Exhibit A

Guidelines for Accepting Water into the Friant-Kern Canal

DRAFT: 6/15/2022

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Guidelines for Accepting Water into the Friant-Kern Canal

Overview

These Guidelines apply to all water introduced into the Friant-Kern Canal ("**FKC**") other than directly from Millerton Lake to the headworks of the FKC (collectively, "**Non-Millerton water**").

These Guidelines describe the Friant Water Authority's ("**FWA**") application review process, implementation procedures, and the responsibilities of water contractors and other parties authorized to introduce or receive Non-Millerton water into or from the FKC (collectively, "**Contractors**"). These Guidelines define the water quality thresholds and the required mitigation associated with introduced Non-Millerton water and corresponding water quality, as well as the methodologies and tools for monitoring and forecasting water quality in the FKC. These Guidelines are intended to ensure that water quality is protected for sustained domestic and agricultural use.

- These Guidelines are applicable to all Non-Millerton water introduced or diverted into the FKC including but not limited to:
- Groundwater pump-ins
- Surface water diversions and pump-ins
- Recaptured and recirculated San Joaquin River Restoration Program Restoration Flows
- Water introduced at the FKC-Cross Valley Canal ("**CVC**") intertie and delivered via reverse flow on the FKC

A Water Quality Advisory Committee composed of Friant Division long-term contractors ("**Friant Contractors"**) and other Contractors and users involved in either introducing or receiving Non-Millerton water to or from the FKC has been established to provide recommendations to FWA on operations and monitoring requirements of the FKC. The Water Quality Advisory Committee will operate under an established charter (see Attachment A). The Water Quality Committee will appoint a Monitoring Subcommittee to assist FWA in the implementation of the Guidelines.

These Guidelines are subject to review and modification by FWA if any of the following conditions occurs:

- A future regulatory cost or equivalent fee is imposed on Friant Contractors and a portion of such fee can reasonably be attributed to the incremental difference of water quality conditions in the FKC.
- When Friant Division Class 1 contract allocation is less than or equal to 25 percent, the Water Quality Advisory Committee will convene as outlined in Attachment A. In these years, mitigation will be accounted for as presented in these Guidelines, but will be deferred to a later date unless those responsible for the put and take mutually agree to put and take the mitigation in the critical year. All monitoring requirements will remain as presented in these Guidelines.
- There is a significant, regulatory change or scientifically based justification and three out of the following five Friant Contractors agree and work with the Water Quality Advisory Committee to recommend a change: (1) Arvin-Edison Water Storage District, (2) Shafter Wasco Irrigation District, (3) Delano-Earlimart Irrigation District, (4) South San Joaquin Municipal Utility District, and (5) Kern-Tulare Water District.

The United States Bureau of Reclamation (Reclamation) may also propose modifications to these Guidelines in coordination with FWA. FWA will provide written notice of any proposed modification to these Guidelines to all Contractors prior to adoption and implementation.

A. General Requirements for Discharge of Water into the Friant-Kern Canal

1. Guidelines Compliance Determination

A Contractor wishing to discharge Non-Millerton water into the FKC must, concurrent with its application for a contract or other applicable approval from Reclamation, obtain a determination from FWA as to compliance with the Guidelines or demonstrate to FWA and Reclamation that the proposed discharge will be subject to comparable and adequate alternative water quality mitigation measures. Reclamation will not approve an application until compliancewith the Guidelines or the provision of alternative mitigation measures is adequately demonstrated and incorporated into the proposed discharge project. Figure 1 shows the concurrent process that a Contractor must pursue to obtain these approvals. The Contractor will be responsible for securing all other requisite Federal, State or local permits.

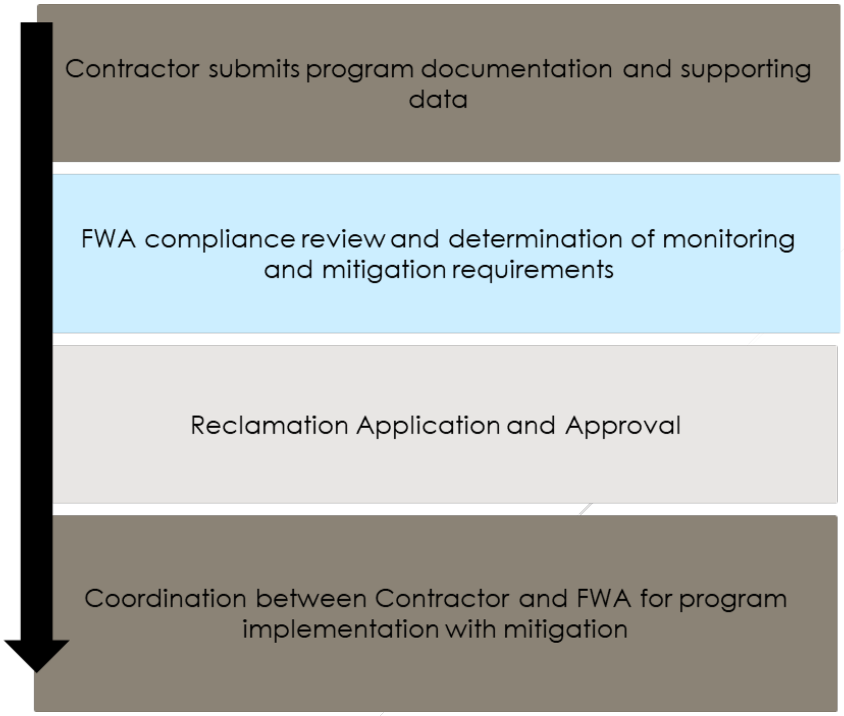

Figure 1. Approval Process Diagram

2. <u>Discharge Facility Approval</u>

Each discharge facility into the FKC must be approved and documented in the manner required by Reclamation, in coordination with FWA. The requisite approvals for the erection and maintenance of structures may be negotiated with Reclamation's South-Central California Area Office (SCCAO) or such other office as Reclamation may designate.

3. <u>Other Discharge and Conveyance Requirements</u>

The discharge of Non-Millerton water into the FKC may not in any way limit the ability of either FWA or Reclamation to operate and maintain the FKC for its intended purpose nor may it adversely impact existing water delivery contracts or any other water supply or delivery agreements. The discharge of Non-Millerton water into the FKC will be permissible only when there is capacity in the system as determined by FWA and/or Reclamation.

B. Water Quality Monitoring and Reporting Requirements

1. <u>General Discharge Approval Requirements</u>

Each source of Non-Millerton water discharged into the FKC must be correctly sampled, completely analyzed, and approved by FWA prior to introduction into the FKC. The Contractor must pay the cost of collection and analyses of the water required under these Guidelines. Other costs associated with the implementation of these Guidelines to be paid by the Contractors are described in Section E below.

2. Water Quality Monitoring and Management

The monitoring program requirements are detailed below. In addition, the requirements are summarized in a single table in Attachment B.

(a) Monitoring Requirements for Discharged Water

All Non-Millerton water discharged into the FKC must be tested at the source (i.e. grab samples at each pump location for groundwater pump-ins or in-prism (i.e., in-situ) grab samples for water being introduced via other conveyances) and sampled by an appropriate party every three years for the complete list of water quality constituents listed in the then current version of Table 1. In addition, all Non-Millerton water discharged into the FKC must be tested and sampled by an appropriate party annually for the short list of water quality constituents listed in Table 5. The analytical laboratory must be a facility approved by Reclamation (See Table 2). The laboratory analytical report and summary of water quality analytical results must be reported to FWA and Reclamation's Contracting Officer for review.

If analytical results show an exceedance of 90% of the threshold for any water quality constituents, defined in Table 5, discharged Non-Millerton water will be tested weekly until water quality results of four consecutive grab samples are below the relevant 90% thresholds. The appropriateness of the 10% threshold buffer (i.e., 90% of the threshold) will be evaluated by the Water Quality Advisory Committee.

If the water quality analytical results show exceedance of any constituent above its threshold in Table 1, 4 or 5 (i.e., not the threshold buffer but the threshold itself), at the discretion of Reclamation such water may not be allowed to be introduced into the FKC. FWA will evaluate monitoring requirements on a case-by-case basis and may impose additional requirements including but not limited to monitoring of the discharge source and downstream in prism quality at the cost of the Contractor.

(b) In-Prism Water Quality Monitoring

FWA will cause to be implemented continuous, real-time monitoring of in-prism water quality conditions in the FKC. Conductivity meters (or sondes) will measure and record real-time in-prism electrical conductivity (EC), measured as microsiemens per centimeter (µS/cm), every 15 minutes at the FKC check structures and corresponding mileposts shown in Table 3. Collected EC data will be uploaded to FWA's Intellisite Operation System ("IOS") in real-time. These continuous, in-prism measurements of EC will provide real-time data on incremental water quality changes and mixing in the canal and will assist in water quality threshold management.

If the Friant Water Quality Model forecasts an in-prism exceedance of 90% of the threshold for any water quality constituents, defined in Table 5, water samples from the FKC will be collected each week by appropriate FWA staff until the sampled concentrations, supported through Friant Water Quality Model forecasted simulations, show four consecutive weeks below the 90% threshold. Each weekly collection will consist of one sample from each downstream check structure shown in Table 3 and where water quality changes are expected, plus one duplicate sample. FWA will deliver the samples to a Reclamation-approved laboratory noted in Table 2. FWA expenses for all water quality monitoring and sampling are subject to reimbursement from Contractors through fees and charges. As was the case for the discharged water, the appropriateness of the 10% threshold buffer will be evaluated by the Water Quality Advisory Committee.

Additional water quality sampling and analysis will be performed during specific FKC operations. FWA will cause to be measured EC using hand-held conductivity meters as needed, such as during:

- servicing of real-time monitoring equipment;
- unexpected real-time monitoring equipment outages;
- confirmation of real-time monitoring equipment measurements; and,
- targeted in-prism measurements.

(c) CVC In-Prism Water Quality Monitoring

Upon initiation of reverse-flow, pump-back activities and/or if it is anticipated that operations within the CVC will significantly change mixed water quality conditions (i.e., influence from California Aqueduct, Kern River, Kern Fan), grab samples will be collected by FWA within the CVC near the FKC/CVC Intertie, and provided to a Reclamation approved, third-party laboratory (see Table 2) for testing of water quality constituents listed in Table 1. In addition, during reverse-flow, pump-back operations, weekly water quality sampling will be performed within the CVC near the FKC/CVC Intertie. Grab samples will be collected by FWA and provided to a Reclamation approved, third-party laboratory for testing (see Table 2). At a minimum, grab samples collected during reverse-flow pump-back operations will be analyzed for the short list of water quality constituents listed in Table 5.

The Water Quality Advisory Committee will evaluate water quality monitoring, sampling, and analysis requirements on a regular basis and provide recommendations for modification of the described requirements.

(d) In-Prism Water Quality Management

FKC in prism water quality will be managed per the following thresholds. If the below thresholds are exceeded, systematic cessation of pump-in or pump-back operations will occur.

1. Title 22. The Domestic Water Quality and Monitoring Regulations specified by the State of California Health and Safety Code (Sections 116270-116755), and Title 22 of the California Code of Regulations (Sections 6440 et seq.), as amended. In prism water quality constituent concentrations may not exceed the Maximum Contaminant Level ("**MCL**") as defined in Table 1, except those constituents listed in Table 4. Current State of California requirements at the time of sampling will prevail over those in the accepted version of this document if MCLs in Table 1 are changed in the future.

2. Water quality thresholds defined in Table 4. Water quality thresholds are representative of constituent thresholds of sensitive crops; leaching requirements; and crop thresholds for regulated deficit irrigation practices that occur during almond hull split from July 1 through August 31; and flexible thresholds in the second half of the contract year, from March 1 through June 30, depending on observed water quality.

    i. Table 4 presents alternative water quality thresholds for Period 3 (September 1 – February 28) that are dependent on the measured water quality during Period 1 (March 1 – June 30). If the measured average chloride concentration for Period 1 exceeds 70 mg/L, the chloride threshold remains at 102 mg/L for Period 3a. If the measured average chloride concentrations for Period 1 are less than or equal to 70 milligrams per liter (mg/L), the allowable chloride concentration increases from 102 mg/L to 123 mg/L for Period 3b.

    ii. It is estimated that an average of one week is required for in-prism water quality to turnover. Prior to the onset of the defined hull split period requirements (July 1), current FKC operations and water quality conditions will be evaluated to determine if this one-week period should be adjusted.

If water quality thresholds are exceeded, or based on modeling appear likely to be imminently exceeded, or operations in the FKC need to change per Guidelines requirements, FWA will immediately notify the Water Quality Advisory Committee, which must convene a meeting of the Monitoring Subcommittee within three days of receiving notification from FWA. The Monitoring Subcommittee and FWA will review operations and water quality data and will seek consensus on determining the best management actions to improve water quality; provided, however, the final operational decision will be made by FWA. In addition, the Monitoring Subcommittee will seek 1:1, unleveraged, and cost-neutral exchanges to limit potential Project water impacts. FWA retains the right to determine and enforce management actions but will work in good faith with the Water Quality Advisory Committee and Monitoring Subcommittee to evaluate options. If required, management actions including any reductions or cessation of pump-in volume must occur within three days of the meeting between FWA and the Monitoring Subcommittee. FWA will order any reduction in pump-in volume in order of greatest mass loading. Finally, the Monitoring Subcommittee will set an appropriate review period to assess if implemented management actions are working and, if not, will agree to reconvene to discuss additional actions necessary to improve water quality.

(e) Uncontrolled Season

Non-Millerton water may not be introduced to the FKC during the Friant Division uncontrolled season as declared by Reclamation unless:

- Deliveries are necessary due to FKC capacity constraints, and if the Non-Millerton water delivered from the Cross Valley Canal remains below the Shafter Check, or
- The Non-Millerton water is below the determined baseline EC threshold of 200 µS/cm and, therefore, does not require mitigation.

3. Water Quality Mitigation

Mitigation for impacted water quality is quantified through use of the Water Quality Mitigation Ledger (“**Ledger**”). The Ledger tracks and accounts for all inflows into and diversions from the FKC in order to determine appropriate mitigation for impacted water quality (attributable to the introduced Non-Millerton water or “**Put**”[1] and the corresponding distribution thereof or “**Take**”). The volume of additional surface water needed for mitigation, expressed as a percentage of the introduced water, or Put, is determined using an established mitigation rating curve. The mitigation rating curve is based on (1) constituent concentrations, and (2) agronomic principles that focus on leaching requirements to prevent constituent accumulation in the rootzone and resulting impacts on crops. This approach aims to balance concerns related to long-term groundwater quality with a multi-layered assessment of agronomic impacts as a durable solution. The process for developing the agronomic impacts evaluation and mitigation rating curve can be found in *Attachment C– Agronomic Impacts and Mitigation.*

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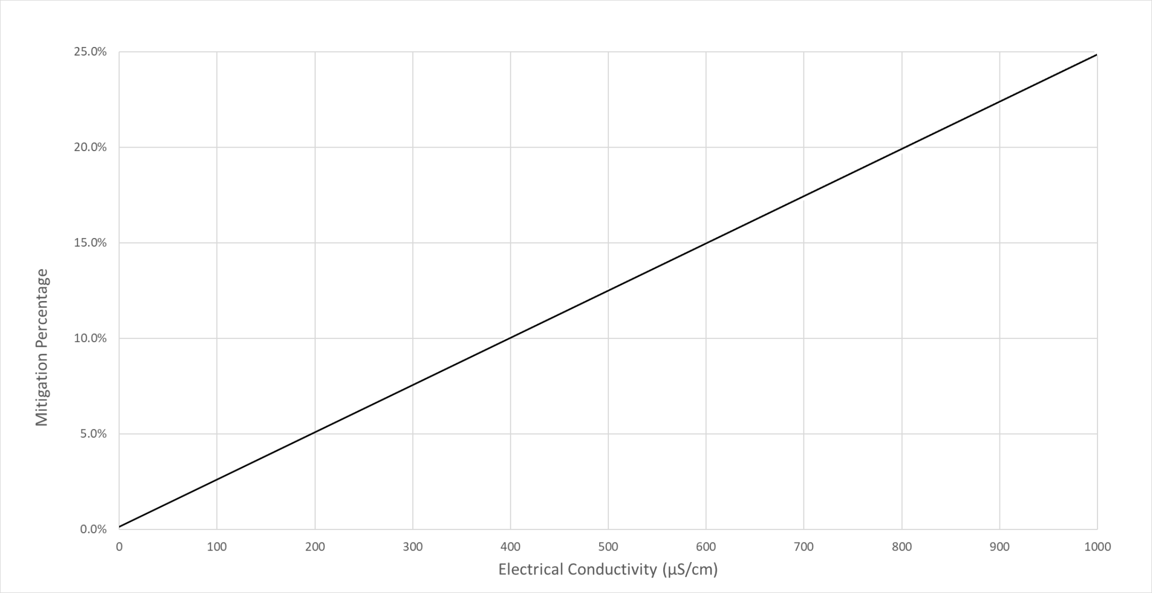
[1] Existing FKC inlet drains are exempt from providing mitigation.

The Ledger quantifies mitigation for Friant Contractors that have an expectation to receive water consistent with quality conditions of Millerton Lake. Specifically, mitigation applies to the Take of Friant Division Class 1, Class 2, Recovered Water Account (RWA [Paragraph 16b]), and Unreleased Restoration Flows supplies. Friant Contractors and/or other Contractors, including but not limited to third parties, whose supplies are not delivered to the headworks of the FKC are not eligible to receive mitigation.

Mitigation percentage is based on the EC of the Put above the established baseline. The established baseline is based on assumptions of current, minimum leaching practices by water users, or growers, in the region. Consistent with good agricultural practices, it is assumed that growers are currently applying at least a five percent (5%) leaching fraction. Under the mitigation rating curve shown in Figure 2, this corresponds to an approximate EC of 200 µS/cm. It is assumed that growers are already managing the effects of applied water quality conditions up to 200 µS/cm of EC, and mitigation is only required for water quality conditions with incremental EC that exceed the baseline EC threshold of 200 µS/cm. Note that the mitigation rating curve extends beyond the maximum EC and mitigation percentage shown in Figure 2 (i.e., at 1,000 µS/cm and 25%) at the same slope of 5% mitigation per 200 µS/cm of EC.

A mitigation volume is calculated based on the Put volume and corresponding mitigation percentage. Mitigation volumes for each Put are distributed to each Friant Contractor receiving an eligible Take, or "**Taker**," downstream based on the volumetric proportion of the Take on a weekly basis. Mitigation occurs in real time by the Contractor and offsets a like volume of each Taker's supply at the end of a reporting period. Additional mitigation is not required to account for the water quality conditions of the mitigation volumes. Water quality conditions and flows are tracked daily. The ledger and required mitigation volumes are balanced weekly and reported and transferred monthly. Accounting and reporting are detailed in the attached Ledger Standard Operating Procedures (see Attachment D).



Key:

µS/cm = microsiemens per centimeter (1 µS/cm = 1 µmhos/cm = 1/1,000 dS/m)

Figure 2. Proposed Mitigation Rating Curve based on Boron Sensitivity and Normalized to Electrical Conductivity

4. Critical Year Management

When Friant Division Class 1 contract allocation is less than or equal to 25 percent, the Water Quality Advisory Committee will convene as outlined in Attachment A. In these years, mitigation will be accounted for as presented in these Guidelines, but will be deferred to a later date unless those responsible for the Put and Take mutually agree to put and take the mitigation in the critical year. All monitoring requirements will remain as presented in these Guidelines.

C. Resolution of Disputes

In the event a Contractor is dissatisfied with the application or interpretation of these Guidelines by FWA staff or consultants, the following dispute resolution procedures will apply:

1. A Contractor may request FWA refer the dispute to Reclamation's Contracting Officer for initial review. FWA will prepare and deliver a written summary of the dispute for Reclamation's Contacting Officer, who will then confer with the parties and issue an advisory opinion regarding the dispute in a timely manner.

2. In addition to or in lieu of the meet and confer process with Reclamation's Contracting Officer above, a Contractor may submit a written appeal to be heard by the FWA Board of Directors. The

written appeal must be submitted to the office of the Chief Executive Officer, who will then place the dispute on the agenda of the Board of Directors for a hearing at a board meeting no later than 60 days from the date of receipt. The decision of the Board of Directors will be final and FWA and the other party(ies) must promptly comply with such decision until the same is stayed, reversed, or modified by a decision of a court of competent jurisdiction.

The Cooperative Agreement between the Contractors and FWA provides additional dispute resolution procedures. In the event of any conflict between the dispute resolution procedures in these Guidelines and the Cooperative Agreement, the provisions in the Cooperative Agreement will control.

D. Water Quality Forecasting and Communications

1. Friant-Kern Canal Water Quality Model

Water quality monitoring and collection of water quality data will be evaluated using the FKC Water Quality Model, a volumetric mass-balance model of the entire FKC. The FKC Water Quality Model will serve as a predictive, water quality forecast tool to assist Friant Contractors and FWA in making real-time operation decisions. The weekly application of this model will require compilation of surface water quality data collected, as described above, as well as forecasts of water orders and periodic model updates.

2. Water quality reporting and communications

IOS will report real-time, continuous FKC in-prism EC measurements. In addition, FWA will cause to be provided a weekly summary report to Friant Contractors and Reclamation on:

- FKC current and forecasted operations;
- FKC current in-prism monitoring and forecasted water quality conditions; and,
- Pertinent pump-in programs' operations and water quality conditions.

E. Implementation Responsibilities and Costs

FWA will be responsible for the following actions:

- Maintain and calibrate conductivity meters
- Perform water quality sampling during pump-in operations
- Coordinate laboratory water quality testing
- Coordinate with Contractors on water quality data monitoring and analysis
- Manage in-prism water quality and manage operations database

- Perform weekly water quality reporting and forecasting using FKC Water Quality Model
- Perform weekly analysis to determine mitigation and distribution to respective Friant Contractors or any other Contractor party(ies) using the FKC Water Quality Mitigation Ledger
- Coordinate with Reclamation's SCCAO on water quality reporting, mitigation, and contractual requirements
- Coordinate and facilitate the work of Water Quality Advisory Committee and the Monitoring Subcommittee.

