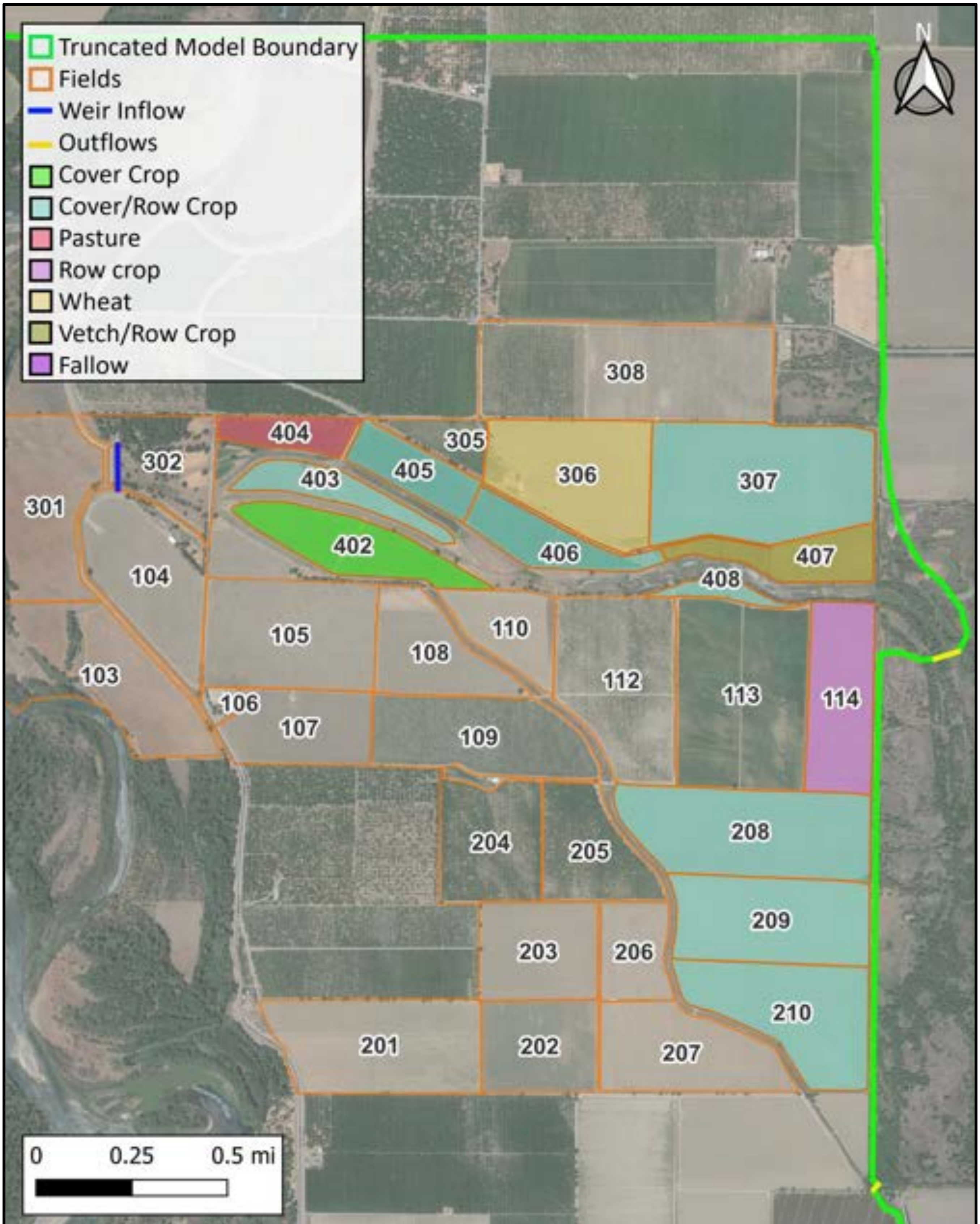
Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

