GEOTECHNICAL & ENGINEERING REPORT

OLNEY CREEK LEVEE EVALUATION PROJECT
CITY OF REDDING, CALIFORNIA

Prepared For:

City of Redding Department of Public Works

PHI

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ENGINEERS • PLANNERS

CGI TECHNICAL SERVICES INC.

CGI TECHNICAL SERVICES INC.

June 21, 2017
CGI: 14-1128.94

Mr. Derick Beard
Assistant Engineer
CITY OF REDDING
Public Works Department, Engineering
777 Cypress Avenue
Redding, California 96001

Subject: **Geotechnical & Feasibility Report**
Olney Creek Levee Evaluation Project
City of Redding, California

Dear Mr. Beard:

CGI Technical Services, Inc. (CGI), is pleased to submit this report to the City of Redding for the Olney Creek Levee Evaluation Project, located in Redding, California. This report is being submitted in accordance with the Agreement for Professional Services established between CGI and the City.

This report presents the results of a geotechnical engineering, hydrological, civil engineering, and feasibility study of the Olney Creek Levee system. The study was performed to identify deficiencies of the levee system, in accordance with U.S. Army Corps of Engineers (USACE) and Federal Emergency Management Agency (FEMA) standards, and to evaluate alternatives for bringing the levee system into compliance with those standards, where necessary, and associated planning-level estimates of costs to implement each of those alternatives.

We appreciate the opportunity to perform this study. If you have any questions pertaining to this report, or if we may be of further service, please contact us at (530) 244-6277 at your earliest convenience.

Regards,

CGI TECHNICAL SERVICES, INC.

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EXECUTIVE SUMMARY

This report presents the results of a geotechnical engineering, hydrological, civil engineering, and feasibility study of the Olney Creek Levee system located in the City of Redding, California. The study was performed to identify deficiencies of the levee system, in accordance with U.S. Army Corps of Engineers (USACE) and Federal Emergency Management Agency (FEMA) standards, and to evaluate alternatives for bringing the levee system into compliance with those standards, where necessary, and associated planning-level estimates of costs to implement each of those alternatives.

Hydrologic evaluations found that levee freeboard is generally adequate relative to 100-year flood elevations within Olney Creek, except near Girvan Road. North of Girvan Road, the freeboard may need to be elevated up to 8 inches for an approximately 460-foot long segment of the levee if the Girvan Road Bridge is not replaced (that bridge is programmed for replacement). In addition, the hydrologic study found insufficient upstream and downstream levee tie-ins, which are required by USACE for accreditation.

Geotechnical engineering evaluations of the levee system found few deficiencies. Those present included excessive vegetation on the levee, modifications of the landside levee slope and toe by landowners, minor erosion features, uncertainty regarding backfill around a sewer pipeline penetration, and significant creek bank scour in a gap area between levee segments that could cause a need to construct a levee in that area if the scour is not mitigated.

Based on the results of those evaluations, three primary alternatives were identified for the project:

- Sacramento Bridge;
- Levee Improvement; and
- Conveyance Improvement.

The "Sacramento Bridge" alternative provides for the replacement of the Sacramento Dr. Bridge at Olney Creek and no implementation of improvements to the existing levee, Olney Creek channel or floodplain. Which allows the levee system to remain out of accreditation. The "Levee Improvement" alternative improves the levee, including construction of appropriate upstream and downstream levee tie-ins, such that accreditation of the levee by FEMA and USACE is viable. The "Conveyance Improvement" alternative modifies the drainage channel adjacent to Olney Creek to increase its carrying capacity to render the levee obsolete, thus making USACE and FEMA accreditation moot.

The following table presents the options evaluated for each alternative identified for the study:

SUMMARY TABLE OF ALTERNATIVES			
Alternative	**Alternative Number**	**Description**	**Estimated Cost**
Sacramento Bridge	SB-1	Sacramento Bridge	$2.81 Million
	SB-2	Assist in obtaining Elevation Certifications	
Levee Improvement Alternative	LI-2	Realign levee to avoid landowner generated defects	$4.52 Million
	LI-3	Remove waterside slope vegetation	
	LI-4	Repair erosion	
	LI-5	Assess and mitigate (as necessary) sewer penetration backfill and settlement	
	LI-6	Stabilize creek bank in "Gap" area & construct tie-in wall/improvement	
	LI-7	Upstream tie-in at Sacramento Drive	
	LI-8	Downstream tie-in at Girvan Road	
	LI-9	Stabilize creek at locations at risk of significant bank erosion	
	LI-10	Interior area flood study	
	LI-11	Operation and Maintenance Manual	
	LI-12	Levee Report or LOMR application	
Conveyance Improvement Alternative	CI-1	Modify Olney Creek channel to increase conveyance, thus, rendering levee obsolete	$3.89 Million
	CI-2	Stabilize creek bank in "Gap" area and at other locations at risk of significant bank erosion	
	CI-3	Improve conveyance at Girvan Road	
	CI-4	FEMA Letter of Map Revision (LOMR)	

It is anticipated that there will be several environmental issues that will arise from implementation of these alternatives. We estimate that construction of the proposed Levee Improvement and Conveyance Improvement alternatives will require clearing of about 7.3 and 8.4 acres of land, respectively. To do so, environmental consultation, agency permitting, compliance with CEQA and NEPA regulations, and environmental mitigations will be required prior to, during, and following this alternative's construction.

A total of 12 properties will be impacted by both the Levee Improvement and Conveyance Improvement alternatives. The City has Open Space easements for parks, trails and floodplain for 5 and 7 of the parcels impacted by the Levee Improvement and Conveyance Improvements, respectively. Temporary construction easements on private properties will be required for both of those alternatives. Permanent easements will be required on two private properties for the Levee Improvement alternative.

Estimated costs for the construction of the Levee Improvement and Conveyance Improvement alternatives are estimated to be about $4.52-million and $3.89-million, respectively. Those costs do not include fees for replacement of Girvan Road and Sacramento Drive Bridges at Olney Creek. Long-term maintenance costs can be expected to range from about $18,000 per year for the conveyance improvement alternative to $30,000 per year for the levee improvement alternative with the potential for greater costs during

years of extreme flows.

The Sacramento Bridge alternative is estimated to have a cost of $2.81 million predominately related to the bridge replacement and assistance in gaining elevation certificates for impacted properties behind the levee. It is estimated that elevation certificates could reduce or eliminate the need for flood insurance for all but 127 to 152 properties out of the total 267 potentially impacted properties. The following table tabulates the impacted within the Sacramento Bridge Alternative.

NUMBERS OF IMPACTED PROPERTIES UNDER SACRAMENTO BRIDGE ALTERNATIVE

Milestone	Number of Impacted Properties	Percent of Reduction of Impacted Properties
USACE Initial Estimate	648	-
PHI Revised Estimate	307	53 %
With Sacramento Drive Bridge Constructed	267	59 %
Homes Eligible for Flood Insurance Rate Insurance Elimination with Elevation Certificate	77-95	71 % to 74 %
Properties Eligible for Reduced Flood Insurance with Elevation Certificate	25-32	-
Properties Estimated to Have to Pay Full Value for Flood Insurance Even with Elevation Certificate	127-152	-

Plate 2 - Summary Map, is a graphical representation of the impacted homes under the "Sacramento Bridge Alternative".

Fees for preparing elevation certificates are currently estimated to $650 if prepared for only one parcel, and $500 if multiple parcels are evaluated at one time. Annual flood insurance rates are estimated to range from $500 to $3,000 per household.

In order to remove properties that are no longer impacted by the 100-year floodplain as a result of the bridge project improvement, the issuance of Letter of Map Revision (LOMR) must be issued by FEMA. This process is initiated by the City through an application to FEMA following the completion of the bridge project.

1 INTRODUCTION

CGI Technical Services, Inc. (CGI), is pleased to present this report providing the results of studies performed for the Olney Creek Evaluation Project, located in the City of Redding, California. This study was performed for the City of Redding (City), for City Project Number 4630. CGI's partners in this study were Pacific Hydrology, Inc. (PHI), and Omni•Means, Ltd. (OmniMeans). The location of the project is shown on Plate 1 – Site Location Map.

The following sections present our understanding of the project, the purpose of this study, and the findings, conclusions, and recommendations of this study. Our services were performed in general conformance with our proposal dated May 8, 2014.

1.1 PROJECT UNDERSTANDING

The U.S. Army Corps of Engineers (USACE) has been evaluating levees throughout the country and cataloging those levees that they have identified as being deficient. Based on those evaluations, we understand that the Olney Creek Levee system has lost its accreditation by the USACE, initially placing 648 properties behind the levee within the 100-year flood plain. Through additional hydrologic studies performed by PHI on the levee system (PHI, 2010), we understand that the number of impacted properties was subsequently reduced to 307. Proposed construction of the Sacramento Drive Bridge will reduce the number of impacted properties to 267.

This study is to evaluate the stability and suitability of the levee to comply with FEMA and USACE requirements and, as needed, to assist the City by identifying alternatives for levee improvement that will bring the levee system into compliance with USACE and FEMA standards.

1.2 SCOPE OF SERVICES

Services performed for this study are in general compliance with the proposed scope of services presented in our May 8, 2014 proposal. Our scope of services included:

- Performance of geotechnical studies to evaluate the stability of the existing levee and to identify geotechnical deficiencies in the levee that do not meet current USACE standards. That study is presented in Appendix A – Geotechnical Studies, of this report;
- Evaluation of hydrologic data to identify freeboard deficiencies in the levee that do not meet current USACE standards. That study (PHI, 2010) is presented in Appendix B – Hydrologic Evaluations, of this report;
- Conception and constraint of alternatives for mitigating identified deficiencies;

- Meetings with project team members and the City to further constrain acceptable alternative measures;
- Performance of hydrologic evaluations for a conveyance modification alternative to constrain hydraulic needs from that alternative. That hydrologic study (PHI, 2015) is presented in Appendix B of this report;
- Preparation of conceptual plans denoting constrained alternatives evaluated during this study. Those plans are presented in Appendix C – Conceptual Plans, attached to this report;
- Performance of a feasibility study to evaluate planning-level costs associated with deficiency mitigation alternatives identified by this study. The results of that study are presented in Appendix D – Cost Estimates, attached to this report; and
- Preparation of this report documenting our findings, conclusions, and projected planning-level costs for bringing the levee into compliance with FEMA and USACE standards.

2 TECHNICAL EVALUATIONS

2.1 GEOTECHNICAL ENGINEERING

2.1.1 Study Overview

A geotechnical evaluation was performed along four cross sections established along the length of the levee. At each of the sections, three to four drill holes were advanced, soil samples taken, and laboratory testing performed. An additional three drill holes were advanced along the margin of Olney Creek at selected locations. Laboratory testing was performed on selected soil samples to help characterize selected engineering properties for use in analyses.

Geotechnical analyses were performed on the cross sections to evaluate the stability of the levee. Those analyses included slope stability, seepage, liquefaction, and settlement. In addition, detailed observations were made along the levee noting areas of vegetation, erosion, settlement, modification of the levee surface, penetrations, bioturbation, and conformance between initial construction drawings and actual field conditions.

2.1.2 Study Results

Geotechnical analyses performed on data collected during the study found few geotechnical conditions that fail to meet USACE standards (deficiencies). Stability, seepage, and settlement evaluations all indicate that the levee is stable in accordance with those standards, except where the levee has been modified, as discussed below. Liquefaction and seismically-induced settlement were estimated to have a potential to occur but are estimated to result in settlement that would not reduce freeboard to below USACE standards in the areas where these conditions might occur.

The geotechnical deficiencies noted during the geotechnical study are as follows:

- Extensive vegetative cover on the waterside and landside slopes and toes of the levee. These include dense thickets of trees, shrubs, brambles, and landscaped areas;
- Landowner modifications to the levee surface on portions of the landside levee slope, as shown on Plate 5 in the Geotechnical report (Appendix A);
- Settlement and unknown characteristics of a sewer line penetration of the levee at about Station 16+40;
- Significant creek bank erosion at the "Gap Area" between about Stations 25+25 and 32+80; and
- Minor surface erosion at local areas.

2.2 HYDROLOGIC

2.2.1 Overview of Studies

A flood study was performed for Olney Creek to estimate the effects of a 100-year storm on the existing levee and the neighborhood located east of the creek (PHI, 2010). That study is included in Appendix B and compared the flood elevations with the levee freeboard, evaluated the effects of a levee breach, and looked at the upstream and downstream levee tie-in considerations for the project

Hydrologic evaluations were later re-evaluated at Cross Sections Section 1875, 2285, 3705, and 5085 to assist the geotechnical evaluations (PHI, 2015a). In addition, a hydrologic evaluation of a conveyance improvement alternative (see Section 3.4 below) was performed to evaluate this alternative's viability and to assist with the Feasibility study. Those evaluations are presented in Appendix B of this report.

2.2.2 Study Results

The PHI (2010) study found that freeboard along the existing levee was adequate to meet minimum USACE standards. One area where the freeboard was in question was along the levee just upstream of Girvan Road, where the existing bridge could form an impingement and require an additional foot of freeboard. If that was the case, then the existing freeboard would be deficient by about 6 to 8 inches. This condition is likely moot because the Girvan Road Bridge is slated for replacement soon and should be designed to remove the threat of impingement.

In addition, the flood study (PHI, 2010) notes that the upstream and downstream tie-ins are lacking for the levee and are not in conformance with USACE requirements.

Hydrologic studies performed for the conveyance alternative (PHI, 2015b; see Section 3.4 below) found that this alternative can be used to make the existing levee system unnecessary, provided channel modifications are made at selected locations along the creek and modeling of a 100-year flood on Olney Creek would not be coincident with a 100-year flood on the controlled flows of the Sacramento River. See Appendix B for this study.

3 ALTERNATIVES IDENTIFIED & EVALUATED

3.1 GENERAL

Based on the results of the geotechnical and hydrologic evaluations, alternatives for the levee system were evaluated. After discussions with team members and the City, three alternatives were identified for the levee system, as follows:

- Sacramento Bridge;
- Levee Improvement; and
- Conveyance Improvement.

Tables presenting the three alternatives are attached to this report. Each of those alternatives is discussed in greater detail below. Plans showing conceptual levee and conveyance improvements associated with the alternatives are presented in Appendix C. It should be noted that some combinations of the alternatives might be viable; however, none of those combinations are considered to be viable as stand-alone alternatives.

3.2 SACRAMENTO BRIDGE ALTERNATIVE

The Sacramento Bridge alternative provides for the replacement of the Sacramento Driver. Bridge at Olney Creek and takes no action to bring the levee into compliance with USACE requirements and allows the current requirements on properties behind the uncertified levee to continue, as noted on Table 1 – Sacramento Bridge Alternative. This alternative provides assistance, if so elected by the City, to obtain elevation certificates for those remaining structures located within the floodplain. An elevation certificate will document a structure's elevation and its relationship to the 100-year flood elevation. Fees for preparing elevation certificates are currently estimated to $650 if prepared for only one parcel, and $500 if multiple parcels are evaluated at one time. Based on the elevation certificate, some properties will be eligible for a Letter of Map Change through FEMA, which will remove their structure from the floodplain and may be relieved from having to purchase flood insurance. Annual flood insurance rates are estimated to range from $500 to $3,000 per household. This alternative provides engineering support for those properties that will ultimately be eligible.

The USACE's original estimate of impacted properties was 648. That was reduced to 307 by further studies performed for the City by PHI. A reduction of another 40 impacted properties, reduced to 267, will occur due to construction of the Sacramento Drive Bridge. An estimated 77 to 95 properties could have their flood insurance eliminated with elevation certificates. An estimated 25 to 32 properties are anticipated to be eligible for a reduced insurance rate based on elevation certificates. In total, an estimated 127-152 impacted properties (167 to 192 if the bridge is not constructed or delayed) will be subject to flood insurance without reduced rates) even with an elevation certificate. The impacted number of properties within the Sacramento Bridge Alternative are noted in the table below.

NUMBERS OF IMPACTED PROPERTIES UNDER SACRAMENTO BRIDGE ALTERNATIVE		
Milestone	**Number of Impacted Properties**	**Percent of Reduction of Impacted Properties**
USACE Initial Estimate	648	-
PHI Revised Estimate	307	53 %
Sacramento Drive Bridge Constructed	267	59 %
Homes Eligible for Flood Insurance Rate Insurance Elimination with Elevation Certificate	77-95	71 % to 74 %
Properties Eligible for Reduced Flood Insurance with Elevation Certificate	25-32	-
Properties Estimated to Have to Pay Full Value for Flood Insurance Even with Elevation Certificate	127-152	-

Plate 2 - Summary Map, is a graphical representation of the impacted homes under the "Sacramento Bridge Alternative".

In order to remove properties that are no longer impacted by the 100-year floodplain as a result of the bridge project improvement, the issuance of Letter of Map Revision (LOMR) must be issued by FEMA. This process is initiated by the City through an application to FEMA following the completion of the bridge project.

3.3 LEVEE IMPROVEMENT ALTERNATIVE

The Levee Improvement alternative implements measures to mitigate deficiencies and to bring the levee into compliance with USACE requirements. It includes the following elements, also noted in Table 2 - Levee Improvement Alternative:

- Realign the levee in selected locations (see Appendix C) in accordance with Plate 8 of the Geotechnical Study (Appendix A);
- Remove vegetation along waterside slopes;
- Repair areas eroded along the levee;
- Evaluate and improve (if necessary) backfill at penetrations;
- Stabilize bank erosion in the "Gap Area" and at other locations at risk of significant bank erosion;
- Construct upstream and downstream levee tie-ins;
- Perform a new interior area flood study;
- Creation of a levee maintenance association and preparation of an operations and maintenance manual; and
- Preparation of a Letter of Map Revision (LOMR) for submittal to FEMA.

The primary focus of this alternative is to realign the levee to avoid areas modified by

landowners, to construct the currently nonexistent upstream and downstream tie-ins, and to stabilize creek banks at selected locations. Specific improvements associated with this alternative are shown in Appendix C and include the following:

- Establishment of a downstream levee tie-in south of Girvan Road in Cascade Park. This tie-in is needed to comply with FEMA and USACE standards (Drawing L-1);
- Relocation of most of the existing levee in a westerly direction;
- Construction of creek bank stabilization measures at three locations in the vicinity of the Gap area (Drawing L-2);
- Repair of erosion and settlement sites (Drawing L-3);
- Reconstruction of the existing floodwall to acceptable standards (Drawing L-4); and
- Establishment of the upstream levee tie-in north of Sacramento Drive to comply with FEMA and USACE standards (Drawing L-4).

It is anticipated that there will be several environmental issues that will arise from implementation of this alternative. We estimate that construction of the proposed improvements will require clearing of about 7.3 acres of land. To do so, environmental consultation, agency permitting, compliance with California Environmental Quality Act (CEQA) and National Environmental Protection Act (NEPA) regulations, and environmental mitigations will be required prior to, during, and following this alternative's construction. Total estimated fees for environmental items are estimated at $1,020,000, as noted in Appendix D.

Based on our evaluations, a total of 12 properties would have some grading/alteration performed within their property boundaries. Those properties are shown in Appendices C and E which have the following Assessor Parcel Numbers (APNs):

APNs of Impacted Properties
050-500-020
050-600-018
050-600-019
050-600-020
050-600-044
050-600-045
050-600-051
050-640-026
050-640-027
050-370-023
050-540-016
050-330-012
Red APNs are private properties. Black APNs are Open Space easements dedicated to City.

The City has dedicated Open Space easements for 5 of the 12 impacted properties. Aside from the Open Space parcels, an estimated seven private properties could be impacted by this alternative. Most of those properties will have creek bank stabilization measures constructed. One property will have the existing flood wall reconstructed to appropriate standards. One property will have the upstream levee tie-in constructed.

Associated with impacts to properties, both permanent easements and temporary construction easements will be needed to implement this alternative. Those anticipated easement locations are shown in Appendix C. Permanent easements are anticipated at APN 050-540-016 for replacement of the existing floodwall at that site and at APN 050-330-012 to establish the upstream levee tie-in. Temporary construction easements are anticipated for the following APNs: 050-600-018, -019, and -020; 050-640-026; and 050-330-012. Fees for right-of-way acquisition and support are estimated at $207,150, as noted in Appendix D.

To comply with FEMA and USACE requirements, an operations and maintenance manual will need to be established for the levee system. That manual will specify the annual and long-term maintenance requirements for upkeep of the levee. At a minimum, that maintenance will include vegetation control, reduction in bioturbation (rodent burrows), observation following peak storms to identify areas of scour and/or erosion on the levee, observation of flap-gates at penetrations to confirm they are operational, etc. It is unclear who will bear responsibility for maintenance operations. Costs for Long-term maintenance are estimated to be about $30,000 per year for this alternative, as noted in Appendix D.

Estimated costs for the construction of this alternative are estimated to be about $4,520,000, as noted in Appendix D. These costs do not include fees for replacement of Girvan Road and Sacramento Drive Bridges at Olney Creek, or long-term maintenance costs.

3.4 CONVEYANCE IMPROVEMENT ALTERNATIVE

The Conveyance Improvement alternative modifies the drainage channel adjacent to Olney Creek to increase its carrying capacity to render the levee obsolete and moot. In addition this alternative assumes, with reasonable confidence, approval from FEMA to use Sacramento River flows less than the 100-yr flow as a downstream starting condition in the Olney Creek backwater model. Thus, the levee would not be needed and accreditation would not be necessary. It includes the following elements, also noted in Table 3 - Conveyance Improvement Alternative:

- Modification of the channel to increase conveyance;
- Stabilizing bank erosion in the "Gap Area" and at other locations at risk of significant bank erosion;
- Improve conveyance at Girvan Road; and
- Preparation of a Letter of Map Revision for submittal to FEMA.

Specific construction tasks for this alternative include:

- Construction of creek bank stabilization measures at three locations in the vicinity of the Gap area (Drawing L-2); and
- Grading and removal of soils from selected locations along the Olney Creek channel and/or floodplain to increase the creek's carrying capacity.

It is anticipated that there will be several environmental issues that will arise from implementation of this alternative. We estimate that construction of the proposed improvements will require clearing of about 8.4 acres of land. To do so, environmental consultation, agency permitting, compliance with CEQA and NEPA regulations, and environmental mitigations will be required prior to, during, and following this alternative's construction. Total estimated fees for environmental items are estimated at $1,570,000, as noted in Appendix D.

Based on our evaluations, a total of 12 properties would have some grading/alteration performed within their property boundaries. Those properties are shown in Appendix C and E which have the following Assessor Parcel Numbers (APNs):

APNs of Impacted Properties
050-500-020
050-500-029
050-600-018
050-600-019
050-600-020
050-600-044
050-600-045
050-600-051
050-640-026
050-640-027
050-370-023
050-370-041
Red APNs are private properties. Black APNs are Open Space easements dedicated to City.

The City has dedicated Open Space easements for 7 of the 12 impacted properties. Aside from the Open Space parcels, an estimated five private properties could be impacted by this alternative. Those private properties will have creek bank stabilization measures constructed.

Acquisition of permanent construction easements are not anticipated for this alternative. Temporary construction easements are anticipated to be needed for five properties located at

APNs 050-600-018, -019, -020, and -044; and 050-640-026. These easements are for clearing and bank stabilization efforts. Fees for right-of-way acquisition and support are estimated at $43,500, as noted in Appendix D.

An operations and maintenance manual will not be needed for this alternative but a maintenance plan should be developed and implemented. That plan should address vegetation management within the channel to maintain its carrying capacity and to address erosion following peak flows. It is unclear who will bear responsibility for maintenance operations. Costs for Long-term maintenance are estimated to be approximately $18,000 per year for this alternative, as noted in Appendix D.

Estimated costs for the construction of this alternative are estimated to be about $3,890,000, as noted in Appendix D. These costs do not include fees for replacement of Girvan Road and Sacramento Drive Bridges at Olney Creek or long-term maintenance costs.

4 DISCUSSION

Along with the projected economic impacts of each alternative, impacts associated with environmental and cultural conditions exist for the Levee and Conveyance Improvement alternatives. The project will require approval under the California Environmental Quality Act (CEQA) and Federal National Environmental Policy Act (NEPA). The City will be the lead agency. On the assumption of strong community support for the project, the CEQA document is anticipated to be a Mitigated Negative Declaration (MND). In support of the MND, the following technical studies are anticipated:

- Cultural Resources Inventory Report;
- Tree Survey;
- Jurisdictional Waters Delineation;
- Updated Hydrology Study/Report;
- Updated Geotechnical Engineering Study/Report;
- Biological Study Report; and
- Biological Assessment.

The following resource agency permits are anticipated:

1. Clean Water Act Section 404 - ACOE Letter of Permission or Individual Permit.
   A. Pursuant to the Endangered Species Act, the ACOE will need to consult with US NOAA NMFS to secure a Biological Opinion on the effects of dredged and fill materials on salmon.
   B. Pursuant to the Endangered Species Act, the ACOE will need to consult with the USFWS to secure concurrence regarding effects to the Valley Elderberry Longhorn Beetle.
2. Clean Water Act Section 401 - RWQCB Water Quality Certification.
3. Fish and Game Code Section 1600 - CDFW Streambed Alteration Agreement.

5 CONCLUSION

Two alternatives were identified that can bring the Olney Creek Levee system into compliance with USACE requirements and allow accreditation (under one alternative) or the lack of need of accreditation to remove homes east of the creek from the Olney Creek flood zone. Those alternatives have costs ranging from about $3.9- to $4.6-million to implement.

Alternatively, a Sacramento Bridge alternative was identified that would cost an estimated $2.8 million and would provide relief for about 40 homes currently mapped within the Olney Creek floods zone and cannot obtain elevation certificates. As of today, 307 homes are affected impacted by potential flooding. An estimated 77 to 95 properties might have flood insurance requirements eliminated with elevation certificates. An estimated 25 to 32 impacted properties might be eligible for reduced flood insurance requirements. The remaining 127 to 152 properties are likely to gain no flood insurance relief, even with elevation certificates. These values are tabulated below. These alternatives are summarized in the table below.

NUMBERS OF IMPACTED PROPERTIES		
Milestone	**Number of Impacted Properties**	**Estimated Cost**
Sacramento Bridge Alternative		
USACE Initial Estimate	648	$2,683,000 Bridge $130,000 Elev. Certs.
PHI Revised Estimate	307	
If Sacramento Drive Bridge Constructed	267	
Homes Eligible for Flood Insurance Rate Insurance Elimination with Elevation Certificate	77 – 95	
Properties Eligible for Reduced Flood Insurance with Elevation Certificate	25 - 32	
Properties Estimated to Have to Pay Full Value for Flood Insurance Even with Elevation Certificate	127-152	
Levee Improvement Alternative		
Levee Improved to FEMA Standards	Reduced to 0	$4,520,000
Conveyance Improvement Alternative		
Conveyance Improved to Make Levee Obsolete	Reduced to 0	$3,890,000

Fees for preparing elevation certificates are currently estimated to $650 if prepared for only one parcel, and $500 if multiple parcels are evaluated at one time. Annual flood insurance rates are estimated to range from $500 to $3,000 per household.

In order to remove properties that are no longer impacted by the 100-year floodplain as a result of the bridge project improvement, the issuance of Letter of Map Revision (LOMR) must be issued by FEMA. This process is initiated by the City through an application to FEMA following the completion of the bridge project.

This information should provide the City a means of further identifying goals and methods to reach those goals for the residents impacted by the de-accreditation of the Olney Creek Levee.

6 LIMITATIONS

This report has been prepared in substantial accordance with the generally accepted geotechnical and civil engineering practices, as they existed in the project area at the time our services were rendered. No other warranty, either express or implied, is made.

Work performed within this study was not intended to be used for final design nor construction of improvements at the Olney Creek Levee. The work performed herein is suitable for planning-level purposes and should be used in that capacity only.
The scope of services provided by CGI and others for this project did not include the investigation and/or evaluation of toxic substances, or soil or groundwater contamination of any type. If such conditions are encountered during site development, additional studies may be required. Further, services provided by CGI and others for this project did not include the evaluation of the presence of critical environmental habitats or culturally sensitive areas.

This report may be used only by our client and their agents and only for the purposes stated herein, within a reasonable time from its issuance. Land use, site conditions, and other factors may change over time that may require additional studies. In the event significant time elapses between the issuance date of this report and construction, CGI shall be notified of such occurrence in order to review current conditions. Depending on that review, CGI may require that additional studies be conducted and that an updated or revised report is issued.

Any party other than our client who wishes to use all or any portion of this report shall notify CGI of such intended use. Based on the intended use as well as other site-related factors, CGI may require that additional studies be conducted and that an updated or revised report be issued. Failure to comply with any of the requirements outlined above by the client or any other party shall release CGI and our partners from any liability arising from the unauthorized use of this report.

- ♦ -

7 REFERENCES

Pacific Hydrologic, Inc. (2010), Flood Study, Olney Creek, City of Redding, unpublished consultant's report prepared for the City of Redding, dated May 12, 46 p.

_____ (2015a), Revised hydrologic profile and cross sections for Section 1875, 2285, 3705, and 5085, dated January 22.

_____ (2015b), Olney Creek Levee, Conveyance Improvement Alternative, unpublished consultant's report prepared for CGI Technical Services, Inc., dated July 9, 3 p. with attachments.

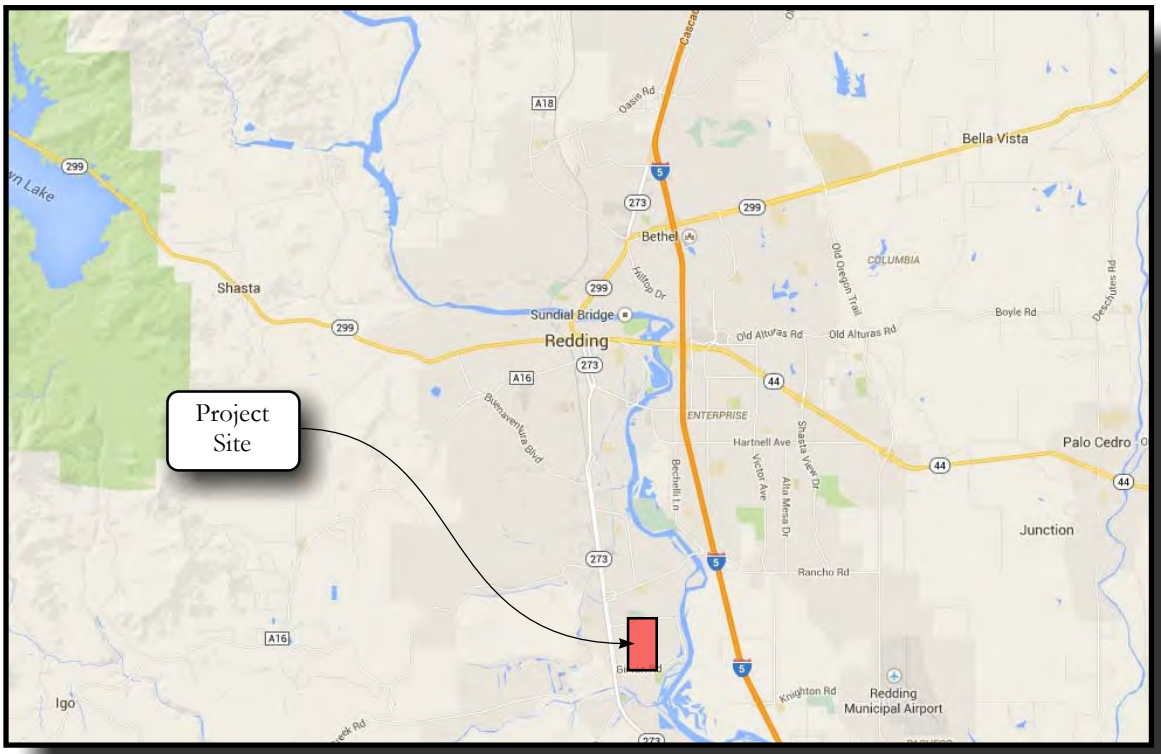
TABLE 1- SACRAMENTO BRIDGE ALTERNATIVE						
ALT. NO.	ELEMENT/ VARIATION	DESCRIPTION	IMPACTS	RELATIVE COST		COMMENTS
				Short-Term	Long-Term	
SB-1	Sacramento Bridge	▪ Construct the Sacramento Bridge	Levee uncertified Possible continued erosion at "Gap" area, potentially undermining 42-inch sewer pipeline.	None for the Levee	None for the Levee	Provides no relief from flood insurance for affected residents. Some landowners can independently obtain relief from flood insurance through filing of Elevation Certificates.
SB-2	Assist in obtaining Elevation Certifications	▪ Perform no mitigations. ▪ Assist applicable residents within 100-year flood area with obtaining Elevation Certifications to flood reduce insurance costs.	Levee uncertified Possible continued erosion at "Gap" area, potentially undermining 42-inch sewer pipeline.	Low	None	Will not apply to all residents. Some will still have to purchase flood insurance.

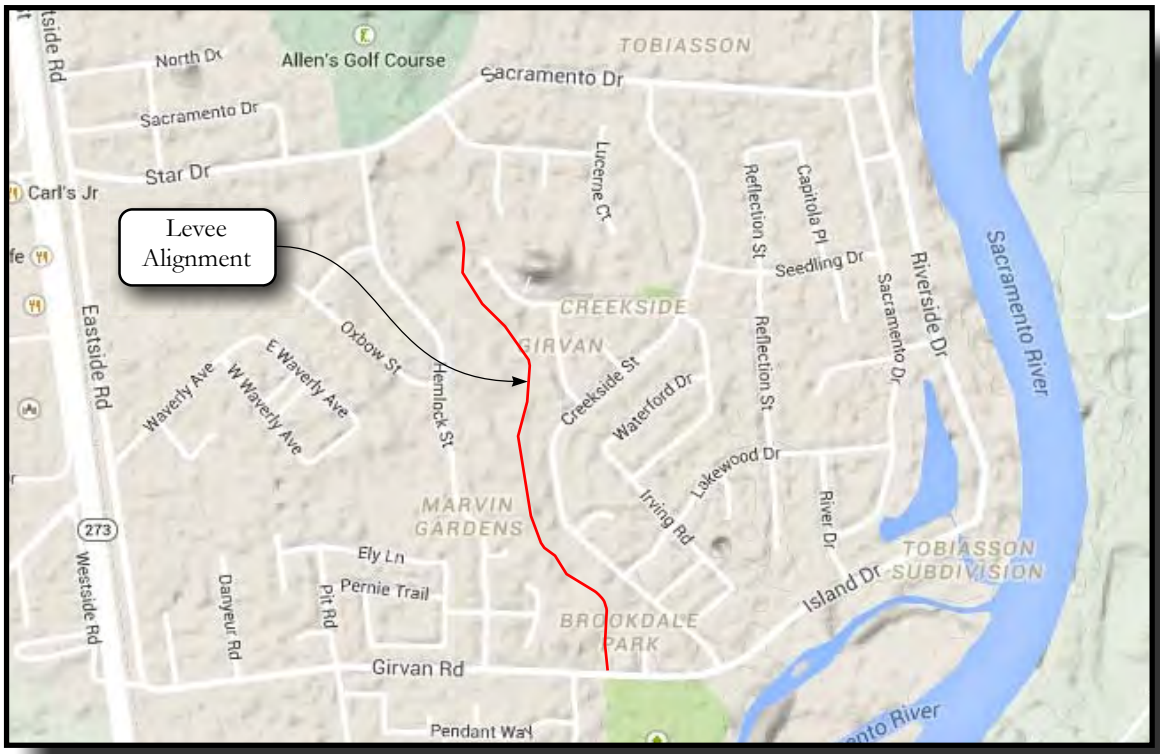
TABLE 2 - LEVEE IMPROVEMENT ALTERNATIVE						
ALT. NO.	ELEMENT/ VARIATION	DESCRIPTION	IMPACTS	RELATIVE COST		COMMENTS
				Short-Term	Long-Term	
~~LI-1~~	~~Correct landowner-caused defects~~	~~▪ Purchase easements~~ ~~▪ Remove improvements constructed on landside levee slope~~ ~~▪ Backfill excavations on landside levee slope~~ ~~▪ Remove landscaping on landside levee slope~~ ~~▪ Remove & relocate fencing~~	~~Will significantly reduce area of some back yards.~~	~~Very high~~	~~Low to moderate~~	~~Landowner property lines along most of levee extend to levee crown. No known easements are in place to inspect and maintain landside of levee. Many landowner alterations (retaining walls, fencing, steepened slopes, landscaping) have been made that do not conform to USACE requirements.~~
LI-2	Realign levee to avoid landowner defects	▪ Relocate levee to west to avoid impacts of landowner improvements ▪ Replace floodwall or extend levee to replace floodwall.	See LI-3 for environmental impacts	High	Low	Will alleviate the need for LI-3 along much of the levee
LI-3	Remove waterside slope vegetation	▪ Remove all vegetation and trees along waterside and landside levee slopes, and crown to a distance of 15 feet from toes to conform to USACE requirements.	Extensive tree removal Cultural?	Low to moderate	Low to moderate	
LI-4	Repair erosion	▪ Backfill areas where minor erosion has occurred.	None	Low	Low	Probably one day's worth of work for a single City crew.
LI-5	Assess and mitigate (as necessary) sewer penetration backfill and settlement	▪ Assess pipe zone and trench zone backfill materials along penetration. If necessary, install low permeability materials. ▪ Repair settlement in levee above this penetration	Temporary construction	Low	Low	If granular backfill is in place within pipezone or trenchzone then seepage forces likely to exceed tolerable USACE limits. Low permeability materials can consist of clay or slurry. Settlement of about 1 to 1.5 feet currently present and needs to be mitigated.
LI-6	Stabilize creek bank in "Gap" area & construct tie-in	▪ Install RSP, gabions, or other revetments to reduce potential for further erosion of bank	Work required within active channel of Olney	Low to moderate	Low	Stabilizing bank is critical for two reasons: 1) to allow adequate room for upstream and downstream tie-ins of levee segments in "Gap" area; and 2) to protect City's 42-inch sewer

TABLE 2 - LEVEE IMPROVEMENT ALTERNATIVE						
ALT. NO.	ELEMENT/ VARIATION	DESCRIPTION	IMPACTS	RELATIVE COST		COMMENTS
				Short-Term	Long-Term	
	wall/improvement	▪ Construct slope leading to top of slope ▪ Construct flood wall, AC berm, or embankment to meet USACE freeboard requirements.	Creek			pipeline that extends near this area.
LI-7	Upstream tie-in at Sacramento Drive	▪ Perform levee design studies for new levee segment ▪ Purchase easement at Allen's Golf Course ▪ Enlarge conveyance beneath Sacramento Drive Bridge ▪ Elevate approaches to Sacramento Drive Bridge ▪ Construct levee tie-in embankment north of Sacramento Drive	Work required within active channel of Olney Creek Raise Sacramento Drive Bridge	Very high	Low to moderate	
LI-8	Downstream tie-in at Girvan Road	▪ Perform levee design studies for new levee segment ▪ Enlarge conveyance beneath Girvan Road Bridge ▪ Elevate approaches to east side of Girvan Road Bridge ▪ Extend levee south of Girvan Road	Work required within active channel of Olney Creek Could require modification of Girvan Road bridge.	Very high	Low to moderate	Can lower 100-yr flood levels at Girvan Road Bridge if FEMA will allow modeling of Olney Creek independent of Sacramento River.
LI-9	Stabilize creek at locations at risk of significant bank erosion	▪ Install RSP, gabions, or other revetments to reduce potential for further erosion of bank ▪ Construct slope leading to top of slope	Work required within active channel of Olney Creek.	Low to moderate	Low	Stabilizing banks will reduce potential for claims against the City relative to stream alteration (increase in real 100-year flood flows) caused loss of or damage to private property
LI-10	Interior area flood study	▪ Conduct new flood study of interior area to identify	None	Low	None	

TABLE 2 - LEVEE IMPROVEMENT ALTERNATIVE						
ALT. NO.	ELEMENT/ VARIATION	DESCRIPTION	IMPACTS	RELATIVE COST		COMMENTS
				Short-Term	Long-Term	
		interior area to be removed from Special Flood Hazard Area (SFHA)				
LI-11	Operation and Maintenance Manual	▪ Prepare O&M manual per FEMA requirements (similar to USACE manual for CCWTP levee)	None	Low	None	
LI-12	Levee Report or LOMR application	▪ Prepare levee report (similar to LOMR application) to correct FEMA Special Flood Hazard Area (SHFA) after implementing project.	None	Low	None	
NOTE: There is some risk that FEMA may not consider a portion or all of the mound on which the golf course clubhouse is constructed. If deemed fill as opposed to natural ground, the upstream tie-in may need to be located farther north.						

TABLE 3 - CONVEYANCE IMPROVEMENT ALTERNATIVE						
ALT. NO.	ELEMENT/ VARIATION	DESCRIPTION	IMPACTS	RELATIVE COST		COMMENTS
				Short-Term	Long-Term	
CI-1	Modify Olney Creek channel to increase conveyance thus rendering levee obsolete	▪ Remove and manage vegetation in improvement area ▪ Grade new conveyance improvements	Extensive work within riparian habitat. Possible Cultural Impacts	High to very high	Moderate	
CI-2	Stabilize creek bank in "Gap" area and at other locations at risk of significant bank erosion	▪ Install RSP, gabions, or other revetments to reduce potential for further erosion of bank ▪ Construct slope leading to top of slope	Work required within active channel of Olney Creek.	Low to moderate	Low	Stabilizing bank will protect City's 42-inch sewer pipeline that extends near this area. Stabilizing banks will reduce the potential for claims against the City regarding stream alteration caused loss of or damage to private property.
CI-3	Improve conveyance at Girvan Road	▪ Enlarge conveyance beneath Girvan Road Bridge	Work required within active channel of Olney Creek Could require modification of Girvan Road bridge.	Moderate to very high	Low	Can lower 100-yr flood levels at Girvan Road Bridge if FEMA will allow modeling of Olney Creek independent of Sacramento River. This may alleviate this Alternative Number.
CI-4	FEMA Letter of Map Revision (LOMR)	▪ Prepare LOMR application to correct FEMA Special Flood Hazard Area (SHFA) after implementing Project	None	Low	None	Backwater model supporting LOMR application will consider increase in flood conveyance associated with known channel enlargement that has occurred since original FEMA study and may reconsider the combination of Olney Creek and Sacramento River floods.