Costs for implementation and administration of these Guidelines will be initially paid out of the FWA Operation, Maintenance, and Replacement (OM&R) budget, and subsequently will be reimbursed by Contractors. The Contractor will pay a dollar per acre-foot ($/acre-foot) fee ("**Water Quality Fee**") for introduced Non-Millerton water, that will be credited to the FWA OM&R budget. The Water Quality Fee will be adopted by the FWA Board of Directors and will be based on an estimate of total annual costs divided by average annual deliveries of pump-in programs into the FKC. The Water Quality Fee will be applied to all introduced Non-Millerton water even if mitigation is not required

Annual costs and deliveries will be reassessed every year and compared to estimates provided in Attachment E to determine if any adjustments are required to the Water Quality Fee.

Definitions

Contractors: Water contractors and other parties authorized to introduce or receive Non-Millerton water into or from the FKC.

Cooperative Agreement: The agreement between FWA and the participating Contractors regarding the establishment, implementation and management of these Guidelines.

CVC: Cross Valley Canal

EC: Salinity measured as electrical conductivity

Friant Contractors: Contractors with long-term contracts with Reclamation.

FWA: Friant Water Authority, a California joint powers agency.

IOS: Intellisite Operation System

Ledger: The Water Quality Mitigation Ledger that tracks and accounts for all inflows into and diversions from the FKC in order to determine appropriate mitigation for impacted water quality attributable to the introduced Non-Millerton water.

Maximum Contaminant Level (MCL): Usually reported in milligrams per liter (parts per million) or micrograms per liter (parts per billion).

Non-Millerton Water: All water introduced into the Friant-Kern Canal other than directly from Millerton Lake to the headworks of the FKC.

OM&R: Operation, Maintenance and Replacement

Put: The introduction of Non-Millerton water into the FKC.

Project: The Friant Division of the Central Valley Project, specifically the Friant-Kern Canal.

Reclamation: United States Bureau of Reclamation.

SCCAO: Reclamation's South-Central California Area Office.

Take: The distribution and delivery of Non-Millerton water.

Taker: A Friant Contractor receiving an eligible Take.

Title 22: The Domestic Water Quality and Monitoring Regulations specified by the State of California Health and Safety Code (Sections 116270-116755), and California Code of Regulations (Sections 6440 et seq.), as amended.

Water Quality Fee: The fee established by FWA for introduced Non-Millerton water to fund this water quality program.

Tables

Attachments

Table 1. Water Quality Constituents

CONSTITUENT OR PARAMETER	Units	Recommended Method	California OHS Maximum Contaminant Level		CAS Registry Number
Primary Constituents (CCR§ 64431)					
Aluminum	µg/L	EPA200.7	1,000		7429-90--5
Antimony	µg/L	EPA200.8	6		7440-36--0
Arsenic	µg/L	EPA200.8	10	16	7440-38-2
Asbestos	MFL > 10µm	EPA 100.2	7		1332-21--4
Barium	µg/L	EPA 200.7	1,000		7440-39-3
Beryllium	µg/L	EPA200.7	**4**		7440-41-7
Cadmium	µg/L	EPA200.7	5		7440-43--9
Chromium	µg/L	EPA200.7	50		7440-47-3
Cyanide	µg/L	EPA335.4	150		57-12-5
Fluoride	mg/L	EPA 300.1	2		16984--48-8
Mercury (inorganic)	µg/L	EPA245.1	2		7439-97-6
Nickel	µg/L	EPA200.7	100		7440-02-0
Nitrate (as N03)	mg/L	EPA300.1	45		7727-37-9
Total Nitrate+ Nitrite (as Nitrogen)	mg/L	EPA353.2	10		
Nitrite (as Nitrogen)	mg/L	EPA 300.1			14797--65--0
Selenium	µg/L	EPA200.8	50		7782-49-2
Thallium	µg/L	EPA200.8	2		7440-28-0
Secondary Constituents (CCR§ 64449)					
Aluminum	µg/L	EPA200.7	200	6	7429-90--5
Chloride	mg/L	EPA300.1	250/500/600	7	16887--00-6
Color	units	**SM** 2120 B	15	6	
Copper	µg/L	EPA200.7	1,000	6	7440-50-8
Foaming agents **(MBAS)**	mg/L	SM 5540C	0.5	6	
Iron	µg/L	EPA200.7	300	6	7439-89-6
Manganese	µg/L	EPA200.7	50	6	7439-96--5
Methyl-tert-butyl ether (MtBE)	µg/L	EPA 524.2	5	6	1634-04--4
Odor - Threshold	threshold units	**SM** 2150 B	3	6	
Silver	µg/L	EPA200.7	100	6	7440-22--4
Specific conductance (EC)	µSiem	SM 2510 B	900/1600/2200	7	
Sulfate	mg/L	EPA300.1	250/500/600	7	14808-79-8
Thiobencarb	µg/L	EPA525.2		6	28249-77--6
Total dissolved solids (TDS)	mg/L	SM 2540 C	500/1000/1500	7	
Turbidity	NTU	EPA180.1	5	6	
Zinc	mg/L	EPA200.7	5	6	7440-66--6

Table 1. Water Quality Constituents

CONSTITUENT OR PARAMETER	Units	Recommended Method	California DHS Maximum Contaminant Level		GAS Registry Number
Other required analyses (CCR§ 64449 (b)(2); CCR § 64670)					
Bicarbonate	mg/L	SM 2320B		8	
Calcium	mg/L	SM3111B		8,12	7440-70-2
Carbonate	mg/L	SM 2320B		8	
Copper	mg/L	EPA200.7	1.3	14	7440-50-8
Hardness	mg/L	SM 2340 B		8	
Hydroxide alkalinity	mg/L	SM 2320B		8,12	
Lead	mg/L	EPA200.8	0.015	14	7439-92-1
Magnesium	mg/L	EPA200.7		8	7439-95-4
Orthophosphate	mg/L	EPA365.1		12	
pH	units	EPA150.1		8,12	
Silica	mg/L	EPA200.7		12	
Sodium	mg/L	EPA200.7		8	7440-23-5
Temperature	degrees C	SM 2550		12	
Radiochemistry (CCR§ 64442)					
Radioactivity, Gross Alpha	pCi/L	SM 7110C	15	3	
Microbiology					
Cryptosporidium	org/liter		No MCL, measure for presence (surface water only)		
Fecal Coliform	MPN/100ml		No MCL, measure for presence (surface water only)		
Giardia	org/liter		No MCL, measure for presence (surface water only)		
Total Coliform bacteria	MPN/100ml		No MCL, measure for presence (surface water only)		
Organic Constituents (CCR § 64444)					
EPA 504.1 method					
Dibromochloropropane (DBCP)	µg/L	EPA504.1	0.2	4	96-12-8
Ethylene dibromide (EDB)	µg/L	EPA504.1	0.05	4	206-93-4
EPA505					
Chlordane	µg/L	EPA505	0.1	4	57-74-9
Endrin	µg/L	EPA505	2	4	72-20-8
Heptachlor	µg/L	EPA505	0.01	4	76-44--8
Heptachlor epoxide	µg/L	EPA505	0.01	4	1024-57-3
Hexachlorobenzene	µg/L	EPA505		4	118-74-1
Hexachlorocyclopentadiene	µg/L	EPA505	50	4	77-47-4
Lindane (gamma-BHC)	µg/L	EPA505	0.2	4	58-89-9
Methoxychlor	µg/L	EPA505	30	4	72-43-5
Polychlorinated biphenyls	µg/L	EPA505	0.5	4	1336-36-3
Toxaphene	µg/L	EPA505	3	4	8001-35-2
EPA 508 Method					
Alachlor	µg/L	EPA508.1	2	4	15972-60-8
Atrazine	µg/L	EPA508.1		4	1912-24-9
Simazine	µg/L	EPA508.1	4	4	122-34-9

Table 1. Water Quallty Constituents

CONSTITUENT OR PARAMETER	Units	Recommended Method	California OHS Maximum Contaminant Level		CAS Registry Number
EPA 515.3 Method					
Bentazon	µg/L	EPA 515	18	4	25057-89-0
2,4-0	µg/L	EPA515.1-4	70	4	94-75-7
Dalapon	µg/L	EPA515.1-4	200	4	75-99-0
Dinoseb	µg/L	EPA515.1-4	7	4	88-85-7
Pentachlorophenol	µg/L	EPA515.1-4		4	87-86-5
Picloram	µg/L	EPA 515.1-4	500	4	1916-02-1
2,4,5-TP (Silvex)	µg/L	EPA515.1-4	50	4	93-72-1
EPA 524.2 Method (Volatile Organic Chemicals)					
Benzene	µg/L	EPA524.2		4	71-43-2
Carbon tetrachloride	µg/L	EPA 524.2	0.5	4	56-23-5
1,2-Dibromomethane	µg/L	EPA 524.2	0.05		106-93-4
1,2-Dichlorobenzene	µg/L	EPA524.2	600	4	95-50-1
1,4-Dichlorobenzene	µg/L	EPA524.2	5	4	106-46-7
1,1-Dichloroethane	µg/L	EPA 524.2	5	4	75-34-3
1,2-Dichloroethane	µg/L	EPA524.2	0.5	4	107-06-2
1,1-Dichloroethylene	µg/L	EPA 524.2	6	4	75-35-4
cis-1,2-Dichloroethylene	µg/L	EPA524.2	6	4	156-59-2
trans-1,2-Dichloroethylene	µg/L	EPA524.2	10	4	156-60-5
Dichloromethane	µg/L	EPA524.2	5	4	75-09-2
1,2-Dichloropropane	µg/L	EPA524.2	5	4	78-87-5
1,3-Dichloropropene	µg/L	EPA524.2	0.5	4	542-75-6
Ethylbenzene	µg/L	EPA524.2	300	4	100-41-4
Methyl-tert-butyl ether (MtBE)	µg/L	EPA524.2	13	4	1634-04-4
Monochlorobenzene	µg/L	EPA524.2	70	4	108-90-7
Styrene	µg/L	EPA524.2	100	4	100-42-5
1,1,2,2-Tetrachloroethane	µg/L	EPA524.2		4	79-34-5
Tetrachloroethylene (PCE)	µg/L	EPA524.2	5	4	127-18-4
Toluene	µg/L	EPA524.2	150	4	108-88-3
1,2,4-Trichlorobenzene	µg/L	EPA 524.2	5	4	120-82-1
1,1,1-Trichloroethane	µg/L	EPA524.2	200	4	71-55-6
1,1,2-Trichloroethane	µg/L	EPA524.2	5	4	79-00-5
Trichloroethylene (TCE)	µg/L	EPA 524.2	5	4	79-01-6
Trichlorofluoromethane	µg/L	EPA 524.2	150	4	75-69-4
1,1,2-Trichloro-1,2,2-trifluoroethane	µg/L	EPA524.2	1,200	4	76-13-1
Total Trihalomethanes	ug/L	EPA524.2	80	10	
Vinyl chloride	µg/L	EPA 524.2	0.5	4	75-01-4
Xylene(s)	µg/L	EPA 524.2	1,750	4	1330-20-7
EPA 525.2 Method					
Benzo(a)pyrene	µg/L	EPA 525.2	0.2	4	50--32-8
Di(2-ethylhexyl)adipate	µg/L	EPA525.2	400	4	103-23-1
Di(2-ethylhexyl)phthalate	µg/L	EPA 525.2	4	4	117-81-7
Molinate	µg/L	EPA 525.2	20	4	2212-67-1
Thiobencarb	µg/L	EPA 525.2	70	4	28249-77-6
EPA 531.1 Method					
Carbofuran	µg/L	EPA531.1-2	18	4	1563-66-2
Oxamyl	µg/L	EPA531.1-2	50	4	23135-22-0

Table 1. Water Quality Constituents

CONSTITUENT OR PARAMETER	Units	Recommended Method	California OHS Maximum Contaminant Level		CAS Registry Number
EPA 547 Method					
Glyphosate	µg/L	EPA547	700	4	1071-83--6
EPA 548.1 Method					
Endothal	µg/L	EPA 548.1	100	4	145-73-3
EPA 549.2 Method					
Diquat	µg/L	EPA549.2	20	4	85-00-7
EPA 613 Method					
2,3,7,8-TCDD (Dioxin)	µg/L	EPA 1613	0.00003	4	1746-01-6

Source Data:

Adapted from Marshack, Jon B. August 2003. A Compilation of Water Quality Goals. Prepared for the California Environmental Protection Agency, Regional Water Quality Control Board.

Table 1. Unregulated Chemicals (CCR § 64450)

			California Department of Health Services			CAS
CONSTITUENT OR PARAMETER	Units	Recommended Method	Notification Level		Response Level	Registry Number
Boron	mg/L	EPA 200.7		9, 17	10	7440-42-8
n-Butylbenzene	µg/L	EPA 524.2	260	17	2,600	104-51-8
sec-Butylbenzene	µg/L	EPA 524.2	260	17	2,600	135-98-8
tert-Butylbenzene	µg/L	EPA 524.2	260	17	2,600	98-06-6
Carbon disulfide	µg/L		160	17	1,600	
Chlorate	µg/L	EPA 300.1	0.8	17	8	
2-Chlorotoluene	µg/L	EPA 524.2	140	17	1,400	95-49-8
4-Chlorotoluene	µg/L	EPA 524.2	140	17	1,400	106-43-4
Dichlorofluoromethane (Freon 12)	µg/L	EPA 524.2	1,000	9,17	10,000	75-43-4
1,4-Dioxane	µg/L	**SM** 8270	3	17	300	123-91-1
Ethylene glycol	µg/L	**SM** 8015	1,400	17	14,000	107-21-1
Formaldehyde	µg/L	**SM** 6252	100	17	1,000	50-00--0
n-Propylbenzene	µg/L		260	17	2,600	
HMX	µg/L	**SM** 8330	350	17	3,500	2691-41-0
Isopropylbenzene	µg/L		770	17	7,700	
Manganese	mg/L			17	5	
Methyl isobutyl ketone	µg/L		120	17	1,200	
Napthalene	µg/L	EPA 524.2	17	17	170	91-20-3
n-nitrosodiethylamine (NDEA)	µg/L	1625	0.01	17	0.1	
n-nitrosodimethylamine (NOMA)	µg/L	1625	0.01	17	0.2	
n-nitroso-n-propylamine (NDPA)	µg/L	1625	0.01	17	0.5	
Perchlorate	µg/L	EPA 314	6	9, 17	60	13477-36-6
Propachlor	µg/L	EPA 507 or 525	90	17	900	1918-16-7
p-Isopropyltoluene	µg/L	EPA 524.2	770	17	7,700	99-87-6
ROX	µg/L	**SM** 8330	0.30	17	30	121-82-4
tert-Butyl alcohol (ethanol)	µg/L	EPA 524.2	12	9,17	1,200	75-65--0
1,2,3-Trichloropropane (TCP)	ug/L	EPA 524.2	0.005	9,17	0.5	96-18-4
1,2,4-Trimethylbenzene	µg/L	EPA 524.2	330	17	3,300	95-63-6
1,3,5-Trimethylbenzene	µg/L	EPA 524.2	330	17	3,300	95-63-6
2,4,6-Trinitrotoluene (TND	µg/L	**SM** 8330		17	100	
Vanadium	mg/L	EPA286.1	0.05	9,17	0.5	7440-62-2

Revised: 05/17/2007

Notes for Table 1

Title 22. California Code of Regulations, California Safe Drinking Water Act and Related Laws and Regulations. February 2007.
http://www.dhs.ca.gov/ps/ddwem/publications/lawbook/PDFs/dwregulations-02-06--07.pdf

[1] Table 64431-A. Maximum Contaminant Levels, Inorganic Chemicals
[2] Table 64432-A. Detection Limits for Purpose of Reporting (DLRs) for Regulated Inorganic Chemicals
[3] Table 644442. Radionuclide Maximum contaminant Levels (MCLs) and Detection Levels for Reporting (DLRs)
[4] Table 64444-A. Maximum Contaminant Levels Organic Chemicals
[5] Table 64445.1-A. Detection Limits for Reporting (DLRs) for Regulated Organic Chemicals
[6] Table 64449-A. Secondary Maximum Contaminant Levels "Consumer Acceptance Levels"
[7] Table 64449-8. Secondary Maximum Contaminant Levels "Consumer Acceptance Levels"
[8] § 64449(b)(2)
[9] Table 64450. Unregulated Chemicals
[10] Appendix 64481-A. Typical Origins of Contaminants with Primary MCLs
[11] Table 64533-A. Maximum Contaminant Levels and Detection Limits for Reporting Disinfection Byproducts
[12] § 64670.(c)
(13] Table 64678-A. DLRs for Lead and Copper
[14] § 64678 (d)
[15] § 64678 (e)
[16] New Federal standard as of 1/23/2006
(17] Dept Health Services Drinkig Water Notification Levels (June 2006)

Table 2. Approved Laboratory List for the Mid-Pacific Region Environmental Monitoring Branch (MP-157)

Basic Laboratory	**Address**	2218 Railroad Avenue Redding, CA 96001 USA
	Contact	Nathan Hawlev, Melissa Hawlev, Rickv Jensen
	P/F	(530) 243-7234 / (530) 243-7494
	Email	nhawley@basiclab.com (QAO), mhawley@basiclab.com (PM).jcady@basiclab.com (quotes), poilar@basiclab.com (sample custody), khawley@basiclab.com (sample custody)
	CC Info	nhawley@basiclab.com, jcady@basiclab.com (sample custody)
	Methods	*Approved only for inorganic parameters (metals, general chemistry)*
BioVir Analytical Laboratories	**Address**	685 Stone Road Unit 6 Benicia, CA 94510 USA
		Rick Danielson, Lab Director
	P/F	(707) 747-5906 / (707) 747-1751
	Email	red(a)biovir.com, csiralbiovir.com, lb(a)biovir.com, OAO Jim Truscott irt(a)biovir.com
	Methods	*Aoproved for all biological and pathoeenic oarameters*
Block Environmental Services	**Address**	2451 Estand Way Pleasant Hill, CA 94523 USA
	Contact	David Block
	P/F	(925) 682-7200 / (925) 686-0399
	Email	dblock(a)blockenviron.com
	Methods	*Aooroved for Toxicity Testini!.*
California Laboratory Services	**Address**	3249 Fitzeerald Road Rancho Cordova, CA 95742
	Contact	Raymond Oslowski
	P/F	(916) 638-7301 / (916) 638-4510
	Emai	rayo(a)califomialab.com
	Methods	*Aooroved for Chromium VI*
Caltest Analytical Laboratory	**Address**	1885 North Kellv Road Naoa, CA 94558
	Contact	Bill Svoboda, Project Manager x29
	P/F	(707) 258-4000 / (707) 226-1001
	Email	bsvoboda(a)caltestlab.com
	Methods	*Approved (or all inorwnic parameters and bioligical parameters*
Columbia Environmental Resource Center	**Address**	4200 New Haven Road Columbia, MO 65201 USA
	Contact	Tom May, Research Chemist
	P/F	1(573) 876-1858 / (573) 876-1896
	Email	tmay(a)usgs.gov
	Methods	*Aooroved (or mercury in bioloi!ical tissue*
Data Chem Laboratories	**Address**	960 West LeVo Drive Salt Lake Ci , UT 84123-2547 USA
	Contact	Bob DiRienzo, Kevin Griffiths-Pro·ect Mana er, Rand Potter - Pro·ect Mana er, asbestos
	P/F	(801) 266-7700 / (801) 268-9992
	Email	griffiths@datachem.com, Potter@datachem.com Invoicing: (Justin) pate@datachem.com
	Methods	*Approved for asbestos, metals, organochlorine pesticides and PCBs in solids*
Dept. of Fish & Game-WPCL	**Address**	2005 Nimbus Road Rancho Cordova, CA 95670 USA
	Contact	David 8. Crane
	P/F	(916) 358-2858 / (916) 985-4301
	Email	dcrane(a)ospr.dfg.ca.gov
	Methods	*Aoproved only (or metals analysis in tissue.*
Frontier Geosciences	**Address**	414 Pontius North Seattle, WA 98109 USA
	Contact	Shelly Fank - QA Officer, Matt Gomes-Project Manager
	P/F	(206) 622-6960 *I* (206) 622-6870
	Email	shellyf(a)frontierneosciences.com, matto/n)frontierneosciences.com
	Methods	*in low level metals analysis.*

Fruit Growers Laboratory	Address	853 Corporation Street Santa Paula, CA 93060 USA
	Contact	David Terz, QA Director
	P/F	(805) 392-2024 / (805) 525-4172
	Email	davidt@fglinc.com
	Methods	*Approved for all inorganic and organic parameters in drinkin water.*
Montgomery Watson/Harza Laboratories	Address	750 Royal Oaks Drive **Ste. 100 Monrovia**, CA 91016 USA
	Contact	Allen Glover (project manager), Bradley Cahoon (quotes)
	P/F	(916) 374-8030, 916-996-5929 (AG-cell) / (916) 374-8061
	Emai	Allen.Glover@us.mwhglobal.com, Bradley.Cahoon@us.mwhglobal.com
	CC Info	cc. Sam on all communications to Allen. Samer.Momani@us.mwhglobal.com
	Methods	*Approved for all inorganic and organic parameters in drinking water*
Olson Biochemistry Laboratories	Addr.	SDSU: Box 2170, ACS Rm. 133 Brookings, SD 57007 USA
	Contact	Nancy Thiex, Laboratorv Director
	P/F	1(605) 688-5466 / (605) 688-6295
	Emai	Nancv.Thiex@sdstate.edu
	CC Info	For re-analysis: contact Zelda McGinnis-Schlobohm and Nancy Anderson
		Zelda.Schobohm@SDSTATE.EDU, Nancy.Anderson@SDSTATE.EDU
		For analysis Questions only: just CC. Nancy Anderson
	Methods	*Approved only for low level selenium analvsis.*
Severn Trent Laboratories	Address	880 Riverside Parkway West Sacramento, CA 95605 USA
	Contact	Jeremy Sadler
	P/F	1(916) 374-4381 / (916) 372-1059
	Email	I isadler(aJstl-inc.com
	Methods	*Approved for all inorganic parameters and hazardous waste organics **except for Ammonia as Nitrogen** .* *Ag analysis in sediment, when known quantity is present, request 60/ OB*
Sierra Foothill Laboratory, Inc.	Address	255 Scottsville Blvd, Jackson, CA 95642
	Contact	Sandy Nurse (Owner) or Dale Gimble (QA Officer)
	P/F	(209) 223-2800 / (209) 223-2747
	Email	sandy(aJsierralab.com, CC: dale(aJsierralab.com
	Methods	*Approved for all inorganic parameters, microbiological parameters, acute and chronic toxicity.*
Twining Laboratories, Inc.	Address	2527 Fresno Street Fresno, CA 93721 USA
	Contact	Jim Brownfield (QA Officer), Sample Control (for Bottle Orders
	P/F	(559) 268-7021 / (559) 268-0740
	fu!!!ll	JimB@twining.com cc. to JosephU@twining.com
	Methods	*Approved only for general chemistry and boron analysis.*
U.S. Geological Survey - Denver	**Address**	Denver Federal Center Building 20, **MS** 973 Denver, CO 80225 USA
	Contact	Stephen A. Wilson
	P/F	(303) 236-2454 / (303) 236-3200
	Email	swilson(aJusgs.gov
	Methods	*Approved onlv for inonwnic parameters in soil .*
USBR Technical Service Center Denver Soils	**Address**	Denver Federal Center Building 67, D-8750 Denver, CO 80225-0007 USA
	Contact	Juli Fahy or Stan Conway
	P/F	1003) 445-2188 / (303) 445-6351
	Email	jfahy(aJdo.usbr.gov
	Methods	*Approved onlv for f!eneral physical analvsis in soils.*
Western Environmental Testing Laboratories	**Address**	475 East Greg Street # 119 Sparks, NV 89431 USA
	Contact	Ginger Peppard (Customer Service Manager), Andy Smith (Lab Director), Michelle Kramer
	P/F	(775) 355-0202 / (775) 355-0817
		ginger@WETLaboratory.com, andy@WETLaboratory.com, michelle@WETLaboratory.com
		Approved only for inorganic parameters (metals, general chemistry).