Moulton Weir Spill Event 01/17/2023 − Aerial Flight Zoom In

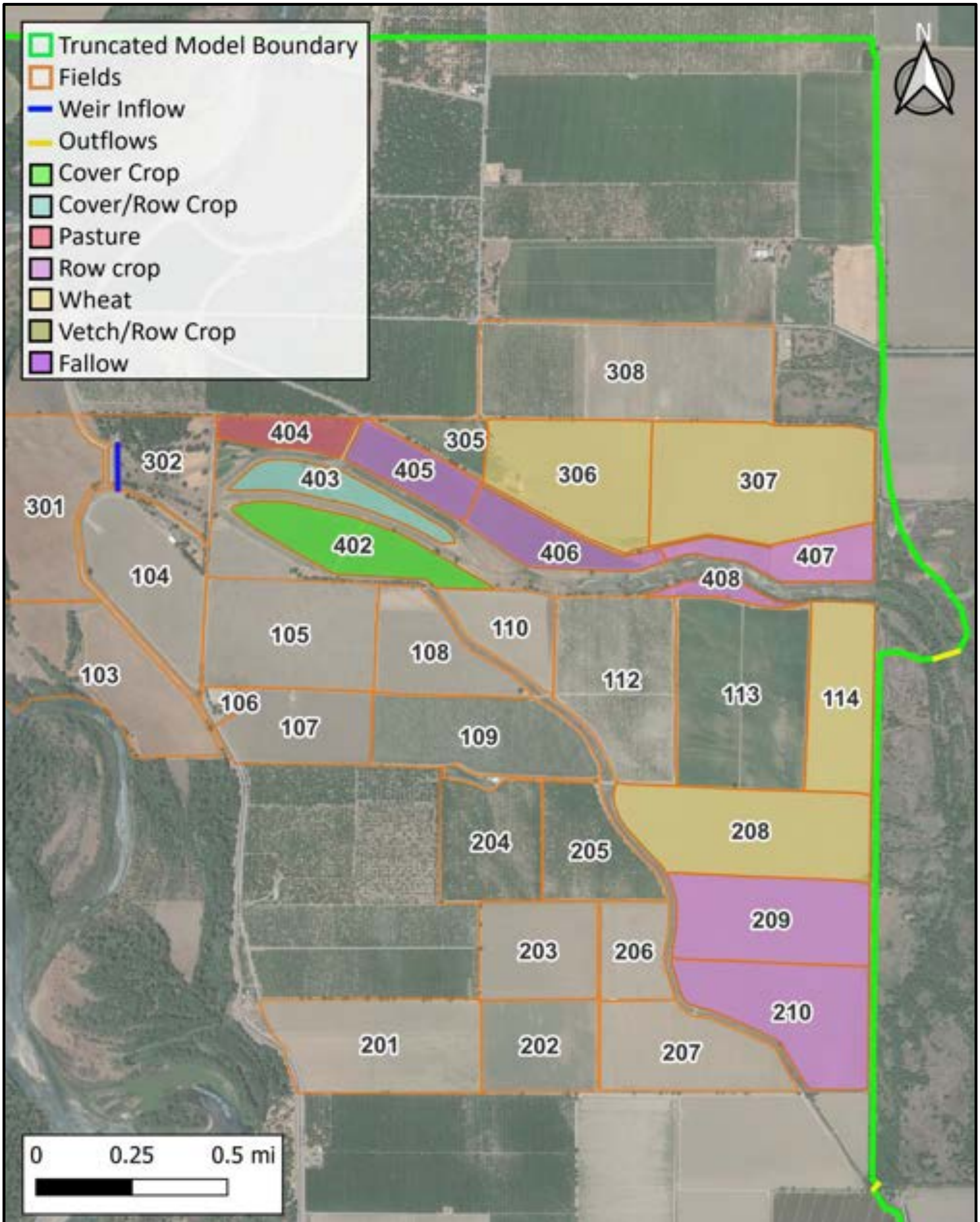
Project No. 21−1028−1	Created By: KMK	Figure 23



Notes:	cbec eco engineering	*Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance* **Benden Farms Crop Cover, 2021**		
		Project No. 21−1028−1	**Created By: KMK**	**Figure 24**



Notes:	cbec eco engineering	*Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance* **Benden Farms Crop Cover, 2022**		
		Project No. 21−1028−1	**Created By: KMK**	**Figure 25**