Basemap from Google Maps

Scale Not Determined

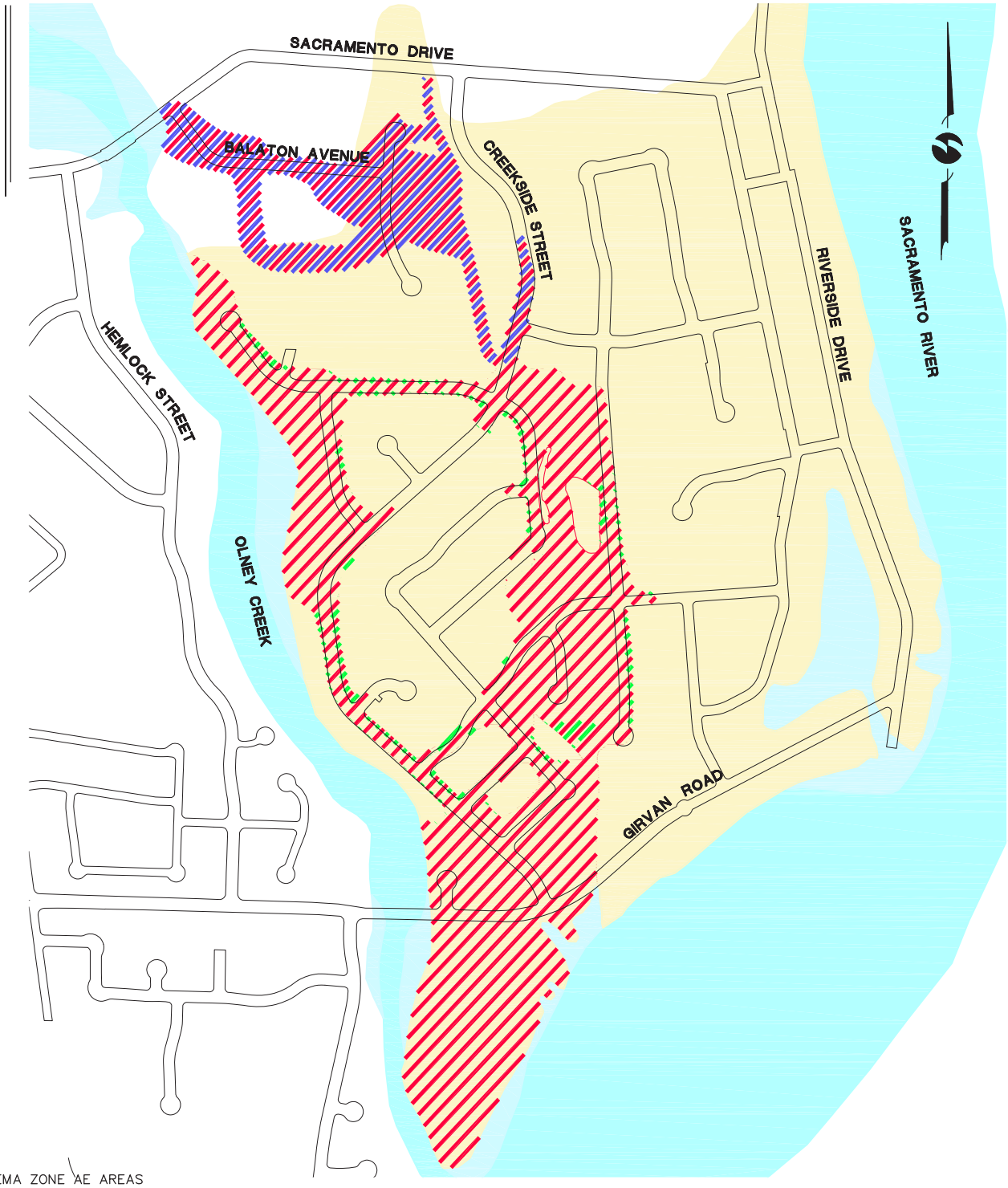
CGI Technical Services Inc.

Project No.: 14-1128.94

SITE LOCATION MAP
OLNEY CREEK LEVEE EVALUATION PROJECT
CITY OF REDDING PUBLIC WORKS DEPARTMENT
REDDING, CALIFORNIA

Plate

1



LEGEND:

- FEMA ZONE AE AREAS
- FEMA FLOODWAY AREAS IN ZONE AE
- AREA SUBJECT TO FLOOD INSURANCE PRIOR TO 2010 PHI FLOOD STUDY (~648 HOMES).
- CURRENT AREA SUBJECT TO FLOOD INSURANCE (~307 HOMES)
- ESTIMATED AREA REMOVED FROM FLOOD INSURANCE REQUIREMENTS DUE TO SACRAMENTO DR. BRIDGE PROJECT (~40 HOMES).
- ESTIMATED AREA REMOVED FROM FLOOD INSURANCE REQUIREMENTS OR QUALIFYING FOR REDUCED RATES DUE TO ELEVATION CERTIFICATES (~102 TO 127 HOMES).

Map created by Omni-Means (2017)

Scale Not Determined

CGI TECHNICAL SERVICES INC.

Project No.: 14-1128.94

SUMMARY MAP
OLNEY CREEK LEVEE EVALUATION PROJECT
CITY OF REDDING PUBLIC WORKS DEPARTMENT
REDDING, CALIFORNIA

Plate

2

Appendix A
Geotechnical Studies

APPENDIX A
GEOTECHNICAL STUDIES

Included within this appendix is the geotechnical study performed by CGI Technical Services, Inc., to evaluate the stability of the levee in accordance with U.S. Army Corps of Engineers standards.

Appendix B
Hydrologic Evaluations

APPENDIX B
HYDROLOGICAL STUDIES

Included within this appendix is the geotechnical study performed by Pacific Hydrology, Inc., for the Olney Creek levee. Those studies were performed in 2010 and 2015 and both are included herein.

Flood Study

Olney Creek

City of Redding

Prepared for:

City of Redding
777 Cypress Avenue
Redding, CA 96001

Prepared by:

Pacific Hydrologic Incorporated
1050 West Street
Redding, CA 96001

Norman S. Braithwaite, P.E.

May 12, 2010
Revised May 21, 2010

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Olney Creek Flood Study

Executive Summary:

Between Sacramento Drive and the Sacramento River, flood water in Olney Creek is separated from residential development along the east side of Olney Creek by an earth levee. This levee was constructed in the early 1980s to appropriate standards. FEMA considered the levee to be effective for preventing Olney Creek overflow from inundating structures within residential development behind the levee during the most probable 100-year flood (Base Flood). By the late 1980s, FEMA had changed the design and maintenance standards for new levees while continuing to consider previously accepted levees as effective. Recent flood events have caused FEMA to reconsider the effectiveness of previously approved levees whether constructed before the new standards of the late 1980s or not. Data and analyses sufficient to meet the current standards of FEMA and necessary to verify that the existing Olney Creek levee is adequate to prevent overflow from inundating structures during the Base Flood are not presently available. Therefore FEMA has identified a large area behind this levee as being at high risk of damage during the Base Flood using very crude approximate or planning level study methods. The Base Floodplain or "Special Flood Hazard Area" (SFHA) identified by FEMA behind the Olney Creek levee is shown in Figure 1 (page 14). New detailed hydrologic and hydraulic analysis has not been conducted by FEMA for accurate determination of current flood risk.

This report documents a new flood study conducted along Olney Creek and along a path of overflow from Olney Creek at Sacramento Drive to better identify the SHFA along Olney Creek and along the overflow floodplain. The new analysis has been conducted using detailed study methods, surveyed channel data, and LIDAR topographic data, none of which were considered by the recent FEMA approximate study methods. In addition to mapping the floodplain along Olney Creek and the overflow floodplain, this study has identified the floodplain associated with a breach of the existing levee, a FEMA requirement for levees that do not meet the minimum FEMA accreditation requirements. This study also includes an analysis to identify improvements necessary to prevent overflow at Sacramento Drive and identifies deficiencies of the existing levee to meet the minimum requirements of FEMA for accreditation.

A flood map identifying the Olney Creek floodplain, the overflow floodplain, shallow overflow associated with the overflow floodplain, and the breach floodplain is shown in Figure 9 (page 21). Two combinations of improvements to prevent overflow from Olney Creek at Sacramento Drive have been identified as well as additional requirements necessary for levee accreditation. The combinations of improvements sufficient to prevent overflow at Sacramento Drive include opening the channel under the Sacramento Drive bridge combined with a downstream channel improvement and raising the deck of the Sacramento Drive bridge combined with the same downstream channel improvement. Details of the improvements and additional levee requirements associated with these improvements are described in this report. Additional Analyses and documentation necessary for levee accreditation are also identified in this report.

The following options may be considered to address flood risk along Olney Creek

- Do nothing (FEMA SFHA shown in Figure 1 will apply)
- Submit analysis to FEMA and request that the FEMA SFHA determined by approximate study methods be replaced by the SFHA determined by the detailed analysis germane to this study (map similar to Figure 9 will apply after FEMA review and acceptance)
- Consider combinations of improvements sufficient to prevent overflow at Sacramento Drive during the Base Flood (SFHA similar to Figure 9 without the overflow floodplain will apply after FEMA review and acceptance)
- Consider maintenance, analyses, and documentation necessary for levee accreditation (SFHA similar to Figure 9 without the breach floodplain will apply after FEMA review and acceptance)
- Consider both of the above options (SFHA similar to Figure 9 without overflow and breach floodplains will apply after FEMA review and acceptance)

Existing Flood Conditions:

The locations of levees presently being relied upon for protection against damage during the FEMA Base Flood are shown in Figure 2 (page 15). With the exception of overflow leaving the Olney Creek channel at Sacramento Drive, all floods in Olney Creek since construction of the levees in the 1980s have been contained within the Olney Creek channel and levees. Flood water was observed leaving the Olney Creek channel at Sacramento Drive during the flood of December 23, 1964. Overflow during this event is shown in Photo 1 (page 13). The recurrence of this flood is not known but it was not likely to be a 100-year flood.

Observations near the mouth of Olney Creek indicate significant channel incision or down cutting in recent years. Evidence of channel incision includes steep banks, exposures of less erodible materials in the bottom of the channel, common root exposures, recent bank failures, and recent tree fall at the edge of the channel. Near Sacramento Drive, few of these indicators are present. In reaches of channel experiencing incision, the capacity of the channel to convey flood flows is expected to be greater than estimated in the 1980s when the levees were constructed.

Bonnyview Drain was constructed to convey flood water from developed areas to the north of Sacramento Drive. Storm drainage from a portion of the development south of Sacramento Drive and east of Olney Creek and the levees is also conveyed by Bonnyview Drain. The capacity of Bonnyview Drain is sufficient to convey the FEMA Base Flood emanating from direct contributing areas. The capacity of Bonnyview Drain to convey the combined flows from direct contributing areas plus overflow from Olney Creek, however, has not been previously studied.

Flood Hydrology:

Flood hydrology from FEMA has been relied upon for the current Olney Creek flood study. The FEMA Base Flood is consistent with flood hydrology developed by the City of Redding. Peak flows during flood events of concern to FEMA are identified in Table 1.

Table 1: FEMA Flood Peak Flows

Flood Recurrence (years)	Peak Flow at Sacramento Drive (cfs)	Peak Flow at Girvan Road (cfs)
10	3000	3000
50	4750	4400
100	5438	5457
500	7700	5900

Existing Condition Hydraulic Analysis Data and Assumptions:

The Corps of Engineers' HEC-RAS version 3.1.2 backwater program (reference 1) has been selected for modeling hydraulic characteristics representing existing conditions in Olney Creek and along the path of overflow from Olney Creek at Sacramento Drive. This program has been selected because of its long history of use (derived from HEC-2), wide acceptance and great flexibility for evaluating structures including bridges and levees. Cross-section data used in the Olney Creek backwater model were from a recent ground survey. Cross-section data used in the overflow model were derived from LIDAR topography and corrected using field measurements at bridges over Bonnyview Drain. Locations of cross-sections used in the backwater models are shown on Figure 3 (page 16). Cross-sections have been adjusted for skew as appropriate. All survey data and elevations are referenced to the NAVD-88 datum. Mannings Roughness coefficients were estimated by observation and comparison with similar channels identified in Roughness Coefficients of Natural Channels (reference 2). Manning's roughness coefficients ranging from 0.035 to 0.040 were used to represent the Olney Creek channel. Olney Creek banks and overbanks were represented using Manning's roughness coefficients of 0.040 for low and groomed grass, 0.050 for open oak with grass understory, 0.060 for moderate density brush and trees, and 0.100 for heavy vegetation. The overflow path and Bonnyview Drain was represented using Manning's roughness coefficients of 0.015 for paved surfaces, 0.040 to 0.050 for earth channels with some vegetation, 0.060 for flow through yards, and 0.100 for flow through dense vegetation. Contraction and expansion coefficients of 0.1 and 0.3 respectively were used to represent natural and artificial channels. These were raised to 0.3 and 0.5 respectively in the vicinity of bridges. Starting water surface elevations were fixed at the Sacramento River Base Flood water surface elevation after adjustment to elevation in the NAVD-88 datum. An elevation of 436.5-feet NAVD-88 was used for the starting water surface elevation at the mouth of Olney Creek and an elevation of 437.5-feet NAVD-88 was used for the starting water surface elevation at the mouth of Bonnyview Drain.

Existing Condition Hydraulic Analysis Results and Floodplain:

Initial hydraulic analysis of Olney Creek indicates that flow will leave the Olney Creek channel during the most probable 50-, 100-, and 500-year flood events. The portion of flow leaving the channel was calculated as described in a following paragraph and removed from the total Olney Creek flow for the purpose of identifying existing flood hydraulic conditions in Olney Creek downstream of Sacramento Drive. All floods up to and including the Base Flood are conveyed under the Girvan Road bridge without overflow. Olney Creek water surface profiles during infrequent floods of concern to FEMA are shown in Figure 4 (page 17). The Base Flood water

surface profile for the overflow path is shown in Figure 5 (page 18). Summary output from the backwater models is included in Appendix A.

FEMA requires that levees have 3.5-feet of freeboard at the upstream end tapering to 3.0-feet of freeboard at the downstream end. The existing levee and floodwall provides the minimum required freeboard. FEMA requires 4-feet of freeboard within 100-feet of constricting bridges. This condition is not met upstream of Girvan Road should it be considered a constricting bridge. FEMA also requires that the upstream and downstream ends of levees tie into high ground. The existing levees and floodwall extend to locations where the Base Flood water surface elevations are below existing ground.

Overflow computed by the backwater model at Sacramento Drive was divided between a flow path to the east and a flow path over the bridge back into Olney Creek proportionate to the area above the overflow crest. Figures 6 through 8 (pages 19, 20) identify the overflow crest, backwater model output showing overflow during the Base Flood, and overflow crest cross-section with division of flow during the Base Flood. The magnitude of overflow during the peak flow of flood events is identified in Table 2.

Table 2: Estimated Overflow at Sacramento Drive

Event	Olney Creek Flow Approaching Sacramento Drive (cfs)	Estimated Overflow at Sacramento Drive (cfs)	Olney Creek Flow Downstream of Sacramento Drive (cfs)
10-year	3000	0	3000
50-year	4750	480	4270
100-year	5438	575	4863
500-year	7700	1560	6140

The existing condition Olney Creek and overflow path floodplain is shown on Figure 9 (page 21). Also shown on this figure are areas of shallow overflow secondary to the primary overflow path and areas of shallow overflow associated with a levee breach. The levee breach overflow is discussed in a following section of this report. The Base Floodplain along Olney Creek was determined by plotting the flood limits computed by the backwater model at each surveyed cross-section and interpolating flood limits between cross-sections based on colorized LIDAR topographic imagery. Shallow overflow secondary to the primary overflow path represents locations where water surface elevations along the primary overflow path exceeded the top of bank elevations adjacent to the primary overflow path. At these locations some overflow will separate from the primary overflow path and flow along a secondary overflow path back to the primary overflow path or another downstream location. The magnitude of overflow at these locations was not calculated but it is unlikely that any of the secondary overflow paths will convey more than 250-cfs during the Base Flood. Recommendations for calculation of water surface elevations along the shallow overflow paths for the purpose of completing elevation certificates are included in Appendix B.

Levee Breach:

FEMA requires that the area behind levees not meeting the minimum accreditation requirements of FEMA be included in the SFHA as appropriate. In most cases the area behind the levee constitutes a bathtub with no alternative exit for flood water and the water surface elevation behind the levee is mapped at the highest water surface elevation in the channel adjacent to the levee or at water surface elevations considering the storage and conveyance capacity behind the levee. The levee along Olney Creek is not typical in that alternative flow paths exist to the Sacramento River and water cannot back up to match water surface elevations in the Olney Creek channel. The breach floodplain therefore becomes a function of the magnitude of flow through the breach and the opportunity for this flow to find alternative paths to the Sacramento River. The magnitude of flood flow through the breach is a function of the size of the breach which is, in turn, a function of the hydraulic height of the levee and the volume of water available to develop the breach. The constitution of soil in the levee is also a factor but this factor is not considered when computing the potential maximum breach dimensions. Empirical equations used for estimating maximum breach widths have been developed by Danny Fread (Reference 3) and recently improved upon by David C. Froehlich (Reference 4). These equations are considered relatively conservative and application of these empirical equations is a standard procedure for determining areas of inundation downstream of earthen dams. These equations are appropriate for estimating the maximum width of a breach in the levee separating Olney Creek from areas to the east. Therefore the maximum breach flow has been estimated as the maximum flow through the maximum breach estimated using the Froehlich dam breach equation.

The difference in elevation between the Base Flood water surface elevation and the ground elevation on the land side of the levee was determined at each surveyed cross-section. The maximum difference was found to be 1.38-feet at cross-section 3705. At this cross-section the flow in Olney Creek having an elevation equal to the ground elevation on the land side of the levee was determined to be 3000-cfs. At this flow in Olney Creek no overflow will occur if the levee were not present. The volume of water available to develop the breach during the Base Flood is therefore represented by all flow in excess of 3000-cfs. This volume of water was computed to be 37 million cubic feet using a hydrograph derived from the City of Redding rainfall-runoff model representing the Base Flood in Olney Creek after accounting for overflow at Sacramento Drive. For the 1.38-foot maximum difference in elevation and the 37 million cubic feet of water, the maximum breach width estimated by the Froehlich dam breach equation for a piping failure is less than 75-feet. Based on a broad crest weir equation with a weir coefficient of 2.0 and a maximum depth of flow of 1.38-feet, the flow through the breach is estimated to be less than 250-cfs. Figures 10 through 14 (pages 22 through 24) identify the difference in elevation between the Base Flood and the ground elevation on the land side of the levee at surveyed cross-sections, Cross-section 3705 with elevation difference identified, the stage discharge relationship at cross-section 3705 identifying the flow associated with the ground elevation on the land side of the levee, the Base Flood hydrograph with volume computation, and calculations of breach width and breach flow.

The estimate of breach flow represents a conservative maximum flow for the following reasons:

- The breach width equation is an enveloping equation, not average
- The breach is assumed to be fully developed by the time flow in Olney Creek peaks
- Material eroded during the formation of the breach is assumed not to impede overflow
- Breach width was computed assuming maximum difference in elevation
- Not all Sacramento Drive overflow was accounted for when calculating the volume of water available in Olney Creek for breach formation.

Breach Floodplain:

Although the breach flow was computed at surveyed cross-section 3705, the breach floodplain has been mapped assuming the breach could occur at any location where properties located east of the levee rely on the levee for protection against damage during the Base Flood in Olney Creek. Based on the capacity of the typical local road section to convey flow, the depth of flooding along the path of flow between the location of the breach and where breach flows enter the Sacramento River has been estimated to be 1.0-foot above the road section shown on LIDAR topography. The typical local road section used for this computation consists of a 40-foot wide paved road section (road, gutters, plus sidewalks) having a slope of 0.5-percent (decimal 0.005). Using a Manning's roughness coefficient of 0.015 to represent the paved section, a hydraulic depth (flow area divided by wetted perimeter - approaches average depth for wide, shallow flow) of 1.0-foot has the capacity to convey 280-cfs. Near Girvan Road, the minimum water surface elevation of overflow is estimated to be 441.5-feet. This represents a depth of flow over Girvan Road of approximately 9-inches. The breach floodplain is shown on Figure 9 (page 21). Recommendations for calculation of water surface elevations along the breach floodplain for the purpose of completing elevation certificates are included in Appendix B.

Conceptual Flood Risk Reduction Measures:

Four flood risk reduction measures have been identified as potentially capable of preventing overflow at Sacramento Drive. Backwater models have been prepared to identify preliminary minimum design requirements and flood hydraulic performance of three of these measures. Previously completed flood hydraulic analysis is sufficient to assess preliminary design requirements and hydraulic performance of the fourth measure. The measures include the following:

- Open channel under Sacramento Drive Bridge
- Raise deck of Sacramento Drive Bridge
- Channel conveyance improvement downstream of Sacramento Drive Bridge
- Extend levee to the north past Sacramento Drive

These measures are described in the following paragraphs along with preliminary minimum requirements and flood hydraulic performance.

Open Channel under Sacramento Drive Bridge: Opening the channel under the Sacramento Drive bridge consists of grading the channel to a uniform elevation of 447.0-feet. This elevation ranges from 0- to 5-feet lower than the existing ground under the bridge. If this measure is

considered, channel protection is recommended to reduce risk of exposure of bridge footings at elevation 443.0 (according to as-built drawings and adjusted to NAVD-88 datum). A sill structure may also be appropriate just upstream of the bridge to reduce the risk of head cutting or channel incision propagating upstream. A backwater model representing this condition indicated that this measure alone is not sufficient to contain the Base Flood within the Olney Creek channel at or immediately downstream of Sacramento Drive. Overflow will continue to occur due to a constricted channel near Cross-section 5675 located approximately 140-feet downstream of the bridge. Cross-section plots showing the existing and excavated channel under the Sacramento Drive bridge are shown in Figures 15 and 16 (page 25).

Raise Deck of Sacramento Drive Bridge: This measure consists of raising the deck of the Sacramento Drive bridge by 1.0-foot without grading under the bridge. If this measure is considered, the embankment under the golf course driveway is relied upon to prevent overflow. This embankment will need to be improved to meet the minimum FEMA requirements for accreditation. The FEMA Levee freeboard requirement approaching the bridge may require that the existing golf course driveway be relocated to the east of the levee. Raising the bridge deck will also require increasing the elevation of Sacramento Drive near the bridge and may affect other driveways as well. Since this measure alone does not address overflow due to the channel constriction near Cross-section 5675, this measure alone will not prevent overflow. Cross-section plots showing the existing and elevated bridge deck cross-section are shown in Figures 17 and 18 (page 26).

Channel Conveyance Improvement: This measure consists of widening the channel downstream of the Sacramento Drive bridge through cross-section 5675. At cross-section 5675 the channel would have a bottom elevation of 446.5-feet and a bottom width of 28-feet. Since this measure alone does not address overflow at Sacramento Drive, this measure alone will not prevent overflow. Cross-section plots showing the existing and excavated channel at cross-section 5675 are shown in Figures 19 and 20 (page 27).

Extend Levee: Extension of the existing levee to high ground north of Sacramento Drive is also capable of preventing overflow at Sacramento Drive. The logical alignment for levee extension is between the two residential structures located adjacent to the south side of Sacramento Drive between Olney Creek and Balaton Avenue. The levee extension would extend to high ground near the golf course club house. It might be possible to implement this alternative without modification of the existing bridge but Sacramento Drive would need to be elevated over the levee extension. Vertical road alignment requirements associated with elevating Sacramento Drive will affect driveways, the intersection of Sacramento Drive and Balaton Avenue, and possibly the elevation of the existing Sacramento Drive bridge deck.

Backwater models were prepared to represent opening the channel under the Sacramento Drive bridge with no other measures and for the channel conveyance improvement combined with each bridge improvement measure. The backwater models representing the channel improvement combined with either bridge improvement indicates that the combination of flood risk reduction measures is sufficient to prevent overflow at and downstream of Sacramento Drive. Flood profiles representing opening the channel under the bridge with no other measures are shown on Figure 21 (page 28). Flood profiles representing the channel improvement combined with opening the channel under the Sacramento Drive bridge and combined with raising the deck of

the Sacramento Drive bridge are shown on Figures 22 and 23 respectively (Pages 29 and 30). Summary backwater model output tables for all three models are included in Appendix A.

Implementation of measures sufficient to contain the Base Flood within the Olney Creek channel will also increase the peak flow of the Base Flood above that for existing conditions downstream of Sacramento Drive but not above the estimate of Base Flood peak flow recognized by FEMA (FEMA analysis of Olney Creek assumes no overflow). Since the existing condition hydraulic analysis for this study relies on overflow at Sacramento Drive, prevention of the overflow will produce slightly higher Base Flood water surface elevations along Olney Creek downstream of Sacramento Drive. The higher Base Flood water surface elevations will affect the top elevations, tie-in locations, and levee stability analysis necessary to meet the minimum FEMA requirements for accreditation. The combination of raising the Sacramento Drive bridge deck with downstream channel improvement relies on the golf course driveway embankment to prevent overflow at Sacramento Drive. Therefore this embankment will be required to meet the minimum standards of FEMA for levee accreditation.

Other Considerations:

Other factors affecting flood risk along Olney Creek include channel stability and bank erosion, vegetation, and drift or debris transported by the flood flow. These factors and their potential influence on flood risk are described in the following paragraphs.

The reach of Olney Creek between Sacramento Drive and the Sacramento River is experiencing a process of channel incision and is considered unstable. The most significant factor contributing to channel incision is flood regulation of the Sacramento River. Prior to construction and operation of Shasta Dam, bank full flows responsible for definition of the Olney Creek channel would combine with high flows in the Sacramento River. Since construction and operation of Shasta Dam, most bank full flows responsible for definition of the Olney Creek channel now combine with low flows in the Sacramento River having lower water surface elevations. Lower water surface elevations in the Sacramento River have produced higher velocities and higher flow gradients in Olney Creek as it approaches the Sacramento River. The higher velocities and gradients have resulted in erosion of the bottom of the channel. Over time, this erosion or channel incision has propagated upstream. Evidence of channel incision is prolific in and along the Olney Creek channel in the vicinity of Girvan Road but is not obvious in the vicinity of Sacramento Drive. Once incised to a new equilibrium gradient, a channel will tend to widen in response to reformation of transient bed deposits such as gravel bars. This condition is evident downstream of Girvan Road where bank erosion is occurring adjacent to a reach of stream channel with a gravel and cobble bed. Bank erosion on the east side of the Olney Creek channel upstream of Girvan Road is most likely not due to this widening process but due to a combination of incision into less erodible materials along the west side of the channel plus heavy vegetation in the channel. The process of incision followed by widening will continue to propagate upstream at a slow rate related to the occurrence of bank full flows in Olney Creek and substantially independent of the levees. Where exposed to high water velocities, embankment protection is required for levee accreditation but this will not preclude the possibility of bank erosion problems at other locations.

Heavy vegetation can impede flood flow and produce higher water surface elevations during infrequent flood events. In general the vegetation along Olney Creek is heavy near the top of

banks. Between the top of bank and the levee, vegetation consists of trees with a relatively open understory and appears to be managed for fire risk reduction. These conditions are reflected in the existing condition backwater model of the Olney Creek channel. Removal of vegetation beyond that represented by present conditions will not prevent existing overflow at Sacramento Drive and will not significantly reduce Base Flood water surface elevations along the levee. Allowing more dense vegetation, especially in the area between Olney Creek and the levee, will increase the Base Flood water surface elevations hence the top elevation and other requirements of the levee. This analysis assumes that vegetation will continue to be managed in a manner similar to vegetation management practices of the recent past.

Olney Creek has the ability to convey modest volumes of drift of small to medium sizes (branches, small trees). Most large and medium size drift entering Olney Creek at upstream locations within the basin will be filtered out of the stream channel by structures located upstream of Eastside Road therefore larger drift in Olney Creek at Sacramento Drive will most likely be from local sources. Most small drift should pass under the Sacramento Drive bridge without much difficulty. Accumulation of drift at the Sacramento Drive bridge may or may not occur during large flood events and if occurring, can reduce the flood capacity of the bridge. This analysis assumes no drift accumulation at the Sacramento Drive bridge because the statistical probability and significance of an accumulation of drift cannot be accurately quantified.

Levee Sufficiency:

The Code of Federal Regulations, section 65.10 identifies the minimum requirements of FEMA for accreditation of levees. These requirements are summarized in the following paragraphs along with and the sufficiency of the existing levee to meet these requirements. The CFR contains additional specifications and details not included in the summary of requirements below.

- Freeboard [44 CFR §65.10(b)(1)]: Levees must provide a minimum of three feet above the water-surface level of the base flood. An additional one foot above the minimum is required within 100 feet in either side of structures (such as bridges) riverward of the levee or wherever the flow is constricted. An additional one-half foot above the minimum at the upstream end of the levee, tapering to not less than the minimum at the downstream end of the levee, is also required.

  The existing levee provides the minimum freeboard at all locations. The Girvan Road bridge may, however, be considered a constriction requiring 4-feet of freeboard for 100-feet upstream of the Girvan Road bridge. The existing levee does not provide 4-feet of freeboard 100-feet upstream of Girvan Road. The downstream end of the existing levee ties into high ground (existing ground elevation is higher than the Base Flood elevation). The upstream end of the levee is below the Base Flood water surface elevation and relies on the existing block flood wall for preventing overflow. The existing block wall ties into high ground. A summary of existing freeboard and minimum required freeboard during the existing condition Base Flood is presented in Table 3. This table reflects the highest top of levee elevations. At some cross-sections the lower top of levee elevation may not meet the minimum freeboard requirement and maintenance may be necessary to restore the top of levee to the minimum required.

Table 3: Existing and Minimum Freeboard

Cross-section	Base Flood WSEL (ft)	Top of Levee Elev. (ft)	Available Freeboard (ft)	Required Freeboard (ft)	Excess Freeboard (ft)
5235	454.27	458.94	4.67	3.50	1.17
5085	454.68	458.80	4.12	3.48	0.64
4715	453.58	457.12	3.54	3.42	0.12
4355	450.88	455.03	4.15	3.37	0.78
3925	450.16	454.69	4.53	3.31	1.22
3705	448.88	452.64	3.76	3.27	0.49
3005	446.21	450.78	4.57	3.17	1.40
1875	441.11	444.72	3.61	3.00	0.61

Implementation of either combination of improvements sufficient to prevent overflow at Sacramento Drive and contain the Base Flood within the Olney Creek flood channel will require slightly higher levee elevations and extend the location of the upstream tie in to high ground.

- Closures: [44 CFR §65.10(b)(2)]: All openings must be provided with closure devices that are structural parts of the system during operation and design (sic) according to sound engineering practice.

  Existing storm drains penetrating the levee are fitted with flap gates that should be sufficient to meet this requirement provided that the flap gates are maintained free of debris.

- Embankment Protection [44 CFR §65.10(b)(3)]: Engineering analysis must be submitted that demonstrate that no appreciable erosion of the levee embankment can be expected during the base flood, as a result of either currents or waves, and that anticipated erosion will not result in failure of the levee embankment or foundation directly or indirectly through reduction of the seepage path and subsequent instability.

  No engineering analysis has been prepared specifically to address this requirement. The backwater models prepared for this analysis are sufficient to evaluate flow velocities and previously prepared studies are sufficient to identify the duration of flooding. An engineering analysis specifically addressing the embankment protection requirement is necessary for levee accreditation.

- Embankment and Foundation Stability Analysis [44 CFR §65.10(b)(4)]: Engineering analyses that evaluate levee embankment stability must be submitted. The analyses shall evaluate expected seepage during loading conditions associated with the base flood and shall demonstrate that seepage into or through the levee foundation and embankment will not jeopardize embankment or foundation stability.

Embankment and foundation stability analyses have not been conducted for the existing levee and will need to be conducted for levee accreditation.

- Settlement [44 CFR §65.10(b)(5)]: Engineering analyses must be submitted that assess the potential and magnitude of future losses of freeboard as a result of levee settlement and demonstrate that freeboard will be maintained within the minimum standards set forth in paragraph (b)(1) of this section.

  Settlement analyses have not been conducted for the existing levee and will need to be conducted for levee accreditation.

- Interior Drainage [44 CFR §65.10(b)(6)]: An analysis must be submitted that identifies the source(s) of such flooding, the extent of the flooded area, and, if the average depth is greater than one foot, the water-surface elevation(s) of the base flood.

  No analysis of interior drainage has been conducted. Data and models prepared for this analysis are sufficient for evaluation of interior drainage when combined with previously prepared City of Redding rainfall-runoff models. An analysis specifically addressing the interior drainage requirements will be necessary for levee accreditation.

- Other Design Criteria [44 CFR §65.10(b)(7)]: FEMA may require that other design criteria and analyses be submitted to show that the levees provide adequate protection.

  Other design criteria or analyses for the levee are not known at present. If additional design criteria or analyses are identified by FEMA, they will need to be addressed for levee accreditation.

- Operation Plans and Criteria [44 CFR §65.10(c)]: For a levee system to be recognized, the operational criteria must be as described below. All closure devices or mechanical systems for internal drainage, whether manual or automatic, must be operated in accordance with an officially adopted operation manual, a copy of which must be provided to FEMA by the operator when levee or drainage system recognition is being sought or when the manual for a previously recognized system is revised in any manner. All operations must be under the jurisdiction of a Federal or State agency, an agency created by Federal or State law, or an agency of a community participating in the NFIP.

  No operation plans or criteria documents are known to exist for the existing levee. The block flood wall located at the north end of the existing levee and being relied upon for the upstream tie into high ground is on private property. A document identifying operation plans and criteria sufficient to meet the requirements of the CFR will need to be prepared for levee accreditation. Additionally necessary for accreditation, an agency of the City of Redding will need to be identified as responsible for operation of the facility and this agency will need to have an agreement with owners of private property where access is required for operation of the facility.

- Maintenance Plans and Criteria [44 CFR §65.10(d)]: For levee systems to be recognized as providing protection from the base flood, the maintenance criteria must be as described herein. Levee systems must be maintained in accordance with an officially

adopted maintenance plan, and a copy of this plan must be provided to FEMA by the owner of the levee system when recognition is being sought or when the plan for a previously recognized system in revised in any manner. All maintenance activities must be under the jurisdiction of a Federal or State agency, an agency created by Federal or State law, or an agency of a community participating in the NFIP that must assume ultimate responsibility for maintenance.

No maintenance plan and criteria documents are known to exist for the existing levee. The block flood wall located at the north end of the existing levee and being relied upon for the upstream tie into high ground is on private property. A document identifying maintenance plans and criteria sufficient to meet the requirements of the CFR will need to be prepared for levee accreditation. Additionally necessary for accreditation, an agency of the City of Redding will need to be identified as responsible for maintenance of the facility and this agency will need to have an agreement with owners of private property where access is required for maintenance of the facility.

Photo 1: Olney Creek Flow over Sacramento Drive During Flood of December 23, 1964