Revised: 04/16/2007 MP-157

Table 3. Check Structure Locations for Real-Time Measurements of Electrical Conductivity

Check Structure	Milepost
Little Dry Creek	5.50
Kings River	28.52
Sand Creek	46.04
Dodge Ave	61.03
Kaweah River	71.29
Rocky Hill	79.25
Fifth Ave	88.22
Tule River	95.67
Deer Creek	102.69
White River	112.90
Reservoir (Woollomes)	121.51
Poso Creek	130.03
Shafter	137.20
Kern River	151.81

Table 4. Friant-Kern Canal In-Prism Water Quality Thresholds

Period	Salinity expressed as EC (µS/cm)	Chloride (mg/L)	Boron (mg/L)[1]	Turbidity (NTU)	Total Suspended Solids (ppm)
Period 1 March 1 – June 30	1,000[2]	102[3]	0.4	40	20
Period 2 July 1 – August 31	500[4]	55[4]	0.4	40	20
Period 3a September 1 – February 28	1,000[2]	102[3]	0.4	40	20
Period 3b September 1 – February 28	1,000[2]	123[5]	0.4	40	20

Notes:
Thresholds adapted from Grieve, C.M., S.R. Grattan and E.V. Maas. 2012. Plant salt tolerance. In. (W.W. Wallender and K.K. Tanji, eds). Agricultural Salinity Assessment and Management (2nd edition). ASCE pp 405-459; and Ayers, R.S. and D.W. Westcot 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper 29 (rev 1). Food and Agriculture Organization of the United Nations. Rome

For addition detail, see Attachment B - Agronomic Impacts and Mitigation.

When Friant-Kern Canal in-prism water quality conditions in this table are exceeded, Friant Division Long-Term Contractors will work together to seek 1:1, unleveraged, and cost-neutral exchanges for pump-in and pump-back programs. This does not apply to spot-market or third-party exchanges.

[1] Grapes are used as a representative crop for boron sensitivity and are prevalent in the Friant Division. They are used as a surrogate for many other sensitive crop types such as apricots, figs, and grapefruits. Threshold assumes conventional irrigation with minimum 20 percent leaching fraction applied.

[2] Threshold assumes minimum of 20 percent leaching requirement applied and adjusted to account for regulated deficit irrigation during almond hull split period (July 1 – August 31) in order to not exceed maximum EC_{et}. Almonds on Nemaguard rootstock are used as a representative crop for salinity sensitivity and are prevalent in the Friant Division. They are used as a surrogate for many other sensitive crop types such as apples, cherries, pears, pistachios, and walnuts.

[3] Threshold assumes minimum of 20 percent leaching requirement applied and then adjusted to account for regulated deficit irrigation during almond hull split period (July 1 – August 31) in order to not exceed maximum Cl-et. Almonds on Nemaguard rootstock used as a representative crop for chloride sensitivity. They are used as a surrogate for other sensitive crops including cherries, pistachios, and walnuts.

[4] Threshold applies to almond hull split period when regulated deficit irrigation is applied to avoid hull rot. This threshold is used assuming irrigation applications are reduced to 50 percent of the tree water requirement and subsequently thresholds applied for the remainder of the year have been adjusted to account for additional salt accumulation. This threshold was developed with consideration of existing program operations, historical water quality data, and absolute water quality thresholds.

[5] If the measured average chloride concentration in Period 1 (March 1 – June 30) is less than or equal to 70 mg/L, the allowable chloride threshold for Period 3 (September 1 – February 28) is increased to 123 mg/L.

Key:
µS/cm = microsiemens per centimeter (1 µS/cm = 1 µmhos/cm = 1/1,000 dS/m)
ASCE = American Society of Civil Engineers
Cl^-_{et} = maximum chloride threshold of the saturated soil paste
EC = electrical conductivity of applied water
EC_{et} = Soil salinity threshold for a given crop
FAO = Food and Agriculture Organization of the United Nations
Friant Division = Friant Division of the Central Valley Project
mg/L = milligrams per liter
TDS = total dissolved solids

Table 5: Friant-Kern Canal Water Quality Constituents Short List

Constituent	Units	Thresholds
1,2,3 TCP	(µg/L)	0.005
Bicarbonate	(mg/L)	--
Boron	(mg/L)	See Table 4
Calcium	(mg/L)	--
Chloride	(mg/L)	See Table 4
Salinity (as EC)	(µS/cm)	See Table 4
Iron	(µg/L)	300
Magnesium	(mg/L)	--
Manganese	(µg/L)	50
Nitrate	(mg/L)	10
pH		--
Selenium	(µg/L)	2
Sodium	(mg/L)	100
TDS	(mg/L)	-- *
TSS	(ppm)	See Table 4
Turbidity	(NTU)	See Table 4

Notes:

Thresholds are Title 22 MCLs unless otherwise noted.

Constituent with threshold denoted as "--" does not have an established MCL.

Refer to Table 1 and Notes for Table 1 for additional details.

*TDS MCL not listed for the purposes of these Guidelines. TDS and EC are both a measure of salinity and the EC thresholds shown in Table 4 are controlling.

Attachment A. Friant-Kern Canal Water Quality Guidelines Water Quality Advisory Committee Draft Charter

Background and Objective

The Friant-Kern Canal Water Quality Guidelines ("Guidelines") were adopted by the Friant Water Authority (FWA) based on the voluntary consensus of and written agreement with a significant majority of the contractors of the Division of the Central Valley Project ("Friant Division"). The Guidelines address concerns regarding the implementation of programs and projects that could introduce water of a lesser quality to the Friant-Kern Canal ("FKC"), when compared to water quality of historic deliveries from Millerton Lake. The Guidelines include water quality constituent thresholds based on agronomic principles and a ledger mechanism to determine the required mitigation for introducing water of lesser quality into the FKC.

The Guidelines provide that the FWA will appoint a Water Quality Advisory Committee ("Committee") composed of Friant Division long-term contractors ("Friant Contractors") and other water contractors and other parties involved in either introducing water to or receiving water from the FKC (collectively, "Contractors"). The Committee will provide recommendations to FWA and Reclamation on operations and water quality monitoring requirements of the FKC as well as potential revisions to the Guidelines. This document describes Committee membership and Committee roles and responsibilities.

Water Quality Advisory Committee Membership

The appointed Committee will be composed of Friant Contractors and other Contractors who may either be introducing water to or receiving water from the FKC. Committee membership is described in Table 1. New members in replacement of an existing member or as a new addition to the membership list requires majority approval following notice to and the consent of the FWA Board of Directors.

Table 1. Water Quality Advisory Committee Membership

Members
Arvin-Edison Water Storage District

Delano-Earlimart Irrigation District
Kern-Tulare Water District
Lindsay Strathmore Irrigation District
Lower Tule River Irrigation District
Pixley Irrigation District
Porterville Irrigation District
Saucelito Irrigation District
Shafter Wasco Irrigation District
South San Joaquin Municipal Utility District
Terra Bella Irrigation District

Roles and Responsibilities

The Committee will convene on an annual basis prior to the irrigation season or planned reverse flow operations. The Committee will:

- Evaluate current year operations related to Guidelines implementation including but not limited to Ledger operation modifications, potential schedule changes, and potential changing to mitigation deliveries.
- Review and approve annual monitoring.
- Make recommendations regarding the costs and budgets associated with administering and implementing the Guidelines.

The Committee may also convene on an as needed basis under the following conditions:

- When Friant Division Class 1 contract allocation is less than or equal to 25 percent.
- If a future regulatory cost or equivalent fee is imposed on Friant Contractors and a portion of such fee can reasonably be attributed to the incremental difference of water quality conditions in the FKC.
- If there is a significant, scientifically based justification and three out of the following five water contractors agree that a change to Guideline principles and/or criteria should be discussed: Arvin-

Edison Water Storage District, Shafter Wasco Irrigation District, Delano-Earlimart Irrigation District, South San Joaquin Municipal Utility District, or Kern-Tulare Water District.

- If FKC water quality continuously exceeds one or more constituent thresholds and pump-in operations must cease.

The Committee will make recommendations to the FWA Board via consensus decision making. If 100% consensus cannot be reached, a recommendation will be made, and minority viewpoints will also be communicated. The Committee with provide all recommendations to the FWA Board. Single-year modifications to Guidelines implementation, monitoring, and/or pump-in operations will be noticed to all Friant Contractors. Recommendations requiring substantial modifications or updates to the Guidelines will be provided to the FWA Board and the FWA will coordinate with Reclamation to implement recommended changes.

Monitoring Subcommittee

The Committee will appoint at least three and no more than five representatives of its members to serve on a Monitoring Subcommittee that will coordinate with FWA on the implementation of the Guidelines particularly with respect to potential or actual exceedance of the water quality thresholds established under these Guidelines and the implementation of required mitigation, including the reduction of discharges of Non-Millerton water into the FKC. The Subcommittee will make recommendations to FWA in accordance with Section B.2.d above, but the final operational decisions will be made by FWA.

Attachment B

Monitoring Program Summary

Summary of requirements for monitoring campaign specified in the Guidelines for Accepting Water into the Friant-Kern Canal

Sample Source/Type		Trigger	Constituents/Bacterial Organisms	Frequency	Location	Communication
Source of Discharge Water						
1	Non-Millerton Lake Source	Routine sampling.	All in Table 1	Every three years	Discharge Location.	Reported to FWA and Reclamation FKC's Contracting Office for review. FWA will report to Friant contractors.
2	Non-Millerton Lake Source	Routine sampling.	All in Table 5	Annually	Discharge Location.	
3	Non-Millerton Lake Source	If routine sampling of Table 5 water quality constituents shows exceedance of an established threshold buffer. **	Any in Table 5 exceeding the established threshold buffer.	Weekly. Until consecutive tests are below the established threshold buffer.	Discharge Location.	
4	Non-Millerton Lake Source	Reclamation on a case-by-case basis per condition of program operations.	Any	Any	Any	
Blended Canal Water						
5	FKC Water	Routine sampling (continuous).	EC	Real-time, Every 15 minutes	Check structures and mile posts in Table 3	Uploaded to FWA's IOS. FWA will regularly calibrate equipment.
6	FKC Water	If Friant Water Quality Model forecasts exceedance of an established threshold buffer. **	Any in Table 5 exceeding the established threshold buffer.	Weekly. Until sampled data, supported through modeling, show four consecutive tests below the established threshold buffer.	Check structures and mile posts in Table 3, where water quality changes are expected.	FWA will deliver to approved Reclamation lab. Forecasted and measured in-prism water quality will be communicated by FWA to Friant contractors.
7	FKC Water	Specific operation disruptions (servicing of real-time equipment, unexpected outages, etc.).	EC	Any	Any	
8	CVC	Reverse-flow, and pump-back operations.	All in Table 5	Weekly	CVC, near Intertie	FWA will deliver to Reclamation lab. Water quality data will be communicated via FWA's IOS.
9	CVC	Initiation of pump-back operations, and/or anticipated that CVC operations will significantly change water quality	All in Table 1 and Table 5	As needed	CVC, near Intertie	FWA will deliver to Reclamation lab. Water quality data will be communicated via FWA's IOS.

Notes: References to tables above (Table 1, 3, 4, 5) from Friant Water Authority draft Guidelines for Accepting Water into the Friant-Kern Canal.

**Threshold buffers that will trigger continued monitoring are 90% of the thresholds established in Table 5.

Key:

EC = electrical conductivity

CVC = Cross Valley Canal

FKC = Friant-Kern Canal

IOS = Intellisite Operation System

Reclamation = U.S. Department of the Interior, Bureau of Reclamation

Friant-Kern Canal Water Quality Policy

Draft Attachment C – Agronomic Impacts and Mitigation

CONTENTS

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

µmhos/cm	micromhos per centimeter (1 µmhos/cm = 1 µS/cm = 1/1,000 dS/m)
µS/cm	microsiemens per centimeter (1 µS/cm = 1 µmhos/cm = 1/1,000 dS/m)
Ad hoc Committee	Ad hoc Water Quality Committee
AEWSD	Arvin-Edison Water Storage District
ATP	adenosine triphosphate
AW	applied water
B	boron
B_e	boron concentration of the saturated soil paste (rootzone boron)
B_{et}	maximum boron threshold of the saturated soil paste
B_w	boron concentration of applied irrigation water
B_{sw}	boron threshold for soil water concentration
Ca	calcium
Ca^{2+}	calcium ion
$CaCO_3$	calcite or calcium carbonate
cfs	cubic feet per second
Check 21	Check Structure 21 at milepost 172,40 on the California Aqueduct
Cl^-	chloride ion
Cl^-_e	chloride concentration of the saturated soil paste (rootzone chloride)
Cl^-_{et}	maximum chloride threshold of the saturated soil paste
Cl^-_w	chloride concentration of applied irrigation water
CO_2	carbon dioxide
CO_3^{2-}	carbonate ion
CVC	Cross Valley Canal
DEID	Delano-Earlimart Irrigation District
dS/m	deciSiemens per meter (1 dS/m = 1,000 µmhos/cm = 1,000 µS/cm)
EC	electrical conductivity
EC_e	electrical conductivity of the saturated soil paste (rootzone salinity)
EC_{dw}	electrical conductivity/salinity of irrigation drainage water
EC_w	electrical conductivity/salinity of applied irrigation water
ET	evapotranspiration
F_c	concentration factor
FKC	Friant-Kern Canal
Friant Division	Friant Division of the Central Valley Project
FWA	Friant Water Authority

HCO_3^-	bicarbonate
Intermediate	Water quality representing the average of California Aqueduct Check 21 and Cross Valley Canal water qualities
KTWD	Kern Tulare Water District
LF	leaching fraction
LR	leaching requirement
Mg^{2+}	magnesium ion
Mg	magnesium
meq/L	milliequivalents per liter
mg/L	milligrams per liter (equivalent to ppm)
Na^+	sodium ion
Na	sodium
pH	Measure of acidity or alkalinity
Policy	Friant-Kern Canal Water Quality Policy
ppm	parts per million (equivalent to mg/L)
RDI	regulated deficit irrigation
SAR	sodium adsorption ratio
SAR_{adj}	adjusted sodium adsorption ratio
SID	Saucelito Irrigation District
SSJMUD	South San Joaquin Municipal Utility District
SWID	Shafter-Wasco Irrigation District
TDS	total dissolved solids

BACKGROUND

The Ad hoc Water Quality Committee (Ad hoc Committee) is working to develop a comprehensive Friant-Kern Canal Water Quality Policy (Policy) to be adopted by the Friant Division of the Central Valley Project (Friant Division). This policy is in response to concerns regarding the implementation of programs and projects that could introduce water of a lesser quality to the Friant-Kern Canal (FKC), when compared to water quality of historic deliveries from Millerton Lake. This Policy would also be referenced in FKC projects as well as other projects that envision introducing water into the FKC. The Ad hoc Committee is composed of water district directors and managers from Arvin-Edison Water Storage District (AEWSD), Delano-Earlimart Irrigation District (DEID), Kern-Tulare Water District (KTWD), Lindsay-Strathmore Irrigation District, Lower Tule River Irrigation District, Pixley Irrigation District, Porterville Irrigation District, Saucelito Irrigation District (SWID), Shafter-Wasco Irrigation District, and Terra Bella Irrigation District. The Ad hoc Committee is proposing a ledger mechanism to determine the required mitigation for introducing water of lesser quality into the FKC. This attachment to the Policy describes agronomic effects, mitigation requirements, maximum water quality thresholds for key constituents developed for the FKC. The thresholds are specific to irrigation periods that correspond to the growing season and agricultural management practices during the year.

AGRONOMIC EFFECTS

When assessing the suitability of water for irrigation, three main hazards or "agronomic thresholds" are considered (Ayers and Westcot, 1985): (1) the salinity hazard (electrical conductivity of the applied irrigation water [EC_w]), (2) the hazard posed by specific ions (chloride [Cl^-], boron [B], and sodium [Na^+]), and (3) the infiltration hazard (sodium adsorption ratio [SAR] and ECw). There are other parameters, such as acidity (pH) or alkalinity, sediments and nutrients that can affect calcite ($CaCO_3$) deposits, emitter clogging, crop development, and corrosion, but these do not fall under "agronomic thresholds."

The primary source of imported water is proposed to come from the Friant-Kern Canal Reverse Pump-Back Project. Water quality conditions from this project could range from existing conditions in the Cross Valley Canal (CVC) to that from the California Aqueduct, depending on respective canal operations. For the analysis presented herein, both CVC and California Aqueduct (measured at Check 21) water qualities were used, as well as a weighted average of those two sources (Intermediate) applied to show the range of potential imported water qualities. Source water quality concentrations are shown in Table 1 and Table 2.

Table 1. Average Concentrations of Various Irrigation Water Quality Constituents

LOCATION	WATER QUALITY CONSTITUENTS			
	TDS (/L)	EC_w (µS/cm)	Boron (B) (mg/L)	Chloride (Cl^-) (mg/L)
FKC[1, 2]	24	40	0.04	1.9
CVC[1, 3]	180	340	0.11	45.0
Intermediate[4]	232	420	0.16	63.2
Check 21[5]	283	500	0.21[6]	81.3

Note:

[1] Water quality data from AEWSD grab samples lab data from 2010 – 2019. Averages exclude months when mixing occurred.

[2] Sample taken at terminus of FKC.

[3] Sample taken at AEWSD CVC, Pumping Plant 6 or 6B Forebay.

[4] Weighted average of CVC and Check 21 water quality.

[5] California Aqueduct measured at Check 21 from 2009-2017.

[6] Check 21 Boron measurements only available for years 1967 – 1976.

Key:
AEWSD = Arvin Edison Water Storage District
Check 21 = Check Structure 21 at milepost 172,40 on the California Aqueduct
CVC = Cross Valley Canal
µS/cm = microsiemens per centimeter (1 µS/cm = 1 µmhos/cm = 1/1,000 dS/m)
EC_w = electrical conductivity of applied water
FKC = Friant-Kern Canal
Intermediate = Water quality representing the average of California Aqueduct Check 21 and Cross Valley Canal water qualities
mg/L = milligrams per liter
TDS = total dissolved solids

Table 2. Average Monthly Electrical Conductivity, Chloride, and Boron Concentrations by Source and Year Type

MONTH	CVC[1]			CHECK 21[2]		
	Wet[3]	Average[4]	Dry[5]	Wet[6]	Average[4]	Critical[7]
Average Monthly Electrical Conductivity Concentrations by Source and Year Type (μS/cm)						
January	431	369	287	309	523	598
February	570	433	378	269	551	680
March	261	273	275	248	545	671
April	240	270	277	255	500	616
May	--	306	306	195	479	575
June	385	384	383	174	471	597
July	257	292	307	206	385	542
August	286	308	335	249	425	643
September	323	326	329	247	524	689
October	429	360	315	539	573	628
November	396	356	330	480	529	614
December	368	349	337	532	554	624
Average Monthly Chloride Concentrations by Source and Year Type (mg/L)						
January	74.5	54.4	27.7	34.0	84.5	99.0
February	104.0	63.0	46.6	31.5	87.4	104.3
March	21.0	21.8	22.0	27.5	82.9	104.3
April	19.0	21.4	22.0	33.5	72.1	100.0
May	--	31.4	31.4	25.0	73.0	88.7
June	48.5	46.1	45.2	19.0	73.4	98.3
July	28.5	33.7	35.8	25.5	55.8	84.0
August	39.6	40.7	42.0	31.0	70.3	109.0
September	53.0	48.4	43.8	22.0	92.6	116.7
October	76.0	55.0	41.0	105.5	101.6	106.7
November	68.5	54.8	45.7	90.5	86.8	95.7
December	55.5	46.7	40.8	101.0	95.5	103.0
Average Monthly Boron Concentrations by Source and Year Type (mg/L)[8]						
January	0.12	0.11	0.10	0.23	0.20	0.20
February	0.16	0.15	0.14	0.30	0.26	0.25
March	0.10	0.11	0.11	0.33	0.31	0.30
April	0.11	0.12	0.12	0.30	0.29	0.10
May	--	0.12	0.12	0.27	0.25	0.20
June	0.16	0.15	0.14	0.20	0.18	0.20
July	0.11	0.11	0.12	0.13	0.16	0.20
August	0.09	0.10	0.12	0.10	0.19	0.20
September	0.08	0.09	0.11	0.10	0.16	0.10
October	0.11	0.10	0.09	0.25	0.19	0.15
November	0.11	0.11	0.11	0.20	0.18	0.15
December	0.11	0.11	0.12	0.20	0.19	0.15

Note:

[1] Water quality data from AEWSD grab samples lab data from 2010 – 2019.

[2] California Aqueduct measured at Check 21 from 2009-2017.

[3] CVC wet year averages represent the monthly average for San Joaquin Index year types below normal, above normal, and wet and excludes months where there is mixing.

[4] Average concentrations shown represent the average of all year types and excludes months where there is mixing.

[5] CVC dry year averages represent the monthly average for San Joaquin Index year types dry and critical and excludes months where there is mixing.

[6] Check 21 wet year averages represent the monthly average for San Joaquin Index wet year types only.

[7] Check 21 critical year averages represent the monthly average for San Joaquin Index critical years only.