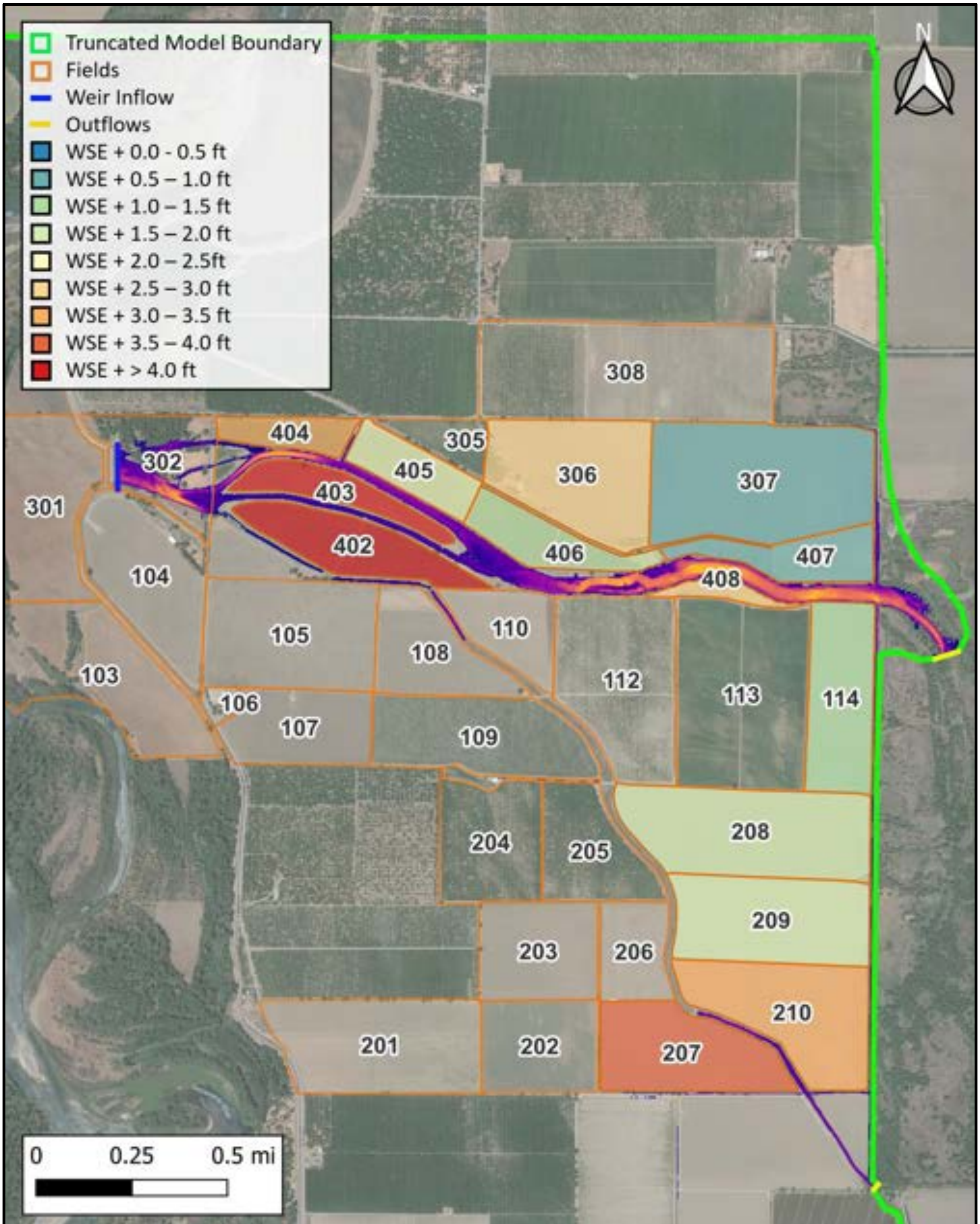


Notes:

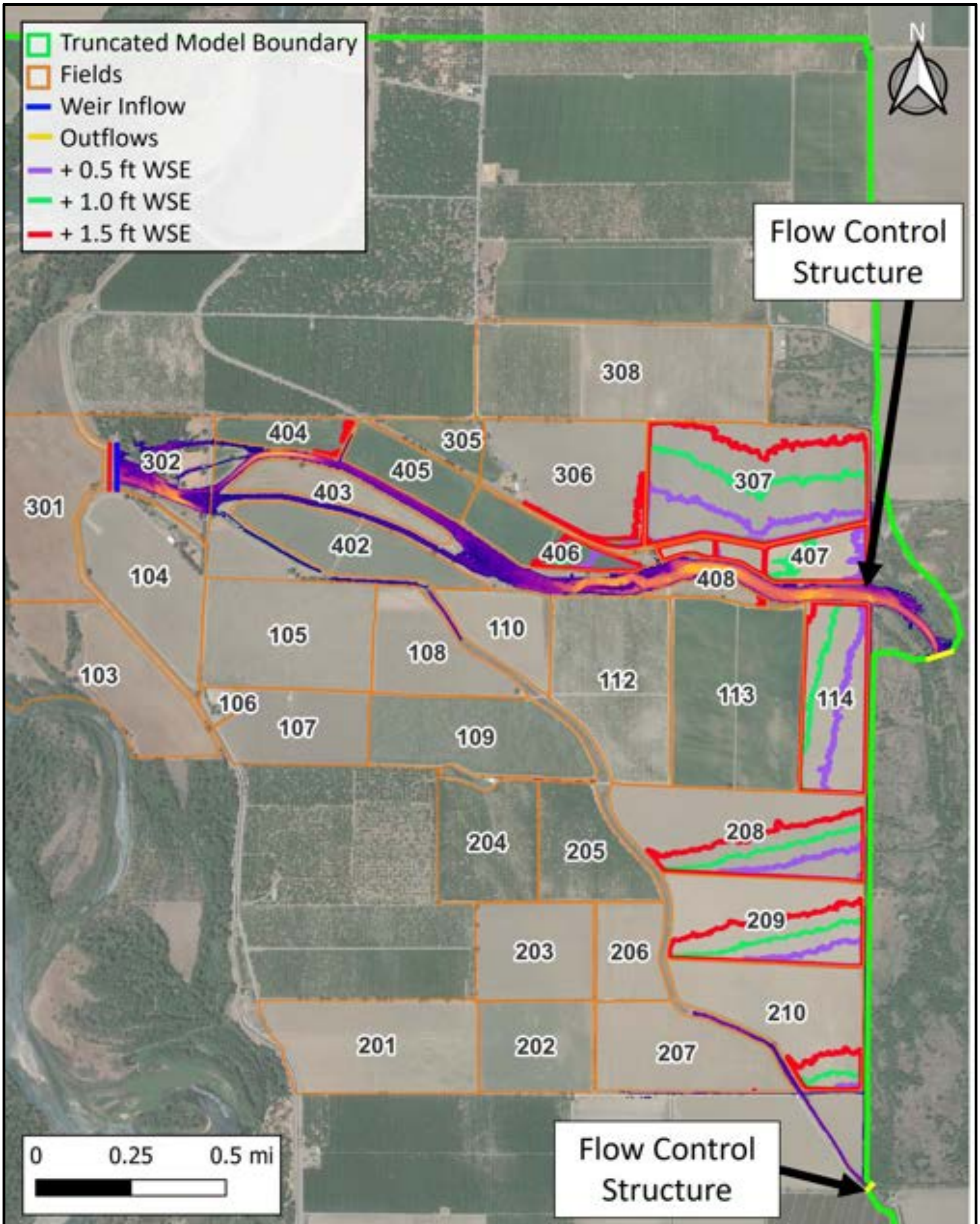
Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