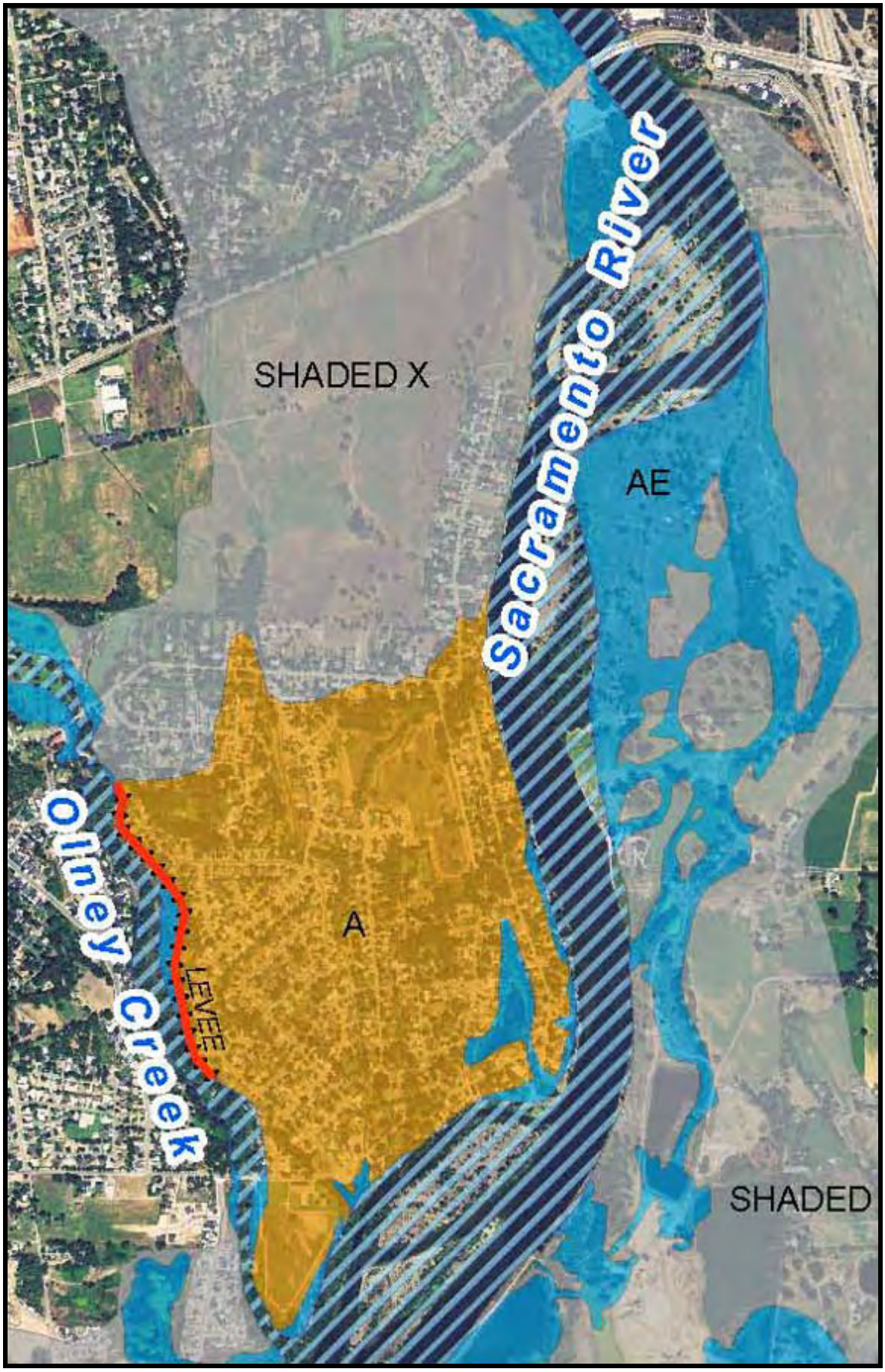


Figure 1: Proposed FEMA SFHA East of Olney Creek Levee

Figure 2: Location of Levees Being Relied Upon for Base Flood Protection

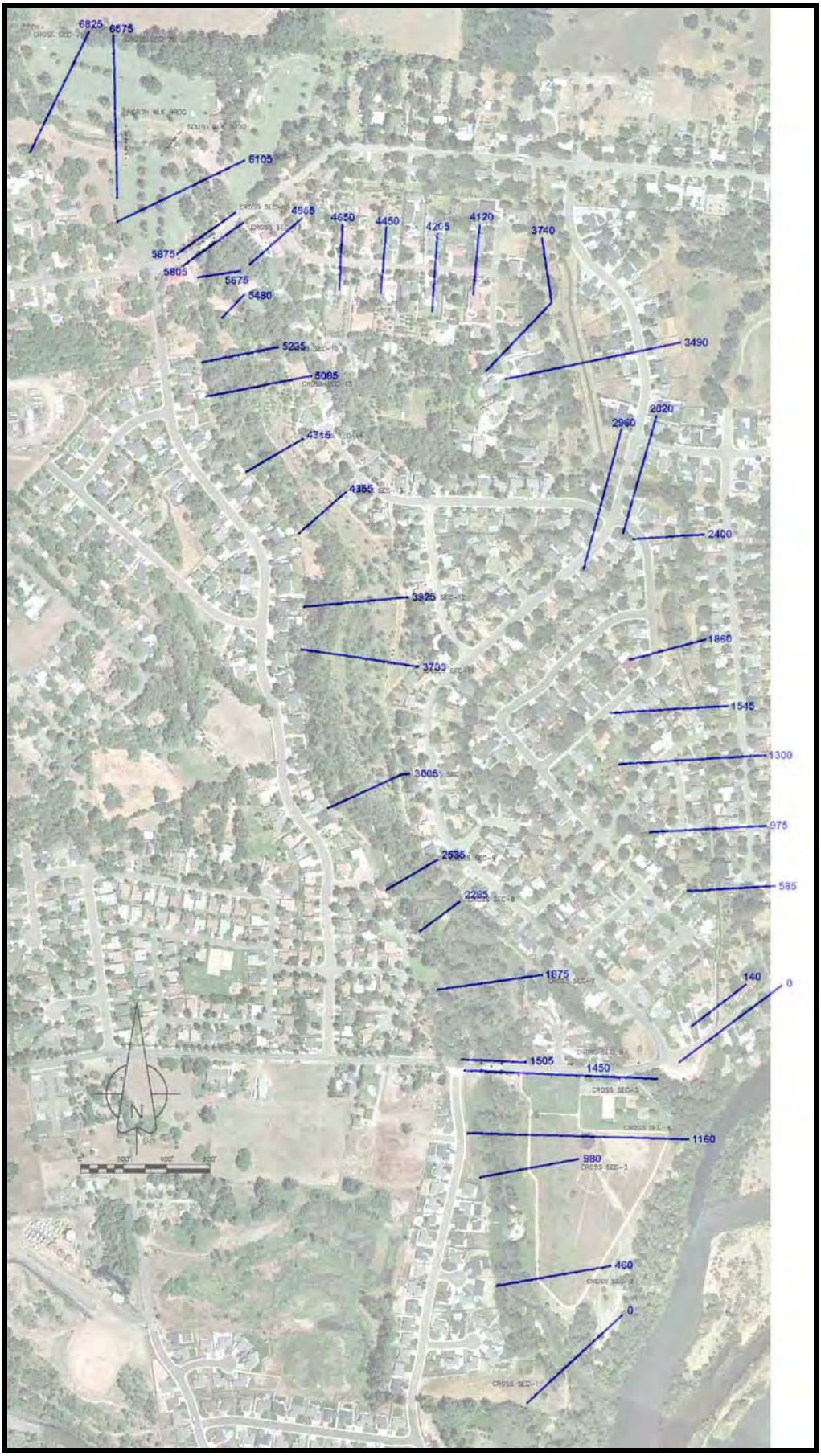


Figure 3: Locations of Backwater Model Cross-sections

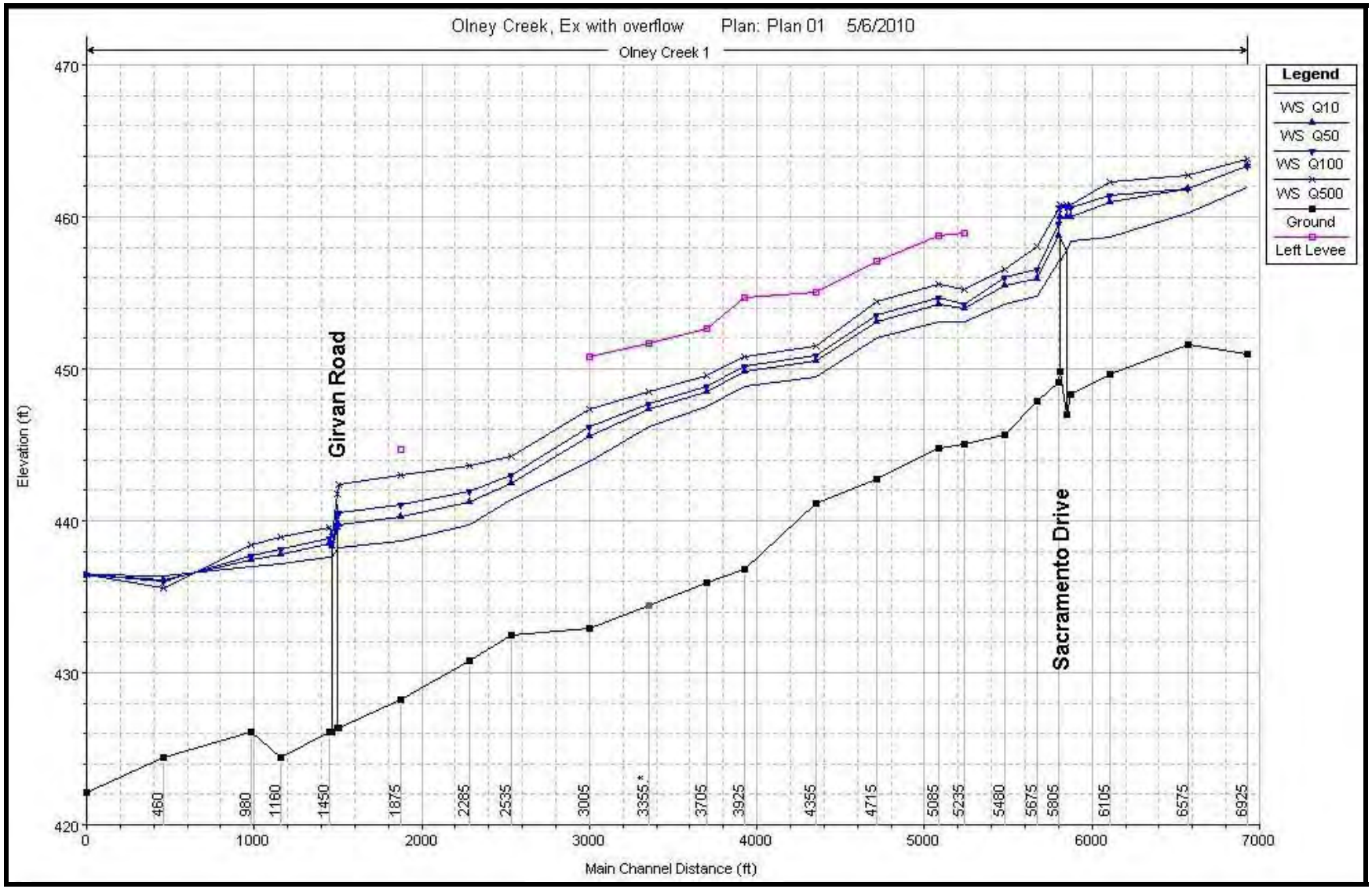


Figure 4: Olney Creek Flood Profiles

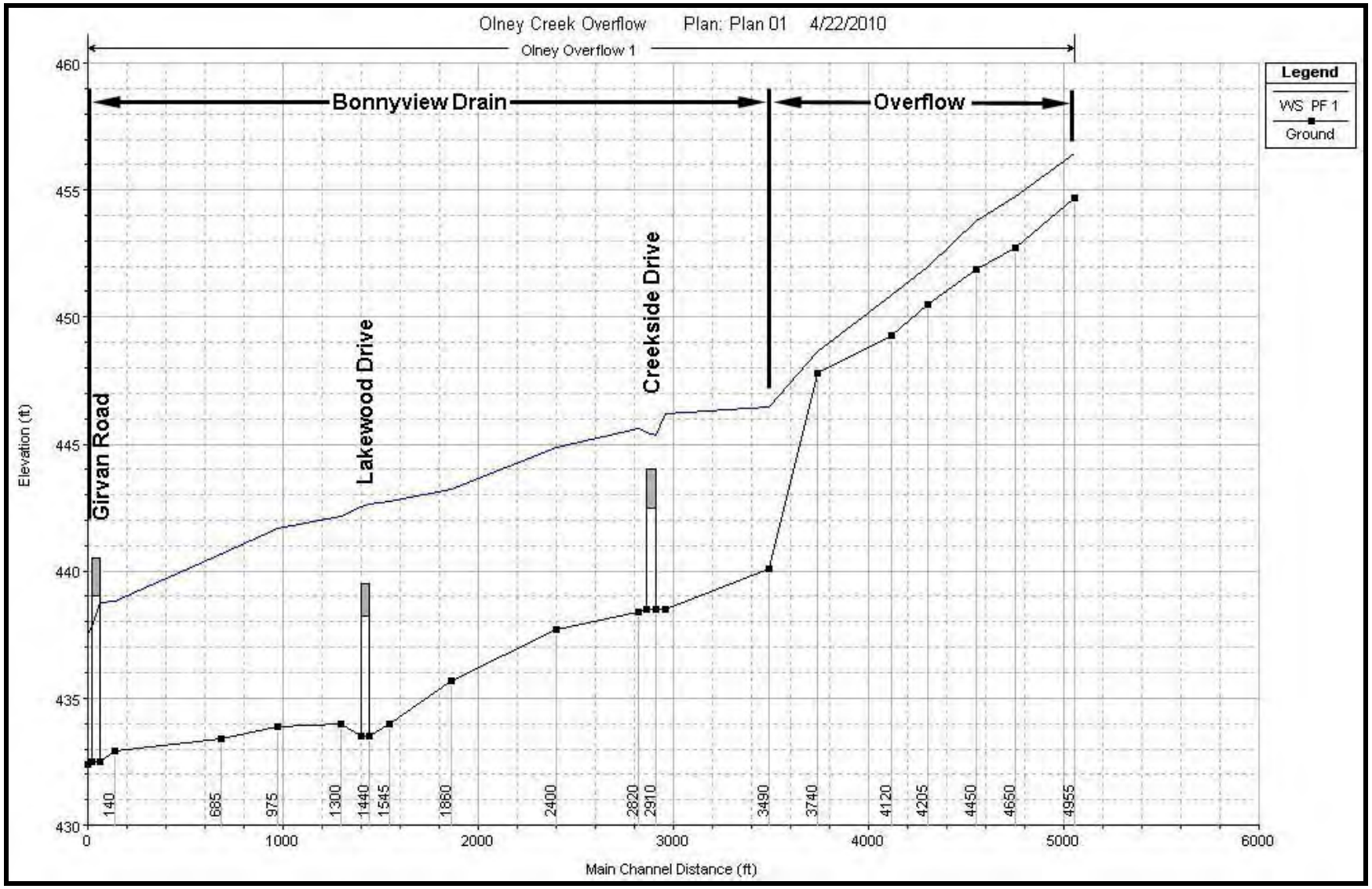


Figure 5: Overflow Path Base Flood Profile

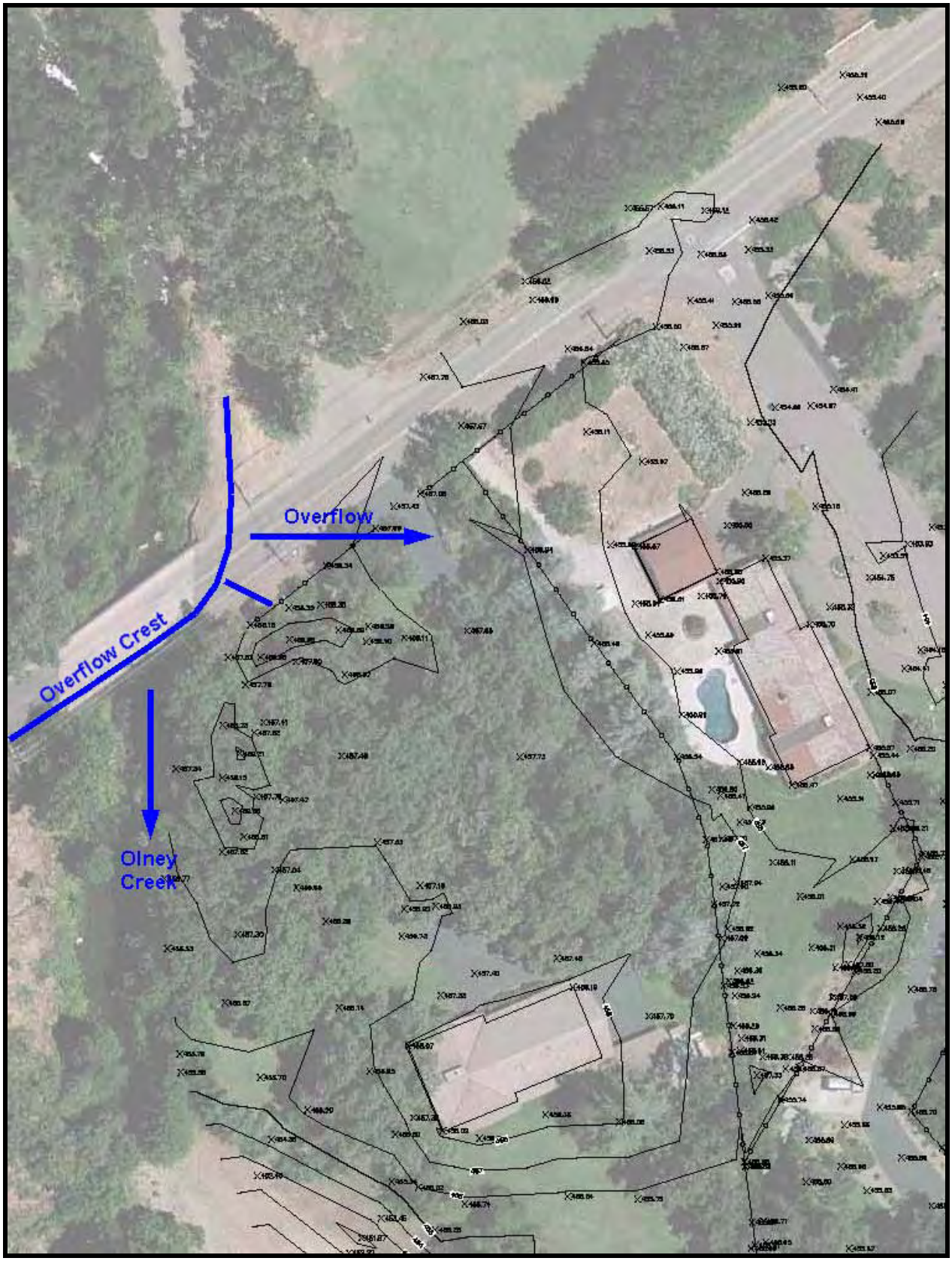


Figure 6: Location of Overflow Crest at Sacramento Drive

Plan: Plan 01 Olney Creek 1 RS: 5848 Profile: Q100

E.G. US. (ft)	461.37	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	460.65	E.G. Elev (ft)	461.37	461.13
Q Total (cfs)	5457.00	W.S. Elev (ft)	460.65	460.65
Q Bridge (cfs)	4209.15	Crit W.S. (ft)	455.65	456.87
Q Weir (cfs)	1247.85	Max Chl Dpth (ft)	13.59	10.84
Weir Sta Lft (ft)	79.35	Vel Total (ft/s)	6.47	5.26
Weir Sta Rgt (ft)	234.97	Flow Area (sq ft)	843.70	1037.99
Weir Submerg	0.14	Froude # Chl	0.36	0.49
Weir Max Depth (ft)	2.49	Specif Force (cu ft)	5168.01	4647.75
Min El Weir Flow (ft)	459.35	Hydr Depth (ft)	5.42	7.18
Min El Prs (ft)	457.82	W.P. Total (ft)	330.35	316.40
Delta EG (ft)	0.57	Conv. Total (cfs)		
Delta WS (ft)	1.10	Top Width (ft)	234.97	244.60
BR Open Area (sq ft)	484.91	Frctn Loss (ft)		
BR Open Vel (ft/s)	8.68	C & E Loss (ft)		
Coef of Q		Shear Total (lb/sq ft)		
Br Sel Method	Press/Weir	Power Total (lb/ft s)		

Figure 7: HEC-RAS Bridge Output Table Showing
Base Flood Water Surface Elevation and Total Weir Flow

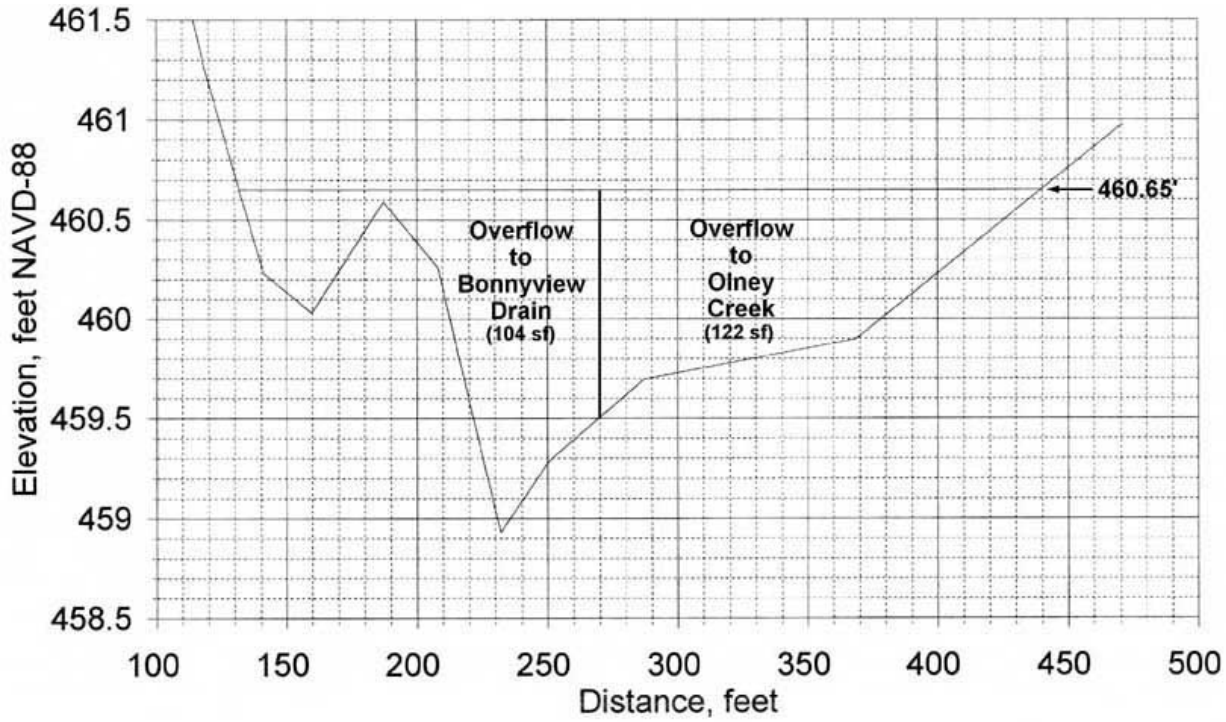


Figure 8: Overflow Crest Profile and Areas Under Base Flood Water Surface Elevation

Overflow = 1250-cfs x 104-sf / (104-sf + 122-sf) = 575-cfs
586-cfs used from prior iteration (minor correction subsequent)

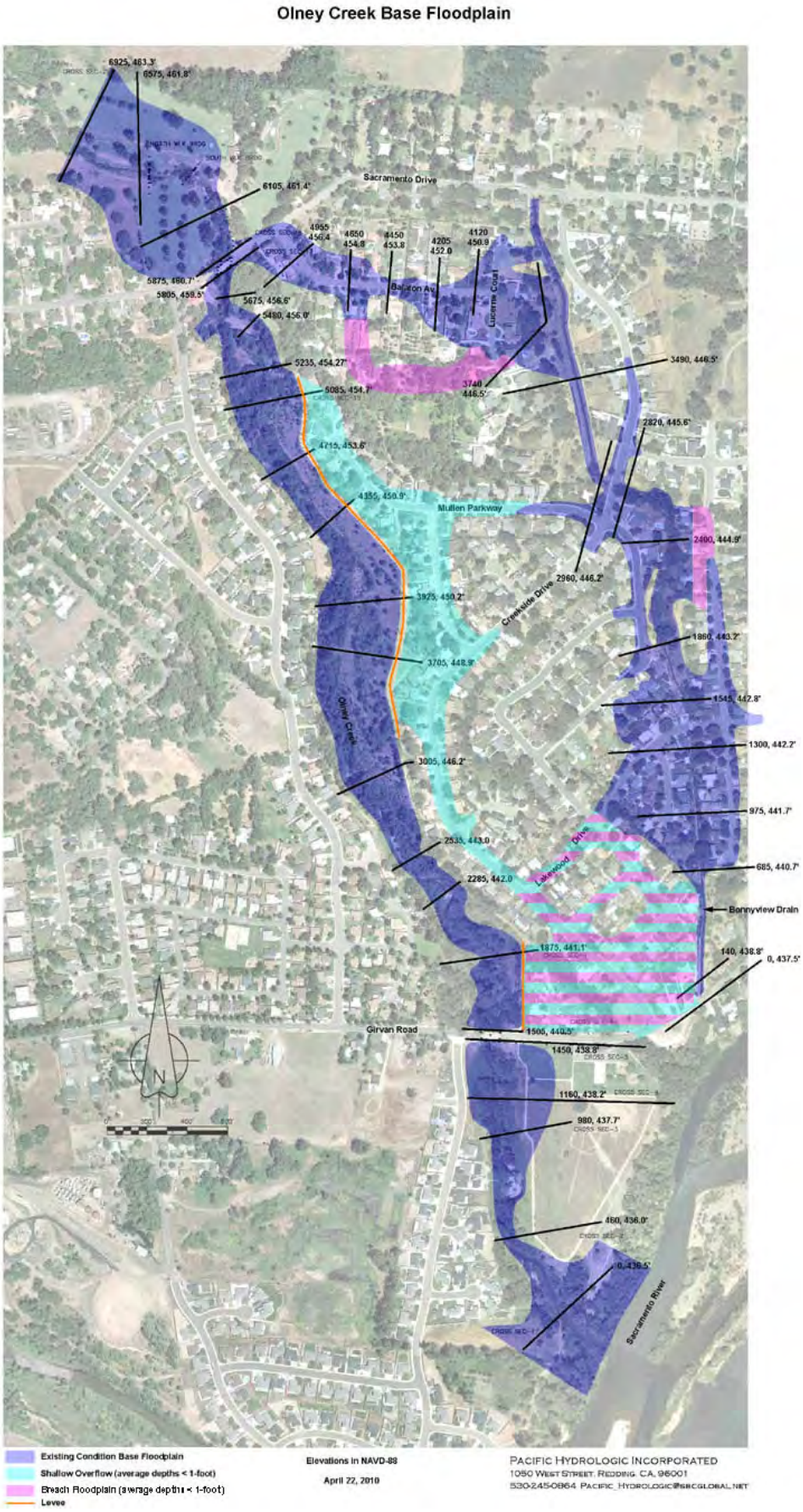


Figure 9: Existing Olney Creek SFHA

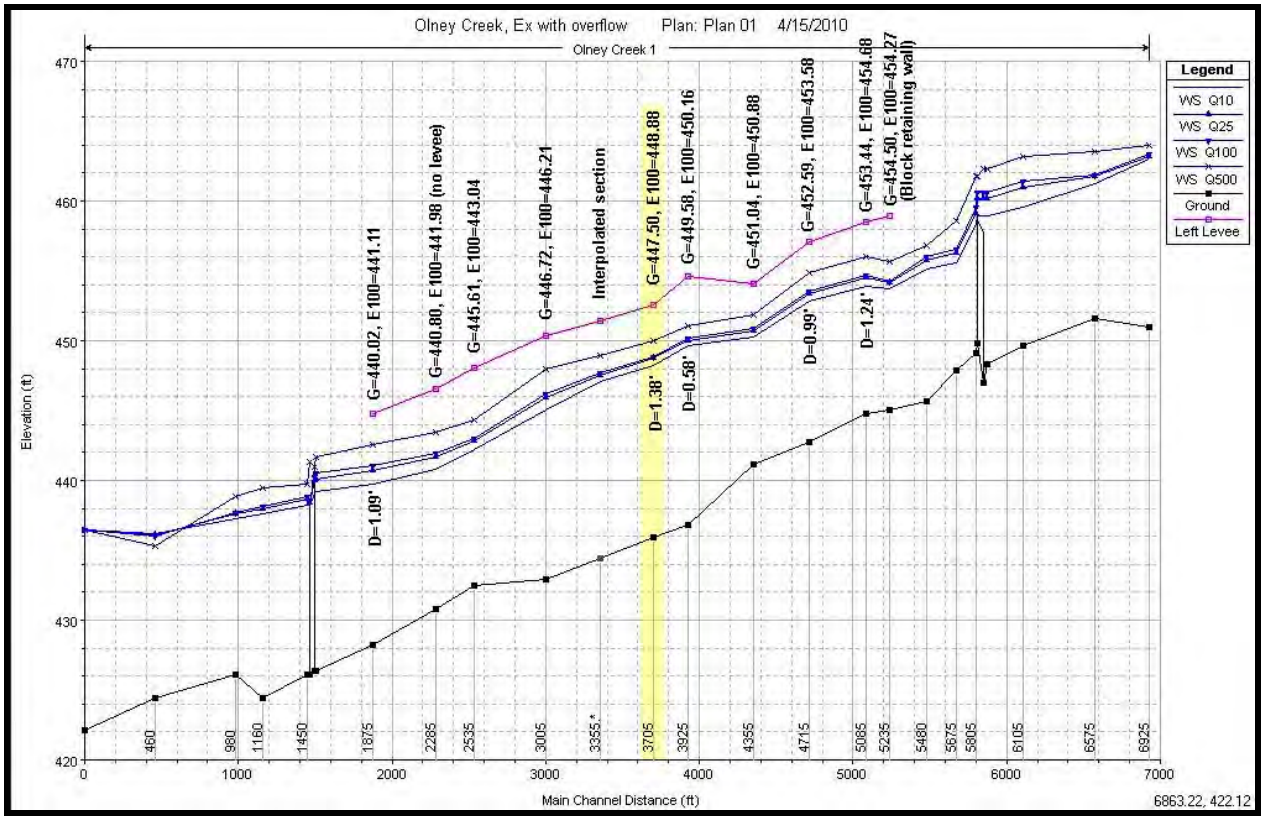


Figure 10: Difference in Elevation between Base Flood Water Surface and Ground Behind Levee
G = Ground Elevation, E = Base Flood Water Surface Elevation, D = Difference

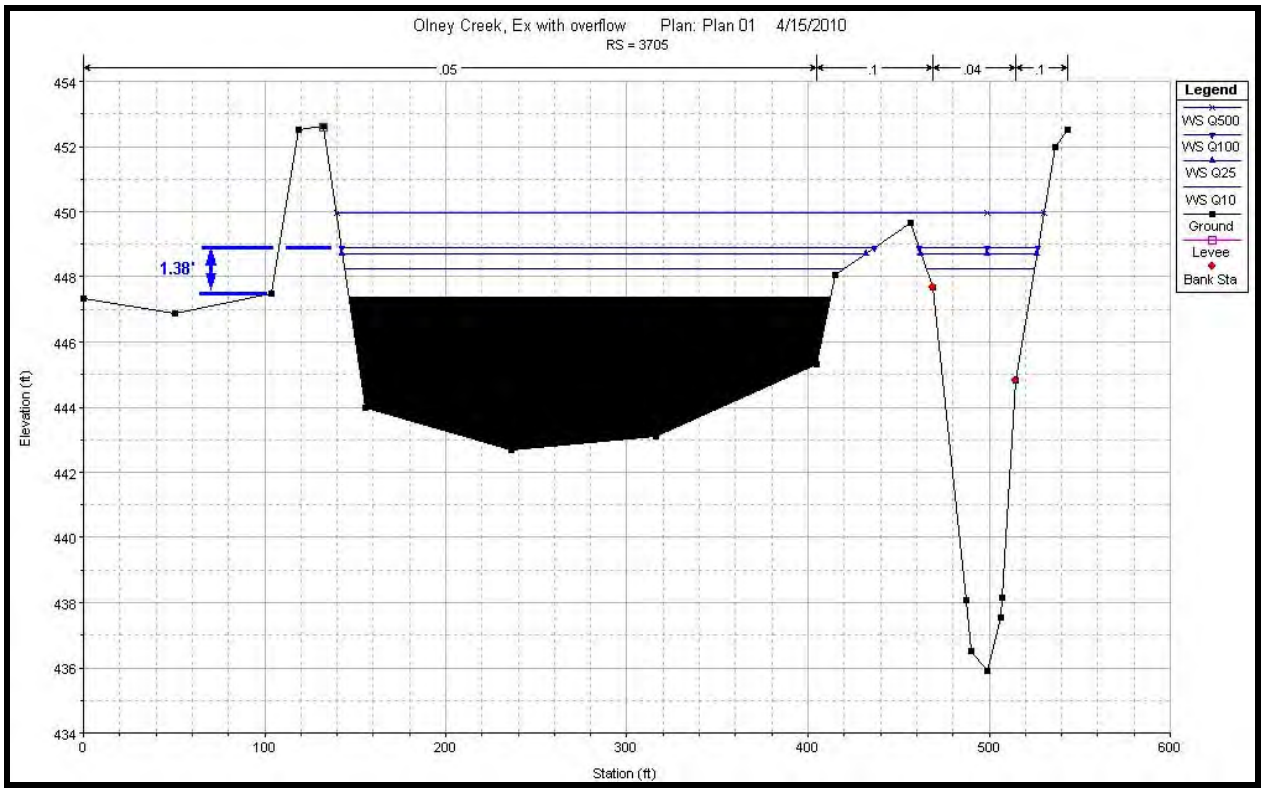


Figure 11: Cross-section 3705 Showing Difference in Elevation

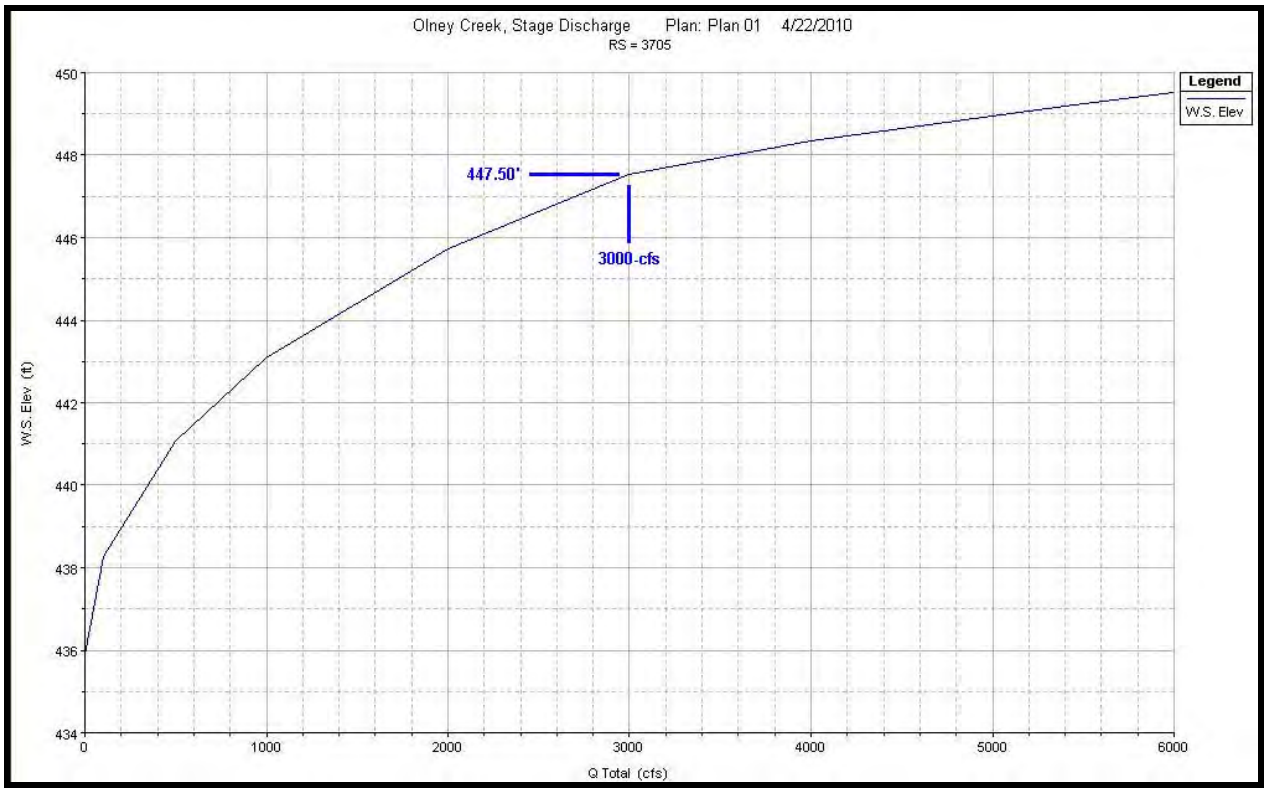


Figure 12: Stage Discharge Curve at Cross-section 3705 Identifying Flow at Ground Elevation

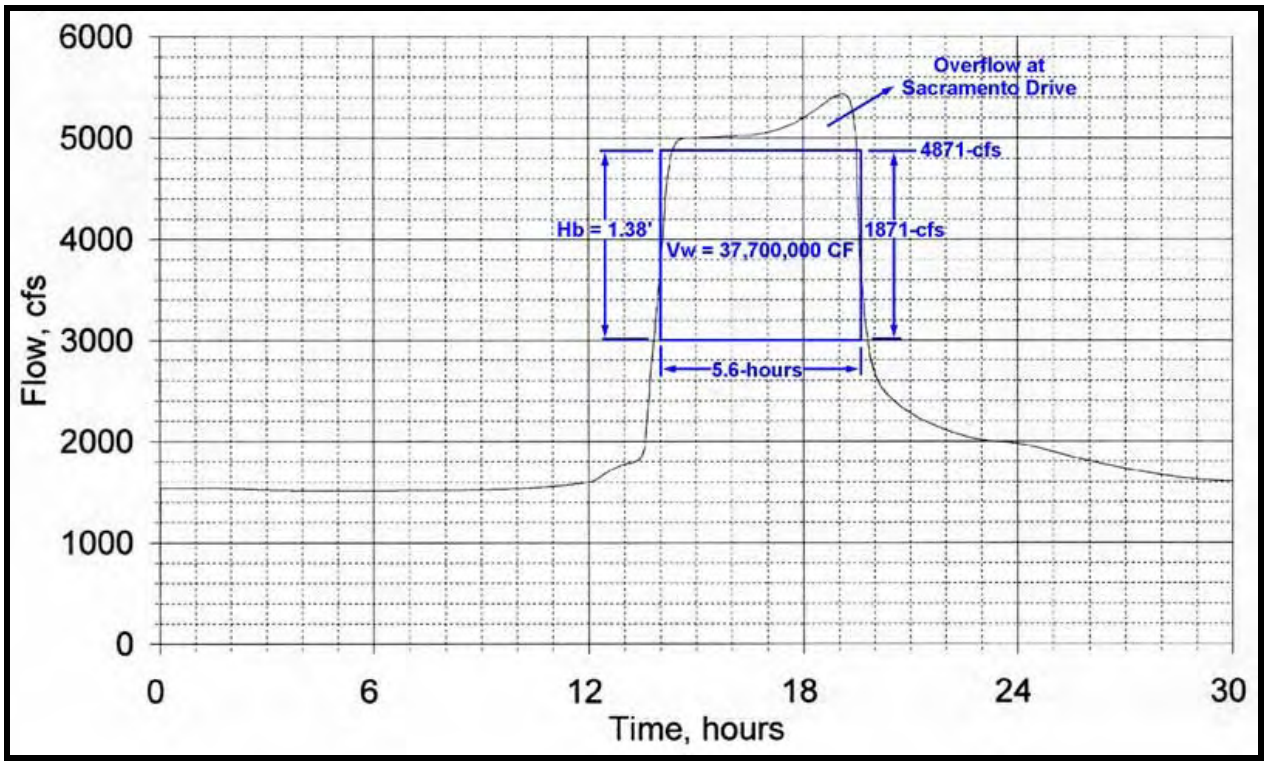


Figure 13: City of Redding Base Flood Hydrograph (Consistent with FEMA)

Froehlich Breach Width Equation:
(***Journal of Hydraulic Engineering***, Vol. 134, No. 12, December 1, 2008)

$B = 0.27(Ko)(Vw)^{0.32}(Hb)^{0.04}$

Ko = 1.0 (piping failure)

Vw = 37,000,000 cubic feet

Hb = 1.38 feet

$B = 0.27(1.0)(37{,}000{,}000)^{0.32}(1.38)^{0.04} = <75\text{-feet}$

Overflow using broad crest weir equation:

$\text{Overflow} = CLH^{3/2}$

C = 2.0

L = 75-feet

H = 1.38-feet

$\text{Overflow} = (2.0)(75)(1.38)^{3/2} = <250\text{-cfs}$

Figure 14: Breach Width and Weir Flow Computations

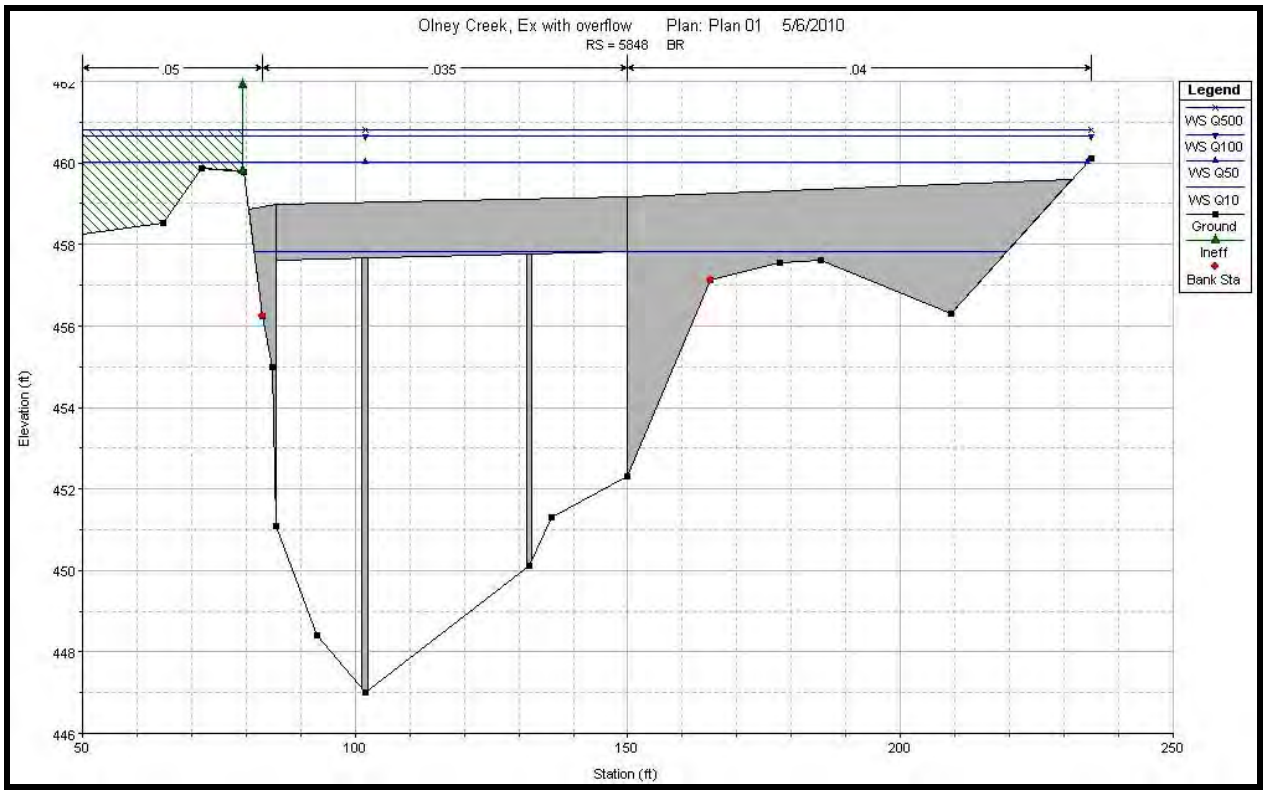


Figure 15: Sacramento Drive Bridge Cross-section, Existing Condition

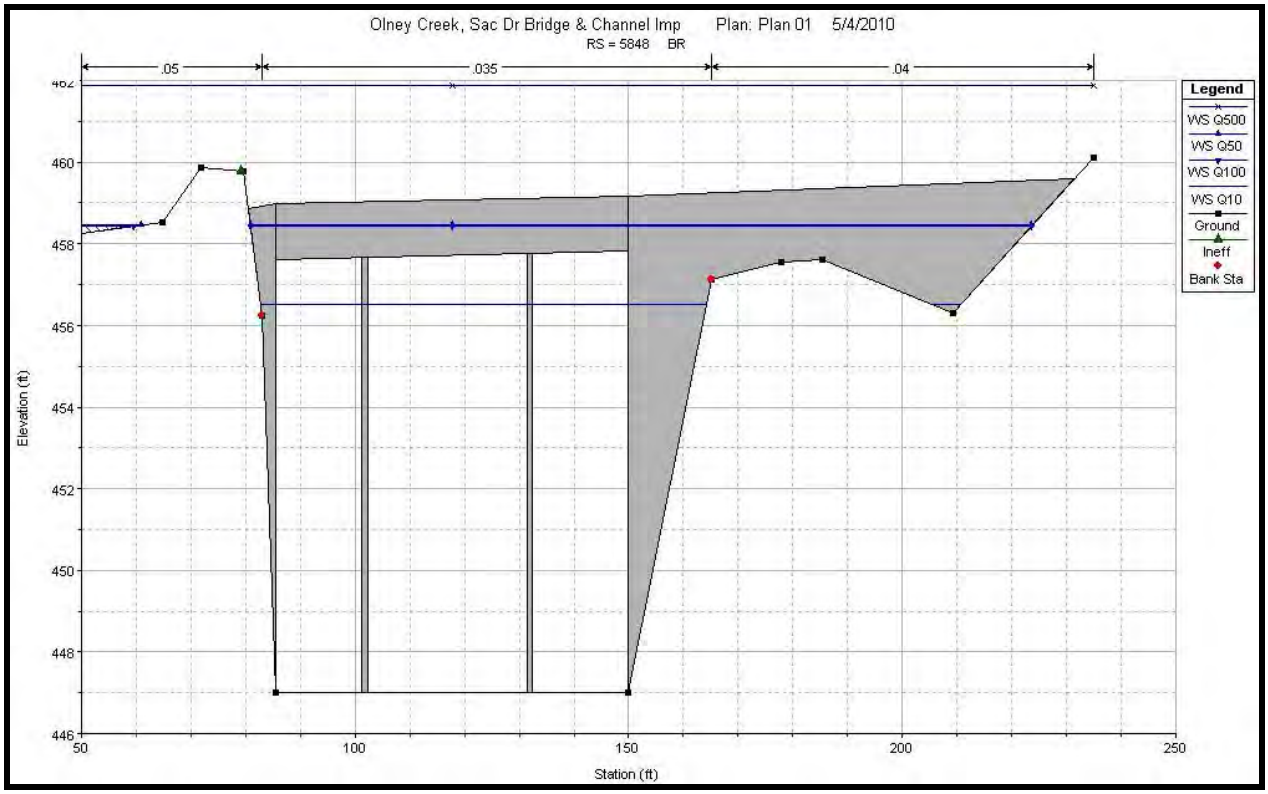


Figure 16: Sacramento Drive Bridge Cross-section, Open Channel Under Bridge

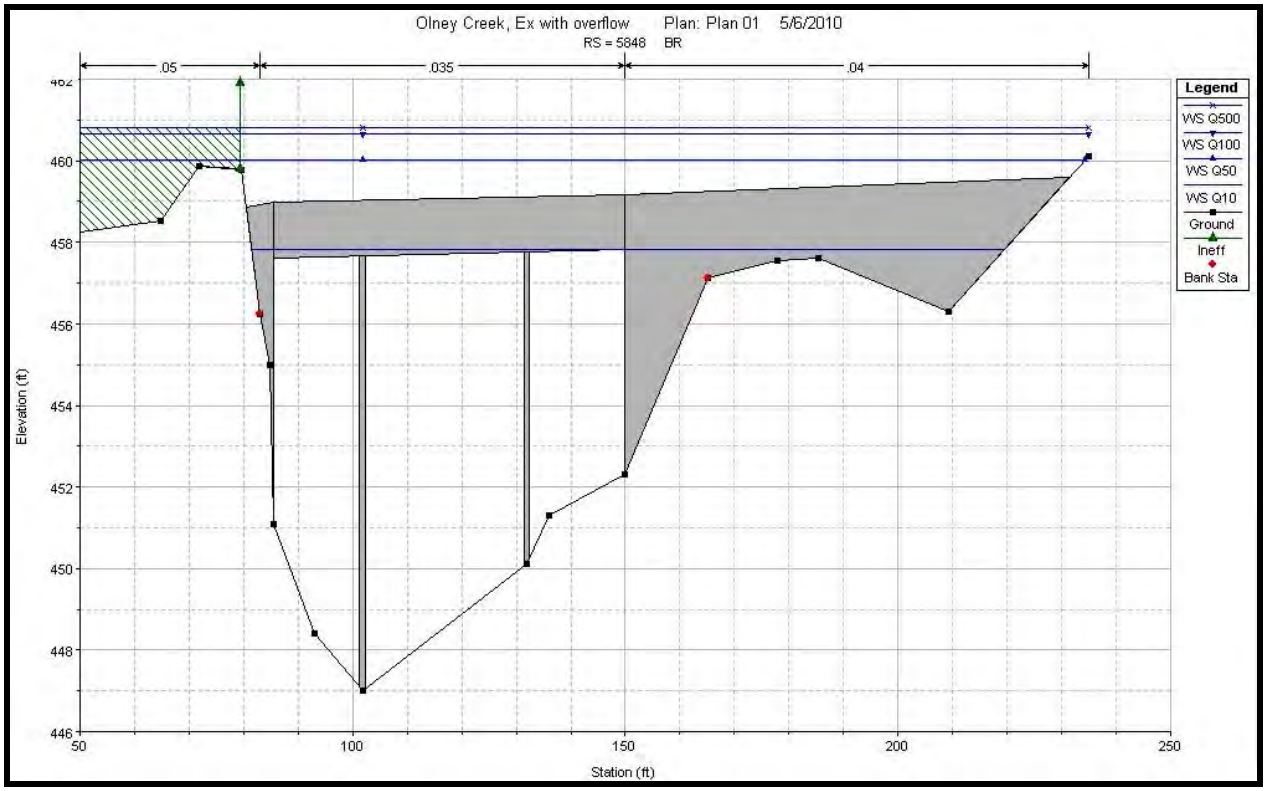


Figure 17: Sacramento Drive Bridge Cross-section, Existing Condition

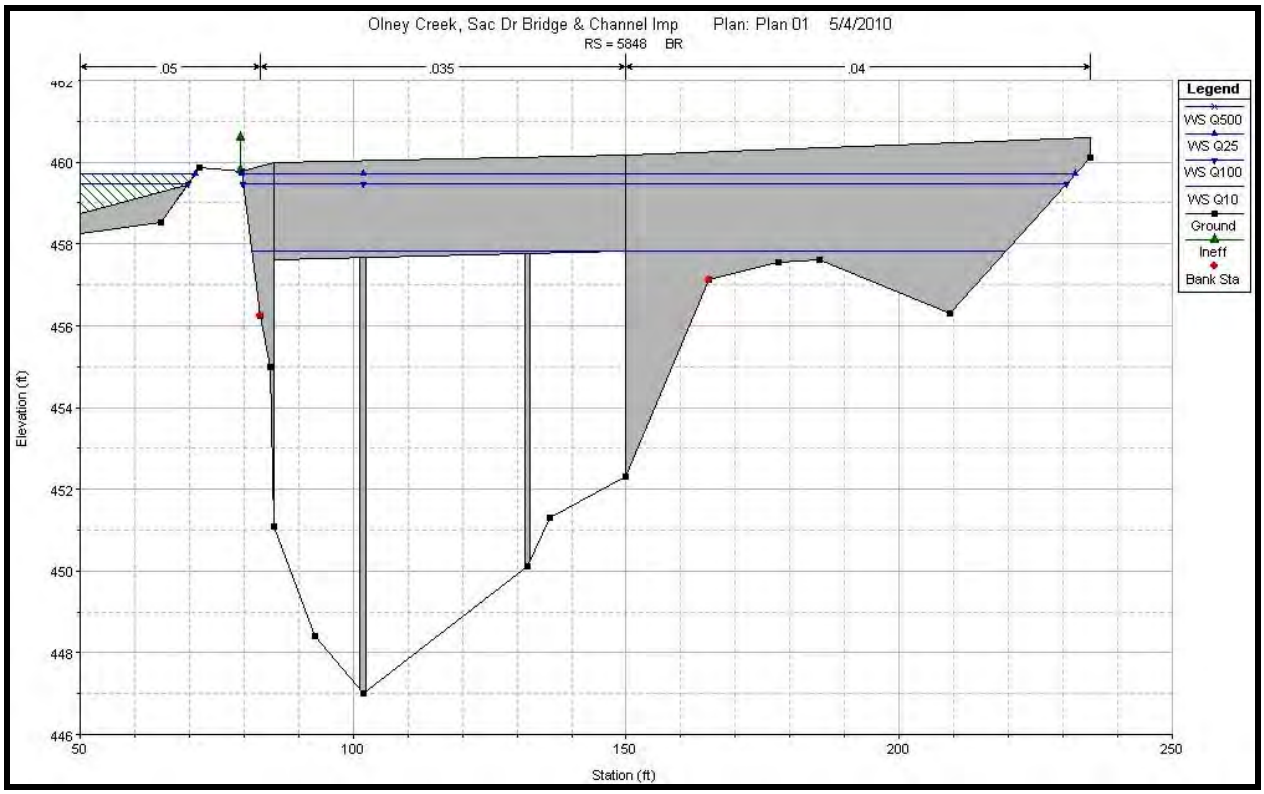


Figure 18: Sacramento Drive Bridge Cross-section, Raise Deck 1.0-foot

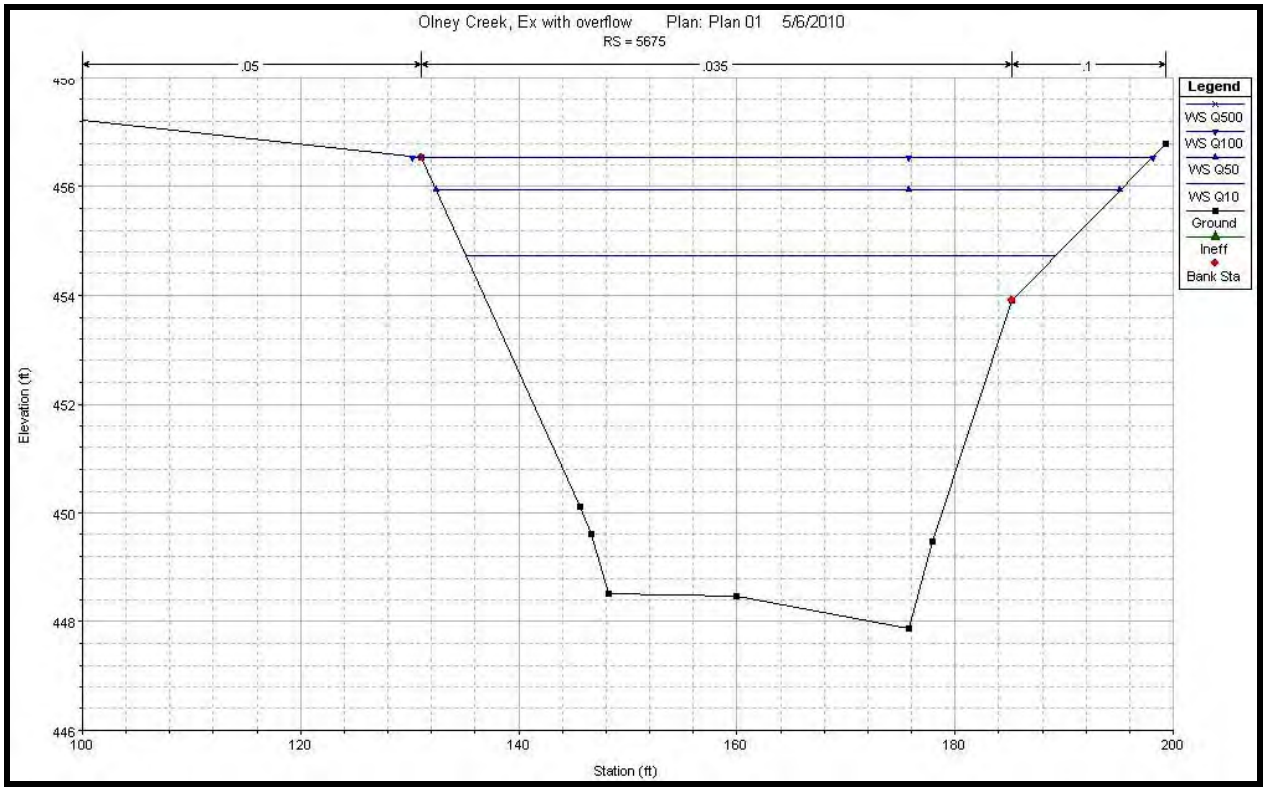


Figure 19: Cross-section 3705, Existing Condition

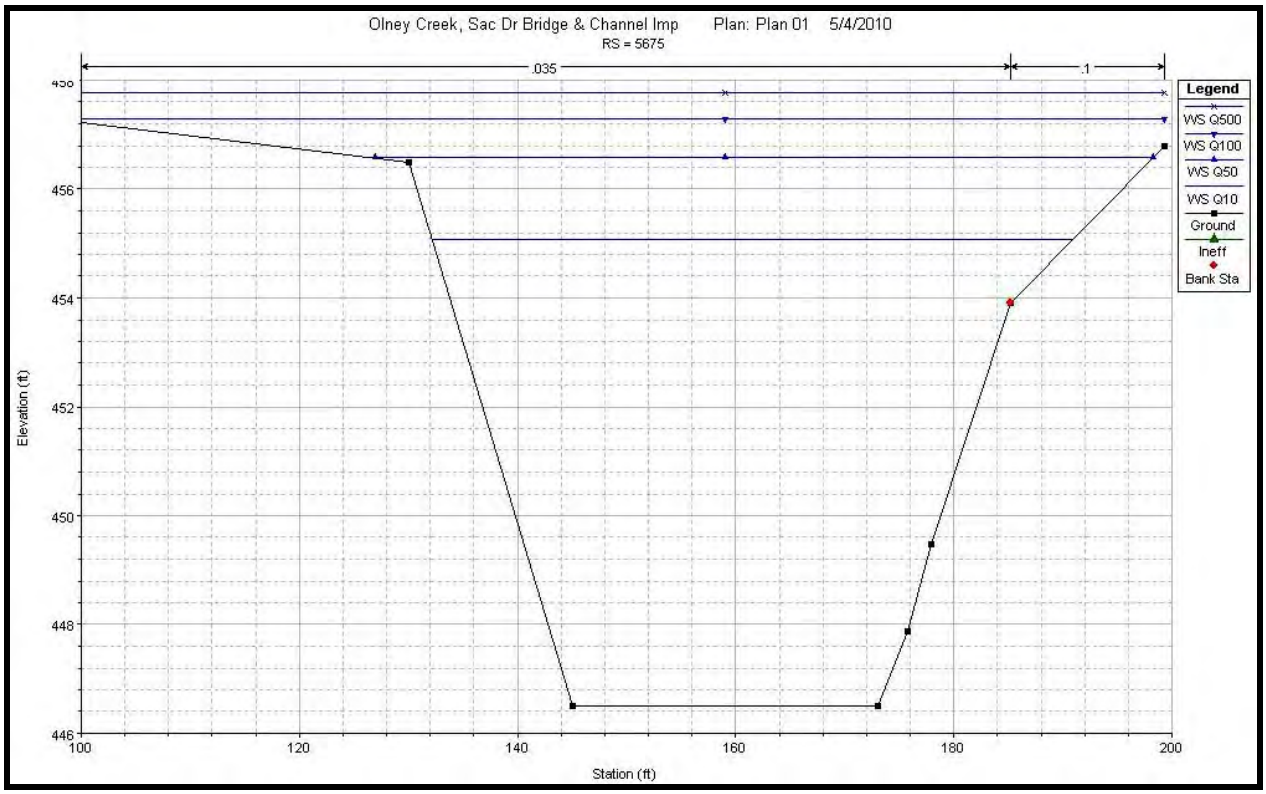


Figure 20: Cross-section 3705, Channel Improvement

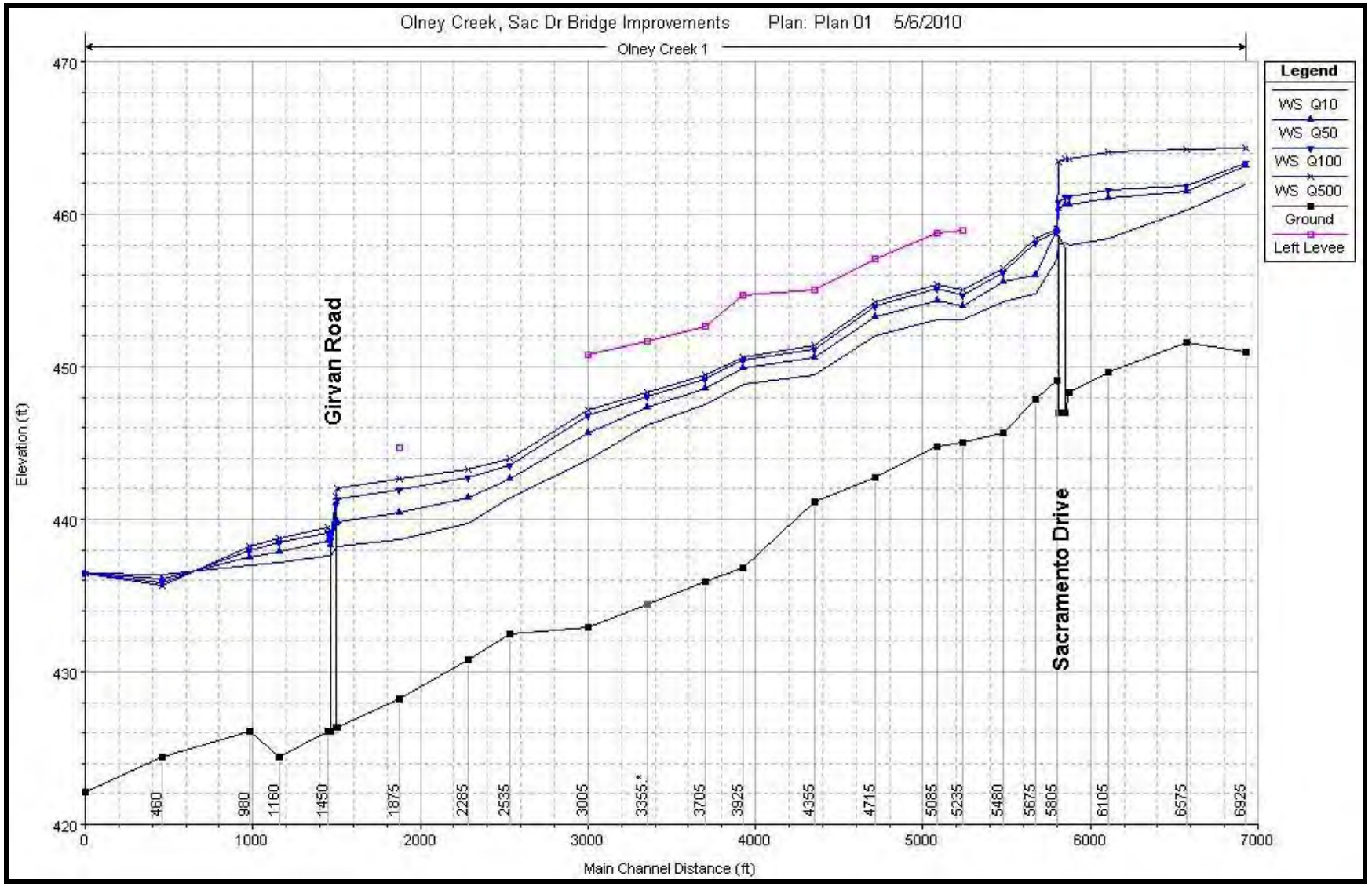


Figure 21: Olney Creek Flood Profiles, Open Channel Under Sacramento Drive Bridge

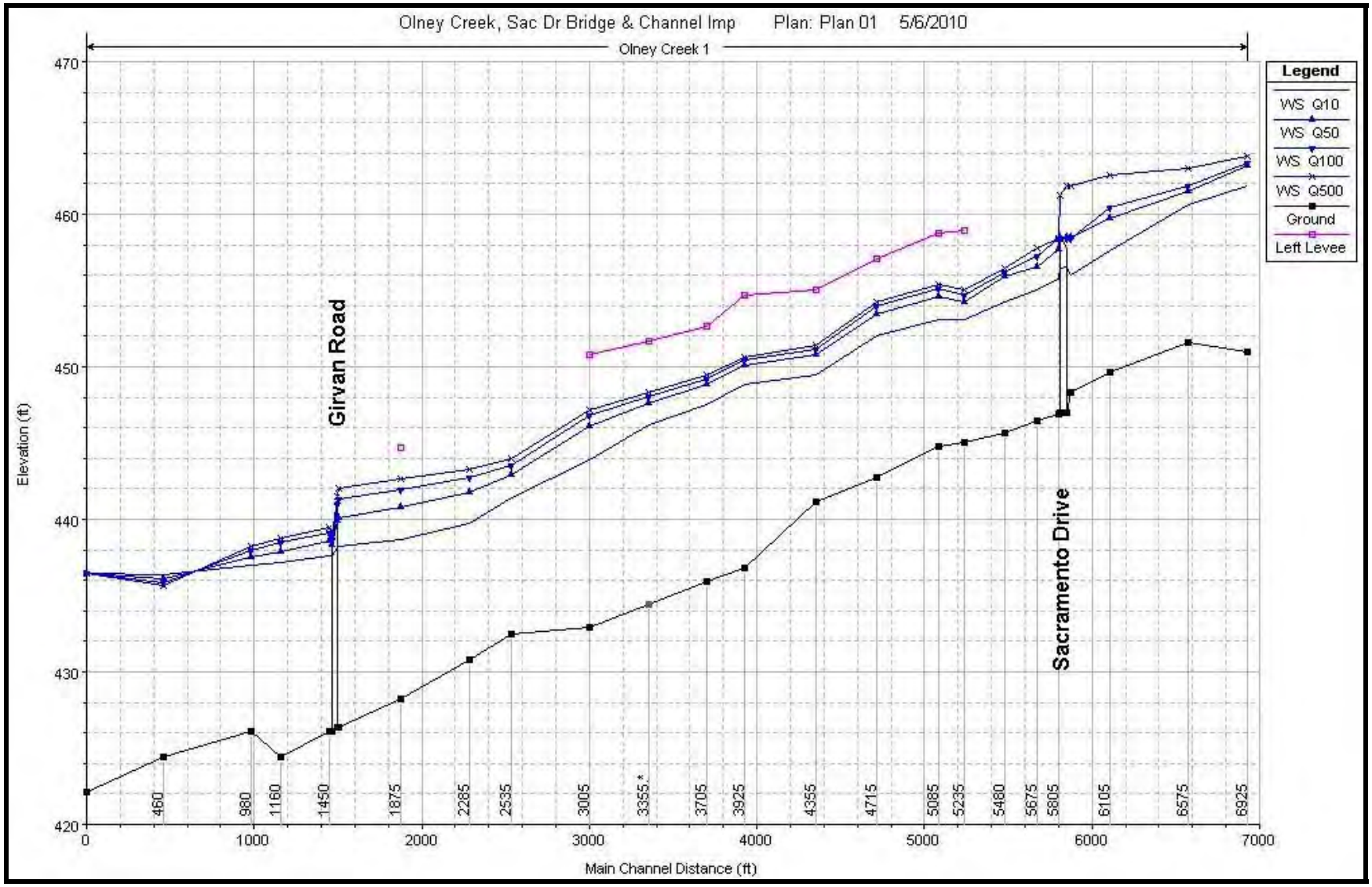


Figure 22: Olney Creek Flood Profiles, Open Channel Under Sacramento Drive Bridge Plus Channel Improvement

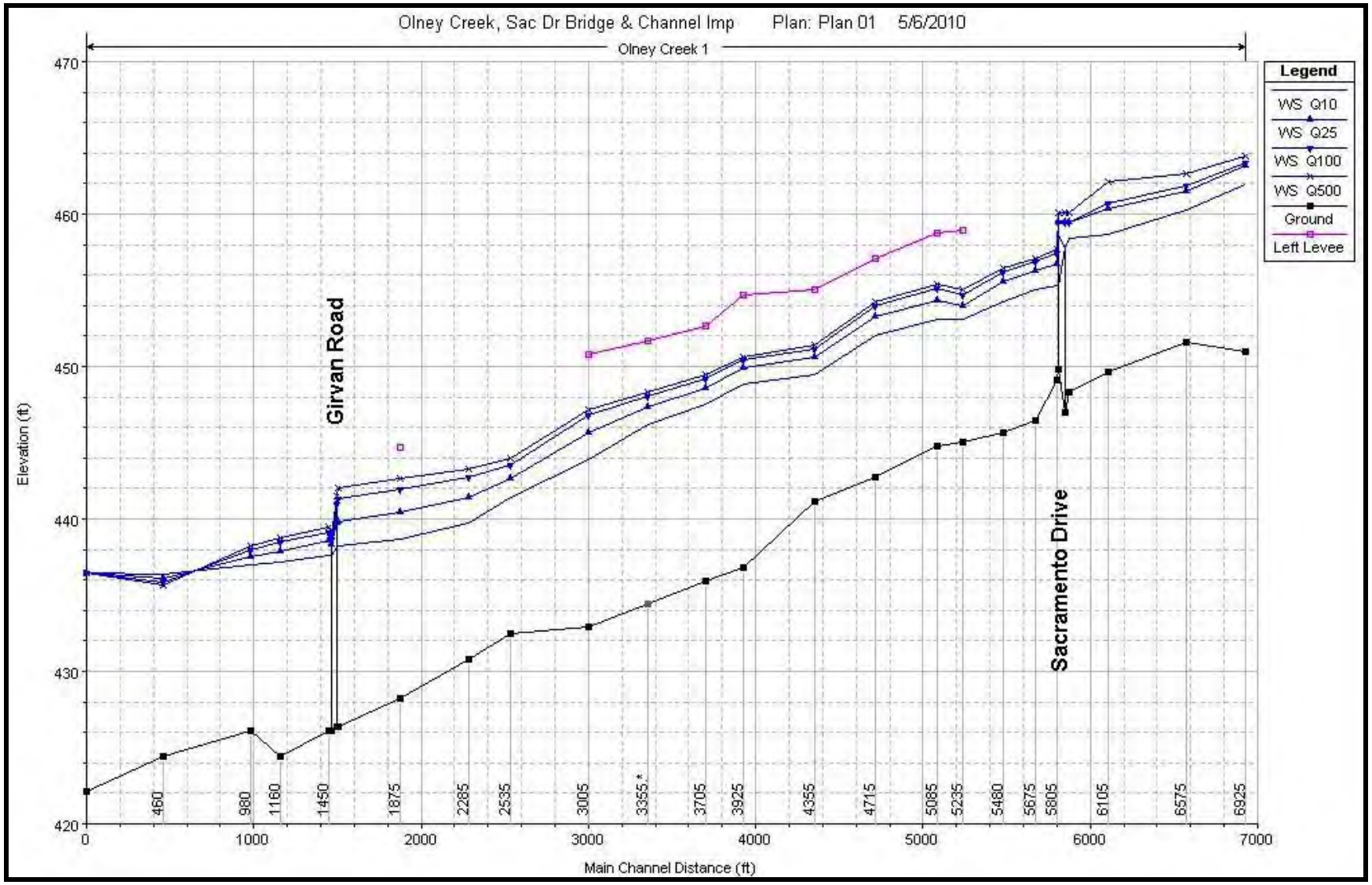


Figure 23: Olney Creek Flood Profiles, Raise Sacramento Drive Deck 1.0-foot Plus Channel Improvement

Appendix A

Additional Hydraulic Data

Backwater Model Summary Output: Existing Condition with Overflow, Page 1

HEC-RAS Plan: Plan 01 River: Olney Creek Reach: 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	6925	Q10	3000	450.97	461.95	460.77	463.33	0.005676	9.47	331.67	262.00	0.71
1	6925	Q50	5438	450.97	463.34	463.34	464.11	0.003573	8.69	1141.82	618.34	0.58
1	6925	Q100	5438	450.97	463.34	463.34	464.11	0.003573	8.69	1141.82	618.34	0.58
1	6925	Q500	7700	450.97	463.79	463.79	464.69	0.004221	9.86	1423.90	619.21	0.64
1	6575	Q10	3000	451.57	460.24	458.69	461.45	0.004822	8.89	379.36	271.34	0.66
1	6575	Q50	5438	451.57	461.83	461.83	462.58	0.003134	8.36	1210.33	736.09	0.55
1	6575	Q100	5438	451.57	461.83	461.83	462.58	0.003134	8.36	1210.33	736.09	0.55
1	6575	Q500	7700	451.57	462.78	462.29	463.27	0.002164	7.56	1972.21	852.15	0.47
1	6105	Q10	3000	449.66	458.67	456.62	459.57	0.003210	7.91	472.81	342.78	0.55
1	6105	Q50	5438	449.66	461.00	459.99	461.40	0.001380	6.38	1442.78	571.75	0.38
1	6105	Q100	5438	449.66	461.43	459.99	461.72	0.000987	5.57	1636.88	574.67	0.33
1	6105	Q500	7700	449.66	462.34	460.57	462.67	0.001046	6.12	2054.72	580.96	0.34
1	5875	Q10	3000	448.31	458.37	455.41	458.93	0.001753	6.13	557.41	198.82	0.41
1	5875	Q50	5438	448.31	460.02	458.00	460.93	0.002338	8.16	801.37	234.26	0.49
1	5875	Q100	5457	448.31	460.65	458.02	461.37	0.001726	7.36	899.23	234.97	0.43
1	5875	Q500	7700	448.31	460.81	459.31	462.17	0.003186	10.11	924.30	234.97	0.58
1	5848		Bridge									
1	5805	Q10	3000	449.13	457.05	455.32	458.10	0.004001	8.22	364.83	100.84	0.60
1	5805	Q50	4270	449.13	458.79	456.46	460.03	0.003483	8.97	489.95	208.70	0.58
1	5805	Q100	4871	449.13	459.54	456.96	460.80	0.003185	9.12	620.20	228.99	0.56
1	5805	Q500	6140	449.13	460.52	457.94	462.04	0.003353	10.09	754.88	244.60	0.59
1	5675	Q10	3000	447.87	454.73	454.55	456.96	0.010110	11.98	251.95	54.05	0.94
1	5675	Q50	4270	447.87	455.93	455.93	458.81	0.010511	13.64	321.93	62.66	0.99
1	5675	Q100	4871	447.87	456.55	456.55	459.59	0.010093	14.04	361.75	87.57	0.98
1	5675	Q500	6140	447.87	458.01	458.01	460.98	0.007641	14.03	499.62	199.32	0.88
1	5480	Q10	3000	445.66	454.23		455.41	0.004430	9.70	418.42	100.11	0.62
1	5480	Q50	4270	445.66	455.46		456.85	0.004707	10.83	549.27	111.86	0.65
1	5480	Q100	4871	445.66	456.03		457.47	0.004673	11.15	614.46	117.21	0.65
1	5480	Q500	6140	445.66	456.52		458.45	0.006040	13.02	674.23	125.55	0.74
1	5235	Q10	3000	445.01	453.12	451.58	454.11	0.005791	7.99	375.34	100.02	0.62
1	5235	Q50	4270	445.01	453.95	452.70	455.42	0.007156	9.75	449.07	154.76	0.71
1	5235	Q100	4871	445.01	454.27	453.17	455.98	0.007746	10.51	489.55	213.71	0.74
1	5235	Q500	6140	445.01	455.22	454.26	456.80	0.006473	10.56	863.03	327.54	0.70
1	5085	Q10	3000	444.77	453.10	450.53	453.38	0.002289	4.48	837.59	287.63	0.35
1	5085	Q50	4270	444.77	454.22	451.53	454.53	0.002195	4.84	1253.70	336.47	0.34
1	5085	Q100	4871	444.77	454.68	451.84	455.00	0.002176	5.00	1410.33	341.24	0.34
1	5085	Q500	6140	444.77	455.56	452.42	455.91	0.002157	5.32	1714.18	350.29	0.34
1	4715	Q10	3000	442.76	452.04	449.81	452.44	0.002930	5.42	655.47	193.26	0.40
1	4715	Q50	4270	442.76	453.13	450.85	453.60	0.003022	5.98	870.07	199.57	0.41
1	4715	Q100	4871	442.76	453.58	451.19	454.07	0.003070	6.22	959.19	202.13	0.42
1	4715	Q500	6140	442.76	454.41	451.88	454.97	0.003174	6.69	1129.60	207.33	0.43
1	4355	Q10	3000	441.12	449.51	449.31	450.85	0.006464	9.79	401.04	153.11	0.66
1	4355	Q50	4270	441.12	450.52	450.30	451.97	0.006612	10.68	562.16	175.00	0.68
1	4355	Q100	4871	441.12	450.88	450.71	452.41	0.006819	11.17	627.87	187.18	0.69
1	4355	Q500	6140	441.12	451.52	451.36	453.23	0.007261	12.12	748.40	190.15	0.72
1	3925	Q10	3000	436.80	448.85	444.73	449.29	0.001679	5.55	716.81	313.94	0.35
1	3925	Q50	4270	436.80	449.84	445.94	450.30	0.001783	6.07	1059.42	375.53	0.36
1	3925	Q100	4871	436.80	450.16	446.47	450.65	0.001876	6.36	1183.42	386.79	0.37
1	3925	Q500	6140	436.80	450.76	447.51	451.30	0.002053	6.90	1419.41	404.57	0.39
1	3705	Q10	3000	435.90	447.54	444.67	448.67	0.004153	8.57	405.47	320.76	0.55
1	3705	Q50	4270	435.90	448.52	446.33	449.64	0.004150	9.24	726.64	345.84	0.56
1	3705	Q100	4871	435.90	448.88	447.03	449.98	0.004066	9.41	856.59	359.74	0.56
1	3705	Q500	6140	435.90	449.59	449.24	450.61	0.003823	9.60	1120.86	386.49	0.55
1	3355.*	Q10	3000	434.41	446.16	443.27	447.18	0.004184	8.24	441.20	261.77	0.54
1	3355.*	Q50	4270	434.41	447.32	444.94	448.23	0.003755	8.44	753.92	287.28	0.52
1	3355.*	Q100	4871	434.41	447.66	445.52	448.60	0.003797	8.73	857.05	304.62	0.53
1	3355.*	Q500	6140	434.41	448.48	447.59	449.35	0.003452	8.85	1121.95	340.91	0.51
1	3005	Q10	3000	432.93	443.93	441.94	445.36	0.006382	9.58	313.56	61.50	0.65
1	3005	Q50	4270	432.93	445.53	443.58	446.71	0.005150	9.32	621.61	214.64	0.60
1	3005	Q100	4871	432.93	446.21	445.52	447.20	0.004398	8.89	770.51	229.75	0.56
1	3005	Q500	6140	432.93	447.37	446.16	448.18	0.003419	8.48	1077.62	291.54	0.50
1	2535	Q10	3000	432.51	441.40		442.55	0.005300	9.26	476.96	108.33	0.60
1	2535	Q50	4270	432.51	442.51		444.03	0.006280	10.86	599.21	112.17	0.67
1	2535	Q100	4871	432.51	443.04		444.67	0.006493	11.40	658.53	113.98	0.68
1	2535	Q500	6140	432.51	444.25		445.99	0.006281	11.98	804.01	127.06	0.68

Backwater Model Summary Output: Existing Condition with Overflow, Page 2

HEC-RAS Plan: Plan 01 River: Olney Creek Reach: 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	2285	Q10	3000	430.84	439.74		440.25	0.015778	5.77	520.38	145.04	0.54
1	2285	Q50	4270	430.84	441.26		441.77	0.010192	5.74	743.31	148.56	0.45
1	2285	Q100	4871	430.84	441.98		442.49	0.008598	5.72	851.94	150.24	0.42
1	2285	Q500	6140	430.84	443.80		444.09	0.006020	5.59	1101.68	162.35	0.37
1	1875	Q10	3000	428.21	438.53	434.20	438.88	0.001305	3.99	759.85	160.82	0.27
1	1875	Q50	4270	428.21	440.26	435.18	440.55	0.001287	4.38	1049.96	185.78	0.27
1	1875	Q100	4871	428.21	441.11	435.54	441.39	0.001182	4.39	1209.01	191.69	0.26
1	1875	Q500	6140	428.21	442.98	436.28	443.24	0.000916	4.29	1595.11	226.89	0.24
1	1505	Q10	3000	426.33	438.20	432.40	438.50	0.000815	4.40	715.17	101.40	0.26
1	1505	Q50	4270	426.33	439.89	433.54	440.13	0.000965	5.32	879.68	125.83	0.29
1	1505	Q100	4871	426.33	440.50	434.05	440.98	0.000964	5.59	992.62	153.32	0.29
1	1505	Q500	6140	426.33	442.38	435.00	442.89	0.000858	5.85	1364.68	221.34	0.29
1	1493		Bridge									
1	1450	Q10	3000	426.07	437.63	433.74	438.14	0.005205	5.75	521.50	127.55	0.41
1	1450	Q50	4270	426.07	438.46	435.09	439.26	0.007457	7.19	594.53	221.11	0.49
1	1450	Q100	4871	426.07	438.84	435.67	439.77	0.008109	7.75	632.24	233.15	0.52
1	1450	Q500	6140	426.07	439.59	436.72	440.77	0.009139	8.74	717.21	584.09	0.56
1	1160	Q10	3000	424.40	437.18	431.88	437.35	0.001165	3.34	953.65	253.99	0.22
1	1160	Q50	4270	424.40	437.80	432.80	438.08	0.001744	4.31	1133.05	417.46	0.27
1	1160	Q100	4871	424.40	438.15	433.17	438.47	0.001889	4.62	1277.44	446.98	0.28
1	1160	Q500	6140	424.40	438.95	433.89	439.30	0.001936	4.97	1854.50	985.88	0.29
1	980	Q10	3000	426.12	436.96		437.19	0.000675	3.90	891.43	174.11	0.24
1	980	Q50	4270	426.12	437.43		437.82	0.001127	5.18	985.98	234.73	0.32
1	980	Q100	4871	426.12	437.70		438.17	0.001306	5.66	1055.54	270.59	0.34
1	980	Q500	6140	426.12	438.39		438.97	0.001534	6.37	1281.79	393.68	0.37
1	460	Q10	3000	424.42	436.33	430.01	436.68	0.001409	4.78	630.29	156.91	0.27
1	460	Q50	4270	424.42	436.13	431.27	436.88	0.003057	6.95	614.74	104.81	0.40
1	460	Q100	4871	424.42	436.00	431.81	437.01	0.004150	8.04	606.06	89.67	0.46
1	460	Q500	6140	424.42	435.62	432.86	437.35	0.007354	10.56	581.40	85.13	0.62
1	0	Q10	3000	422.13	436.50	428.56	436.51	0.000054	1.12	3595.48	629.33	0.06
1	0	Q50	4270	422.13	436.50	429.52	436.53	0.000110	1.59	3595.48	629.33	0.09
1	0	Q100	4871	422.13	436.50	429.92	436.53	0.000143	1.81	3595.48	629.33	0.10
1	0	Q500	6140	422.13	436.50	430.75	436.55	0.000228	2.28	3595.48	629.33	0.12

Backwater Model Summary Output: Existing Condition Overflow

HEC-RAS Plan: Plan 01 River: Olney Overflow Reach: 1 Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	4955	PF 1	585	454.70	456.43	456.43	457.05	0.002280	6.44	125.50	167.26	0.90
1	4850	PF 1	585	452.70	454.75	454.75	455.27	0.001727	6.34	219.30	294.96	0.81
1	4450	PF 1	585	451.90	453.81	453.81	454.62	0.002594	7.32	97.90	75.52	0.98
1	4205	PF 1	585	450.50	451.96	451.96	452.44	0.002730	5.94	177.60	261.17	0.94
1	4120	PF 1	585	449.30	450.86	450.62	451.06	0.002123	5.59	353.24	340.03	0.85
1	3740	PF 1	585	447.80	448.64	448.64	448.85	0.048155	4.45	178.73	436.58	0.91
1	3490	PF 1	1090	440.10	446.46	444.21	446.88	0.000411	5.18	219.30	203.28	0.44
1	2960	PF 1	1090	438.50	446.20	442.57	446.45	0.001555	4.03	273.85	242.72	0.32
1	2910		Bridge									
1	2820	PF 1	1090	438.40	445.60	442.94	445.80	0.001666	3.87	423.21	376.26	0.33
1	2400	PF 1	1090	437.70	444.87		445.10	0.001783	4.19	380.58	280.57	0.35
1	1860	PF 1	1090	435.70	443.23		443.39	0.006942	3.25	368.61	190.18	0.27
1	1545	PF 1	1090	434.00	442.75	439.06	442.82	0.000760	2.54	784.34	500.03	0.19
1	1440		Bridge									
1	1300	PF 1	1090	434.00	442.18		442.55	0.000389	5.74	728.37	564.21	0.37
1	975	PF 1	1090	433.90	441.66	439.56	442.37	0.000592	6.89	211.91	534.45	0.51
1	685	PF 1	1090	433.40	440.68	439.68	442.05	0.001341	9.46	142.13	105.30	0.73
1	140	PF 1	1090	432.90	438.81	438.81	440.97	0.002677	11.80	92.36	21.62	1.01
1	60		Bridge									
1	0	PF 1	1090	432.40	437.50	436.58	438.28	0.007561	7.08	153.86	45.71	0.68

Backwater Model Summary Output: Open Area Under Sacramento Drive Bridge, Page 1

HEC-RAS Plan: Plan 01 River: Olney Creek Reach: 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(c/s)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	6925	Q10	3000	450.97	461.94	460.77	463.32	0.005719	9.49	330.49	258.19	0.71
1	6925	Q50	4750	450.97	463.14	463.14	463.90	0.003438	8.37	1024.31	612.09	0.57
1	6925	Q100	5438	450.97	463.34	463.34	464.11	0.003573	8.69	1141.82	618.34	0.58
1	6925	Q500	7700	450.97	464.32	463.79	464.84	0.002447	7.86	1750.30	619.21	0.49
1	6575	Q10	3000	451.57	460.30	458.69	461.46	0.004623	8.74	395.38	275.44	0.65
1	6575	Q50	4750	451.57	461.52	461.52	462.37	0.003459	8.52	985.23	700.10	0.58
1	6575	Q100	5438	451.57	461.85	461.83	462.58	0.003054	8.27	1225.83	737.55	0.55
1	6575	Q500	7700	451.57	464.23	462.29	464.37	0.000571	4.34	3216.18	867.75	0.25
1	6105	Q10	3000	449.66	458.37	456.62	459.45	0.004011	8.56	413.63	272.65	0.61
1	6105	Q50	4750	449.66	461.06	459.56	461.35	0.001001	5.46	1470.80	572.17	0.33
1	6105	Q100	5438	449.66	461.60	459.99	461.86	0.000865	5.29	1717.58	575.89	0.31
1	6105	Q500	7700	449.66	464.04	460.57	464.19	0.000404	4.22	2830.72	595.84	0.22
1	5875	Q10	3000	448.31	457.99	455.41	458.65	0.002220	6.64	503.09	175.35	0.46
1	5875	Q50	4750	448.31	460.65	457.12	461.09	0.001122	5.93	1097.35	234.97	0.35
1	5875	Q100	5438	448.31	461.14	458.00	461.61	0.001135	6.18	1213.76	234.97	0.35
1	5875	Q500	7700	448.31	463.64	459.31	464.03	0.000765	5.91	1801.04	234.97	0.30
1	5848		Bridge									
1	5805	Q10	3000	449.13	457.06	455.33	458.10	0.003984	8.21	365.34	101.42	0.60
1	5805	Q50	4400	449.13	459.07	456.56	460.28	0.003262	8.87	535.60	212.64	0.56
1	5805	Q100	5457	449.13	459.82	457.40	460.82	0.005595	11.39	508.28	208.93	0.73
1	5805	Q500	5900	449.13	459.04	457.75	461.23	0.005939	11.94	532.43	212.08	0.76
1	5675	Q10	3000	447.87	454.75	454.52	456.97	0.010253	11.96	250.92	50.03	0.94
1	5675	Q50	4400	447.87	458.02	456.02	459.02	0.011294	13.90	316.53	52.93	1.00
1	5675	Q100	5457	447.87	458.10	458.10	460.06	0.005727	11.68	598.03	185.18	0.73
1	5675	Q500	5900	447.87	458.38	458.38	460.36	0.005722	11.91	648.87	185.18	0.73
1	5480	Q10	3000	445.66	454.23		455.41	0.004430	9.70	418.42	100.11	0.62
1	5480	Q50	4400	445.66	455.59		456.99	0.004700	10.90	563.49	113.07	0.65
1	5480	Q100	5457	445.66	456.21		457.91	0.005438	12.15	635.69	120.24	0.70
1	5480	Q500	5900	445.66	456.42		458.26	0.005823	12.71	661.29	123.80	0.73
1	5235	Q10	3000	445.01	453.12	451.58	454.11	0.005791	7.99	375.34	100.02	0.62
1	5235	Q50	4400	445.01	454.02	452.80	455.55	0.007263	9.92	457.65	171.91	0.72
1	5235	Q100	5457	445.01	454.73	453.63	456.37	0.007045	10.51	703.85	325.36	0.72
1	5235	Q500	5900	445.01	455.05	454.02	456.66	0.006677	10.56	807.38	326.78	0.70
1	5085	Q10	3000	444.77	453.10	450.63	453.38	0.002269	4.48	837.69	287.63	0.35
1	5085	Q50	4400	444.77	454.32	451.60	454.64	0.002168	4.88	1288.95	337.55	0.34
1	5085	Q100	5457	444.77	455.10	452.12	455.44	0.002165	5.16	1554.39	345.56	0.34
1	5085	Q500	5900	444.77	455.40	452.31	455.75	0.002159	5.26	1659.07	348.66	0.34
1	4715	Q10	3000	442.76	452.04	449.81	452.44	0.002930	5.42	655.47	193.26	0.40
1	4715	Q50	4400	442.76	453.24	450.93	453.71	0.003026	6.03	890.60	200.17	0.41
1	4715	Q100	5457	442.76	453.98	451.50	454.50	0.003121	6.44	1040.20	204.44	0.42
1	4715	Q500	5900	442.76	454.26	451.73	454.81	0.003157	6.60	1098.83	206.09	0.43
1	4355	Q10	3000	441.12	449.51	449.31	450.85	0.006464	9.79	401.04	153.11	0.66
1	4355	Q50	4400	441.12	450.60	450.38	452.07	0.006674	10.79	576.70	185.70	0.68
1	4355	Q100	5457	441.12	451.19	451.02	452.80	0.007016	11.61	686.23	188.64	0.71
1	4355	Q500	5900	441.12	451.41	451.24	453.08	0.007173	11.94	727.19	189.64	0.72
1	3925	Q10	3000	436.80	448.85	444.73	449.29	0.001679	5.55	716.81	313.94	0.35
1	3925	Q50	4400	436.80	449.91	446.05	450.38	0.001803	6.14	1087.33	378.09	0.36
1	3925	Q100	5457	436.80	450.45	446.96	450.96	0.001964	6.62	1295.38	396.33	0.38
1	3925	Q500	5900	436.80	450.65	447.32	451.18	0.002024	6.81	1376.40	401.80	0.39
1	3705	Q10	3000	435.90	447.54	444.67	448.67	0.004153	8.57	405.47	320.76	0.55
1	3705	Q50	4400	435.90	448.60	446.48	449.72	0.004133	9.28	755.40	348.96	0.56
1	3705	Q100	5457	435.90	449.22	448.98	450.28	0.003964	9.52	979.16	372.39	0.55
1	3705	Q500	5900	435.90	449.46	449.16	450.50	0.003873	9.58	1071.32	381.62	0.55
1	3355.*	Q10	3000	434.41	446.16	443.27	447.18	0.004184	8.24	441.20	261.77	0.54
1	3355.*	Q50	4400	434.41	447.39	445.09	448.31	0.003785	8.53	774.46	290.82	0.52
1	3355.*	Q100	5457	434.41	448.03	447.38	448.95	0.003675	8.84	973.47	323.06	0.52
1	3355.*	Q500	5900	434.41	448.33	447.58	449.21	0.003530	8.85	1069.55	337.56	0.52
1	3005	Q10	3000	432.93	443.93	441.94	445.36	0.006382	9.58	313.56	61.50	0.65
1	3005	Q50	4400	432.93	445.69	443.73	446.81	0.004960	9.22	654.89	216.59	0.59
1	3005	Q100	5457	432.93	446.77	445.85	447.67	0.003893	8.63	909.12	266.53	0.53
1	3005	Q500	5900	432.93	447.16	446.05	448.00	0.003577	8.54	1018.44	290.01	0.51
1	2535	Q10	3000	432.51	441.40		442.55	0.005300	9.28	476.96	108.33	0.60
1	2535	Q50	4400	432.51	442.62		444.17	0.006342	10.99	611.78	112.55	0.67
1	2535	Q100	5457	432.51	443.57		445.28	0.006510	11.78	720.53	118.92	0.69
1	2535	Q500	5900	432.51	444.01		445.74	0.006379	11.92	773.55	124.16	0.68

Backwater Model Summary Output: Open Area Under Sacramento Drive Bridge, Page 2

HEC-RAS Plan: Plan 01 River: Olney Creek Reach: 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	2285	Q10	3000	430.84	439.74		440.25	0.015778	5.77	520.38	145.04	0.54
1	2285	Q50	4400	430.84	441.41		441.92	0.009818	5.74	766.37	148.92	0.45
1	2285	Q100	5457	430.84	442.70		443.20	0.007385	5.68	960.51	151.91	0.40
1	2285	Q500	5900	430.84	443.29		443.78	0.006450	5.62	1051.14	158.38	0.38
1	1875	Q10	3000	428.21	438.63	434.20	438.88	0.001305	3.99	759.85	160.82	0.27
1	1875	Q50	4400	428.21	440.44	435.26	440.73	0.001267	4.39	1083.35	187.04	0.27
1	1875	Q100	5457	428.21	441.94	435.89	442.21	0.001069	4.37	1371.33	202.65	0.25
1	1875	Q500	5900	428.21	442.62	436.15	442.89	0.000964	4.32	1515.04	218.52	0.24
1	1505	Q10	3000	426.33	438.20	432.40	438.50	0.000815	4.40	715.17	101.40	0.26
1	1505	Q50	4400	426.33	439.86	433.64	440.31	0.000968	5.39	901.57	131.61	0.29
1	1505	Q100	5457	426.33	441.32	434.47	441.82	0.000939	5.78	1134.29	197.47	0.29
1	1505	Q500	5900	426.33	442.01	434.81	442.52	0.000887	5.83	1283.07	220.18	0.29
1	1493		Bridge									
1	1450	Q10	3000	426.07	437.63	433.74	438.14	0.005205	5.75	521.50	127.55	0.41
1	1450	Q50	4400	426.07	438.54	435.22	439.37	0.007610	7.32	602.50	223.75	0.50
1	1450	Q100	5391	426.07	439.16	436.12	440.19	0.008574	8.18	666.34	292.03	0.54
1	1450	Q500	5900	426.07	439.45	436.53	440.59	0.008966	8.56	700.54	548.32	0.56
1	1160	Q10	3000	424.40	437.18	431.68	437.35	0.001165	3.34	953.65	253.99	0.22
1	1160	Q50	4400	424.40	437.88	432.68	438.17	0.001783	4.39	1164.65	423.64	0.27
1	1160	Q100	5391	424.40	438.47	433.47	438.81	0.001949	4.81	1417.11	751.46	0.29
1	1160	Q500	5900	424.40	438.80	433.76	439.14	0.001952	4.94	1573.63	918.88	0.29
1	980	Q10	3000	426.12	436.96		437.19	0.000675	3.90	891.43	174.11	0.24
1	980	Q50	4400	426.12	437.48		437.90	0.001169	5.29	1000.51	242.09	0.32
1	980	Q100	5391	426.12	437.96		438.49	0.001428	6.01	1133.12	311.95	0.36
1	980	Q500	5900	426.12	438.25		438.81	0.001510	6.27	1228.04	363.95	0.37
1	460	Q10	3000	424.42	436.33	430.01	436.68	0.001409	4.78	630.29	156.91	0.27
1	460	Q50	4400	424.42	436.11	431.38	436.91	0.003274	7.18	612.93	101.60	0.41
1	460	Q100	5391	424.42	435.87	432.24	437.13	0.005231	9.03	597.31	87.58	0.52
1	460	Q500	5900	424.42	435.71	432.67	437.28	0.006621	10.05	587.01	85.99	0.59
1	0	Q10	3000	422.13	436.50	428.56	436.51	0.000054	1.12	3595.48	629.33	0.06
1	0	Q50	4400	422.13	436.50	429.61	436.53	0.000117	1.64	3595.48	629.33	0.09
1	0	Q100	5391	422.13	436.50	430.27	436.54	0.000175	2.00	3595.48	629.33	0.11
1	0	Q500	5900	422.13	436.50	430.67	436.55	0.000210	2.19	3595.48	629.33	0.12