[8] Check 21 Boron measurements represent years 1967 – 1976 per available data.

Key:

-- = no available data. CVC water quality in wet years during May were only mixed water quality.

AEWSD = Arvin-Edison Water Storage District

Check 21 = Check Structure 21 at milepost 172,40 on the California Aqueduct

CVC = Cross Valley Canal

μS/cm = microsiemens per centimeter (1 μS/cm = 1 μmhos/cm = 1/1,000 dS/m)

mg/L = milligrams per liter

SALINITY EFFECTS ON CROPS

The effects of salinity on crops are due to two separate properties in the saline media that can impact the crop individually but more often collectively (Läuchli and Grattan, 2012): (1) Salinity increases the electrical conductivity (EC) of the soil solution which reduces its the osmotic potential and (2) specific ions (I.e. Cl-, Na+ and B) in the soil solution can potentially be toxic to certain crops.

Osmotic effects occur when the concentration of salt in the soil solution is too high to allow for normal for crop growth. Dissolved salts reduce the osmotic potential of the soil solution. Plants must adjust osmotically through either the absorption of ions from the soil solution, or the synthesis and/or accumulation of organic solutes in the root cells. The synthesis of compatible organic solutes allows a plant to adjust osmotically and survive, but at the expense of plant growth (Munns and Tester, 2008). The synthesis of organic solutes requires a considerable amount of metabolic energy (i.e., adenosine triphosphate (ATP)) that is used for cell maintenance and osmotic adjustment that could otherwise be used for growth. As a result, salt-stressed plants are stunted, even though they may appear healthy in all other regards. Both processes of adjustment (accumulation of ions and synthesis of organic solutes) occur but the extent by which one process dominates depends on the type of crop and level of salinity (Läuchli and Grattan, 2012). And in a cell, compartmentalization is critical to keep toxic ions away from sensitive metabolic processes in the cytoplasm (Hasegawa et al., 2000). Such compartmentation is controlled by transport processes in the plasma membrane and tonoplast (i.e., vacuolar membrane). The efficiency of ion transport processes, as well as metabolic costs for organic-solute synthesis, differ from crop to crop and even within a species giving rise to different salinity tolerances.

TOXIC ION EFFECTS

Specific ions (i.e., Na^+, Cl^-, and B) in the soil solution can cause direct injury to crops, causing further crop damage from what occurs from osmotic effects. Typically, toxic ion effects are commonly found in woody perennials, such as tree and vine crops, while most annual row crops remain injury free unless salinity stress is severe. Woody perennial crops have little ability to exclude sodium or chloride from their leaves, and the plants are long-lived; hence, they often suffer toxicities at even moderate soil salinities. Typically, toxic ion effects become more critical to sensitive tree and vine crops over the years.

Chloride

Chloride and sodium toxicity can damage a plant/tree physically, biochemically and physiologically. As sodium and chloride move in the transpiration stream, they are deposited in the leaves. Older leaves have more water transpire from them and consequently have higher concentrations of sodium and chloride. Once accumulated in a leaf, sodium and chloride typically do not remobilize to other tissues. As the concentration in that leaf increases, the salts can physically desiccate cells causing injury in the form of leaf burn. Necrotic leaves no longer photosynthesize and produce carbohydrates for the tree, which in turn, will impact growth and production. But even before salts accumulate in leaves to levels that cause physical injury, those salts can reduce the chlorophyll content in leaves (Dejampour et al., 2012) and interfere with enzymatic activities affecting key metabolic pathways in both respiration and photosynthesis (Munns and Tester, 2008).

Boron

Although not a main “salinizing” constituent in applied irrigation water, boron can also cause injury to the crop. Boron is an essential micronutrient for plants, but the concentration range of plant-available boron in the soil solution optimal for growth for most crops is very narrow. Above this narrow range, toxicity occurs (Grieve et al., 2012). Boron toxicity, including how and where it is expressed in the plant, is related to the mobility of boron in the plant. Boron is thought to be immobile in most species where it accumulates in the margins and tips of the oldest leaves where injury occurs. However, boron can be re-mobilized by some species due to high concentrations of sugar alcohols (polyols) where they bind with boron and carry it to younger tissues (Brown and Shelp, 1997). These boron-mobile plants include almond, apple, grape, and most stone fruits. For these crops, boron concentrations are higher in younger tissue than in older tissue, and injury is expressed in young, developing tissues in the form of twig die back, gum exudation, and reduced bud formation. Boron-immobile plants such as pistachio, tomato, and walnut do not have high concentrations of polyols, and the boron concentrates in the margins of older leaf tissues. Injury in these crops is expressed as the classical necrosis on leaf tips and margins.

Sodium

Sodium can be problematic to a crop in several ways. It can be directly toxic to the plant, it can interfere with the nutritional status of the plant (e.g., Na^+-induced calcium [Ca^{2+}] deficiency), or it can indirectly affect the crop due to its adverse effect on soil structure. Some trees are very sensitive and can develop Na^+ toxicity when concentrations of Na^+ are as low of 5 milliequivalents per liter (meq/L) (115 mg/L) in the soil water. However, this observation was made before scientists realized the importance of adequate Ca^{2+} in the soil water for root membrane stability to maintain their selectivity for ion uptake. With adequate Ca^{2+}, such as that provided by gypsum applications, sodium toxicity may never be observed in these sensitive trees at such low sodium concentrations. Therefore, rather than having a threshold for Na^+ per se, the sodium-calcium ratio in the soil solution is a better indicator of Na^+ toxicity. The SAR of the applied irrigation water has been used as a surrogate for the sodium-calcium ratio, and the general rule is an SAR < 3 is not problematic.

$$SAR = \frac{Na^+}{\sqrt{\frac{(Ca^{2+} + Mg^{2+})}{2}}}$$

Where Na^+, Ca^{2+}, and magnesium ion (Mg^{2+}) concentrations are expressed in meq/L.

This is different when assessing sodium's indirect effect on soil structural stability (see the Infiltration Hazard section that follows). Table 3 shows critical SAR of the applied irrigation water above which can cause injury or nutritional distress in sensitive crops. Table 4 shows the seasonal average SAR for various water sources.

Table 3. Critical SAR of Applied Irrigation Water

CROP[1]	CRITICAL SAR OF APPLIED IRRIGATION WATER
All Crops	< 3

Note:

[1] Many tree crops are sensitive to Na+ toxicity after several years when sapwood converts to heartwood releasing Na^+ from the root to the shoot. Most annual crops are insensitive to Na^+ per se provided there is sufficient Ca^{2+} in the soil solution to maintain membrane integrity and ion selectivity. Hence, the ratio of sodium to calcium is more critical (Grattan and Grieve, 1992).

Key

Ca^{2+} = calcium ions

Na^+ = sodium ions

SAR = sodium adsorption ratio

Table 4. Seasonal Average SAR for Various Water Sources

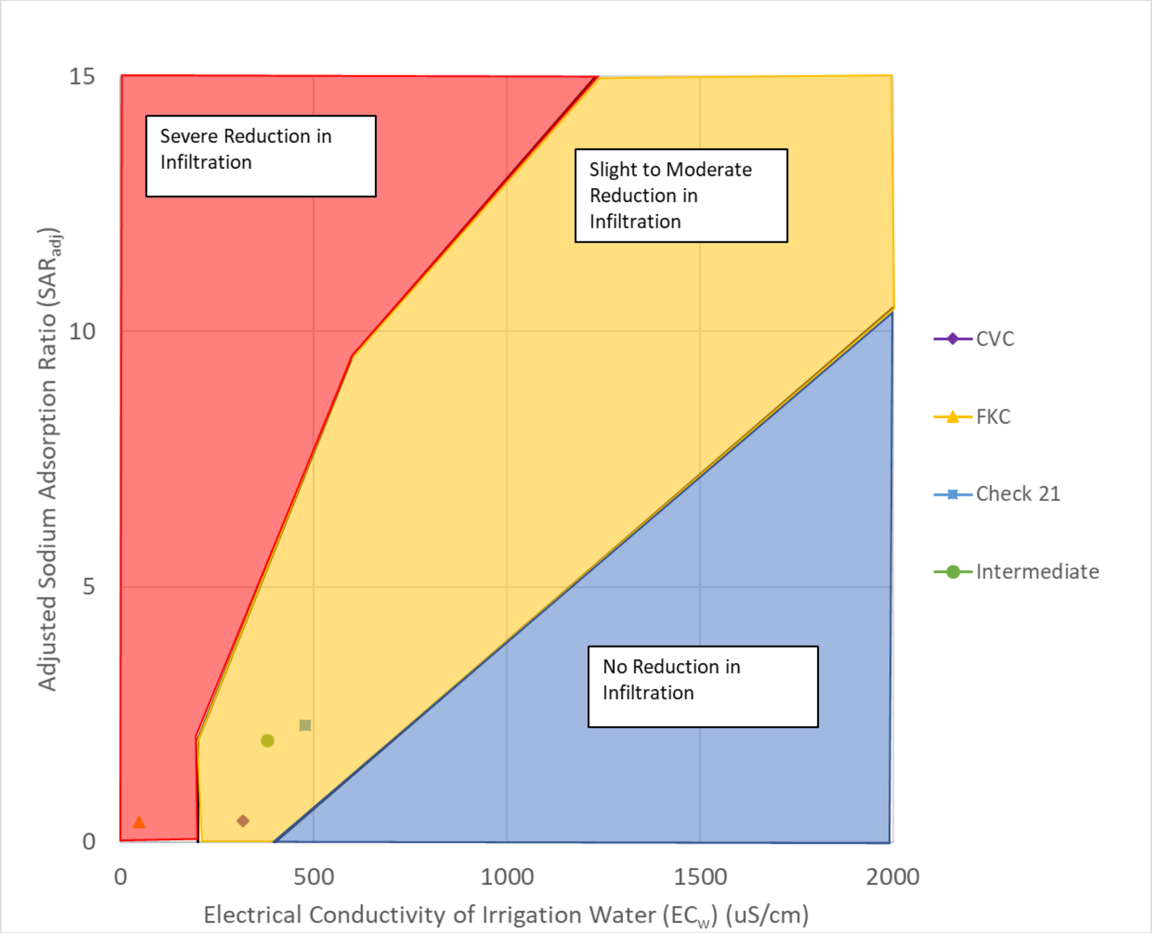
VALUE[1]	FKC[2, 3]	CVC[2, 4]	INTERMEDIATE[5]	CHECK 21[6]
Average	0.46	1.68	1.99	2.27
Maximum	0.87	2.04	2.46	2.96
Minimum	0.28	1.10	1.61	1.79

Note:
[1] March through October period.
[2] Water quality data from AEWSD grab samples lab data from 2011 – 2017.
[3] Sample taken at terminus of FKC.
[4] Sample taken at AEWSD CVC, Pumping Plant 6 or 6B Forebay.
[5] Weighted average of CVC and Check 21 water quality.
[6] California Aqueduct measured at Check 21 from 1968-2017.
Key
AEWSD = Arvin Edison Water Storage District
Check 21 = Check Structure 21 at milepost 172,40 on the California Aqueduct
CVC = Cross Valley Canal
FKC = Friant-Kern Canal
Intermediate = Water quality representing the average of California Aqueduct Check 21 and Cross Valley Canal water qualities
SAR = sodium adsorption ratio

INFILTRATION HAZARD

Sodium Adsorption Ratio

The SAR has been the standard used for assessing the infiltration hazard of applied irrigation water (Ayers and Westcot, 1985). But the actual infiltration hazard is assessed by balancing the opposite effects of salinity (EC_w) and sodicity (i.e., SAR) on aggregate stability. High salinity and low SAR are both important in maintaining adequate soil structure, which promotes better infiltration. Even though coarse-textured soils infiltrate faster than fine-textured soils, the hazard exists for all soil types. Typically, the adjusted SAR (SAR_{adj}) is used rather than the SAR as it more accurately accounts for $CaCO_3$, precipitation, and dissolution processes in the soil solution near the soil surface that control the free Ca^{2+} concentration. Figure 1 shows the relationship between the EC_w of the applied irrigation water and the SAR_{adj} as it relates to zones of “likely reductions” in infiltration rates (red), “slight to moderate reductions” in infiltration rates (yellow) and “no reductions” in infiltration rates (blue), adapted from Hanson et al., 2006. The threshold value is, therefore, variable and is considered to be the line that separates the “blue” and “yellow” zones on Figure 1. It is very important to note that low EC_w concentration (i.e., $EC_w < 200$ µS/cm) causes a reduction in water infiltration regardless of the SAR. Figure 1 also compares this relationship with various water sources. Note that FKC water falls in the red ”severe reduction in infiltration” zone because of its low EC_w concentration, while water from the CVC or mixed with CVC water falls in the yellow ”slight to moderate reduction in infiltration” zone. The addition of gypsum to FKC water increases the EC_w concentration, moving the point to the right and away from the ”severe reduction in infiltration” zone while slightly reducing the SAR.



Key:
µS/cm = microsiemens per centimeter
Check 21 = California Aqueduct Check 21
CVC = Cross Valley Canal
FKC = Friant-Kern Canal
Intermediate = Water quality representing the average of California Aqueduct Check 21 and Cross Valley Canal water qualities

Figure 1. Comparison of Various Water Source Relationship between the Salinity of Applied Irrigation Water and the Adjusted Sodium Adsorption Ratio

Calcium-Magnesium Ratio

Calcium nutrition can be problematic under several conditions. Calcium deficiency can occur under low-saline conditions when the concentration of free calcium [Ca^{2+}] is $\leq$ 1-2 millimoles/L in the soil solution. Deficiency can also occur under high sodic conditions where the SAR exceeds 10-15 in sensitive plants due to high sodium-calcium ratios or in alkaline conditions where Ca^{2+} precipitates out of the soil solution as it forms $CaCO_3$. Due to competition in the plant between calcium and magnesium at the root membrane, calcium nutrition could potentially be compromised when the calcium-magnesium ratio is generally less than 1 (Rhoades, 1992). Table 5 shows the seasonal average calcium-magnesium ratio for various water sources. Note the ratios for both FKC and CVC water are considerably higher than 1, while the ratio at California Aqueduct Check 21 is very close to 1 but will likely increase in the soil solution as the infiltrating water dissolves existing gypsum in the soil from previous amendment use. Therefore, calcium deficiencies, using CVC or Check 21 water or any mixture of the two, are unlikely.

Table 5. Seasonal Average Calcium-Magnesium Ratio for Various Water Sources

VALUE[1]	FKC,[2 3]	CVC[2, 4]	INTERMEDIATE[5]	CHECK 21[6]
Average	3.54	4.37	1.55	0.92
Maximum	6.16	8.24	2.00	1.00
Minimum	0.17	2.14	1.20	0.77

Note:
Based on molar or equivalent concentrations.
[1] March through October period.
[2] Water quality data from AEWSD grab samples lab data from 2011 – 2017.
[3] Sample taken at terminus of FKC.
[4] Sample taken at AEWSD CVC, Pumping Plant 6 or 6B Forebay.
[5] Weighted average of CVC and Check 21 water quality.
[6] California Aqueduct measured at Check 21 from 1968-2017.
Key
AEWSD = Arvin Edison Water Storage District
Check 21 = Check Structure 21 at milepost 172,40 on the California Aqueduct
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Intermediate = Water quality representing the average of California Aqueduct Check 21 and Cross Valley Canal water qualities
SAR = sodium adsorption ratio

PH AND BICARBONATE EFFECTS

The pH of both the applied irrigation water and the soil solution are important factors that may affect either the suitability of water for irrigation or its effect on nutrient availability to the crop. And many of the adverse effects of pH are associated with combined high alkalinity (high concentrations of bicarbonate [HCO_3^-] and carbonate [CO_3^{-2}]). In slightly alkaline waters (pH 7- 8.3), the alkalinity is from bicarbonate. Only when the pH exceeds 8.3 does carbonate become present. The pH of the water is an indication of the activity of the hydrogen ion. The numerical pH value is expressed on a negative log scale such that a one-unit increase or decrease corresponds to a ten-fold increase or decrease in the hydrogen ion activity. Therefore, a change of soil pH from 6 to 8 corresponds to a hundred-fold decrease in the hydrogen ion activity.

The pH of applied irrigation water can affect irrigation equipment or cause calcite (i.e. lime) deposits on vegetation. Regarding irrigation equipment, the pH is one of several water quality factors than can influence corrosion of galvanized pipes or other metallic parts. The pH can also influence precipitation of calcite ($CaCO_3$) at the orifices of drip emitters or minisprinklers which will affect the system's overall performance. This can be problematic if alkaline irrigation water, combined with sufficiently high bicarbonate and calcium concentrations, is used over the long term without periodic acid flushes to reduce scale buildup. Calcite precipitation becomes more problematic if the pH of the applied irrigation water exceeds 8.5. In addition, if such water is sprinkler irrigated above the canopy, it can cause unsightly white deposits that form on leaves and fruit. While these deposits typically do not cause harm to the crop, they nonetheless can affect the aesthetic quality. Acid additions to the irrigation water will not only reduce the pH but will reduce the [HCO_3^-], reducing the potential for $CaCO_3$ precipitation. Acid additions convert bicarbonate to carbon dioxide (CO_2) gas.

As the applied irrigation water infiltrates the soil, it interacts with the soil minerals. Therefore, the pH of the infiltrating water will change as it interacts with soil minerals, but soils are typically well buffered, as are soils in the FWA service area. Well buffered soils resist large changes in pH in the soil solution. The seasonal average pH of the irrigation water ranges from 7.1 to 8.4 depending upon the mixture of FKC water and California Aqueduct water. Because of the buffering capacity of the soil, this range in applied irrigation water pH will make little impact of the pH of the soil solution.

The pH of the soil solution has a profound influence on plant nutrient availability, nutrient uptake and ion toxicity to plants. The vast majority of soils that are cultivated for crop production around the world fall within the neutral, slightly acid and slightly basic pH range (i.e. pH 6-8). This is the general range where nutrient availability is optimal. However, there are those soils where the pH falls far from this normal range and these, if not corrected to an adequate range, can pose adverse effects on crops. Soils that are highly acidic (pH < 5.5) or highly alkaline (pH > 8.5) present a spectrum of challenges for the plant including nutrient availability, ion toxicities, and nutrient imbalances influencing the ion relations and nutrition within the plant itself (Läuchli and Grattan, 2012).

Most nutrients are not equally available to plants across the pH spectrum (Epstein and Bloom, 2005). Several mineral nutrients are severely affected in these non-optimal pH soils, particularly calcium, potassium, phosphorus, and iron. The reactions of plants to these nutrient elements under extreme soil pH conditions can affect plant growth, physiological processes and their morphological development (Läuchli and Grattan, 2012). The majority of the soils irrigated with waters from districts within the FWA, however, fall in the slightly alkaline range with the pH in the rootzone between 7.5 and 8.3 (UC Davis Soilweb https://casoilresource.lawr.ucdavis.edu/gmap/). Therefore, these soils are slightly alkaline, based largely on the natural abundance of calcite in the soil, and are at the upper end of the optimal pH range. Depending on the alkalinity of the soil water and [Ca^{2+}], some of the Ca^{2+} can precipitate out as $CaCO_3$ which decreases the calcium-magnesium ratio. Intermittent injection of acids in the applied irrigation water will reduce the pH and, consequently, the alkalinity of the water. Not only is this a maintenance measure to reduce calcite buildup on the orifices of drip emitters and minisprinklers, it drops the pH of the water which decreases bicarbonate, increases the [Ca^{2+}] and availability of other plant nutrients. Most growers in the San Joaquin Valley have some maintenance, acid-injection program in place. However, in Kern county, this may not be common practice in all districts. Acid applications, the residual gypsum in the soil and periodic applications of additional gypsum, are all a means of providing sufficient free Ca^{2+} in soils in Kern country. Moreover, increasing the [Ca^{2+}] in the soil water simultaneously improves the calcium-magnesium ratio.

Sprinkler irrigated fruit and vegetable crops (approximately 20% of studied districts) could be susceptible to formation of white deposits on leaves and fruit, or “white wash,” and reduced marketability if bicarbonate concentrations, or [HCO_3], in applied irrigation water are too high (> 1.5 meq/L, leaving a white residue on the crop surface. Bicarbonate concentrations in the California Aqueduct water theoretically could cause “white washing” under sprinkler irrigation, especially during dry and breezy conditions. “White washing” is a concern to some growers and has been seen by growers occasionally in the study area; however, it is not known what the exact cause of the “white washing” was, whether it was from undiluted California Aqueduct water or some other source. Bicarbonate levels of 1.5 meq/L or 92 mg/L and higher may increase formation of white deposits. The seasonal average for [HCO_3] of CVC water is 78.5 mg/L. While this concentration is less than 92 mg/L, special management practices may be needed to mitigate or avoid “white wash” impacts during periods of elevated bicarbonate levels. These may include blending with higher quality sources or changing irrigation methods away from sprinklers that wet the foliage (Provost & Pritchard, 2012).

CORROSION AND DEGRADATION OF MATERIALS

The comparison of corrosion potential of California Aqueduct water and FKC water from Millerton Lake was performed by Provost & Pritchard in 2012 on several chemical constituents and calculated indices including: pH, Langelier Index, Ryzner Index, EC, resistivity, sulfates, and chlorides. This comparison generally showed that FKC water has a slight tendency to degrade concrete structures by leaching out minerals, but metallic corrosion will be low. Comparatively, California Aqueduct water will have a lower tendency to leach out minerals from concrete, and will have a more corrosive effect on metals, although there is only a slight difference between the two water sources in either case (Provost and Pritchard, 2012).