Benden Farms Crop Cover, 2023

Project No. 21−1028−1 | **Created By: KMK** | **Figure 26**



Notes: WSE – Water Surface Elevation. Outlet WSE derived from 1K cfs Run	cbec eco engineering	*Landscape Scale Multi–Benefit Floodplain Feasibility Study – Benden Farms Technical Assistance* **Field Mean Elevation Above Outlet WSE**		
		Project No. 21–1028–1	**Created By: KMK**	**Figure 27**

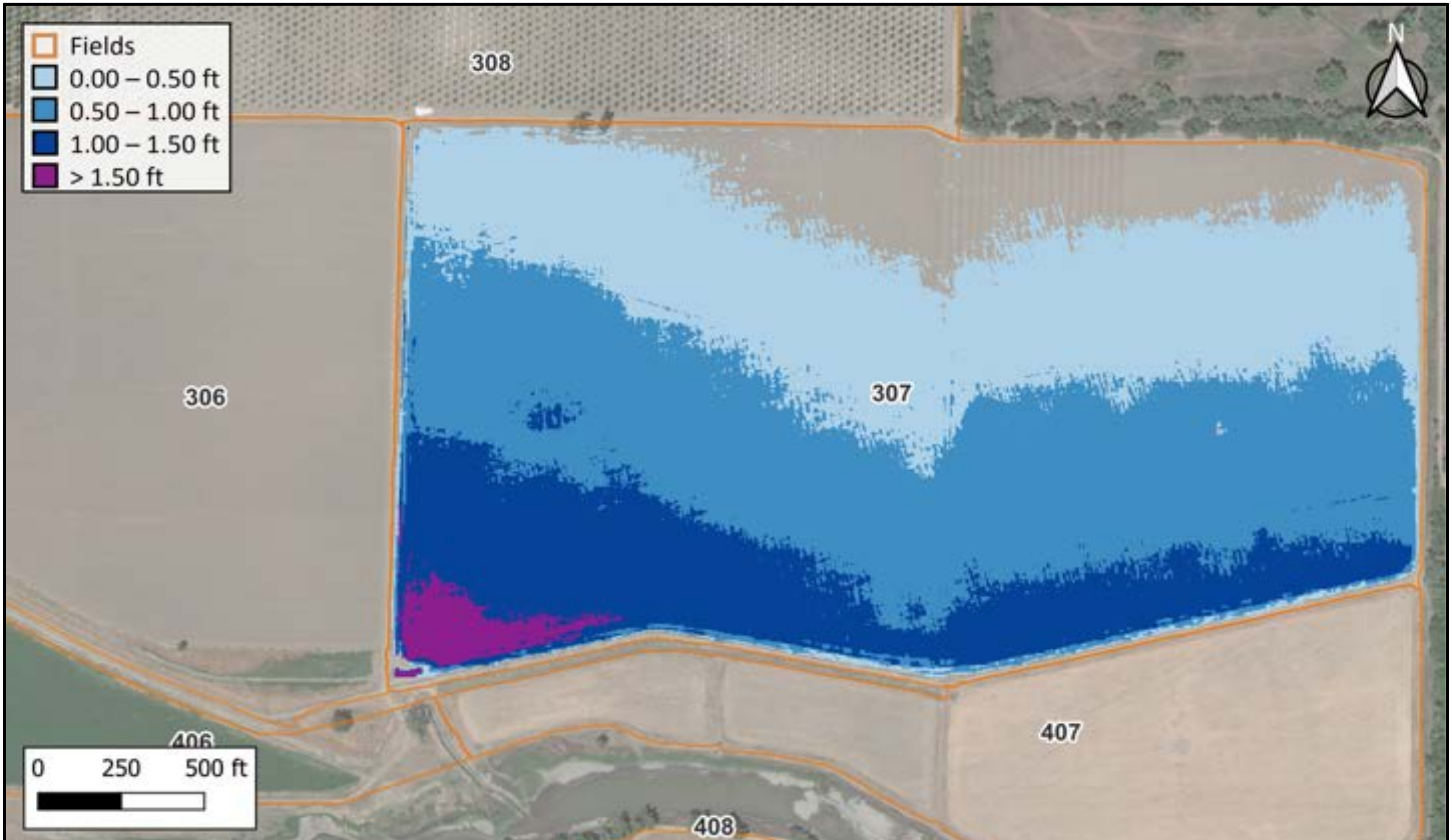


Notes: Estimated habitat derived from incrimental increases (+0.5 ft) to outlet Water Surface elevation (WSE) from 1K cfs run.

Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

Estimated Overbank Field Habitat

Project No. 21−1028−1	**Created By: KMK**	**Figure 28**



Notes: Field inundation dervied from outlet Water Surface Elevation (WSE) + 1.5 ft from 1K cfs run.