Backwater Model Summary Output: Open Area Under Sacramento Drive Bridge Plus Channel Improvement, Page 1

HEC-RAS Plan: Plan 01 River: Olney Creek Reach: 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	6925	Q10	3000	450.97	461.85	460.77	463.29	0.006025	9.66	322.79	231.90	0.72
1	6925	Q50	4750	450.97	463.14	463.14	463.90	0.003438	8.37	1024.31	612.09	0.57
1	6925	Q100	5438	450.97	463.34	463.34	464.11	0.003573	8.69	1141.82	618.34	0.58
1	6925	Q500	7700	450.97	463.79	463.79	464.69	0.004221	9.86	1423.90	619.21	0.64
1	6575	Q10	3000	451.57	460.62	458.69	461.52	0.003579	7.89	488.10	347.59	0.57
1	6575	Q50	4750	451.57	461.52	461.52	462.37	0.003459	8.52	985.23	700.10	0.58
1	6575	Q100	5438	451.57	461.83	461.83	462.58	0.003134	8.36	1210.33	736.09	0.55
1	6575	Q500	7700	451.57	462.98	462.29	463.36	0.001752	6.92	2142.65	854.73	0.43
1	6135	Q10	3000	449.66	457.61	456.62	459.24	0.006684	10.27	299.74	215.19	0.78
1	6135	Q50	4750	449.66	459.69	459.56	460.72	0.003500	9.12	850.11	562.78	0.59
1	6135	Q100	5438	449.66	460.46	459.99	461.09	0.002188	7.71	1199.20	568.07	0.48
1	6135	Q500	7700	449.66	462.60	460.57	462.89	0.000889	5.74	2172.59	582.72	0.31
1	5875	Q10	3000	448.31	456.05	455.41	457.55	0.007727	9.82	305.41	66.84	0.81
1	5875	Q50	4750	448.31	458.45	457.12	459.79	0.004188	9.55	568.93	203.73	0.64
1	5875	Q100	5438	448.31	458.43	458.00	460.20	0.005565	10.98	565.64	202.33	0.73
1	5875	Q500	7700	448.31	461.87	459.31	462.57	0.001602	7.70	1384.21	234.97	0.42
1	5848		Bridge									
1	5805	Q10	3000	446.87	455.74	453.36	456.67	0.003236	7.73	387.98	61.67	0.54
1	5805	Q50	4750	446.87	457.72	455.12	459.06	0.003453	9.28	512.77	131.49	0.57
1	5805	Q100	5457	446.87	458.44	455.69	459.92	0.003480	9.78	571.62	192.38	0.58
1	5805	Q500	5900	446.87	458.36	456.03	460.13	0.004181	10.67	564.15	185.41	0.64
1	5675	Q10	3000	446.50	455.07	452.75	456.18	0.003504	8.44	358.56	58.74	0.57
1	5675	Q50	4750	446.50	456.57	454.66	458.39	0.004959	10.83	454.00	93.95	0.70
1	5675	Q100	5457	446.50	457.29	455.32	459.17	0.007440	11.04	517.06	198.83	0.83
1	5675	Q500	5900	446.50	457.77	455.74	459.42	0.006109	10.55	662.10	199.32	0.76
1	5480	Q10	3000	445.66	454.23		455.41	0.004430	9.70	416.42	100.11	0.62
1	5480	Q50	4750	445.66	455.92		457.35	0.004677	11.08	601.54	116.11	0.65
1	5480	Q100	5457	445.66	456.21		457.91	0.005438	12.15	635.69	120.24	0.70
1	5480	Q500	5900	445.66	456.42		458.26	0.005823	12.71	661.29	123.80	0.73
1	5235	Q10	3000	445.01	453.12	451.58	454.11	0.006791	7.99	375.34	100.02	0.62
1	5235	Q50	4750	445.01	454.21	453.08	455.87	0.007641	10.37	480.83	202.82	0.74
1	5235	Q100	5457	445.01	454.73	453.63	456.37	0.007045	10.51	703.85	325.36	0.72
1	5235	Q500	5900	445.01	455.05	454.02	456.66	0.006677	10.56	807.38	326.78	0.70
1	5085	Q10	3000	444.77	453.10	450.63	453.38	0.002289	4.48	637.69	287.63	0.35
1	5085	Q50	4750	444.77	454.59	451.79	454.91	0.002179	4.97	1379.66	340.31	0.34
1	5085	Q100	5457	444.77	455.10	452.12	455.44	0.002165	5.16	1554.39	345.56	0.34
1	5085	Q500	5900	444.77	455.40	452.31	455.75	0.002159	5.26	1659.07	348.66	0.34
1	4715	Q10	3000	442.76	452.04	449.81	452.44	0.002930	5.42	655.47	193.26	0.40
1	4715	Q50	4750	442.76	453.49	451.13	453.98	0.003059	6.17	941.89	201.64	0.42
1	4715	Q100	5457	442.76	453.98	451.50	454.50	0.003121	6.44	1040.20	204.44	0.42
1	4715	Q500	5900	442.76	454.26	451.73	454.81	0.003157	6.60	1098.85	206.09	0.43
1	4355	Q10	3000	441.12	449.51	449.31	450.85	0.006464	9.79	401.04	153.11	0.66
1	4355	Q50	4750	441.12	450.81	450.47	452.32	0.006780	11.07	615.14	186.81	0.69
1	4355	Q100	5457	441.12	451.19	451.02	452.80	0.007016	11.61	686.23	188.64	0.71
1	4355	Q500	5900	441.12	451.41	451.24	453.08	0.007173	11.94	727.19	189.64	0.72
1	3925	Q10	3000	436.80	448.85	444.73	449.29	0.001679	5.55	716.81	313.94	0.35
1	3925	Q50	4750	436.80	450.10	446.37	450.59	0.001857	6.30	1159.38	384.63	0.37
1	3925	Q100	5457	436.80	450.45	446.98	450.96	0.001964	6.62	1295.38	396.33	0.38
1	3925	Q500	5900	436.80	450.65	447.32	451.18	0.002024	6.81	1376.40	401.80	0.39
1	3705	Q10	3000	435.90	447.54	444.67	448.67	0.004153	8.57	405.47	320.76	0.55
1	3705	Q50	4750	435.90	448.81	446.89	449.92	0.004084	9.38	830.93	357.04	0.56
1	3705	Q100	5457	435.90	449.22	448.98	450.28	0.003964	9.52	979.16	372.39	0.55
1	3705	Q500	5900	435.90	449.46	449.16	450.50	0.003873	9.68	1071.32	381.62	0.55
1	3355.*	Q10	3000	434.41	446.16	443.27	447.18	0.004184	8.24	441.20	261.77	0.54
1	3355.*	Q50	4750	434.41	447.59	445.48	448.52	0.003811	8.70	834.13	300.86	0.53
1	3355.*	Q100	5457	434.41	448.03	447.38	448.95	0.003675	8.84	973.47	323.08	0.52
1	3355.*	Q500	5900	434.41	448.33	447.58	449.21	0.003530	8.85	1069.55	337.56	0.52
1	3005	Q10	3000	432.93	443.93	441.94	445.36	0.006382	9.58	313.56	61.50	0.65
1	3005	Q50	4750	432.93	446.08	445.46	447.10	0.004515	8.95	741.92	223.03	0.56
1	3005	Q100	5457	432.93	446.77	445.85	447.67	0.003893	8.66	909.12	266.53	0.53
1	3005	Q500	5900	432.93	447.16	446.05	448.00	0.003577	8.54	1018.44	290.01	0.51
1	2535	Q10	3000	432.51	441.40		442.55	0.005300	9.26	476.96	105.33	0.60
1	2535	Q50	4750	432.51	442.89		444.53	0.006567	11.37	642.19	113.48	0.68
1	2535	Q100	5457	432.51	443.57		445.28	0.006510	11.76	720.53	118.92	0.69
1	2535	Q500	5900	432.51	444.01		445.74	0.006379	11.92	773.55	124.16	0.68

Backwater Model Summary Output: Open Area Under Sacramento Drive Bridge Plus Channel Improvement, Page 2

HEC-RAS Plan: Plan 01 River: Olney Creek Reach: 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	2285	Q10	3000	430.84	439.74		440.25	0.015778	5.77	520.38	145.04	0.54
1	2285	Q50	4750	430.84	441.73		442.26	0.009449	5.84	813.95	149.66	0.44
1	2285	Q100	5457	430.84	442.70		443.20	0.007385	5.68	960.51	151.91	0.40
1	2285	Q500	5900	430.84	443.29		443.78	0.006450	5.62	1051.14	158.38	0.38
1	1875	Q10	3000	428.21	438.63	434.20	438.88	0.001305	3.99	759.85	160.82	0.27
1	1875	Q50	4750	428.21	440.76	435.48	441.06	0.001296	4.51	1142.16	189.23	0.28
1	1875	Q100	5457	428.21	441.94	435.89	442.21	0.001069	4.37	1371.33	202.65	0.25
1	1875	Q500	5900	428.21	442.62	436.15	442.89	0.000964	4.32	1515.04	218.52	0.24
1	1505	Q10	3000	426.33	438.20	432.40	438.50	0.000815	4.40	715.17	131.40	0.26
1	1505	Q50	4750	426.33	440.12	433.94	440.61	0.001036	5.66	936.80	140.41	0.30
1	1505	Q100	5457	426.33	441.32	434.47	441.82	0.000939	5.78	1134.29	197.47	0.29
1	1505	Q500	5900	426.33	442.01	434.81	442.52	0.000887	5.83	1283.07	220.18	0.29
1	1493		Bridge									
1	1450	Q10	3000	426.07	437.63	433.74	438.14	0.005205	5.75	521.50	127.55	0.41
1	1450	Q50	4400	426.07	438.54	435.22	439.37	0.007610	7.32	602.50	223.75	0.50
1	1450	Q100	5391	426.07	439.13	436.12	440.19	0.008574	8.18	666.34	292.03	0.54
1	1450	Q500	5900	426.07	439.45	436.53	440.59	0.008966	8.56	700.54	548.32	0.56
1	1160	Q10	3000	424.40	437.18	431.88	437.35	0.001165	3.34	953.65	253.99	0.22
1	1160	Q50	4400	424.40	437.88	432.88	438.17	0.001783	4.39	1154.85	423.64	0.27
1	1160	Q100	5391	424.40	438.47	433.47	438.81	0.001949	4.81	1417.11	751.46	0.29
1	1160	Q500	5900	424.40	438.80	433.78	439.14	0.001952	4.94	1573.63	918.88	0.29
1	980	Q10	3000	426.12	436.96		437.19	0.000675	3.90	891.43	174.11	0.24
1	980	Q50	4400	426.12	437.48		437.90	0.001169	5.29	1000.51	242.09	0.32
1	980	Q100	5391	426.12	437.96		438.49	0.001428	6.01	1133.12	311.95	0.36
1	980	Q500	5900	426.12	438.25		438.81	0.001510	6.27	1228.04	363.95	0.37
1	460	Q10	3000	424.42	436.33	430.01	436.66	0.001409	4.78	630.29	156.91	0.27
1	460	Q50	4400	424.42	436.11	431.38	436.91	0.003274	7.18	612.93	101.60	0.41
1	460	Q100	5391	424.42	435.87	432.24	437.13	0.005281	9.03	597.31	87.58	0.52
1	460	Q500	5900	424.42	435.71	432.67	437.28	0.006621	10.05	587.01	85.99	0.59
1	0	Q10	3000	422.13	436.50	428.56	436.51	0.000054	1.12	3595.48	629.33	0.06
1	0	Q50	4400	422.13	436.50	429.61	436.53	0.000117	1.64	3595.48	629.33	0.09
1	0	Q100	5391	422.13	436.50	430.27	436.54	0.000175	2.00	3595.48	629.33	0.11
1	0	Q500	5900	422.13	436.50	430.67	436.55	0.000210	2.19	3595.48	629.33	0.12

Backwater Model Summary Output: Raise Sacramento Drive Bridge Deck PlusChannel Improvement, Page 1

HEC-RAS Plan: Plan 01 River: Olney Creek Reach: 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	6925	Q10	3000	450.97	461.95	460.77	463.33	0.005676	9.47	331.68	262.02	0.71
1	6925	Q25	4750	450.97	463.14	463.14	463.90	0.003438	8.37	1024.31	612.09	0.57
1	6925	Q100	5438	450.97	463.34	463.34	464.11	0.003573	8.69	1141.82	618.34	0.58
1	6925	Q500	7700	450.97	463.79	463.79	464.69	0.004221	9.86	1423.90	619.21	0.64
1	6575	Q10	3000	451.57	460.24	458.69	461.45	0.004823	8.89	379.29	271.33	0.66
1	6575	Q25	4750	451.57	461.52	461.52	462.37	0.003459	8.52	985.23	700.10	0.58
1	6575	Q100	5438	451.57	461.83	461.83	462.58	0.003134	8.36	1210.33	736.09	0.55
1	6575	Q500	7700	451.57	462.63	462.29	463.21	0.002572	8.14	1839.06	850.12	0.51
1	6105	Q10	3000	449.68	458.67	456.62	459.57	0.003207	7.91	473.12	343.17	0.55
1	6105	Q25	4750	449.68	460.31	459.56	460.86	0.001914	7.12	1131.58	567.04	0.44
1	6105	Q100	5438	449.68	460.70	459.99	461.20	0.001782	7.09	1304.63	569.66	0.43
1	6105	Q500	7700	449.68	462.13	460.57	462.50	0.001203	6.46	1956.96	579.49	0.36
1	5875	Q10	3000	448.31	458.38	455.42	458.93	0.001752	6.13	557.63	198.91	0.41
1	5875	Q25	4750	448.31	459.47	457.10	460.33	0.002367	7.86	717.60	220.49	0.49
1	5875	Q100	5438	448.31	459.47	458.02	460.60	0.003102	9.00	717.65	220.49	0.56
1	5875	Q500	7700	448.31	460.05	459.31	461.86	0.004597	11.48	807.42	234.53	0.69
1	5848		Bridge									
1	5805	Q10	3000	449.13	455.34	455.33	457.43	0.011668	11.59	258.82	61.36	0.99
1	5805	Q25	4400	449.13	456.69	456.56	459.25	0.010504	12.86	342.08	62.40	0.97
1	5805	Q100	5457	449.13	457.42	457.40	460.49	0.010885	14.07	388.19	120.24	1.00
1	5805	Q500	5900	449.13	457.74	457.74	460.98	0.010787	14.44	409.49	132.20	1.00
1	5675	Q10	3000	446.50	455.07	452.75	456.18	0.003504	8.44	358.56	58.74	0.57
1	5675	Q25	4400	446.50	456.27	454.29	457.96	0.004513	10.45	433.45	66.41	0.67
1	5675	Q100	5457	446.50	456.89	455.33	459.09	0.005371	11.95	478.76	145.42	0.73
1	5675	Q500	5900	446.50	457.11	455.73	459.54	0.005712	12.55	499.22	182.84	0.76
1	5480	Q10	3000	445.66	454.23		455.41	0.004430	9.70	418.42	100.11	0.62
1	5480	Q25	4400	445.66	455.59		456.99	0.004700	10.90	563.49	113.07	0.65
1	5480	Q100	5457	445.66	456.21		457.91	0.005438	12.15	635.69	120.24	0.70
1	5480	Q500	5900	445.66	456.42		458.26	0.005823	12.71	661.29	123.80	0.73
1	5235	Q10	3000	445.01	453.12	451.58	454.11	0.005791	7.99	375.34	100.02	0.62
1	5235	Q25	4400	445.01	454.02	452.80	455.55	0.007283	9.92	457.65	171.91	0.72
1	5235	Q100	5457	445.01	454.73	453.63	456.37	0.007045	10.51	703.85	325.36	0.72
1	5235	Q500	5900	445.01	455.05	454.02	456.66	0.006677	10.56	807.38	326.78	0.70
1	5085	Q10	3000	444.77	453.10	450.63	453.38	0.002289	4.48	837.69	287.63	0.35
1	5085	Q25	4400	444.77	454.32	451.60	454.64	0.002188	4.88	1288.95	337.55	0.34
1	5085	Q100	5457	444.77	455.10	452.12	455.44	0.002165	5.16	1554.39	345.56	0.34
1	5085	Q500	5900	444.77	455.40	452.31	455.75	0.002159	5.26	1659.07	348.66	0.34
1	4715	Q10	3000	442.76	452.04	449.81	452.44	0.002930	5.42	655.47	193.26	0.40
1	4715	Q25	4400	442.76	453.24	450.93	453.71	0.003026	6.03	890.60	200.17	0.41
1	4715	Q100	5457	442.76	453.98	451.50	454.50	0.003121	6.44	1040.20	204.44	0.42
1	4715	Q500	5900	442.76	454.26	451.73	454.81	0.003157	6.60	1098.86	206.09	0.43
1	4355	Q10	3000	441.12	449.51	449.31	450.85	0.006464	9.79	401.04	153.11	0.66
1	4355	Q25	4400	441.12	450.60	450.38	452.07	0.006674	10.79	576.70	185.70	0.68
1	4355	Q100	5457	441.12	451.19	451.02	452.80	0.007016	11.61	686.23	188.64	0.71
1	4355	Q500	5900	441.12	451.41	451.24	453.08	0.007173	11.94	727.19	189.64	0.72
1	3925	Q10	3000	436.80	446.85	444.73	449.29	0.001679	5.55	716.81	313.94	0.35
1	3925	Q25	4400	436.80	449.91	446.05	450.38	0.001803	6.14	1087.33	378.09	0.36
1	3925	Q100	5457	436.80	450.45	446.96	450.96	0.001964	6.62	1295.38	396.33	0.38
1	3925	Q500	5900	436.80	450.65	447.32	451.18	0.002024	6.81	1376.40	401.80	0.39
1	3705	Q10	3000	435.90	447.54	444.67	448.67	0.004153	8.57	405.47	320.76	0.55
1	3705	Q25	4400	435.90	448.60	446.48	449.72	0.004133	9.28	755.40	348.96	0.56
1	3705	Q100	5457	435.90	449.22	448.98	450.28	0.003964	9.52	979.16	372.39	0.55
1	3705	Q500	5900	435.90	449.46	449.16	450.50	0.003873	9.58	1071.32	381.62	0.55
1	3355.*	Q10	3000	434.41	446.16	443.27	447.18	0.004184	8.24	441.20	261.77	0.54
1	3355.*	Q25	4400	434.41	447.39	445.09	448.31	0.003785	8.53	774.46	290.82	0.52
1	3355.*	Q100	5457	434.41	448.03	447.38	448.95	0.003675	8.84	973.47	323.08	0.52
1	3355.*	Q500	5900	434.41	448.33	447.58	449.21	0.003530	8.85	1069.55	337.56	0.52
1	3005	Q10	3000	432.93	443.93	441.94	445.36	0.006382	9.58	313.56	51.50	0.65
1	3005	Q25	4400	432.93	445.69	443.73	446.81	0.004960	9.22	654.89	216.59	0.59
1	3005	Q100	5457	432.93	446.77	445.85	447.67	0.003893	8.66	909.12	288.53	0.53
1	3005	Q500	5900	432.93	447.16	446.05	448.00	0.003577	8.54	1018.44	290.01	0.51
1	2535	Q10	3000	432.51	441.40		442.55	0.005300	9.26	476.96	108.33	0.60
1	2535	Q25	4400	432.51	442.62		444.17	0.006342	10.99	611.78	112.55	0.67
1	2535	Q100	5457	432.51	443.57		445.28	0.006510	11.76	720.53	118.92	0.69
1	2535	Q500	5900	432.51	444.01		445.74	0.006379	11.92	773.55	124.16	0.68

Backwater Model Summary Output: Raise Sacramento Drive Bridge Deck Plus Channel Improvement, Page 2

HEC-RAS Plan: Plan 01 River: Olney Creek Reach: 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
1	2285	Q10	3000	430.84	439.74		440.25	0.015778	5.77	520.38	145.04	0.54
1	2285	Q25	4400	430.84	441.41		441.92	0.009818	5.74	766.37	148.92	0.45
1	2285	Q100	5457	430.84	442.70		443.20	0.007385	5.68	960.51	151.91	0.40
1	2285	Q500	5900	430.84	443.29		443.78	0.006450	5.62	1051.14	158.38	0.38
1	1875	Q10	3000	428.21	438.63	434.20	438.88	0.001305	3.99	759.85	180.82	0.27
1	1875	Q25	4400	428.21	440.44	435.26	440.73	0.001267	4.39	1083.35	187.04	0.27
1	1875	Q100	5457	428.21	441.94	435.89	442.21	0.001069	4.37	1371.33	202.65	0.25
1	1875	Q500	5900	428.21	442.62	436.15	442.89	0.000964	4.32	1515.04	218.52	0.24
1	1505	Q10	3000	426.33	438.20	432.40	438.50	0.000815	4.40	715.17	101.40	0.26
1	1505	Q25	4400	426.33	439.86	433.64	440.31	0.000968	5.39	901.57	131.61	0.29
1	1505	Q100	5457	426.33	441.32	434.47	441.82	0.000939	5.78	1134.29	197.47	0.29
1	1505	Q500	5900	426.33	442.01	434.81	442.52	0.000887	5.83	1283.07	220.18	0.29
1	1493		Bridge									
1	1450	Q10	3000	426.07	437.63	433.74	438.14	0.005205	5.75	521.50	127.55	0.41
1	1450	Q25	4400	426.07	438.54	435.22	439.37	0.007610	7.32	602.50	223.75	0.50
1	1450	Q100	5391	426.07	439.18	436.12	440.19	0.008574	8.18	666.34	292.03	0.54
1	1450	Q500	5900	426.07	439.45	436.53	440.59	0.008966	8.56	700.54	548.32	0.56
1	1160	Q10	3000	424.40	437.18	431.88	437.35	0.001165	3.34	953.65	253.99	0.22
1	1160	Q25	4400	424.40	437.88	432.88	438.17	0.001783	4.39	1164.85	423.64	0.27
1	1160	Q100	5391	424.40	438.47	433.47	438.81	0.001949	4.81	1417.11	751.46	0.29
1	1160	Q500	5900	424.40	438.80	433.76	439.14	0.001952	4.94	1573.63	918.88	0.29
1	980	Q10	3000	426.12	436.96		437.19	0.000675	3.90	891.43	174.11	0.24
1	980	Q25	4400	426.12	437.48		437.90	0.001169	5.29	1000.51	242.09	0.32
1	980	Q100	5391	426.12	437.96		438.49	0.001428	6.01	1133.12	311.95	0.36
1	980	Q500	5900	426.12	438.25		438.81	0.001510	6.27	1228.04	363.95	0.37
1	460	Q10	3000	424.42	436.33	430.01	436.68	0.001409	4.78	630.29	156.91	0.27
1	460	Q25	4400	424.42	436.11	431.38	436.91	0.003274	7.18	612.93	101.60	0.41
1	460	Q100	5391	424.42	435.87	432.24	437.13	0.005281	9.03	597.31	87.58	0.52
1	460	Q500	5900	424.42	435.71	432.67	437.28	0.006621	10.05	587.01	85.99	0.59
1	0	Q10	3000	422.13	436.50	428.56	436.51	0.000054	1.12	3595.48	629.33	0.06
1	0	Q25	4400	422.13	436.50	429.61	436.53	0.000117	1.64	3595.48	629.33	0.09
1	0	Q100	5391	422.13	436.50	430.27	436.54	0.000175	2.00	3595.48	629.33	0.11
1	0	Q500	5900	422.13	436.50	430.67	436.55	0.000210	2.19	3595.48	629.33	0.12

Appendix B

Recommendations for Determining Base Flood Water Surface Elevations in Areas of Shallow Overflow and Along the Breach Floodplain

Areas of Shallow Flooding Adjacent to Overflow Floodplain[1]

Location	Approach
Private drive south of Balaton Avenue	Compute the water surface elevation at the upstream end of the structure of interest such that the area below the water surface elevation divided by the wetted perimeter of the road plus adjacent ground equals 1.0-foot. Consider the potential flow limiting effects of fences, walls, and structures
Adjacent to Bonnyview Drain	Use Bonnyview Drain Base Flood water surface elevation adjacent to the upstream end of the structure of interest
Lakewood Drive and southwest	Use elevation 441.5-feet NAVD-88

Note: 1) For properties in and along the overflow floodplain, use the overflow floodplain Base Flood water surface elevations.

Breach Floodplain

Location	Approach
Structures located adjacent to levee	Use Olney Creek Base Flood water surface elevation adjacent to the upstream end of the structure of interest.
Structures along Mullen Parkway, Brookside Drive, and Lakewood Drive and not adjacent to levee	Compute the water surface elevation at the upstream end of the structure of interest such that the area below the water surface elevation divided by the wetted perimeter of the road plus gutters plus sidewalks equals 1.0-foot. Do not include yards behind the sidewalks.
Lakewood Drive and southwest	Use elevation 441.5-feet NAVD-88

Appendix C

References

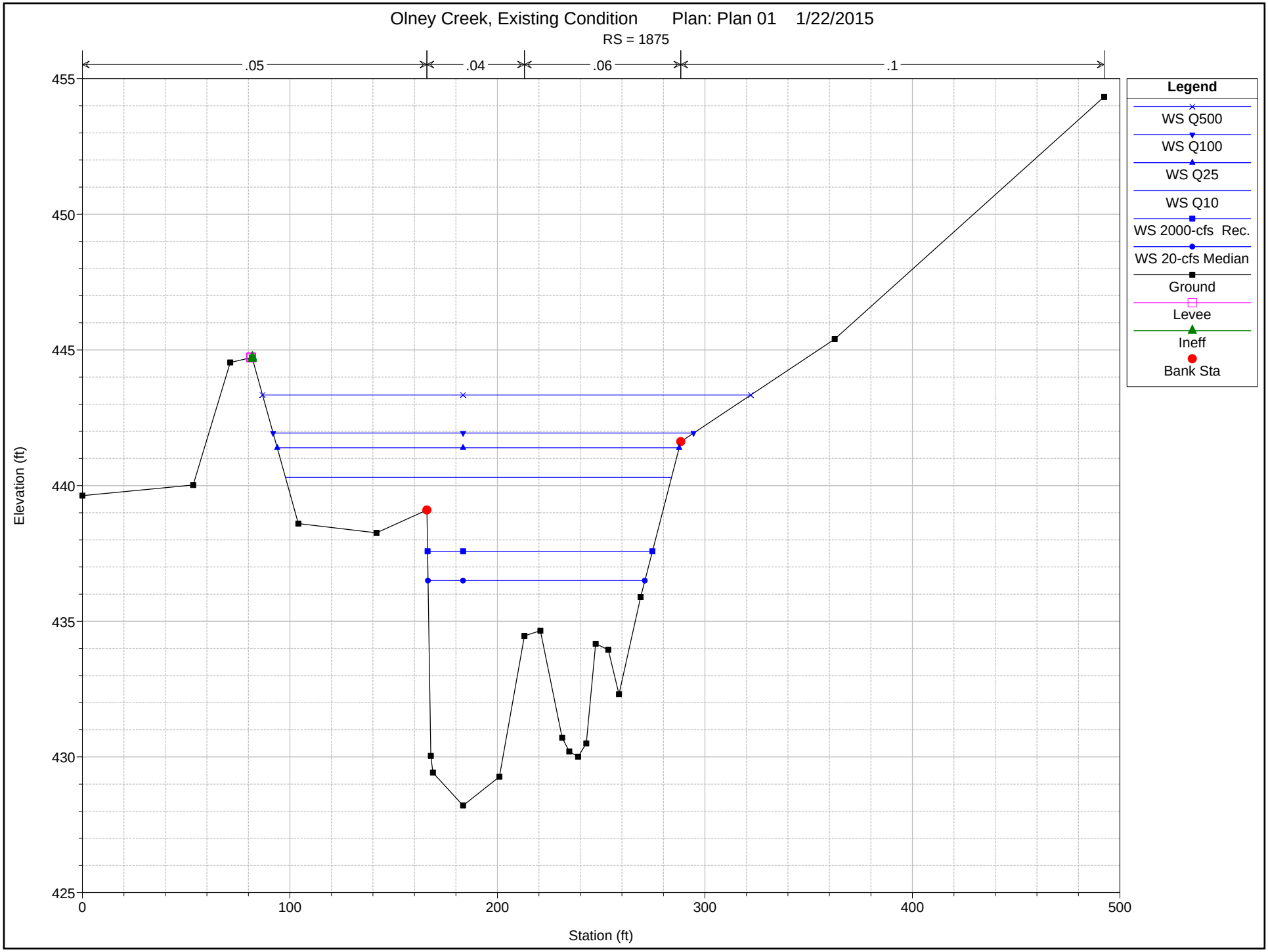
REFERENCES

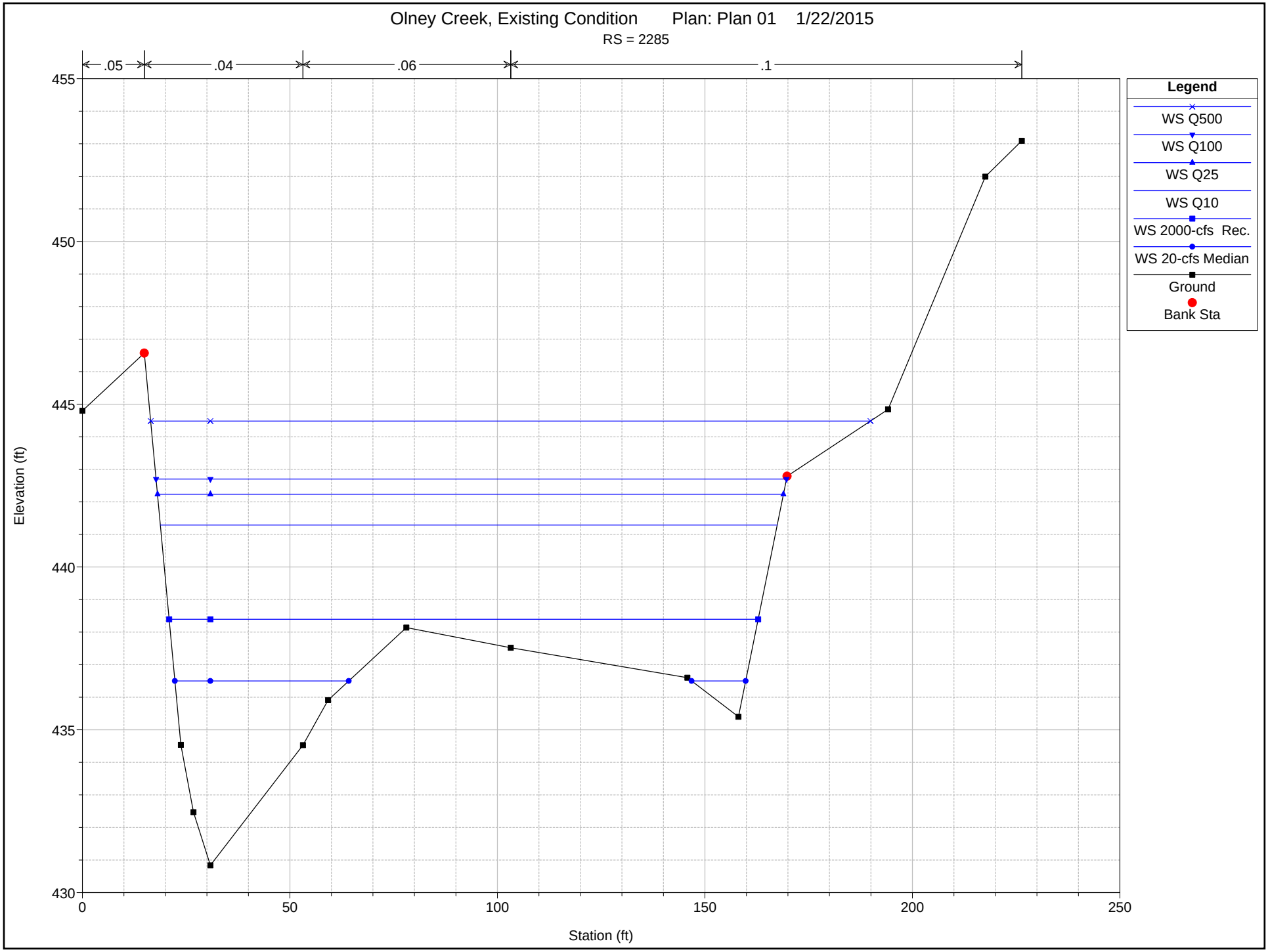
1) United States Army Corps of Engineers, 1997, "HEC-RAS, River Analysis System, Applications Guide," Publication No. CPD-70, Version 3.1.2, Hydraulic Engineering Center, Davis, CA.

2) United States Geological Survey, Harry Barnes Jr., 1967, "Roughness Characteristics of Natural Channels," U.S.G.S. Water Supply Paper 1849, U.S.G.S., Denver Federal Center, Denver, CO.

3) Fread, D.L., 1988, "The NWS DAMBRK Model: Theoretical Background / User Documentation", National Weather Service, Silver Spring, MD.

4) Froehlich, David C., 2008, "Embankment Dam Breach Parameters and Their Uncertainties", Journal of Hydraulic Engineering, American Society of Civil Engineers, Vol 134, No 12, December 2008


Olney Creek, Existing Condition Plan: Plan 01 1/22/2015
RS = 1875
.05
.04
.06
.1
Elevation (ft)
Station (ft)
455
450
445
440
435
430
425
0
100
200
300
400
500
Legend
WS Q500
WS Q100
WS Q25
WS Q10
WS 2000-cfs Rec.
WS 20-cfs Median
Ground
Levee
Ineff
Bank Sta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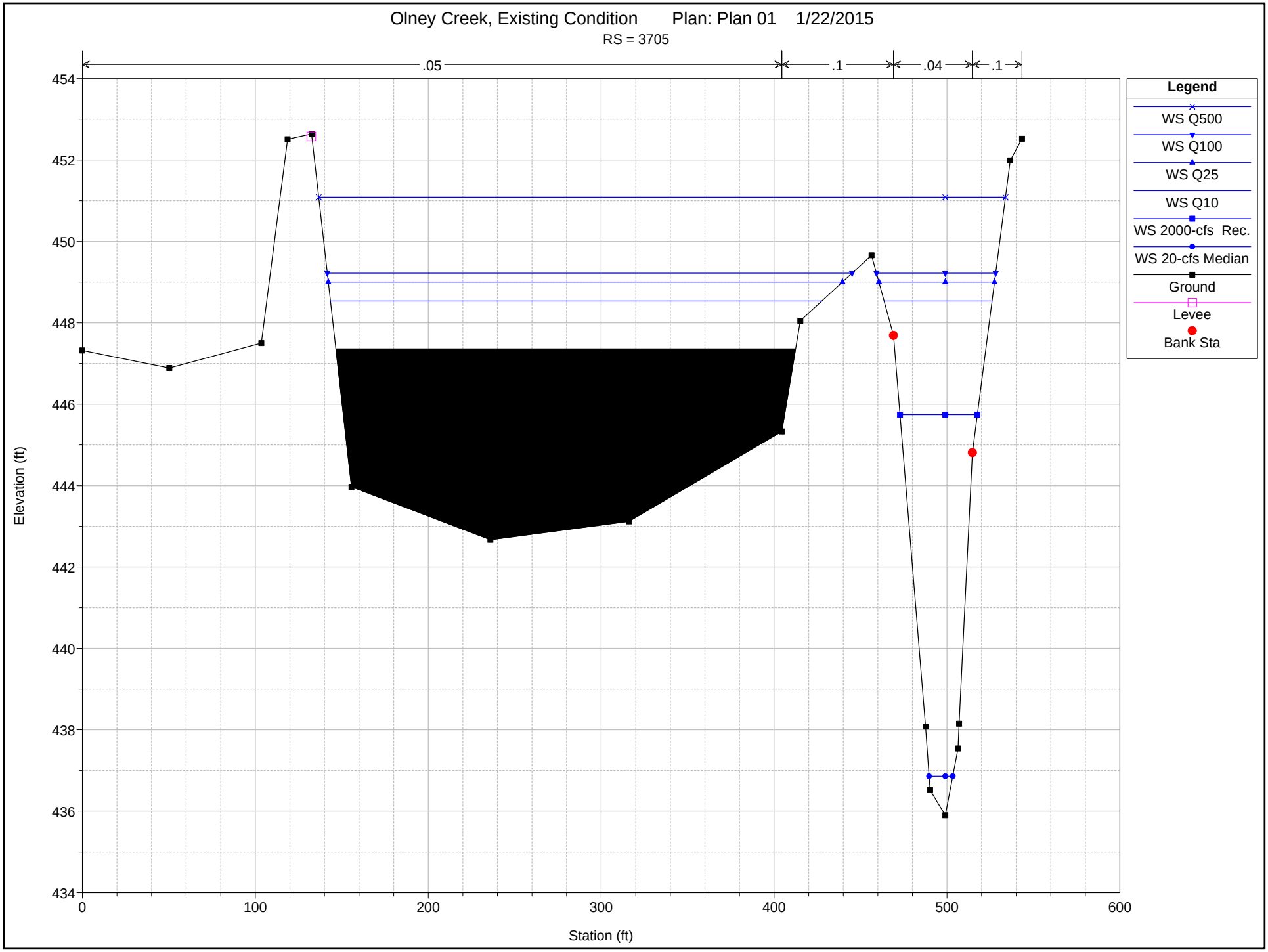
.05
.04
.06
.1
455
450
445
440
435
430
Elevation (ft)
0
50
100
150
200
250
Station (ft)
Legend
WS Q500
WS Q100
WS Q25
WS Q10
WS 2000-cfs Rec.
WS 20-cfs Median
Ground
Bank Sta


Olney Creek, Existing Condition Plan: Plan 01 1/22/2015
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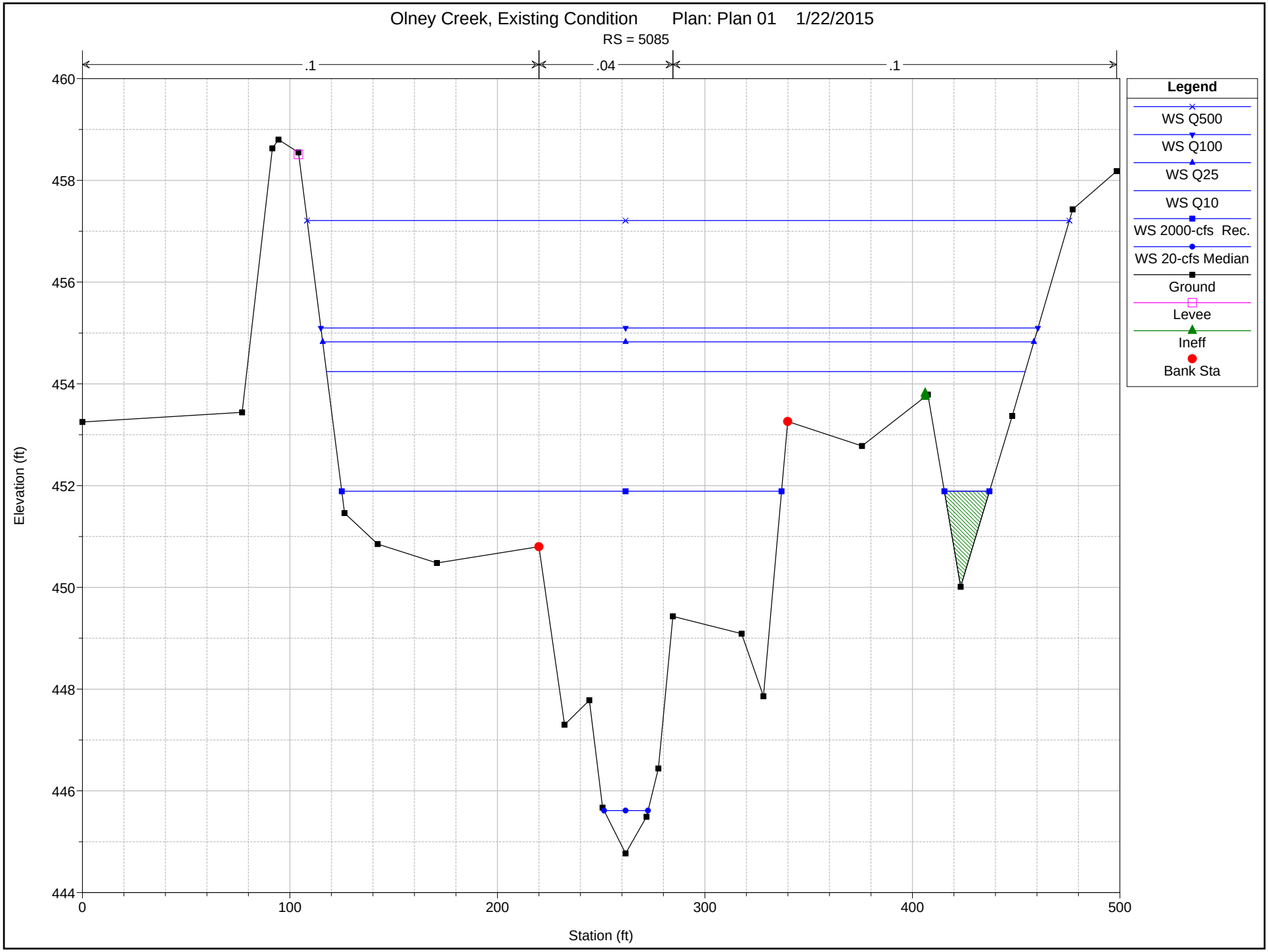
.05
.1
.04
.1
Legend
WS Q500
WS Q100
WS Q25
WS Q10
WS 2000-cfs Rec.
WS 20-cfs Median
Ground
Levee
Bank Sta
Elevation (ft)
454
452
450
448
446
444
442
440
438
436
434
0
100
200
300
400
500
600
Station (ft)


Olney Creek, Existing Condition Plan: Plan 01 1/22/2015
RS = 5085
.1
.04
.1
Legend
WS Q500
WS Q100
WS Q25
WS Q10
WS 2000-cfs Rec.
WS 20-cfs Median
Ground
Levee
Ineff
Bank Sta
Elevation (ft)
460
458
456
454
452
450
448
446
444
0
100
200
300
400
500
Station (ft)

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TECHNICAL MEMORANDUM

To: Jim Bianchin
CGI Technical Services, Inc

Date: July 9, 2015

Re: Olney Creek Levee
Conveyance Improvement Alternative

Background:

The Federal Emergency Management Agency (FEMA) has recently revoked certification of the Olney Creek Levee due to deficiencies in ownership, operation and maintenance, stability documentation, terminations, and other concerns. As a consequence, many residents located behind the levee are now within the Special Flood Hazard Area (SHFA) and are required to pay high flood insurance rates. These residents have requested that the City of Redding investigate options to remove their homes from the SHFA thus removing the requirement to purchase flood insurance. Options to remove the residences from the SHFA include measures to bring the levee in compliance with FEMA certification requirements and implementation of conveyance improvements to render the levee obsolete. This memorandum identifies in general terms and documents the conveyance improvement measures necessary to render the levee obsolete. Measures required to bring the levee into compliance with FEMA certification requirements are being investigated and documented separately.