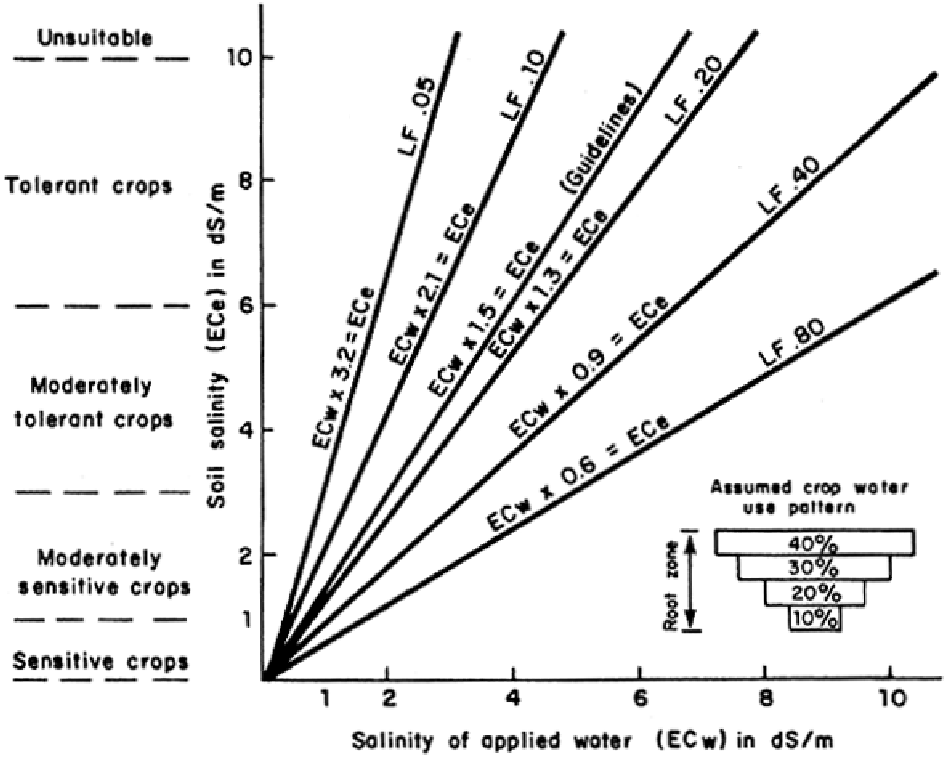
Materials such as brass, bronze, PVC, polyethylene, and stainless steel usually have a high corrosion tolerance, and therefore would not likely be affected by the exchange of source waters. The forecasted increase in corrosion from using more California Aqueduct water is likely manageable with the use of special coatings and proper selection of new materials and would likely result in minor increase in O&M costs (Provost and Pritchard, 2012).

AGRONOMIC LEACHING REQUIREMENTS

Agronomic leaching is the application of irrigation water in excess of the soil water holding capacity to neutralize the agronomic effects associated with increased salinity and ion toxicity in the crop rootzone. This approach aims to balance concerns related to long-term groundwater quality with a multi-layered assessment of agronomic impacts as a durable solution. The amount of leaching required, referred herein as maintenance leaching, depends upon the sensitivity of the crop to salinity and the irrigation water salinity. The higher the salinity of the applied irrigation water and the more sensitive the crop is to salinity, the greater the amount of leaching is required. This same leaching concept can also be applied to chloride and boron.

LEACHING FRACTION VS LEACHING REQUIREMENT

Often, leaching fraction (LF) and leaching requirement (LR) are used interchangeably. The two, in fact, are different. The LF is defined as the volume of water that drains below the rootzone divided by the volume of water that infiltrates the soil surface (equivalent to applied irrigation water assuming no surface runoff or evaporation). The LF can also be estimated based on the salinity of the applied irrigation water, or [EC_w], and that of the drainage water, or [EC_{dw}], where LF = EC_w/EC_{dw}. The crop roots extract water from the rootzone leaving the salts behind. If the crop rootzone is divided in quarters, typically the top quarter uses 40% of the water, the second quarter 30%, third quarter 20% and bottom quarter 10%. Therefore, the salt concentration increases with soil depth. The lower the LF, the more salts accumulate and concentrate at lower depths. Figure 2 is a representation of this relationship under conventional irrigation. The relationship between irrigation water salinity (EC_w) and soil salinity (EC_e) is linear but the slopes of the relationships are dependent upon the LF. The slopes decrease with increasing LF. The higher the LF, the higher the irrigation water salinity can be to maintain the yield of a crop. In Figure 2, note the dashed lines along the y-axis indicating the general salt tolerant categories as the salinity of the applied irrigation water changes.



Key:
dS/m = deciSiemens per meter (1 µS/cm = 1 µmhos/cm = 1/1,000 dS/m)
LF = leaching fraction

Figure 2. Relationship Between Soil Salinity (EC_e) and Salinity of the Applied Irrigation Water (EC_w) under a Series of Steady-State Leaching Fractions (0.05 to 0.80) (from Ayers and Westcot, 1985)

The LF concept is attractive in that it allows predictions of average rootzone salinity (EC_e) conditions from the applied irrigation water EC (EC_w) and assumed LF. Knowing the scientifically determined salinity threshold value (EC_{et}) for a particular crop, one can use this relationship to determine the maximum irrigation water salinity (EC_w) for a given LF. The relationship between EC_w, EC_e, and LF also depends on irrigation management. That is, EC_e = Concentration Factor (F_c) * EC_w where 'F_c' depends not only on the LF but the type of irrigation method. Applicable F_c values for conventional irrigation methods such as furrow or flood, and high frequency irrigation methods, such as drip and minisprinklers, are provided in Table 6.

Table 6. Concentration Factor Values for Conventional and High Frequency Irrigation (adapted from Suarez, 2012)

LEACHING FRACTION (LF)	CONCENTRATION FACTOR (F_c)	
	Conventional Irrigation	High Frequency Irrigation
0.05	2.79	1.79
0.10	1.88	1.35
0.20	1.29	1.03
0.30	1.03	0.87
0.40	0.87	0.77
0.50	0.77	0.70

The difference in F_c values between conventional and high frequency irrigation is largely based on how crop roots respond to the salinity in the rootzone. Under conventional irrigation, crops typically respond to the average rootzone salinity (i.e. the seasonal average of the four rootzone quarters of salinity). Under high frequency irrigation, crops respond to the water uptake weighted salinity (i.e. the salinity in the top quarter is weighted 40 percent, salinity in the second quarter is weighted 30 percent, and so on). Because the salinity in the top quarter is lower where evapotranspiration (ET) is higher and higher in bottom where ET is lower, the average rootzone salinity is lower under high frequency irrigation.

The LR, on the other hand, is the lowest LF needed to sustain maximum yield given the applied irrigation water salinity concentration, or [EC_w], and yield threshold for the given crop. In other words, it is the minimum leaching needed, given the crop type and water quality, to maintain the salinity (or chloride or boron), at the maximum rootzone concentration in the rootzone that the crop can tolerate. Any increase in rootzone concentration above this maximum level will cause injury or yield reductions. LR is an attractive concept because, given an irrigation water quality and crop sensitivity, the minimum leaching needed to sustain the rootzone salinity EC_e, rootzone chloride (Cl^-_e), or rootzone boron (B_e) at levels that would avoid or reduce damage or yield losses can be estimated.

LR can be estimated using the following equation (Rhoades and Merrill, 1976; Ayers and Westcot, 1985):

$$LR\% = \frac{EC_w}{5(EC_{et}) - EC_w}\, x\, 100$$

EC_w= Electrical conductivity of irrigation water
EC_{et}= Soil salinity threshold for a given crop

Note that the LR relationship can apply to chloride and boron by substituting their respective irrigation water concentrations (i.e. Cl^-_w or B_w) and their threshold values (Cl^-_{et} or B_{et}). The LR equation assumes that crops respond to an average rootzone salinity created by a 40-30-20-10% root water extraction pattern, similar to LF predictions using conventional irrigation. The difference is that LR predicts the minimal LF to achieve maximal yields whereas the LF approach assumes an LF first, then predicts what the EC_e will be given the EC_w of the irrigation water. Both are similar but solve the problem from different directions.

LIMITATIONS TO THE STEADY-STATE LEACHING CONCEPT

The leaching fraction or requirement is an attractive concept but has limitations. First, the leaching concept assumes steady-state conditions and thus has no time element. Therefore, there is no accounting for how long leaching will take, which will differ depending upon the permeability of the soils. Second, the evapotranspiration (ET) of the crop is assumed to be independent of the average rootzone salinity, but it is not (Letey and Feng, 2007). A salt-stressed crop will use less water than a non-stressed crop. Consequently, crop ET will be reduced, and leaching, with the same quantity of applied irrigation water, will be increased. And third, in drip irrigated fields, actual LFs are difficult to quantify because LF, soil salinity, soil water content, and root density all vary with distance and depth from the drip lines.

In light of these limitations, recent studies have shown that the EC_w and EC_e relations described by Ayers and Westcot (1985), which are based on steady-state LF conditions, tend to be too conservative and overestimate soil salinity and, therefore, overestimate yield losses in most cases (Corwin and Grattan, 2018; Letey et al., 2011). Transient-state models may more accurately predict soil salinity, as well as soil chloride, sodium and boron, but they are more complicated and require many more site-specific inputs and assumptions. Therefore, transient models are still too cumbersome and time consuming to replace steady-state models.

The LF and LR concepts are both steady-state, so they assume the amount of irrigation is not limiting. The amount of water needed for irrigation can be estimated as:

$$AW = ET/(1-LR)$$

AW = applied water
ET = evapotranspiration or crop water requirement
LR = leaching requirement

The units for applied water (AW) and ET or crop requirement are typically depths of water (i.e. inches or millimeters). But in many cases, the amount of water is limiting and therefore crops can be under-irrigated and therefore not achieve the required leaching. In this case, the salts in the crop rootzone will increase over time. At some point, depending upon the salinity of the imported water and crop sensitively, the salt content (or chloride or boron) can exceed the threshold level. Because the threshold values are based on seasonal averages, exceedances above the threshold are allowed to some degree without experiencing a reduction in yield. For example, if the average Cl^-_e was 100 mg/L for the first 2/3 the season and then reached 200 mg/L for the last 1/3 of the season due to insufficient leaching, almonds on “Nemaguard” rootstock would not be expected to be damaged because the seasonal average Cl^-_e would be 133 mg/L given the Cl^-_e threshold is 150 mg/L. Nevertheless, if the required leaching is not achieved, reclamation leaching would be required. Similarly, if the preseason soil salinity is over 150 mg/L and little to no leaching is applied during the season, injury would be expected to develop on almonds on “Nemaguard” rootstock. Therefore, the LR values for various crops and salinities are based on soils where the maintenance leaching fraction is achieved each irrigation. If the pre-existing soil salinity is initially high, then the soil is not at steady-state.

DIFFERENCE BETWEEN MAINTENANCE LEACHING AND RECLAMATION LEACHING

There is a distinct difference between maintenance leaching and reclamation leaching. Maintenance leaching occurs during each irrigation by applying more irrigation water than the soil can hold. This is the leaching fraction or requirement concept described above. Therefore, the AW is higher than the ET to accommodate the necessary leaching (see equation above). Reclamation leaching, on the other hand, occurs at the end of the irrigation season by applying excess irrigation water to flush the salts from the crop rootzone. Ideally, reclamation leaching would not be required if correct maintenance leaching is achieved each irrigation during the irrigation season. However, because some fields may not get the necessary leaching, salts can accumulate, and fields may require reclamation leaching at some time. In addition, low pressure systems such as drip and mini-sprinkler systems produce characteristic salt accumulation patterns in fields, even with sufficient downward leaching. Whether salts are building up in the rootzone or between drippers or minisprinklers, reclamation leaching is a valuable preventative measure from time to time at the end of the irrigation season.

At the end of the irrigation season, salt can be removed by sprinkler irrigation (i.e equivalent to intermittent ponding). Figure 3 shows the extent of leaching needed to address rootzone salinity. For example, if the average rootzone salinity (ECe) at the end of the season is 3000 µS/cm and the goal is to reduce the salinity in the soil down to 600 µS/cm the salinity needs to be reduced to 600/3000 = 0.2 (y-axis) or 20% of what it was before leaching. Then the amount of sprinkler irrigation water to apply is 0.5 ft (x-axis) for every foot of soil to reclaim. If the goal is to reduce the top 2 feet, then 0.5 x 2ft = 1ft of water would be needed. This assumes the combined rainfall and applied reclamation leaching water needed.

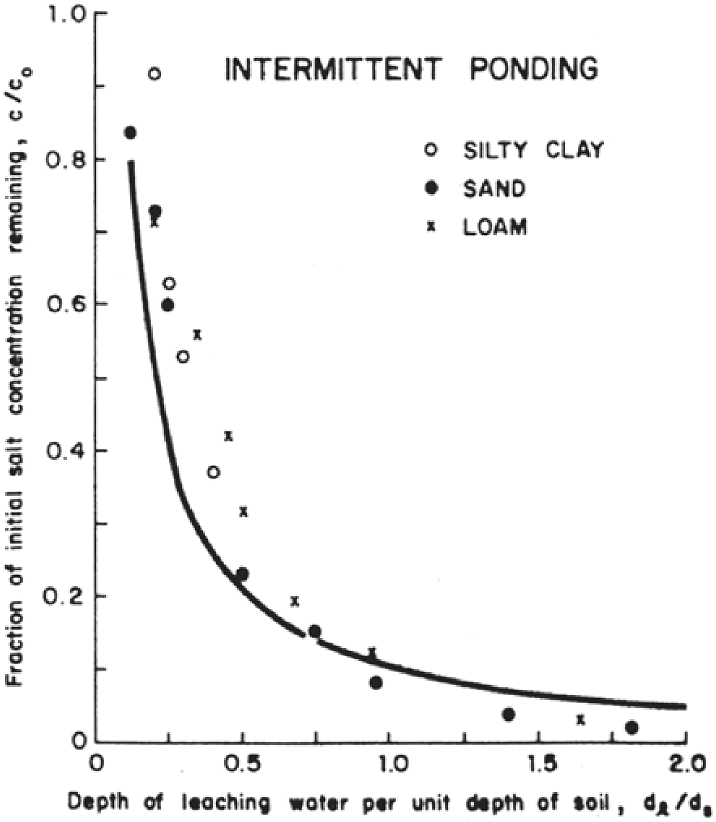


Figure 3. Reclamation Leaching Function under Sprinkler Irrigation or Intermittent Ponding (Ayers and Westcot, 1985).

The amount of reclamation leaching can be reduced by the amount of effective rainfall. To take advantage of rainfall, reclamation leaching should ideally take place after the rainfall season but before spring budding and leaf out begins, typically from October/November through March.

LEACHING AND NITROGEN MANAGEMENT

It is also important to address nitrogen management strategies combined with the salt leaching strategies. Unlike salts, nitrogen is very dynamic in the rootzone as it undergoes form changes from organic pools to inorganic fractions (primarily nitrate [NO_3^-] and ammonium [NH_4^+]). Ammonium, and particularly nitrate, are the forms primarily taken up by plants. Nitrate, being an anion, is relatively mobile in soils and is highly susceptible to leaching below the rootzone. Once nitrate leaches below the rootzone, chemical transformations are less likely to occur, and nitrate commonly continues leaching downward and eventually ends up in the aquifers. A 2002 study conducted by the Lawrence Livermore National Laboratory concluded that nitrate contamination in groundwater is “the number-one contaminant threat to California’s drinking water supply” (LLNL 2002).

Rootzone salinity control and nitrogen management is a conflicting problem. It is necessary to leach salt from the rootzone to avoid damage from salinity or ion toxicity, but nitrates will unavoidably be leaching below the rootzone as well. If soil salinity is low at the beginning of the irrigation season (see reclamation versus maintenance leaching), then leaching at less than the critical LR is possible to avoid salt damage. Then, salinity in the profile will steadily build up over the season while soil nitrogen will be depleted due to crop uptake. At the end of the irrigation season, salinity will be the highest, and nitrate will be the lowest. Therefore, reclamation leaching can be implemented at the end of the irrigation season, and the process cycle repeats itself.

MITIGATION LEACHING REQUIREMENTS

ESTIMATING LEACHING REQUIREMENTS FOR MOST SENSITIVE CROPS

The most sensitive crops in the Friant Division were used for this analysis. Crops selected were based on their varied sensitivities to salinity, chloride, and boron. By using the most sensitive crops, all crops with higher tolerances should also be protected. The most salt-sensitive crops, or those with the lowest soil salinity threshold (EC_{et}), are beans, carrots, onions (seed), melons, and strawberries. All have an EC_{et} of 1000 µS/cm. For chloride, the most sensitive crops are almonds and other stone fruits on "Nemaguard" rootstock. The threshold Cl^{-}_{et}[1] is estimated to be 150 mg/L. The relationship between boron in the applied irrigation water and the saturated soil paste is more complicated because of boron's high affinity to adsorb onto the soil. Irrigation water with higher boron concentrations than predicted can be used until the boron saturates the soil adsorption sites. Because of this complexity, Ayers and Westcot (1985) concluded that the "…maximum concentration (of boron) in the irrigation water are approximately equal to these values (boron tolerance reported based on soil water bases) or slightly less," suggesting that applied irrigation water tolerances would be 0.5 – 0.75 mg/L which would protect the most sensitive crops.. However, over the long term (more than several years), boron will behave similarly to salts and chloride (D. Suarez, US Salinity Laboratory, personal communication). With the boron threshold for soil water ranging from 0.5 – 0.75 mg/L, the B_{et} is equivalent to half of the soil water concentration, or 0.25 – 0.375 mg/L. For more information on conversions from saturated soil paste to soil water concentrations, see Ayers and Westcot (1985). To be conservative, and based on the above tree and vine crop sensitivities, the B_w threshold is assumed to be 0.25 mg/L.

Table 7 shows the acreage and percentage of sensitive crops for representative water districts, and sensitivities to boron, chloride, and EC within each representative water district.

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[1] It is important to note that most 'threshold' values for chloride and boron reported in literature (e.g. Grieve et al., 2012) are based on the soil water concentration. The saturated soil paste concentration (i.e. Cl^{-}_{e} or B_e) for most mineral soils is about half this value over the long-term (Ayers and Westcot 1985).

Table 7. Percentage and Area of Sensitive Crop Types within Representative Water Districts

	WATER DISTRICT											
	AEWSD		DEID		KTWD		SID		SSJMUD		SWID	
CROP TYPE	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**	**%**	**Acres**
Boron Sensitive[5]	**15%**	**18,883**	**5%**	**2,842**	**30%**	**5,969**	**6%**	**1,211**	**8%**	**4,629**	1%	**358**
Berries[1]	1%	761	2%	873	1%	200	n/a		<1%	63	n/a	
Cherries	2%	2,196	<1%	228	1%	160	<1%	22	<1%	211	1%	358
Citrus	11%	15,024	2%	1,301	28%	5,609	4%	825	7%	4,355	n/a	
Stone Fruits[4]	1%	902	1%	440	n/a		2%	364	n/a		n/a	
Chloride Sensitive[6]	**6%**	**7,593**	**22%**	**12,399**	**5%**	**1,040**	**17%**	**3,366**	**22%**	**13,577**	**56%**	**21,649**
Almonds (Nemaguard rootstock)	6%	7,593	22%	12,399	5%	1,040	17%	3,366	22%	13,577	56%	21,649
EC Sensitive[7]	**7%**	**8,490**	**<1%**	**175**	**n/a**		**<1%**	**50**	**1%**	**375**	**2%**	**862**
Carrots	3%	3,748	<1%	100	n/a		n/a		<1%	148	2%	784
Melons[2]	1%	777	<1%	74	n/a		<1%	50	n/a		<1%	75
Onions[3]	3%	3,961	n/a		n/a		n/a		<1%	228	<1%	1
Strawberries	<1%	4	n/a		n/a		n/a		n/a		<1%	2

Source: Data compiled from California Department of Water Resources Land Use Viewer (2017) developed by LandIQ using 2014 land use data. Districts provided updates to 2017 land use data where appropriate. DEID data was provided by the District, and data gaps were filled with LandIQ data.

Notes:

Grape Crops in DEID take up 43% (26,443 ac) of the District's land area.

"n/a" indicates that there is zero amount of a crop type in a district.

[1] Data Source lists Berries as "Bush Berries"

[2] Data Source groups Melons with Squash and Cucumbers

[3] Data Source groups Onions with Garlic

[4] Stone Fruits include Apricots, Nectarines, Peaches, Plums, and Prunes

[5] Boron Sensitive Crops include Berries, Citrus, and Stone Fruits

[6] Chloride Sensitive Crops include Almonds

[7] EC Sensitive Crops include Carrots, Melons, Onions, and Strawberries

Key:
% = percentage
AEWSD = Arvin-Edison Water Storage District
DEID = Delano-Earlimart Irrigation District
KTWD = Kern-Tulare Water District
n/a = not applicable
SID = Saucelito Irrigation District
SSJMUD = South San Joaquin Municipal Utility District
SWID = Shafter-Wasco Irrigation District

DEVELOPING MITIGATION LEACHING CURVES

This section describes quantification of mitigation based on leaching requirements for sensitive crops. This approach does not directly address the physical characteristics or dynamic nature of the rootzone, but rather is specific to sensitive crop types grown in the region and implementing sufficient leaching volumes to prevent crop injury. In addition, the volumetric mitigation quantified through this approach is not specific to a water district but is representative of all crops grown in the Friant Division.

For salinity, EC_{et} values were used to calculate LR values, as presented in Table 8 in percentages. For chloride or boron the same LR equation is used except irrigation water concentrations (i.e. Cl^-_w and B_w) in mg/L are used in place of EC_w and respective threshold Cl^-_e and B_e are used in place of EC_{et}. At each location, the quantified LR by water quality constituent is based on the most stringent LR, which assumes all water is applied to the most sensitive crop. Analysis shows a long-term LR between 5.2 and 19 percent, using the average, seasonal statistics for EC, chloride, and boron concentrations.

Table 8. Leaching Requirements for Various Sensitive Crops by Water Source and Water Quality Constituent

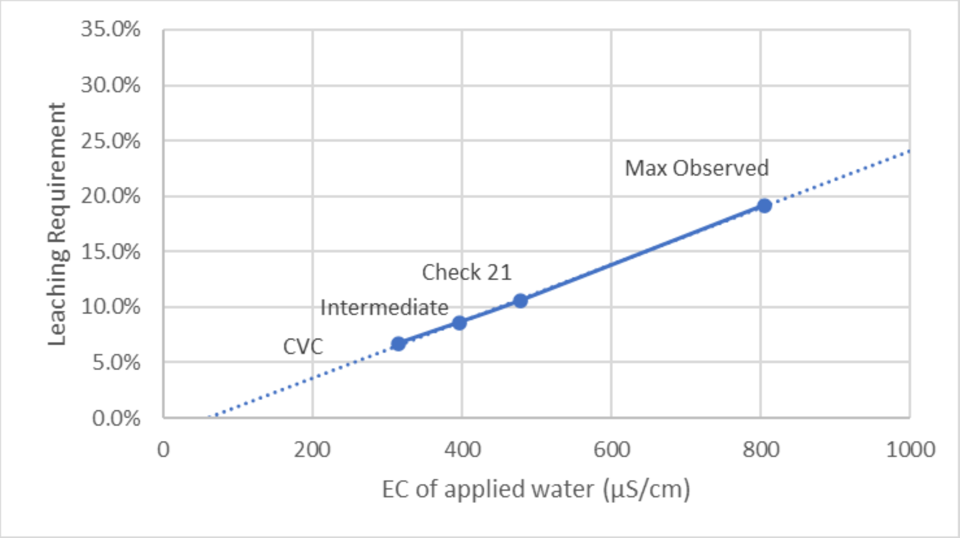
MOST SENSITIVE CROP	CVC			INTERMEDIATE			CHECK 21		
	EC	Cl^-	B	EC	Cl^-	B	EC	Cl^-	B
Carrots, onions, melons, strawberries	6.7%	-	-	8.6%	-	-	10.6%	-	-
Almonds (Nemaguard rootstock)	-	5.2%	-	-	8.1%	-	-	11.1%	-
Stone fruits, citrus, berries	-	-	8.0%	-	-	13.6%	-	-	19.0%

Key:
B = boron
Check 21 = Check Structure 21 at milepost 172,40 on the California Aqueduct
Cl^- = chloride
CVC = Cross Valley Canal
EC = electrical conductivity
Intermediate = Water quality representing the average of California Aqueduct Check 21 and Cross Valley Canal water qualities

Figures 4 through 6 show mitigation rating curves based on LR percentages, source water quality, and constituents of concern. Each mitigation rating curve was extended to show the maximum observed concentration from historical water quality data for both CVC and California Aqueduct Check 21 sources.