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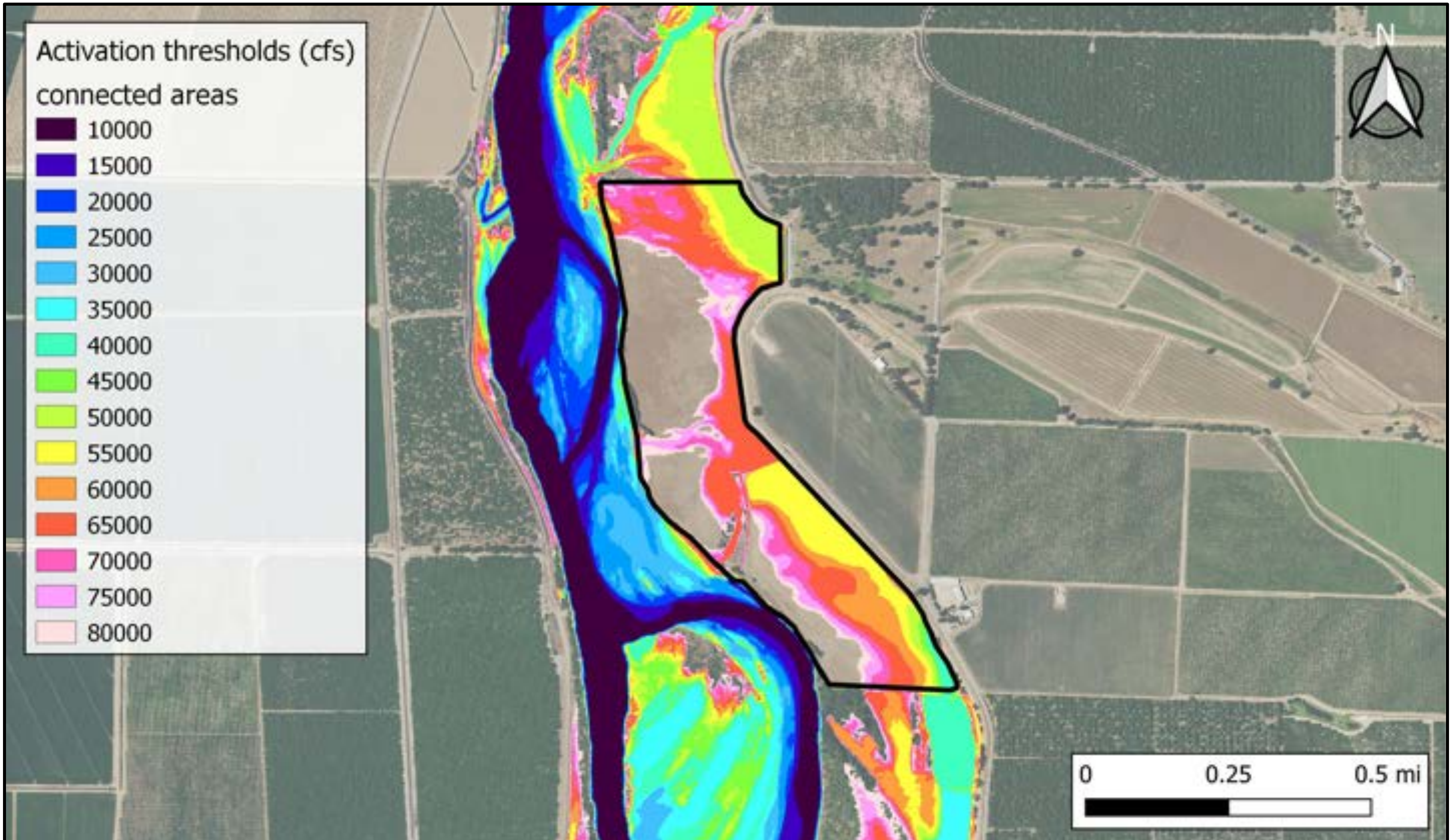
Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

Field 307 Inundation Map

Project No. 21−1028−1	Created By: KMK	Figure 29



Notes: 1D hydrodynamic model results derived from the regional Butte Basin Model. 1D model utilizes cross sections surveyed in 2010 via single beam survey with an accuracy of +/−3−feet to +/−6−feet horizontally and +/−0.5−feet to +/−1.0−feet vertically depending on the depth of water. EcoFIP results were overlayed on 2018 USGS 3 DEP LiDAR surface for the Sacramento River.