Hydraulic Analysis: In order for the levee to be rendered obsolete, the peak water surface elevation during the most probable 100-year flood must not exceed the elevation of the natural ground between the channel and the development. Along the levee, this elevation is defined by the toe elevation of the levee opposite the channel. Conveyance improvement measures include management of vegetation within and adjacent to the channel, replacement or modification of encroachments supporting infrastructure (Girvan Road bridge), and physical changes to the channel and floodplain geometry. These options were investigated sequentially in the order identified above by modifying data in a copy of the existing condition backwater model to reflect the measures. After each conveyance improvement iteration backwater model results from the modified data set were compared to the adjacent natural ground elevation to identify sufficiency of the measure, whether or not it was necessary to consider further measures, and to modify measures as necessary to meet the water surface elevation goal.

Results: Implementation of a reasonable vegetation management program was found very insufficient to lower the peak water surface elevation during the most probable 100-year flood at critical locations. Considering that funding for replacement of the Girvan Road bridge has been approved, model data was modified to reflect a reasonable replacement bridge having little encroachment at Girvan Road in an attempt to reduce 100-year flood water surface elevations at Cross-section 1875 below natural ground. Vegetation management plus replacement of the Girvan Road bridge were not sufficient to address the critical location at cross-section 1875. Therefore a physical conveyance improvements were also considered at cross-sections 460 and 1450 (cross-sections representing some level of channel constriction) in an effort to address the critical location at cross-section 1875. Even with the significant conveyance improvements, the goal at cross-section 1875 could not be met. Further modeling considering the 100-year flood combining with the most probable 50- and 10-year floods in the Sacramento River indicated that the goal at cross-section 1875 can be met if FEMA will consider the most probable 10-year flood in the Sacramento River to be appropriate for assessing flood risk in Olney Creek during the most probable 100-year flood. A flood hydrologic study of the combination of flood events will likely support this combination but FEMA's position on such this combination of events is unknown (FEMA is required to map flood risk for the 100-year flood event based on the best understanding of such an event but past experience indicates they prefer conservative analyses and data).

Upstream of cross-section 1875 there are two more critical locations for meeting the FEMA requirement of the peak water surface elevation during the most probable 100-year flood being at or below the adjacent natural ground. These locations are at cross-sections 3705 and 5085. As was the case for cross-section 1875, vegetation management alone was not sufficient to meet the FEMA requirement. A combination of vegetation management, removal of the existing inner earth berm (immediately adjacent to stream channel), and substantial physical channel improvements were found to reduce the peak water surface elevation during the most probable 100-year flood below the adjacent natural ground. Upstream of cross-section 5085 anticipated replacement of the Sacramento Drive bridge along with associated channel conveyance improvements are sufficient to bring the peak water surface elevation during the most probable 100-year flood to an elevation at or below the adjacent natural ground.

Flood profiles showing the peak water surface elevation during the most probable 100-year flood for the existing condition, the condition representing completion of the Sacramento Drive bridge project, and the condition after implementing the conveyance improvement measures with FEMA restudy combining the Olney Creek 100-year flood with the Sacramento River 10-year flood are shown on an attached figure. The flood profile figure also identifies the natural ground elevations at selected critical cross-sections. A second attached figure identifies locations of cross-sections and locations of physical conveyance improvements plus removal of the inner earth berm. Following these figures are a set of figures showing changes in cross-section geometry defining the physical conveyance improvements and the relationship between peak 100-year water surface elevations and adjacent natural ground.

Conclusions:

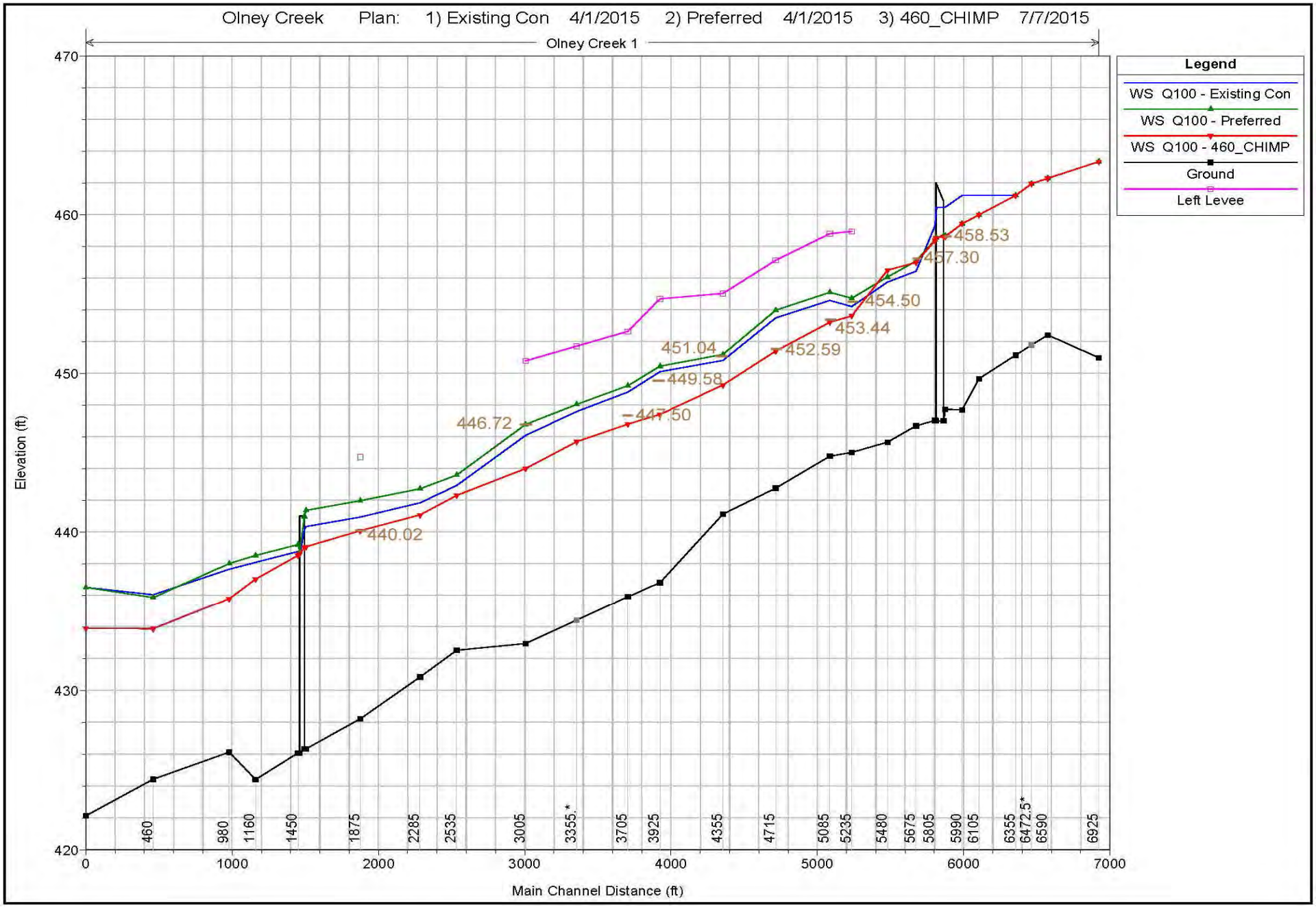
The following measures are necessary to meet the FEMA requirement to render the existing levee obsolete:

- Vegetation management
- Replacement of the Girvan Road bridge
- Physical channel conveyance improvements
- Removal of the inner berm
- Restudy considering Olney Creek 100-year flood combining with Sacramento River 10-year flood

Recommendations:

If the conveyance improvement alternative is to be implemented further analysis will be required for design of the conveyance improvement measures to refine details and to assure that the FEMA requirement is met at all locations rather than just at the surveyed cross-sections. Additionally, increases in the risk of bank erosion associated with physical changes to the channel and with increased velocities of flood water related to conveyance improvements will need to be mitigated.

Norman S. Braithwaite, PE, President
Pacific Hydrologic Incorporated
CA C-37924

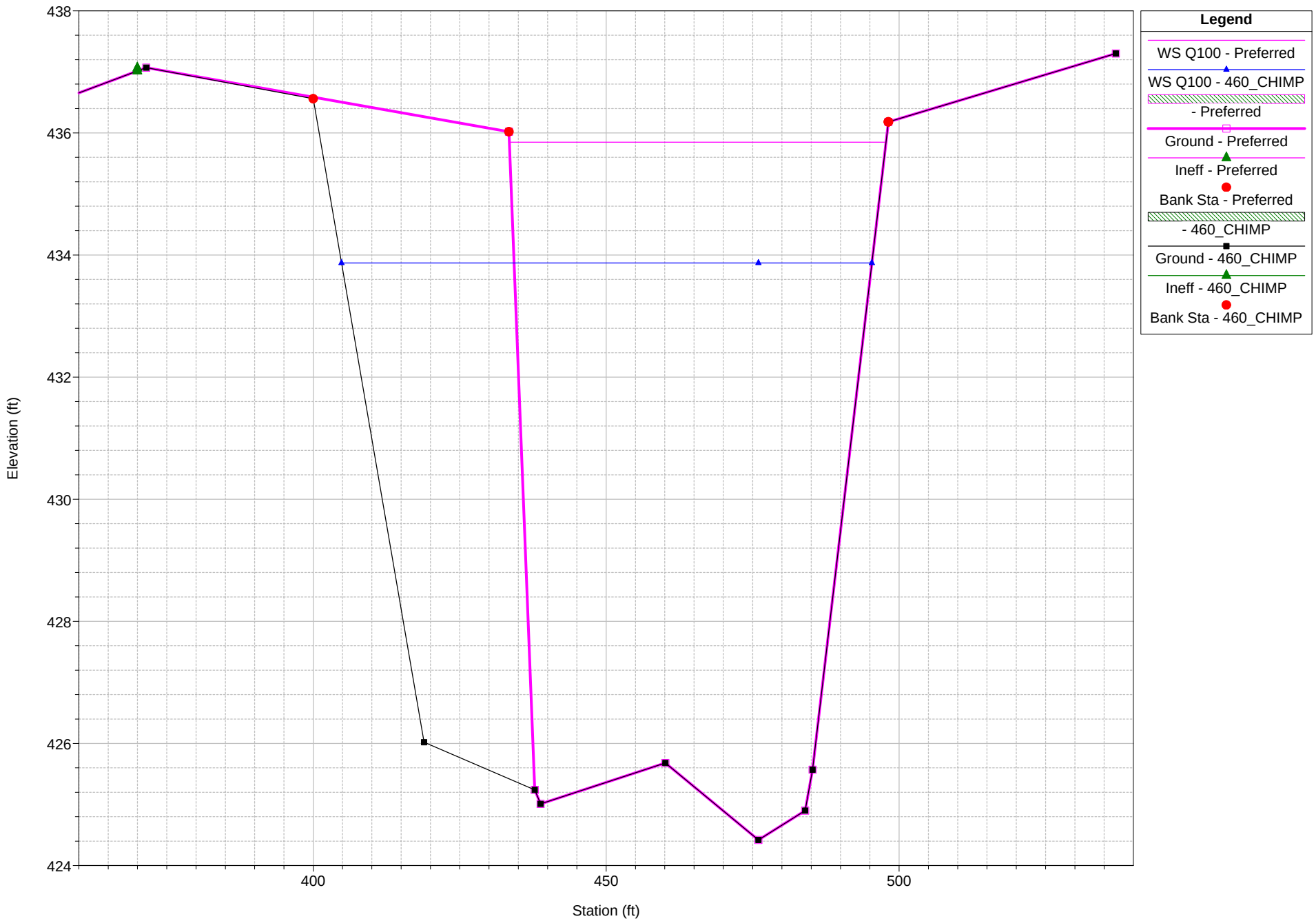


Flood Profiles and Natural Ground adjacent to Channel

Locations of Cross-sections and Physical Conveyance Improvements (brown)

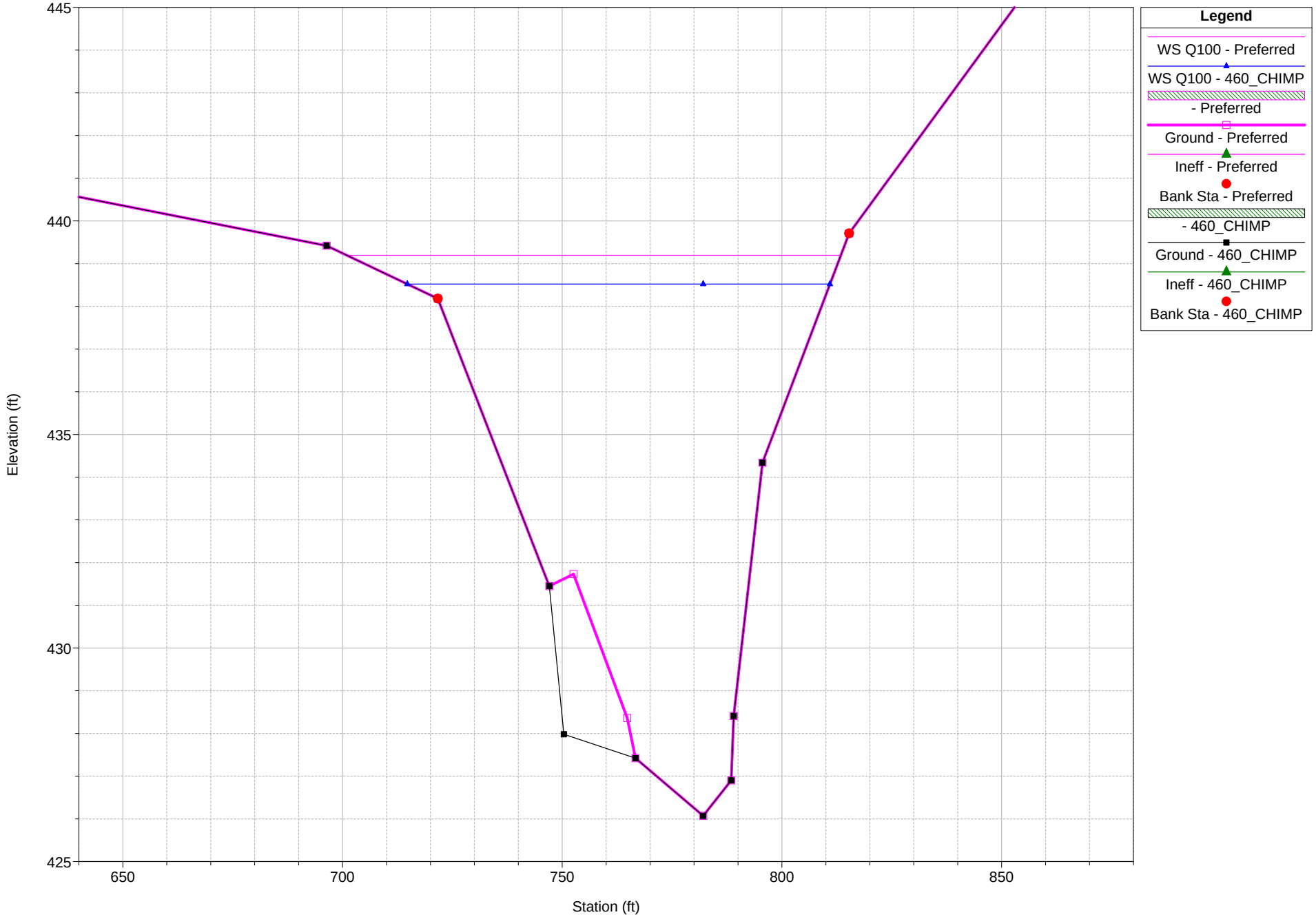
Olney Creek Plan: 1) 460_CHIMP 2) Preferred

RS = 460



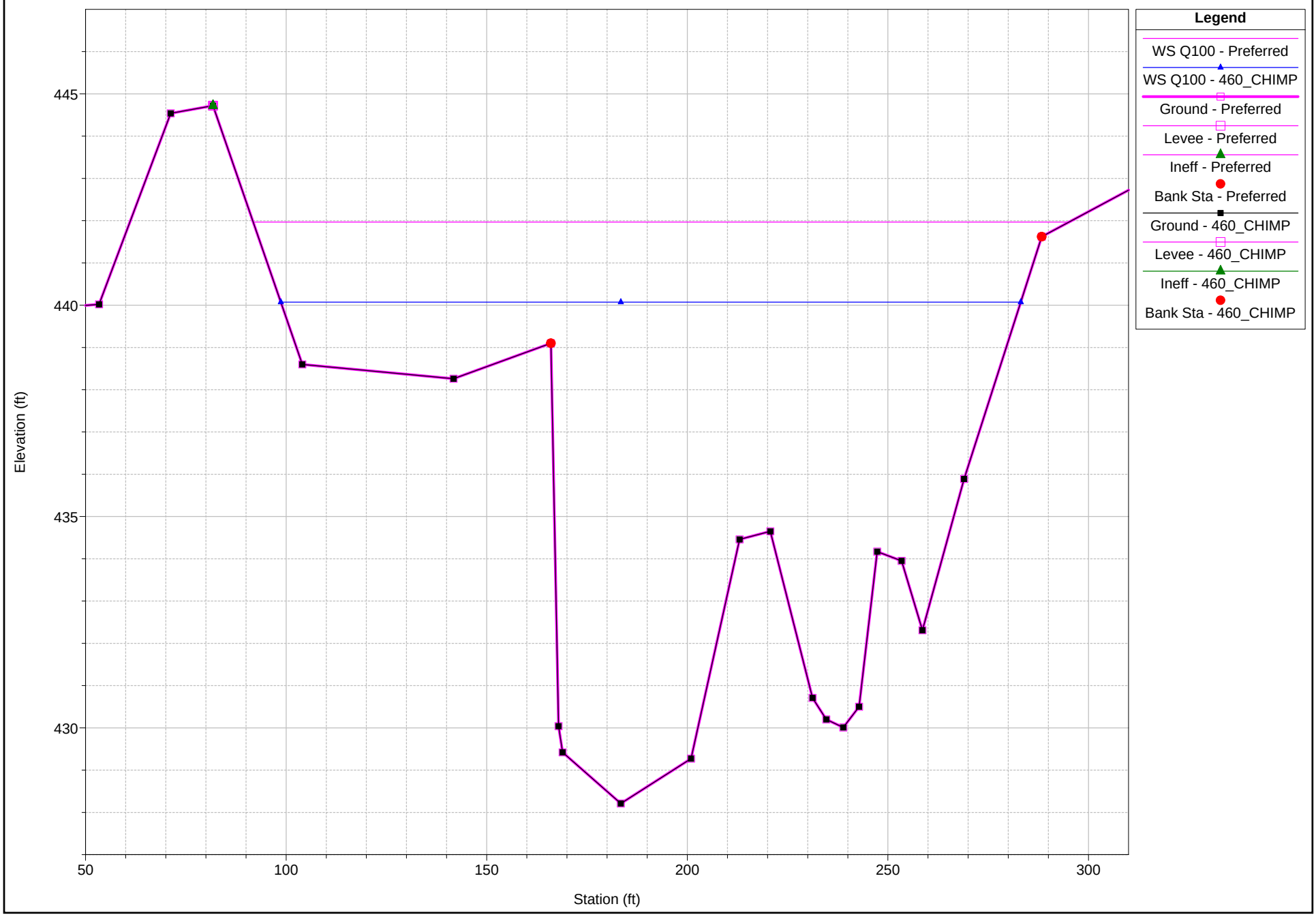
Olney Creek Plan: 1) 460_CHIMP 2) Preferred

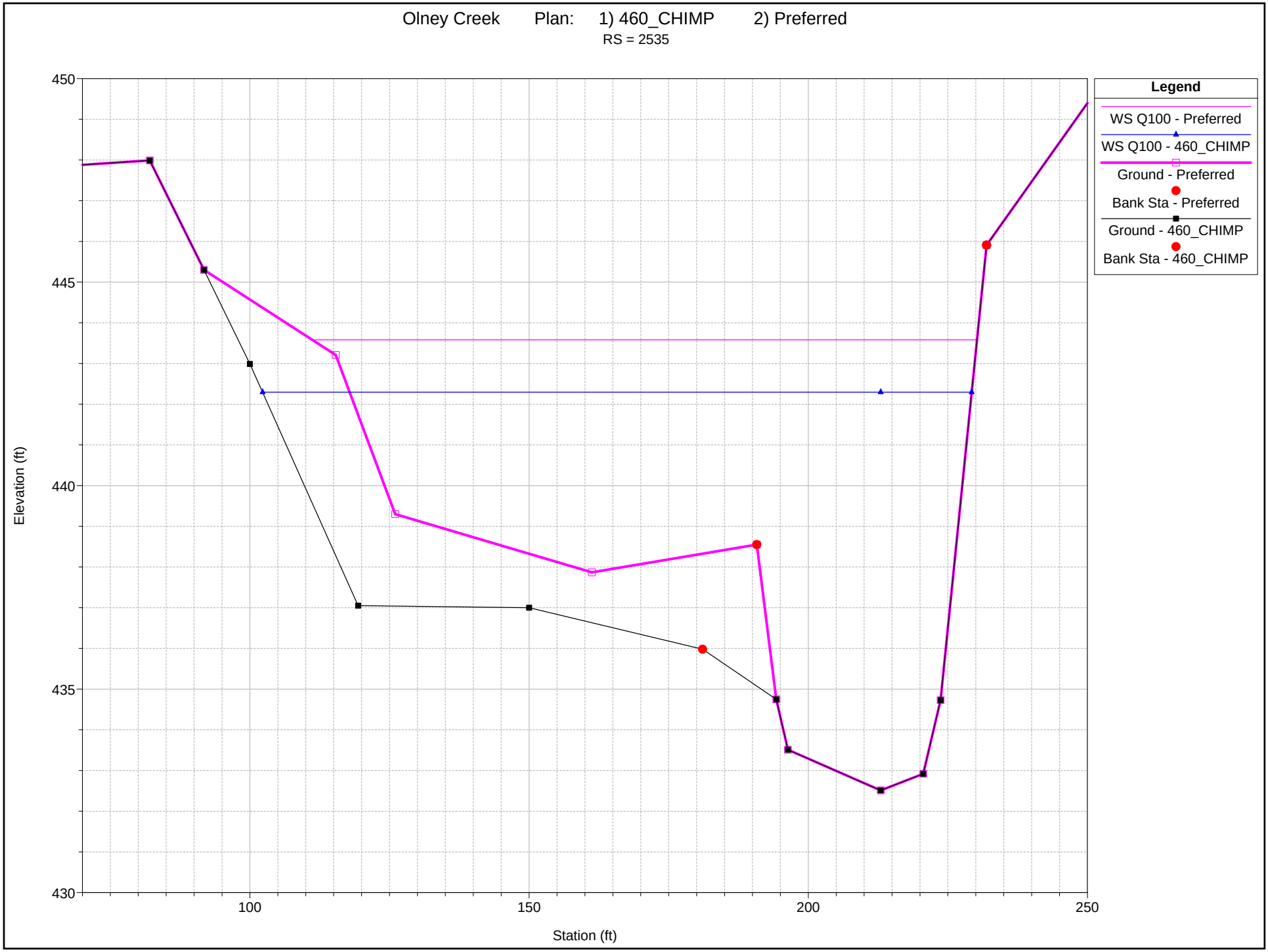
RS = 1450



Olney Creek Plan: 1) 460_CHIMP 2) Preferred

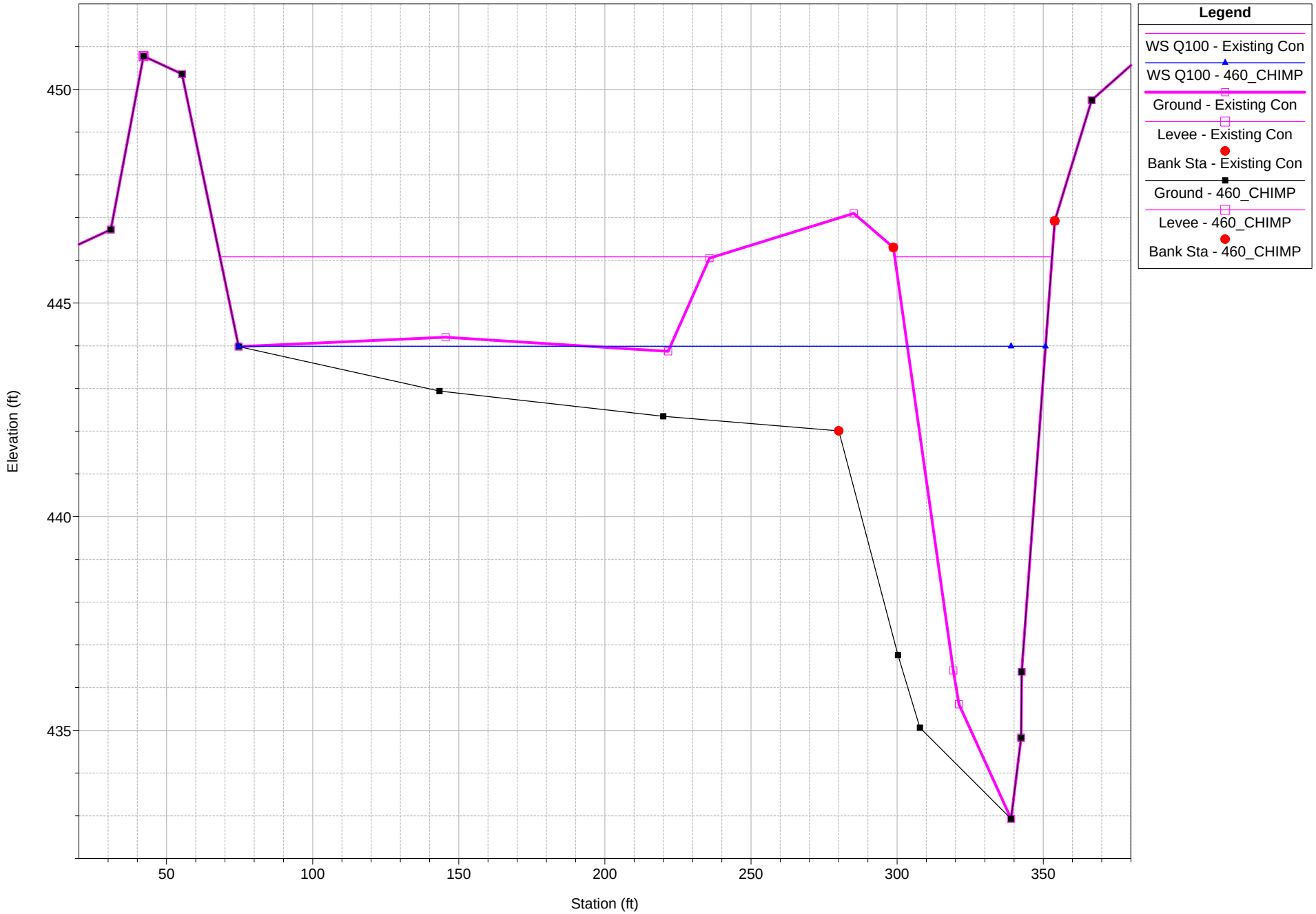
RS = 1875




Olney Creek Plan: 1) 460_CHIMP 2) Preferred
RS = 2535
Legend
WS Q100 - Preferred
WS Q100 - 460_CHIMP
Ground - Preferred
Bank Sta - Preferred
Ground - 460_CHIMP
Bank Sta - 460_CHIMP
Elevation (ft)
450
445
440
435
430
Station (ft)
100
150
200
250

Olney Creek Plan: 1) 460_CHIMP 2) Existing Con

RS = 3005



Olney Creek Plan: 1) 460_CHIMP 2) Existing Con

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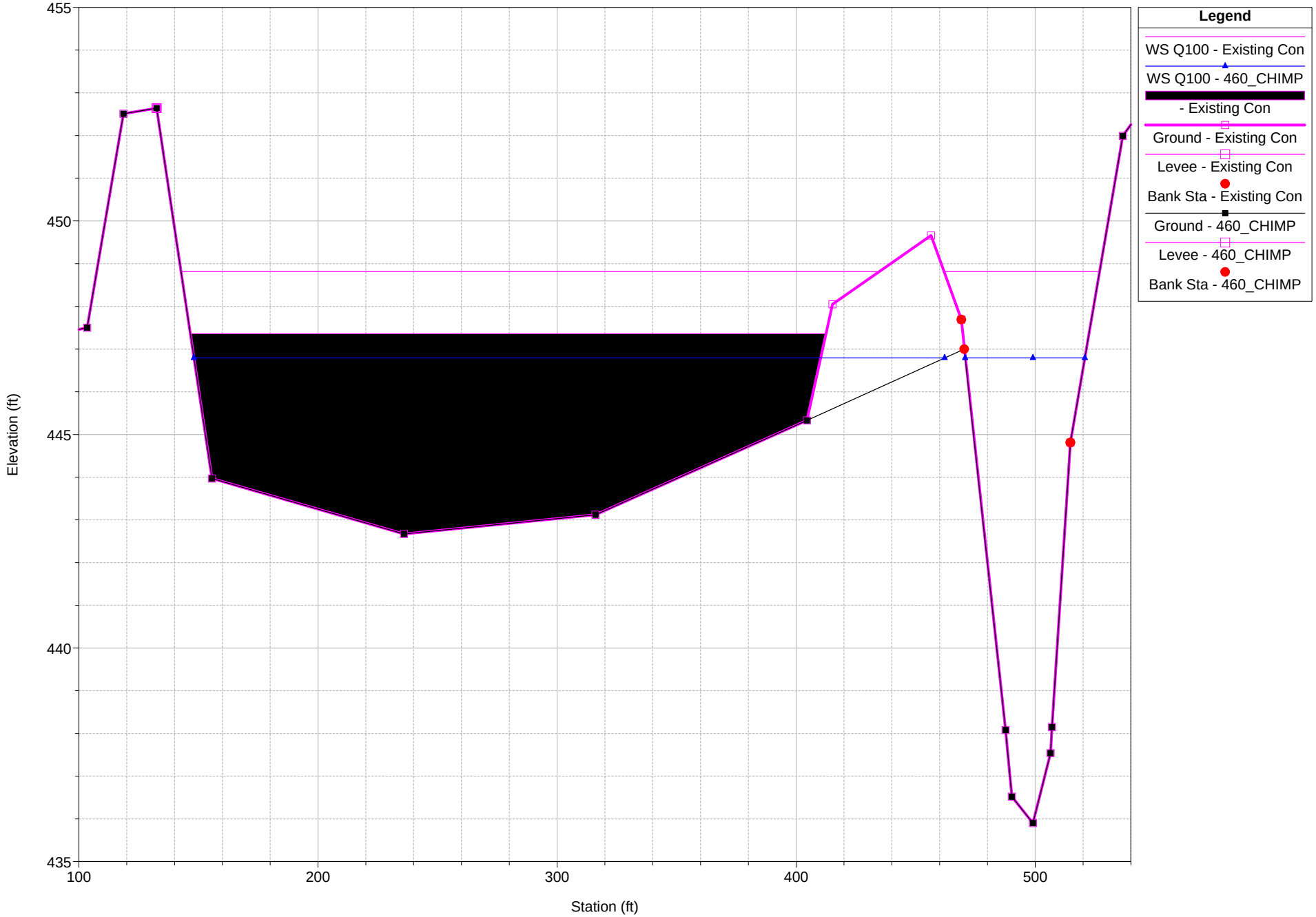
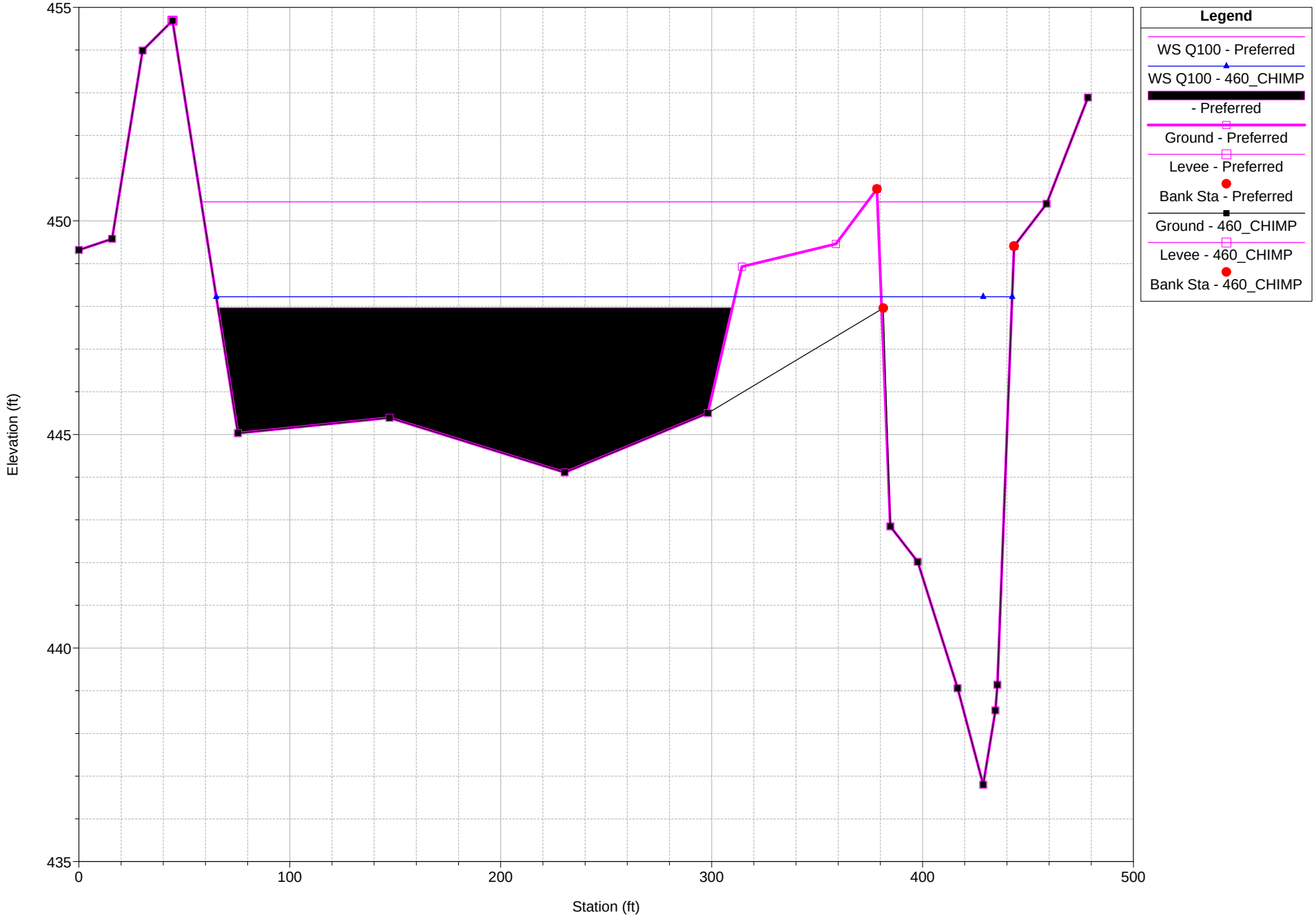