The LR percentages presented in Table 8 and Figures 4 through 6 represent quantified volumetric mitigation that would be applied as maintenance leaching. Maintenance leaching occurs at each irrigation by applying more water than the soil can hold, or in other words, the applied irrigation water is more than the crop requirement to accommodate the necessary leaching. The quantified LR assumes long-term steady-state conditions and does not account for leaching from rain or end-of-season reclamation practices. Any rain or end-of-season leaching will decrease the presented values.

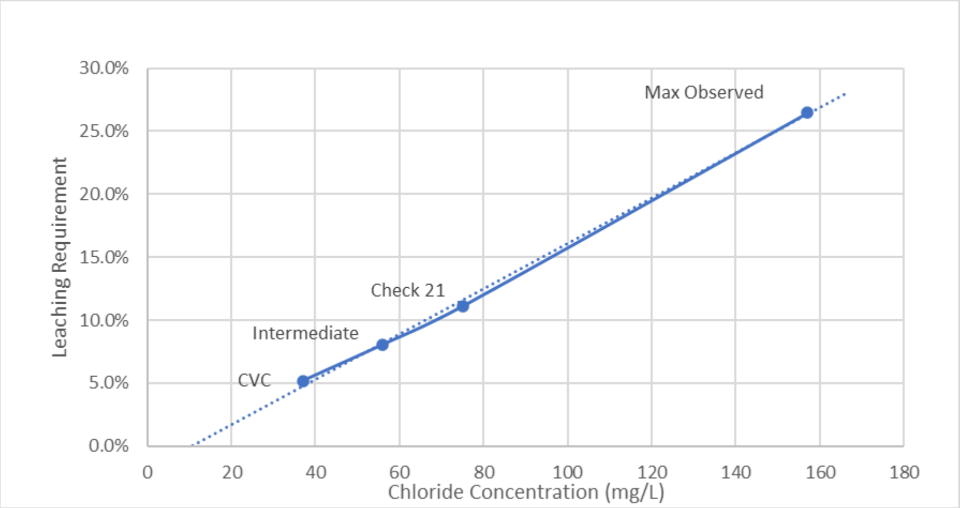
The quantified LR assumes mitigation water is delivered and applied at the same time as surface water delivery is taken. In addition, it assumes mitigation water is of the same water quality as the surface water delivery. Therefore, mitigation is only quantified for water of the same imported quality and not for both reverse flow pump-back and Millerton Lake supplies. If maintenance leaching practices are followed, reclamation leaching is unnecessary, except for in driest of years when surface supply does not meet irrigation demand or to leach salts that have accumulated between drip emitters and mini sprinklers. Using the most stringent LR, it is assumed all mitigation water is applied to the most sensitive crop.



Key:

Check 21 = California Aqueduct Check 21
CVC = Cross Valley Canal
EC = electrical conductivity
µS/cm = microsiemens per centimeter (1 µS/cm = 1 µmhos/cm = 1/1,000 dS/m)
Intermediate = Water quality representing the average of California Aqueduct Check 21 and Cross Valley Canal water qualities

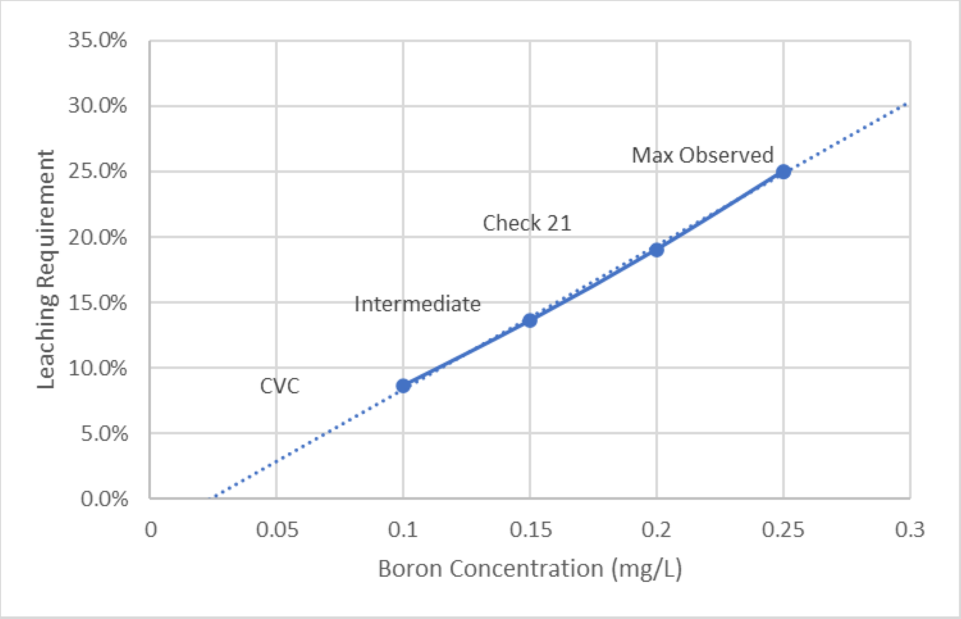
Figure 4. Leaching Requirement for Electrical Conductivity



Key:

Check 21 = California Aqueduct Check 21
CVC = Cross Valley Canal
EC = electrical conductivity
Intermediate = Water quality representing the average of California Aqueduct Check 21 and Cross Valley Canal water qualities
mg/L = milligrams per liter

Figure 5. Leaching Requirement for Chloride

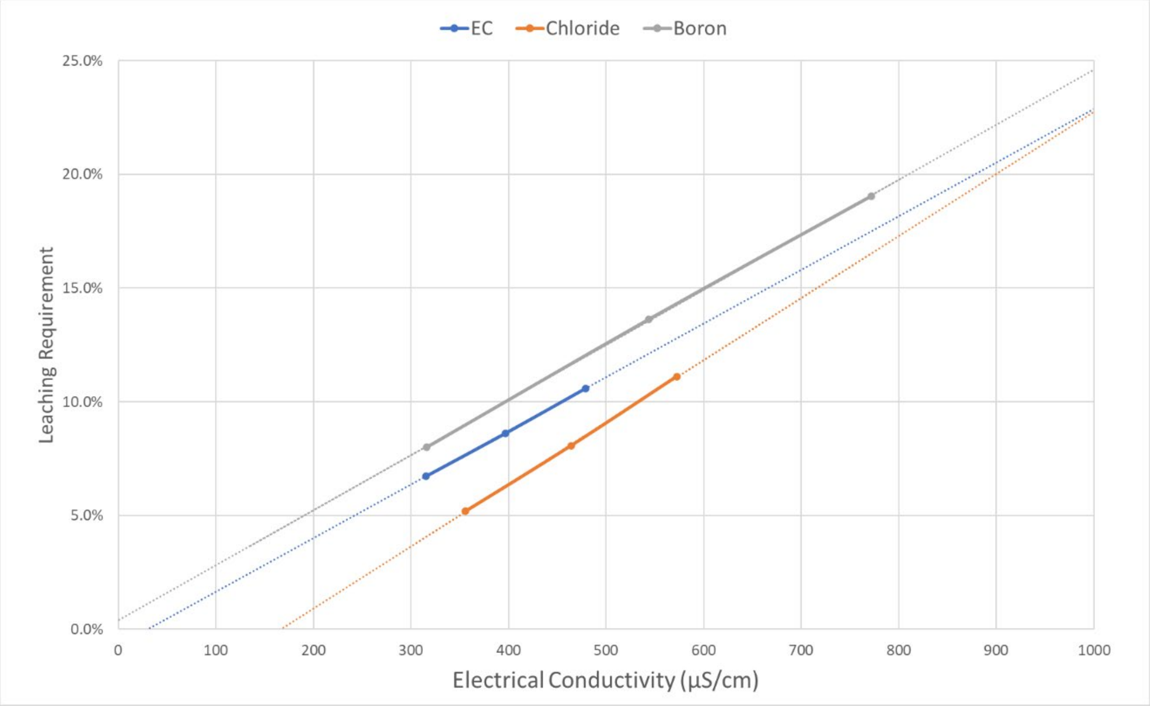


Key:
Check 21 = California Aqueduct Check 21
CVC = Cross Valley Canal
Intermediate = Water quality representing the average of California Aqueduct Check 21 and Cross Valley Canal water qualities
mg/L = milligrams per liter

Figure 6. Leaching Requirement for Boron

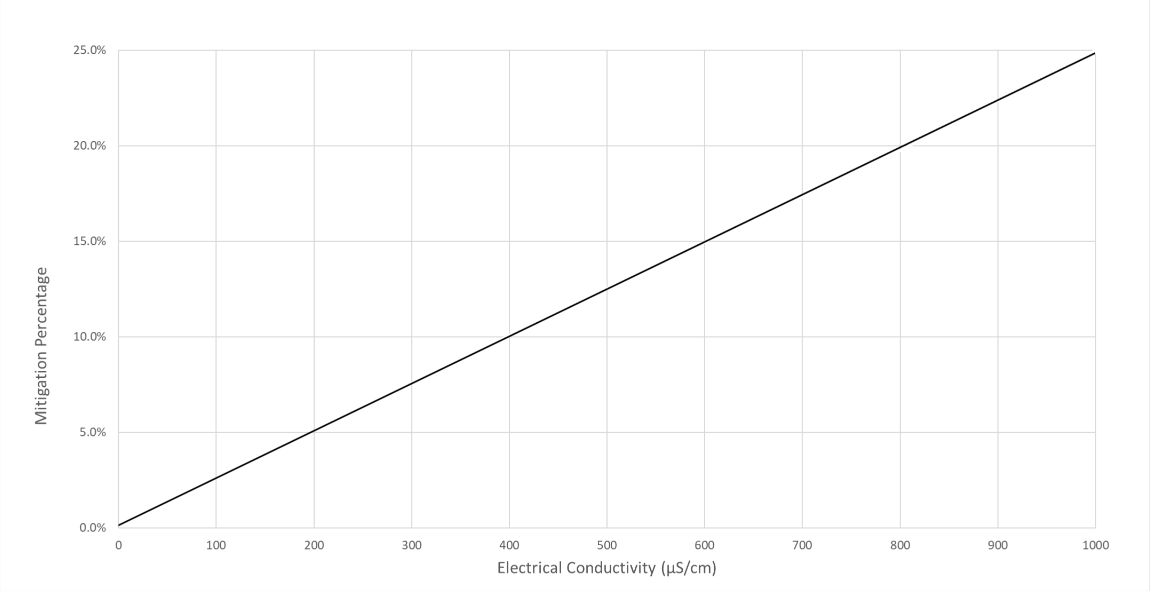
Leaching Requirement Normalization

In order to best understand the LR relationships amongst EC, chloride, and boron and to confirm the dominant constituent trend, individual rating curves were normalized to an EC concentration scale. The EC concentration was used as it can be easily measured in real-time. Figure 7 shows the stacked, normalized mitigation rating curves for all three constituents of concern. Boron is the dominant or driving constituent and has the highest LR, regardless of source water quality. The required leaching based on that curve would be sufficient to prevent crop injury due to increased EC or chloride concentrations in applied irrigation water, and, therefore, the boron curve is the proposed mitigation rating curve for the Water Quality Mitigation Ledger (Figure 8). The method for normalizing each constituent curve is described below.



Key:
µS/cm = microsiemens per centimeter (1 µS/cm = 1 µmhos/cm = 1/1,000 dS/m)
EC = electrical conductivity

Figure 7. Rootzone Leaching Curves for Electrical Conductivity, Chloride, and Boron Normalized to an Electrical Conductivity



Key:
µS/cm = microsiemens per centimeter (1 µS/cm = 1 µmhos/cm = 1/1,000 dS/m)

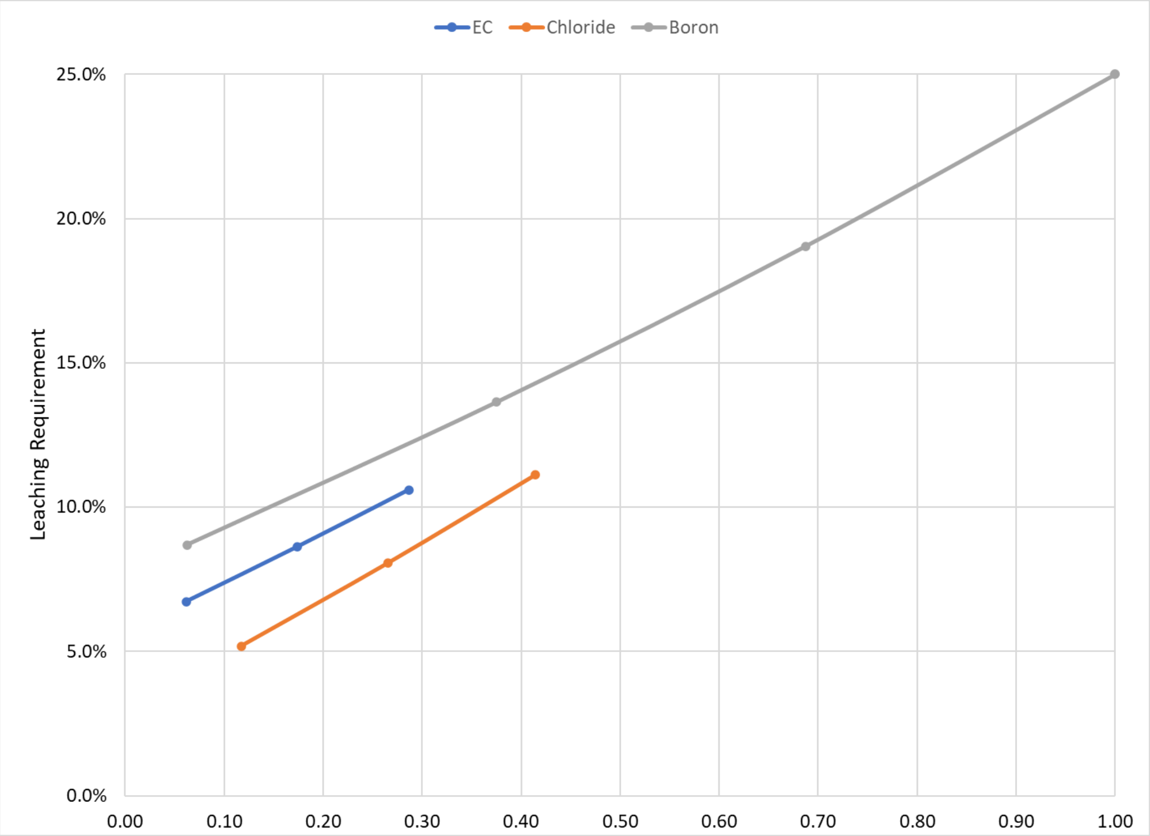
Figure 8. Proposed Mitigation Rating Curve based on Boron Sensitivity and Normalized to Electrical Conductivity

Normalization Method

As the three constituent curves have differing concentration scales and they do not show direct correlations to each other, the constituents were normalized to a common scale using the below equation.

$$X_{new} = \frac{X - X_{min}}{X_{max} - X_{min}}$$

In the equation, X represents the constituent concentration for EC, chloride, or boron. X_{min} is the minimum average, seasonal, observed concentration for a given constituent from either California Aqueduct Check 21 or CVC water quality data. The maximum observed concentration corresponded with varying leaching requirements for each of the constituents. To ensure that all constituents were normalized to the same scale and the full range of possible constituent concentrations was considered beyond the highest observed concentration for California Aqueduct Check 21 water, X_{max} represents the constituent concentration corresponding to a 25 percent LR. Figure 9 displays the normalized curves, and Table 9 presents the normalized data.



Key:
EC = electrical conductivity

Figure 9. Normalized Leaching Requirement curves for Electrical Conductivity, Chloride, and Boron

Normalized concentration values were then converted back to EC using the equation below, where X_{norm} represents the normalized concentration for chloride or boron. LR curves were then replotted using an EC scale (Figure 7).

$$EC = X_{norm}(EC_{max} - EC_{min}) + EC_{min}$$

Table 9. Constituent Normalization

SOURCE WATER	ELECTRICAL CONDUCTIVITY			CHLORIDE			BORON		
	Observed Concentration (µS/cm)	Normalized Value	Leaching Requirement	Observed Concentration (Seasonal Average) (mg/L)	Normalized Value	Leaching Requirement	Observed Concentration (Seasonal Average) (mg/L)	Normalized Value	Leaching Requirement
CVC	315	0.06	6.7%	37.00	0.12	5.2%	0.10	0.06	8.0%
Intermediate	397	0.17	8.6%	56.00	0.27	8.1%	0.15	0.38	13.6%
Check 21	479	0.29	10.6%	75.00	0.41	11.1%	0.20	0.69	19.0%
Maximum Observed	805	0.73	19.2%	157.00	1.05	26.5%	0.25	1.00	25.0%
Maximum normalization (25% Leaching Requirement)	1000	1.00	25.0%	150.00	1.00	25.0%	0.25	1.00	25.0%

Key:
CVC = Cross Valley Canal
µS/cm = microsiemens per centimeter
mg/L = milligrams per liter

APPLIED AGRONOMIC THRESHOLDS

The Policy includes maximum water quality thresholds for the FKC. Although the mitigation rating curve quantifies mitigation water to account for appropriate maintenance leaching, FKC water quality thresholds for EC, chloride, boron, and SAR were developed and are proposed herein. These thresholds aim to (1) balance supply reliability, water quality concerns, and agricultural practices, such as regulated deficit irrigation (RDI); and (2) ensure that the EC_{et}, Cl^{-}_{et}, or B_{et} limits are not exceeded for the most prevalent and sensitive crops in the Friant Division. The thresholds are specific to three irrigation periods that correspond to the growing season and agricultural management practices during the year:

- Period one represents the beginning of the growing season (March 1 – June 30);
- Period 2 represents timing of hull split and the duration of RDI practices in the Friant Division (July 1 – August 31); and
- Period 3 is inclusive of the remainder of the growing season and contract year (September 1 – February 28).

Table 10 shows the established water quality constituent thresholds for each period as defined in the Policy. The threshold variations in Period 3, shown as Periods 3a and 3b, are described in more detail in the Threshold Flexibility subsection below.

Sections below describe methods applied to account for annual RDI practices; development of water quality thresholds, including thresholds for RDI; and adjustments to water quality thresholds to accommodate flexibility for water management within the Friant Division.

Table 10. Friant-Kern Canal In-Prism Water Quality Thresholds

Period	Salinity Threshold expressed as EC (µS/cm)	Chloride Threshold (mg/L)	Boron Threshold (mg/L)[1]	SAR
Period 1 March 1 – June 30	1,000[2]	102[3]	0.4	3
Period 2 July 1 – August 31	500[4]	55[4]	0.4	3
Period 3a September 1 – February 28	1,000[2]	102[3]	0.4	3
Period 3b September 1 – February 28	1,000[2]	123[5]	0.4	3

Notes:

Thresholds adapted from Grieve, C.M., S.R. Grattan and E.V. Maas. 2012. Plant salt tolerance. In. (W.W. Wallender and K.K. Tanji, eds). Agricultural Salinity Assessment and Management (2nd edition). ASCE pp 405-459; and Ayers, R.S. and D.W. Westcot 1985. Water quality for agriculture. FAO Irrigation and Drainage Paper 29 (rev 1). Food and Agriculture Organization of the United Nations. Rome

For addition detail, see *Attachment A - Agronomic Impacts and Mitigation.*

When Friant-Kern Canal in-prism water quality conditions in this table are exceeded, Friant Division Long-Term Contractors will work together to seek 1:1, unleveraged, and cost-neutral exchanges for pump-in and pump-back programs. This does not apply to spot-market or third-party exchanges.

[1] Grapes are used as a representative crop for boron sensitivity and are prevalent in the Friant Division. They are used as a surrogate for many other sensitive crop types such as apricots, figs, and grapefruits. Threshold assumes conventional irrigation with minimum 20 percent leaching fraction applied.

[2] Threshold assumes minimum of 20 percent leaching requirement applied and adjusted to account for regulated deficit irrigation during almond hull split period (July 1 – August 31) in order to not exceed maximum EC_{et}. Almonds on Nemaguard rootstock are used as a representative crop for salinity sensitivity and are prevalent in the Friant Division. They are used as a surrogate for many other sensitive crop types such as apples, cherries, pears, pistachios, and walnuts.

[3] Threshold assumes minimum of 20 percent leaching requirement applied and then adjusted to account for regulated deficit irrigation during almond hull split period (July 1 – August 31) in order to not exceed maximum Cl^{-}_{et}. Almonds on Nemaguard rootstock used as a representative crop for chloride sensitivity. They are used as a surrogate for other sensitive crops including cherries, pistachios, and walnuts.

[4] Threshold applies to almond hull split period when regulated deficit irrigation is applied to avoid hull rot. This threshold is used assuming irrigation applications are reduced to 50 percent of the tree water requirement and subsequently thresholds applied for the remainder of the year have been adjusted to account for additional salt accumulation. This threshold was developed with consideration of existing program operations, historical water quality data, and absolute water quality thresholds.

[5] If the measured average chloride concentration in Period 1 (March 1 – June 30) is less than or equal to 70 mg/L, the allowable chloride threshold for Period 3 (September 1 – February 28) is increased to 123 mg/L.