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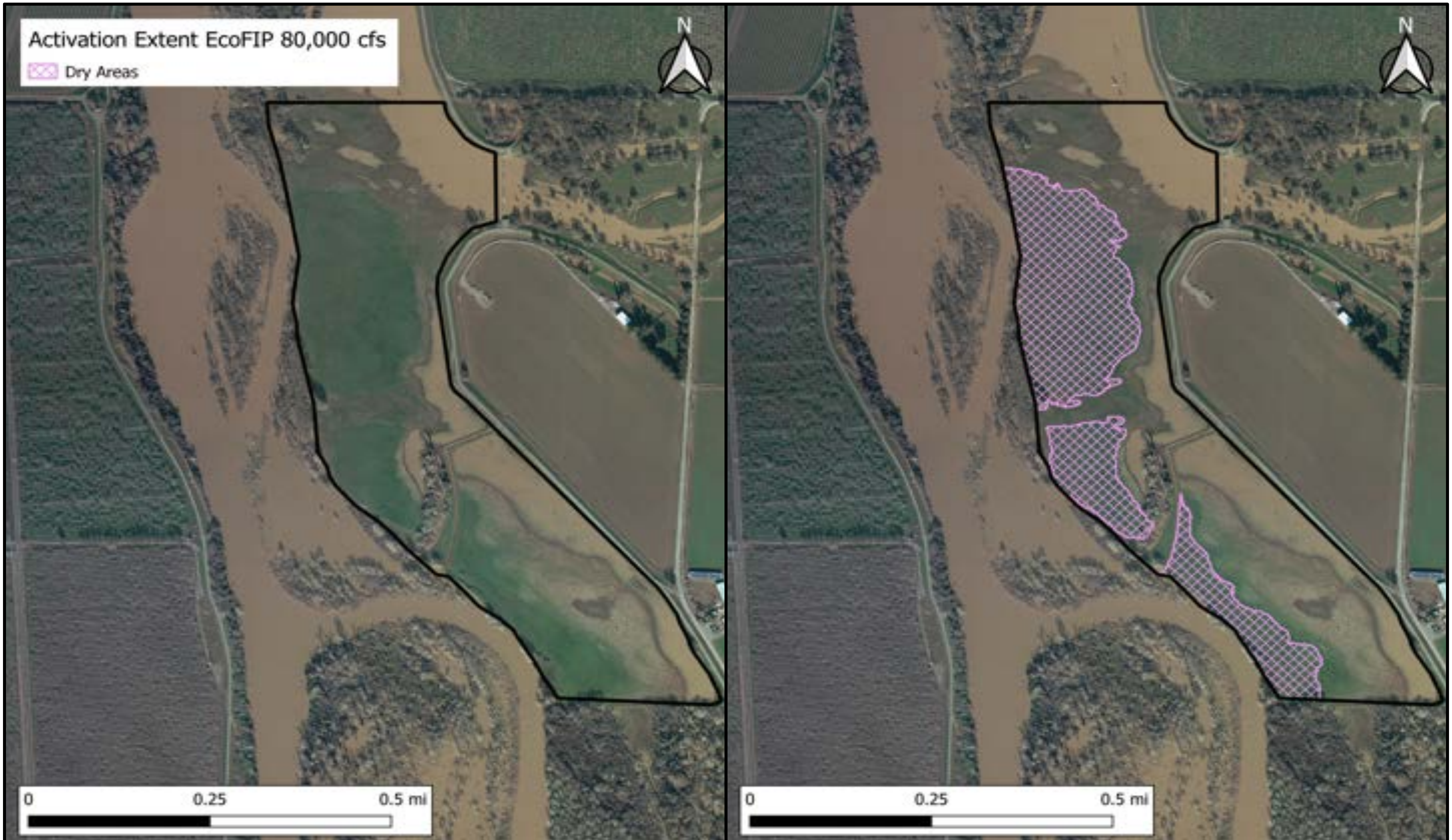
Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

Sacramento River In Corridor EcoFIP Flow Activation

Project No. 21−1028−1 | **Created By: KMK** | **Figure 30**



Notes: EcoFIP 80,000 cfs activation flow contour comapred to flood extent from 1/14 − 18/2023 flood event(Max flow = 81,636 cfs , Sacramento River at Ord Ferry – Main Channel Gage (ORD), California Data Exchange Center (CDEC)) . Flood extent indicated by brown discoloration on fields.

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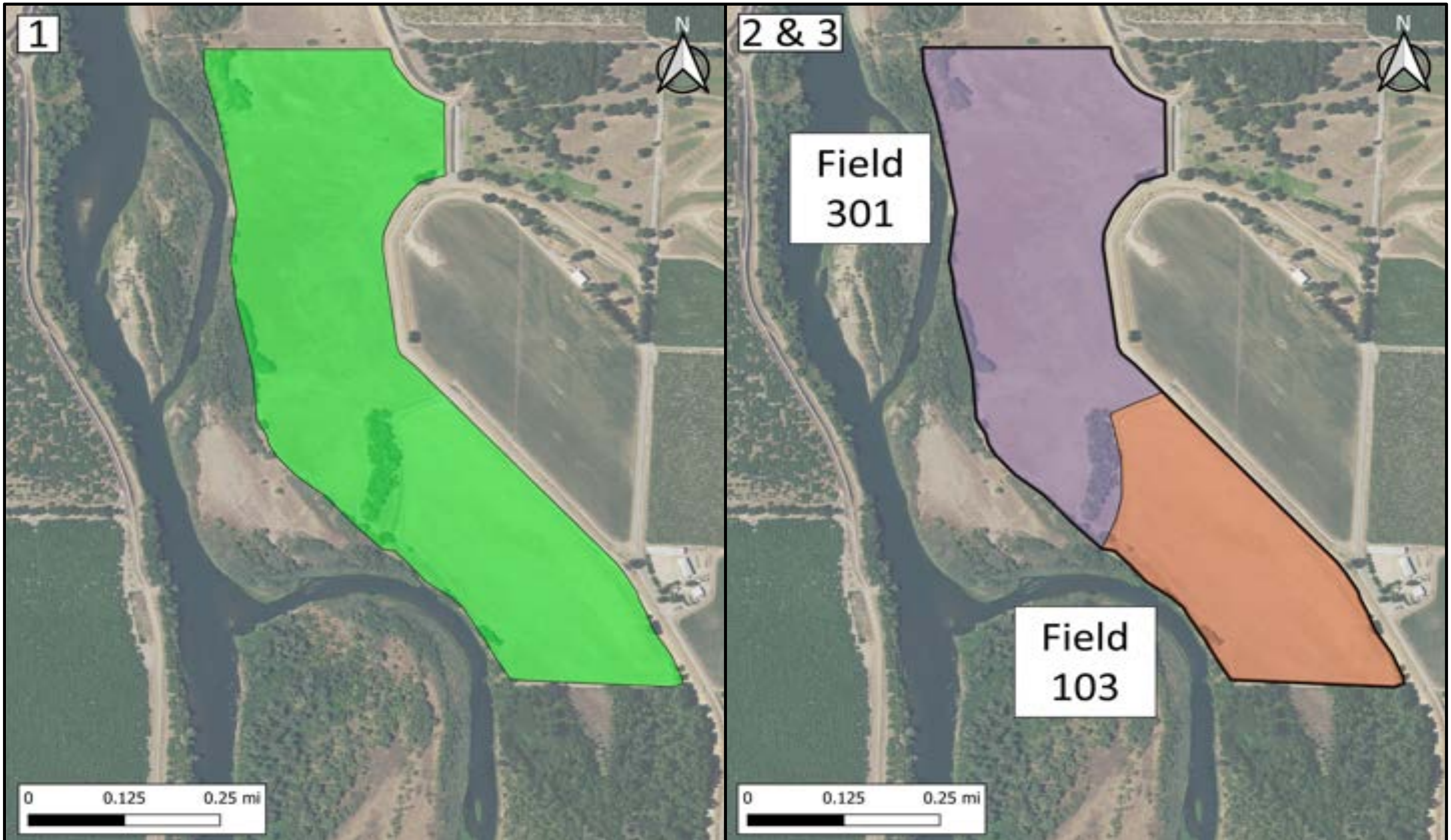
Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