Olney Creek Plan: 1) 460_CHIMP 2) Preferred

RS = 3925



Olney Creek Plan: 1) 460_CHIMP 2) Preferred

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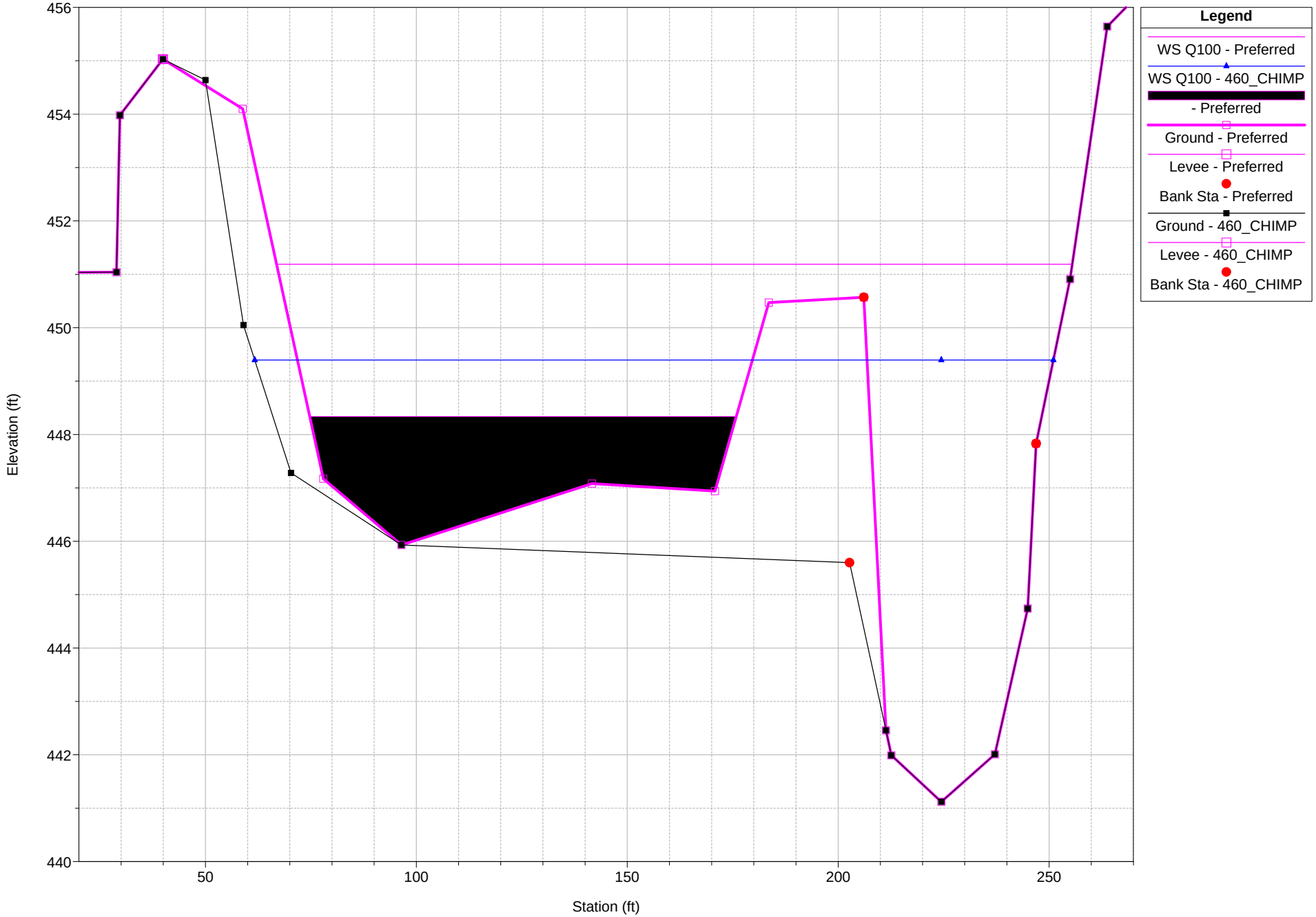
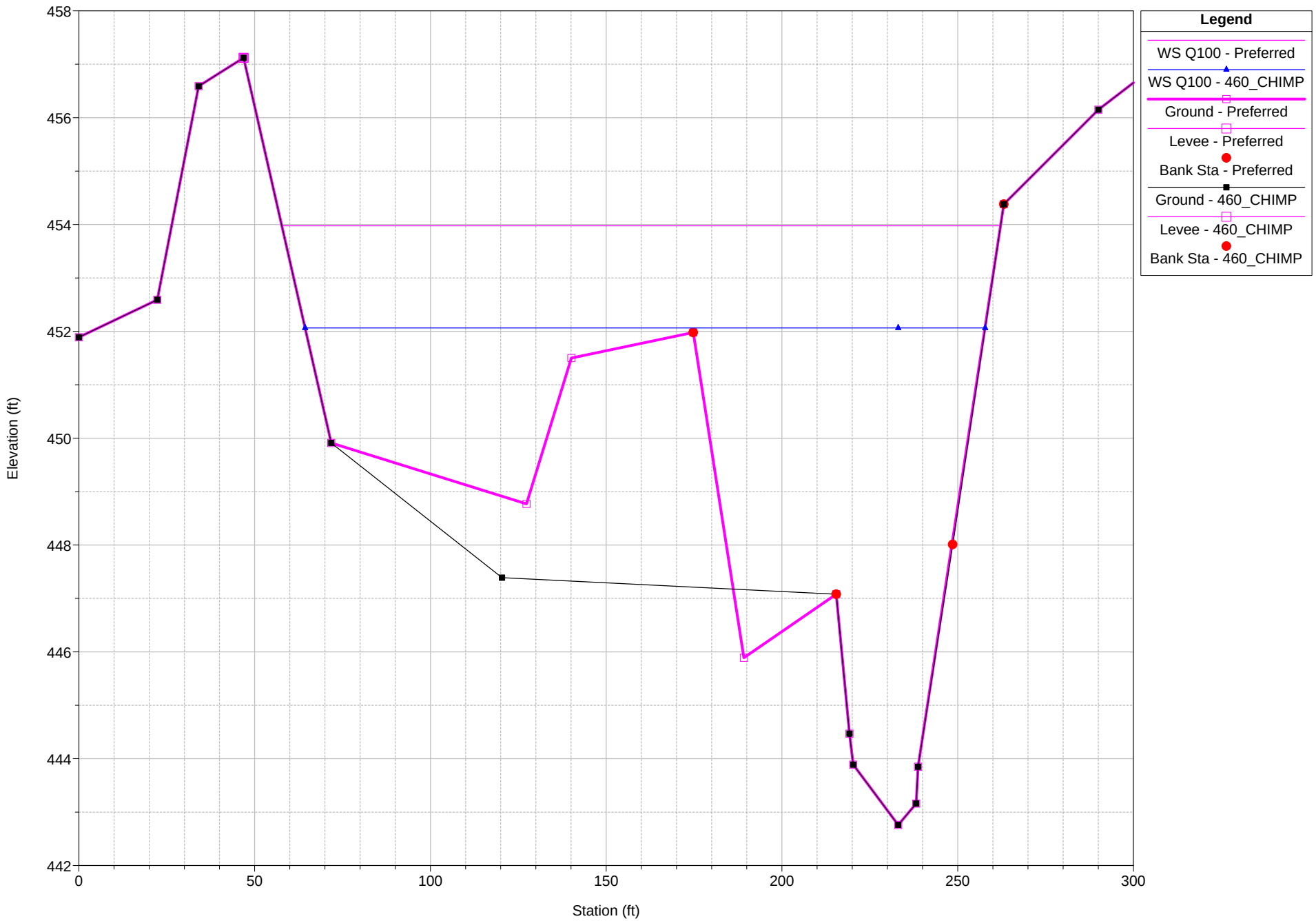
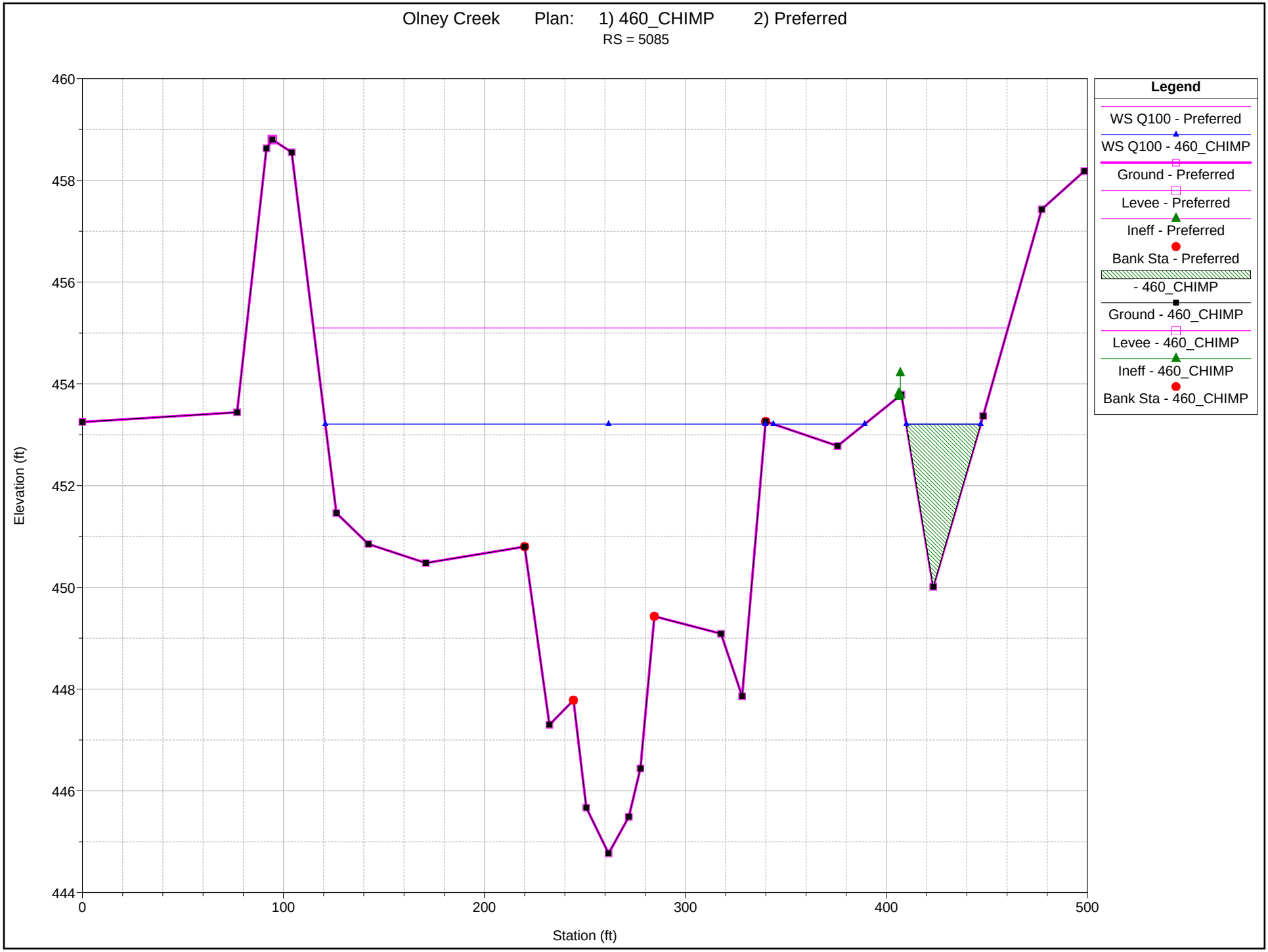
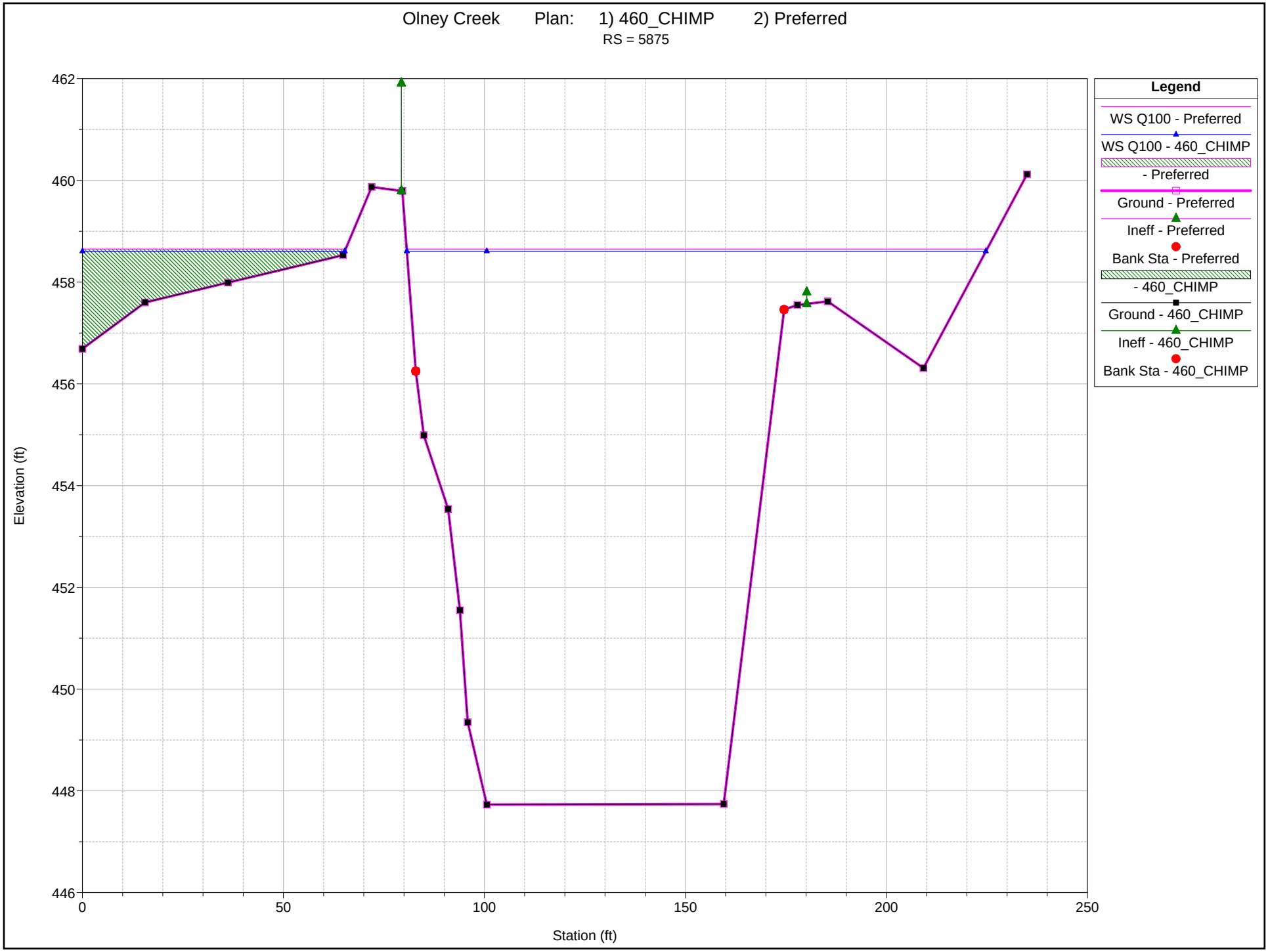


Olney Creek Plan: 1) 460_CHIMP 2) Preferred

RS = 4715




Olney Creek Plan: 1) 460_CHIMP 2) Preferred
RS = 5085
Elevation (ft)
Station (ft)
460
458
456
454
452
450
448
446
444
0
100
200
300
400
500
Legend
WS Q100 - Preferred
WS Q100 - 460_CHIMP
Ground - Preferred
Levee - Preferred
Ineff - Preferred
Bank Sta - Preferred
- 460_CHIMP
Ground - 460_CHIMP
Levee - 460_CHIMP
Ineff - 460_CHIMP
Bank Sta - 460_CHIMP


Olney Creek Plan: 1) 460_CHIMP 2) Preferred
RS = 5875
Elevation (ft)
Station (ft)
462
460
458
456
454
452
450
448
446
0
50
100
150
200
250
Legend
WS Q100 - Preferred
WS Q100 - 460_CHIMP
- Preferred
Ground - Preferred
Ineff - Preferred
Bank Sta - Preferred
- 460_CHIMP
Ground - 460_CHIMP
Ineff - 460_CHIMP
Bank Sta - 460_CHIMP

Appendix C
Conceptual Plans

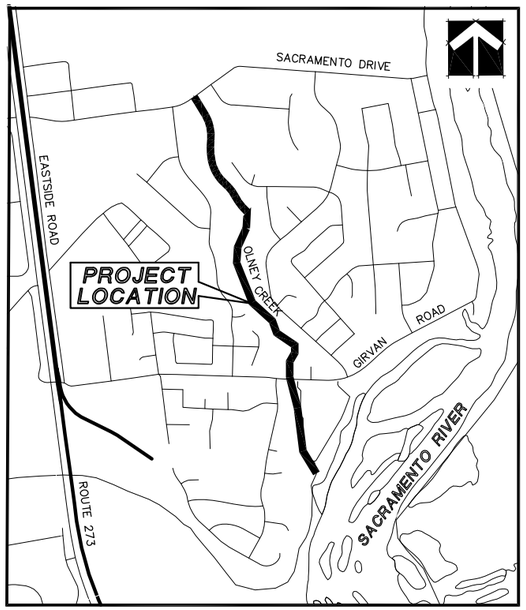
APPENDIX C
CONCEPTUAL PLANS

Based on the identified alternatives noted in Tables 2 and 3 within the text, conceptual plans were developed that illustrate each of those alternatives. The plans were prepared by Omni•Means, Ltd., and are attached to this appendix.

CONCEPTUAL PLANS FOR THE

OLNEY CREEK LEVEE IMPROVEMENT ALTERNATIVE

IN THE CITY OF REDDING



PROJECT LOCATION

NTS

SHEET INDEX

CIVIL

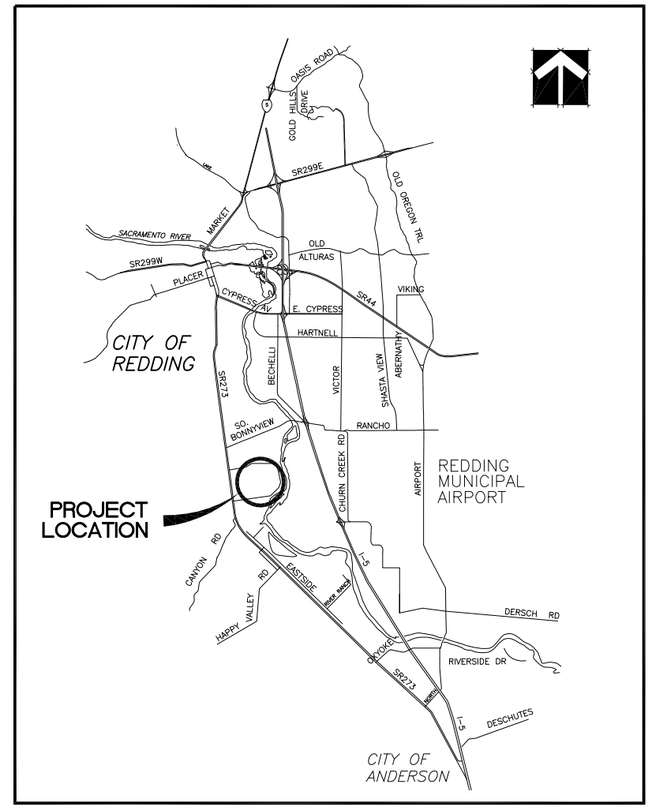
SHEET 1	TITLE SHEET
SHEET 2	LAYOUT SHEET
SHEET 3	LAYOUT SHEET
SHEET 4	LAYOUT SHEET
SHEET 5	LAYOUT SHEET

LEGEND

CLEARING

GABION WALL

RSP



VICINITY MAP

NTS

REGISTERED PROFESSIONAL ENGINEER
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CIVIL
STATE OF CALIFORNIA
PRELIMINARY

ORIGINAL SCALE IN INCHES 0 1 2

DESIGNED BY RFB
DRAWN BY ASH
REVIEWED BY RAW

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REDDING 2320 Breslin Ave. Suite B (530) 242-1700 www.omni-means.com
also in: ROSEVILLE SACRAMENTO MOUNTAIN VIEW SAN LUIS OBISPO & LAPA

CITY OF REDDING
PUBLIC WORKS DEPARTMENT

OLNEY CREEK LEVEE IMPROVEMENT ALTERNATIVE

JOB NO. XXXX BID SCH NO. XXXX

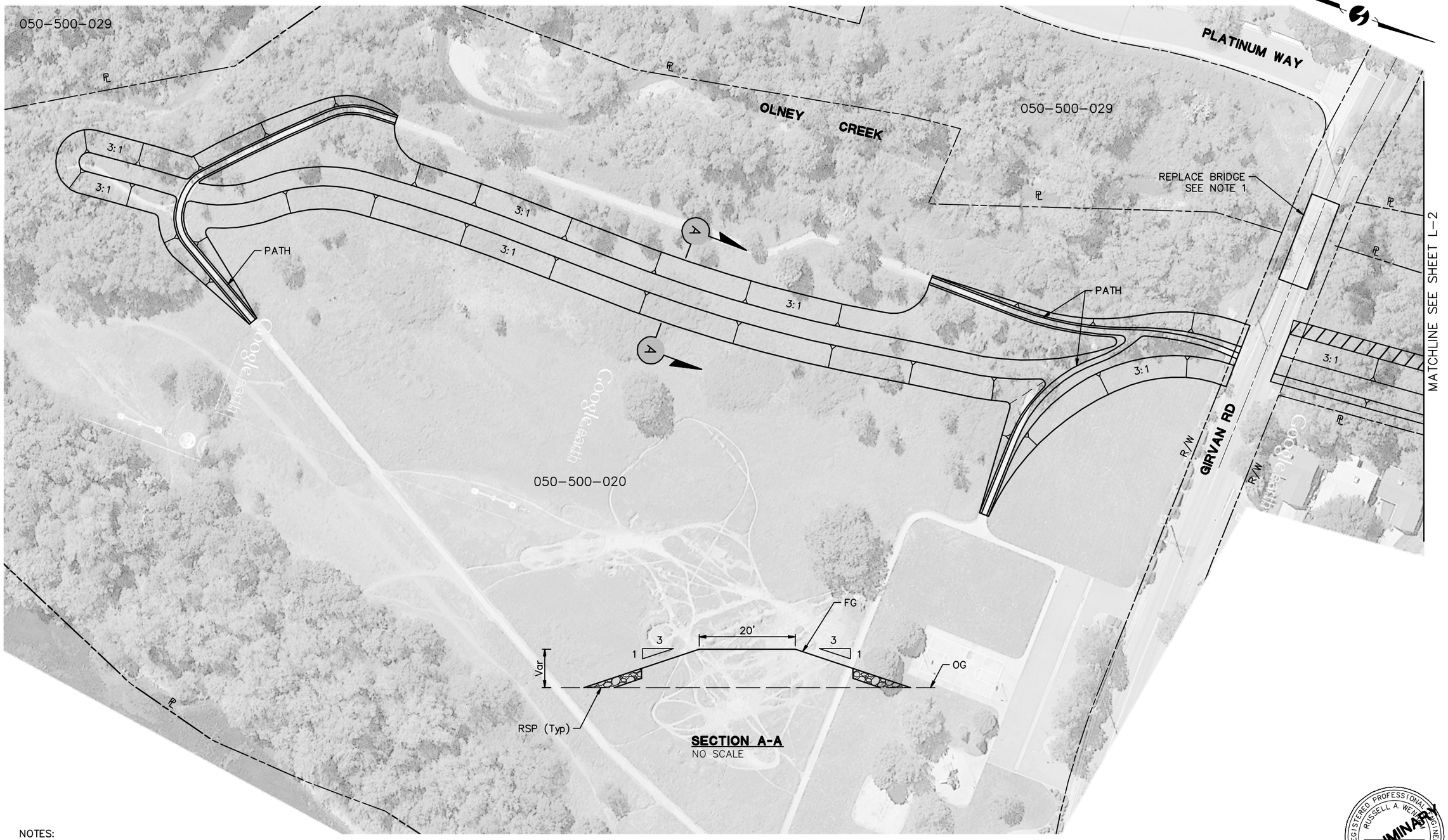
TITLE SHEET

T-1

ORIGINAL SCALE: NTS

DATE: 4/26/17

SHEET 1 OF 5



SECTION A-A
NO SCALE

NOTES:

1.) GIRVAN ROAD/OLNEY CREEK BRIDGE REPLACEMENT PROJECT IS FUNDED SEPARATELY.

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0 1 2

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PUBLIC WORKS DEPARTMENT

OLNEY CREEK LEVEE
IMPROVEMENT ALTERNATIVE

JOB NO. XXXX
BID SCH NO. XXXX

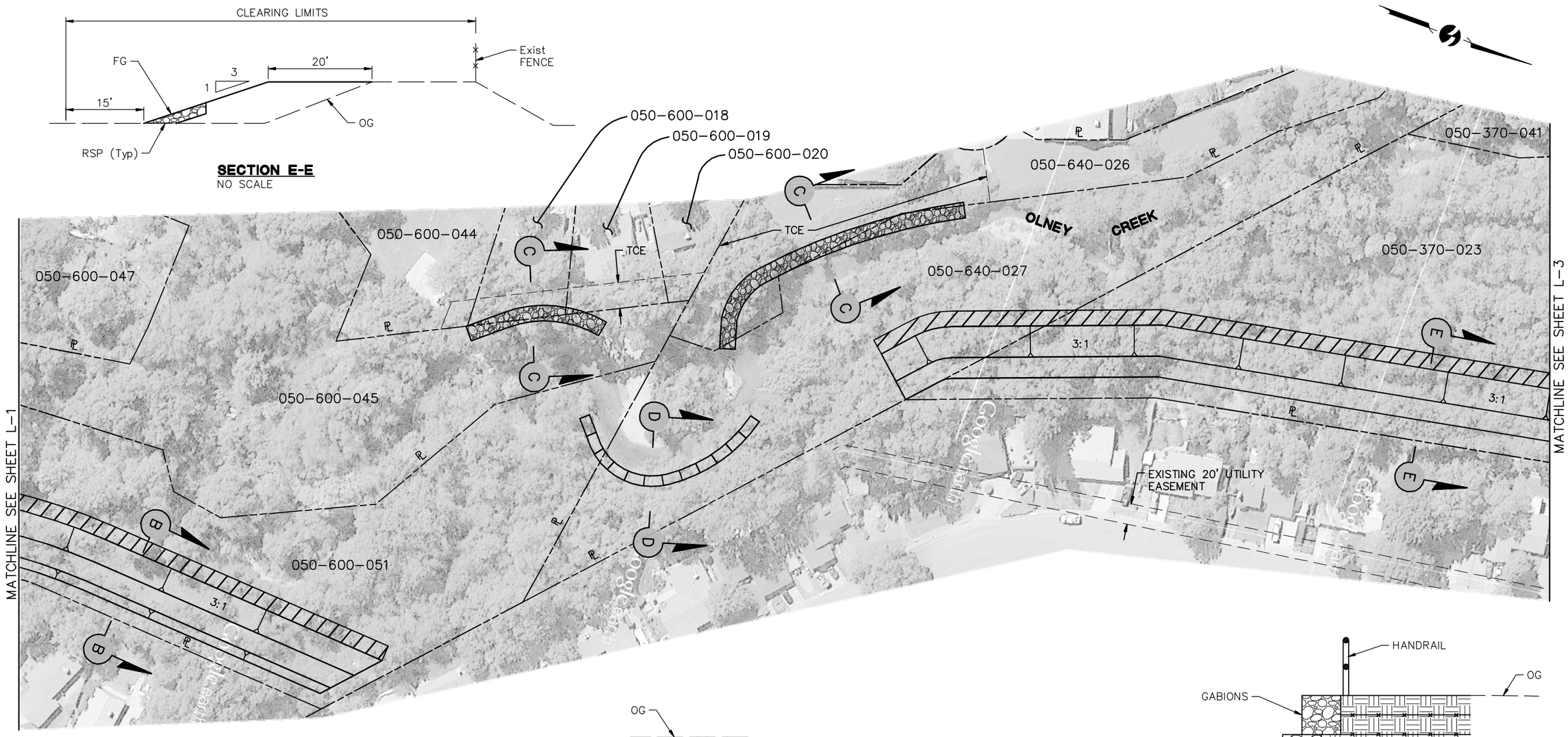
LAYOUT SHEET

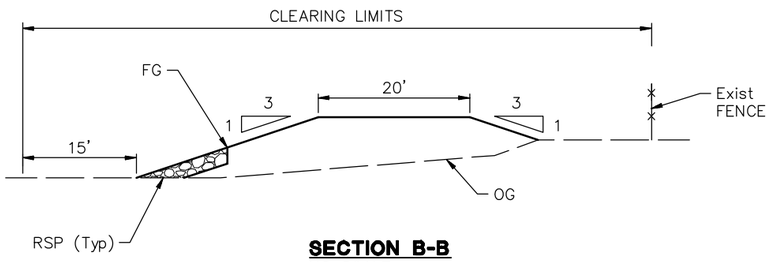
L-1

ORIGINAL SCALE:
1"=50'

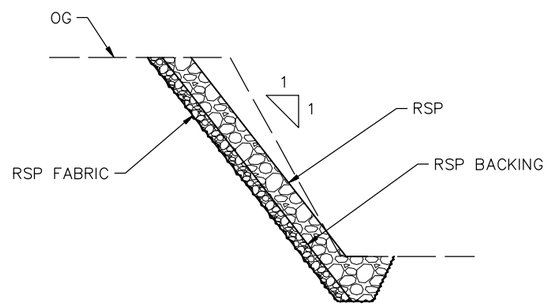
DATE: 4/26/17

SHEET 2 OF 5

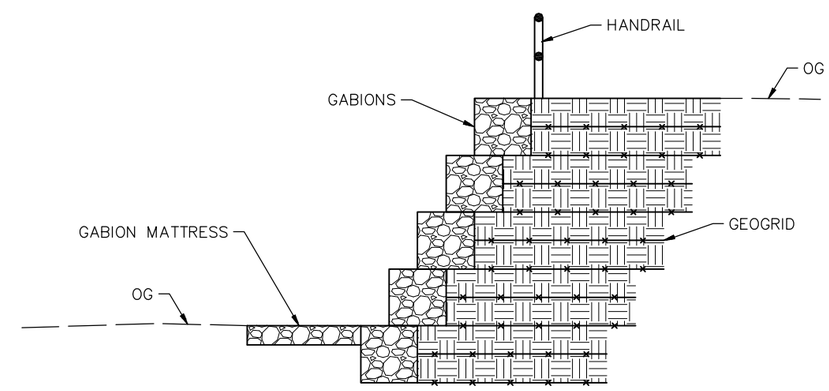




SECTION B-B
NO SCALE



SECTION C-C
NO SCALE



SECTION D-D
NO SCALE

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STATE OF CALIFORNIA
PRELIMINARY

ORIGINAL SCALE IN INCHES 0 1 2

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DRAWN BY ASH
REVIEWED BY RAW

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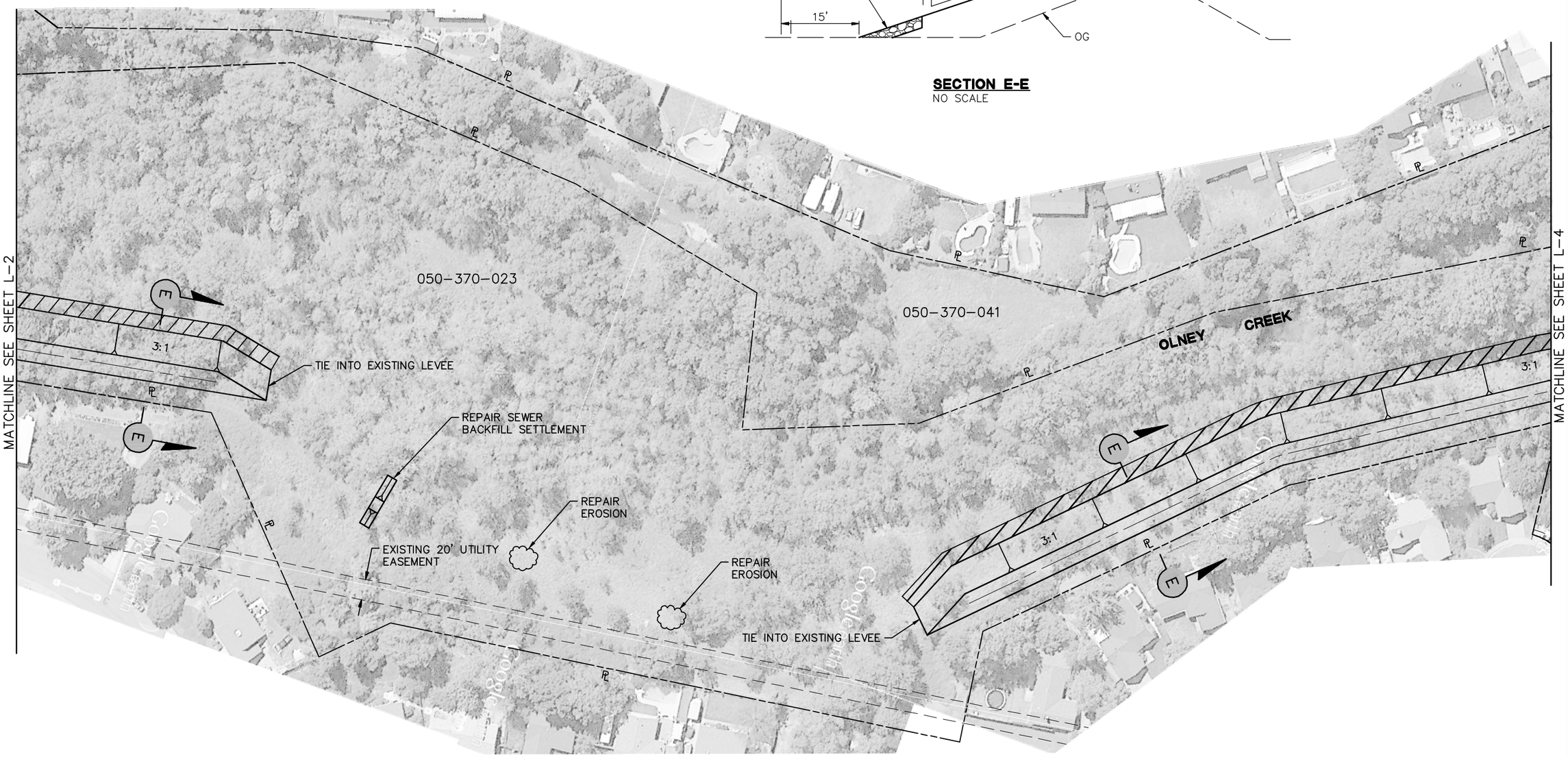
www.omnimeans.com

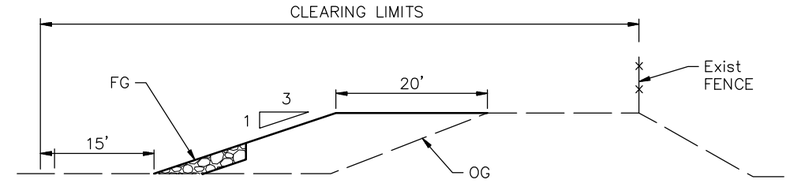
CITY OF REDDING
PUBLIC WORKS DEPARTMENT

OLNEY CREEK LEVEE IMPROVEMENT ALTERNATIVE
LAYOUT SHEET

JOB NO. XXXX
BID SCH NO. XXXX

L-2
ORIGINAL SCALE: 1"=50'
DATE: 4/26/17
SHEET 3 OF 5





SECTION E-E
NO SCALE

PRELIMINARY
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ORIGINAL SCALE IN INCHES 0 1 2

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DRAWN BY ASH
REVIEWED BY RAW

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CITY OF REDDING
PUBLIC WORKS DEPARTMENT

OLNEY CREEK LEVEE
IMPROVEMENT ALTERNATIVE

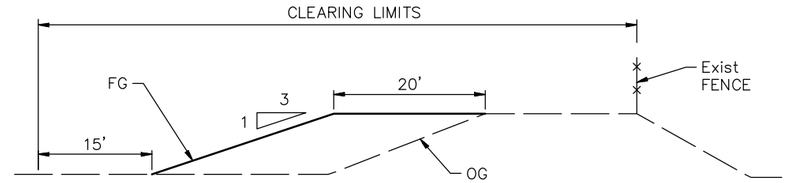
JOB NO. XXXX
BID SCH NO. XXXX

LAYOUT SHEET

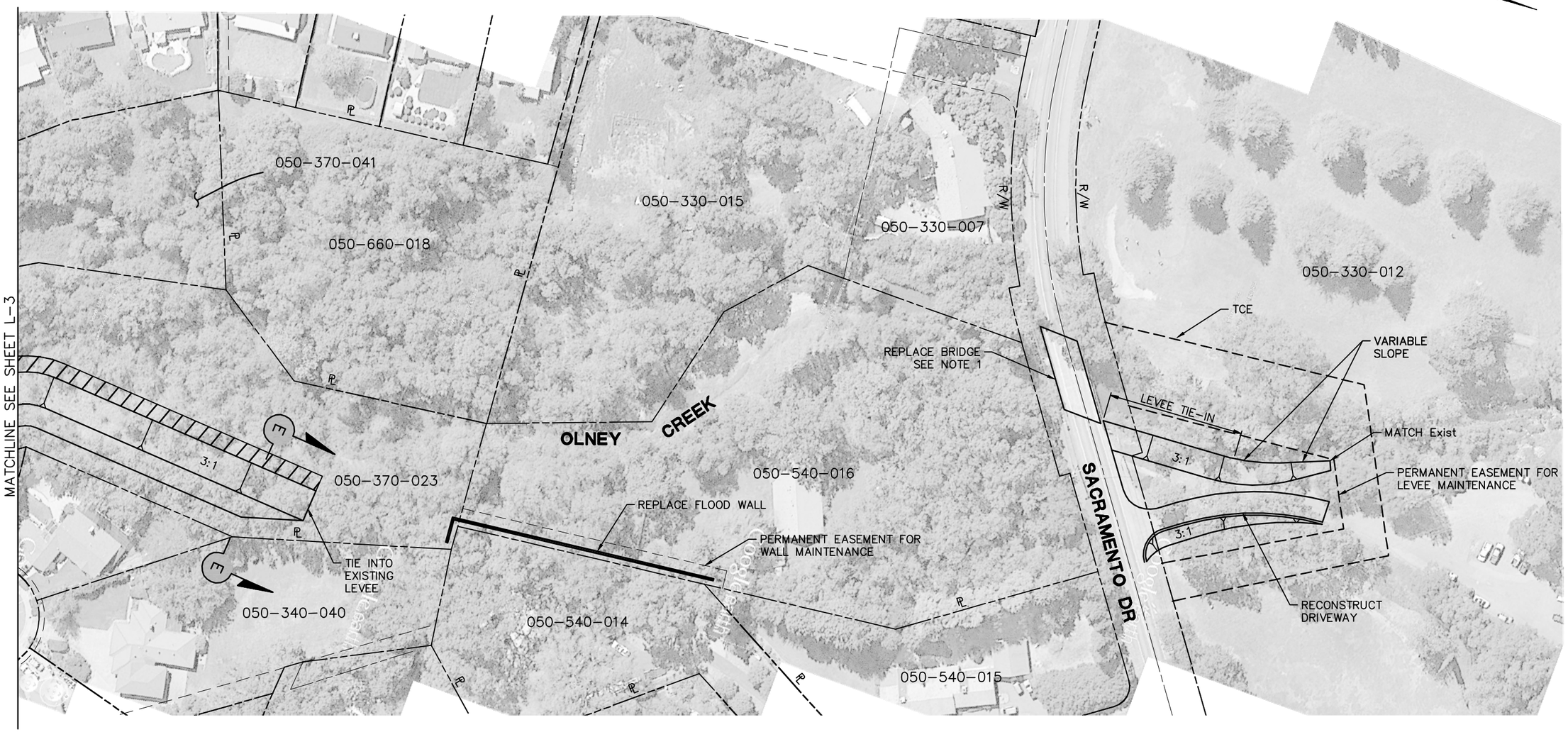
L-3
ORIGINAL SCALE: 1"=50'
DATE: 4/26/17
SHEET 4 OF 5

NOTES:

1.) SACRAMENTO DRIVE/OLNEY CREEK BRIDGE REPLACEMENT PROJECT IS FUNDED SEPARATELY.



SECTION E-E
NO SCALE



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PUBLIC WORKS DEPARTMENT

OLNEY CREEK LEVEE
IMPROVEMENT ALTERNATIVE

JOB NO. XXXX
BID SCH NO. XXXX

LAYOUT SHEET

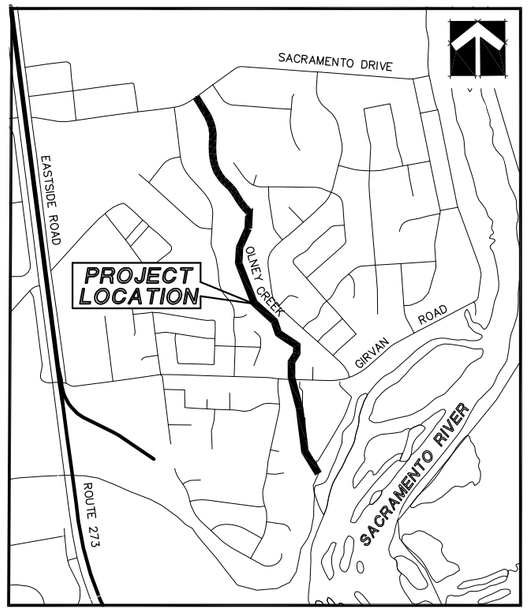
L-4

ORIGINAL SCALE: 1"=50'
DATE: 4/26/17
SHEET 5 OF 5

CONCEPTUAL PLANS FOR THE

OLNEY CREEK CONVEYANCE IMPROVEMENT ALTERNATIVE

IN THE CITY OF REDDING



PROJECT LOCATION

NTS

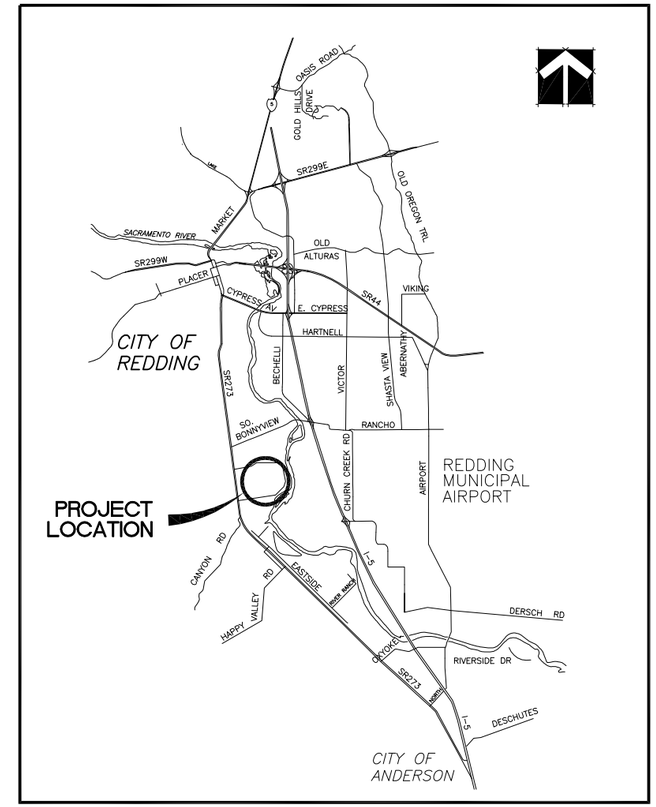
SHEET INDEX

CIVIL

SHEET 1	TITLE SHEET
SHEET 2	LAYOUT SHEET
SHEET 3	LAYOUT SHEET
SHEET 4	LAYOUT SHEET
SHEET 5	LAYOUT SHEET

LEGEND

- CLEARING AND GRADING
- EXCAVATION
- GABION WALL
- RSP



VICINITY MAP

NTS

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REVIEWED BY RAW

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MOUNT OREM 1000 E. 100 S. Suite 203 Provo, UT 84606 (801) 377-9111
SAN LUIS OBISPO 1344 Emerald St. San Luis Obispo, CA 93401 (805) 544-3011

CITY OF REDDING
PUBLIC WORKS DEPARTMENT

OLNEY CREEK CONVEYANCE IMPROVEMENT ALTERNATIVE

JOB NO. XXXX
BID SCH NO. XXXX

TITLE SHEET

T-1

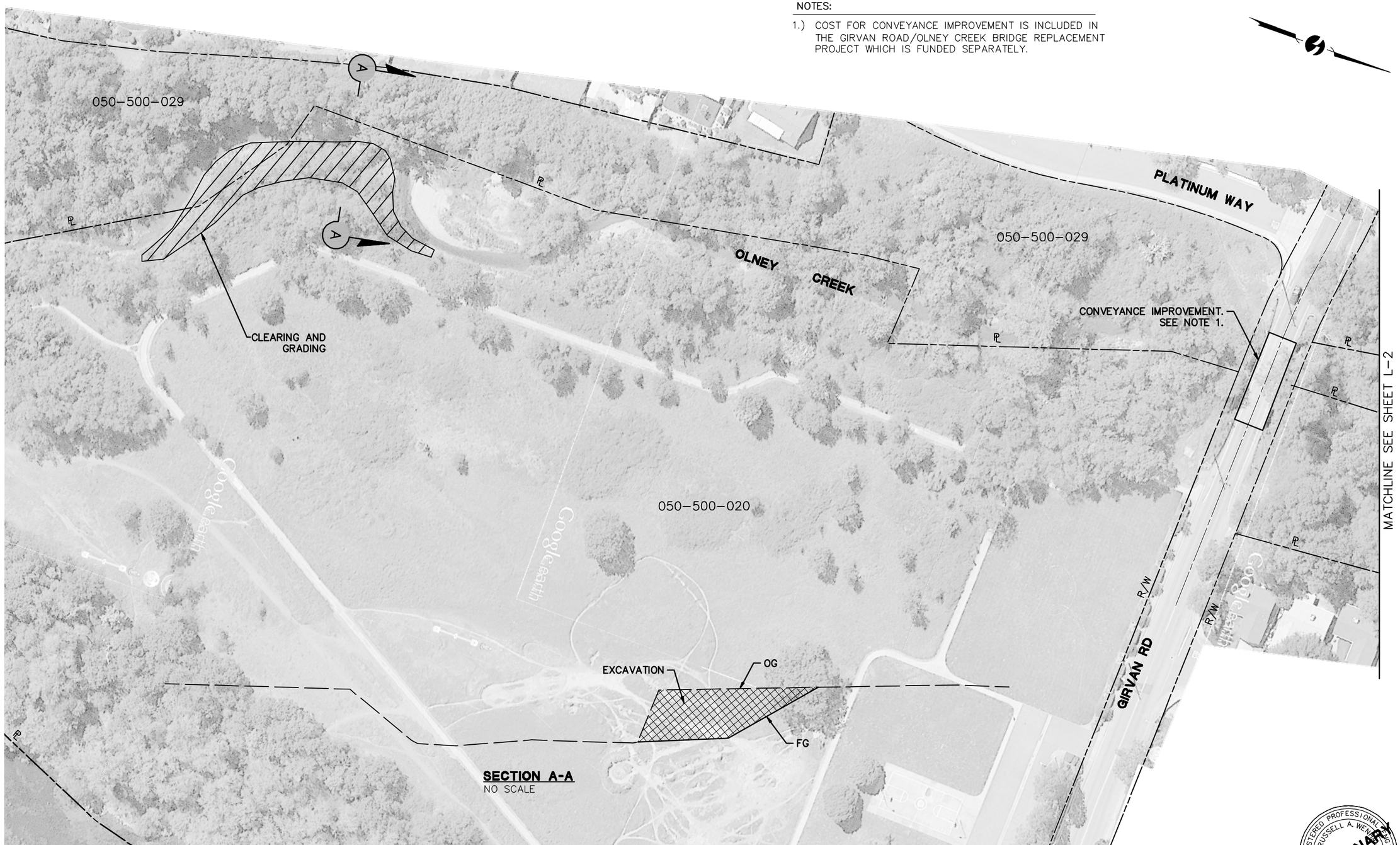
ORIGINAL SCALE: NTS

DATE: 4/26/17

SHEET 1 OF 5

NOTES:

1.) COST FOR CONVEYANCE IMPROVEMENT IS INCLUDED IN THE GIRVAN ROAD/OLNEY CREEK BRIDGE REPLACEMENT PROJECT WHICH IS FUNDED SEPARATELY.



