CHAPTER 1.0
INTRODUCTION

Although source waters, particularly surface waters, are subject to treatment and disinfection before supply for municipal use, the presence of pathogens is a major concern, because of the potential of pathogen breakthrough into treated drinking water supplies. Pathogens are a concern also because the degree of treatment for drinking water is based on total coliform levels in source waters. Following implementation of the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), additional actions may be required based on *Cryptosporidium* levels detected in source waters. This report presents a conceptual model of pathogens in the waters of the Central Valley, summarizing existing data and identifying potential sources and transformations. The rivers of the Central Valley, particularly as they flow into the Sacramento-San Joaquin Delta (hereafter referred to as the Delta) are a vital source of water to more than 23 million people in the Southern California, Central Coast, and San Francisco Bay regions (CALFED Water Quality Program Plan, 2000). The tributaries of the Sacramento and San Joaquin rivers that originate in the Sierra Nevada Mountains generally have high quality water; however, as the tributaries flow into lower elevations, they are affected by urban, industrial, and agricultural land uses, natural processes, and a highly managed water supply system.

The Central Valley Drinking Water Policy Workgroup (CVDWPWG) is working with the Central Valley Regional Water Quality Control Board (Regional Board) to conduct the technical studies needed to develop a policy that will ensure reasonable protection to drinking water supplies in the Central Valley. The policy is initially focused on five categories of constituents: organic carbon, nutrients, salinity, bromide, and pathogens and indicator organisms. This conceptual model report is focused on pathogens and coliforms routinely monitored as indicators of pathogens. The geographic scope of this conceptual model is the Central Valley, comprising the Sacramento and San Joaquin River basins, and the Delta.

A variety of pathogens and indicators are currently regulated in finished drinking water supply as summarized in Table 1-1. These are legally enforceable standards that apply to public water suppliers. In addition to these standards other regulations

apply to ambient waters for other beneficial uses, specifically recreation and shellfish harvesting. These criteria are summarized in Table 1-2.

Epidemiological data does indicate that in some regions of the developed world (Australia, Canada) there are adverse health impacts from consumption of tap water (Payment et al., 1991, 1997; Hellard et al., 2001). However, these findings are not uniform, likely due to the presence of different pathogens in different areas as well as potential problem in survey techniques. Pathogens in source waters are a concern because of the potential risk of breaking through due to plant failure or operational errors during treatment. The wide variety of land uses in the watershed that can potentially serve as pathogen sources, such as urban land, grazing land, and confined animal feeding operations also indicate the potential presence of pathogens in source waters.

Unlike other constituents of concern evaluated in preceding work (organic carbon, Tetra Tech, 2006a; nutrients, Tetra Tech, 2006b; salinity, Harader et al., 2006), pathogens differ in that there is considerably less available information on their abundance, sources, and transport in the Central Valley. Most data that does exist is on indicator organisms. Furthermore, there is a great variety of potential pathogen species in source waters for which the analysis is not routinely done. Although many of these pathogens are not currently regulated, some are on US EPA's candidate contaminant list, and may be considered for future regulation. Yet others may draw public attention because of widespread outbreaks they cause (FDA, 2006), such as the recent infections due to the pathogenic strains of *E. coli* O157:H7 in California farms. For these reasons, this conceptual model evaluates data on fecal indicators, where quantification is possible, and also includes qualitative descriptions of currently regulated and emerging pathogens of concern to assist in long-term planning and data collection.

The objective of this report is to present a summary of relevant information on fecal indicators and pathogens in the Central Valley and Delta and to identify the importance of different sources, where the data allow. Recommendations are provided for future work, balancing the focus of indicator organisms, which are relatively easy to measure but not always predictive of pathogens, versus measurements of true pathogens.

Table 1-1 National Primary Drinking Water Regulations for Microorganisms and Related Contaminants (Source: USEPA, 2006)

Contaminant	MCLG[1] *(mg/L)2*	MCL or TT[1] *(mg/L)2*	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Cryptosporidium	zero	TT[2]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and fecal animal waste
Giardia lamblia	zero	TT[2]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste
Heterotrophic plate count (HPC)	n/a	TT[2]	Heterotrophic plate count (HPC) has no health effects; it is an analytic method used to measure the number of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a variety of bacteria that are naturally present in the environment
Legionella	zero	TT[2]	Legionnaires' disease, a type of pneumonia	Found naturally in water; multiplies in heating systems
Total Coliforms (including fecal coliform and *Escherichia coli*)	zero	5.0%[3]	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present.	Coliforms are naturally present in the environment as well as feces. Fecal coliforms and *E. coli* only come from human and animal fecal waste.
Turbidity	n/a	TT[2]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms could be present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria.	Soil runoff
Viruses (enteric)	zero	TT[2]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste

[1] Definitions:
Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
Maximum Contaminant Level Goal (MCLG) - The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
Treatment Technique (TT) - A required process intended to reduce the level of a contaminant in drinking water.