Key:
µS/cm = microsiemens per centimeter (1 µS/cm = 1 µmhos/cm = 1/1,000 dS/m)
ASCE = American Society of Civil Engineers
Cl^{-}_{et} = maximum chloride threshold of the saturated soil paste
EC = electrical conductivity of applied water
EC_{et} = Soil salinity threshold for a given crop
FAO = Food and Agriculture Organization of the United Nations
Friant Division = Friant Division of the Central Valley Project
mg/L = milligrams per liter
SAR = sodium adsorption ratio
TDS = total dissolved solids

REGULATED DEFICIT IRRIGATION

This section describes methods applied to account for annual RDI practices in the Friant Division for EC and chloride agronomic thresholds, specific to almonds. Note, grapes may also be deficit irrigated during the blooming period; however, the deficit irrigation period for grapes is not aligned with that of almonds, and grapes are most prone to boron toxicities. Consequently, a similar RDI analysis and threshold adjustment is unnecessary for grapes. See Boron Thresholds subsection in Water Quality Thresholds section for additional discussion on applied boron thresholds for grapes in the Friant Division.

Hull Rot Control

Hull rot is problematic in almond orchards in the San Joaquin Valley, and trees are particularly sensitive during the hull split period. Hull split is where 1 percent of the almonds exhibit split, and it typically lasts one to two weeks. The initiation of hull split depends on the almond variety, weather conditions, and tree stress. Although variety has the largest influence on hull-split timing, the temperature 90 days after flowering also affects the hull split initiation. Unseasonably cool temperatures delay hull split while unseasonably warm weather accelerates it.

Hull rot occurs due to infestation by one of two types of fungi, *Monilinia fructicola* or *Rhizopus stolonifera* (Holtz, 2009). Some almond varieties, particularly Nonpareil and Monterey, are more susceptible to fungal attack than are other varieties. High nitrogen application to an orchard combined with full irrigation, or irrigation to completely meet tree ET demands, at the time of hull split can make trees considerably more vulnerable to hull rot.

Hull rot can be largely controlled through a combination of nitrogen management, water management, and antifungal sprays. It is best controlled by RDI practices. A 2001 study showed that by cutting back irrigation to 50 percent of the trees' water requirements between June 1 to July 31 (70 percent regulated) or July 1 to July 15 (85 percent regulated), hull rot was substantially reduced as evidenced by fewer dead leaf clusters and fewer dead spurs and branches (Teviotdale et al., 2001). Such mild to moderate water stress results in drier hull conditions, making trees less vulnerable to fungal attack. Many almond growers in the San Joaquin Valley have adopted RDI practices to help synchronize hull split timing and reduce potential for hull rot. To monitor the degree of tree stress, these growers have implemented the University of California recommendation of trying to maintain a stem water potential between -14 to -16 bars using pressure chambers by drying down the soil rootzone (B. Sanden, Personal communication, April 5-6, 2020). The more negative the number, the more stress the tree experiences. It could take between one to six weeks to achieve this stress level, depending on soil type and irrigation systems (B. Lampinen, personal communication, April 7, 2020). Growers should take care to not to stress trees too much because that could compromise kernel size as kernels continue to grow at the onset of hull split (Doll and Shackel, 2015). After almond harvest, irrigation is critical to maximize floral bud development for the subsequent season.

During the RDI period when there is no effective leaching, irrigation application is reduced to 50 percent of the tree water requirement, and some additional salts and chlorides accumulate in the rootzone. Absent leaching, the steady-state model breaks down because the salt content in the applied water would need to be zero to maintain the same rootzone salinity. In this situation, preseason irrigation management should target an adjusted soil salinity to maintain the appropriate soil salinity thresholds and avoid crop injury.

Regulated Deficit Irrigation Analysis

The RDI analysis applied a predictive model based on timing of flowering to estimate hull split for various types of almond varieties in different parts of the Central Valley (UC Fruit & Nut Research & Information Center, 2020). From the model and historical California Irrigation Management Information System (CIMIS) data from the AEWSD weather station, hull split was determined to typically initiate around the end of June or beginning of July and, depending upon the variety, continue through mid-August (B. Sanden, personal communication, April 6, 2020). To account for potential variances in hull split initiation in the Friant Division, an 8-week period (July 1 to August 31) was assumed for this RDI analysis. Determination of water quality thresholds during the RDI practices period, or Period 2, also considered effective rootzone depth, applied irrigation water quality, soil capacity, and irrigation requirements. The RDI analysis is considered to be conservative because: (1) rainfall was not considered; (2) surface irrigation was assumed, despite the fact that crops under high frequency drip irrigation (typical for most water districts in the Friant Division) are able to tolerate higher salinity for the same assumed LF; and (3) steady-state models typically overestimate rootzone salinity (Corwin and Grattan, 2018).

The RDI analysis was completed for both EC and chloride. Salt accumulation was quantified as a percentage increase, and then rootzone and applied irrigation water thresholds (assuming 20 percent maintenance leaching) were adjusted to maintain maximum EC_{et} or Cl^{-}_{et} through the season. Assuming steady-state leaching, the analysis targeted maintenance of rootzone salinity at soil salinity thresholds of 150 mg/L for chloride, and 1,500 µS/cm for EC, resulting in adjustments to Cl^{-}_{w} and EC_w thresholds.

The RDI calculation assumed the effective rootzone to be between three and five feet (UC Almond Rootzone Workgroup, 2015). Soil was considered to be at field capacity meaning that volumetric soil moisture content was 25 percent, based on monthly average ET or irrigation water requirements for mature almonds in Kern County during months of July and August, 9.5 inches and 8.8 inches, respectively (Sanden, personal communication, April 6, 2020; Goldhamer 2012). The RDI calculation included soil water concentration thresholds of 300 mg/L for Cl^{-}_{sw}, and 3,000 µS/cm for EC_{sw}, or twice that of the thresholds expressed on a saturated soil paste basis.

During the RDI period, water was assumed to be applied at 50 percent ET_c. The total amount of irrigation water required for 100 percent irrigation application, in inches, was calculated but then halved to account for 50 percent deficit irrigation. The amount of irrigation water during RDI periods was then multiplied by the irrigation water concentrations of salt and chloride to determine the percentage increase above the salt and chloride concentrations in the rootzone. Calculating the percentage increase of chloride in the rootzone meant first determining irrigation water and soil water amounts.

For example, 50 percent of the total ET for July and August was 9.1 inches, and the total water in the effective rootzone was 15 inches (rootzone depth (5 ft, or 60 inches) * 25 percent water content = 1.25 feet, or 15 inches). The 15 inches of soil water had 300 mg/L chloride at the beginning of the RDI period. After 9.1 inches of water was applied, adding salts to the soil water in the rootzone, the irrigation water concentration was 55 mg/L. The percentage of additional salt was determined by calculating the ratio of the salt added in the deficit irrigation water to that in the soil water, (9.1 inches x 55 mg/L) / (15 inches x 300 mg/L) = 11 percent. If the salt level in the rootzone remained at critical soil threshold levels at the end of the RDI period, the Cl^{-}_{e} at the beginning of RDI period would have needed to be proportionally lower than the critical soil salinity threshold of 150 mg/L, such that the 150 mg/L threshold concentration would be achieved at the end of the season. Thus, the Cl^{-}_{et} is reduced to 122 mg/L and the corresponding Cl^{-}_{w} becomes 102 mg/L.

WATER QUALITY THRESHOLDS

This section presents the RDI analysis-based chloride and EC thresholds, boron thresholds, and adjustments to water quality thresholds to provide water management flexibility in the Friant Division.

Chloride and Electrical Conductivity Thresholds

Tables 11a and 11b show the RDI analysis for a variety of applied irrigation water qualities for chloride and EC, respectively. In consideration of historical water quality data representative of Kern-Fan or CVC programs that currently introduce water into the FKC, as well as temporal water quality trends, an applied irrigation water threshold for the RDI period was selected to be 55 mg/L Cl^{-}_{w}. The Cl^{-}_{w} value of 55 mg/L during the RDI period correlated to an adjusted Cl^{-}_{w} of 102 mg/L for the remainder of the year, assuming a three-foot (36 inch) effective rootzone – a conservative assumption as the effective rootzone is assumed to be three to five feet (Table 12a).

The same logic described above for Cl^{-}_{w} thresholds was applied to determine RDI EC_w and adjusted EC_w thresholds. The chloride threshold for the RDI period (55 mg/L) was approximately 49 percent greater than the average historical water quality of representative Kern-Fan programs for all year types during months of July and August (37 mg/L). The average EC_w during July and August for all year types representative of Kern-Fan programs was 300 µS/cm, and a 49 percent increase is 447 µS/cm. Rounding up, the RDI threshold for EC_w is 500 µS/cm, and, in order to maintain an EC_{et} of 1,500 µS/cm, the adjusted EC_w for the remainder of the year was 1,000 µS/cm.

Table 11a. Regulated Deficit Irrigation Analysis for Chloride

Cl^-_w (mg/L)	Effective Rootzone (in)	Sum ET_c Average (in)[1]	RDI %	RDI Water (in)	Rootzone Water (in)[2]	% Cl^- Increase	Adjusted Cl^-_e Needed (mg/L)	Adjusted Cl^-_w (mg/L)
10	36	18.3	50%	9.2	9	3.4%	145	121
10	60	18.3	50%	9.2	15	2.0%	147	122
20	36	18.3	50%	9.2	9	6.8%	140	117
20	60	18.3	50%	9.2	15	4.1%	144	120
30	36	18.3	50%	9.2	9	10.2%	135	112
30	60	18.3	50%	9.2	15	6.1%	141	117
40	36	18.3	50%	9.2	9	13.6%	130	108
40	60	18.3	50%	9.2	15	8.1%	138	115
50	36	18.3	50%	9.2	9	16.9%	125	104
50	60	18.3	50%	9.2	15	10.2%	135	112
55	36	18.3	50%	9.2	9	18.6%	122	102
55	60	18.3	50%	9.2	15	11.2%	133	111

Notes:

[1] ETc averages from Sanden and Goldhamer based on water use of mature almond trees in Wasco area for July and August (Goldhamer and Girona 2012).

[2] Rootzone at field capacity is 25 percent by volume.

Key:

Cl^- = chloride
Cl^-_e = chloride concentration in saturated soil paste or rootzone chloride
Cl^-_w = chloride concentration in applied irrigation water
ET_c = evapotranspiration or tree water use
in = inches
mg/L = milligrams per liter
RDI = regulated deficit irrigation

Table 11b. Regulated Deficit Irrigation Analysis for Electrical Conductivity

EC_W (µS/cm)	Effective Rootzone (in)	Sum ET_c Average (in)[1]	RDI %	RDI Water (in)	Rootzone Water (in)[2]	% EC Increase	Adjusted EC_e Needed (µS/cm)	Adjusted EC_w (µS/cm)
200	36	18.3	50%	9.2	9	6.8%	1,400	1,120
200	60	18.3	50%	9.2	15	4.1%	1,440	1,150
300	36	18.3	50%	9.2	9	10.2%	1,350	1,080
300	60	18.3	50%	9.2	15	6.1%	1,410	1,130
400	36	18.3	50%	9.2	9	13.6%	1,300	1,040
400	60	18.3	50%	9.2	15	8.1%	1,380	1,100
500	36	18.3	50%	9.2	9	16.9%	1,250	1,000
500	60	18.3	50%	9.2	15	10.2%	1,350	1,080
600	36	18.3	50%	9.2	9	20.3%	1,200	960
600	60	18.3	50%	9.2	15	12.2%	1,320	1,050

Notes:

[1] ET_c averages from Sanden and Goldhamer based on water use of mature almond trees in Wasco area for July and August (Goldhamer and Girona 2012).

[2] Rootzone at field capacity is 25 percent by volume.

Key:

µS/cm = microsiemens per centimeter
EC = electrical conductivity
EC_e = electrical conductivity of saturated soil paste or rootzone salinity
EC_w = electrical conductivity of applied irrigation water
ET_c = evapotranspiration or tree water use
in = inches
RDI = regulated deficit irrigation

By adjusting the Cl^-_e and EC_e thresholds for non-RDI irrigation periods, LR volumes for the assumed 20 percent leaching were adjusted by default, as LR is a function of the saturated soil paste concentration. Adjusted LR volumes and constituent thresholds affect the mitigation curve slope for each constituent. The adjusted curves for chloride and EC were plotted and were below the governing line, so the mitigation curve remained unchanged and further confirmed the conservative nature of the mitigation curve in ensuring that all constituents would be sufficiently mitigated.

Boron Thresholds

Table 12 shows B_w thresholds for tree and vine crops above which injury occurs under differing irrigation management practices, or LF values of 10 and 20 percent. Grapes have a boron tolerance of 0.4 mg/L when the LF is between 10 to 25 percent (Grattan et al., 2015). The actual boron threshold tolerance range is 0.3-0.5 mg/L if one considers different combinations of the soil water threshold (B_{sw}) tolerance (0.5 - 0.75 mg/L) and LF (10 - 25%).

The maximum in-prism water quality threshold for boron was set at 0.4 mg/L for all three irrigation periods (Periods 1, 2, and 3). Grapes were used as the representative crop for boron sensitivity because of their prevalence in the Friant Division, serving as a surrogate for other sensitive crop types, such as apricot, fig, and most citrus. The applied threshold assumed conventional irrigation with a LF of 10-25 and was used rather than the LR concept that was used in development of the mitigation curves.

Table 12. Boron Tolerance of Various Crops

CROP	**BORON CONCENTRATION OF APPLIED WATER (B_w) (mg/L)**	
	Leaching Fraction 10%	**Leaching Fraction 25%**
Alfalfa	2.0	2.8
Apricot	0.4	0.4
Asparagus	4.8	6.7
Barley	1.4	1.9
Bean (kidney, lima, mung)	0.4	0.6
Bean, snap	0.5	0.6
Beet, red	2.0	2.8
Bluegrass, Kentucky	1.2	1.7
Broccoli	0.5	0.6
Cabbage	1.2	1.7
Carrot	0.7	0.9
Cauliflower	1.6	2.2
Celery	3.8	5.3
Cherry	0.4	0.4
Clover, sweet	1.2	1.7
Corn	1.2	1.7
Cotton	3.1	4.3
Cucumber	0.7	0.9
Fig, Kadota	0.4	0.4
Garlic	1.7	2.4
Grape	0.4	0.4
Grapefruit	0.4	0.4
Lemon	<0.3	<0.4
Lettuce	0.6	0.8

Note: Adapted from data in Grattan, S.R., F.J. Diaz, F. Pedrero and G.A. Vivaldi. 2015. Assessing the suitability of saline waste waters for irrigation of citrus: Emphasis on boron and specific ions interactions. Agric Water Manag. 157:48-58.

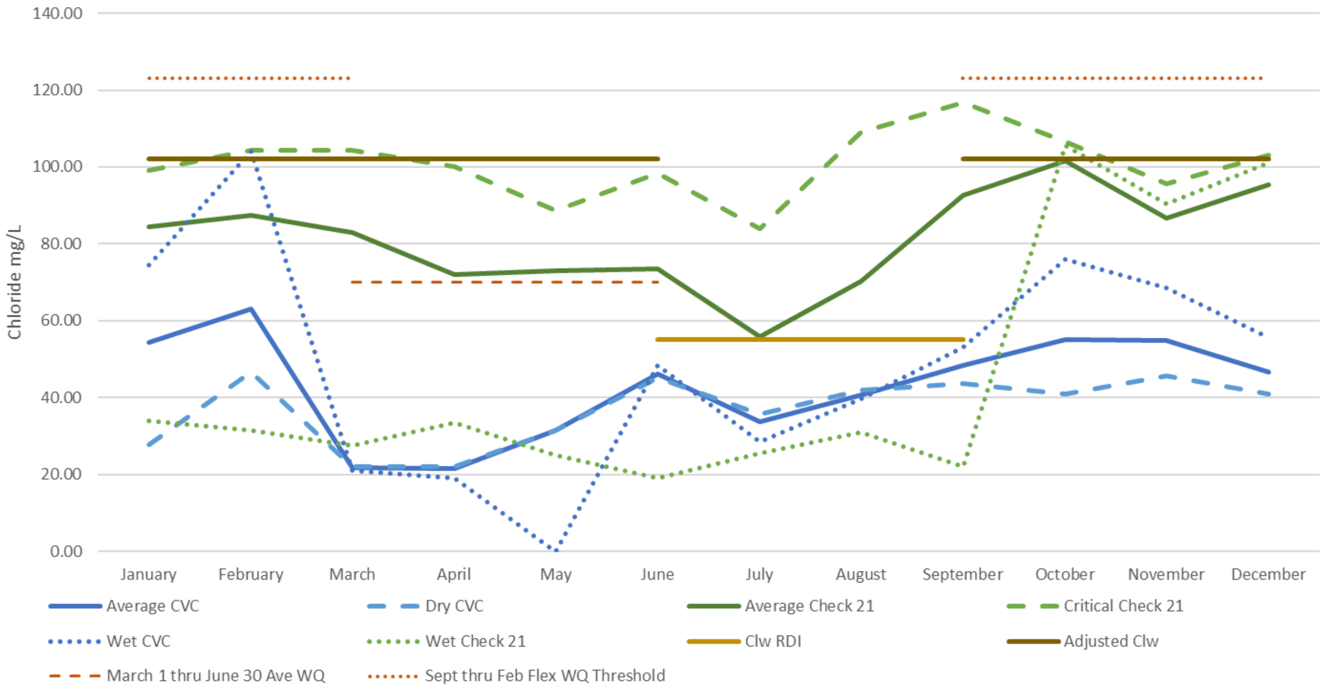
Key:
mg/L = milligrams per liter

In addition, the applied B_w threshold of 0.4 mg/L was far more conservative than those defined in literature by Ayers and Westcot (1985). This analysis indicated that B_{sw} could be used as protective irrigation water thresholds (B_e) because of the complexities related to boron adsorption and equilibrium concentrations with the soil water. Historical water quality data also indicate that CVC or California Aqueduct water would be below this threshold.

Threshold Flexibility

In evaluating and comparing the developed, in-prism water quality thresholds with temporal water quality trends during Period 1 (March 1 to June 30), or prior to the RDI period (July 1 to August 31), observed average constituent concentrations were typically below the proposed thresholds. If water with lower constituent concentrations was applied to a crop for the first four months of the growing season, assuming that the rootzone concentration was properly maintained, the rootzone concentration would decrease below the threshold and, even with reductions in irrigation and LFs, could allow the application of higher irrigation water concentrations during the post-RDI period. The period following RDI, or Period 3 (September 1 to February 28), is often used for reclamation leaching; however, it is also the period in which new sources of water may be available for the Friant Division. Thus, having flexibility in the allowable irrigation water quality could be opportune for increasing supply reliability for the region.

Based on the RDI analysis and evaluation of water quality temporal trends, the Policy proposes an alternative water quality threshold for chloride for Period 3 to provide flexibility for irrigation management. Determination of whether the alternative chloride threshold for Period 3 is applied is based on the average chloride concentration of the irrigation water during Period 1. The alternative value was developed considering historical, temporal water quality trends and applying a weighted average calculation to meet the targeted rootzone chloride threshold. If the average measured chloride concentration for Period 1 is less than or equal to 70 mg/L, the allowable chloride concentration threshold increases from 102 mg/L to 123 mg/L for Period 3. If the measured average chloride concentrations for Period 1 exceed 70 mg/L, the chloride threshold remains at 102 mg/L for Period 3. Figure 10 shows the proposed thresholds compared to the chloride water quality trends for CVC and California Aqueduct water sources by year type.



Key:
Average = Average of all San Joaquin Index year types and excludes months where there is mixing.
Cl^-_w = chloride concentration of applied irrigation water
CVC = Cross Valley Canal
Dry= Monthly average for San Joaquin Index year types dry and critical and excludes months where there is mixing.
mg/L = milligrams per liter
RDI = regulated deficit irrigation
Wet = Monthly average for San Joaquin Index year types below normal, above normal, and wet and excludes months where there is mixing.

Figure 10. Chloride water quality trends by source water and year type with proposed water quality thresholds

Because the average water quality for Kern-Fan or CVC programs for Period 1 (March 1 to June 30) was approximately 30 mg/L (see Table 2), 70 mg/L was chosen as a midpoint between the adjusted Cl^-_w threshold determined in the RDI analysis and the average historic water quality. Using a weighted average approach, if 70 mg/L water was applied for the four months in Period 1, assuming an LR of 20 percent, the resulting Cl^-_e would be 84 mg/L. With the target weighted average for Cl^-_e of 122 mg/L, the necessary Cl^-_e for Period 3, the six months post-RDI (September 1 – February 28) was determined using the following equation:

$$84\frac{mg}{L} * .4 + Cl_e * .6 = 122$$

The resulting Cl^-_e was 147 mg/L, correlating to a Cl^-_w of 123 mg/L with an assumed 20 percent LR. This approach was conservative in that observed chloride concentrations for Kern-Fan programs were significantly lower than 70 mg/L, and these calculations did not consider rainfall or any reclamation leaching applied in addition to the assumed 20 percent maintenance leaching.

Note that adjusting the Cl^-_e thresholds for non-RDI irrigation periods (Period 1 and Period 3) would adjust the LR volumes for the assumed 20 percent leaching provided by the mitigation curve. Adjusted curves were plotted and it was confirmed that even with a reduced Cl^-_e, the established mitigation curve would provide adequate mitigation.

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Friant-Kern Canal Water Quality Guidelines – Standard Operating Procedures

Draft Attachment D

CONTENTS

FIGURES

ACRONYMS AND ABBREVIATIONS

μS/cm	microsiemens per centimeter (1 μS/cm = 1 μmhos/cm = 1/1,000 dS/m)
AF	acre-feet
Ad hoc Committee	Ad hoc Water Quality Committee
CV-SALTS	Central Valley Salinity Alternatives for Long-term Sustainability
CVC	Cross Valley Canal
CVP	Central Valley Project
EC	electrical conductivity
FKC	Friant-Kern Canal
Friant Contractor	Friant Division long-term contractor
Friant Division	Friant Division of the Central Valley Project
FWA	Friant Water Authority
Guidelines	Friant-Kern Canal Water Quality Policy Guidelines
Ledger	Friant Kern Canal Water Quality Ledger
mg/L	milligrams per liter
Policy	Friant-Kern Canal Water Quality Policy
Pool	Section of the Friant-Kern Canal between Check Structures
TDS	total dissolved solids
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RWA	Recovered Water Account
SJRRP	San Joaquin River Restoration Program
SOP	Standard Operation Procedure
URF	Unreleased Restoration Flow

PURPOSE

This document describes the proposed standard operating procedures for implementing the Friant Kern Canal Water Quality Ledger (Ledger) that is associated to Friant-Kern Canal Water Quality Policy Guidelines (Guidelines). The concept for the Ledger was developed in late 2019 with the Ad hoc Water Quality Committee's Small Workgroup during development of the Guidelines. The Ledger determines the required mitigation for introducing water of lesser quality in the Friant Kern Canal (FKC). An initial, proof-of-concept version of the Ledger included a calculation of the pump-in mitigation percentage, total volume of mitigation water to be added to the FKC, and distribution of mitigation water to affected water users. As the Guidelines move toward implementation and the Ledger is being fully developed, it is important that the defined Ledger process integrates with Friant Water Authority's (FWA) operations and accounting.