EcoFIP Flow Activation Comparison, 1/14 − 18/2023 Flood Event

Project No. 21−1028−1	**Created By: KMK**	**Figure 31**



Notes:

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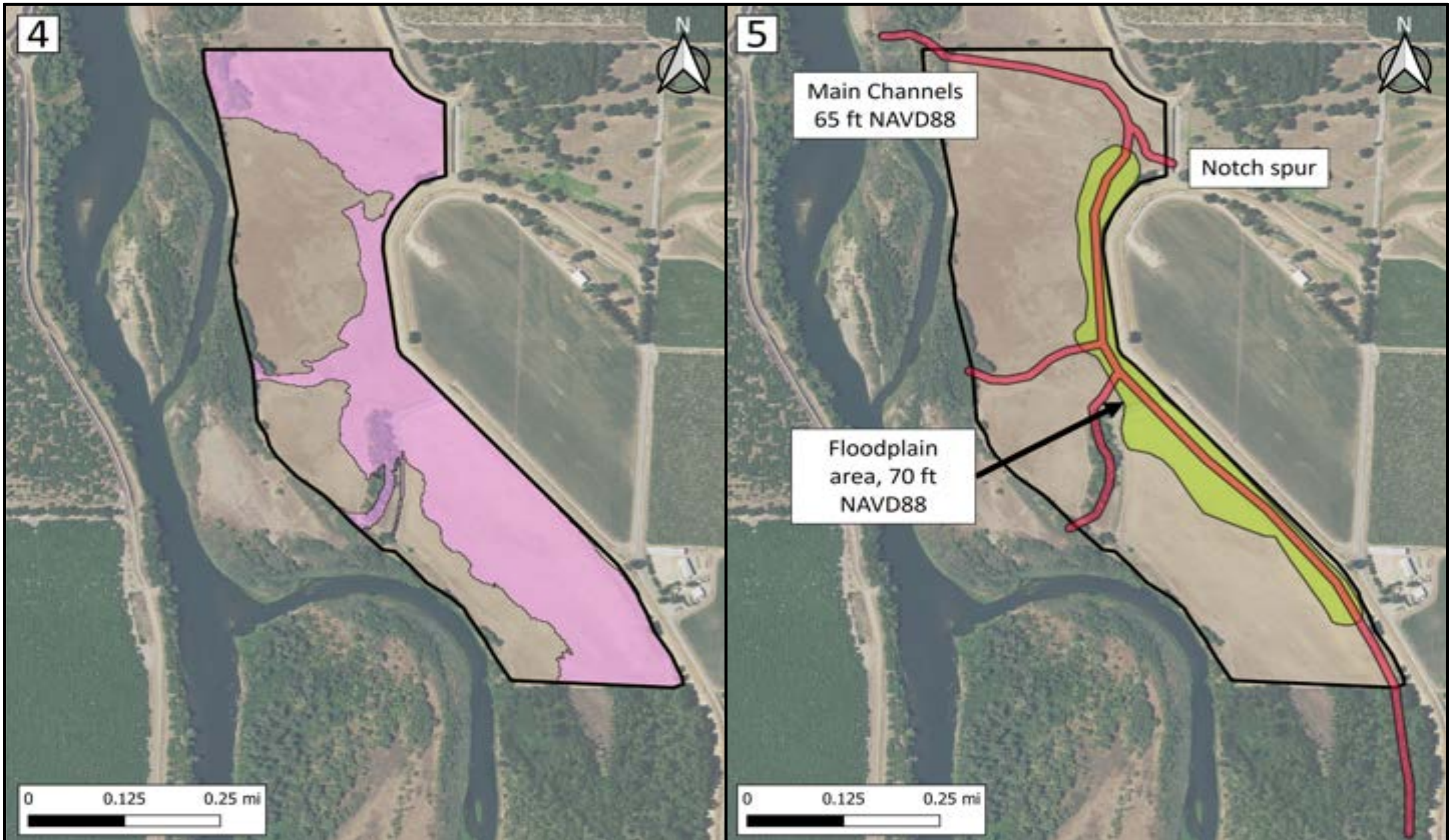
Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