[2] EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:
***Cryptosporidium*:** (as of1/1/02 for systems serving >10,000 and 1/14/05 for systems serving <10,000) 99% removal.
***Giardia lamblia*:** 99.9% removal/inactivation
Viruses: 99.99% removal/inactivation
Legionella: No limit, but EPA believes that if *Giardia* and viruses are removed/inactivated, *Legionella* will also be controlled.
Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelolometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of January 1, 2002, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.
HPC: No more than 500 bacterial colonies per milliliter.
Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 2005); Surface water systems or GWUDI (Groundwater under the direct influence of surface water) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, *Cryptosporidium* removal requirements, updated watershed control requirements for unfiltered systems).
Filter Backwash Recycling; The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.
Long Term 2 Enhanced Surface Water Treatment Rule (Published in January, 2006); applied to all systems. WTPs will be granted credit toward *Cryptosporidium* removal, depending on the filtration technology used: conventional treatment (includes softening), 3 log credit; direct filtration, 2.5 log credit; slow sand or diatomaceous earth filtration, 3.0 log credit; and alternative filtration technologies, determined by state. For systems required to sample *Cryptosporidium*, the average *Cryptosporidium* level determines the additional treatment required: < 0.075 oocysts/L, no additional treatment; 0.075 to <1.0 oocysts/L, 1 log or 1.5 log additional treatment; 1.0 to <3.0 oocysts/L, 2.0 log or 2.5 log additional treatment required, > 3.0 oocysts/L, 2.5 log or 3 log additional treatment required.

[3] More than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or *E. coli* if two consecutive TC-positive samples, and one is also positive for *E.coli* fecal coliforms, system has an acute MCL violation.

Table 1-2 Pathogen Indicator Criteria for Beneficial Uses Other than Municipal Water Supply for Surface Waters (Source: USEPA, 2001)

Beneficial Use	Indicator Organism	Criteria[1]
Recreation	*E. coli*	Geometric mean of 126 CFU per 100 mL, based on not less than 5 samples equally spaced over a 30-day period; no sample should exceed a one-sided confidence limit (CL) calculated using the following as guidance: designated bathing beach - 75% CL; moderate use for bathing - 82% CL; light use for bathing - 90% CL; infrequent use for bathing - 95% CL; based on a site-specific log standard deviation, or if site data are insufficient to establish a log standard deviation, then using 0.4 as the log standard deviation.
	Enterococci	Geometric mean of 33 CFU per 100 mL, based on not less than 5 samples equally spaced over a 30-day period; no sample should exceed a one-sided confidence limit (CL) calculated using the following as guidance: designated bathing beach - 75% CL; moderate use for bathing - 82% CL; light use for bathing - 90% CL; infrequent use for bathing - 95% CL; based on a site-specific log standard deviation, or if site data are insufficient to establish a log standard deviation, then using 0.4 as the log standard deviation. Geometric mean of 200 CFU per 100 mL, based on not less than 5 samples equally spaced over a 30-day period and no more than 10 percent of the samples exceeding 400 CFU per 100 mL during any 30-day period. [Note: fecal coliform criteria are used by many states; however, EPA recommends the use of the E. coli and enterococci criteria.]
	Fecal coliform	Geometric mean of 200 CFU per 100 mL, based on not less than 5 samples equally spaced over a 30-day period and no more than 10 percent of the samples exceeding 400 CFU per 100 mL during any 30-day period. [Note: fecal coliform criteria are used by many states; however, EPA recommends the use of the *E. coli* and enterococci criteria.]
Shellfish harvesting	Total coliform	Geometric mean of 70 MPN per 100 mL, with not more than 10 percent of the samples taken during any 30-day period exceeding 230 MPN per 100 mL.
	Fecal coliform	Median concentration should not exceed 14 MPN per 100 mL with not more than 10 percent of the samples taken during any 30-day period exceeding 43 MPN per 100 mL.

[1]Definition
MPN/100 ml = Most probable number per 100 ml
CFU/100 ml = Colony forming units per 100 ml

The contents of the chapters that follow are briefly summarized below:

- Chapter 2 presents an overview of regulated and emerging pathogens in water supplies, their routes of transmission, and the role of indicator species.
- Chapter 3 summarizes the data on pathogens and indicator organisms that have been reported in the Central Valley. This includes information collected by the Central Valley Drinking Water Policy Workgroup as well as other sources.
- Using the data summarized in Chapter 3, Chapter 4 provides an estimate of loads of pathogen indicators from key sources in and near the Delta.
- Chapter 5 identifies recommendations for data collection to better understand the sources of pathogens and highlights the key findings of the analysis presented in this conceptual model.