This Standard Operating Procedure (SOP) for implementing the Ledger is intended to serve two purposes:

1) Define the complete process for pump-in project operations and agency responsibilities relating to project approval, notification, mitigation water accounting, and reporting.
2) Document Ledger calculation assumptions.

PROCESS FOR IMPLEMENTING WATER QUALITY GUIDELINES

The Guidelines identify the need to develop standard operating procedures for a mitigation program and its administration. The processes and procedures for FWA implementation and management of the Guidelines will directly impact the way the Ledger is developed, including the assumptions and calculations within the Ledger tool itself. The process for the implementation of the Ledger as part of the Guidelines includes:

- Approve of pump-in projects.
- Measure, report, and track pump-in water quality.
- Collect pump-in project delivery data.
- Calculate preliminary mitigation water distribution.
- Final water accounting.
- Report volumetric deliveries and balance to U.S. Department of the Interior, Bureau of Reclamation (Reclamation).

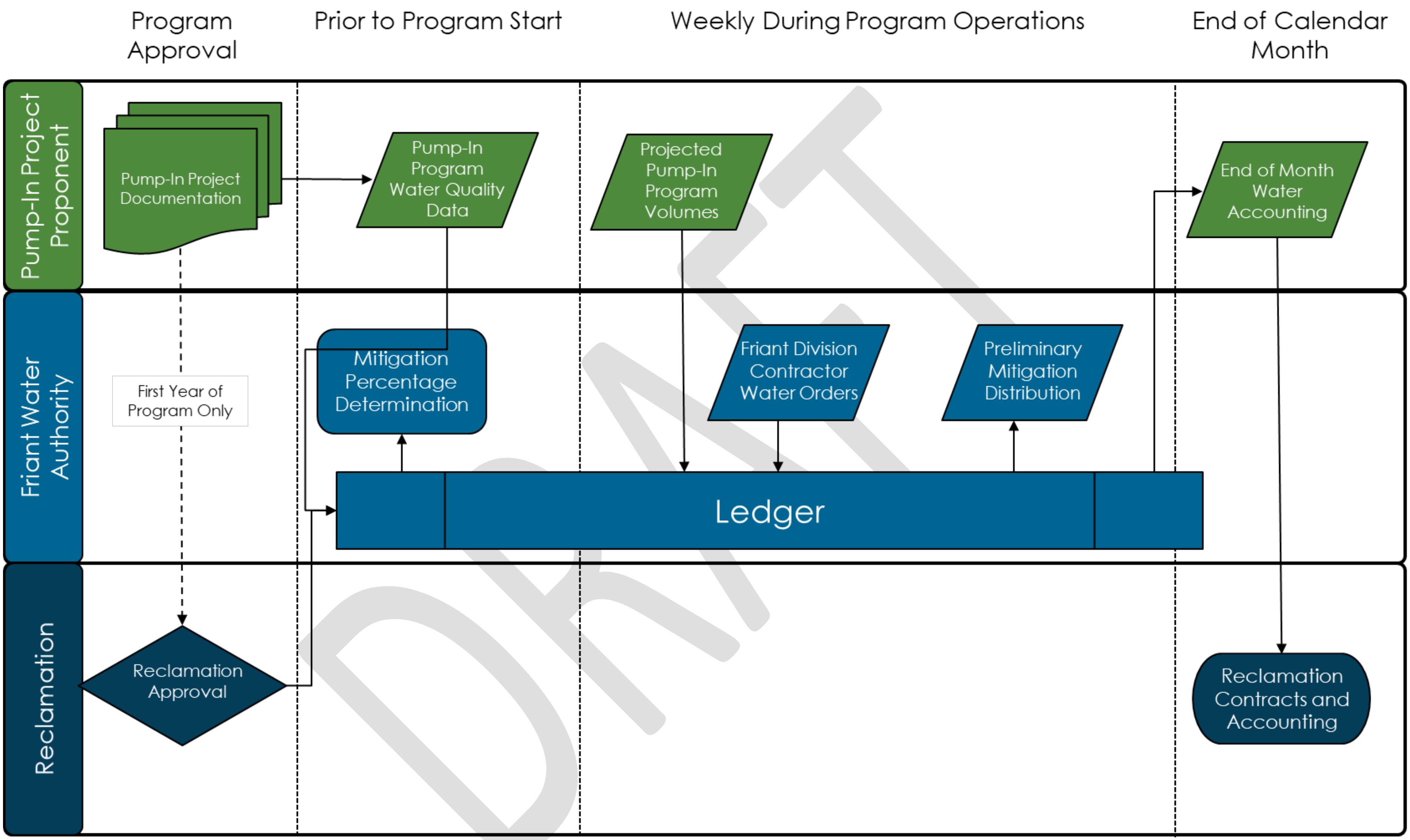

Figure 1. Water Quality Guidelines Implementation Process

PUMP-IN PROJECT APPROVALS

In consideration of the Ledger, a pump-in project (or program) is any project that introduces water into the FKC from a source other than Millerton Lake. Reclamation, with acknowledgement from FWA, provides the final approval for any pump-in project once the Warren Act Contract, other agreements, and environmental documentation is completed. Because the Warren Act Contract and environmental documentation for a pump-in project may have different effective durations, Reclamation will approve the necessary documentation to implement a pump-in project at the appropriate times. Each pump-in project will have a defined duration and maximum volume that can be introduced into the FKC. The pump-in project proponent will identify a point of contact who will work with the FWA to coordinate required responsibilities outlined in the Guidelines.

PUMP-IN PROJECT WATER QUALITY

As described in section C2 of the Guidelines , all waters discharged into the FKC must be tested annually. Pump-in projects that introduce a single source water quality and pump-in projects that bring water into the FKC via the Cross Valley Canal (CVC) will have different methods for collecting and reporting water quality data.

Mitigation Percentage Determination

Pump-in project water quality will be an input to the Ledger to determine the required mitigation water percentage and corresponding mitigation volume per pump-in project volume. Groundwater and CVC water quality are input to the Ledger at different frequencies as described below.

Single-Source Pump-In Projects via the FKC – Single-source pump-in projects include projects with Warren Act Contracts that introduce surface water or banked groundwater into the FKC. Before an approved pump-in project begins, the FWA will work with the proponent to collect water quality data for the potential introduced surface water or groundwater to determine the required mitigation water percentage to be applied to the volume moved through the FKC. The determination of the required mitigation percentage will be calculated using the Ledger. Collection of the water quality data will follow requirements outlined in the Guidelines for Accepting Water into the Friant-Kern Canal.

Pump-In Projects via the CVC - As described in Section C2 of the Guidelines, weekly water quality sampling will be performed by the FWA during reverse flow pump-back operations and water quality data will be provided to Reclamation. Mitigation will be based on the weekly average electrical conductivity (EC) concentrations measured continuously at the Kern Check, representative of CVC water quality conditions. The CVC water quality conditions may represent multiple pump-in projects and will be updated in the Ledger at a greater frequency than once per year. The FWA will coordinate with the pump-in project proponents regarding the required mitigation water percentage as determined by changes in water quality conditions.

The Ledger will document the water quality conditions for all pump-in projects and calculate the required mitigation percentage for each.

Ledger Calculations

As described above, pump-in project water quality data will be input to the Ledger. For each pump-in project, the Ledger will calculate the required mitigation water percentage. FWA will communicate this mitigation percentage to pump-in project proponents prior to operation and introduction.

Assumptions

- Water quality conditions for each pump-in project will be measured once per year or at a set frequency agreed to in the Pump-In Project Approval and will determine the required mitigation water percentage.
- The Mitigation Percentage process follows the approach outlined in the Guidelines.

Friant-Kern Canal Water Quality Monitoring and Management

All pump-in projects must adhere to the water quality monitoring requirements stipulated in the Guidelines. FWA will implement continuous, real-time monitoring of in-prism water quality conditions in the FKC and at the FKC/CVC Intertie during reverse-flow, pump-back operations. Continuous, in situ measurements of electrical conductivity will provide real-time data on incremental water quality changes and mixing in the FKC and will assist in water quality threshold management. If water quality thresholds are exceeded, FWA shall incrementally direct pump-in project proponents to cease operations of pump-in projects with the highest concentration of the critical water quality constituent until the water quality drops below defined thresholds.

PUMP-IN PROJECT DELIVERY PROJECTED DATA COLLECTION

During a contract year in which a pump-in project will be operated, FWA will work with the pump-in project proponent to implement the requirements stipulated in the Guidelines. This includes the addition of mitigation water to the FKC consistent with the pump-in project water quality conditions and quantity delivered. Pump-in project forecasted deliveries, calculated projected mitigation water, and all coordination related to project pump-in project operations will be completed on a weekly basis.

Projected Pump-In Project Volumes

FWA will coordinate with pump-in project proponents to get an estimated volume of water to be introduced and conveyed in the FKC. The required mitigation water volume for the pump-in project is assumed to be included as part of that estimated volume. FWA will calculate losses, when appropriate, based on the total volume of water to be introduced into the FKC. The mitigation volume will be based on the total volume minus the appropriate losses. This method for calculating losses shall be consistent with the current method for pump-in projects.

Ledger Calculations

The Ledger uses the mitigation water percentage for each pump-in project based on measured water quality, and the forecasted gross weekly delivery volume for the pump-in project to calculate the losses, and the net pump-in project volume to determine the projected mitigation volume requirement.

Assumption

- Mitigation volumes are calculated based on projected weekly volume of a pump-in project and verified using measured volumes at the end of each month.
- Mitigation volumes are added to the FKC in real time with other pump-in project deliveries.
- FWA will have weekly volume, or weekly average flow, projections from pump-in project proponents.

PRELIMINARY MITIGATION DISTRIBUTION

The Ledger will be used to distribute mitigation water volumes to the impacted Friant Contractors. As described in the Pump-In Project Delivery Projected Data Collection section, mitigation water is introduced into the FKC simultaneously with the pump-in project volume introduction. FWA will add weekly water order data to the Ledger to distribute the mitigation volume based on volumetric proportioning. The preliminary mitigation distribution will be used by the FWA **for communication purposes only**. Actual mitigation water distribution will be updated at the end of each calendar month based on quality-controlled delivery data.

Ledger Calculation

The FWA will input water order data into the Ledger to be used in the mitigation water distribution calculations. The Ledger will determine the average weekly mixing interface position based on the weekly volumes for periods during FKC pump-back operations.

Assumptions

- Deliveries will be aggregated by Friant Division Long-Term contractor, and divided into pools, defined as the canal section between check structures.
- The division of deliveries by a Friant-Division Long-Term contractor that has turnouts in multiple pools will be based on historical deliveries.
- Only Central Valley Project (CVP) (Class 1, Class 2, 215, and San Joaquin River Restoration Program (SJRRP) Recovered Water Account (RWA) and Unreleased Restoration Flow (URF)) deliveries for the Friant Division Long-Term Contractors will be used to calculate the mitigation distribution.
- The Interface, or location along the FKC that receives water from both gravity and reverse flow, will be determined using a weekly mass balance.
- The FKC Pool with the Interface will be assumed to be fully mixed with gravity and reverse flow.

END OF MONTH WATER ACCOUNTING

At the end of each month that a pump-in project is operating, the preliminary mitigation water distribution will be updated based on quality-controlled delivery data for both the pump-in project and Friant Contractors. The updated mitigation distribution volume will be shared with impacted Friant Contractors and included as part of their normal water accounting. The mitigation volume will be assumed to be the first water taken for their monthly deliveries. For pump-in project proponents that take more water than pump-in project delivery minus the mitigation volume, proponents will be assumed to make up that delivery with their CVP contract supply. For pump-in projects that end with water delivery to a Friant Contractor, adjustments for mitigation volumes are not needed.

For pump-in projects that do not end with delivery to a Friant Contractor there is potential need for a mitigation volume adjustment. For these pump-in projects, FWA will track pump-in project water introduced into the FKC, and deliveries to the non-Friant Contractor. If the volume of mitigation water is not equal to the expected volume, FWA will contact the pump-in project proponent to either increase the mitigation volume or increase their own delivery.

Assumptions

- Mitigation water delivery to impacted Friant Contractors is the first water to be delivered.
- If delivery to a pump-in project proponent exceeds pump-in project input to FKC minus the mitigation volume, the remainder will be accounted for as CVP delivery.

Ledger Calculation

FWA will add quality-controlled data to the Ledger at the end of each calendar month. The Ledger will replace the preliminary data and recalculate the mitigation water distribution to determine the monthly volumes of mitigation delivery, pump-in project delivery, and CVP delivery.

FINAL WATER ACCOUNTING

The end of the month water accounting will be provided to the Friant Contractors for confirmation and their use for accounting with Reclamation.

WATER QUALITY ANNUAL REPORTING

The water quality for each year will be maintained in a database by FWA. The mitigation curve developed for the Ledger, as part of the Guidelines, uses relationships between water quality constituents of concern and in-prism measurements of EC. At the conclusion of each year, the relationships will be updated with new water quality data collected during the year. The updated relationship will be shared with the Friant Contractors. Reclamation reserves the right to change the Guidelines at any time, subject to consultation with Friant Contractors. Additionally, the Guidelines may be re-evaluated if any of the following conditions occurs:

- A future regulatory cost or equivalent fee is imposed on Friant Contractors and a portion of such fee can reasonably be attributed to the incremental difference of water quality conditions in the FKC.
- There is significant, regulatory change or scientifically based justification (e.g., agronomic effects) and three out of five Friant Contractors (Arvin-Edison Water Storage District, Shafter-Wasco Irrigation District, Delano-Earlimart Irrigation District, South San Joaquin Municipal Utility District, or Kern-Tulare Water District) agree and work with the Water Quality Advisory Committee to recommend a change.

Attachment E – FKC Water Quality Guidelines Cost Allocation

Special Project
Summary Sheet
Budget Sheet

Project Title: Friant-Kern Canal Water Quality Guidelines

Job Code: 6370

Project Location: Friant-Kern Canal (entire 152 miles)

Project Description: Friant Water Authority implementation and administration of the Friant-Kern Canal (FKC) Water Quality Guidelines (Guidelines). The Guidelines include requirements of discharge of water into the FKC, monitoring and reporting requirements, management, mitigation, communications, and forecasting.

Estimated Annual Project Costs (x1000): $175.6

Materials and Laboratory

The continuous, real-time sampling of electrical conductivity (EC) at each of the specified check structures requires FWA to install fourteen (14) Seametrics CT2X conductivity meters at each structure. Costs for purchase and installation of the real-time water quality monitoring equipment, including integration with IOS, is approximately $56,690 ($1,780 per unit cost and total of $31,770 for installation). It is assumed the useful life of a Seametrics CT2X conductivity meter is about 10 years at an interest rate of 3%. Additionally, FWA staff will maintain two (2) existing handheld Hanna DIST5 conductivity meters. In addition, real-time water quality monitoring equipment and handheld conductivity meters will be calibrated and maintained according to manufacturer recommendations. Costs for maintenance of equipment is estimated to be about 10% of the capital cost ($5,670 annually, shown as Item 5 in Table 1 below).

Table 1 summarizes the annual materials and lab costs of each monitoring requirement. Specifically, the item numbers in Table 1 refer to the sample source/type item numbers presented in Attachment B – Monitoring Program Summary. Details regarding assumptions are outlined in the narrative following Table 1.

Table 1: Materials and laboratory costs associated with monitoring activities.

Item[1]	Description	Estimated Annual Cost
5	Annual maintenance of equipment for continuous, real-time sampling of electrical conductivity at each specified check structure	$5,670
6	Estimated exceedance testing	$880
8	Weekly testing at FKC-CVC Intertie during pump-back operations	$22,360
9	Testing during initiation of FKC-CVC Intertie pump-back operations	$10,800
	Materials and Lab Testing Subtotal:	**$39,710**

[1] Item numbers refer to sample source/type item numbers presented in Attachment B.

Attachment E – FKC Water Quality Guidelines Cost Allocation

Most requirements of the monitoring program (items 6 through 9 in Table 1) require FWA to collect samples and send them to labs for testing. Testing can include a full list of Tittle 22 constituents in Table 1 of the Guidelines, the short list of constituents in Table 5 of the Guidelines, or single constituents. Testing costs can vary significantly by lab. To be conservative, it was assumed that testing for full Title 22 constituents would be $5,400, testing for the short list of constituents in Table 5 of the Guidelines would be $860, and testing for single constituents would be $55/constituent.

For a given year, it was assumed that single constituents would exceed the thresholds for two months per year and would result in 16 tests annually (4 weekly tests for each month with an exceedance, and 4 weekly tests below the threshold after the exceedance). This results in a total cost of $880 for testing because of exceedances (item 6 in Table 1). Costs for EC testing during operations outages was not included as this will be done with the handheld units by FWA staff. It was assumed that pump-back operations would occur during 6 months of the year, which would require 26 samples of the full list of constituents in Table 5 of the Guidelines. This results in a total cost of $22,360 for testing because of pump-back operations (item 8 in Table 1). Finally, it was assumed that full Title 22 testing due to initiation of pump-back operations or anticipated Cross Valley Canal operations that will impact water quality will occur two times per year, and will cost $10,800.

Annualized Capital Install and Replacement of Equipment Subtotal:	*$6,646*
Annual Materials and Lab Testing Subtotal:	*$39,710*

Friant Water Authority Staff
For implementation of the Guidelines, the following activities will be required of FWA staff:

- Maintain and calibrate conductivity meters on a bi-weekly basis
- Perform water quality sampling during pump-in operations
- Coordinate laboratory water quality testing
- Coordinate with Friant Division Long-Term Contractors on water quality data monitoring and analysis
- Manage water quality and operations database
- Perform weekly water quality reporting and forecasting using FKC Water Quality Model
- Perform weekly analysis to determine mitigation and distribution to respective Friant Division Long-Term Contractors using the FKC Water Quality Mitigation Ledger
- Coordinate with U.S. Department of the Interior, Bureau of Reclamation's South-Central California Area Office on water quality reporting, mitigation, and contractual requirements
- Coordinate and facilitate FWA committee on water quality

The annual cost for FWA Executive Team and Operations staff is estimated below:

Executive Team (WRM)………104 hrs @$102.89/hr	$10,700
Water Operations (Senior Engineer)………1664 hrs @$71.25/hr	$118,560

Annual Staff Labor Subtotal:	*$129,260*

Attachment E – FKC Water Quality Guidelines Cost Allocation

General Justification: The Board of Directors, at the request of the Water Quality Ad Hoc Committee requested that staff develop new water quality guidelines for non-Millerton water introduced into the FKC. This plan originally stemmed from the environmental compliance requirements of both the Long-Term Recapture and Recirculation Plan and the FKC Reverse Pump-back Project.

Operating Impact: This estimate assumes implementation of the Guidelines will occur. Although the costs for finalizing the Guidelines, agreements, and environmental compliance will be applied separately, the administration and water quality monitoring outlined in the Guidelines will be applied to 6370. A portion of these costs will be reimbursed through a surcharge applied to those Friant contractors that introduce water into the FKC once the Guidelines are implemented.

Cost Allocation: Costs for implementation and administration of the Policy will be paid initially by the subset of Friant Division Long-Term Contractors who pay for FKC O&M to the FWA and subsequently will be reimbursed by contractor's that introduce water (Put) into the FKC (Contributor). The Contributor will pay a dollar per acre-foot ($/acre-foot[AF]) surcharge, or 'Guidelines Surcharge,' that will be credited back to the Friant Division Long-Term Contractors who pay for O&M to the FWA. The Guidelines Surcharge is based on an estimate of total annual costs divided by average annual deliveries of pump-in programs into the FKC. The Guidelines Surcharge will be applied to all introduced water even if it is not required to provide mitigation as defined in the Guidelines.

Current pump-in programs pump approximately 36.6 thousand acre-feet (TAF) year into the FKC based on recent 5-year average (2013-2018) as shown in Table 2.

Table 2: Current Pump-In Program 5-year Average (2013-2018)

Source	Annual Average (TAF)	Annual Maximum[1] (TAF)
Sierra Water	17.8	344
Groundwater	14.7	117
CVC	4.1	149
Total Annual Average	**36.6**	**610**

[1] Based on existing compliance and approvals and anticipated renewals.

The potential annual maximum is much greater than annual average; however, for purposes of setting an initial Guidelines Surcharge, an estimated 40 TAF per year of pump-ins is assumed occur. This estimate includes the recent average of existing programs and anticipated 10% initial increase due to new programs or greater use of existing programs.

Based on this, the initial **Policy Surcharge is $4.39 per AF** and will be escalated 3% per year. Annual costs and deliveries will be reassessed every year by the Water Quality Advisory Committee and compared to estimates provided in this attachment to determine if any adjustments are required to the Guidelines Surcharge.

Attachment E – FKC Water Quality Guidelines Cost Allocation

Extraordinary Maintenance Projects
Cost Summary

Project Title: Friant Kern Canal Water Quality Program

Project Location and Department: Friant-Kern Canal (entire 152 miles) / Operations Department

Estimated Total Project Cost (x1000): $175.6

Estimated Total Material Cost (Including Fuel Costs, x1000): $46.4

Breakdown of Estimated Costs

All costs outside of Friant staff costs for CEQA compliance are not covered as part of this program cost budget.

Materials and Laboratory

Annualized Capital Install and Replacement of Equipment	$6,646
Annual Materials and Lab Testing	$39,710

Subtotal: $46,356

Regular Labor (Hours and Cost):

Executive Team (WRM)………104 hrs @$102.89/hr	$10,700
Water Operations (Senior Engineer)………1664 hrs @$71.25/hr	$118,560

Subtotal: $129,260

Total: $175,616

Policy Surcharge is $4.39 per AF