In Corridor Habitat Enhancement Concepts 1,2, & 3

Project No. 21−1028−1	**Created By: KMK**	**Figure 32**

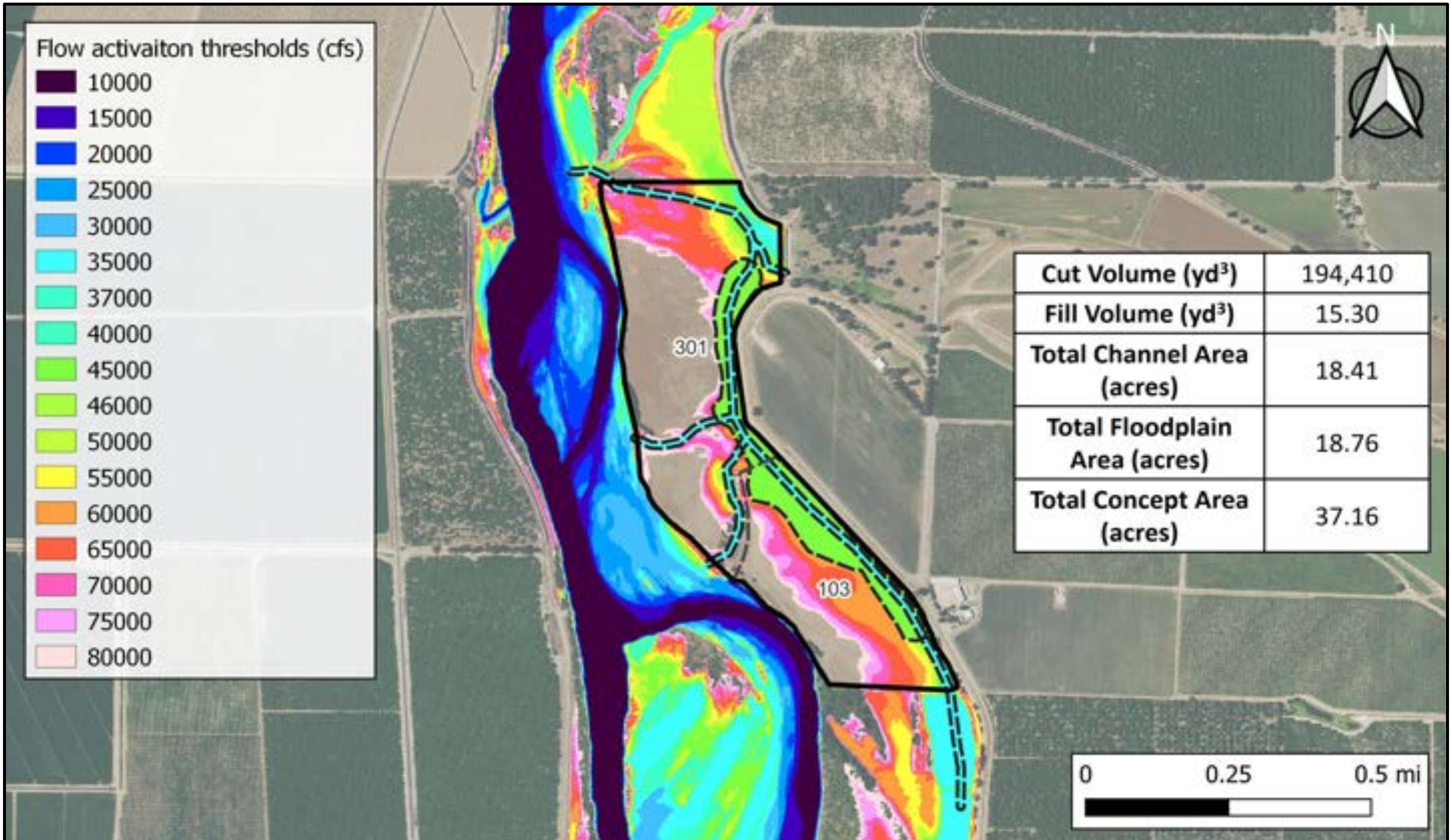


Notes:

Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

In Corridor Habitat Enhancement Concepts 4 & 5

Project No. 21−1028−1	**Created By: KMK**	**Figure 33**



Cut Volume (yd³)	194,410
Fill Volume (yd³)	15.30
Total Channel Area (acres)	18.41
Total Floodplain Area (acres)	18.76
Total Concept Area (acres)	37.16

Notes:

Landscape Scale Multi−Benefit Floodplain Feasibility Study − Benden Farms Technical Assistance

Prelimianry EcoFIP Results − In Corridor Habitat Enhancement Concept 5

Project No. 21−1028−1	**Created By: KMK**	**Figure 34**