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STATE OF CALIFORNIA
PRELIMINARY

ORIGINAL SCALE IN INCHES 0 1 2

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REVIEWED BY RAW

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PUBLIC WORKS DEPARTMENT

OLNEY CREEK CONVEYANCE IMPROVEMENT ALTERNATIVE

JOB NO. XXXX
BID SCH NO. XXXX

LAYOUT SHEET

L-1

ORIGINAL SCALE: 1"=50'

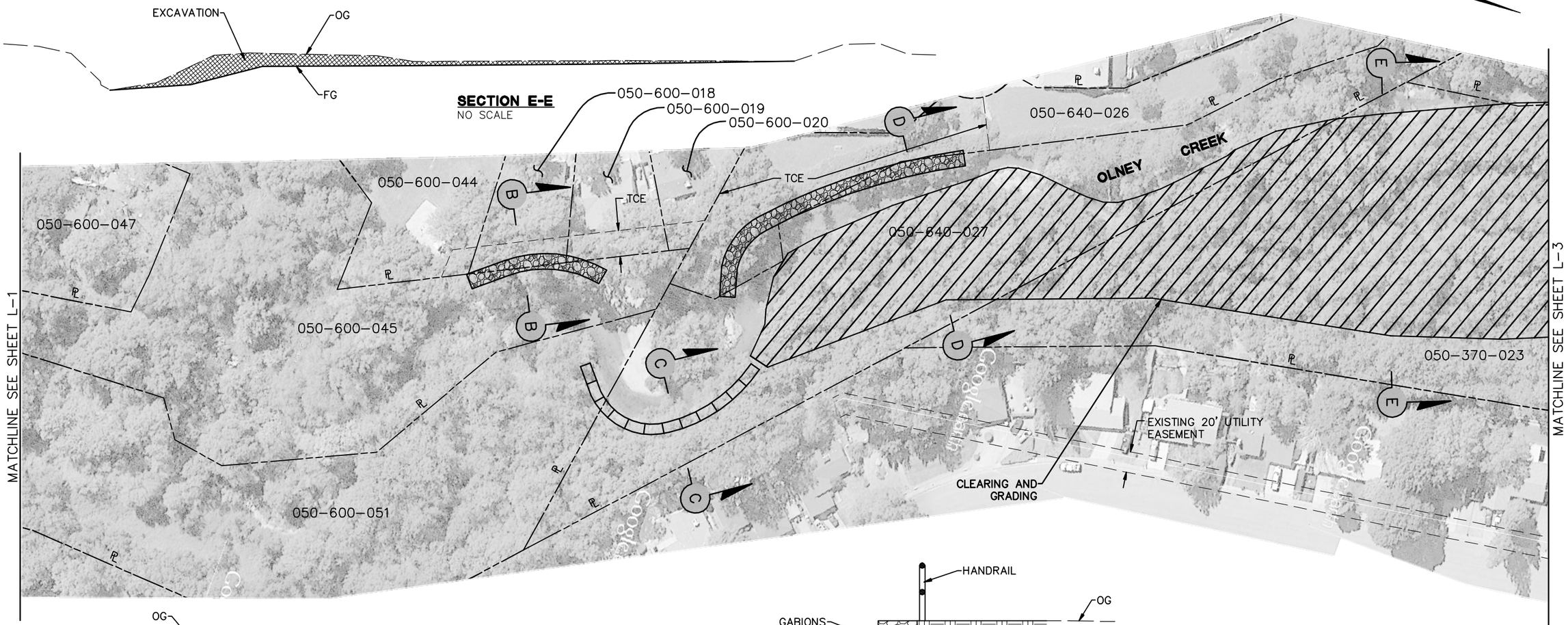
DATE: 4/26/17

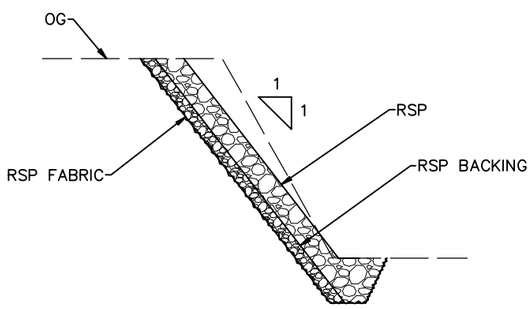
SHEET 2 OF 5

NOTES:

1.) SACRAMENTO DRIVE/OLNEY CREEK BRIDGE REPLACEMENT PROJECT IS FUNDED SEPARATELY.

SECTION E-E
NO SCALE





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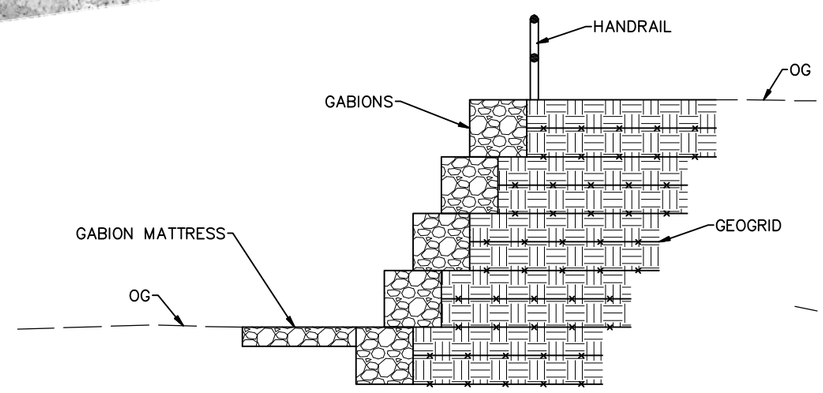

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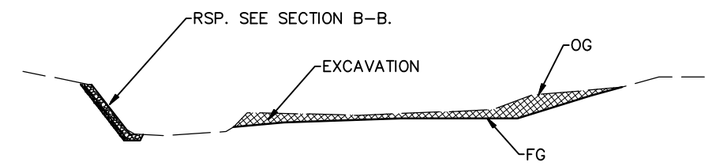

SECTION D-D
NO SCALE

REGISTERED PROFESSIONAL ENGINEER
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STATE OF CALIFORNIA
PRELIMINARY

ORIGINAL SCALE IN INCHES 0 1 2

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DRAWN BY ASH
REVIEWED BY RAW

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SAN LUIS OBISPO & SANTA MARIA

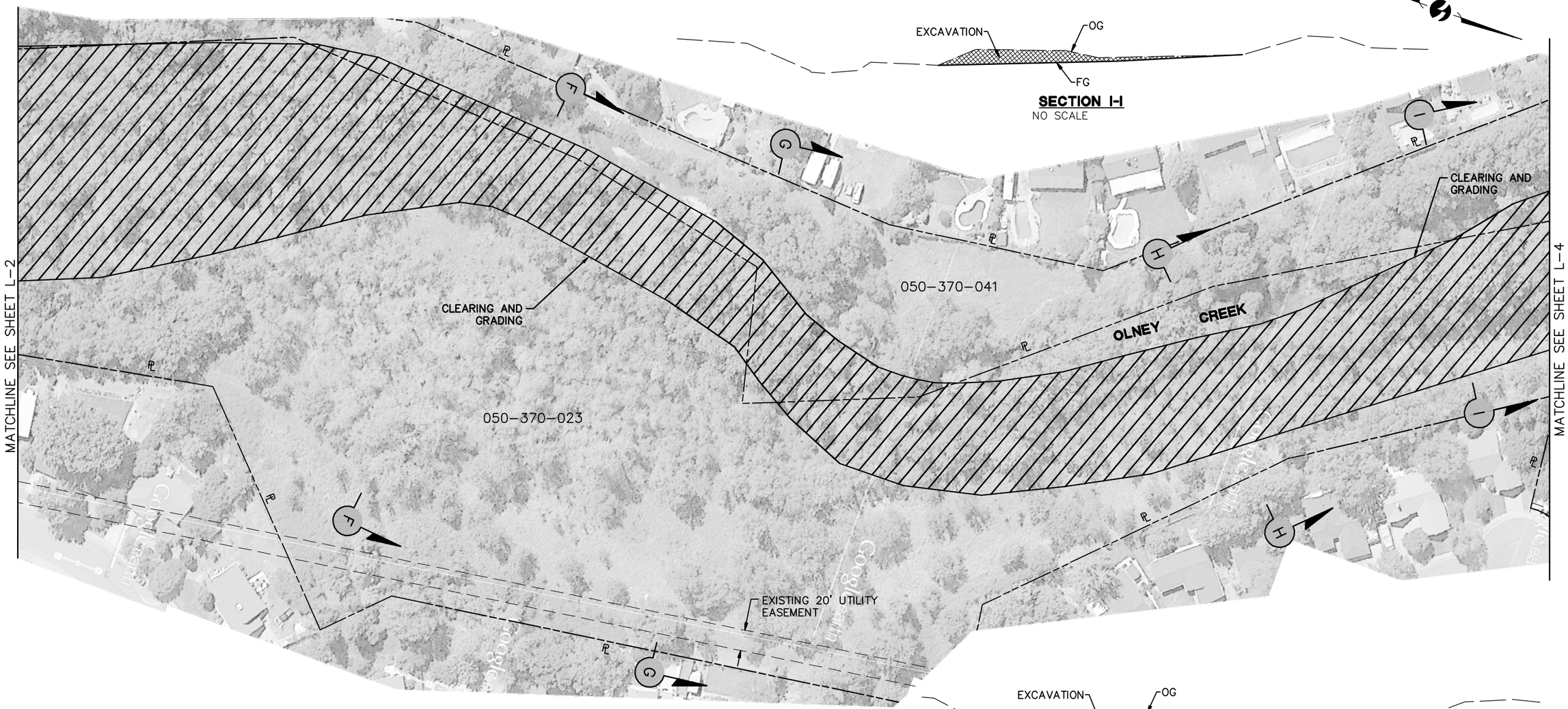
CITY OF REDDING
PUBLIC WORKS DEPARTMENT

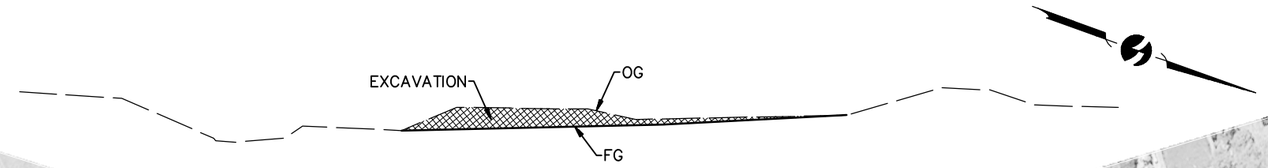
OLNEY CREEK CONVEYANCE IMPROVEMENT ALTERNATIVE

JOB NO. XXXX
BID SCH NO. XXXX

LAYOUT SHEET

L-2
ORIGINAL SCALE: 1"=50'
DATE: 4/26/17
SHEET 3 OF 5

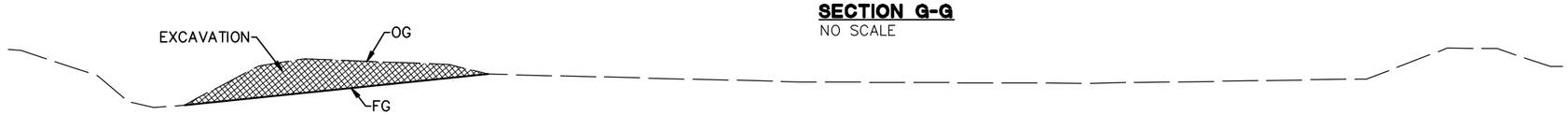




SECTION I-I
NO SCALE

SECTION H-H
NO SCALE

SECTION G-G
NO SCALE



SECTION F-F
NO SCALE

REGISTERED PROFESSIONAL ENGINEER
RUSSELL A. WENDT
43162
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STATE OF CALIFORNIA
PRELIMINARY

ORIGINAL SCALE IN INCHES
0 1 2

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REVIEWED BY RAW

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CITY OF REDDING
PUBLIC WORKS DEPARTMENT

OLNEY CREEK CONVEYANCE IMPROVEMENT ALTERNATIVE

JOB NO. XXXX
BID SCH NO. XXXX

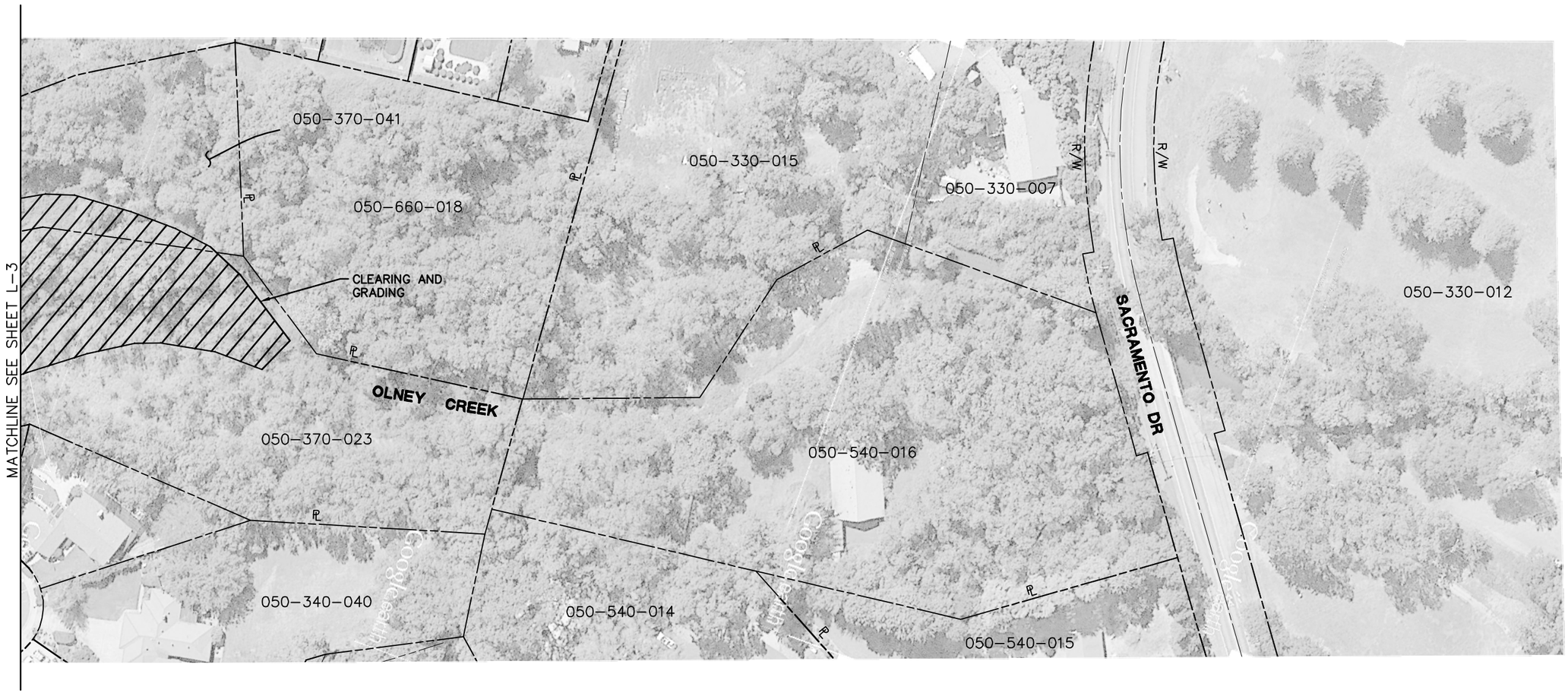
LAYOUT SHEET

L-3

ORIGINAL SCALE: 1"=50'

DATE: 4/26/17

SHEET 4 OF 5



PRELIMINARY

REGISTERED PROFESSIONAL ENGINEER
RUSSELL A. WEINMANN
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CIVIL
STATE OF CALIFORNIA

ORIGINAL SCALE IN INCHES
0 1 2

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SACRAMENTO
SAN LUIS OBISPO & SANTA

CITY OF REDDING
PUBLIC WORKS DEPARTMENT

OLNEY CREEK CONVEYANCE IMPROVEMENT ALTERNATIVE

JOB NO. XXXX
BID SCH NO. XXXX

LAYOUT SHEET

L-4

ORIGINAL SCALE: 1"=50'

DATE: 4/26/17

SHEET 5 OF 5

Appendix D
Cost Estimates

APPENDIX D
COST ESTIMATES

Planning-level cost estimates were developed by Omni•Means, Ltd., for each of the alternatives discussed within the text. Attached are those estimates.

PRELIMINARY OPINION OF SHORT TERM PROJECT COST 2/16/2017

Olney Creek - "Sacramento Bridge" Alternative[1] by: RFB

City of Redding

ITEM NO	ITEM DESCRIPTION		TOTAL
CONSTRUCTION ITEMS			
	N/A	$	-
	TOTAL - CONSTRUCTION ITEMS	**$**	**-**
ENVIRONMENTAL ITEMS			
	N/A	$	-
	TOTAL - ENVIRONMENTAL ITEMS	**$**	**-**
RIGHT-OF-WAY ITEMS			
	N/A		
	TOTAL - RIGHT-OF-WAY ITEMS	**$**	**-**
ENGINEERING			
DN-2	Elevation Certifications[5]	$	108,000.00
	TOTAL - ENGINEERING	**$**	**108,000.00**
CONSTRUCTION SUPPORT			
	N/A		
	TOTAL - CONSTRUCTION SUPPORT	**$**	**-**
CONTINGENCIES (20%)		**$**	**21,600.00**
RECOMMENDED TOTAL "SACRAMENTO BRIDGE" BUDGET		**$**	**129,600.00**
		USE $	**130,000.00**

Notes and Assumptions:

1.) City to assist residents within the special flood hazard area with obtaining Elevation Certifications to reduce flood insurance costs.

2.) This estimate assumes approximately 40 homes (out of 307 total) are removed from the Special Flood Hazard Area due to the construction of Sacramento Drive Bridge. This estimate also assumes an additional 5% (13) of the homes are not paying for flood insurance because they are owned outright and there is no lending requirement for flood insurance.

3.) The current annual cost for flood insurance premiums to the remaining 254 residences within the special flood hazard area is estimated to be $180,000 to $300,000 per year. This assumes that flood insurance rates vary between $500 to $3,000 per year per household, depending on depth of water damage anticipated, the deductible amount, and additional coverage options.

4.) It is estimated that only 40-50% (102 to 127 homes) of the homes will be eligible for flood insurance rate reduction after flood elevation certificates are completed. Of those homes, this estimate assumes 75% (77 to 95 homes) will no longer require flood insurance and the remainder (25 to 32 homes) will qualify for a rate reduction. The anticipated savings on flood insurance is estimated to be $70,000 to $140,000 annually, depending on the results of the flood elevation certificates.

5.) This estimate assumes a unit price of $500 per elevation certificate and multiple elevation certificates will be performed at a time. The unit cost for performing a single elevation certificate would be approximately $650 per elevation certificate.

6.) This estimate assumes there are no long-term maintenance costs.

7.) This estimate is preliminary only. The actual number of homes that would qualify for a rate reduction or elimination of flood insurance due to elevation certificates could only be determined with additional topographic surveys, additional hydrology analysis, and knowing all of the individual insurance rates paid by the homeowners involved.

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DN-2 Assist Residents with Obtaining Elevation Certificates

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY	ITEM PRICE	TOTAL
1	Elevation Certificate[1]	EA	216	$ 500.00	$ 108,000.00
2					$ -
3					$ -
4					$ -
5					$ -
6					$ -
7					$ -
	TOTAL				**$ 108,000.00**

Notes:

1.) Unit price assumes multiple elevation certificates will be performed at the same time and therefore the unit price will be less.

2.) Estimate assumes flood elevation certificates will be performed on 85% of the homes within the Olney Creek special flood hazard area.

PRELIMINARY OPINION OF SHORT TERM PROJECT COST[3] 2/2/2017
Olney Creek - Conveyance Improvement Alternative by: RFB
City of Redding

ITEM NO	ITEM DESCRIPTION		TOTAL
CONSTRUCTION ITEMS			
CI-1	Modify Olney Creek channel to increase conveyance thus rendering levee obsolete	$	990,500.00
CI-2	Stabilize creek bank in "Gap" area and at other locations at risk of significant bank erosion	$	223,890.00
CI-3	Improve conveyance at Girvan Road		See Note 1
	TOTAL - CONSTRUCTION ITEMS	**$**	**1,214,390.00**
ENVIRONMENTAL ITEMS			
	Staff Time	$	30,000.00
	Environmental Studies/Documents	$	90,000.00
	Agency Permit Fees	$	65,000.00
	Environmental Mitigation	$	1,385,000.00
	TOTAL - ENVIRONMENTAL ITEMS	**$**	**1,570,000.00**
RIGHT-OF-WAY ITEMS			
	R/W Engineering and Support	$	30,000.00
	Permanent R/W Acquisition	$	-
	Temporary Construction Easements	$	13,500.00
	Title and Escrow Fees	$	-
	TOTAL - RIGHT-OF-WAY ITEMS	**$**	**43,500.00**
ENGINEERING			
CI-4	FEMA Letter of Map Revision (LOMR)[2]	$	32,000.00
	Plans and Specifications (Surveying & Engineering)	$	182,000.00
	TOTAL - ENGINEERING	**$**	**214,000.00**
CONSTRUCTION SUPPORT			
	Construction Engineering	$	182,000.00
	Construction Staking	$	18,000.00
	TOTAL - CONSTRUCTION SUPPORT	**$**	**200,000.00**
CONTINGENCIES (20%)		**$**	**648,378.00**
RECOMMENDED TOTAL CONVEYANCE IMPROVEMENT BUDGET		**$**	**3,890,268.00**
	USE	**$**	**3,890,000.00**

Notes:

1.) Cost for conveyance improvement is included in the Girvan Road/Olney Creek Bridge Replacement Project which is funded separately.

2.) Includes FEMA review fee of $7,000.

3.) Long term maintenance costs are not included. Long term maintenance costs would include vegetation management/removal and erosion repair. Assuming the maintenance would be limited to approximately 3 days per year, annual maintenance costs are estimated at approximately $18,000 per year. This includes Labor, Materials (purchasing rock slope protection), and Equipment (dump truck and excavating equipment).

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CI-1 Modify Olney Creek Channel to increase conveyance thus rendering levee obsolete

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY		ITEM PRICE		TOTAL
1	Clearing and Grubbing	LS	1	$	60,000.00	$	60,000.00
2	General excavation	CY	43,500	$	20.00	$	870,000.00
3	Stormwater	LS	1	$	15,000.00	$	15,000.00
4	Erosion Control (Hydroseed)	ACRE	6.4	$	5,000.00	$	32,000.00
5	Erosion Control (Netting)	SQFT	30,000	$	0.45	$	13,500.00
6	Filter Fabric	SQYD	0	$	5.00	$	-
7	Rock Slope Protection	CY	0	$	80.00	$	-
	TOTAL					**$**	**990,500.00**

Notes:

1.) Assume excavation will be hauled off-site.

CI-2a Stabilize creek bank in "Gap" area

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY		ITEM PRICE		TOTAL
1	Dewatering	LS	1	$	25,000.00	$	25,000.00
2	Stormwater	LS	1	$	2,800.00	$	2,800.00
3	Structure Excavation	CY	1,000	$	25.00	$	25,000.00
4	Gabion	CY	300	$	200.00	$	60,000.00
5	Gabion Matress	CY	60	$	200.00	$	12,000.00
6	Structure Backfill	CY	1,000	$	25.00	$	25,000.00
7	Chain Link Fence	LF	250	$	28.00	$	7,000.00
	TOTAL					**$**	**156,800.00**

Notes:

1.) 250 LF of creek bank stabilization repair. Assume it will only be 8 feet high for this alternative

2.) Assume bank stabilization will consist of a gabion wall.

CI-2b Stabilize creek bank at locations at risk of significant bank erosion

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY		ITEM PRICE		TOTAL
1	Stormwater	LS	1	$	990.00	$	990.00
2	General excavation	CY	440	$	15.00	$	6,600.00
3	Filter Fabric	SQYD	700	$	5.00	$	3,500.00
4	Rock Slope Protection	CY	700	$	80.00	$	56,000.00
	TOTAL					**$**	**67,090.00**

Notes:

1.) Assume 500 linear feet of bank repair (12 feet high)

Environmental Items

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY	ITEM PRICE	TOTAL
Staff Time		LS	1	$ 30,000.00	$ 30,000.00
Environmental Studies/Documents		LS	1	$ 90,000.00	$ 90,000.00
Agency Permit Fees		LS	1	$ 65,000.00	$ 65,000.00
Environmental Mitigation[1]					
	Temporary Impacts (10-year monitoring)	ACRE	2.0	$ 50,000.00	$ 100,000.00
	Permanent Impacts (Mitigation bank)	ACRE	8.4	$ 150,000.00	$1,260,000.00
	Mitigation plans/documents	LS	1	$ 25,000.00	$ 25,000.00
	TOTAL				**$1,570,000.00**

Notes:

1.) Based on the quantity of acres cleared for construction.

Right-of-Way Items

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY	ITEM PRICE	TOTAL
R/W Engineering and Support					
	Plats and Legals	EA	0	$ 2,000.00	$ -
	Appraisals & Negotiations	EA	5	$ 6,000.00	$ 30,000.00
Permanent R/W Acquisition (Easements)		SF	0	$ 5.00	$ -
Temporary Construction Easements		SF	27,000	$ 0.50	$ 13,500.00
Title & Escrow Fees		EA	0	$ 2,500.00	$ -
	TOTAL				**$ 43,500.00**

PRELIMINARY OPINION OF SHORT TERM PROJECT COST[4] 2/2/2017
Olney Creek - Levee Improvement Alternative by: RFB
City of Redding

ITEM NO	ITEM DESCRIPTION	TOTAL
CONSTRUCTION ITEMS		
LI-2	Realign Levee to avoid landowner defects	$ 466,500.00
LI-3	Remove waterside slope vegetation	$ 71,700.00
LI-4	Repair erosion	$ 2,255.00
LI-5	Assess and mitigate sewer penetration backfill and settlement	$ 4,300.00
LI-6	Stabilize creek bank in "Gap" area & construct tie-in wall improvement	$ 200,800.00
LI-7	Upstream tie-in at Sacramento Drive[1]	$ 76,100.00
LI-8	Downstream tie-in at Girvan Road[2]	$ 786,000.00
LI-9	Stabilize creek at locations at risk of significant bank erosion	$ 67,100.00
LI-13	Replace Flood Wall	$ 220,200.00
	TOTAL - CONSTRUCTION ITEMS	**$ 1,894,955.00**
ENVIRONMENTAL ITEMS		
	Staff Time	$ 15,000.00
	Environmental Studies/Documents	$ 75,000.00
	Agency Permit Fees	$ 55,000.00
	Environmental Mitigation	$ 875,000.00
	TOTAL - ENVIRONMENTAL ITEMS	**$ 1,020,000.00**
RIGHT-OF-WAY ITEMS		
	R/W Engineering and Support	$ 46,000.00
	Permanent R/W Acquisition	$ 119,200.00
	Temporary Construction Easements	$ 36,950.00
	Title and Escrow Fees	$ 5,000.00
	TOTAL - RIGHT-OF-WAY ITEMS	**$ 207,150.00**
ENGINEERING		
LI-10	Interior area flood study	$ 15,000.00
LI-11	Operation and Maintenance manual	$ 5,000.00
LI-12	Levee Report or LOMAR application[3]	$ 25,000.00
	Plans and Specifications (Surveying & Engineering)	$ 284,000.00
	TOTAL - ENGINEERING	**$ 329,000.00**
CONSTRUCTION SUPPORT		
	Construction Engineering	$ 284,000.00
	Construction Staking	$ 28,000.00
	TOTAL - CONSTRUCTION SUPPORT	**$ 312,000.00**
CONTINGENCIES (20%)		**$ 752,621.00**
RECOMMENDED TOTAL LEVEE IMPROVEMENT BUDGET		**$ 4,515,726.00**
	USE	**$ 4,520,000.00**

Notes:

1.) Cost includes upstream levee tie-in only. Sacramento Drive/Olney Creek Bridge Replacement Project is funded separately.
2.) Cost includes downstream levee tie-in only. Girvan Road/Olney Creek Bridge Replacement Project is funded separately.
3.) Assumes no FEMA review fee will be required.
4.) Long term maintenance costs are not included. Long term maintenance costs would include vegetation management/removal and erosion repair. Assuming the maintenance would be limited to approximately 5 days per year, annual maintenance costs are estimated at approximately $30,000 per year. This includes Labor, Materials (purchasing rock slope protection), and Equipment (dump truck and excavating equipment).

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LI-2 Realign levee to avoid landowner defects

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY		ITEM PRICE		TOTAL
1	Replace Fence	LF	100	$	30.00	$	3,000.00
2	Imported Borrow	CY	12,000	$	35.00	$	420,000.00
3	Stormwater	LS	1	$	6,900.00	$	6,900.00
4	Erosion Control (Hydroseed)	ACRE	3.0	$	5,000.00	$	15,000.00
5	Erosion Control (Netting)	SQFT	48,000	$	0.45	$	21,600.00
	TOTAL					**$**	**466,500.00**

LI-3 Remove waterside slope vegetation

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY		ITEM PRICE		TOTAL
1	Clearing and Grubbing	ACRE	4	$	10,000.00	$	40,000.00
2	Stormwater	LS	1	$	1,100.00	$	1,100.00
3	Erosion Control (Hydroseed)	ACRE	1.8	$	5,000.00	$	9,000.00
4	Erosion Control (Netting)	SQFT	48,000	$	0.45	$	21,600.00
	TOTAL					**$**	**71,700.00**

LI-4 Repair erosion

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY		ITEM PRICE		TOTAL
1	General excavation	CY	30	$	15.00	$	450.00
2	Structure Backfill	CY	30	$	25.00	$	750.00
3	Stormwater	LS	1	$	200.00	$	200.00
4	Filter Fabric	SQYD	11	$	5.00	$	55.00
5	Rock Slope Protection	CY	10	$	80.00	$	800.00
	TOTAL					**$**	**2,255.00**

LI-5 Assess and mitigate sewer penetration backfill and settlement

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY		ITEM PRICE		TOTAL
1	Geotech Evaluation	LS	1	$	2,500.00	$	2,500.00
2	Stormwater	LS	1	$	200.00	$	200.00
3	General excavation	CY	40	$	15.00	$	600.00
4	Structure Backfill	CY	40	$	25.00	$	1,000.00
	TOTAL					**$**	**4,300.00**

LI-6 Stabilize creek bank in "Gap" area & construct tie-in wall improvement

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY		ITEM PRICE		TOTAL
1	Dewatering	LS	1	$	25,000.00	$	25,000.00
2	Stormwater	LS	1	$	2,800.00	$	2,800.00
3	Structure Excavation	CY	1,400	$	25.00	$	35,000.00
4	Gabion	CY	420	$	200.00	$	84,000.00
5	Gabion Matress	CY	60	$	200.00	$	12,000.00
6	Structure Backfill	CY	1,400	$	25.00	$	35,000.00
7	Chain Link Fence	LF	250	$	28.00	$	7,000.00
	TOTAL					**$**	**200,800.00**

LI-7 Upstream tie-in at Sacramento Drive

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY		ITEM PRICE		TOTAL
1	Clearing and Grubbing	LS	1	$	1,500.00	$	1,500.00
2	General excavation	CY	800	$	15.00	$	12,000.00
3	Structure Backfill	CY	400	$	25.00	$	10,000.00
4	Stormwater	LS	1	$	1,100.00	$	1,100.00
5	Erosion Control (Hydroseed)	ACRE	0.1	$	5,000.00	$	500.00
6	Filter Fabric	SQYD	600	$	5.00	$	3,000.00
7	Rock Slope Protection	CY	600	$	80.00	$	48,000.00
	TOTAL					**$**	**76,100.00**

Notes:

1.) Assume no reconstruction of Sacramento Drive is required.

2.) Assume no reconstruction of golf course driveway.

LI-8 Downstream tie-in at Girvan Road

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY		ITEM PRICE		TOTAL
1	Clearing and Grubbing	LS	1	$	6,500.00	$	6,500.00
2	General excavation	CY	2,500	$	15.00	$	37,500.00
3	Imported Borrow	CY	15,600	$	35.00	$	546,000.00
4	Path Surfacing	SQFT	6,000	$	8.00	$	48,000.00
5	Stormwater	LS	1	$	11,000.00	$	11,000.00
6	Erosion Control (Hydroseed)	ACRE	2.4	$	5,000.00	$	12,000.00
7	Erosion Control (Netting)	SQFT	60,000	$	0.45	$	27,000.00
8	Filter Fabric	SQYD	2,000	$	5.00	$	10,000.00
9	Rock Slope Protection	CY	1,100	$	80.00	$	88,000.00
	TOTAL					**$**	**786,000.00**

Notes:

1.) Assume no reconstruction of Girvan Road is required.

LI-9 Stabilize creek at locations at risk of significant bank erosion

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY		ITEM PRICE		TOTAL
1	Stormwater	LS	1	$	990.00	$	1,000.00
2	General excavation	CY	440	$	15.00	$	6,600.00
3	Filter Fabric	SQYD	700	$	5.00	$	3,500.00
4	Rock Slope Protection	CY	700	$	80.00	$	56,000.00
	TOTAL					**$**	**67,100.00**

Notes:

1.) Assume 500 linear feet of bank repair (12 feet high)

LI-13 Replace Flood Wall

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY		ITEM PRICE		TOTAL
1	Dewatering	LS	1	$	8,000.00	$	8,000.00
2	Stormwater	LS	1	$	2,800.00	$	2,800.00
3	Structure Excavation	CY	500	$	25.00	$	12,500.00
4	Structural Concrete	CY	240	$	450.00	$	108,000.00
5	Reinforcing Steel	LB	48,000	$	1.30	$	62,400.00
6	Structure Backfill	CY	300	$	65.00	$	19,500.00
7	Chain Link Fence	LF	250	$	28.00	$	7,000.00
	TOTAL					**$**	**220,200.00**

Environmental Items

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY	ITEM PRICE	TOTAL
Staff Time		LS	1	$ 15,000.00	$ 15,000.00
Environmental Studies/Documents		LS	1	$ 75,000.00	$ 75,000.00
Agency Permit Fees		LS	1	$ 55,000.00	$ 55,000.00
Environmental Mitigation[1]					
	Temporary Impacts (10-year monitorning)	ACRE	2.3	$ 50,000.00	$ 115,000.00
	Permanent Impacts - (Mitigation bank)	ACRE	5.0	$ 150,000.00	$ 750,000.00
	Mitigation plans/documents	LS	1.0	$ 10,000.00	$ 10,000.00
	TOTAL				**$1,020,000.00**

Notes:

1.) Based on quantity of acres cleared for construction.

Right-of-Way Items

ITEM NO	ITEM DESCRIPTION	UNIT OF MEASURE	ESTIMATED QUANTITY	ITEM PRICE	TOTAL
R/W Engineering and Support					
	Plats and Legals	EA	2	$ 2,000.00	$ 4,000.00
	Appraisals & Negotiations	EA	7	$ 6,000.00	$ 42,000.00
Permanent R/W Acquisition (Easements)		SF	23,840	$ 5.00	$ 119,200.00
Temporary Construction Easements		SF	73,900	$ 0.50	$ 36,950.00
Title & Escrow Fees		EA	2	$ 2,500.00	$ 5,000.00
	TOTAL				**$ 207,150.00**

Appendix E

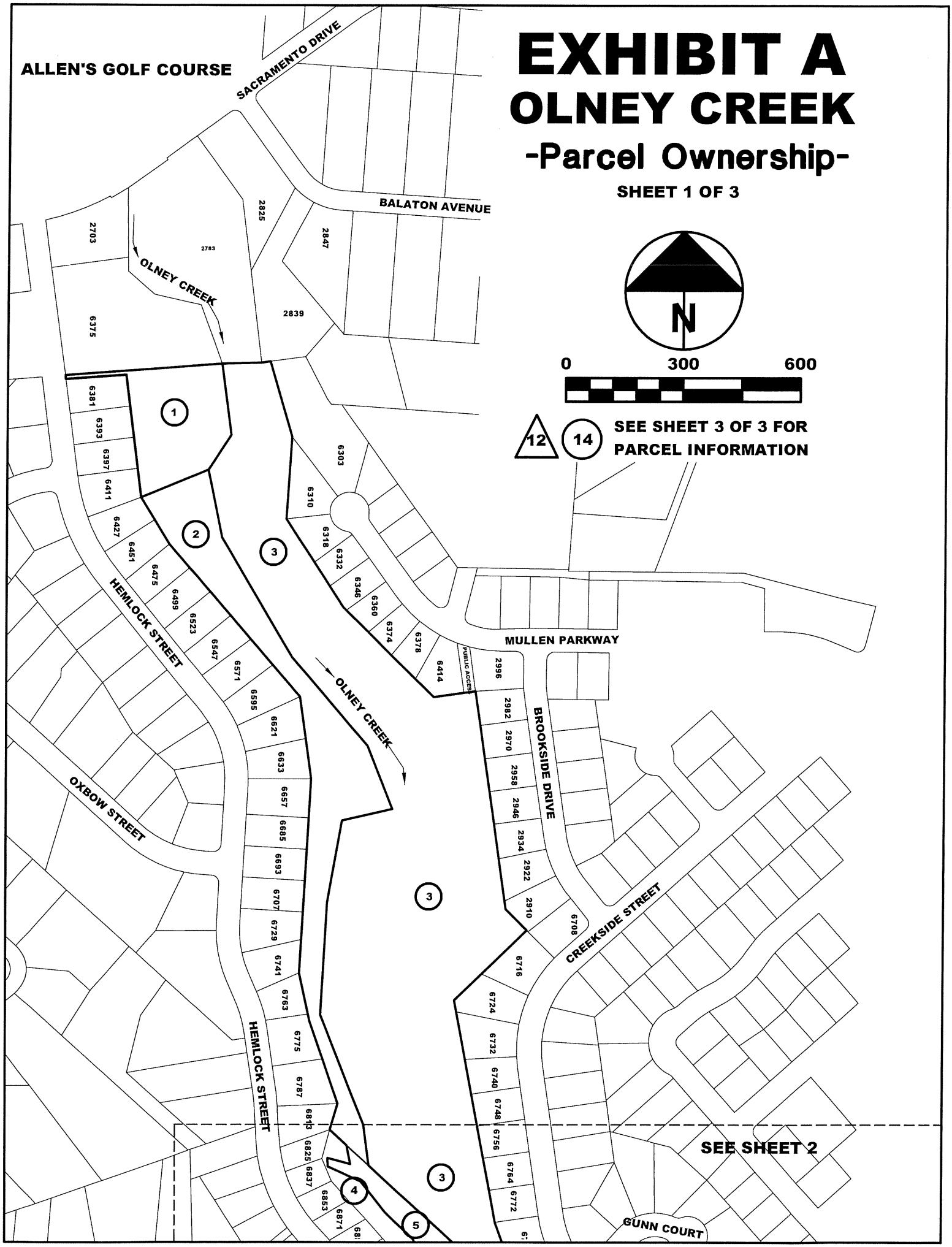
Olney Creek Parcel Ownership Map

APPENDIX E
OLNEY CREEK PARCEL OWNERSHIP MAP

The City has Open Space easements for parks, trails and floodplain as shown in the attached map. This map was compiled by the City.

EXHIBIT A
OLNEY CREEK
-Parcel Ownership-

SHEET 1 OF 3



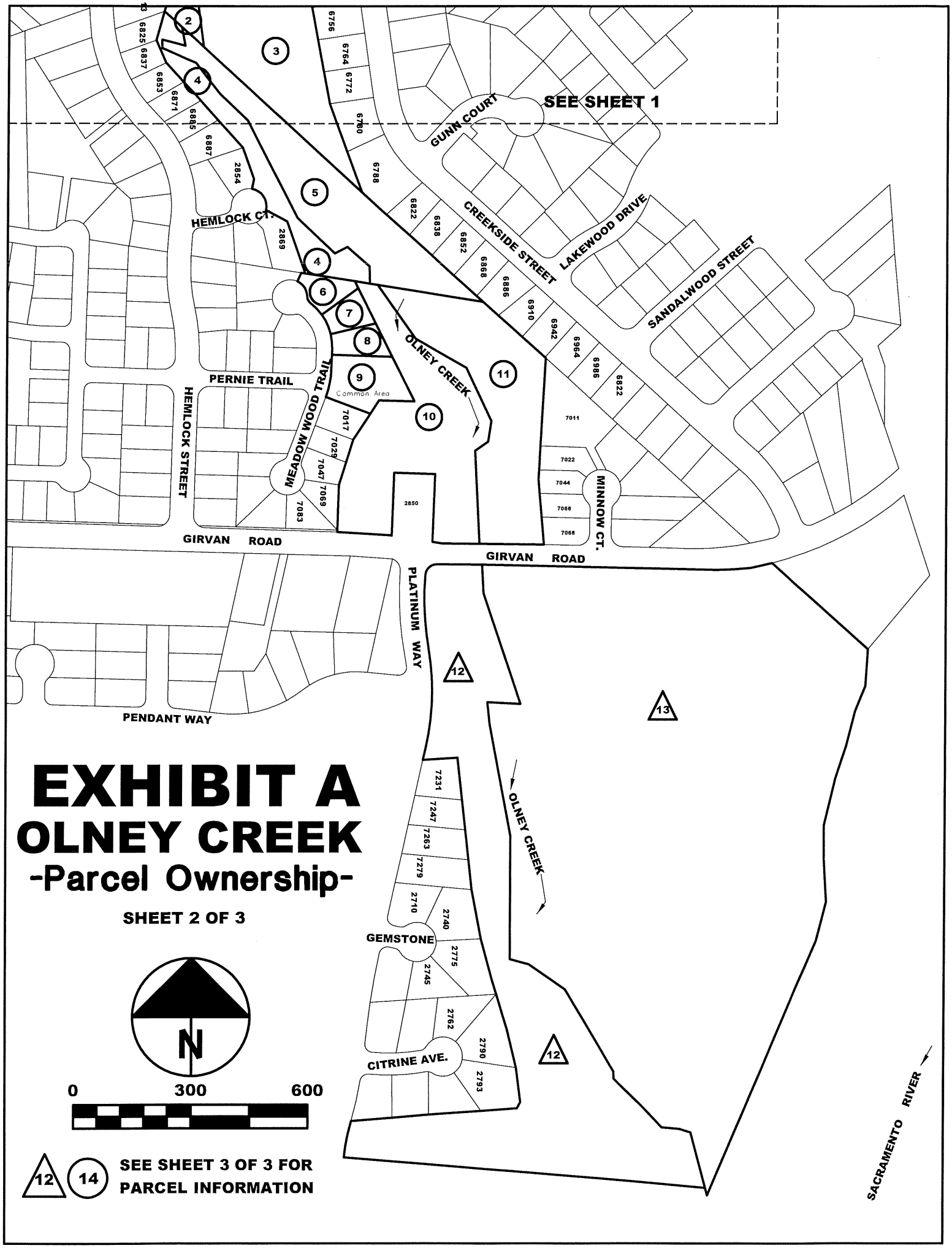


EXHIBIT A
OLNEY CREEK
-Parcel Ownership-

SHEET 2 OF 3

EXHIBIT A
OLNEY CREEK
-Parcel Ownership-

SHEET 3 OF 3

A.P.N. #	OWNER	DESCRIPTION
1 050-660-018	THREE SEASONS DEVELOPMENT, INC.	DEDICATED OPEN SPACE TO CITY OF REDDING PER 19 - MAPS - 74
2 050-370-041	THREE SEASONS DEVELOPMENT, INC.	DEDICATED OPEN SPACE, PSE, PARKS,FLOOD PLAIN AND TRAIL TO CITY OF REDDING PER 20 - MAPS - 58
3 050-370-023	BONNYVIEW MEADOWS LIMITED PARTNERSHIP	DEDICATED OPEN SPACE TO CITY OF REDDING PER 16 - MAPS - 72
4 050-640-026	MARVIN GARDENS	PARCEL "B", PER 18 - MAPS - 34
5 050-640-027	(MARVIN GARDENS) FREDERIC NEUNZIG	PARCEL "C" DEDICATED FLOODPLAIN, OPEN SPACE AND PARK TO CITY OF REDDING PER 18 - MAPS - 34
6 050-600-020	PAUL A. CORBISIERO	LOT 20, MEADOW WOOD ESTATES, 17-MAPS-16
7 050-600-019	THOMPSON REVOCABLE TRUST	LOT 19, MEADOW WOOD ESTATES, 17-MAPS-16
8 050-600-018	KIMBERY DUNN	LOT 18, MEADOW WOOD ESTATES, 17-MAPS-16
9 050-600-044	MEADOW WOODS ESTATES	COMMON SPACE, MEADOW WOOD ESTATES, 17-MAPS-16
10 050-600-045	REDDING INVESTMENTS / LOCKWOOD REALTY	DEDICATED OPEN SPACE TO CITY OF REDDING PER 22 - PM - 6
11 050-600-051	(BROOKDALE PARK SUBDIVISION) JAMES & GAY SCHMITT	PARCEL "A" DEDICATED OPEN SPACE, PARK, AND FLOOD PLAIN TO CITY OF REDDING PER 18 - MAPS - 31. EASEMENT FOR CONSTRUCTION & MAINTENANCE OF OLNEY CREEK AND AND FLOODWAY PER 1765 O.R. 653
12 050-500-020	CITY OF REDDING	CASCADE PARK IN FEE PER 1703 O.R. 012
13 050-500-029	CITY OF REDDING	DEDICATED OPEN SPACE IN FEE TO CITY OF REDDING PER 22 - MAPS - 80